SURREY
CITY OF PARKS

Township of Langley
Est. 1873

Little Campbell River
Integrated Stormwater Scoping Study

VOLUME 1

Final Report
March 2011

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

March 2, 2011

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Dear Ms Lee and Ms McKay:

RE: LITTLE CAMPBELL RIVER
INTEGRATED STORMWATER SCOPING STUDY
Final Report
Our File 471.180

We are pleased to submit two (2) hard copies of the *Little Campbell River Integrated Stormwater Scoping* Study Final Report. The report is separated into two volumes:

Volume 1: Main text complete with tables and appendices; and
Volume 2: Report figures.

This allows the reader to review report text and tables simultaneously with viewing report figures without flipping back and forth. A DVD of digital information is also included in Appendix A.

It was our sincere pleasure to have the opportunity to complete this interesting and challenging assignment on the behalf of the City of Surrey and Township of Langley. Please do not hesitate to contact the undersigned for any additional information regarding the *Integrated Stormwater Scoping Study*.

Yours truly,

KERR WOOD LEIDAL ASSOCIATES LTD.

Crystal Campbell, P.Eng.
Project Manager

CWC/am
Encls.

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Little Campbell River Integrated Stormwater Scoping Study

VOLUME 1

Final Report
March 2011

KWL File No. 471.180

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

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EXECUTIVE SUMMARY

The City of Surrey (COS) and the Township of Langley (TOL) initiated this study to guide the development of Integrated Stormwater Management Plans (ISMPs) for subwatersheds in the Little Campbell River (LCR) watershed. ISMPs are component of Metro Vancouver's Liquid Waste Management Plan (LWMP) that describe stormwater management strategies to balance future growth and environmental protection. They are typically undertaken in urbanized or developing watersheds that are ideally between 500 and 750 ha in size. Because of the large size of the Little Campbell River watershed (7,580 ha), this study developed an approach to proceed with ISMPs in priority subwatersheds. Several areas including Grandview Heights, Fernridge, Campbell Heights, and Douglas are expected to be developed over the next several years which will increase the effects on urbanization on watershed health.

WATERSHED CHARACTERISTICS OF LITTLE CAMPBELL RIVER WATERSHED

The Little Campbell River watershed is largely situated within the Township of Langley and the City of Surrey with portions within the City of White Rock, the State of Washington, and the Semiahmoo First Nation Reserve No. 1. Existing land use in the watershed is predominantly agricultural with several urban areas. Additional future urban development is expected largely in the Ferndale, Campbell Heights, Douglas, and Grandview Heights areas.

The LCR has significant environmental values including:

- **Diverse and abundant fish populations:** It is one of the most important salmon rivers in the Lower Mainland relative to its size, and contains productive, low-gradient fish habitat.
- **Poor to fair riparian corridor integrity:** The mainstem riparian corridor remains approximately 40% forested; much of the riparian corridor in the LCR has been fragmented by road construction and land clearing for agricultural or rural development.
- **Habitat for species at risk:** The mid-basin wetland and associated riparian areas in Campbell Valley Regional Park and the marine foreshore on Semiahmoo Bay provide habitat for Oregon Forestsnail, Pacific Water Shrew, Red-legged Frog, Vancouver Island beggarticks, and other species.
- **Moderate stream health:** Indicators of stream health in the LCR mainstem range from fair to poor and show improving health with distance upstream. The Fergus Creek sites fall within the very poor category.
- **Water quality problems:** MOE has previously conducted an extensive water quality study due to closures of Boundary Bay foreshore problems. The priority water quality issues are fecal coliforms, low dissolved oxygen and high summer water temperature, and turbidity from construction and bank erosion.

SCOPE OF THIS STUDY

Due to the large size of LCR, a typical ISMP process would be prohibitively extensive in data collection, analysis and development of mitigative alternatives and plans. Therefore this scoping collected basic overview information and framed the watershed and subwatershed issues to develop an approach to ISMP planning. Overview inventories and assessments were undertaken for the following:

- existing and future land use;
- lumped hydrology modelling using XP-SWMM;
- mainstem drainage structures, erosion and hydraulic modelling using MIKE 11;
- water quality and benthic invertebrates;
- fish and fish habitats; and
- biodiversity.

The findings are summarized in this report. In general, bank erosion was found throughout the inventoried portion of the LCR mainstem. Some erosion appeared to be natural but at many locations the causes of erosion included riparian deforestation, livestock access, and high flows from development. Of the 23 LCR mainstem crossings assessed, 12 appear to be undersized for and may be overtopped during the existing land use 200-year flow.

APPROACH TO INTEGRATED STORMWATER MANAGEMENT PLANNING IN THE LCR

The LCR watershed was discretized into more manageable ISMP areas and prioritized for further study based on the extent and timing of future development as follows:

1. Fernridge / Campbell Heights ISMP - 872 ha;
2. Sam Hill / Twin Creeks ISMP – 1,028 ha;
3. Kuhn Creek ISMP – 931 ha;
4. Jacobsen / Highland Creeks ISMP – 1,090 ha – ISMP;
5. Upper Little Campbell River Agricultural Study – 2,415 ha; and
6. McNally Creek ISMP Lite – 426 ha.

Issues specific to each ISMP area were identified and information to guide the future studies were outlined.

Because development will continue in the watershed while the ISMPs are being undertaken, interim criteria are proposed to strive to maintain watershed health. The municipalities should ensure all future development and redevelopment have designs to meet the applicable municipal criteria and bylaws for flood protection, water quality treatment during and post-construction activities, rate control for environmental, erosion and flood protection, and riparian setbacks. It would also be beneficial to implement an interim stormwater volume reduction criterion that requires source controls to capture on-site the runoff from a 25 mm (50% of 2-year rainfall event). This criterion would provide guidance to development proceeding before the completion of the ISMPs.

Development of typical examples and standards of source controls to achieve the above mentioned criterion is also recommended to expedite implementation and construction of source controls. Once each ISMP is completed, the generic criterion and standards may be replaced by ISMP-specific criteria and standards.

Proposed studies within the LCR system are estimated to cost approximately $1 million, detailed as follows:

Estimated Budgets for Proposed LCR Studies

Study	Budget $
1. Interim Criteria Bylaw and Source Control Typical Examples and Standards	50,000
2. Fernridge / Campbell Heights ISMP	200,000
3. Sam Hill / Twin Creeks ISMP	150,000
4. Kuhn Creek ISMP	150,000
5. Jacobsen / Highland Creek ISMP	200,000
6. Upper Little Campbell River Agricultural Study	100,000
7. McNally Creek ISMP Lite	100,000
8. Recalibrate Main Stem Model and Update Flood Levels	50,000
Total	1,000,000

Report recommendations also include the development and implementation of a long-term performance monitoring program for each ISMP area and the Little Campbell River watershed as a whole. Because integrated stormwater management planning is an evolving approach to a complex natural system, an adaptive management program is suggested to provide opportunities to revisit ISMP outcomes and recommendations to assess what is working and what is not. The future management of LCR watershed will require a process to modify and optimize mitigative approaches and measures as needed and adjust source control and/or BMP sizing and/or designs if monitoring results show trend of decreasing watershed health.

Section 1

Introduction

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1. INTRODUCTION

1.1 BACKGROUND

The City of Surrey (COS) and Township of Langley (TOL) initiated this Integrated Stormwater Scoping Study for the 7,580 ha Campbell River ("Little Campbell River - LCR") watershed. The scoping study includes all the tributaries, including:

- Kerfoot Creek (224 ha);
- Jacobson Creek (608 ha);
- Highland Creek (368 ha);
- East and West Twin Creeks (418 ha);
- Sam Hill Creek (511 ha);
- Kuhn Creek (355 ha);
- Fergus Creek (813 ha); and
- McNally Creek (210 ha).

While 98% of the watershed is in B.C., the remaining area of the watershed is located in Washington State. The headwaters begin in the Township of Langley and the channel drains westerly through Surrey and the Semiahmoo First Nation Reserve No. 1. Eastern areas of White Rock also drain to Little Campbell River. The Little Campbell River study area is shown on Figure 1-1.

LITTLE CAMPBELL RIVER ISMP SCOPING STUDY PURPOSE AND OBJECTIVES

The objectives for Little Campbell River (LCR) Scoping Study are summarized as follows:

- develop a hydrologic model for the entire watershed and a hydraulic model for the mainstem;
- determine the watershed issues;
- discretize and prioritize sub-watersheds for future Integrated Stormwater Management Plan (ISMP) studies; and
- recommend next steps for addressing watershed issues.

SCOPE OF WORK

The scope of work for this study included:

- review of extensive background information;
- drainage and environmental field inventory;
- hydrologic/hydraulic modelling and analysis;

- environmental review;
- identification and prioritization of ISMP watershed issues;
- develop ISMP approach for subwatersheds;
- stakeholder consultation and public open house; and
- meetings and report.

1.2 ISMP PROCESS

METRO VANCOUVER ISMP PROCESS

Under the current 2001 Metro Vancouver Liquid Waste Management Plan (LWMP) the member municipalities have made certain commitments for stormwater management. The LWMP stormwater commitments include:

- **C36. Interagency Liaison Group** – Stormwater management planning will build on the information and knowledge base developed and expanded by the group.

- **C37. Stakeholder Participation** – The community, local and regional agencies, and other stakeholders will be invited to participate in the ISMP process to proactively address issues on a long-term basis.

- **C38. Policies and Bylaws** – Municipalities commit to adopting or updating policies and bylaws related to improving stormwater management for at least two stormwater issues over the 5-year period after adoption of the LWMP.

- **C39. Rate of Watershed-scale Stormwater Planning Work** – Municipalities undertake to perform or review integrated stormwater management planning (ISMP) at a watershed scale for urban watersheds where less than 80% of the watershed is in the Green Zone and each watershed plan will be reviewed at least once every twelve years. The ISMP approach is defined under the Policies section in the LWMP to be a proactive approach, evaluating stormwater issues and concerns on a watershed scale and including a wide range of stakeholders and interests in the planning process.

Metro Vancouver commissioned the ISMP Terms of Reference Template in 2002 and updated it in 2005. The Integrated Stormwater Management Planning Technical Process is show in Figure 2-5 of the ISMP Template and is reproduced as Figure 1-2 here.

Legislation does not explicitly regulate stormwater discharges; however, there are regulatory requirements that significantly influence stormwater management. They are listed, according to organization, in Table 1-1.

Table 1-1: Regulatory Requirements Related to Stormwater Management

Agency	Statute/Regulation
DFO	Fisheries Act: ▪ Concerned with any project, work or undertaking that could result in "harmful alteration, disruption or destruction" of fish habitat or "deposit of a deleterious substance" in fish-bearing waters. ▪ Policy objective: No-net-loss of productive capacity of habitat. Net gain of productive capacity for fisheries resources through fish habitat conservation, restoration and development.
Environment Canada	Fisheries Act: ▪ Administers the pollution prevention provisions that prohibit the discharge of deleterious substances into waters frequented by fish. ▪ Regulates response to spills and inspections of industrial facilities, requests for remedial plans and specifications.
Ministry of Environment	Water Act: ▪ Requires approval for all short-term use, storage and diversion of water and alterations and work in and about streams. Water Protection Act: ▪ Prohibits large scale diversion or removal of water between watersheds or outside of B.C. Fish Protection Act: ▪ Protects fish stocks and fish habitat through the possible regulation of riparian areas, water withdrawals and stormwater runoff management. ▪ Requires review of subdivision and development applications. Streamside Protection Regulation: ▪ Protects riparian areas that support fish life processes from residential, commercial, and industrial development.
Ministry of Agriculture and Foods	▪ Responsible for managing farmlands and farming practices (SWM related activities: development of agricultural BMPs and runoff control strategies, and participation on committees and task groups).
Metro Vancouver	▪ Develop and administer the LWMP, manage of inter-municipal drainage areas, Environmental Management Plan, Green Zones Plan, and Liveable Regions Strategic Plan.
Municipalities	▪ Responsible for planning, operating, and maintaining SWM systems with significant influence over land development and SWM on private property. ▪ Responsible for meeting the drainage needs of the community, facilitating growth, and protecting the community's natural resources. Must provide adequate drainage and flood control for public safety.
Source: Table C-2 of GVRD Template for Integrated Stormwater Management Planning 2005.	

Metro Vancouver is in the process of updating its 2001 LWMP. The Draft March 2009 LWMP Update includes the following actions relevant to stormwater management planning:

- Manage rainwater runoff at the site level which reduces negative quality and quantity impacts.
- Promote the collection and use of rainwater for irrigation and other non-potable water uses.
- Maximize the number of watershed scale ISMPs completed.

Metro Vancouver and its members provide a progress report to the province every two years and will review/update the LWMP on a ten year cycle.

BENEFITS OF THE ISMP

The ISMP process has substantial benefits for the watershed, the residents of the area, and the municipality, especially over the long term. The benefits of the ISMP process include that it:

- allows development and redevelopment in the watershed, including the associated increase in impervious area coverage, while protecting the creek in multiple ways;
- allows flexibility in planning for development within the watershed, by illustrating the trade-offs that can allow development and provide off-setting compensation elsewhere in the watershed;
- encourages and incorporates public awareness of the watershed issues and value to the community and the environment;
- allows public and other stakeholder involvement in the big-picture decision making process for the watershed;
- incorporates leading-edge solutions such as water re-use, "the purple pipe", as stormwater management tools for mitigating development impacts;
- utilizes four of the concepts from BC's Living Water Smart initiative to improve the responsible management of water in the province; and
- provides consistency with provincial policies, which allows the city to meet its goals and obligations under the LWMP and therefore be eligible for government grants and funding in the future.

1.3 STORMWATER CRITERIA

Both the City of Surrey and the Township of Langley have stormwater criteria included in their respective bylaws and development manuals. Table 1-2 summarizes the relevant criteria.

Table 1-2: Summary of Stormwater Criteria

Application		Criteria/Methodology
Flood Protection	Minor drainage system	▪ 5-year return period design event typically.[1, 2]
	Major drainage system	▪ 100-year return period design event.[1, 2]
	Rate Control	▪ Limit post-development flows from 5-year and 100 year events to pre-development levels.[2]
	Agricultural drainage system (ARDSA)	▪ Limit flooding to 5 days during 10-year, 5-day winter storm.[4] ▪ Limit flooding to 2 days during 10-year, 2-day growing season storm.[4] ▪ Provide 1.2 m of freeboard during base-flow between storm events.[4]
Environmental & Erosion Protection	Volume Reduction	▪ 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	▪ 6-month 24-hour storm (72% of the 2-year 24-hour storm).[3]
	Erosion and Sediment Control	▪ Limit total suspended solids (TSS) from site runoff to 75 mg/L and 25/75 NTU.[1, 2]
	Rate Control	▪ Limit post-development flows from the 2-year and 5-year event to pre-development levels.[2] ▪ Limit the 5-year post-development flow to: 50% of 2-year post-development rate; or 5-year pre-development rate, whichever is more stringent.[1] ▪ Control post-development flows to pre-development levels for 6-month, 2-year, and 5-year 24-hour event.[3]
	Riparian	▪ Establish riparian setbacks to comply with provincial *Riparian Areas Regulation* and TOL Streamside Protection Bylaw.[2]

1 **City of Surrey**
Design Criteria Manual May 2004,
2-Year Rainfall Event Maximum Runoff Rates

Existing Conditions	Release Rate (L/s/ha)	Existing Conditions	Release Rate (L/s/ha)	Existing Conditions	Release Rate (L/s/ha)
Wooded	5	Rural Residential	10	Town House	25
Grassland	7	Single Family	17	Apartment	29
				Industrial / Commercial	37

Erosion and Sediment Control By-law 2006 No. 16138

2 **Township of Langley** *Subdivision and Development Control Bylaw*, 1994 (rev. 2006),
Erosion *and Sediment Control Bylaw 2009 No. 4381,*
Langley Official Community Plan Bylaw 1979 No. 1842 Amendment (Streamside Protection) Bylaw 2006 No. 4485.

3 DFO Urban Stormwater Guidelines and BMPs for the Protection of Fish and Fish Habitat, 2001.

4 ARDSA = Agri-food Regional Development Subsidiary Agreement.

1.4 STUDY TEAM

This study was undertaken by the following team:

Table 1-3: Study Team

Organization	Team Members
City of Surrey	Jeannie Lee, P.Eng. Carrie Baron, P.Eng. Remi Dube, P.Eng.
Township of Langley	Kristi McKay, P.Eng. Sudu Vatagodakumbura**,** P.Eng. Brad Badelt, P.Eng.
Kerr Wood Leidal Associates Ltd.	Crystal Campbell, P.Eng., Project Manager David Zabil, M.Sc., P.Eng., Project Engineer Jennifer Young, E.I.T., Modelling Engineer
Raincoast Applied Ecology	Nick Page, M.Sc., R.P.Bio., Environmental Biologist Patrick Lilley, M.Sc., R.P.Bio., Biologist

1.5 STAKEHOLDER CONSULTATION PROGRAM

The Little Campbell River Stakeholder Group was assembled to provide input into the study to ensure that all the relevant watershed issues are brought forward. The Stakeholder Group includes:

- Bill Stillwell, Surrey Environmental Advisory Committee (EAC);
- Bill Stewart, Surrey Agricultural Advisory Committee (AAC);
- Glen Carlson, Kristen Vinke, A Rocha Canada;
- Roy Thomson, Semiahmoo Fish & Game Club & Hatchery;
- David Riley, Little Campbell Watershed Society;
- Marg Cuthbert, Friends of Semiahmoo Bay Society;
- Deb Jack, Surrey Environmental Partners;
- Kathy Whittemore, resident;
- Jeannie Lee, Carrie Baron, Remi Dube, City of Surrey;
- Brad Badelt, Sudu Vatagodakumbura, Township of Langley;
- S. Peterson, City of Blaine;
- H. Culverwell, Whatcom County;
- Dave Pollock, City of White Rock;
- Joanne Charles, Semiahmoo First Nations;
- Julia Brydon, Shared Waters Alliance;
- Donna Passmore, Fraser Valley Conservation Coalition;
- Will McKenna, GVRD – Parks;
- Langley Environmental Partners Society;
- Anne Savenye, White Rock-Surrey Naturalists; and
- Kathleen Zimmerman, BC Ministry of Agriculture.

The Stakeholder meeting with the group was held on June 26, 2007 and a separate meeting with Semiahmoo First Nations was held on September 27, 2007.

KEY WATERSHED ISSUES IDENTIFIED BY STAKEHOLDERS

The following table summarizes the key watershed issues raised by the Stakeholder Group:

Table 1-4: Summary of Watershed Key Issues Identified by Stakeholders

Engineering	**Flooding** ▪ LCR connects with Nooksack River during large flood events. ▪ River is flashy, flooding washed out habitat enhancements at Hatchery. **River/ Groundwater** ▪ Protect baseflows – creek does dry out. ▪ Protect/restore water quality. ▪ Elevated sediment and turbidity from construction. ▪ Manage water extractions from creek and aquifer. ▪ Protect aquifer water quality and water levels. ▪ Manage post-development flows.
Land Use	**Development** ▪ U.S. development. ▪ Increasing imperviousness of development (in favour of higher buildings, smaller footprints). ▪ Greenhouses covering soils in ALR. ▪ Agriculture impacts on water quality (sediment, fecal coliforms, and nutrients), riparian loss, aquifer contamination, aquifer levels (withdrawals for irrigation). **Policy/Bylaws** ▪ Protect trees, Improve Tree Preservation Bylaws. ▪ Strengthen Sediment and Erosion Control Bylaws. ▪ Developers need firm direction and enforcement. ▪ Education required. ▪ Separate LCR policy?
Environmental	▪ Water quality in Semiahmoo Bay (shellfish closures, recreational concerns). ▪ Low baseflows and high summer water temperatures. ▪ Maintain biodiversity, ESAs. ▪ Protect wildlife (bear, cougar, coyotes, deer, raccoons) and connected corridors. ▪ Protect birds and amphibians. ▪ Wetlands drying up. ▪ Protect fish and fish habitat. ▪ Manage invasive species.

1.6 REPORT FORMAT

This report presents the overall findings and recommendations of Little Campbell River Scoping Study. There are two report documents: one of the main body of the report together with tables and appendices, and a separately bound document of the report figures. This allows the reader to review report text and tables simultaneously with viewing report figures without flipping back and forth. The report format is as follows:

- Sections 2 to 6 summarize the overall LCR inventory and assessments undertaken in this study:

  - drainage;
  - hydrologic and mainstem hydraulic modeling;
  - water quality and benthic invertebrates;
  - fish and fish habitat; and
  - biodiversity.

- Section 7 summarizes the delineation and prioritization of the individual ISMP areas for further study and outlines general guidance for future ISMP studies;

- Sections 8 to 13 summarize information and figures specific to each individual ISMP area, namely:

  - Fernridge / Campbell Heights;
  - Sam Hill /Twin Creeks;
  - Kuhn Creek;
  - Jacobsen / Highland Creeks;
  - Upper Little Campbell River; and
  - McNally Creek;

- Section 14 presents a summary of findings during the scoping study of the overall Little Campbell River watershed; and

- Section 15 provides a summary of recommendations from the study.

Section 2

Drainage Overview

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2. DRAINAGE OVERVIEW

2.1 BACKGROUND INFORMATION

The following background reports were gathered and reviewed during this study:

Environmental, Water Quality, Benthic Invertebrates

- 2007 DRAFT Appendix B. Models for Understanding Watershed Processes, Watershed Characterization of Clark County, Washington Department of Ecology.
- 2006 Reconnaissance Analysis of the Little Campbell River Watershed, Aquatic Informatics.
- 2006 Potential Pollution Sources in the Little Campbell River Watershed, MOE.
- 2005 Benthic Invertebrate Sampling Program (Data Report), City of Surrey.
- 2005 Protecting Aquatic Ecosystems: A Guide for Puget Sound Planners to Understand Watershed Processes, Washington Department of Ecology.
- 2003 Semiahmoo Bay Water Quality Project, Environment Canada.
- 2003 Semiahmoo Bay Circulation Study, Hay & Company.
- 2003 Status of Water Quality Conditions in the Little Campbell, Serpentine, and Nicomekl Rivers from 1971 to 2002, MWLAP.
- 2001 Horne Pit Biophysical and Proposed Development, Strix Environmental Consulting and Gordon Smith Environmental Planning and Site Design.

Additional references are cited in the environmental assessment in Appendix C.

Hydraulic Studies

- 1992 Campbell River Flood Control Study, Simons Crippen.
- 2007 Hydraulic Assessment of Little Campbell River Upstream of 216 Street, EarthTech.

Sub-watershed / Development Areas

- 2007 Fergus Creek ISMP, McElhanney Consulting Services.
- 2001 Fergus Creek MDP Updated, New East Consulting Services.
- 1996 Fergus Creek Drainage Study, New East Consulting Services.
- 2000 Ocean Bluff and McNally Creek Drainage Assessment, Urban Systems.
- 2007 Douglas Neighbourhood Concept Plan, CH2M Hill.
- 2005 Grandview Heights General Land Use Plan, City of Surrey.
- City of Surrey OCP, 2002 (2006 review).
- Township of Langley OCP, 2006.

Miscellaneous

- 2001 Hazelmere Agricultural Servicing Study, EarthTech.

2.2 WATERSHED OVERVIEW

The Little Campbell River watershed area is 7,580 ha and covers many jurisdictions including Township of Langley, City of Surrey, Semiahmoo First Nation Reserve No. 1, City of White Rock, and the United States. Much environmental and engineering related work has been done in the watershed. This section provides an overview of the drainage issues in terms of the following:

- site description in Langley and Surrey;
- soils and aquifers;
- land use;
- erosion severity;
- channel obstructions; and
- field reviews

A series of figures (see Figures 2-1A to 2-1F) are included to illustrate the location of the Little Campbell River along with locations of items noted in the field surveys including bridge crossings, culvert locations and areas of erosion. Selected photos are also included on each figure to show some of the findings of the field survey. Reference is made in the report to these figures.

DOWNSTREAM REACHES IN SURREY

The 2.8 km long portion of the Little Campbell River downstream of Highway 99 is encompassed by Semiahmoo First Nation Reserve No. 1, and is predominantly characterized by undeveloped mature coniferous woodland. Water levels appear to be tidally influenced through this lower portion of the river. Substrate is comprised of predominantly fine-grained sand and silt. The Burlington Northern Santa Fe (BNSF) railroad crosses the river immediately upstream of its mouth at Semiahmoo Bay on a riveted steel bridge. Refer to Figure 2-1A.

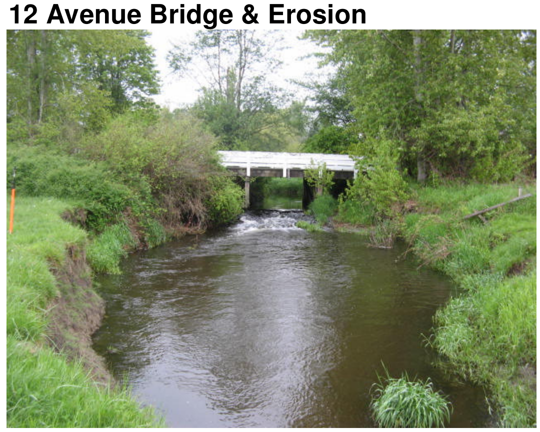
The next 500 m reach flows through the Peace Portal Golf Course, where mowed grass fairways extend to both banks of the river. At four locations within the golf course pedestrian/cart paths cross the river; wooden piers support one of these bridge crossings, while the other three are clear span prefabricated steel structures. The downstream boundary of the golf course occurs at Highway 99, where three 2,600 mm high by 3,500 mm wide arch shape CMP culverts convey the river under the six-lane highway. Refer to Figure 2-1A.

Upstream of the golf course, the river flows through a reach of undeveloped mature coniferous woodland roughly 1 km long, centered around the 172 Street crossing. Several natural channel obstructions were noted in this reach. Refer to Figure 2-1A.

Downstream of 184 Street to roughly midway between the 172 and 176 Street crossings is characterized by mainly agricultural land use. Grass fields extend to both banks along much of this 5.5 km long portion of the river. Significant undermining at both banks and deep scouring of the channel bottom was noted along much of this reach, with substrate material comprised mainly of fine-grained sand and silt. Livestock access to the creek was noted in several locations. Major road crossings occur at 184 Street, 12 Avenue, 8 Avenue and 176 Street; private bridge crossings were noted in three additional locations. Refer to Figures 2-1A and 2-1B.

184 Street Culverts

12 Avenue Bridge & Erosion



Between the Surrey/Langley border at 196 Street and 184 Street the river channel flows through mainly mature coniferous woodland. Substrate is more granular, with significant sand and gravel bars forming at meander bends. Natural channel obstructions begin to appear with some regularity, due in part to the presence of large trees at both banks and heavy beaver activity. One major road crossing is found within this reach at 16 Avenue. The downstream boundary of this roughly 9 km long reach occurs near the Little Campbell Hatchery (immediately upstream of the 184 Street crossing), where two private bridges and a steel fish gate cross the river. Refer to Figure 2-1B.

Beaver Dam

Fish Hatchery

UPSTREAM REACHES IN LANGLEY

Between 204 Street at 20 Avenue and 196 Street, the river channel flows through mixed residential areas and mature coniferous woodland. Substrate is granular, with significant sand and gravel bars forming at meander bends. Pedestrian access to the river becomes more common, with several private bridges crossing the river and residential development encompassing both banks in many areas. Major road crossings within this reach occur at 24 Avenue near 204 Street, at 200 Street, and at 24 Avenue east of 196 Street. Refer to Figure 2-1C.

The upper reaches of the Little Campbell River are dominated by a large wetland, extending nearly 12 km from its headwaters near 240 Street to the south boundary of the Fernridge residential area, near the intersection of 20 Avenue and 204A Street. Refer to Figure 2-4. This wetland area is characterized by a broad, flat valley, dense low shrubs, and fine silty substrate. The channel is poorly defined, with the majority of the valley bottom submerged even at low water levels. Flow velocities are almost imperceptible due to the nearly flat longitudinal gradient through this reach. The lower 5 km portion of the wetland area, downstream of 216 Street, is encompassed by the Campbell Valley Park, where a network of gravel trails and boardwalks provides pedestrians, cyclists and horseback riders with limited access to the river. Major road crossings within the wetland area occur at 232 Street, 224 Street, 216 Street, and at 16 Avenue west of 208 Street. The upper reaches of the river in Langley are shown on Figures 2-1D to 2-1F.

Wetland - 16 Avenue near 204 Street – Looking Upstream

SOILS

The soils within the watershed appear to be predominantly silt and clay, with large pockets of gravel and sand, sand, and till. Figure 2-2 shows soils identified by Canadian Geographic Services.

AQUIFERS

Many aquifers underlie the Little Campbell River watershed as shown on MOE's 2006 map identified here on Figure 2-3. The aquifers within the watershed include:

- Grandview – confined aquifer in Surrey and Langley;
- Hazelmere – confined aquifer in Surrey;
- Hazelmere Valley – confined aquifer in Surrey;
- Whiterock – confined aquifer in Surrey and White Rock;
- Abbotsford – unconfined aquifer in Langley;
- Border – confined aquifer in Surrey and Langley;
- Brookswood – unconfined aquifer in Surrey and Langley;
- Central Hopington – unconfined aquifer in Langley;
- Langley Upland/Inter-till –confined aquifer in Langley; and
- South of Hopington – unconfined aquifer in Langley.

2.3 LAND USE

The existing land use from an aerial perspective along with golf courses and parks are shown on Figure 2-4 and also in greater detail on Figures 8-1, 9-1, 10-1, 11-1, 12-1, and 13-1 in the latter sections of the report. Land use is predominantly agricultural with small pockets of urbanization. Most of the existing development is in Surrey's tributaries to the lower reach, namely in Fergus Creek and McNally Creek watersheds.

Major changes in land use are shown on Figure 2-5. The Langley OCP shows residential development planned (Fernridge and High Point – already under construction) mid-watershed adjacent to the Surrey-Langley border. The Surrey OCP shows industrial development within Campbell Heights, residential development within Douglas and Grandview Heights, and commercial and industrial along the Hwy 99 corridor. These developments are tributary to the mainstem, Twin Creek, Sam Hill Creek and Fergus Creek. For the purpose of this scoping study, no changes in land use were considered in the portions of catchments within Washington State. A detailed investigation of land use changes should be performed as part of the upcoming ISMPs.

2.4 DRAINAGE FIELD INVENTORY

The goals of the inventory field work program were to identify:

- locations of significant erosion and to rate these sites based on relative severity and potential risk;
- natural and anthropogenic channel obstructions and to rate these obstructions based on relative stability;
- locations of significant deposition;
- drainage control structures; and

- past channel stabilization/enhancement works.

To accomplish this, the creek bed was traversed on foot and locations of interest were identified and recorded with a Trimble GeoXT single frequency handheld global positioning system (GPS) receiver. Measurements, photographs and additional anecdotal information were recorded as attributes associated with these positions to create a comprehensive geographical information system (GIS) database.

Raw field observations were subsequently differentially code corrected against reference station observations to achieve final horizontal accuracies within 5 m for 90% of positions, and within 2 m for 51% of positions. Horizontal positions were recorded in a universal transverse mercator (UTM) projection, based on the North American Datum of 1983 (NAD83), Zone 10 North. Municipal survey control monuments were tied-in where possible and GPS observations were compared with published coordinates to confirm the horizontal positional accuracy of the data.

Detailed inventory field work on the Little Campbell River mainstem focused on the 9 km long channelized natural portion of the watercourse, between the 184 Street crossing and the intersection of 20 Avenue and 204A Street. The 1 km long portion immediately upstream of the Peace Portal Golf Course was also investigated in detail.

The 5.5 km long agricultural reach downstream of 184 Street was not investigated in the same level of detail, nor was the portion encompassed by the Peace Portal Golf Course, as channel properties and land use were observed to be more uniform along these portions. The upper 12 km long wetland reaches were investigated mainly at the major road crossings and pedestrian boardwalk crossings, due in combination to the lack of access to much of this portion of the river and to the apparent uniformity of the channel properties and land use.

Inventory field work took place between June 5 and June 19, 2007. Figures 2-1A to 2-1F show the inventory findings including selected photos and areas of erosion, deposition, bridges and culverts and channel obstructions. The complete listing of all survey points and all photos taken are included on the DVD in Appendix A.

2.5 EROSION SEVERITY AND CONSEQUENCE RATINGS

Sites of significant erosion were identified and assigned a relative severity level of low, moderate or high, based on a visual assessment that took into account the following parameters, where they could be observed:

- the total height of eroded bank;
- the apparent rate of erosion;
- the apparent capacity of bank material to resist further erosion; and
- the depth of scour holes in the channel bed.

In addition to rating the severity of these sites, the potential consequences of the erosion activity was also evaluated and assigned a relative risk level of low, medium or high. This was based on a visual assessment that took into account the perceived level of risk to human life, property damage or destruction, wildlife habitat, and water quality.

Severity and consequence were evaluated independently from one another for each site. Consequently an area of minor erosion with residential structures in close proximity to the eroding bank could receive a low severity rating, but a high consequence rating. Conversely, major erosion sites in undeveloped areas with no apparent risk to habitat or water quality may receive a high severity rating but a low consequence rating.

A summary of observed severe erosion sites is listed in Table 2-1 and shown in the photos on Figures 2-1A to 2-1F. The complete inventory of erosion points along the LCR mainstem and all related erosion photos are included on the DVD in Appendix A.

2.6 CHANNEL OBSTRUCTION CLASSIFICATION AND STABILITY RATINGS

Channel obstructions were classified as either natural or anthropogenic; anthropogenic obstructions were noted in very few locations, while natural channel obstructions were quite common. Heavy beaver activity was noted at several locations, with trees up to 600 mm in diameter being harvested from the banks of the river and introduced to the channel to create dams. Some of these major beaver dams appeared quite resilient and showed evidence of surviving significant past flood events. Others were comprised mainly of small wood debris (SWD) and appeared to have been recently constructed. A summary of observed mainstem channel obstructions is listed in Table 2-2. Also refer to the photos on Figures 2-1A to 2-1F. The complete inventory of channel obstructions on the LCR mainstem and all related obstruction photos are included on the DVD in Appendix A.

In addition to noting the material and apparent origin of the channel obstructions, each site were assigned a stability rating of stable or unstable, based on a visual assessment that took in to account the following parameters, where they could be observed:

- the materials and construction of the obstruction;
- the presence and apparent age of scarring or polishing at the top surface of the obstruction;
- indications of maintenance activity (beaver or human) carried out on the obstruction; and
- the presence of substrate deposition at the upstream side of the obstruction.

In many cases channel obstructions, particularly major beaver dams, appeared to be significantly augmenting erosion of the banks and channel bottom. The presence of deep scour holes and severe bank erosion was noted near major obstructions in several locations.

2.7 HYDRAULIC STRUCTURE AND CHANNEL CROSS-SECTION SURVEY

Detailed topographic surveys were carried out at all major road crossings, allowing measurement of invert elevations, hydraulic capacity, and total length for all culverts and bridge crossings. Additionally, cross sections were surveyed at the upstream and downstream faces of all major road crossings and at regular intervals throughout the channel between major crossings to allow accurate measurement of hydraulic capacity along the total length of the river. Generally, channel cross sections between major road crossings were spaced 500 m to 1,000 m apart, with additional cross sections added where channel properties appeared to change significantly.

To accomplish this, survey control points were established at major road crossings and additional proposed cross section locations using a high accuracy Trimble R8 real time kinematic (RTK) GPS receiver and a Trimble S6 robotic total station. Municipal survey control monuments in both the Township of Langley and the City of Surrey were located and tied by RTK GPS around the perimeter of the scope of work. These ties allowed confirmation of horizontal positional accuracy against published UTM NAD83 coordinates, and confirmation of vertical positional accuracy against published geodetic elevations.

The detailed hydraulic structure and cross section surveys that followed were carried out using a Trimble S6 robotic total station, and were positioned based on ties to this network of survey control points. All ground level distances measured by total station were subsequently scaled horizontally to UTM grid level before calculating final coordinates by applying a combined scale factor of 0.9996.

All elevations were derived from ties to municipal survey control monuments based on published geodetic values vertically adjusted to the 2005 GVRD regional refresh. The magnitude of this vertical adjustment varied from -0.089 m near the eastern edge of the scope of work (240 Street) to -0.125 m at the western edge (Semiahmoo Bay). Ties to unadjusted municipal monuments were found to be in general 0.08 to 0.13 m lower than published elevations.

Hydraulic structure and cross section surveys took place between April 16 and May 10, 2007. The complete inventory of the surveyed hydraulic structures and cross sections are included on the DVD in Appendix A.

Table 2-1: Summary of Observed Severe Erosion Sites

EROSION ID	MAINSTEM CHAINAGE	LOCATION	SEVERITY	CONSEQUENCE	LENGTH (m)	DEPTH (m)	COMMENT
TOWNSHIP OF LANGLEY							
E-203	16+808	Left Bank	High	Low	16	3	
E-202	16+753		High	Low	16	2	
E-201	16+725	Right Bank	High	Low	12	2	
E-197	16+320	Right Bank	High	Low	25	3	
E-195	16+201	Left Bank	High	Low	15	2	Active erosion continues at d/s end, gabions and old farm gate placed at u/s end
E-193	16+129	Left Bank	High	Moderate	12	5	House ~12m Back
CITY OF SURREY							
E-176	15+065	Left Bank	High	Moderate	8	4	Chainlink fence undermined at top of bank, house is >10m back
E-167	13+930	Left Bank	High	Moderate	16	8	Risk of further slope failure
E-163	13+552	Right Bank	High	Moderate	25	2	Bank undermined up to 1.5m. 800mm cedar & 700mm fir at risk
E-156	12+913	Left Bank	High	Low	20	4	Large piece of grassy bank slid into creek. Bank eroded up to 8 m back.
E-152	12+695	Right Bank	High	Low	10	5	Chunks of clay spalling off 3m high near vert face
E-148	12+479	Right Bank	High	Low	0	4	Severe scouring of bed (exposed hard clay till) along r bank toe
E-147	12+410	Left Bank	High	Low	14	4	
E-145	12+314	Right Bank	High	Moderate	18	2	>2m Nurse stump at edge of bank. Exposed hard clay till at r bank and creek bed
E-143	12+155	Right Bank	High	Moderate	18	5	Standing 1m cedar w/ root structure slid into creek, roots damaged by beavers
E-138	11+597	Left Bank	High	Low	30	2	Beaver pool, up to 8m of field eroded at l bank
E-132	11+001	Right Bank	High	Moderate	0	3	15-20 400-800mm cedars at risk
E-137	11+437	Left Bank	High	Low	20	2	Large section of bank lost to erosion. Exposed hard clay till at creek bed
E-134	11+208	Left Bank	High	Moderate	25	1	Large section of bank & wooden fence washed out due to mid channel erosion
E-133	11+149	Left Bank	High	Low	16	3	Exposed hard clay till at l bank & creek bed
E-115- E-117	9+316	Both	High	Low			
E-60- E-112	7+368- 7+240		High	Low			
E-58, E-59	7+235	Both	High	Low			
E-57	7+174	Both	High	Low			
E-55, E-56	7+054	Both	High	Low			
E-48	6+829	Both	High	Low			
E-38	6+459	Both	High	Low			
E-25- E-36	6+120- 6+355	Both	High	Low			
E-16- E-20	5+708- 5+927	Both	High	Low			
E-14	5+607	Both	High	Moderate			
E-11, E-12	5+386- 5+438	Both	High	Low			
E-2	3+904	Left Bank	High	Low	30.000	1.800	Severity increases progressing downstream

Refer to Figures 2-1A and 2-1F for mainstem chainage locations

Table 2-2: Summary of Observed Major Channel Obstructions

OBSTUCTION ID	MAINSTEM CHAINAGE	CAUSE	STABILITY	TYPE	D/S DROP	COMMENT
TOWNSHIP OF LANGLEY						
O-54	18+033	Anthropogenic	Fixed	Abandoned bridge piles	0	4 rows of 4 x 150 pvc
O-53	18+009	Anthropogenic	Fixed	Debris barrier?	0	
O-51	16+805	Natural	Stable	Logjam		Flow restricted to l side, augmenting erosion at l bank
O-50	16+720	Natural	Stable	Fallen tree	1	
O-48	16+174	Natural	Stable	Fallen tree w/ logjam		
O-47	16+117	Anthropogenic	Stable	Cables from ruined susp bridge		~2m above bed at l side, buried in sed & debris at r side
O-45	15+396	Natural	Stable	Logjam	1	Fine gravel & sand accumulated on u/s side
O-44	15+354	Natural	Stable	Logjam	0	
O-43	15+269	Natural	Stable	Fallen tree	0	Significant midchannel erosion under tree & on u/s side
CITY OF SURREY						
O-42	15+086	Natural	Stable	Fallen tree w/ logjam	1	Blocking left channel
O-41	14+952	Natural	Stable	Fallen tree	0	
O-40	14+867	Natural	Stable	Fallen tree	0	
O-38	14+610	Natural	Stable	Beaver dam	0	Large pool behind dam
O-37	14+294	Natural	Stable	Logjam		
O-35	14+151	Natural	Stable	Beaver dam	1	Gravel deposited up to top surface of dam on u/s side
O-34	13+957	Natural	Stable	Fallen tree w/ beaver dam		
O-33	13+930	Natural	Stable	Beaver dam		Augmenting slope failure @ l bank
O-31	13+803	Natural	Stable	Beaver dam		
O-30	13+686	Natural	Stable	Beaver dam	1m	
O-29	13+673	Natural	Stable	Beaver dam		
O-28	13+614	Natural	Stable	Fallen tree	0	
O-27	13+046	Natural	Stable	Logjam	0	0.3-0.7m high x 5m wide space under log on r side of channel
O-26	12+940	Natural	Stable	Beaver dam	0	
O-25	12+898	Natural	Stable	Beaver dam		
O-24	12+759	Natural	Stable	Old 800mm log	1	
O-23	12+745	Natural	Stable	Logjam	1	2 old 450mm logs w/ accumulated swd
O-22	12+698	Natural	Stable	Beaver dam	2	
O-21	12+675	Anthropogenic	Stable	Ruined bridge (old truck deck)	0	Flow allowed under deck
O-20	12+499	Natural	Stable	Fallen tree w/ logjam	0	
O-19	11+822	Natural	Stable	4 fallen trees. Beaver dam under construction at u/s tree	0	
O-18	11+712	Natural	Stable	Fallen 800mm cedar w/ beaver dam	0	
O-17	11+597	Natural	Stable	Fallen tree w/ beaver dam		
O-16	11+565	Natural	Stable	Fallen tree	1	
O-15	11+471	Anthropogenic	Stable	Bent wideflange beam w/ accumulated wood debris	1	Middle of beam buried in creek bed, ends near bankfull elev
O-14	11+458	Natural	Stable	3 fallen trees	0	Flow allowed under trees. Likely augmenting l bank erosion downstream
O-13	11+207	Natural	Stable	Fallen tree	0	Creek has cut new channel through l bank
O-12	10+673	Natural	Stable	Logjam	1-2m	Major obstruction ~80m^3 logs & debris
O-11	10+597	Natural	Stable	Fallen tree	1	
O-8	4+372	Natural	Stable	Fallen tree	0	
O-5	3+986	Natural	Stable	Beaver dam	0	Rotten old log w grass
O-4	3+957	Natural	Stable	Fallen tree w log jam	0	
O-3	3+892	Natural	Fixed	Major log jam		
O-2	3+753	Natural	Stable	Logjam		

Refer to Figures 2-1A and 2-1F for mainstem chainage locations

Section 3

Hydrologic and Mainstem Hydraulic Modelling

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3. HYDROLOGIC AND MAINSTEM HYDRAULIC MODELLING

3.1 INTRODUCTION

This section summarizes the hydrologic and hydraulic modelling analysis. A hydrologic model of the entire watershed and a hydraulic model of the mainstem of Little Campbell River were developed. The purpose of the modelling was to determine peak design flows and water levels at strategic locations under existing and future conditions.

This section summarizes the development of the models including:

- selection of stormwater modeling software;
- description of the hydrologic and hydraulic model development; and
- calibration and validation of the hydrologic model to ensure accurate predictions of watershed rainfall-runoff response.

The resulting hydrologic/hydraulic model was used to estimate peak flows and water levels at key locations within the watershed.

3.2 MODEL SELECTION

Hydrology for portions of the Little Campbell River watershed were previously modelled using the OTTHYMO, PCSWMM, and MIDUSS hydrologic models. Hydraulic modelling was also done on portions of the Little Campbell River main stem using HEC-2 and PCSWMM. The most recent modelling was completed in 2007 by EarthTech using PCSWMM and included the catchment upstream of 216 Street.

The study team expressed a desire for the selected model to have some capability to model water quality for potential future projects or studies. Some of the obvious possible software choices included XP-SWMM for hydrologic, hydraulic and water quality modelling, MIKE11 for hydraulic modelling with water quality add-ons, and QHM (QUALHYMO) and HSPF for hydrologic and water quality modelling.

XP-SWMM (version 10.0 j) was selected for the hydrologic modelling of the watershed. XP-SWMM is a physically-based model which maximizes the number of parameters that can be measured through field investigations and minimizes those which must be estimated based on engineering tradition or judgement. The physical basis enables the same model to be used for all antecedent design conditions, and for both frequent and extreme events. It is also suitable for continuous (multi-year or typical year) modelling.

With the selection of XP-SWMM – RUNOFF for the hydrologic modelling, a seamless integration with XP-SWMM – HYDRAULICS is possible. However, XP-SWMM – HYDRAULICS is better suited to storm sewer networks simulation rather than river channels. MIKE11 was developed specifically for river modelling and is well-suited for modelling the Little Campbell River mainstem with tidal influences at the river mouth. For this reason MIKE11 was selected for the hydraulic modelling. The catchment runoff and groundwater flow hydrographs were exported from XP-SWMM RUNOFF into MIKE11 input files. Water Quality add-ons are available for both XP-SWMM and MIKE11 should it be needed in the future.

3.3 HYDROLOGIC/HYDRAULIC MODEL DEVELOPMENT

Two models were developed for the Little Campbell River watershed, XP-SWMM RUNOFF for hydrology and MIKE11 for hydraulics. XP-SWMM RUNOFF uses inputs such as rainfall and catchment characteristics (area, slope, soil type, etc.). MIKE11 requires channel and crossing characteristics.

The hydrologic and hydraulic model was developed with the aid of the City of Surrey (CoS) and Township of Langley (ToL) GIS databases.

XP-SWMM MODEL CATCHMENTS

The Little Campbell River watershed was discretized into sub-catchments using contours, field watercourse information, and existing drainage information. The major model sub-catchments are shown in Figure 3-1.

In total, 48 catchments were created and imported into the XP-SWMM model. Catchments were assigned the following attributes:

- slopes, using contour information;
- existing impervious area, using 2006 aerial photographs to determine land use and the CoS land use impervious percentage information;
- impervious area for future land use scenarios, using the CoS and ToL OCP Zoning; and
- groundwater parameters based on typical values for soils shown in the soil map (Figure 2-2).

Impervious Percentage

Existing land use impervious percentages were estimated based on the land use type visible in the aerial photography and Table 5.3(h) – *Impervious Percentages by Land Use* in the 2004 CoS *Design Criteria Manual* repeated in Table 3-1 below. These land use impervious percentage values match well with those in the ToL Subdivision and Development Control Bylaw and therefore were applied throughout the Little Campbell River catchment.

The future land use impervious percentages were derived using the OCP zoning information combined with the CoS *Impervious Percentages by Land Use* table.

Table 3-1: Impervious Percentages by Land Use

Land Use Zone	Description	Corresponding OCP Designation (Assumed)	Total Impervious Percentage
LDR	Residential – Low Density	Lower Density Residential Areas	50%
MDR	Residential – Medium Density	Medium Density Residential Areas	55%
HDR	Residential – High Density	High Density Residential Areas	65%
Agri	Rural Agricultural	Agricultural	20%
Lakes	Water Bodies	Lakes, Large Water Bodies	100%
Com	Commercial	Commercial Areas	90%
Ind	Industrial	Industrial Areas	90%
Inst	Institutional	Institutional Areas	80%
Undev	Forested Areas	Forested Areas, Environmentally Sensitive Areas	0%

Soil Parameters

The groundwater portion of XP-SWMM – RUNOFF was used to estimate the groundwater and interflow portions of the runoff hydrograph. Figure 2-2 shows the surficial geology that was used to determine soil parameters. The majority of the watershed is silt-clay soils, with some gravel, sands, till and peat.

The infiltration and groundwater parameters used in the models were based on KWL's database of calibrated model parameters for similar soil conditions with refinement made during the calibration process.

MIKE11 MODEL

A MIKE11 model was developed for the Little Campbell River main stem channel from 240 Street to the mouth at Semiahmoo Bay and for the downstream portions (approximately 100 m long) of the large tributaries. The model includes all bridges and culverts along the Little Campbell River main stem except those located within the Semiahmoo I.R. lands located at the mouth of the river. Figures 2-1A to 2-1F show the culvert and bridge locations and Figure 3-1 shows the extent of the modelled channel reaches. Channel cross-sections (maximum of 500 m apart) and culvert/bridge sizes were obtained from the field survey conducted in 2007.

Boundary Conditions

The river outlet to Semiahmoo Bay was simulated using water level boundary conditions to assess tidal impacts on the flood profile along the river. For the calibration and verification simulations, astronomic tide patterns were estimated using the X-Tide predictor for the selected calibration and validation dates.

3.4 XPSWMM AND MIKE 11 MODEL CALIBRATION AND VALIDATION

XPSWMM MODEL CALIBRATION AND VALIDATION

Model calibration involves the adjustment of parameters, within reasonable ranges, until a set of objectives is met. The Little Campbell River model was calibrated in such a way as to:

1. maximize the physical basis of the XP-SWMM algorithms; and
2. calibrate to all respects of the runoff hydrograph (peak flow, volumes, the receding portion of the hydrograph from groundwater, and seasonal groundwater baseflow).

The XP-SWMM existing land use and existing conveyance system model was calibrated with two historic events and subsequently validated with two others. The model parameters were adjusted uniformly over the various subcatchments of similar type in the watershed during calibration.

CLIMATE AND FLOW MONITORING DATA

For the calibration and verification process, rainfall from three local climate stations was used: Semiahmoo Fish and Game Club station, Langley TL36 GVRD station, and White Rock WK47 GVRD station (see Figure 3-1).

Water level and flow monitoring data from the 12 Avenue Flow Monitoring Station in Surrey was used (see Figure 3-1 for gauge location). The area tributary to the flow-monitoring gauge is mostly agricultural with a few rural residential properties. The period of record includes 1961-64 and 2000-2007. However, data collected between 2003 and 2006 had truncated peak flows due to problems with the monitoring transducer which was replaced in 2007. Therefore, events from the 2000-2003 dataset were used for calibration and verification process as listed in the following table.

Table 3-2: Calibration Storm Events

Application	Date	Rainfall Depth[1]		Duration of Rainfall
		Semiahmoo	TL36	
Calibration Events	December 2001	79.4	190.2	One month continuous
	January 2002	108.2	173.4	One month continuous
Validation Events	December 2000	112.3	111.5	One month continuous
	January 2001	94.0	117.6	One month continuous

1. Semiahmoo Fish and Game Club Station and GVRD Gauge TL36.z
All events were preceded by wet saturated conditions.

Graphs of annual rainfall from the Semiahmoo station and flow from the 12 Avenue gauge within 2000-2009 are shown in Appendix B. Please note that the 2008 and 2009 data was not available at time of calibration.

XP-SWMM WET WEATHER CALIBRATION EVENTS

The calibration process is ideally completed using several storms of various sizes that occur at different times of the year. The more significant events were selected to ensure the model's ability to accurately estimate peak flows. The December 2001 and January 2002 storm events were selected as the largest events in the data set. Model parameters were refined during the calibration process. Figures 3-2 and 3-3 show comparisons between predicted and recorded flows for December 2001 and January 2002 respectively.

The model predictions for both months showed good approximations to the recorded events. The December 2001 results showed the model overestimated volumes (by 8%) and peak flows (by 16%). The January 2002 results showed the model overestimated volume (by 23%) and overestimated the peak flow (6%).

XP-SWMM MODEL WET WEATHER VALIDATION

Once calibrated, it is important to validate the hydrologic model with additional events. This serves as an independent check on the assumptions made during the calibration process.

The December 2000 and January 2001 storm events were used for model validation, again representing wet antecedent conditions. There were multiple rainfall events in the weeks preceding the events. Figures 3-4 and 3-5 show the model predictions relative to rainfall and recorded flow.

The model overestimated both the runoff volume (by 32%) and peak flow (by 49%) during the December 2000 event. The January 2001 event validation is better with an overestimated modelled volume (by 21%) and underestimated peak flow (by 21%).

The calibration/validation performed in this study was performed using a coarse first iteration model with large lumped catchments, no detailed hydraulic information within the large catchments, no stormwater management features, and only one location with recorded flows to which to compare model results. The overestimation of the peak flows in the models, with the exception of the January 2001 storm, will result in conservative estimates in predicted design flows and thus conservative peak flood levels presented in this study. It is proposed that the modelling be updated with the detailed information that will be collected and modelled in the individual ISMP studies. Each of the ISMPs will produce a more detailed model that will be calibrated to a local gauge within each area and therefore it is expected that once all the ISMP models are combined together, the overall calibration at the 12 Avenue gauge will improve.

MIKE11 MODEL WET WEATHER CALIBRATION AND VALIDATION

The same selected rainfall months were used in the calibration and validation process for the MIKE11 hydraulic model. Channel roughness in the model was adjusted to match the recorded water levels at 12 Avenue. Because only one water level station was available, the channel roughness was adjusted uniformly throughout the model. A composite roughness for both the channel and overbanks was set to 0.075 (Manning's 'n'). Conduit roughness values were assigned based on typical values for the various conduit materials. Crossings were modelled to allow conveyance via overtopping if upstream water levels reached the bridge deck or road crest elevations.

The December 2001 to January 2002 event calibration model result slightly overestimates the peak water level (by less than 0.2 m) and underestimates the baseflow water level (by up to 0.15 m). The results are shown in Figure 3-6.

The hydraulic model was validated as an independent check on assumptions made during the calibration. Refer to Figure 3-7. The December 2000 to January 2001 storm event validation showed that the model overestimated peak water level (by less than 0.2 m) and underestimated baseflow water levels (by up to 0.2 m).

Baseflow water levels were slightly underestimated at the gauge, however the model will confidently predict high flows and water levels, and is suitable for design storm simulation. It is recommended that staff gauges be installed at all road crossings and water levels (and dates/times) be manually recorded during future large storms so that the hydraulic model can be calibrated along its entire length once the ISMPs are completed and hydrologic model details incorporated.

Once the existing land use condition model was calibrated and validated, the future land use conditions model was developed based on the Official Community Plans from the City of Surrey and the Township of Langley. Refer to Figure 2-5 for land use changes.

3.5 DESIGN STORMS

The City of Surrey drainage criteria state that protection from flooding will be provided up to the 200-year level in the floodplain areas of the Little Campbell, Serpentine, Nicomekl, and Fraser Rivers. The Township of Langley design criteria state that the 100-year storm should be used for major systems but under special circumstances, drainage facilities in major watercourses may be required to accommodate greater than 100-year flows.

Neither the City of Surrey or Township of Langley have a 200-year design event in their current bylaw, however a 200-year 5-day storm was developed for the Serpentine-Nicomekl system. This storm was used for the Little Campbell River analysis and adapted to local rainfall.

The ARDSA 10-year 5-day storm from the City of Surrey Design Criteria Manual was also used and adapted for the Langley Lochiel station by factoring up the Municipal Hall storm to total 156 mm. A 2-year storm was also developed using the City of Surrey 24-hour design storm distribution. The 200-year, 10-year, and 2-year rainfall totals for the three climate stations are summarized in Table 3-3. For catchments within each municipality, the appropriate rainfall was applied.

Table 3-3: Design Storms

Climate Station	Period of Record (years)	Total Rainfall (mm)		
		200-Year 5-Day Design Event	10-Year 5-Day Design Event	2-Year 24-Hour Design Event
Langley Lochiel (AES)	15	322.9	156.0	57.6
Surrey Municipal Hall (AES)	36	296.9	143.4	55.2
WK-47 White Rock PS (GVRD)	14	278.3	115.6	50.6

3.6 MODEL SCENARIOS AND TIDAL BOUNDARY CONDITIONS

The following model scenarios were simulated:

- pre-development (all forested);
- existing land use (as per 2006 air photo); and
- future land use (as per Surrey and Langley OCPs).

The following design storms were run together with the indicated tidal boundary conditions at the Little Campbell River mouth:

- **Extreme flow event with average winter high tide:** 200-year, 5-day rainfall with average winter high tide (peak tide WL = 1.94 m). This is the same tidal pattern used in the Serpentine-Nicomekl 200-year design storm analysis.

- **High flow event with average winter high tide:** 10-year, 5-day rainfall with average winter high tide (peak tide WL = 1.94 m). This is the same tidal pattern used in the Serpentine-Nicomekl 10-year design storm analysis.

- **Annual average flow event with an extreme tide:** 2-year, 24-hour rainfall with 200-year storm surge sea level (peak tide WL = 2.63 m). This is the amplified December 1982 storm surge event adjusted for Boundary Bay as presented in the KWL *Delta Flood Management Study* draft report dated May 2007.

- **Winter Baseflow conditions with astronomic tide:** 0.061 L/s/ha baseflow with December astronomic tide pattern (peak tide WL = 1.79 m).

- **Summer Baseflow conditions with astronomic tide:** 0.020 L/s/ha baseflow with July astronomic tide pattern (peak tide WL = 1.58 m).

The XP-SWMM and MIKE11 models are included on the DVD in Appendix A.

3.7 PEAK FLOW AND WATER LEVEL ESTIMATES

To estimate design peak flows and water levels associated with pre-development, existing and future land use conditions, the models were run with saturated soils typical of winter conditions. The peak flow estimates at strategic locations are summarized in the Table 3-4 and water level profiles are shown on Figures 3-8A to 3-8C.

The 2-year, 10-year, and 200-year peak flows per hectare were checked against unit flows estimated for similar creeks in the City of Surrey and in the Lower Mainland. In general, the peak flows are slightly on the lower end of the range of unit flows for a catchment with similar slopes and impervious percentage. It has been observed that watersheds that are mostly pervious in the upper catchment and developed near the downstream end of the channel tend to have lower unit peak flows as the impervious area flows pass through the system before the flows from the upper catchment peak. Therefore it is reasonable that the Little Campbell River, which is agricultural in the upstream catchments and developed near the downstream end would tend to have unit peak flows on the lower end of the range.

Table 3-4: Peak Flow Estimates

Location	Area (ha)	Peak Flow Estimate (m^3/s)						
		2-year	10-year	200-year			Baseflow	
		Exist.	Exist.	Predev.	Exist.	Future	Winter	Summer
Un-routed SWMM Subcatchment Flows								
Kerfoot Cr.	224	0.67	1.38	3.30	5.95	6.40	0.016	0.005
Jacobsen Cr.	608	1.88	3.87	7.46	14.12	16.35	0.037	0.012
Highland Cr	368	1.00	1.96	4.63	6.94	7.08	0.022	0.007
Twin Cr	418	1.65	3.42	4.77	12.55	14.70	0.025	0.008
Kuhn Cr	355	0.96	2.02	3.61	7.66	9.95	0.022	0.007
Sam Hill Cr.	511	1.69	3.42	4.42	10.82	14.91	0.031	0.010
Fergus Cr	813	4.94	6.83	6.71	23.25	29.85	0.050	0.016
McNally Cr.	210	2.07	2.88	2.87	8.82	9.38	0.013	0.004
Routed MIKE11 Flows								
Surrey/TOL Border 14+630	**2,956** (2,738 TOL) (34 SUR) (184 WASH)	6.96	11.56	26.34	36.75	40.09	0.180	0.059
Total Watershed 0+000[1]	**7,575** (3,168 TOL) (3,717 SUR) (524 WASH) (166 WR)	30.51	34.37	61.24	76.96	83.88	0.462	0.152
McNally Creek 3+120[2]	**7,149** (3,168 TOL) (3,457 SUR) (524 WASH)	16.60	25.43	54.76	72.36	78.82	0.436	0.143
Fergus Creek 3+157[2]	**6,366** (3,168 TOL) (2,644 SUR) (524 WASH)	14.96	22.89	48.45	64.83	70.41	0.388	0.127
Kuhn Creek 7+321[2]	**5,405** (3,168 TOL) (1,852 SUR) (385 WASH)	13.15	20.69	44.00	62.22	71.71	0.330	0.108
Sam Hill / Twin Creeks 9+185[2]	**4,377** (3,168 TOL) (824 SUR) (385 WASH)	11.04	17.31	37.27	51.96	57.99	0.267	0.088
Jacobsen / Highland Creeks 11+549[2]	**3,287** (2,738 TOL) (365 SUR) (184 WASH)	7.91	13.07	29.34	41.21	45.26	0.201	0.066
Fernridge / Campbell Heights 18+864[2]	**2,415** (2,231 TOL) (184 WASH)	6.32	10.67	23.70	33.06	35.78	0.147	0.048

[1]Tidally influenced.
[2]Location is on LCR mainstem at upstream boundary of ISMP area.

WATER LEVEL PROFILES

Figures 3-8A to 3-8C show the 200-year water level profiles for the pre-development, existing, and future OCP land uses. The model results are based on lumped catchment models which do not include any stormwater management facilities that may be present in the watershed. Including this level of detail was beyond the scope of this study however, it should be included in the ISMP studies that will follow and the proposed Little Campbell River main stem MIKE11 model update. The bridge deck elevations for the major river crossings as well as the 2-year and 10-year peak water level profiles are also shown. Undersized culverts and inadequate bridge openings and freeboard can cause backwatering and flooding. Table 3-5 summarizes the 200-year water levels for each major crossing and 200-year flood depth for those locations that experience flooding. Figure 3-9 shows the locations of the undersized major crossings.

The water levels in the lower reaches of the Little Campbell River are tidally influenced. Two scenarios were examined to determine a 200-year return period peak water level in these lower reaches. First, a 200-year peak flow within the river with an average winter high tide level (El. = 1.94 m) was simulated. Second, a high tide plus 200-year storm surge peak sea level (El. = 2.63 m) was modelled in combination with an average (2-year) peak flow in the Little Campbell River. The higher of the two water levels was taken as the 200-year peak water level. Downstream of river chainage of approximately 1+900 m the 200-year sea level model governs the peak water levels in Little Campbell River.

The models show a noticeable increase in peak water level from pre-development (forested) to existing land use conditions. The existing and future land use water levels are similar upstream of 12 Avenue but show a noticeable increase downstream of 12 Avenue where a majority of the future development is planned.

EXTENTS OF FLOODPLAIN

The OCP shows areas that will be further developed in the future. Several of these areas may encroach on the Little Campbell River floodplain, causing possible floodplain loss. Table 3-6 lists the 200-year peak water levels at the development areas that are adjacent to the river. The 200-year floodplain extents were estimated based on the modelled future land use with existing conveyance system 200-year peak water levels and the available 1 m contour mapping. Figure 3-9 shows the overall Little Campbell River mainstem floodplain extents. More detailed figures in specified ISMP areas are shown on Figures 8-3, 9-3, 10-3, 11-3, 12-2, and 13-2.

Table 3-5: 200-Year Flood Levels at LCR Mainstem Crossings

Location	Bridge / Culvert ID#	Roadway Elevation (m)	200-Year Pre-dev.		200-Year Existing		200-Year Future	
			Flood Levels (m)	Overtopping Depth (m)	Flood Levels (m)	Overtopping Depth (m)	Flood Levels (m)	Overtopping Depth (m)
Hwy 99	C-1, C-2, C-3	8.00	4.15		5.44		6.00	
172 St.	C-5, C-6	7.89	5.14		6.21		6.82	
176 St.	C-7, C-8	9.53	5.67		6.9		7.61	
Private Rd (17948 8 Ave.)	B-9	6.08	5.92		7.00	0.92	7.68	1.60
8 Ave.	C-11	7.59	7.39		7.94	0.35	8.16	0.57
12 Ave.(WL Gauge)	B-12	8.98	9.13	0.15	9.42	0.44	9.50	0.52
184 St.	C-13,C-14, C-15	11.60	11.69	0.09	12.24	0.64	12.33	0.73
Fish and Game Club Rd.	B-14	13.07	12.44		12.95		13.19	0.12
16 Ave. (At 194 St.)	B-22	29.21	29.34	0.13	29.58	0.37	29.64	0.43
24 Ave. (At 198 St.)	C-19, C-20, C-21	42.26	41.93		42.44	0.18	42.54	0.28
200 St.	B-26, B-27, B-28	48.20	47.90		48.43	0.23	48.50	0.30
Private Rd (20162 27 Ave.)	B-30	50.90	50.34		50.55		50.54	
24 Ave. (At 204 St.)	B-35, B-36	53.80	53.01		53.22		53.26	
Old 16 Ave.	B-37	54.57	54.11		54.62	0.05	54.72	0.15
16 Ave. (East of 200 St.)	B-38	56.83	54.42		54.89		54.99	
Trail	B-39	54.58	54.42		54.89	0.31	54.99	0.41
North Boardwalk	B-40	54.60	54.46		54.91	0.31	55.01	0.41
South Boardwalk	B-41	55.20	54.60		55.02		55.13	
216 St.	B-42	58.91	58.94	0.03	59.02	0.11	59.03	0.12
Private Rd (21982 6 Ave.)	B-43	59.80	59.84	0.04	60.06	0.26	60.06	0.26
224 St.	B-44	61.64	60.92		61.39		61.43	
232 St.	B-47	65.51	64.54		65.00		65.07	
240 St.	C-25	73.00	70.75		71.79		71.98	

Refer to Figures 2-1 A-F for locations of crossings

Table 3-6: Flood Levels at OCP Development Areas Adjacent to Little Campbell River

Location	Existing Land Use 200-year Peak Water Level (m)	Future Land Use 200-year Peak Water Level (m)
Fernridge (LCR6_L)	36.06	36.11
Campbell Heights (LCR7_S)	30.37	30.43

3.8 SUMMER AND WINTER BASEFLOWS

The flow records at the 12 Avenue gauge were reviewed to estimate the average winter and summer baseflows within the Little Campbell River. The winter baseflow was estimated at approximately 0.3 m^3/s, which equates to a unit baseflow of 0.061 L/s/ha. The summer baseflow was approximately 0.1 m^3/s or 0.020 L/s/ha.

Piteau Associates studies have found that creeks in southwestern B.C. generally indicate unit baseflow rates vary between about 0.01 to 0.05 L/s/ha. Bertrand Creek in Langley, which generally has lower baseflows, showed a baseflow range from 0.002 to 0.007 L/s/ha (KWL, 2006). Thus the recorded Little Campbell River baseflows appear reasonable.

It should also be noted that the baseflows recorded at the 12 Avenue gauge include the effects of licensed water withdrawals upstream of this location. The Township of Langley groundwater study (Golder, June 2006) indicated that from 1961 to 2003 there was an observed 4% reduction in Little Campbell River baseflows and predicted a further 5% reduction in baseflows from 2003 to 2018. The lower baseflows are due to increased water withdrawals from aquifers.

The unit baseflows (0.061 L/s/ha winter and 0.020 L/s/ha summer) were applied to each catchment area to determine a baseflow for input into the MIKE11 model. The baseflow depth estimates at strategic locations are summarized in Table 3-7.

As shown in the table, the baseflow depths are generally less than 1 m. The variability in the baseflow depths is due to the irregular bed profile. The depths in excess of 1 m are likely taken in a deeper pool upstream of a controlling cross section in the channel while the shallow depths are likely at the controlling sections.

Table 3-7: Water Depths During Baseflow Conditions

Location	Bridge / Culvert ID#	Summer Baseflow Depth (m)	Winter Baseflow Depth (m)
Hwy 99	C-1, C-2, C-3	1.09 (tidally influenced)	1.39 (tidally influenced)
172 St.	C-5, C-6	0.62	0.95
176 St.	C-7, C-8	0.95	1.14
Private Rd. (17948 8 Ave.)	B-9	0.11	0.35
8 Ave.	C-11	0.09	0.24
12 Ave. (WL Gauge)	B-12	0.58	0.68
184 St.	C-13,C-14, C-15	0.20	0.29
Fish and Game Club Rd.	B-14	0.04	0.11
16 Ave. (At 194 St.)	B-22	0.11	0.20
24 Ave. (At 198 St.)	C-19, C-20, C-21	0.08	0.13
200 Ave.	B-26, B-27, B-28	0.14	0.25
Private Rd. (20162 27 Ave.)	B-30	0.13	0.22
24 Ave. (At 204 St.)	B-35, B-36	0.08	0.13
16 Ave. (East of 200 St.)	B-38	0.24	0.39
South Boardwalk	B-41	0.10	0.20
216 St.	B-42	0.10	0.16
Private Rd. (21982 6 Ave.)	B-43	0.17	0.24
224 St.	B-44	0.10	0.19
232 St.	B-47	0.07	0.16
240 St.	C-25	0.40	0.43
Refer to Figures 2-1 A-F for locations of crossings			

Section 4

Water Quality and Benthic Invertebrates

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4. WATER QUALITY AND BENTHIC INVERTEBRATES

The environmental assessment component of the Little Campbell River Integrated Stormwater Scoping Study is separated into three parts:

1. water quality and benthic invertebrates;
2. fish and fish habitat; and
3. biodiversity.

Sections 4, 5, and 6 present a summary of the environmental assessment. The environmental assessment in its entirety is included in Appendix C.

4.1 INTRODUCTION

Many watersheds in the Metro Vancouver region where ISMPs or other watershed-scale planning has been undertaken are relatively urbanized watersheds with limited water uses and little existing data on water quality. With respect to water quality, the Little Campbell River (LCR) is unique from most Metro Vancouver watersheds in several ways:

- Detailed water quality data is available for a wide range of water quality parameters as a result of ongoing monitoring in the watershed.
- Specific water quality issues have been identified by previous studies.

  There are a larger number of potentially sensitive water uses in the LCR relative to most Metro Vancouver watersheds.
- Specific water quality objectives have been previously set for the LCR watershed.
- There are a larger range of land uses and land use activities in the LCR than many Metro Vancouver watersheds that are potential sources of pollution.
- Water quality impacts of the LCR to its receiving environment are an important international environmental protection and wildlife conservation issue.

These unique characteristics of the LCR are a result of the importance of downstream water uses that depend on adequate water quality (e.g., fisheries, shellfish harvesting, wildlife and aquatic life), longstanding concerns from several levels of government about water quality in the watershed, and the presence of several active stakeholder groups interested in water quality.

4.2 SUMMARY OF EXISTING WATER QUALITY INFORMATION

This section summarizes available information from the above sources (and others) on different water quality indicators relevant to watershed health in the LCR. First, it is explained how each indicator relates to watershed health and general factors that can affect that indicator's status. Using the above data and reporting, then each parameter's current status is assessed in the LCR (if known) relative to established water quality objectives, any observed trends over time, and any known or suspected relationships to land use in the watershed.

BACTERIOLOGICAL/FECAL COLIFORM

Fecal coliform (FC) bacteria originate in waste from warm blooded organisms including humans, cattle, birds, dogs, and wildlife. FC bacteria are not pathogenic but are an indicator of other enteric pathogens such as *E. coli* bacteria[1], protozoa, and viruses. These pathogens can cause gastro-intestinal illnesses in humans and farm animals.

The West Sub-watershed (the lower 16% of the LCR watershed, including City of White Rock) appears to be the greatest contributor of FC contamination across all seasons, but especially in the summer. The key findings for fecal coliform in the watershed are:

- Fecal coliform levels in the LCR watershed have improved compared to the 1970s but are still elevated and periodically exceed guidelines, particularly in the lower watershed.
- The West Sub-watershed (including City of White Rock) is the largest contributor of fecal coliforms to the LCR mainstem, especially but not exclusively in the summer months.
- Urban runoff from stormwater outfalls is the largest contributor to fecal coliform loadings at the LCR mouth.
- Agricultural runoff is a secondary source of fecal coliform contamination but effects are largely localized.
- Failing on-site sewage disposal systems do not appear to contribute to fecal coliform contamination at this time.

[1] *E. coli* bacteria can be measured directly but *E. coli* records for the LCR are sparse and have not been used as an indicator of bacteriological water quality in the watershed to date. Fecal coliform has been used as an indicator in the LCR watershed since 1973.

TURBIDITY AND SUSPENDED SOLIDS

Turbidity is a measure of the amount of light intercepted by suspended particles in the water column, including sediments, microscopic organisms, and pollutants. It is typically measured in NTUs[2]. Total suspended solids (TSS) measures the amount of mass of suspended particles in a given volume of water. Turbidity and suspended solids are somewhat related, however, they often have different causes and effects. High turbidity is generally caused by very fine particles in the water column such as colloidal particles (e.g., clays) whereas high TSS is often caused by larger particles, such as silt and sand.

Some turbidity and suspended solids are a result of natural erosion and decay processes within aquatic ecosystems. However, human activities that remove riparian vegetation or change stream hydrology (i.e. through channelization or dyking) can disrupt natural patterns of sediment transport and increase erosion, which can substantially increase suspended solids. Both turbidity and suspended solids in the LCR frequently exceed the water quality objectives for these parameters. The key findings for turbidity and TSS in the watershed are:

- Both turbidity and total suspended solids regularly exceed guidelines in the LCR mainstem as measured at the 12 Avenue monitoring station.
- Construction runoff has likely contributed to extreme turbidity events and large increases in sediment loading.
- Non-point turbidity and sediment sources (e.g., agriculture, riparian removal) may also increase turbidity and suspended solids during high rainfall periods.

DISSOLVED OXYGEN

Dissolved oxygen (DO) is a measure of the amount of gaseous oxygen dissolved in water. In streams, oxygen enters the water through diffusion from the surrounding air, by aeration as water moves over substrates, and from photosynthetic activity. High and stable oxygen levels are important to maintaining suitable conditions for many aquatic biota, including spawning and rearing salmon, and benthic invertebrates. DO can be affected by many factors, including water temperature, pH, flow conditions, and the photosynthetic rates of algae and aquatic plants.

[2] NTU = Nephelometric Turbidity Unit. The term *nephelometric* refers to the way the instrument estimates how light is affected by suspended particulate material in the water. A nephelometer, also called a turbidimeter, uses a photocell to estimate scattered rather than absorbed light. This measurement generally provides a very good correlation with the concentration of particles in the water that affect clarity.

DO reaches extremely low levels (<2.0 mg/L) in the LCR in summer/early fall and is a serious issue for aquatic life in the upper reaches of the watershed, particularly for juvenile salmonid populations. The key findings for dissolved oxygen in the watershed are:

- DO reaches extremely low levels in the upper reaches of the LCR in summer/early fall causing periodic mortality of coho fry.
- DO levels are also often below minimum objectives from October to February when salmonid eggs, larvae and alevin are present.
- Extremely low DO levels in the upper watershed in summer are likely caused by low flows and high water temperatures.
- Reduced DO levels in winter may be due to high BOD from nutrient and sediment loading in surface runoff.

NUTRIENTS

Dissolved nutrients in streams occur naturally and are essential to the functioning of aquatic ecosystems. However, high levels of some nutrients, such as nitrogen (including ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-)) and phosphorus (e.g., orthophosphate) from anthropogenic sources can result in toxicity to fish or can cause eutrophication which lowers dissolved oxygen levels. Nutrient enrichment from excess application of manure or chemical fertilizers to agricultural fields is a concern to water quality worldwide.

LCR-specific water quality objectives for nutrients have been developed for ammonia and nitrite. These objectives have been met regularly since attainment monitoring began. The key findings for nutrients in the watershed are:

- Ammonia and nitrite levels consistently meet objectives in the LCR watershed and are consistent with low levels of anthropogenic enrichment.
- While nutrient objectives directly protect aquatic life against toxicity, it is unclear whether these objectives will protect against indirect effects, such as eutrophication in the LCR watershed.
- Nitrate and orthophosphate levels are well below national and provincial guidelines in the mainstem but may be higher than desirable within specific sub-catchments (e.g., Twin Creeks).

WATER TEMPERATURE

Maintaining suitable water temperatures is important to the survival and growth of fish and other aquatic life in streams. Water temperatures can affect the development of fish eggs, rearing of juvenile fish, and the return of adult salmonids to spawn. Fish and invertebrate assemblages in the LCR watershed are generally adapted to cold water conditions.

Historical records of surface water temperatures in the LCR provide evidence that water temperatures likely often exceed the preferred range for fish, especially (but not limited to) during the summer months and in the upper portions of the watershed. While it is known that water temperatures exceed suitable levels for salmonids, the magnitude and duration of temperature effects in the LCR is largely unknown. The key findings for water temperature in the watershed are:

- Water temperatures in the LCR periodically reach levels capable of inducing chronic effects on salmonid growth and survival, especially during the summer months in the upper reaches of the watershed.
- The magnitude and duration of these elevated temperatures is currently unknown but are being assessed.
- Increased water temperatures are likely caused by lack of riparian vegetation and low water levels due to ground and surface water extraction.

pH

pH measures the relative acidity or alkalinity of a solution. The pH scale runs from 0 to 14 (i.e. very acidic to very alkaline), with pH 7 representing a neutral condition (pure water, for example). Stream pH level depends on the geology of the surrounding area, and usually falls between 6.5 and 8.0.

pH objectives have been met historically and are met currently in the LCR watershed. pH is not a current water quality concern.

OTHER CONTAMINANTS

Other contaminants of potential concern in the LCR watershed include metals, persistent organic pollutants, endocrine disrupting chemicals, and antibiotics/pharmaceuticals but levels and effects are largely unknown. Some metals may exceed recommended guidelines at localized sites in the watershed and are generally associated with more urbanized catchments.

4.3 SUMMARY OF BENTHIC INVERTEBRATES INFORMATION

The ISMP Template emphasizes the use of benthic invertebrates to assess and monitor watershed health. Under the Template, benthic communities are assessed using the Benthic Index of Biological Integrity (B-IBI) score which ranges from 10 in highly degraded streams to 50 in pristine, old growth watersheds. Pristine, second growth watersheds in the lower mainland have scores of approximately 40. Through the City of Surrey's benthic invertebrate sampling program, four B-IBI sampling sites were established in the Surrey portion of the Little Campbell River watershed to provide baseline information in advance of ISMP planning initiatives (see Figure 4-1). To our knowledge, no benthic invertebrate sampling has occurred in the Township of Langley portion of the watershed.

Available sampling results to date indicate that B-IBI scores in the LCR mainstem range from 18 to 28. Generally, stream conditions are better at the upstream site versus the downstream site. The Fergus Creek sites have a fairly consistent B-IBI score of 14. Stream conditions within the Fergus Creek tributary are substantially degraded compared with the mainstem sites.

Benthic invertebrate sampling has also been undertaken using the reference condition approach (RCA) within the Surrey portion of the LCR watershed. The RCA approach advocated by the Canadian Aquatic Biomonitoring Network (CABIN) results show that the status of invertebrate communities at some sites became more stressed in 2008 with greater impacts from urban development.

4.4 PRIORITY ISSUES

Several priority water quality issues have emerged from existing water quality and benthic invertebrate data that should be specifically addressed in ISMP planning:

1. **Fecal coliform from urban sources** – The largest sources of fecal coliform contamination to the LCR and the waters of Semiahmoo Bay appear to be urban runoff from stormwater outfalls near the LCR mouth.

2. **Low dissolved oxygen/high temperatures during summer months** – Low dissolved oxygen levels and high temperatures in the summer months, particularly in the upstream portions of the LCR mainstem, are a significant and ongoing threat to salmon and trout populations and other aquatic life in the watershed. Maintaining or improving DO and temperature conditions through the provision of adequate flows, remediation of runoff, and restoration of riparian vegetation should be a top priority to stormwater planning in the watershed. Involvement in the ISMP process from the provincial government, which regulates water withdrawals, is important to addressing this issue.

3. **Construction-phase turbidity from development** – Preliminary continuous monitoring data and anecdotal reports suggest that turbidity from the construction phase of large development projects at several locations in the watershed, including Campbell Heights and High Point, are increasing turbidity to levels detrimental to stream health. Management and control of sediment on these construction sites is not

adequately preventing sediment from entering watercourses, despite better sediment and erosion control planning and municipal regulation.

4. **Bank erosion** – Riparian vegetation removal and channelization of sections of the LCR mainstem have destabilized stream banks and increased channel scouring and bank erosion. Future development has the potential to increase impervious area, increasing peak flows by replacing subsurface flow with more rapid surface flows. This will increase erosion problems in areas of the LCR mainstem.

4.5 MANAGEMENT OBJECTIVES FOR WATER QUALITY IN ISMP PLANNING

The ISMP Template requires consideration of water quality in stormwater management planning. However, the current ISMP Template does not require that specific conditions be maintained, water quality objectives be met, or that watershed-specific objectives be set. The current ISMP Template does not adequately meet the needs of planning in the LCR and the obligations under the LWMP with respect to water quality. A revision to the ISMP Template is planned for 2011 which may address the above concern.

In addition to the ISMP Template, several acts, plans, and bylaws regulate the impacts of stormwater on water quality the LCR watershed (see Appendix C for details).

For ISMPs in the LCR to remain relevant to water quality in this watershed and fulfill its obligations under the LWMP, the ISMP process used should address the most sensitive water uses and tie in to existing water quality objectives that are specifically aimed at protecting these objectives.

Section 5

Fish and Fish Habitat

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5. FISH AND FISH HABITAT

This section presents a summary of the fish and fish habitat portion of the environmental assessment. The environmental assessment in its entirety is included in Appendix C.

5.1 INTRODUCTION

One of the drivers of stormwater management planning in Metro Vancouver is the protection of fish and fish habitat. This stems from the importance of the federal Fisheries Act in regulating both direct and indirect effects of urbanization on fish populations, but also the historical focus on fish, particularly salmonids, in environmental management in coastal B.C.

The City of Surrey, through its Natural Drainage Policy, and the Township of Langley have chosen to maintain and, where possible, enhance open watercourses. As a result, both municipalities have natural streams that are important spawning and rearing habitat for several species of salmonids. Fish and fish habitat are an important consideration in both the City of Surrey's and the Township of Langley's stormwater management and overall planning.

The ISMP Template addresses fish and fish habitat in Clause 9. Clause 9 mandates the inventory of aquatic species and their habitat and the identification of opportunities for environmental enhancement. Emphasis in previous ISMPs completed in Metro Vancouver has been on protecting aquatic habitats for salmonids. Common foci of planning include removing barriers to fish migration within stream reaches (such as raised culverts), enhancing spawning and rearing habitat (e.g., cover, substrates), and protecting water quality and flow regimes (hydrology).

5.2 SALMON AND TROUT POPULATIONS

The LCR is one of the most highly productive salmon rivers in the Lower Mainland relative to its size. Five species of salmonids have self-sustaining wild populations in the watershed (Table 5-1). Records of sockeye and pink salmon also exist for the LCR but these occurrences are likely due accidental migrations of individual fish up the wrong home stream. Several of the salmonid populations in the LCR have been or are currently augmented by regular hatchery releases of fry or smolts into the river by the Semiahmoo Fish & Game Club (as denoted in Table 5-1).

Table 5-1: Salmon and Trout Species in the LCR Watershed

Common name	Scientific name	Source	Status/comments
Chinook salmon	*Oncorhynchus tshawytscha*	SFGC, FISS 2008	Wild and hatchery pop'ns
Chum salmon	*Oncorhynchus keta*	SFGC, FISS 2008	Wild pop'ns[1]
Coho salmon	*Oncorhynchus kisutch*	SFGC, FISS 2008	Wild and hatchery pop'ns
Pink salmon	*Oncorhynchus gorbuscha*	FISS 2008	Unverified; accidental?
Sockeye salmon	*Oncorhynchus nerka*	FISS 2008	Unverified; accidental?
Steelhead/rainbow trout[1,2]	*Oncorhynchus mykiss*	SFGC, FISS 2008	Wild and hatchery pop'ns
Cutthroat trout	*Oncorhynchus clarki*	SFGC, FISS 2008	Wild and hatchery pop'ns

Abbreviations for sources: SFGC = Semiahmoo Fish & Game Club, FISS = Fisheries Information Summary System
[1]Approximately 500 hatchery-raised chum fry were released in 2009 from LCR wild stock taken in fall 2008. This was an initial trial by SFGC at hatchery raising this species. No other hatchery augmentation had occurred prior to this trial.
[2]includes both anadromous (sea-run) and non-anadromous (resident) forms.
[3]Steelhead are an anadromous form of rainbow trout that migrate to sea and return to their home streams to spawn.

Coho salmon is the most abundant salmon species with a long term adult escapement of around 2,150 fish per year. Long-term average escapement for other species (wild and hatchery fish combined) are: chum (249); chinook (179), steelhead (147), and cutthroat trout (30). Steelhead and sea-run cutthroat trout populations have declined substantially since the 1980s, and coho salmon have declined to less than half their long-term average since 2004.

5.3 FISH HABITAT

Both the City of Surrey and Township of Langley have classified all watercourses within their boundaries using colour codes according to their potential to be salmon bearing. Anadromous[3] wild fish have access to at least 26 km upstream (240 Street) on the Little Campbell River mainstem; to at least 1 km upstream of the mouth of McNalley Creek; to 14 Avenue on Fergus Creek (where there is an impassable culvert); to the headwaters of Sam Hill Creek; and to the 8 Avenue culvert on Jacobson Creek (CMN 2008). Good potential rearing habitat exists in the middle reaches of the watershed in the area of the mid-basin wetlands at Campbell Valley Regional Park but this potential is offset by low water flows during the summer months (CMN 2008).

Sensitive Habitat Inventory and Mapping (SHIM)[4] has also been used in the watershed to inventory and map fish habitat features and threats. SHIM has identified that the best spawning and rearing habitat is currently found in the lower reaches of the watershed (CMN 2008).

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3 Anadromous = describes fish which migrate from the ocean to fresh water to reproduce (spawn).

4 Sensitive Habitat Inventory and Mapping (SHIM) = a protocol for mapping watercourses with a Global Positioning System (GPS) unit and marking down the location of notable features such as culverts, obstructions, wetlands, erosion points, and fish sightings. See Mason and Knight (2001) for more info on the methods.

5.4 RIVER CHANNEL ASSESSMENT

Existing and newly collected data were used on channel conditions to describe general patterns of river channel characteristics in the LCR mainstem. The river's mainstem was divided into thirty 1 km long segments from the mouth to upstream of 240 Street which were used to characterize general channel conditions (see Figure 5-1). From a perspective of reach characterization, the LCR has only five main reaches:

1. tidal estuary;
2. lowland agricultural reaches to 184 Street;
3. gravel reaches from 184 Street to 24 Avenue;
4. mid-basin wetlands (to 232 Street); and
5. low gradient headwater reaches (above 232 Street).

Representative photos of each river segment are included on Figure 5-1. Key observations on channel conditions include:

- The LCR is a lowland river with average channel gradient under 0.5% and rarely greater than 1%.
- The mid-basin wetland complex is unique component of the LCR mainstem and influences the movement of sediment, large wood, and other organic materials from the headwaters to the lower reaches.
- Channelization and culvert or bridge installation has caused relatively little change to the LCR mainstem.
- Much of the bank erosion observed in the watershed is considered a natural part of river channel processes.
- The frequency of large woody debris (LWD) was extremely variable in river segments but generally low.
- Stream bed substrates are predominantly gravel and sand with increasing amounts of silt near the estuary.

5.5 RIVER CORRIDOR ASSESSMENT

Riparian land cover has a critical function for fish habitat because of its influence on physical, biological and chemical processes in the river, as well as the degree which these processes are affected by anthropogenic activities. Analyses were undertaken for a 250 m wide buffer and a 30 m wide corridor which is similar to the riparian forest integrity analysis described in the ISMP template.

For the 250 m buffer, land cover was predominantly forest (40.9%) and agriculture (24.9%). Table 5-2 shows the complete breakdown of land cover within the 250 m buffer.

Table 5-2: Land Cover Within 250 m (including 30 m riparian corridor) of the LCR Mainstem

Habitat Class	Area (%)	Area (ha)
Agriculture	24.9%	30.8
Developed	9.2%	11.3
Forest	40.9%	50.6
Grassland	4.1%	5.1
Landscaped	7.0%	8.7
Shrub Land	3.3%	4.1
Sparsely Vegetated	1.1%	1.3
Wetland / River Channel	9.5%	11.8
Total	**100.0%**	**123.7**

For the 30 m buffer, land cover was dominated by forest (39.9%), wetland (31.5%), grass (9.5%), and agriculture (8.3%). There are only 2.3% developed areas within 30 m of the centreline of the river.

The primary patterns of land cover in the river corridor are:

- low levels of developed and agricultural land cover in the lower segments (1–4), particularly in Semiahmoo First Nation's lands;
- rapidly increasing agriculture land cover through Segments 5–11 with over 85% of the river corridor used for agriculture in Segment 8. These segments are also associated with cattle grazing in some areas (e.g., upstream from 8 Avenue), bank erosion, and reed canary grass in floodplain areas;
- segments 9–17 have a high amount of forest cover; these areas, perhaps because of soil or topographic conditions, were not cleared as much for agriculture;
- increasing wetland occurrence through the mid-basin area (Segments 19–25); and
- more agriculture in Segment 18, and in Segments 24–30.

Section 6

Biodiversity

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6. BIODIVERSITY

This section presents a summary of the biodiversity portion of the environmental assessment. The environmental assessment in its entirety is included in Appendix C.

6.1 INTRODUCTION

Biodiversity (or biological diversity) is the variety and abundance of living organisms in a particular region. For this report, biodiversity is defined broadly to include both the diversity of animal and plant species as well as the diversity of ecosystems and habitats that sustain them. Biodiversity is an especially important consideration to planning initiatives in the LCR watershed for the following reasons:

- The LCR watershed has regionally significant populations of several priority and at-risk aquatic and terrestrial species.
- The mid-basin wetland and associated riparian areas in Campbell Valley Regional Park and the marine foreshore on Semiahmoo Bay are regionally significant reservoirs for biodiversity.
- The receiving waters of the LCR are an internationally recognized Important Bird Area (IBA).
- The LCR is a relatively intact watershed with a large amount of undeveloped and semi-natural land, relatively to other Metro Vancouver watersheds.
- Maintenance of biodiversity is an important part of community values and water uses.

6.2 SUMMARY OF EXISTING BIODIVERSITY INFORMATION

Limited biodiversity monitoring has been carried out on a watershed-wide basis to date and therefore the available biodiversity information is summarized as rare species occurrences and important habitats.

RARE SPECIES

Past surveys of habitats in the LCR have identified occurrences of several rare species in the watershed (see Appendix C for details). Rare species are distributed widely throughout the watershed although Campbell Valley Regional Park, several smaller wetlands (Latimer Pond, Horne Pit), and Fergus Creek are important habitats for multiple rare species.

REVIEW OF IMPORTANT HABITATS

A review of important habitats in the LCR was completed using existing information, orthophotography, and mapping, as well as personal knowledge of the authors. New mapping of the riparian corridor and forest cover were undertaken as part of this study (see Appendix C for details).

Table 6-1 shows the classification scheme developed to discuss habitat for biodiversity in the LCR. Note that the three broad classes of habitat are the same habitat types that currently define each of the biodiversity-related clauses of the current ISMP Template. This habitat classification may be suitable for future more detailed work.

Table 6-1: Classification Scheme for Habitats Important to Biodiversity in LCR Watershed

Habitat Class	Habitat Subclass	Habitat Type
Aquatic	Rivers and streams	▪ LCR mainstem and larger tributaries ▪ Off-channel habitats ▪ Small tributaries/headwater streams
	Wetlands	▪ Fluvial wetlands ▪ Ponds ▪ Seasonally-flooded fields ▪ LCR Estuary
Riparian		▪ Riparian forest ▪ Non-forested riparian communities
Upland terrestrial	Forest	▪ Large forest patches ▪ Small forest patches and isolated trees
	Agricultural-associated habitats	▪ Old fields ▪ Hedgerows

Aquatic Habitats

Many species are dependent on aquatic habitats for all or a part of their life cycle. Because aquatic habitats are directly influenced by the quantity and quality of water entering from upstream sources, these habitats are the most sensitive to stormwater management decisions.

Rivers and Streams

Rivers and streams provide important spawning and rearing habitat for salmonids and other fish as well as movement and migration corridors between other habitats (e.g., oceans and lakes). Unique components of LCR's watercourses used directly by wild salmonid populations at different life history stages are:

1. LCR mainstem and larger tributaries;
2. Off-channel habitats; and
3. Small tributaries/headwater streams.

Rivers and streams and associated biodiversity are threatened by changes to the quality and quantity of runoff in developed areas. Fecal coliform contamination from urban areas is of ongoing concern in the LCR. Turbidity and sedimentation from the construction phase of development is also a problem in some areas. Decreased dissolved oxygen and increased water temperatures during the summer months may be a result of water withdrawals and the loss of riparian vegetation along sections of the LCR mainstem. Channelization, dyking, dredging, culverting, loss of woody debris, and changes in sediment transport patterns because of channel modifications or flow changes can all alter valuable fish habitat.

Wetlands

After tropical rainforests, wetlands are among the most biodiversity-rich habitats in the world. Wetlands provide habitat to a wide variety of unique plants, invertebrates, fishes, amphibians, reptiles, and mammals, as well as both migratory and resident waterbirds. Wetlands store surface water and release it gradually, reduce water velocity and erosion, and help to purify water by removing pollutants, such as nitrogen, phosphorus, and fecal coliform. Major wetland types in the LCR include:

1. Fluvial wetlands;
2. Ponds;
3. Seasonally-flooded fields; and
4. The LCR Estuary.

Wetlands and associated biodiversity in the LCR are threatened by the draining and infilling from urban development and agriculture. When wetlands are lost, their important functions in protecting aquatic resources are also lost or disrupted. Indirect impacts on wetlands can also occur from surrounding development through changes in water table infiltration from imperviousness or water withdrawals. Pollution and runoff from agriculture, such as pesticides and fertilizers, are also a concern. Invasive species are increasing in their distribution and abundance in the watershed.

Riparian Habitats

Riparian habitats (also called the riparian zone) are the portion of land adjacent to the normal high water line in a stream, river, lake, or pond. Because of their proximity to water, riparian zones have moist, rich soils that support unique riparian plants, such as skunk cabbage (*Lysichiton americanus*) and Indian-plum *(Oemleria cerasiformis).* Many riparian-specialist species depend on both the aquatic and terrestrial component of these habitats for different activities or life history stages. Riparian corridors along watercourses are important movement corridors for some species. Intact riparian zones can also stabilize streambanks subject to erosion, regulate water temperatures, and filter pollutants from surface runoff before they enter watercourses. Riparian habitats in the LCR can be divided into riparian forest and non-forested riparian communities.

Much of the riparian corridor in the LCR has been fragmented by road construction and land clearing for agricultural or rural development. This has resulted in loss of riparian forest and shifted some riparian areas from coniferous forest to more pioneering deciduous and herbaceous species. Riparian forest loss also causes increased soil erosion and higher stream temperatures, impacting the quality of aquatic habitats. In some areas, stream channelization and agricultural activities such as livestock watering have also impacted riparian habitats. Pollution, garbage, yard waste dumping, and introductions of invasive species are also detrimental to riparian habitats in the LCR.

Upland Terrestrial Habitats

Upland terrestrial habitats are natural or semi-natural habitats away from watercourses and other aquatic habitats. These habitats include areas of original or second-growth vegetation (such as coniferous and deciduous forests) or agricultural lands. The presence of these natural habitats is important from a stormwater perspective for evapotranspiration and infiltration (groundwater recharge) of precipitation, stabilizing slopes, and reducing soil erosion.

Forest

Forested habitats in the LCR can be divided into large forest patches and small forest patches and isolated trees. Fragmentation and clearing are the major threats to forests and forest-dependent species. Increasing edge and open areas lead to increased light and temperature and loss of moisture within the interior of the remaining patches. Forest dependent species then become vulnerable to introduced species and predators.

Agricultural-Associated Habitats

The locations of important agricultural-associated habitats in the LCR have not yet been assessed but in general include old fields and hedgerows. Urban and industrial development of agricultural lands is a threat to the ongoing persistence of old field habitats. The Agricultural Land Reserve (ALR) currently protects against this conversion but land removal from the ALR, while rare, does occur. The return of old fields to active cultivation, or conversion to non-compatible agricultural uses, such as greenhouses, also threaten the habitat value of old fields. Off-road vehicle activity is also a problem in some areas.

6.3 PRIORITY ISSUES

Several priority issues for biodiversity have emerged from existing information that should be specifically addressed in ISMP planning.

1. **Habitat impacts on fish populations** – Salmonid populations are under stress from the cumulative impacts of changes in water quality and quantity in the LCR mainstem and its tributaries, as well as changes to the physical structure of habitat. In some reaches, channelization has destabilized the stream channel, increasing scouring and erosion, and decreasing available spawning habitat. Dyking in some areas has

reduced the amount of available off-channel habitat. Barriers to fish migration are present in the watershed.

2. **Encroachment into mid-basin wetlands** – The significance of the mid-basin wetlands within Campbell Valley Regional Park to biodiversity is partially dependent on its adjacency to intact riparian and upland forest habitats. Continued developments in the Campbell Heights (Surrey), Fernridge (Langley), and High Point (Langley) areas of the watershed are decreasing natural habitats in the vicinity of the park.

3. **Loss and fragmentation of riparian forest** – The riparian corridor along the LCR mainstem has been deforested along some key sections due to clearing for agricultural development. Some riparian restoration has occurred but efforts to date have been largely volunteer-led and occurred at a small scale.

4. **Loss and fragmentation of upland forest** – Similar to the riparian corridor, land clearing for urban, rural, and agricultural development has reduced the amount and connectivity of forest cover in the upland portions of the watershed, especially in the lower portions of the watershed (west of 184 Street).

5. **Exotic species introductions** – With increasing development in proximity to natural areas within the LCR watershed, exotic species are becoming more prevalent in key areas important to biodiversity in the watershed. With the exception of Campbell Valley Regional Park, regular monitoring and control of invasive species is not occurring.

6. **Human disturbance** – Population growth is occurring rapidly in some parts of the LCR. This leads to increased pressure on natural areas to support human recreation. Uses may be incompatible with the presence of some species or may physically impact sensitive habitats.

6.4 MANAGEMENT OBJECTIVES FOR BIODIVERSITY IN ISMP PLANNING

The ISMP Template focuses the majority of effort on gathering existing information, inventory of fish and fish habitat, and assessing the integrity of the riparian corridor. However, while the current ISMP Template suggests that important areas and values are identified for protection, the template does not prescribe methods for identifying these areas or values, particularly for non-stream habitats. Currently, these objectives must be developed on a case-by-case basis with reference to other existing regulations.

In addition to the ISMP Template, several acts, plans, and bylaws regulate or guide the impacts of development or stormwater specifically on biodiversity in the LCR watershed and should be considered during the development of ISMPs (see Appendix C for details).

Section 7

Individual ISMP Scoping Issues and Prioritization

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7. INDIVIDUAL ISMP SCOPING ISSUES AND PRIORITIZATION

7.1 ISMP AREA DISCRETIZATION

A summary of the Little Campbell River watershed characteristics is included in Table 7-1. The overall watershed is divided into tributary subwatersheds based on topography. However, for the purposes of discretization into ISMP areas, some smaller tributary watersheds were combined and the portions of the Little Campbell River mainstem between major tributaries needed to be considered. The goal was to create ISMP areas in the order of 1,000 ha or less to make them manageable. Consideration was also given to the proposed land use within the subcatchments when deciding on the ISMP area delineation and size.

The major ISMP area delineation that was agreed upon by the municipalities is shown on the figures in the preceding sections. The ISMP areas and their sizes are summarized as follows, starting at the downstream end:

1. McNally Creek – 426 ha;
2. Fergus Creek – 813 ha;
3. Kuhn Creek – 931 ha;
4. Sam Hill / Twin Creeks – 1,028 ha;
5. Jacobsen / Highland Creeks – 1,090 ha;
6. Fernridge / Campbell Heights – 872 ha; and
7. Upper Little Campbell River – 2,415 ha.

For simplicity, all seven areas will be referred to as "ISMP areas" in this report. In general, all seven ISMP areas will have some increase in impervious area, some more than others. Riparian areas, fish habitat, water quality, and declining baseflows are an issue in all ISMP areas. Most of the areas also have large agricultural areas and should include recommendations for farm practices.

AGRICULTURAL SUBWATERSHED

The Upper Little Campbell River subwatershed is much larger than the target value. However, this subwatershed is not expected to undergo a significant amount of development and therefore consideration was given to whether the current ISMP process is relevant. The issues in this watershed relate to agricultural uses and water quality. A study and process that reviews agricultural use and recommends changes to farm practices would be more suitable. It is recommended that the next revision of the ISMP Template consider including a process for non-urban watersheds so that municipal obligations under the LWMP can be met effectively in such areas. A study to address farm practices, fertilizer application, sediment control, restricting livestock access to creek banks, irrigation water supply, and field drainage should be considered as a better alternative to the current ISMP process in non-urban watersheds.

Table 7-1: Summary of Little Campbell River Watershed Parameters

	Watershed Parameters		
Information	Drainage Area (ha)		7575
	Jurisdiction		
	White Rock		√
	Surrey		√
	Langley		√
	Blaine/Whatcom County		√
	First Nation		√
Land Use	Existing TIA - ha (% of subwatershed)[1]		11%
	Future TIA - ha (% of subwatershed)[1]		31%
	Change in TIA - ha (% of subwatershed)		21%
	New Development or Redevelopment (ha)		1554
	Existing Agriculture (ALR) (area in ha / % of subwatershed)		1,972 / 26%
	Existing Urban/Suburban (area in ha / % of subwatershed)		1,070.6 / 14%
	Existing Commerical/Industrial (area in ha / % of subwatershed)		107.0 / 1.4%
Surface Water	Flooding of Campbell River Crossings in 200-year (Pre-dev / Existing / Future)		5 / 9 / 10
	200-year Campbell River Floodplain area (ha)		387.5
	Erosion along Campbell River (# of points/total length)		110 points /1,478 m
	Sedimentation along Campbell River (# of points/length/width/area)		46 points / 939 m / 300 m / 150,636 m^2
	Natural Hazards on Campbell River (obstruction) (# of points)		55 points
	Baseflows- L/s (winter/summer)		0.06 / 0.02 L/s/ha
	Surface Water Extractions(# of PODs & flow (igpd))		81 / 1,161,689
Environmental	Existing Riparian Forest Cover - RFI (% of riparian area)		46%
	Existing Watershed Forest Cover (% of subwatershed)	(from MOE Report)	32%
		(from EMS)	34%
	Projected Watershed Forest Cover (% of watershed)		13%
	Projected Change in Watershed Forest Cover (% of watershed)		-21%
	Number of On-site Sewage Disposal Systems		2175
	Wetlands and Floodplain Areas (% of watershed)		7.3%
	Hydric Soils (% of watershed)		12.0%
	Fish and Fish Habitat	Fish-bearing streams (km/km^2)	14
		Major spawning/rearing areas	yes
	EMS Hubs (# of hubs / % of watershed)		33 / 22.2%
	EMS Corridors (km/km^2)		0.66
	Interior Forest from EMS (area in ha / % of watershed)		781.4 / 10%
	Species at Risk/Raptor Nests (# of species / # of known occurences)		23 / 33
	Wildlife Value (high/med/low)		high
Groundwater	Underlying Aquifer (name & confined/unconfined)		Brookswood / unconf. Langley Upland Intertill / conf. (deep) S. of Hopington / conf. Border / conf. Abbotsford / uncof. Central Hopington / conf. White Rock / conf. Hazelmere Valley / conf. Hazelmere / conf. Grandview / conf.
	Declining Aquifer Water Levels		yes
	Groundwater Extractions (# of wells / flow (igpm))		1,085 / 17, 405
	Infiltration Capability/Soils		Silt and Clay, Sand, Till, Peat, Sand and Gravel

[1] Total Impervious Area (TIA) does not reflect the effects of BMPs which reduce the Effective Impervious Area (EIA). EIA values do not necessarily equal TIA values, however estimating EIA values was beyond the scope of this study and should be done as part of the proposed ISMP studies.

7.2 SUMMARY OF WATERSHED AND SUBWATERSHED HEALTH

Figure 7-1 shows the existing and predicted future watershed health (B-IBI score) based on the indicators of impervious area and riparian forest integrity (RFI) on the Watershed Health Tracking System (WHTS). The existing and future impervious areas were estimated in this study and the RFI values were taken from the "Potential Pollution Sources in the Little Campbell River Watershed" (MOE, 2006) report. The WHTS shows that all seven proposed ISMP areas will likely experience a loss of health if future increases in impervious area are not mitigated. The future points do not include the effects of mitigation BMPs. The largest potential degradation is predicted for the Fernridge / Campbell Height ISMP area (9 B-IBI point reduction) and the smallest change is predicted for the McNally Creek ISMP area (<2 B-IBI point reduction).

7.3 ISMP SCOPING ISSUES AND PRIORITIZATION

Taking into account the various key issues and the timing of future development, the seven ISMP areas were ranked in order of priority to establish the order in which the studies should proceed.

In general, nearly all the ISMP areas had similar environmental issues (fecal coliforms from urban outfalls and agriculture, high TSS mainly from construction activities, low dissolved oxygen in summer and winter, high water temperature due to lack of riparian and low flows, baseflows dropping as water is withdrawn from aquifers, watershed forest cover loss and fragmentation, non-native species of plants and animals) and therefore the prioritization was largely based on the level of future development.

ISMP areas that are about to be developed should be the highest priority because the largest benefits can be realized if the ISMP recommendations are incorporated in the planning and design stages of the proposed developments. Developed ISMP areas where rehabilitation of existing development would result in large improvements should be the next highest priority. Refurbishing existing systems is much more difficult than incorporating BMPs into new development. Lastly, ISMP areas with little existing development, minor anticipated future development, and best environmental health should be the lowest priority studies. The seven ISMP areas were prioritized for further study as follows:

1. **Fergus Creek** – 813 ha - ISMP is already completed. The Fergus Creek ISMP (McElhanney Consulting Services, 2007) and the Fergus Creek Master Drainage Plan Update (New East Consulting Services, 2001) are already complete for the Fergus Creek area. The study area has considerable urban development and more is planned or underway. The predicted TIA increase is from 34% to 53%. The WHTS shows a current B-IBI score of 14 which could drop to 12 if mitigation processes are not in place for future development. It is recommended that the findings of the ISMP and MDP studies be followed along with other prudent development mitigation procedures.

2. **Fernridge / Campbell Heights** – 872 ha - ISMP to be completed. This area includes large development sites and a predicted TIA increase from 7% to 46%. Development is underway and more is anticipated.

3. **Sam Hill / Twin Creeks** – 1,028 ha - ISMP to be competed. Substantial development is planned with a predicted TIA increase from 10% to 34%. The area includes portions of Grandview Heights and Campbell Heights developments.

4. **Kuhn Creek** – 931 ha - ISMP to be completed. Development is planned and could have a predicted TIA increase from 4% to 32%. The Douglas NCP area is located in Kuhn Creek.

5. **Jacobsen / Highland Creeks** – 1,090 ha - ISMP to be completed. The High Point development is already under construction and includes LIDs and detention facilities. More development expected east of 204 Street with a predicted TIA increase from 3% to 22%.

6. **Upper Little Campbell River** – 2,415 ha – the current ISMP process is not recommended for this agricultural watershed. Study to recommend sustainable farm practices to be completed.

7. **McNally Creek** – 426 ha - ISMP Lite to be completed. Minor infill development is expected with a predicted TIA increase from 46% to 61%. The watershed is already highly developed.

Each ISMP area will be detailed with issues, summaries, and recommendations in subsequent sections.

7.4 INTERIM CRITERIA FOR IMMINENT DEVELOPMENT

The completion of the proposed ISMPs is anticipated to occur over the next several years. Meanwhile development is proceeding in a number of areas within the watershed. To minimize any potential watershed health losses in the interim, it would be useful to establish basic stormwater criteria and source control standards/examples to guide development until the ISMPs are completed. The interim criteria and standards may be replaced by the sub-watershed-specific criteria, source controls and regional facilities when they are completed.

The existing municipal stormwater and drainage criteria will apply to all development and re-development. This will include:

- flood protection criteria;
- detention criteria for flood, erosion and environmental protection;
- erosion and sediment control bylaw standards for the protection of water quality during construction and post-construction; and
- riparian protection and restoration using the provincial Riparian Areas Regulation and municipal bylaw(s) where appropriate.

Additional interim criterion to protect watercourse health and minimize erosion should include:

- **Volumetric Reduction for Environmental and Erosion Protection**: Provide 25 mm of capture during a 25 mm 24-hour rainfall event through evaporation, evapotranspiration, infiltration, or reuse in poor-draining soils. This capture amount corresponds to approximately 50% of the 2-year 24-hour rainfall. This target is less onerous than the DFO guideline, but is the target recommended in the Provincial Stormwater Guidebook and has been used in a number of other Surrey projects.

Typical examples and standards to meet this criterion would be useful to ensure implementation of source controls. The TOL and COS should adjust the interim BMP sizing and/or design if monitoring results show trend of decreasing watershed health. Once each ISMP study is completed, the typical examples and standards may be replaced by the specific source controls and regional facilities recommended.

7.5 GUIDANCE FOR INDIVIDUAL ISMP AREA STUDIES

The proposed individual ISMP area studies should review the recommendations of all applicable previous reports and determine the status of previously recommended works. The following general study guidance should apply to all the individual ISMP .studies while specific guidance and figures are outlined in Sections 8 - 13.

DATA COLLECTION AND REVIEW

Review existing relevant reports and files for the ISMP areas and gather relevant information from streamkeepers, environmental groups and the TOL and COS.

HYDROGEOLOGY / GEOTECHNICAL

Determine the existing geophysical and hydrogeological features for the ISMP areas, including base flows, ground water discharge / recharge zones, soil types, surficial soils infiltration rates, and stream geomorphology utilizing existing information. Use this information to set watershed-specific targets for volumetric reduction, infiltration, baseflow release, etc.

DRAINAGE SYSTEM INVENTORY

The existing digital information on the mainstem drainage system inventory will be provided and should be utilized in the study. The collection and review of additional data for the ISMP areas should be collected to complete the inventory.

In the interim, the TOL and COS should implement the interim criteria for development (see Section 7.4) occurring prior to completion of the ISMP studies.

WATER QUALITY AND BENTHIC INVERTEBRATES INVENTORY/ASSESSMENT

Given the importance of maintaining specific water uses that depend on adequate water quality, the ecological significance of the LCR watershed and Boundary Bay ecosystem, and the specific regulatory requirements, the following recommendations are made to guide the development of ISMPs.

1. Research and Information Gaps

- Continue to identify sources of fecal coliform bacteria from urban areas such as cross-connections and domestic animal populations (pet feces), and identify options to mitigate the impacts.
- Improve the understanding how the combined hydrological effects of urbanization and agricultural water withdrawals exacerbate low dissolved oxygen and high water temperature problems in the LCR.
- Investigate the cause of low winter dissolved oxygen levels and their possible link to increased biological oxygen demand from nutrient-rich runoff.
- Investigate the possible interaction between elevated turbidity and fecal coliform concentrations; turbidity may reduce mortality of fecal coliform bacteria and fine sediment may provide sites for bacterial adhesion and transport.

2. ISMP Process

- Incorporate the assessment, protection, and restoration of landscape-level watershed processes for water quality management into future ISMPs in the LCR (use Stanley et al. 2005 as template).

- Clarify the use and relevance of current MOE water quality objectives for the LCR in ISMP development.

- Consider an array of specific measures that address both point and non-point sources of water pollution, based on the best management practices available from other jurisdictions.

3. Assessment

- Assess landscape processes that allow natural mitigation of non-point sources of pollution as part of ISMP assessment (using *Protecting Aquatic Resources using Landscape Characterization: A Guide to Puget Sound Planners* by Stanley et al. 2005 as template). This should include GIS-based assessment of terrestrial upslope forests, riparian forests, mineral wetlands (including seasonally flooded areas), and floodplains and periodically inundated areas.

- Assess infiltration and recharge at an ISMP scale and its role in maintaining water quality during summer baseflow.

- Because of the greater range of land uses, water uses, and environmental sensitivities within the LCR, it is recommended to expand the assessment of water quality beyond benthic invertebrate sampling (B-IBI) and collection of basic water quality data during summer baseflow (see Clauses 12 and 13 of the ISMP template) to include items listed in the Monitoring section below.

4. Implementation

- Focus ISMP implementation on protecting and restoring natural watershed processes that regulate water quality such as denitrification and sediment removal in natural wetlands.

- Incorporate low impact development measures into new developments such as source controls and seasonally flooded wetlands to emulate natural watershed processes and maintain pre-development infiltration.

- Incorporate various measures to retrofit existing stormwater management systems to reduce non-point sources of pollution. Examples include catch basin inserts and oil/grease interceptors.

- Incorporate best management practices that target specific sources of stormwater and stream pollution. Examples include regular street sweeping and community spill prevention education programs (e.g., "All Drains Lead to Fish Habitat").
- Protect and restore riparian forest along all sections of the Little Campbell River and tributary streams as an essential method for protecting stream health, including water temperature and dissolved oxygen. The highest priority area for restoration is the reach of the mainstem between 176 and 184 Avenue with intensive and historic riparian forest loss from agriculture.
- Recognize that the development phase is an important contributor to some forms of water quality impairment from suspended sediment and turbidity increases in the LCR and that conventional sediment and erosion control measures have been unsuccessful. Incorporate more stringent sediment and erosion control measures including phasing for larger projects, winter construction halts, and better monitoring.

5. Monitoring

- Monitor the following water quality parameters at the ISMP scale during the pre-development, development, and early post-development (5 years) phase:
  1. continue the B-IBI monitoring on the Little Campbell River mainstem using the City of Surrey's collection and analysis methods and establish new sampling sites in the ISMP areas;
  2. summer and winter measurement of fecal coliform concentrations in streamwater (at least 5 samples in 30 days to calculate geometric mean);
  3. continuous monitoring of water temperature, dissolved oxygen, and turbidity during the development phase; and
  4. collection of sediment samples within developing catchments to track long-term changes to concentrations of metals.
- Require fecal coliform concentrations in new stormwater systems be tested at least three times during the first year following construction to detect cross-connections; alternately, new developments should be dye-tested.
- Collaborate with MOE to continue to sample parameters specified in water quality objectives for the LCR (fecal coliform bacteria, dissolved oxygen, total suspended solids, water temperature, nitrite, ammonia, total lead, and pH) at 216 Street and 176 Street. Improve the consistency of this monitoring program by specifying that a minimum of five samples should be collected during baseflow conditions from August 15 to October 15 annually.

To reduce costs, monitoring could be carried out at the watershed scale and in coordination with other agencies and groups conducting monitoring within the watershed, such as BC Ministry of Environment, the Little Campbell Watershed Society, and A Rocha Canada.

FISH AND FISH HABITAT INVENTORY / ASSESSMENT

The existing digital information on the mainstem biophysical inventory will be provided and should be utilized in the study. The collection and review of additional data for the ISMP areas should be collected to complete the inventory and identify important habitat and biological features of any tributaries in the ISMP areas.

The following recommendations are made to guide the development of ISMPs, with emphasis on fish and fish habitat components.

1. Research and Information Gaps

- Assess fish use in the mid-basin wetlands.
- Identify juvenile rearing areas most affected by declining summer baseflows as a means of looking at temporary and long-term mitigation options.

2. ISMP Process

- Review and refine the direction of Clause 9 of the ISMP Template to provide more specific direction on the consistent assessment of fish and fish habitat in all permanent, fish-bearing streams. This could include more emphasis on assessing structural habitat features such as large wood frequency, channel dimensions, and substrate characteristics. Non-permanent streams should be assessed for fish use and access.
- Review options for assessing sediment transport changes accompanying urbanization, with emphasis on maintaining pre-development rates and volumes of coarse and fine sediment.

3. Assessment

- Review and refine fish habitat mapping on an ISMP scale to identify the spatial distribution of habitat use (spawning, rearing, migration) by different species during different times of the year. Existing SHIM data likely includes most information needed for this task, although some new field assessment may be necessary. As part of this mapping, assess, and map the annual extent of dewatered stream reaches.

- Map substrate composition in creeks and tributaries undergoing ISMP planning as a component of fish habitat, as well as a monitoring tool.

- Map large wood frequency in fish bearing reaches as a measure of habitat quality and to assist in restoration planning.

- Avoid the use of detailed field inventories for ISMP planning unless they contribute to management of restoration goals or are useful for other purposes (e.g., hydraulic modelling). For example, detailed spatial information on small-scale channel obstructions, storm outfalls, pedestrian bridges, and other point features are not useful for fish habitat management.

4. Implementation

- Emphasize the protection of all components of fish habitat including water flows, water quality, sediment, structural channel features, natural disturbance processes, off-channel habitats during ISMP planning. Consider the fish community and the habitat on which it depends to be temporally and spatially dynamic with some habitat features such as off-channel wetland being critical habitat only for a portion of the year.

- Protect the pre-development rate and volume of sediment (input, transport, and deposition) to the gravel reach of the LCR through the management of sediment transport in tributary streams.

- Restore large woody debris in the lower reaches of the LCR; combine with riparian restoration projects and bank stabilization.

- Work with the Semiahmoo Fish and Game Club, DFO, and MOE, A Rocha Canada, and other stakeholder groups to evaluate the hatchery program to ensure protection of wild stocks and other biodiversity values (e.g., amphibians).

5. Monitoring

- Support ongoing fish escapement monitoring by the Semiahmoo Fish and Game Club through continued in-kind assistance and suitable recognition of these efforts.

- Explore the usefulness of other forms of quantitative fish habitat monitoring, including monitoring using standard watershed assessment protocols (e.g., B.C. Forest and Range Evaluation Program), juvenile salmon abundance, and other ecological indicators of stream health (e.g., freshwater mussels). Consider engaging universities or other local research organizations to develop and implement these methods.

BIODIVERSITY INVENTORY AND ASSESSMENT

Because of the significance of habitats in the LCR watershed and the adjacent Boundary Bay ecosystem for biodiversity and the potential for effects of stormwater on these habitats, the following recommendations are provided to guide the biodiversity aspects of ISMPs.

1. Research and Information Gaps

- Investigate the habitat requirements for species at risk which depend on habitats in the LCR watershed (e.g., minimum patch sizes, habitat attributes within patches, etc.).
- Promote the use of the LCR watershed among universities, colleges, conservation organizations, and other researchers as a research site for biodiversity studies, specifically habitat–species relationships.

2. ISMP Process

- Review and incorporate biodiversity more explicitly into stormwater planning activities.
- Better integrate the biodiversity aspects of ISMPs with current local (municipal) and regional biodiversity objectives, including the City of Surrey's Ecosystem Management Study which is currently in progress.
- Review the effectiveness of current tools typically used to assess biodiversity and their habitats in ISMPs and consider incorporating landscape- or regional-scale approaches to biodiversity and habitat assessment for future ISMPs in the LCR.
- Consider developing sub-watershed or watershed-wide goals for maintaining habitat for biodiversity on developed and undeveloped land (i.e., amount of forest, distribution of forest patch sizes), during ISMP processes or as part of Official Community Plans (OCPs).

3. Assessment

- Use the results of the current Ecosystem Management Study to identify undeveloped and other lands in the LCR most critical to the watershed's long-term ecological health. The Ecosystem Management Study includes a GIS-based "Green Infrastructure Assessment" based on the principles of landscape ecology and conservation biology which systematically assesses both structural and functional habitat attributes to identify the most important hubs and corridors for biodiversity. During the ISMP process, the analysis should be examined at the watershed scale and sub-watershed scale and includes the Township of Langley as well. Important attributes for biodiversity include:

1. distribution of different habitat types, such as upland forest cover, riparian forest cover, wetlands, and old fields;
2. amount of interior and edge forest;
3. size distribution of habitat patches; and
4. connectivity of habitat patches.

- Identify potential habitat for rare species likely to occur in the watershed (e.g., Pacific Water Shrew, Western Toad, Red-Legged Frog) based on known habitat requirements and preferences. Apply habitat suitability or capability models, where available. Conduct surveys at high priority sites to identify occupied sites for protection and stewardship.

- Establish one or more focal species or species groups (both aquatic and terrestrial) to use as indicators of the status of biodiversity across different habitat types in the watershed. Table C3-5 in Appendix C provides recommendations of suitable focal species. Establish standardized methodology and monitoring sites for these species based on the above habitat assessment.

4. Implementation

- Protect all large forest patches and wetlands for their important hydrologic functions and biodiversity value. One of the environmental goals in Surrey's Sustainability Charter (2008) is to retain natural areas such as existing forests and other natural vegetation, and maximize the City's tree canopy. An interconnected ecological network for protection and enhancement has also been defined in Surrey's Ecological Management Study (in progress). Consider setting goals for forest cover retention within the LCR and restoring forested areas in key locations of the network.

- Establish an "ecological buffer zone" to limit further encroachment into the undeveloped lands surrounding the mid-basin wetlands and Campbell Valley Regional Park.

- Minimize stormwater impacts on the quality of aquatic habitat by adopting policies to reduce point and non-point source pollution and reduce the effective impervious area of developments.

- Protect and restore important wildlife corridors to retain and enhance habitat connectivity for wildlife using the results of Surrey's Ecological Management Study (in progress).

- Encourage adoption of provincial Best Management Practices (BMP's) for known habitat for rare and other species (e.g., raptors) found in the watershed. Encourage implementation of BMP's for high priority potential habitat, where possible.

- Take measures to actively improve the value of existing protected habitats by restoring portions of riparian corridor and actively managing exotic species.

- Continue to support the work of the Salmon Habitat and Restoration Program (SHaRP) and Langley Environmental Partners Society (LEPS) as well as local naturalist and stewardship groups to encourage stewardship on private land (only 12% of the watershed is currently protected).

5. Monitoring

- Support City-wide GIS-based monitoring of habitat attributes at the watershed and ISMP scale as an important resource for ISMP planning. Include attributes such as:

  1. distribution of upland forest cover, riparian forest cover, wetlands, and old fields;
  2. amount of interior and edge forest;
  3. size distribution of habitat patches; and
  4. connectivity of habitat patches.

  Data from the Ecosystem Management Study represents baseline data for this work and updates are recommended to occur every 5 years. Ongoing monitoring may be best carried out at a broader scale as part of City-wide biodiversity initiatives.

- Collaborate with local stewardship, naturalist, and streamkeeper groups to carry out the monitoring of focal species on an annual basis (e.g., through annual bird counts, amphibian surveys).

RIPARIAN ASSESSMENT

The existing digital information on the mainstem riparian assessment will be provided and should be utilized in the study. The collection and review of additional data for the ISMP areas should be collected to complete the assessment. Establish an "ecological buffer zone" to limit further encroachment into the undeveloped lands surrounding the Little Campbell River wetlands.

In the interim, the TOL and COS should look for opportunities to secure the riparian area along Little Campbell River mainstem and in the agricultural areas where RAR does not apply to protect the stream health.

AGRICULTURAL AREAS

Studies with agricultural areas should consider the *Environmental Farm Plan* program, the *Code of Agricultural Practice for Waste Management*, and the draft standard for *Agricultural Building Setbacks From Watercourses in Farming Areas*.

Environmental Farm Plan Program

The Environmental Farm Plan (EFP) is a voluntary program that farmers and ranchers can use to identify both environmental strengths and potential risks on their land. As part of the watershed studies, EFPs will help protect water quality, water quantity and biodiversity in Little Campbell River. Because the Riparian Areas Regulation does not apply to agricultural lands, the EFP outlines practices for managing livestock access to watercourses and improving riparian vegetation to prevent bank erosion and improve fish habitat. The EFP program is initiated by Agriculture and Agra-Food Canada and is implemented at the provincial level through the BC Ministry of Agriculture and Lands (MAL), and the BC Agriculture Council. Please refer to the following website:
http://www.bcac.bc.ca/efp_documents.htm

It is recommended that the TOL and COS encourage and support the implementation of the Environmental Farm Plan (EFP) in the agricultural (ALR) portions of the area.

Code for Environmental Practice in Waste Management

Because portions of the ISMP areas are predominantly rural and agricultural land use, agricultural practices have a large bearing on the creek water quality and riparian areas. The Code of Agricultural Practice for Waste Management is summarized on the following website:
http://www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/131_92.htm

The Code defines prohibited application of agricultural waste and conditions unfavourable to waste application. Control of water contamination from agricultural wastes depends on compliance with the Code.

Riparian Setback Standards for Agriculture

The BC MAL has also produced a draft standard for *Agricultural Building Setbacks From Watercourses in Farming Areas*. This is a prescriptive approach where the distance from a watercourse to the nearest new building, or other impervious area, is determined based on the type of watercourse classification and the nature of the building. For instance building containing solid agricultural waste should be set 30 m from a natural stream while a greenhouse can be set 15 m away. This standard complements the *Riparian Area Regulation* that has been set for urban areas.

TRANS-BOUNDARY CONSIDERATIONS

Many of the watershed areas of the proposed ISMPs fall within multiple jurisdictions including the City of White Rock, the Semiahmoo IR, the City of Surrey, the Township of Langley, and Washington State. However, it is likely that a single municipality will lead each ISMP in most cases and therefore the ISMPs must consider trans-boundary issues including but not limited to:

- surface water and groundwater catchment extents in each jurisdiction;
- future land use in all jurisdictions within the ISMP study area;
- drainage paths crossing the boundaries;
- any existing flow controls that may be present at the boundaries;
- any controls that may be needed to avoid impacting adjacent jurisdictions such as avoiding backing-up water into and flooding upstream jurisdictions or excessively increasing peak flows and flooding downstream jurisdictions;
- wildlife corridor continuity across boundaries;
- park/trail continuity across boundaries;
- effects of water diversions/uses on downstream jurisdictions; and
- criteria differences between jurisdictions.

7.6 COSTS FOR MUNICIPAL BUDGETING PURPOSES

Approximate costs for conducting ISMP studies and monitoring and sampling activities proposed for the ISMP areas are estimated. The cost estimates do not take into account saving in reporting that could be realized if all or some parameters were reported together in one document and therefore represent conservative estimates for budgeting purposes.

FLOW MONITORING

Flow monitoring is proposed in each of the ISMP areas so that a model can be calibrated and the watershed monitored over the long term into the future. The cost of equipment, station setup, first year of monitoring/maintenance, and developing a rating curve is approximately $20,000 to $25,000 per station. The cost of ongoing monitoring and maintenance is approximately $7,000 to $10,000 per station.

A total of eight stations are proposed for the Little Campbell River ISMP areas (Fergus none, Sam Hill/Twin two, Jacobsen/Highland two, and all others one). The total cost of flow monitoring would be $160,000 to $200,000 for the first year and $56,000 to $80,000 per year for subsequent years.

WATER QUALITY CONTINUOUS MONITORING

The continuous monitoring of water quality is proposed at a number of sites in the LCR watershed. The cost of equipment and station setup is approximately $8,000 per station.

Annual maintenance, data summary, and reporting would cost approximately $6,000 per station.

BENTHIC SAMPLING

Annual Benthic sampling is proposed for each of ISMP areas at a location with a gravel bottom stream. The cost of collecting, analyzing, and reporting results is approximately $2,000 per site per year.

SEDIMENT SAMPLING

Sediment sampling is proposed at a number of sites in the LCR watershed. It is anticipated that sediment samples would be taken at the same time as the Benthic samples. The cost of sediment sampling would be less than $1,000 per site which would include the lab analysis and reporting.

FECAL COLIFORM SAMPLING

Annual fecal coliform sampling is proposed at a number of sites in the LCR watershed. The cost of sample collection (10 dates per year), lab analysis, and reporting is approximately $3,000 per site per year.

RESEARCH PROJECTS

Some of the research items presented in Section 7.5 address information gaps across all urbanizing watersheds, not just the LCR, and are appropriate for university theses. However, the following three research studies are more related to specific issues in the LCR which should be funded:

- Fecal coliform source tracking study to identify sources of fecal coliform bacteria in LCR watershed ($10,000). Similar studies have recently been completed in several District of North Vancouver watersheds. This study would likely best be conducted in collaboration with MOE and Environment Canada as they share an interest in water quality.

- Fish habitat study to identify fish use of mid-basin wetlands and map locations of juvenile stranding during summer low flows ($20,000). The Pacific Salmon Foundation is a possible source of funding for this study.

- Surveys for Species at Risk and/or habitat suitability mapping to further identify rare species habitat in the LCR watershed ($15,000). No extensive surveys for Species at Risk in the watershed have been previously completed. The Habitat Stewardship Program for Species at Risk is a potential source of funding for this study.

ISMP STUDY BUDGETS

Typically ISMP studies vary in cost between $100,000 for a very simple ISMP-Lite style study to approximately $300,000 for a complex study with existing watershed issues/problems and stakeholder consultation requirements. The study costs also depend on the extent of hydrotechnical modelling and analyses, multi-jurisdiction extents and involvement, and number of alternatives required. For the purposes of setting budgets, the following study costs are estimated.

Table 7-2: Study Budgets

Study	Budget $
1. LID/BMP Standards and Typical Examples	50,000
2. Fernridge / Campbell Heights ISMP	200,000
3. Sam Hill / Twin Creeks ISMP	150,000
4. Kuhn Creek ISMP	150,000
5. Jacobsen / Highland Creek ISMP	200,000
6. Upper Little Campbell River Agricultural Study	100,000
7. McNally Creek ISMP Lite	100,000
8. Recalibrate Main Stem Model and Update Flood Levels	50,000

Section 8

Proposed Fernridge / Campbell Heights ISMP

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8. PROPOSED FERNRIDGE / CAMPBELL HEIGHTS ISMP

8.1 INTRODUCTION

The Fernridge / Campbell Heights area has been ranked second for an ISMP study for following reasons:

- there is large development coverage (predicted TIA increase from 7% to 46%);
- development is underway but more is anticipated; and
- the WHTS shows a current B-IBI score of 23 which could drop to 14 if future development is not mitigated.

Figure 8-1 shows the 872 ha Fernridge / Campbell Heights ISMP area along with water quality and benthic sampling locations for that section of main stem. The anticipated change in land use is shown on Figure 8-2. Figure 8-3 presents the floodplain and key findings from the drainage inventory, namely erosion sites, bridges and culverts along Little Campbell River. Table 8-1 summarizes the key area parameters.

8.2 DRAINAGE OVERVIEW

The findings of the drainage overview for Fernridge / Campbell Heights are summarized as follows:

- The 872 ha ISMP area is situated within the Township of Langley and the City of Surrey.

- Key features along the Little Campbell River mainstem include portions of the Campbell Valley Park.

- The ISMP area intersects six individual aquifers.

- The existing land use in the ISMP area is predominantly agricultural (ALR) (15%) with urban (12%) and commercial / industrial (3%) areas. Some future development is expected in this area.

- This portion of the Little Campbell River mainstem was hiked and inventoried with the following findings: 85 erosion points totalling 1,078 m, 30 sedimentation points totalling 112,455 m^2, and 40 natural hazards were found. See Figure 8-3 for the locations of these points. The inventory details are included on the DVD in Appendix A.

Table 8-1: Summary of Fernridge / Campbell Heights Area Parameters

	Study Area Parameters		
Information	Drainage Area (ha)		872
	Jurisdiction		
	White Rock		
	Surrey		√
	Langley		√
	Blaine/Whatcom County		
	First Nation		
Land Use	Existing TIA - ha (% of subwatershed)[1]		7%
	Future TIA - ha (% of subwatershed)[1]		46%
	Change in TIA - ha (% of subwatershed)		39%
	New Development or Redevelopment (ha)		341
	Timing of Development (now, 5-yrs, 10-yrs)		now/10-yrs
	Existing Agriculture (ALR) (area in ha / % of subwatershed)		128 / 15%
	Existing Urban/Suburban (area in ha / % of subwatershed)		101.9 / 12%
	Existing Commercial/Industrial (area in ha / % of subwatershed)		29 / 3%
Surface Water	Flooding of Campbell River Crossings in 200-year (Pre-dev / Existing / Future)		16 Ave / 16 Ave, 24 Ave, 200 St / 16 Ave, 24 Ave, 200 St
	200-year Campbell River Floodplain area (ha)		89.7
	Erosion along Campbell River (# of points/total length)		85 points / 1078 m
	Sedimentation along Campbell River (# of points/length/width/area)		30 points / 595m / 189m / 112,455m^2
	Natural Hazards on Campbell River (obstruction) (# of points)		40 points
	Baseflows- L/s (winter/summer)		53.2 / 17.5
	Surface Water Extractions(# of PODs & flow (igpd))		13 / 353,490
Environmental	Existing Riparian Forest Cover - RFI (% of riparian area)		53%
	Existing Watershed Forest Cover (% of subwatershed)	(from MOE Report)	36%
		(from EMS)	41%
	Projected Watershed Forest Cover (% of subwatershed)		8%
	Projected Change in Watershed Forest Cover (% of subwatershed)		-33%
	Surface Water Quality (high/med/low)	for Aquatic Life (general)	high
		for Human Health (fecal coliform, etc.)	med
		Development Phase (turbidity, etc.)	high
	Number of On-site Sewage Disposal Systems		414
	Wetlands and Floodplain Areas (% of subwatershed)		15.8%
	Hydric Soils (% of subwatershed)		3.0%
	Fish and Fish Habitat	Fish-bearing streams (km/km^2)	2.26
		Major spawning/rearing areas	yes
	EMS Hubs (# of hubs / % of subwatershed)		10 / 29.1%
	EMS Corridors (km/km^2)		0.8
	Interior Forest from EMS (area in ha / % of subwatershed)		87.0 / 10.0%
	Species at Risk/Raptor Nests (# of species / # of known occurences)		4 / 6
	Wildlife Value (high/med/low)		high
Groundwater	Underlying Aquifer (name & confined/unconfined)		Hazelmere Valley / conf. Grandview / conf. Brookswood / unconf. Langley Upland Intertill / conf. (deep)
	Declining Aquifer Water Levels		
	Groundwater Extractions (# of wells / flow (igpm))		303 / 2,751
	Infiltration Capability/Soils		Silt and Clay, Till, Gravel and Sand, Sand

[1] Total Impervious Area (TIA) does not reflect the effects of BMPs which reduce the Effective Impervious Area (EIA). EIA values do not necessarily equal TIA values, however estimating EIA values was beyond the scope of this study and should be done as part of the proposed ISMP studies.

- This portion of the Little Campbell River mainstem has three crossings (16 Avenue, 24 Avenue east of 196 Street, and 200 Street) flooded during various 200-year storm events. See Table 8-1 for the crossing information.

- The ISMP area has 89.7 ha of land within the 200-year Little Campbell River floodplain area (see Figure 8-3).

8.3 HYDROLOGIC AND HYDRAULIC MODELLING

Based on the hydrologic and hydraulic modelling, the estimated flows in the LCR mainstem at the upstream end of the ISMP area are presented in Table 8-2.

Table 8-2: Fernridge / Campbell Heights LCR Mainstem Flow Summary

Location	Area (ha)	Peak Flow Estimate (m^3/s)						
		2-year	10-year	200-year			Baseflow	
		Exist.	Exist.	Predev.	Exist.	Future	Winter	Summer
LCR 18+864[1]	**2,415** (2,231 TOL) (184 WASH)	6.32	10.67	23.70	33.06	35.78	0.147	0.048

[1]Location is on LCR mainstem at upstream boundary of ISMP area.

The upstream flow boundary and the downstream water level boundary for the 2-year 24-hour, 10-year 5-day, and 200-year 5-day design events on the Little Campbell River Mainstem are included on the DVD in Appendix A. These boundaries can be used for future modelling of the Fernridge / Campbell Heights ISMP.

8.4 ENVIRONMENTAL OVERVIEW

The key environmental issues are as follows:

- Currently, 41% of the Campbell Heights / Fernridge ISMP area is forested and the area has 53% riparian forest integrity.

- The watershed forest cover is projected to decline from 41% to 8% as a result of future development.

- Increased turbidity and sedimentation from construction sites is an ongoing concern due the large scale of development in this area.

- Summer low flows in upper portions of the LCR mainstem in this area (downstream of Campbell Valley Regional Park) are a concern due to low dissolved oxygen levels and the potential for juvenile fish stranding.

- The LCR mainstem through this area has extremely high fish habitat value as spawning and rearing habitat for Coho, Chum, Chinook, Steelhead, and Cutthroat trout. Spawning habitat is also found in the lower reaches of the 194 Street Channel also up to the 20 Avenue alignment and in an unnamed tributary running north at the 198 Street alignment.

- Due to several large intact forest patches in this area, wildlife habitat value in the ISMP area is high.

- Species at Risk known from this area include Vancouver Island beggarticks (*Bidens amplissima*) and false-pimpernel (*Lindernia dubia* var. *anagallidea*) at Latimer Lake, and Red-legged Frog (*Rana aurora*) along the 194 Street channel. Western Toad (*Bufo boreas*) has been observed in forested areas between 192 Street and the LCR mainstem, south of the Campbell Heights Industrial Area.

- One Red-tailed Hawk (*Buteo jamaicensis*) nest is known in the area.

8.5 SUMMARY OF KEY ISSUES

The key issues within this watershed are listed in Table 8-1. The Fernridge / Campbell Heights watershed will have a 39% increase in impervious area. Riparian areas, fish habitat, water quality, and declining baseflows are an issue in this watershed.

Figure 7-1 shows the existing and predicted future watershed health (B-IBI score) based on the indicators of impervious area and riparian forest integrity (RFI) on the Watershed Health Tracking System (WHTS). The impervious areas were estimated in this study and the RFI values were taken from the “Potential Pollution Sources in the Little Campbell River Watershed” (MOE, 2006) report. The WHTS shows that Fernridge / Campbell Heights will likely experience a loss of health if future increases in impervious area are not mitigated. Of all the proposed ISMP areas, this area is predicted to have the largest potential degradation (9 B-IBI point reduction).

Key issues that were identified during the course of this study include:

- 16 Avenue (near 194 Street) crossing is insufficient for 200-year flow;
- 24 Avenue (near 198 Street) crossing is insufficient for 200-year flow;
- 200 Street crossing is insufficient for 200-year flow;
- impervious area increase from Campbell Heights development;
- impervious area increase from Fernridge Area development;
- potential residential development in floodplain in Fernridge Area;
- potential impervious area increase in agricultural area (greenhouses);
- very wide floodplain along Little Campbell River in the Township;
- potential development encroachment into wetlands;
- high opportunity for infiltration (gravel and sand soils);
- watershed spans multiple jurisdictions (Surrey, Township of Langley);
- runoff water quality from development and from agricultural areas;

- moderate riparian area integrity;
- bank erosion; and
- high fish habitat values along LCR mainstem in this area.

8.6 PROPOSED MINIMUM ISMP REQUIREMENTS

The ISMP proposed for the Fernridge / Campbell Heights area should include the following basic requirements:

- Flow monitoring, perhaps on the watercourse running along the west side of 196 Street, to be commenced prior to ISMP.
- Goals for watershed health impact (no-net-loss, net gain, or other).
- Determine the existing condition of the watershed (indicators of health).
- Set volumetric reduction (capture) criteria.
- Set peak flow attenuation (detention) criteria.
- Set water quality criteria.
- Propose riparian setbacks (RAR minimum).
- Recommend and size specific measures to achieve the criteria.
- Predict the future condition of the watershed and check that level of impact is consistent with the goal set in the first bullet above.
- Recommend a monitoring program to track watershed health over the course of development. Monitoring is to include flow monitoring, water quality sampling and continous monitoring, sediment quality sampling, benthic sampling, forest cover mapping from orthophotos, and collaboration with local stewardship groups to perform fish and wildlife counts.
- Recommend an adaptation strategy for adjusting the measures if targets are not being met.

Section 9

Proposed Sam Hill / Twin Creeks ISMP

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9. PROPOSED SAM HILL / TWIN CREEKS ISMP

9.1 INTRODUCTION

The Sam Hill / Twin Creeks ISMP area has been ranked third for the following reasons:

- Substantial development is planned (predicted TIA increase from 10% to 34%).
- The ISMP area includes portions of Grandview Heights and Campbell Heights developments.
- The WHTS shows a current B-IBI score of 19 which could drop to 14 if future development is not mitigated.

Figure 9-1 shows the 1,028 ha Sam Hill / Twin Creeks ISMP area along with water quality and benthic sampling locations for that section of main stem. The anticipated change in land use is shown on Figure 9-2. Figure 9-3 presents the floodplain area and key findings from the drainage inventory, namely erosion sites, bridges and culverts along Little Campbell River. Table 9-1 summarizes the key area parameters.

9.2 DRAINAGE OVERVIEW

The findings from the Sam Hill / Twin Creeks drainage review are summarized as follows:

- The 1,028 ha ISMP area is situated within the City of Surrey.
- Key features along the Little Campbell River mainstem in this area include the 12 Avenue gauge.
- The ISMP area intersects four individual aquifers.
- The existing land use in the watershed is predominantly agricultural (ALR) (50%) with urban (13%) and commercial / industrial (1.3%) areas. Future development is expected in this area.
- This portion of the Little Campbell River mainstem was not surveyed in detail and the sedimentation and obstruction hazards are not known in this area. There are 55 erosion points present. See Figure 9-3 for the locations of these points. The inventory details are included on the DVD in Appendix A.

Table 9-1: Summary of Sam Hill / Twin Creeks Area Parameters

	Study Area Parameters		
Information	Drainage Area (ha)		1028
Information	Jurisdiction		
Information	White Rock		
Information	Surrey		√
Information	Langley		
Information	Blaine/Whatcom County		
Information	First Nation		
Land Use	Existing TIA - ha (% of subwatershed)[1]		10%
Land Use	Future TIA - ha (% of subwatershed)[1]		34%
Land Use	Change in TIA - ha (% of subwatershed)		25%
Land Use	New Development or Redevelopment (ha)		252
Land Use	Timing of Development (now, 5-yrs, 10-yrs)		5-yrs
Land Use	Existing Agriculture (ALR) (area in ha / % of subwatershed)		511 / 50%
Land Use	Existing Urban/Suburban (area in ha / % of subwatershed)		133.5 / 13%
Land Use	Existing Commercial/Industrial (area in ha / % of subwatershed)		13.0 / 1.3%
Surface Water	Flooding of Campbell River Crossings in 200-year (Pre-dev / Existing / Future)		12 Ave / 12 Ave / 12 Ave
Surface Water	200-year Campbell River Floodplain area (ha)		17.2
Surface Water	Erosion along Campbell River (# of points/total length)		55 points / unknown
Surface Water	Sedimentation along Campbell River (# of points/length/width/area)		not surveyed in detail
Surface Water	Natural Hazards on Campbell River (obstruction) (# of points)		not surveyed in detail
Surface Water	Baseflows- L/s (winter/summer)		60.5 / 19.9
Surface Water	Surface Water Extractions(# of PODs & flow (igpd))		20 / 273,510
Environmental	Existing Riparian Forest Cover - RFI (% of riparian area)		33%
Environmental	Existing Watershed Forest Cover (% of subwatershed)	(from MOE Report)	25%
Environmental		(from EMS)	26%
Environmental	Projected Watershed Forest Cover (% of subwatershed)		11%
Environmental	Projected Change in Watershed Forest Cover (% of subwatershed)		-15%
Environmental	Surface Water Quality (high/med/low)	for Aquatic Life (general)	high
Environmental		for Human Health (fecal coliform, etc.)	high
Environmental		Development Phase (turbidity, etc.)	high
Environmental	Number of On-site Sewage Disposal Systems		379
Environmental	Wetlands and Floodplain Areas (% of subwatershed)		0.6%
Environmental	Hydric Soils (% of subwatershed)		22.2%
Environmental	Fish and Fish Habitat	Fish-bearing streams (km/km^2)	2.36
Environmental		Major spawning/rearing areas	yes
Environmental	EMS Hubs (# of hubs / % of subwatershed)		7 / 18.1%
Environmental	EMS Corridors (km/km^2)		1.6
Environmental	Interior Forest from EMS (area in ha / % of subwatershed)		47.8 / 4.8%
Environmental	Species at Risk/Raptor Nests (# of species / # of known occurences)		4 / 6
Environmental	Wildlife Value (high/med/low)		med
Groundwater	Underlying Aquifer (name & confined/unconfined)		Hazelmere / conf. Hazelmere Valley / conf. Grandview / conf. Brookswood / unconf.
Groundwater	Declining Aquifer Water Levels		
Groundwater	Groundwater Extractions (# of wells / flow (igpm))		127 / 1,139
Groundwater	Infiltration Capability/Soils		Silt and Clay, Sand, Till, Peat, Gravel and Sand

[1] Total Impervious Area (TIA) does not reflect the effects of BMPs which reduce the Effective Impervious Area (EIA). EIA values do not necessarily equal TIA values, however estimating EIA values was beyond the scope of this study and should be done as part of the proposed ISMP studies.

- This portion of the Little Campbell River mainstem has one crossing (12 Avenue) that floods during various 200-year storm events. See Table 9-1 for the crossing information.
- The ISMP area has 17.2 ha of land within the 200-year Little Campbell River floodplain area (see Figure 9-3).

9.3 HYDROLOGIC AND HYDRAULIC MODELLING

Based on the hydrologic and hydraulic modelling, the estimated flows in the LCR mainstem at the upstream end of the ISMP area are presented in Table 9-2.

Table 9-2: Sam Hill/Twin Creeks ISMP LCR Mainstem Flow Summary

Location	Catchment Area (ha)	Peak Flow Estimate (m^3/s)						
		2-year	10-year	200-year			Baseflow	
		Exist.	Exist.	Predev.	Exist.	Future	Winter	Summer
LCR 9+185[1]	**4,377** (3,168 TOL) (824 SUR) (385 WASH)	11.04	17.31	37.27	51.96	57.99	0.267	0.088

[1] Location is on LCR mainstem at upstream boundary of ISMP area.

The upstream flow boundary and the downstream water level boundary for the 2-year 24-hour, 10-year 5-day, and 200-year 5-day design events on the Little Campbell River Mainstem are included on the DVD in Appendix A. These boundaries can be used for future modelling of the Sam Hill / Twin Creeks ISMP.

9.4 ENVIRONMENTAL OVERVIEW

The findings from the environmental review are as follows:

- Currently, 26% of the Sam Hill / Twin Creeks ISMP area is forested and the area has 33% riparian forest integrity.
- Watershed forest cover is projected to decline from 26% to 11% as a result of future development.
- High fecal coliform levels have been found in West Twin Creek at times during past sampling.
- The LCR mainstem through this area is important migration and rearing habitat for salmonids. Sam Hill Creek is important spawning and rearing habitat for Coho (and likely Chum) into its headwaters.

- Due to a small number of moderately-sized forest patches in this area, wildlife habitat value in the ISMP area is moderate.

- Barn Owl (*Tyto alba*), listed as a Threatened species under the federal *Species at Risk Act*, is found on several farms in the area.

- One Bald Eagle (*Haliaeetus leucocephalus*) and two Red-tailed Hawk (*Buteo jamaicensis*) nests are known in the area.

9.5 SUMMARY OF KEY ISSUES

The key issues within this watershed are listed in Table 9-1. The Sam Hill / Twin Creeks watershed will have a 25% increase in impervious area. Riparian areas, fish habitat, water quality, and declining baseflows are an issue in this watershed.

Figure 7-1 shows the existing and predicted future watershed health (B-IBI score) based on the indicators of impervious area and riparian forest integrity (RFI) on the Watershed Health Tracking System (WHTS). The impervious areas were estimated in this study and the RFI values were taken from the "Potential Pollution Sources in the Little Campbell River Watershed" (MOE, 2006) report. The WHTS shows that Sam Hill / Twin Creeks will likely experience a loss of health if future increases in impervious area are not mitigated.

Key issues that were identified during the course of this study include:

- 12 Avenue crossing is insufficient for 200-year flow;
- impervious area increase from Grandview Heights development;
- impervious area increase from Campbell Heights development;
- potential impervious area increase in agricultural area (greenhouses);
- runoff water quality from development and from agricultural areas;
- wide 200-year floodplain along Little Campbell River;
- poor riparian area integrity; and
- bank erosion.

Also investigate mechanisms to protect and restore riparian forest along the Little Campbell River and tributary streams as an essential method for protecting stream health, including water temperature and dissolved oxygen. The highest priority area for restoration is the reach of the mainstem between 176 and 184 Avenue with intensive and historic riparian forest loss from agriculture.

9.6 PROPOSED MINIMUM ISMP REQUIREMENTS

The ISMP proposed for Sam Hill / Twin Creek area should include the following basic requirements:

- Flow monitoring on Sam Hill Creek, perhaps at 176 Street, and on Twin Creek, perhaps at 16 Avenue, to be commenced prior to ISMP.
- Propose a goal for watershed health impact (no-net-loss, net gain, or other).
- Determine the existing condition of the watershed (indicators of health).
- Set volumetric reduction (capture) criteria.
- Set peak flow attenuation (detention) criteria.
- Set water quality criteria.
- Propose riparian setbacks (RAR minimum).
- Recommend and size specific measures to achieve the criteria.
- Predict the future condition of the watershed and check that level of impact is consistent with the goal set in the first bullet above.
- Recommend a monitoring program to track watershed health over the course of development.
- Recommend an adaptation strategy for adjusting the measures if targets are not being met.

Section 10

Proposed Kuhn Creek ISMP

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associates limited
CONSULTING ENGINEERS

10. PROPOSED KUHN CREEK ISMP

10.1 INTRODUCTION

The Kuhn Creek ISMP area has been ranked fourth for the following reasons:

- development planned with a predicted TIA increase from 4% to 32%;
- the ISMP area includes the Douglas NCP area; and
- the WHTS shows a current B-IBI score of 20 which could drop to 14 if future development is not mitigated.

Figure 10-1 shows the Kuhn Creek 913 ha ISMP area along with water quality and benthic sampling locations for that section of main stem. The anticipated change in land use is shown on Figure 10-2 and Figure 10-3 presents the floodplain and key findings from the drainage inventory, namely erosion sites, bridges and culverts along Little Campbell River. Table 10-1 summarizes the key area parameters.

10.2 DRAINAGE OVERVIEW

The findings from the Kuhn Creek drainage review are as follows:

- The 931 ha Kuhn Creek ISMP area is situated within the City of Surrey and the State of Washington.

- Key features along the Little Campbell River mainstem section include portions of the Peace Portal Golf Course and the Hazelmere Country Club.

- The ISMP area intersects two individual aquifers.

- The existing land use in the watershed is predominantly agricultural (ALR) (58%) with urban (8%) and commercial / industrial (2%) areas. Some future development is expected in this area.

- This portion of the Little Campbell River mainstem was not surveyed in detail downstream of 176 Street. The detailed survey upstream of 176 Street found seven erosion points totalling 128 m, no sedimentation points, and nine natural hazards were found in this ISMP area. See Figure 10-3. The inventory details are included on the DVD in Appendix A.

- This portion of the Little Campbell River mainstem has two crossings (8 Avenue and private road) flooded during various 200-year storm events. See Table 10-1 for the crossing information.

Table 10-1: Summary of Kuhn Creek Area Parameters

	Study Area Parameters		
Information	Drainage Area (ha)		931
	Jurisdiction		
	White Rock		
	Surrey		√
	Langley		
	Blaine/Whatcom County		√
	First Nation		
Land Use	Existing TIA - ha (% of subwatershed)[1]		4%
	Future TIA - ha (% of subwatershed)[1]		32%
	Change in TIA - ha (% of subwatershed)		28%
	New Development or Redevelopment (ha)		262
	Timing of Development (now, 5-yrs, 10-yrs)		now/5-yrs
	Existing Agriculture (ALR) (area in ha / % of subwatershed)		539 / 58%
	Existing Urban/Suburban (area in ha / % of subwatershed)		77.9 / 8%
	Existing Commercial/Industrial (area in ha / % of subwatershed)		15.6 / 2%
Surface Water	Flooding of Campbell River Crossings in 200-year (Pre-dev / Existing / Future)		none / 17948 8 Ave, 8 Ave / 17948 8 Ave, 8 Ave
	200-year Campbell River Floodplain area (ha)		45.5
	Erosion along Campbell River (# of points/total length)		7 points / 128 m (not surveyed in detail downstream of 176 St)
	Sedimentation along Campbell River (# of points/length/width/area)		none (not surveyed in detail downstream of 176 St)
	Natural Hazards on Campbell River (obstruction) (# of points)		9 points (not surveyed in detail downstream of 176 St)
	Baseflows- L/s (winter/summer)		56.8 / 18.7
	Surface Water Extractions(# of PODs & flow (igpd))		15 / 92,757
Environmental	Existing Riparian Forest Cover - RFI (% of riparian area)		36%
	Existing Watershed Forest Cover (% of subwatershed)	(from MOE Report)	32%
		(from EMS)	28%
	Projected Watershed Forest Cover (% of subwatershed)		15%
	Projected Change in Watershed Forest Cover (% of subwatershed)		-13%
	Surface Water Quality (high/med/low)	for Aquatic Life (general)	high
		for Human Health (fecal coliform, etc.)	high
		Development Phase (turbidity, etc.)	med
	Number of On-site Sewage Disposal Systems		60
	Wetlands and Floodplain Areas (% of subwatershed)		6.4%
	Hydric Soils (% of subwatershed)		38.2%
	Fish and Fish Habitat	Fish-bearing streams (km/km^2)	2.35
		Major spawning/rearing areas	unknown
	EMS Hubs (# of hubs / % of subwatershed)		6 / 23.5%
	EMS Corridors (km/km^2)		1.02
	Interior Forest from EMS (area in ha / % of subwatershed)		73.2 / 7.9%
	Species at Risk/Raptor Nests (# of species / # of known occurences)		4 / 10
	Wildlife Value (high/med/low)		med
Groundwater	Underlying Aquifer (name & confined/unconfined)		Hazelmere Valley / conf. Border / conf.
	Declining Aquifer Water Levels		
	Groundwater Extractions (# of wells / flow (igpm))		81 / 1,672
	Infiltration Capability/Soils		Silt and Clay, Sand, Till

[1] Total Impervious Area (TIA) does not reflect the effects of BMPs which reduce the Effective Impervious Area (EIA). EIA values do not necessarily equal TIA values, however estimating EIA values was beyond the scope of this study and should be done as part of the proposed ISMP studies.

- The Kuhn Creek ISMP area has 45.5 ha of land within the 200-year Little Campbell River floodplain area (see Figure 10-3).

10.3 HYDROLOGIC AND HYDRAULIC MODELLING

Based on the hydrologic and hydraulic modelling, the estimated flows in the LCR mainstem at the upstream end of the ISMP area are presented in Table 10-2.

Table 10-2: Kuhn Creek ISMP LCR Mainstem Flow Summary

Location	Catchment Area (ha)	Peak Flow Estimate (m^3/s)						
		2-year	10-year	200-year			Baseflow	
		Exist.	Exist.	Predev.	Exist.	Future	Winter	Summer
LCR 7+321[1]	**5,405** (3,168 TOL) (1,852 SUR) (385 WASH)	13.15	20.69	44.00	62.22	71.71	0.330	0.108

[1]Location is on LCR mainstem at upstream boundary of ISMP area.

The upstream flow boundary and the downstream water level boundary for the 2-year 24-hour, 10-year 5-day, and 200-year 5-day design events on the Little Campbell River Mainstem are included on the DVD in Appendix A. These boundaries can be used for future modelling of the Kuhn Creek ISMP.

10.4 ENVIRONMENTAL OVERVIEW

The environmental overview is as follows:

- Currently, 28% of the Kuhn Creek ISMP area is forested and the area has 36% riparian forest integrity.
- Watershed forest cover is projected to decline from 28% to 15% as a result of future development.
- Specific water quality concerns in this area have not been previously identified.
- Bank erosion is of moderate concern on this section of the LCR mainstem.
- The LCR mainstem through this area is important migration and rearing habitat for salmonids. Some spawning of Coho may occur in the lower reaches of Kuhn Creek.
- Due to larger lot sizes with a fair amount of tree cover and an intact riparian corridor in this area, wildlife habitat value in the ISMP area is moderate.
- Several Species at Risk are known from this area. Vancouver Island beggarticks (*Bidens amplissima*) was historically found along the LCR mainstem through Peace

Portal Golf Course. Henderson's checkermallow (*Sidalcea hendersonii*) is historically known from the vicinity of Hall's Prairie Road. Red-legged Frog (*Rana aurora*) is known from several private ponds in the area. Oregon Forestsnail (*Allogona townsendiana*) and Trowbridge's Shrew (*Sorex trowbridgii*) has been found in the riparian corridor along the LCR mainstem. Barn Owl (*Tyto alba*) is found on several farms in the area.

- Four Bald Eagle (*Haliaeetus leucocephalus*) nests are known in the area.

10.5 SUMMARY OF KEY ISSUES

The key issues within this watershed are listed in Table 10-1. The Kuhn Creek watershed will have a 28% increase in impervious area. Riparian areas, fish habitat, water quality, and declining baseflows are an issue in this watershed.

Figure 7-1 shows the existing and predicted future watershed health (B-IBI score) based on the indicators of impervious area and riparian forest integrity (RFI) on the Watershed Health Tracking System (WHTS). The impervious areas were estimated in this study and the RFI values were taken from the "Potential Pollution Sources in the Little Campbell River Watershed" (MOE, 2006) report. The WHTS shows that Kuhn Creek will likely experience a loss of health if future increases in impervious area are not mitigated.

Key issues that were identified during the course of this study include:

- private crossing at 17948 8 Avenue is insufficient for 200-year flow;
- 8 Avenue crossing is insufficient for 200-year flow;
- impervious area increase from Douglas NCP Area development;
- potential impervious area increase in agricultural area (greenhouses);
- potential infiltration opportunities in sand soils areas;
- runoff water quality from development and from agricultural areas;
- wide floodplain along Little Campbell River;
- watershed spans multiple jurisdictions (Surrey, Washington);
- poor riparian area integrity; and
- bank erosion.

Also investigate mechanisms to protect and restore riparian forest along the Little Campbell River and tributary streams as an essential method for protecting stream health, including water temperature and dissolved oxygen. The highest priority area for restoration is the reach of the mainstem between 176 and 184 Avenue with intensive and historic riparian forest loss from agriculture.

10.6 PROPOSED MINIMUM ISMP REQUIREMENTS

The ISMP proposed for Kuhn Creek area should include the following basic requirements:

- Flow monitoring on Kuhn Creek, perhaps at 184 Street, to be commenced prior to ISMP.
- Propose a goal for watershed health impact (no-net-loss, net gain, or other).
- Determine the existing condition of the watershed (indicators of health).
- Set volumetric reduction (capture) criteria.
- Set peak flow attenuation (detention) criteria.
- Set water quality criteria.
- Propose riparian setbacks (RAR minimum).
- Recommend and size specific measures to achieve the criteria.
- Predict the future condition of the watershed and check that level of impact is consistent with the goal set in the first bullet above.
- Recommend a monitoring program to track watershed health over the course of development.
- Recommend an adaptation strategy for adjusting the measures if targets are not being met.

Section 11

Proposed Jacobsen / Highland Creeks ISMP

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

11. PROPOSED JACOBSEN / HIGHLAND CREEKS ISMP

11.1 INTRODUCTION

The Jacobsen / Highland Creeks ISMP area has been ranked fifth for the following reasons:

- The High Point development is already approved and includes LIDs and detention facilities.
- More development is expected east of 204 Street (predicted TIA increase from 3% to 22%).
- The WHTS shows a current B-IBI score of 27 which could drop to 18 if future development is not mitigated.
- Currently best predicted watershed health.
- Riparian protection and restoration would greatly improve watershed health.

Figure 11-1 shows the 1,090 ha Jacobsen / Highland Creeks ISMP area along with water quality and benthic sampling locations for that section of main stem. The anticipated change in land use is shown on Figure 11-2. Figure 11-3 presents the floodplain and key findings from the drainage inventory, namely erosion sites, bridges and culverts along Little Campbell River. Table 11-1 summarizes the key area parameters.

11.2 DRAINAGE OVERVIEW

The Jacobsen / Highland Creeks drainage overview is as follows:

- The 1,090 ha Jacobsen / Highland Creeks ISMP area is situated within the City of Surrey, the Township of Langley, and the State of Washington.
- Key features along the Little Campbell River mainstem include the Little Campbell Hatchery.
- The Jacobsen / Highland Creeks ISMP area intersects three individual aquifers.
- Underlying aquifers in this ISMP area have declining water levels.
- The existing land use in the watershed is predominantly agricultural (ALR) (38%) with urban (1.6%) and commercial / industrial (1.2%) areas. Some future development is expected in this area.

Table 11-1: Summary of Jacobsen / Highland Creeks Area Parameters

	Study Area Parameters		
Information	Drainage Area (ha)		1090
	Jurisdiction		
	White Rock		
	Surrey		√
	Langley		√
	Blaine/Whatcom County		√
	First Nation		
Land Use	Existing TIA - ha (% of subwatershed)[1]		3%
	Future TIA - ha (% of subwatershed)[1]		22%
	Change in TIA - ha (% of subwatershed)		18%
	New Development or Redevelopment (ha)		201
	Timing of Development (now, 5-yrs, 10-yrs)		now
	Existing Agriculture (ALR) (area in ha / % of subwatershed)		418 / 38%
	Existing Urban/Suburban (area in ha / % of subwatershed)		17.2 / 1.6%
	Existing Commerical/Industrial (area in ha / % of subwatershed)		13.1 / 1.2%
Surface Water	Flooding of Campbell River Crossings in 200-year (Pre-dev / Existing / Future)		184 St / 184 St / 184 St, Fish & Game Club Road
	200-year Campbell River Floodplain area (ha)		14.9
	Erosion along Campbell River (# of points/total length)		18 points / 272 m
	Sedimentation along Campbell River (# of points/length/width/area)		16 points / 344m / 111m / 38,184m^2
	Natural Hazards on Campbell River (obstruction) (# of points)		6 points
	Baseflows- L/s (winter/summer)		66.5 / 21.9
	Surface Water Extractions(# of PODs & flow (igpd))		15 / 367,072
Environmental	Existing Riparian Forest Cover - RFI (% of riparian area)		58%
	Existing Watershed Forest Cover (% of subwatershed)	(from MOE Report)	40%
		(from EMS)	41%
	Projected Watershed Forest Cover (% of subwatershed)		18%
	Projected Change in Watershed Forest Cover (% of subwatershed)		-23%
	Surface Water Quality (high/med/low)	for Aquatic Life (general)	med
		for Human Health (fecal coliform, etc.)	med
		Development Phase (turbidity, etc.)	high
	Number of On-site Sewage Disposal Systems		187
	Wetlands and Floodplain Areas (% of subwatershed)		1.2%
	Hydric Soils (% of subwatershed)		4.7%
	Fish and Fish Habitat	Fish-bearing streams (km/km^2)	2
		Major spawning/rearing areas	yes
	EMS Hubs (# of hubs / % of subwatershed)		9 / 35.9%
	EMS Corridors (km/km^2)		0.95
	Interior Forest from EMS (area in ha / % of subwatershed)		182.7 / 16.8%
	Species at Risk/Raptor Nests (# of species / # of known occurences)		2 / 2
	Wildlife Value (high/med/low)		
Groundwater	Underlying Aquifer (name & confined/unconfined)		Hazelmere Valley / conf. Border / conf. Brookswood / unconf.
	Declining Aquifer Water Levels		√
	Groundwater Extractions (# of wells / flow (igpm))		192 / 1,977
	Infiltration Capability/Soils		Sand, Till, Gravel and Sand, Silt and Clay

[1] Total Impervious Area (TIA) does not reflect the effects of BMPs which reduce the Effective Impervious Area (EIA). EIA values do not necessarily equal TIA values, however estimating EIA values was beyond the scope of this study and should be done as part of the proposed ISMP studies.

- This portion of the Little Campbell River mainstem was surveyed in detail. Eighteen erosion points totalling 272 m, 16 sedimentation points totalling 38,184 m^2, and six natural hazards were found in this ISMP area. See Figure 11-3 for the locations of these points. The inventory details are included on the DVD in Appendix A.

- This portion of the Little Campbell River mainstem has two crossings (184 Street and private driveway) flooded during various 200-year storm events. See Table 11-1 for the crossing information.

- The Jacobsen / Highland Creeks ISMP area has 14.9 ha of land within the 200-year Little Campbell River floodplain area (see Figure 11-3).

11.3 HYDROLOGIC AND HYDRAULIC MODELLING

Based on the hydrologic and hydraulic modelling, the estimated flows in the LCR mainstem at the upstream end of the ISMP area are presented in Table 11-2.

Table 11-2: Jacobsen/Highland Creeks ISMP LCR Mainstem Flow Summary

Location	Catchment Area (ha)	Peak Flow Estimate (m^3/s)						
		2-year	10-year	200-year			Baseflow	
		Exist.	Exist.	Predev.	Exist.	Future	Winter	Summer
LCR 11+549[1]	**3,287** (2,738 TOL) (365 SUR) (184 WASH)	7.91	13.07	29.34	41.21	45.26	0.201	0.066

[1]Location is on LCR mainstem at upstream boundary of ISMP area.

The upstream flow boundary and the downstream water level boundary for the 2-year 24-hour, 10-year 5-day, and 200-year 5-day design events on the Little Campbell River Mainstem are included on the DVD in Appendix A. These boundaries can be used for future modelling of the Jacobsen / Highland Creeks subcatchment.

11.4 ENVIRONMENTAL OVERVIEW

The environmental overview is as follows:

- Currently, 41% of the Jacobsen / Highland Creek ISMP area is forested and the area has 58% riparian forest integrity.

- Watershed forest cover is projected to decline from 41% to 18% as a result of future development.

- Specific water quality concerns in this area have not been previously identified.

- Bank erosion is of high concern on this section of the LCR mainstem.

- The LCR mainstem through this area is important migration and rearing habitat for salmonids. Spawning occurs up to the 8 Avenue culvert on Jacobsen Creek.

- Due to some intact ravine habitat in this area, wildlife habitat value in the ISMP area is moderate.

- Barn Owl (*Tyto alba*), listed as a Threatened species under the federal *Species at Risk Act*, is known on one farm in the area. Red-legged Frogs (*Rana aurora*) have also been observed in the ravine section of Jacobsen Creek.

- No raptor nests are currently known in the area.

11.5 SUMMARY OF KEY ISSUES

The key issues within this watershed are listed in Table 11-1. The Jacobsen / Highland Creeks ISMP area will have an 18% increase in impervious area. Riparian areas, fish habitat, water quality, and declining baseflows are an issue in this watershed.

Figure 7-1 shows the existing and predicted future watershed health (B-IBI score) based on the indicators of impervious area and riparian forest integrity (RFI) on the Watershed Health Tracking System (WHTS). The impervious areas were estimated in this study and the RFI values were taken from the "Potential Pollution Sources in the Little Campbell River Watershed" (MOE, 2006) report. The WHTS shows that the Jacobsen / Highland Creeks area will likely experience a loss of health if future increases in impervious area are not mitigated.

Key issues that were identified during the course of this study include:

- 184 Street crossing is insufficient for 200-year flow;
- Semiahmoo Fish and Game Club private crossing is insufficient for 200-year flow;
- impervious area increase from development including High Point;
- potential impervious area increase in agricultural area (greenhouses);
- impacts from proposed Grandis Pond development along the border in Blaine, WA;
- watershed spans multiple jurisdictions (Surrey, Township of Langley, Washington);
- moderate riparian area integrity; and
- bank erosion.

11.6 PROPOSED MINIMUM ISMP REQUIREMENTS

The ISMP proposed for Jacobsen / Highland Creeks area should include the following basic requirements:

- Flow monitoring on Jacobsen Creek, perhaps at 200 Street, and on Highland Creek, perhaps at 8 Avenue, to be commenced prior to ISMP.
- Propose a goal for watershed health impact (no-net-loss, net gain, or other).
- Determine the existing condition of the watershed (indicators of health.
- Set volumetric reduction (capture) criteria.
- Set peak flow attenuation (detention) criteria.
- Set water quality criteria.
- Propose riparian setbacks (RAR minimum.
- Recommend and size specific measures to achieve the criteria.
- Predict the future condition of the watershed and check that level of impact is consistent with the goal set in the first bullet above.
- Recommend a monitoring program to track watershed health over the course of development.
- Recommend an adaptation strategy for adjusting the measures if targets are not being met.

Section 12

Proposed Upper LCR Agricultural Study

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CONSULTING ENGINEERS

12. PROPOSED UPPER LCR AGRICULTURAL STUDY

12.1 INTRODUCTION

The Upper Little Campbell subwatershed has been ranked sixth for the following reasons:

- minor development expected (predicted TIA increase from 4% to 15%);
- second highest predicted watershed health;
- the WHTS shows a current B-IBI score of 24 which could drop to 19 if future farm or rural development is not mitigated;
- farm practices can be changed to improve water quality; and
- riparian protection and restoration would greatly improve watershed health.

The Upper Little Campbell River subwatershed is much larger than the target value. However, this subwatershed is not expected to undergo a significant amount of development and therefore consideration was given to whether the current ISMP process is relevant. The issues in this watershed relate to agricultural uses and water quality. A study and process that reviews agricultural use and recommends changes to farm practices would be more suitable. This area would be suited to a study to address farm practices, fertilizer application, sediment control, restricting livestock access to creek banks, irrigation water supply, and field drainage. Based on the above, an ISMP is not recommended, as this watershed is not an urban watershed.

Figure 12-1 shows the 2,415 ha Upper Little Campbell River study area along with water quality and benthic sampling locations for that section of main stem. Figure 12-2 presents the floodplain and key findings from the drainage inventory, namely bridges and culverts along Little Campbell River. Table 12-1 summarizes the key area parameters.

12.2 DRAINAGE OVERVIEW

An overview of the drainage characteristics is as follows:

- The 2,415 ha Upper Little Campbell River subwatershed is situated within the Township of Langley and the State of Washington.

- Key features along the Little Campbell River mainstem in Upper Little Campbell section include the headwaters near 240 Street, a large 12 km long wetland reach in the TOL, and a large portion of Campbell Valley Park.

- The Upper Little Campbell subwatershed intersects six individual aquifers.

- Underlying aquifers in this subwatershed have declining water levels.

Table 12-1: Summary of Upper Little Campbell River Area Parameters

	Study Area Parameters		
Information	Drainage Area (ha)		2415
	Jurisdiction		
	White Rock		
	Surrey		
	Langley		√
	Blaine/Whatcom County		√
	First Nation		
Land Use	Existing TIA - ha (% of subwatershed)[1]		4%
	Future TIA - ha (% of subwatershed)[1]		15%
	Change in TIA - ha (% of subwatershed)		12%
	New Development or Redevelopment (ha)		280
	Timing of Development (now, 5-yrs, 10-yrs)		ongoing agricultural development
	Existing Agriculture (ALR) (area in ha / % of subwatershed)		2,168 / 90%
	Existing Urban/Suburban (area in ha / % of subwatershed)		10.02 / 0%
	Existing Commercial/Industrial (area in ha / % of subwatershed)		0 / 0%
Surface Water	Flooding of Campbell River Crossings in 200-year (Pre-dev / Existing / Future)		216 St, 21982 6 Ave / 216 St, 21982 6 Ave / 216 St, 21982 6 Ave
	200-year Campbell River Floodplain area (ha)		174.0
	Erosion along Campbell River (# of points/total length)		not surveyed in detail
	Sedimentation along Campbell River (# of points/length/width/area)		not surveyed in detail
	Natural Hazards on Campbell River (obstruction) (# of points)		not surveyed in detail
	Baseflows- L/s (winter/summer)		147.2 / 48.3
	Surface Water Extractions(# of PODs & flow (igpd))		9 / 37,409
Environmental	Existing Riparian Forest Cover - RFI (% of riparian area)		50%
	Existing Watershed Forest Cover (% of subwatershed)	(from MOE Report)	39%
		(from EMS)	42%
	Projected Watershed Forest Cover (% of subwatershed)		16%
	Projected Change in Watershed Forest Cover (% of subwatershed)		-27%
	Surface Water Quality (high/med/low)	for Aquatic Life (general)	low
		for Human Health (fecal coliform, etc.)	low
		Development Phase (turbidity, etc.)	low
	Number of On-site Sewage Disposal Systems		746
	Wetlands and Floodplain Areas (% of subwatershed)		10.0%
	Hydric Soils (% of subwatershed)		5.6%
	Fish and Fish Habitat	Fish-bearing streams (km/km^2)	1.63
		Major spawning/rearing areas	unknown
	EMS Hubs (# of hubs / % of subwatershed)		4 / 18.8% (partial only)
	EMS Corridors (km/km^2)		0.03
	Interior Forest from EMS (area in ha / % of subwatershed)		348.5 / 14.4%
	Species at Risk/Raptor Nests (# of species / # of known occurences)		6 / 6
	Wildlife Value (high/med/low)		high
Groundwater	Underlying Aquifer (name & confined/unconfined)		Brookswood / unconf. Langley Upland Intertill / conf. (deep) S. of Hopington / conf. Border / conf. Abbotsford / uncof. Central Hopington / conf.
	Declining Aquifer Water Levels		√
	Groundwater Extractions (# of wells / flow (igpm))		299 / 8,032
	Infiltration Capability/Soils		Silt and Clay, Gravel and Sand, Peat, Till

[1] Total Impervious Area (TIA) does not reflect the effects of BMPs which reduce the Effective Impervious Area (EIA). EIA values do not necessarily equal TIA values, however estimating EIA values was beyond the scope of this study and should be done as part of the proposed ISMP studies.

- The existing land use in the watershed is predominantly agricultural (ALR) (90%) with urban (<1%) and no commercial / industrial (0%) areas. Ongoing agricultural development is expected in this area.

- This portion of the Little Campbell River mainstem was not surveyed in detail and the sedimentation, erosion and obstruction hazards are not known in this area.

- This portion of the Little Campbell River mainstem has two road crossings (old 16 Avenue and 216 Street) and three boardwalks in Campbell Valley Park flooded during various 200-year storm events. See Table 12-1 for the crossing information.

- The Upper Little Campbell subwatershed has 174 ha of land within the 200-year Little Campbell River floodplain area (see Figure 12-2).

12.3 HYDROLOGIC AND HYDRAULIC MODELLING

The downstream water level boundaries for the 2-year 24-hour, 10-year 5-day, and 200-year 5-day design events on the Little Campbell River Mainstem are included on the DVD in Appendix A. These boundaries can be used for future modelling of the Upper Little Campbell subcatchment.

12.4 ENVIRONMENTAL OVERVIEW

An environmental overview is as follows:

- Currently, 42% of the Upper Little Campbell subwatershed is forested and the area has 50% riparian forest integrity.

- Watershed forest cover is projected to decline from 42% to 16% as a result of future development.

- Summer low flows in upper portions of the LCR mainstem are a concern due to low dissolved oxygen levels and the potential for juvenile fish stranding.

- The LCR mainstem through this area is important rearing habitat for juvenile salmonids. Some spawning may occur upstream of the mid-basin wetlands (from 232 Street to the headwaters).

- Due to the large mid-basin wetlands and associated intact riparian forest in and around Campbell Valley Regional Park, wildlife habitat value in this area is high.

- Two elusive and sensitive blue-listed bird species, Green Heron (*Butorides virescens*) and American Bittern (*Botaurus lentiginosus*), are infrequently observed within the mid-basin wetlands.

- No raptor nests are currently known in the area.

12.5 SUMMARY OF KEY ISSUES

The key issues within this watershed are listed in Table 12-1. The Upper Little Campbell watershed will have a 12% increase in impervious area. Riparian areas, fish habitat, water quality, and declining baseflows are an issue in this watershed.

Figure 7-1 shows the existing and predicted future watershed health (B-IBI score) based on the indicators of impervious area and riparian forest integrity (RFI) on the Watershed Health Tracking System (WHTS). The impervious areas were estimated in this study and the RFI values were taken from the "Potential Pollution Sources in the Little Campbell River Watershed" (MOE, 2006) report. The WHTS shows that the Upper Little Campbell will likely experience a loss of health if future increases in impervious area are not mitigated.

Key issues that were identified during the course of this study include:

- 216 Street crossing is insufficient for 200-year flow;
- private crossing at 21982 6 Avenue is insufficient for 200-year flow;
- potential impervious area increase in agricultural area (greenhouses);
- watershed spans multiple jurisdictions (Township of Langley, Washington);
- very wide floodplain along Little Campbell River;
- potential encroachment into wetlands;
- runoff water quality from agricultural areas; and
- moderate riparian area integrity.

12.6 PROPOSED ISMP PRIORITIZATION

The Upper Little Campbell subwatershed has been ranked sixth for the following reasons:

- Minor development expected (predicted TIA increase from 4% to 15%).

- Second highest predicted watershed health.

- The WHTS shows a current B-IBI score of 24 which could drop to 19 if future farm or rural development is not mitigated.

- Farm practices can be changed to improve water quality.

- Riparian protection and restoration would greatly improve watershed health.
- ISMP is not recommended, as this watershed is not an urban watershed. Study to recommend sustainable farm practices to be completed by 2015.

Section 13

Proposed McNally Creek ISMP Lite

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13. PROPOSED MCNALLY CREEK ISMP LITE

13.1 INTRODUCTION

The McNally Creek ISMP area has been ranked seventh for the following reasons:

- minor infill development expected (predicted TIA increase from 46% to 61%);
- area is already highly developed;
- worst predicted watershed health;.
- the WHTS shows a current B-IBI score of 14 which could drop to 12 if future development is not mitigated;
- close to mouth of Little Campbell River;
- detention Pond assessment under way; and
- prescriptive approaches should be recommended for development and redevelopment to improve water quality.

Figure 13-1 shows the 426 ha McNally Creek study area along with water quality and benthic sampling locations for that section of main stem. Little change in land use other than densification is anticipated. Figure 13-2 presents the floodplain and key findings from the drainage inventory, namely bridges and culverts along Little Campbell River. Table 13-1 summarizes the key area parameters.

13.2 DRAINAGE OVERVIEW

An overview of the drainage characteristics is as follows

- The 426 ha McNally Creek ISMP area is situated within the City of Surrey, the City of White Rock and the Semiahmoo First Nation Reserve No. 1.

- Key features along the Little Campbell River mainstem in Upper Little Campbell section include the Semiahmoo First Nation Reserve No. 1 at the mouth.

- The McNally Creek ISMP area intersects two individual aquifers.

- The existing land use in the watershed is predominantly urban (72%), with agricultural (ALR) (1%) and commercial / industrial (2.2%) areas. Future urban re-development and limited development is expected in this area.

- This portion of the Little Campbell River mainstem was not surveyed in detail and the sedimentation, erosion and obstruction hazards are not known in this area.

Table 13-1: Summary of McNally Creek Area Parameters

	Study Area Parameters		
Information	Drainage Area (ha)		426
	Jurisdiction		
	White Rock		√
	Surrey		√
	Langley		
	Blaine/Whatcom County		
	First Nation		√
Land Use	Existing TIA - ha (% of subwatershed)[1]		46%
	Future TIA - ha (% of subwatershed)[1]		61%
	Change in TIA - ha (% of subwatershed)		15%
	New Development or Redevelopment (ha)		65
	Timing of Development (now, 5-yrs, 10-yrs)		5-yrs
	Existing Agriculture (ALR) (area in ha / % of subwatershed)		4 / 1%
	Existing Urban/Suburban (area in ha / % of subwatershed)		305.7 / 72%
	Existing Commercial/Industrial (area in ha / % of subwatershed)		9.5 / 2.2%
Surface Water	Flooding of Campbell River Crossings in 200-year (Pre-dev / Existing / Future)		none
	200-year Campbell River Floodplain area (ha)		41.6
	Erosion along Campbell River (# of points/total length)		55 points / unknown
	Sedimentation along Campbell River (# of points/length/width/area)		not surveyed in detail
	Natural Hazards on Campbell River (obstruction) (# of points)		not surveyed in detail
	Baseflows- L/s (winter/summer)		26 / 8.5
	Surface Water Extractions(# of PODs & flow (igpd))		1 / 13,391
Environmental	Existing Riparian Forest Cover - RFI (% of riparian area)		50%
	Existing Watershed Forest Cover (% of subwatershed)	(from MOE Report)	18%
		(from EMS)	15%
	Projected Watershed Forest Cover (% of subwatershed)		4%
	Projected Change in Watershed Forest Cover (% of subwatershed)		-11%
	Surface Water Quality (high/med/low)	for Aquatic Life (general)	med
		for Human Health (fecal coliform, etc.)	high
		Development Phase (turbidity, etc.)	low
	Number of On-site Sewage Disposal Systems		35
	Wetlands and Floodplain Areas (% of subwatershed)		21.7%
	Hydric Soils (% of subwatershed)		6.4%
	Fish and Fish Habitat	Fish-bearing streams (km/km^2)	2.07
		Major spawning/rearing areas	yes
	EMS Hubs (# of hubs / % of subwatershed)		2 / 20.9%
	EMS Corridors (km/km^2)		0.07
	Interior Forest from EMS (area in ha / % of subwatershed)		22.0 / 5.1%
	Species at Risk/Raptor Nests (# of species / # of known occurences)		3 / 3
	Wildlife Value (high/med/low)		high
Groundwater	Underlying Aquifer (name & confined/unconfined)		White Rock / conf. Hazelmere Valley / conf.
	Declining Aquifer Water Levels		
	Groundwater Extractions (# of wells / flow (igpm))		16 / 60
	Infiltration Capability/Soils		Silt and Clay, Sand, Till

[1] Total Impervious Area (TIA) does not reflect the effects of BMPs which reduce the Effective Impervious Area (EIA). EIA values do not necessarily equal TIA values, however estimating EIA values was beyond the scope of this study and should be done as part of the proposed ISMP studies.

- This portion of the Little Campbell River mainstem has no crossings flooded during various 200-year storm events.
- The McNally Creek ISMP area has 41.6 ha of land within the 200-year Little Campbell River floodplain area (see Figure 13-2).

13.3 HYDROLOGIC AND HYDRAULIC MODELLING

Based on the hydrologic and hydraulic modelling, the estimated flows in the LCR mainstem at the upstream end of the ISMP area are presented in Table 13-2.

Table 13-2: McNally ISMP LCR Mainstem Flow Summary

Location	Catchment Area (ha)	Peak Flow Estimate (m^3/s)						
		2-year	10-year	200-year			Baseflow	
		Exist.	Exist.	Predev.	Exist.	Future	Winter	Summer
LCR 3+120[1]	**7,149** (3,168 TOL) (3,457 SUR) (524 WASH)	16.60	25.43	54.76	72.36	78.82	0.436	0.143

[1] Location is on LCR mainstem at upstream boundary of ISMP area.

The upstream flow boundary and the downstream water level boundary for the 2-year 24-hour, 10-year 5-day, and 200-year 5-day design events on the Little Campbell River Mainstem are included on the DVD in Appendix A. These boundaries can be used for future modelling of the McNally Creek ISMP.

13.4 ENVIRONMENTAL OVERVIEW

An environmental overview is presented as follows:

- Due to high levels of urbanization in this area, only 15% of the McNally Creek ISMP area is forested. The area currently has 50% riparian forest integrity.
- Watershed forest cover is projected to decline from 15% to 4% as a result of future development.
- Water quality concerns include high fecal coliform levels originating from several stormwater outfalls near the LCR mouth which drains areas of the City of White Rock. Metals contamination from urban areas is also a concern.
- The LCR mainstem through this area is important migration and rearing habitat for salmonids. Spawning occurs in McNally Creek upstream to approximately 8 Avenue.

- Due to the proximity of this area to the LCR estuary and because of the large amount of intact forest and mature nest trees around the LCR mainstem on the Semiahmoo Reserve, wildlife habitat value in this area is high.

- Great Blue Heron (*Ardea herodias fannini*) has nested historically on the Semiahmoo Reserve. Two blue-listed plant species (angled bitter-cress, *Cardamine angulata* and field dodder, *Cuscuta campestris*) were found historically in and around the LCR mouth.

- One Bald Eagle (*Haliaeetus leucocephalus*) nest is known in the area.

13.5 SUMMARY OF KEY ISSUES

The key issues within this watershed are listed in Table 13-1. The McNally Creek ISMP area will have a 15% increase in impervious area. Riparian areas, fish habitat, water quality, and declining baseflows are an issue in this watershed.

Figure 7-1 shows the existing and predicted future watershed health (B-IBI score) based on the indicators of impervious area and riparian forest integrity (RFI) on the Watershed Health Tracking System (WHTS). The impervious areas were estimated in this study and the RFI values were taken from the "Potential Pollution Sources in the Little Campbell River Watershed" (MOE, 2006) report. The WHTS shows that the McNally Creek will likely experience a loss of health if future increases in impervious area are not mitigated.

The following issues have been identified in background reports:

- local drainage problems;
- inadequate conveyance systems;
- seepage and standing water on private property;
- minor erosion in creek;
- debris jams and fish passage barriers in creek;
- unstable banks 12 to 15 m high in places;
- litter in ravines; and
- creek located on private property (no ROW).

Key issues that were identified during the course of this study include:

- watershed is largely built out but there is potential impervious area increase on the Semiahmoo First Nations land;

- potential flooding of access road to Semiahmoo First Nations land adjacent to Little Campbell River;

- watershed spans multiple jurisdictions (Surrey, White Rock, First Nations); and

- moderate riparian area integrity.

13.6 PROPOSED MINIMUM ISMP REQUIREMENTS

The ISMP proposed for the McNally Creek area should include the following basic requirements:

- Flow monitoring on McNally Creek, perhaps at 8 Avenue or 10 Avenue, to be commenced prior to ISMP.
- Propose a goal for watershed health impact (no-net-loss, net gain, or other).
- Determine the existing condition of the watershed (indicators of health).
- Set volumetric reduction (capture) criteria.
- Set peak flow attenuation (detention) criteria.
- Set water quality criteria.
- Propose riparian setbacks (RAR minimum.
- Recommend and size specific measures to achieve the criteria.
- Predict the future condition of the watershed and check that level of impact is consistent with the goal set in the first bullet above.
- Recommend a monitoring program to track watershed health over the course of development.
- Recommend an adaptation strategy for adjusting the measures if targets are not being met.

Section 14

Little Campbell River Watershed Summary

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14. LITTLE CAMPBELL RIVER WATERSHED SUMMARY

14.1 INTRODUCTION

- The City of Surrey and Township of Langley initiated this Integrated Stormwater Scoping Study for the Little Campbell River watershed.

- The objectives for the Scoping Study are to develop a hydrologic model for the entire watershed and a hydraulic model for the mainstem, determine the watershed issues, and discretize and prioritize sub-watershed ISMP studies.

- Two stakeholder meetings were held in 2007 to discuss the watershed issues.

14.2 DRAINAGE OVERVIEW

- The 7,580 ha Little Campbell River watershed is largely situated within the Township of Langley and the City of Surrey with portions within the City of White Rock, the State of Washington, and the Semiahmoo First Nation Reserve No. 1.

- Key features along the Little Campbell River include the headwaters near 240 Street, a large 12 km long wetland reach in the TOL, Campbell Valley Park, the Little Campbell Hatchery, the Peace Portal Golf Course, and the Semiahmoo First Nation Reserve No. 1 at the mouth.

- The Little Campbell River watershed intersects ten individual aquifers.

- The existing land use in the watershed is predominantly agricultural with several urban areas. Future urban development is expected largely in the Ferndale, Campbell Heights, Douglas, and Grandview Heights areas.

- An extensive field inventory was undertaken to document crossing, cross sections, and erosion/deposition areas along the Little Campbell River mainstem.

- Severity and consequence ratings were assigned to noted erosion locations.

- Channel obstructions were categorized and assessed for stability.

14.3 HYDROLOGIC AND HYDRAULIC MODELLING

- An XP-SWMM hydrologic model was developed for the subcatchments within the watershed for the pre-development (forested), existing, and future land uses.

- A MIKE11 hydraulic model of the Little Campbell River main stem was developed.
- Both models were calibrated to the recorded flows and water levels at 12 Avenue.
- The 2-year 24-hour, 10-year 5-day, and 200-year 5-day design events were modelled.
- The Little Campbell River mainstem crossing capacities were assessed. The model showed overtopping during the existing land use 200-year event at the following road crossings: 8 Avenue, 12 Avenue, 184 Street, 16 Avenue near 194 Street, 24 Avenue near 198 Street, 200 Street, and 216 Street.
- The winter and summer baseflow rates measured at the 12 Avenue gauge are approximately 0.061 L/s/ha and 0.020 L/s/ha, respectively.

14.4 WATER QUALITY AND BENTHIC INVERTEBRATES

- Fecal coliform levels in the LCR watershed are elevated and periodically exceed guidelines, particularly in the lower watershed.
- Urban runoff from stormwater outfalls is the largest contributor to fecal coliform loadings at the LCR mouth.
- Both turbidity and total suspended solids regularly exceed guidelines. Construction runoff has likely contributed to extreme turbidity events and sediment loading.
- Extremely low dissolved oxygen levels caused by low flows and high water temperatures in the upper reaches of the LCR in summer/early fall causing periodic mortality of Coho fry.
- Dissolved oxygen levels below minimum objectives perhaps due to high BOD occur from October to February when salmonid eggs, larvae and alevin are present.
- Ammonia and nitrite levels consistently meet objectives in the LCR watershed and are consistent with low levels of anthropogenic enrichment.
- Nitrate and orthophosphate levels are well below national and provincial guidelines in the mainstem but may be higher than desirable within specific sub-catchments (e.g., Twin Creeks).
- Water temperatures in the LCR periodically reach levels capable of inducing chronic effects on salmonid growth and survival, especially during the summer months in the upper reaches of the watershed.

- Increased water temperatures are likely caused by lack of riparian vegetation and low water levels due to ground and surface water extraction.

- pH objectives have been met historically and are currently met in the LCR watershed.

- Other contaminants of potential concern in the LCR watershed include metals, persistent organic pollutants, endocrine disrupting chemicals, and antibiotics/ pharmaceuticals but levels and effects are largely unknown.

- Some metals may exceed recommended guidelines at localized sites in the watershed and are generally associated with more urbanized catchments.

- Indicators of stream health in the LCR mainstem range from fair to poor and are show improving health with distance upstream. The Fergus Creek sites fall within the very poor category. Sites further west within the watershed, with greater impacts from urban development, appear more stressed.

- The priority water quality issues listed in order of importance are:

  1. fecal coliforms;
  2. low dissolved oxygen and high summer water temperature;
  3. turbidity from construction; and
  4. bank erosion.

- ISMPs are required to address the impacts of stormwater management on relevant community values and water uses.

- Water quality objectives in the LCR under the LWMP were set to protect the most sensitive water uses.

- The current LWMP requires ongoing monitoring for exceedance of water quality objectives and an environmental risk assessment can be triggered by exceedance of objectives caused by stormwater (or other) discharges.

14.5 FISH AND FISH HABITAT

- The LCR is one of the most highly productive salmon rivers in the Lower Mainland relative to its size. Five species of salmonids, including four species Pacific salmon and one species of trout, have self-sustaining wild populations in the watershed.

- Salmon and trout are widely distributed in the LCR mainstem and tributaries, although the gravel reaches from 184 Street to upstream of 200 Street are the most critical for spawning.

- Good potential rearing habitat exists in the middle reaches of the watershed in the area of the mid-basin wetlands at Campbell Valley Regional Park.

- Channelization and culvert or bridge installation has caused relatively little change to the LCR mainstem.

- Much of the bank erosion observed in the watershed is considered a natural part of river channel processes.

- The frequency of large woody debris was extremely variable in river segments but generally low and stream bed substrates are predominantly gravel and sand.

- Within 250 m of the LCR mainstem centreline, land cover was predominantly forest (40.9%), agriculture (24.9%), and wetlands or river channel (9.5%), and developed areas such as roads and buildings (9.2%).

- Within 30 m of the LCR mainstem centreline, land cover was dominated by forest (39.9%), wetland (31.5%), grass (9.5%), and agriculture (8.3%).

14.6 BIODIVERSITY

- The LCR watershed has regionally significant populations of several priority and at-risk aquatic and terrestrial species.

- The mid-basin wetland and associated riparian areas in Campbell Valley Regional Park and the marine foreshore on Semiahmoo Bay are regionally significant reservoirs for biodiversity.

- Past surveys of habitats in the LCR have identified occurrences of several rare species in the watershed: one fish, three amphibians, three birds, two mammals, one terrestrial mollusc, and five plant species.

- Unique components of LCR's watercourses used directly by wild salmonid populations at different life history stages are:

  1. the LCR mainstem and larger tributaries;
  2. off-channel habitats; and
  3. small tributaries/headwater streams.

  Rivers and streams and associated biodiversity are threatened by changes to the quality and quantity of runoff in developed areas, channelization, dyking, dredging, culverting, loss of woody debris, and changes in sediment transport.

- Major wetland types in the LCR include:

1. fluvial wetlands;
2. ponds;
3. seasonally-flooded fields; and
4. the LCR Estuary.

Wetlands and associated biodiversity in the LCR are threatened by the draining and infilling from urban development and agriculture, changes in water table (reduction in infiltration due to development and withdrawal from wells), pollution, and invasive species.

- Riparian habitats in the LCR can be divided into: 1) riparian forest and 2) non-forested riparian communities. Much of the riparian corridor in the LCR has been fragmented by road construction and land clearing for agricultural or rural development. Pollution, garbage, yard waste dumping, and introductions of invasive species are also detrimental to riparian habitats.

- Forested habitats in the LCR can be divided into: 1) large forest patches and 2) small forest patches and isolated trees. Fragmentation and clearing are the major threats to forests and forest-dependent species.

- Important agricultural-associated habitats in the LCR include: 1) old fields and 2) hedgerows. Old field habitats are threatened by urban and industrial development of agricultural lands, the return of old fields to active cultivation, conversion to non-compatible agricultural uses such as greenhouses, and off-road vehicle activity.

- The priority biodiversity issues listed in order of importance are:

  1. habitat impacts on fish;
  2. encroachment into mid-basin wetlands;
  3. loss and fragmentation of riparian forest;
  4. loss and fragmentation of upland forest;
  5. introduction of exotic species; and
  6. human disturbance.

- Consideration of biodiversity in ISMPs is a way of meeting both regulatory requirements and important local and regional biodiversity objectives. However, there is currently no established link between ISMP planning and these biodiversity objectives.

- Future inventory and assessment of biodiversity needs to occur at the landscape or watershed scale to provide the scale-appropriate information needed to set priorities for management and prescribe appropriate protection measures.

Section 15

Recommendations

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15. RECOMMENDATIONS

Based on the foregoing, it is recommended that: the City of Surrey and the Township of Langley undertake the following:

1. Initiate Individual Subcatchment ISMP / Studies

- Commence monitoring flow and benthic sampling at least one strategic locations in each of the five ISMP areas ahead of initiating the ISMPs in order to have a longer record of data and simultaneous data from all parts of the watershed for comparison purposes.

- Initiate the following individual ISMP studies:

  1. Fernridge / Campbell Heights ISMP;
  2. Sam Hill / Twin Creeks ISMP;
  3. Kuhn Creek ISMP;
  4. Jacobsen / Highland Creeks ISMP; and
  5. McNally Creek ISMP-Lite.

  Each study should follow guidance and recommendations outlined in Section 7.5 and each individual ISMP area Sections 8 to 13.

- Review and initiate any additional work required in addition to the completed Fergus Creek ISMP (McElhanney, 2007).

- Initiate an Upper Little Campbell River Agricultural Study that focuses on agricultural practices and procedures to protect or enhance watershed environmental values.

2. Implement Interim Stormwater Volume Reduction Criterion

- Ensure all future development and redevelopment must have designs to meet the applicable municipal criteria and bylaws for flood protection, water quality treatment during and post-construction activities, rate control for environmental, erosion and flood protection, and riparian setbacks.

- Implement an interim stormwater volume reduction criterion to capture on-site the runoff from a 25 mm (50% of 2-year) rainfall event. This criterion will provide guidance to development before the completion of the ISMPs and will strive to maintain watershed health in the interim. Once each ISMP is completed, the interim criterion may be replaced by subwatershed-specific criteria.

- Develop typical examples and standards of source controls to achieve the above mentioned criterion to expedite implementation and construction of source controls. Once each ISMP is completed, the generic standards may be replaced by subwatershed-specific standards.

3. **Monitoring**

- Monitor the stream health (B-IBI indicator, water quality, and flow measurements) over the period of development near the mouth of each major tributary (McNally, Kuhn, Sam Hill, Twin, Highland, and Jacobsen Creeks) and continue the B-IBI monitoring on the Little Campbell River and Fergus Creek.

- Develop and implement a long-term performance monitoring program for each ISMP area and the Little Campbell River watershed as a whole.

- Develop and implement an adaptive management program to modify/optimize mitigative approaches and measures as needed. Adjust source control and/or BMP sizing and/or designs if monitoring results show trend of decreasing watershed health.

- Install staff gauges at all Municipal crossings of the Little Campbell River main stem and manually record high water levels, dates, and times during future large storm events so that this information can be used in the future to calibrate the hydraulic model of the main stem.

4. **Longer Term Actions**

- Look for opportunities to secure the riparian area along Little Campbell River and its tributaries in the agricultural areas where RAR does not apply to protect the stream health.

- Update the overall Little Campbell River hydrologic and mainstem hydraulic models, calibration and hydrotechnical assessment after completion of the individual area ISMPs. Use the individual studies' hydrology and staff gauge measurements. Evaluate the design peak water level profiles, floodplain extents mapping and assess the adequacy of the conveyance capacity of the mainstem crossings.

5. **Provide Input to Metro Vancouver ISMP Process Template Update**

The Metro Vancouver ISMP Template is being reviewed and updated in 2011. The following items should be brought forward in that process to be reviewed and addressed if agreed upon by the contributing stakeholders:

- Consider incorporating a process for non-urban watersheds, i.e. agricultural watersheds.

- Consider inclusion of specific water quality objectives as criteria for management and using existing data to set specific targets for improvement over time.

- Review and refine the direction of Clause 9 of the ISMP Template to provide more specific direction on the consistent assessment of fish and fish habitat in all permanent, fish-bearing streams. This could include more emphasis on assessing structural habitat features such as large wood frequency, channel dimensions, and substrate characteristics. Non-permanent streams should be assessed for fish use and access.

- Provide better direction for assessing natural versus accelerated or anthropogenic bank and channel erosion.

- Incorporate biodiversity more explicitly into stormwater planning activities.

15.1 REPORT SUBMISSION

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD. **RAINCOAST APPLIED ECOLOGY**

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Appendix A

DVD of Digital Information

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Appendix B

12^{th} Avenue Flow Monitoring Graphs

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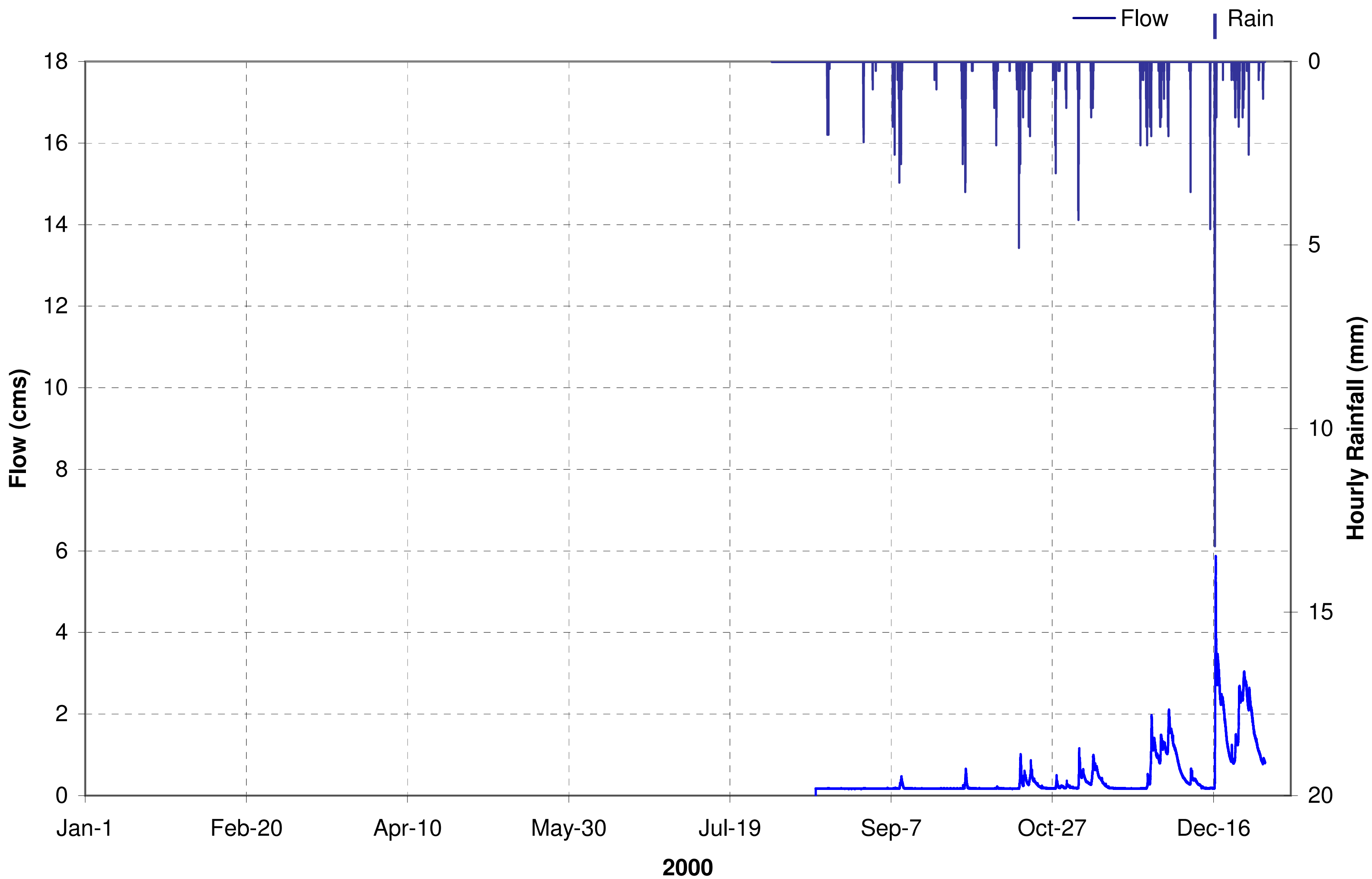
2000
Flow Monitoring at Little Campbell River 12th Ave. Station & Rainfall at Semiahmoo Fish and Game Club Rain Gauge



Kerr Wood Leidal Associates Ltd.
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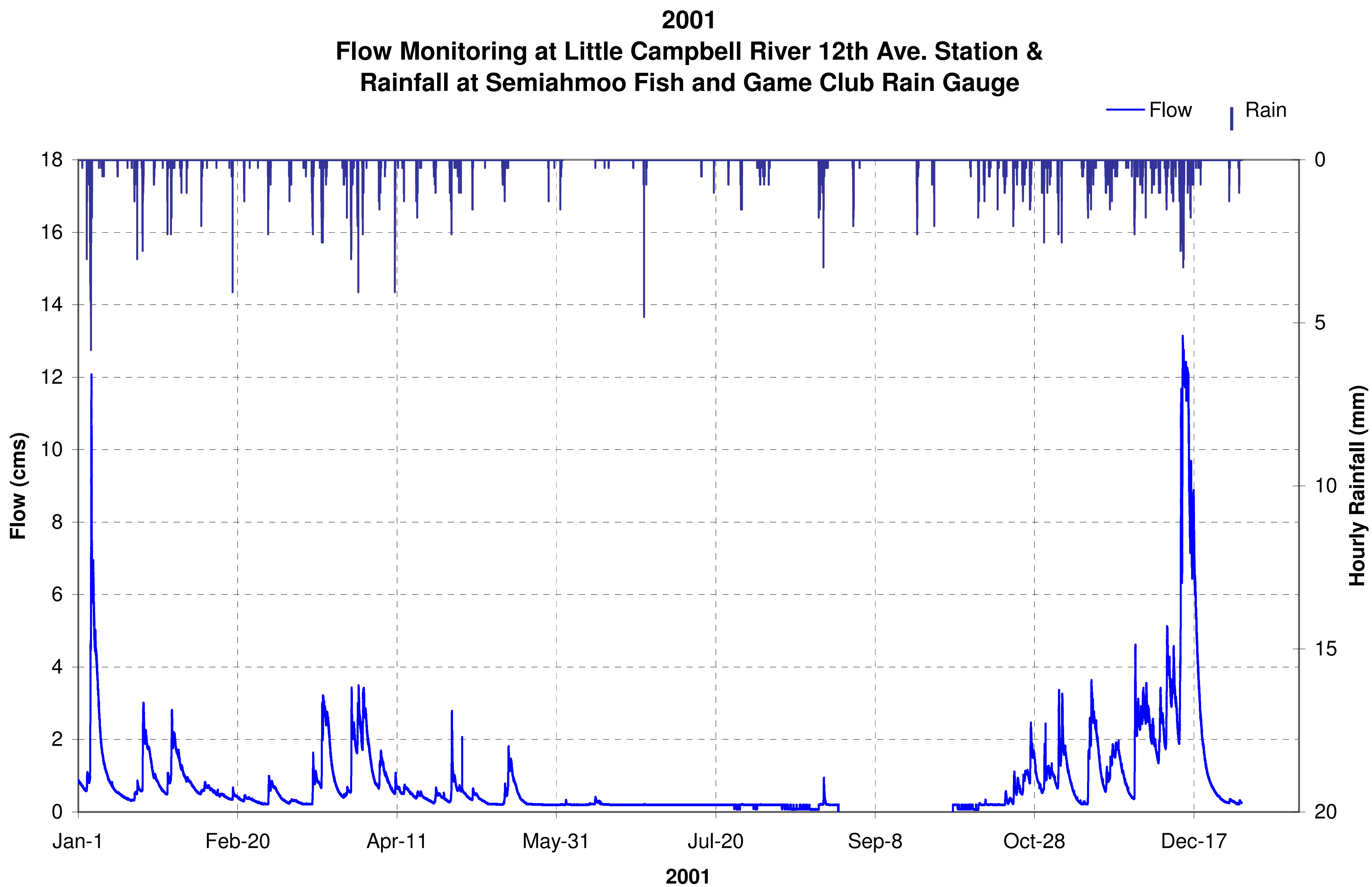

Kerr Wood Leidal Associates Ltd.

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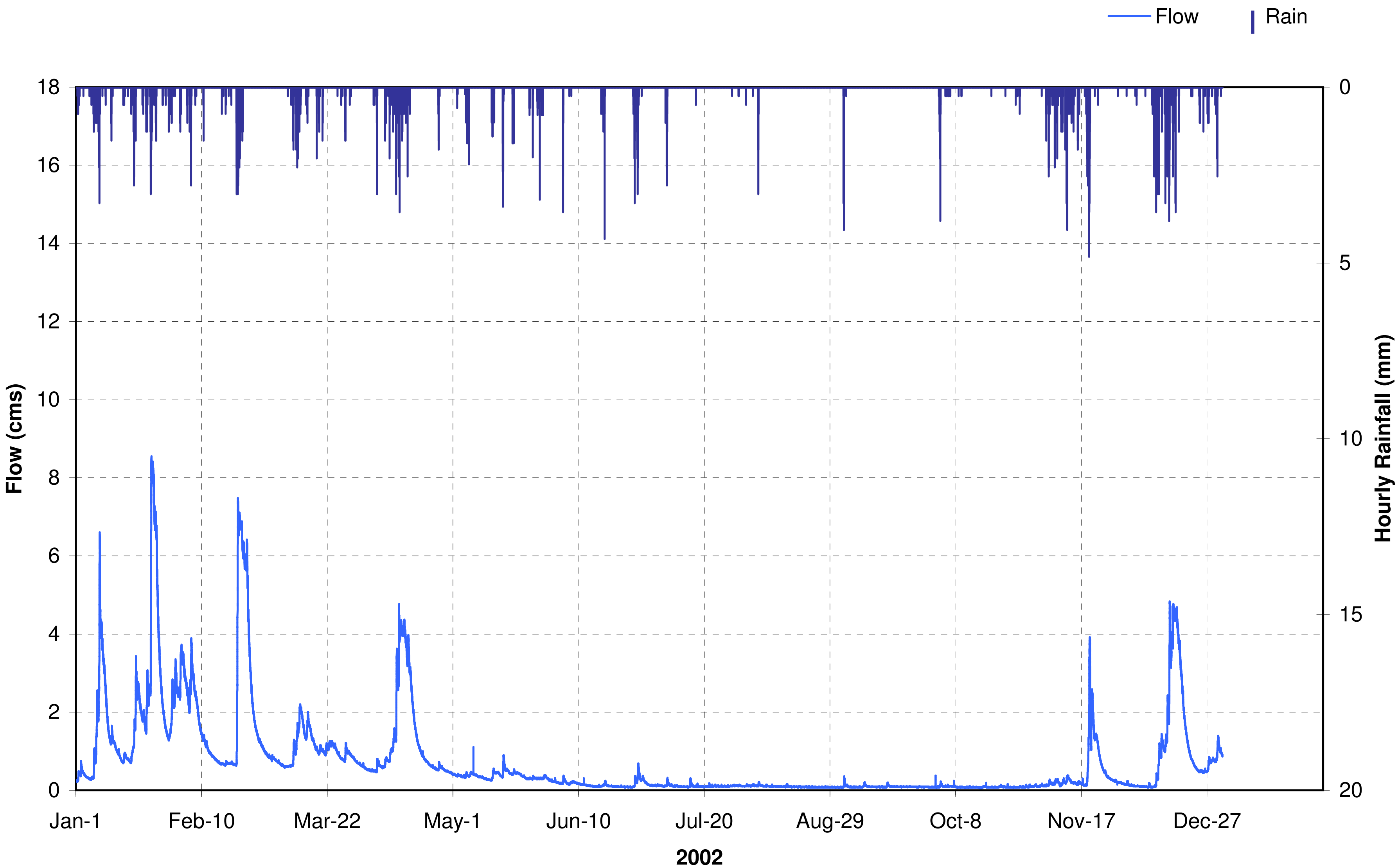
2002
Flow Monitoring at Little Campbell River 12th Ave. Station &
Rainfall at Semiahmoo Fish and Game Club Rain Gauge



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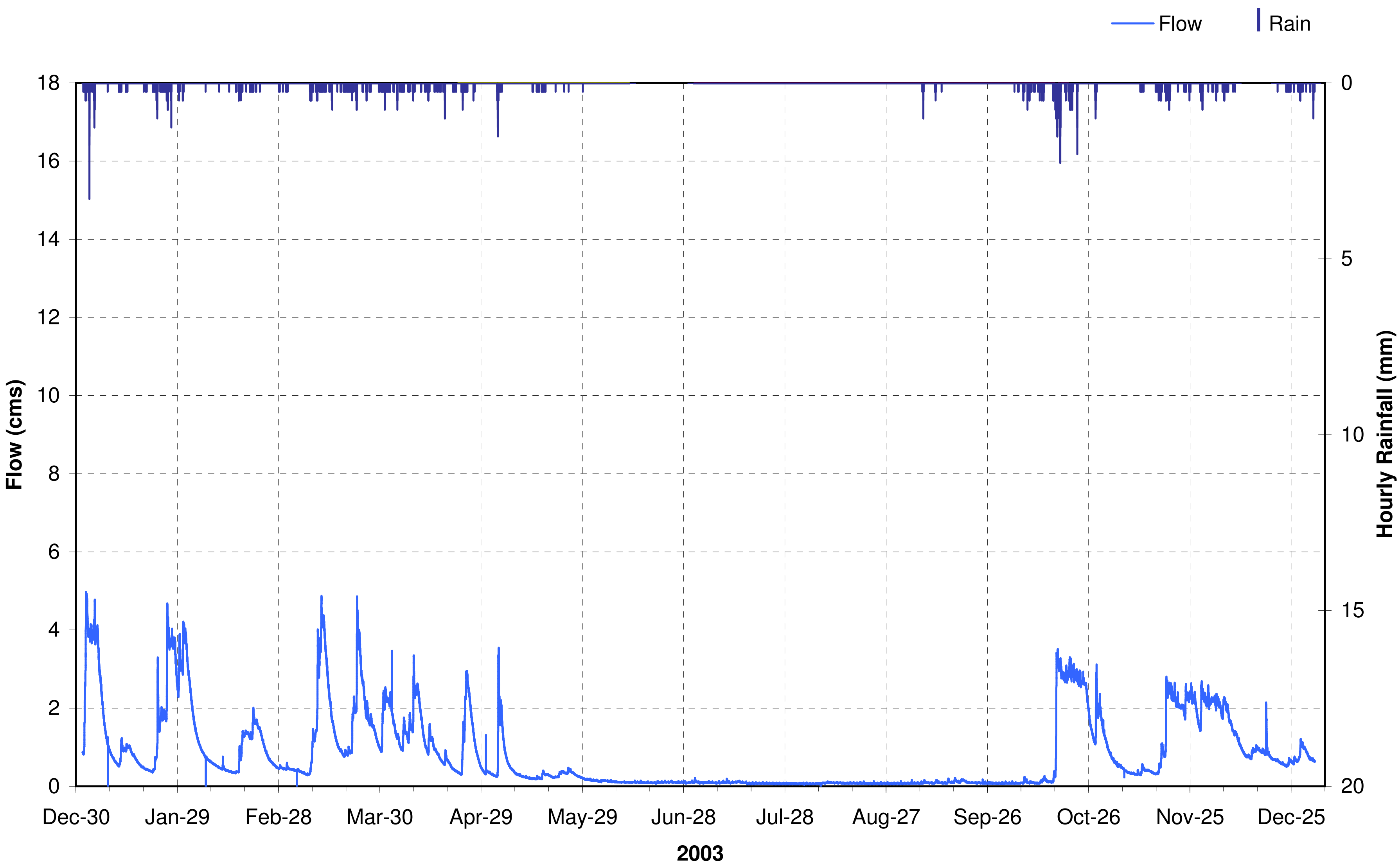

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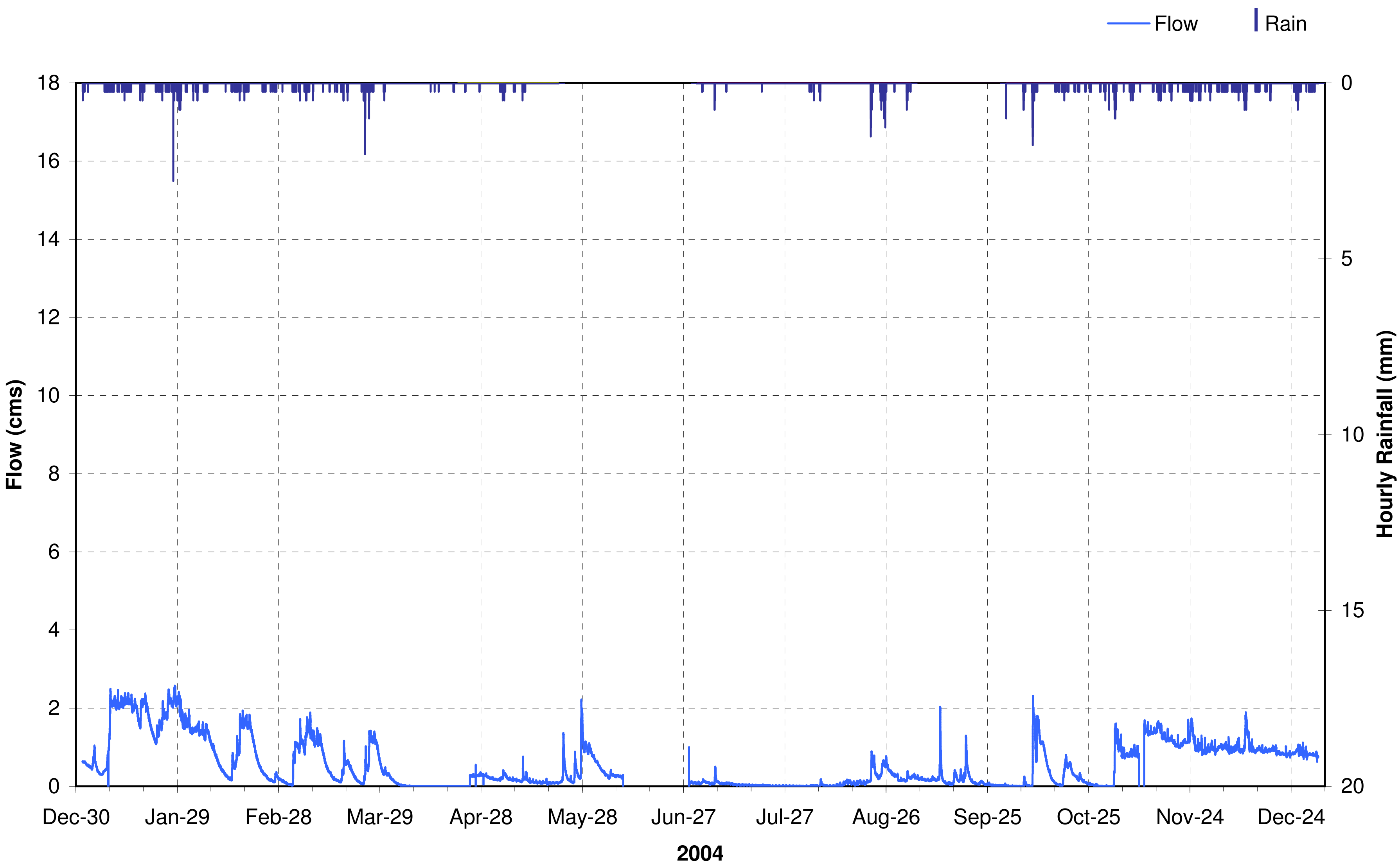

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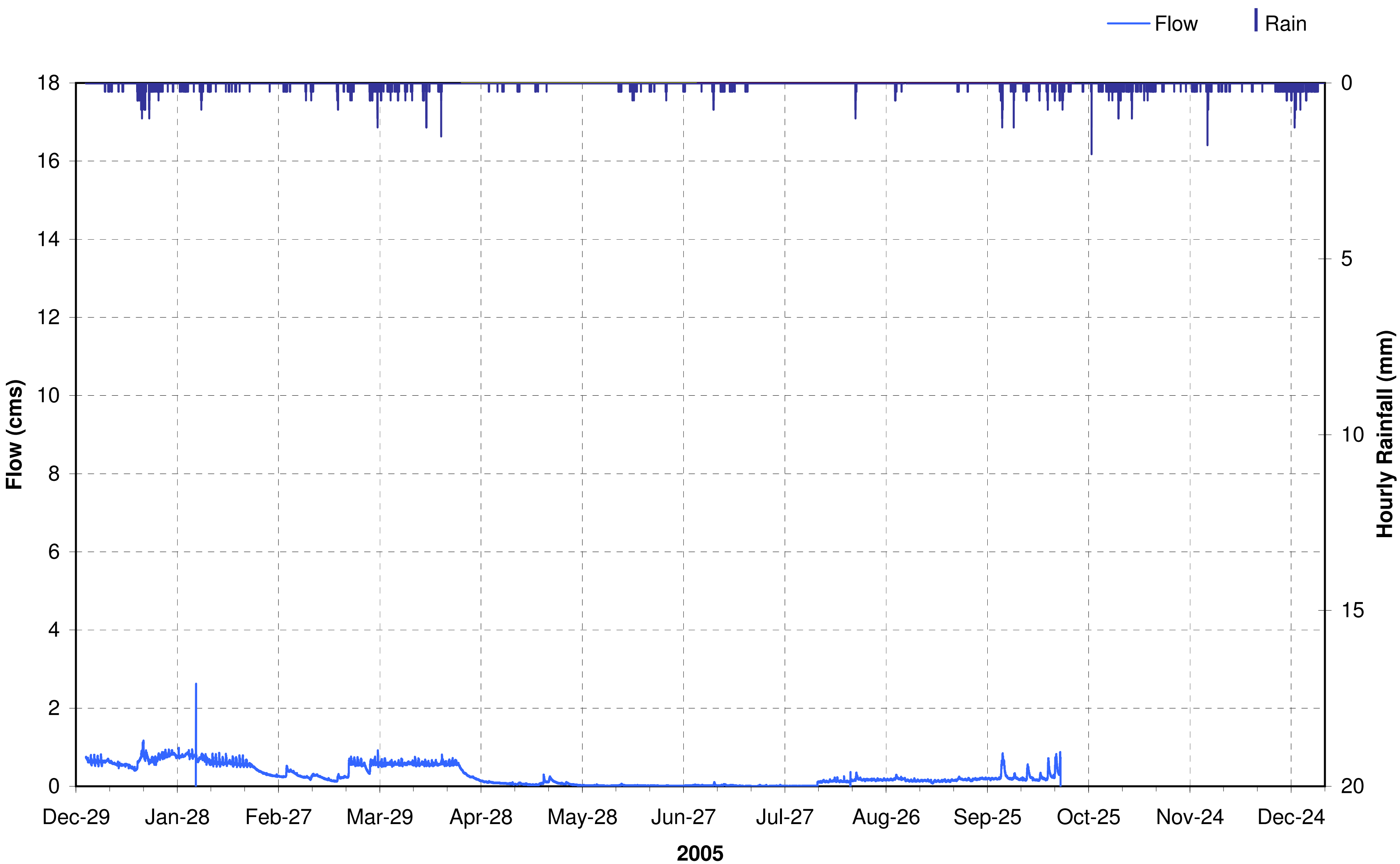

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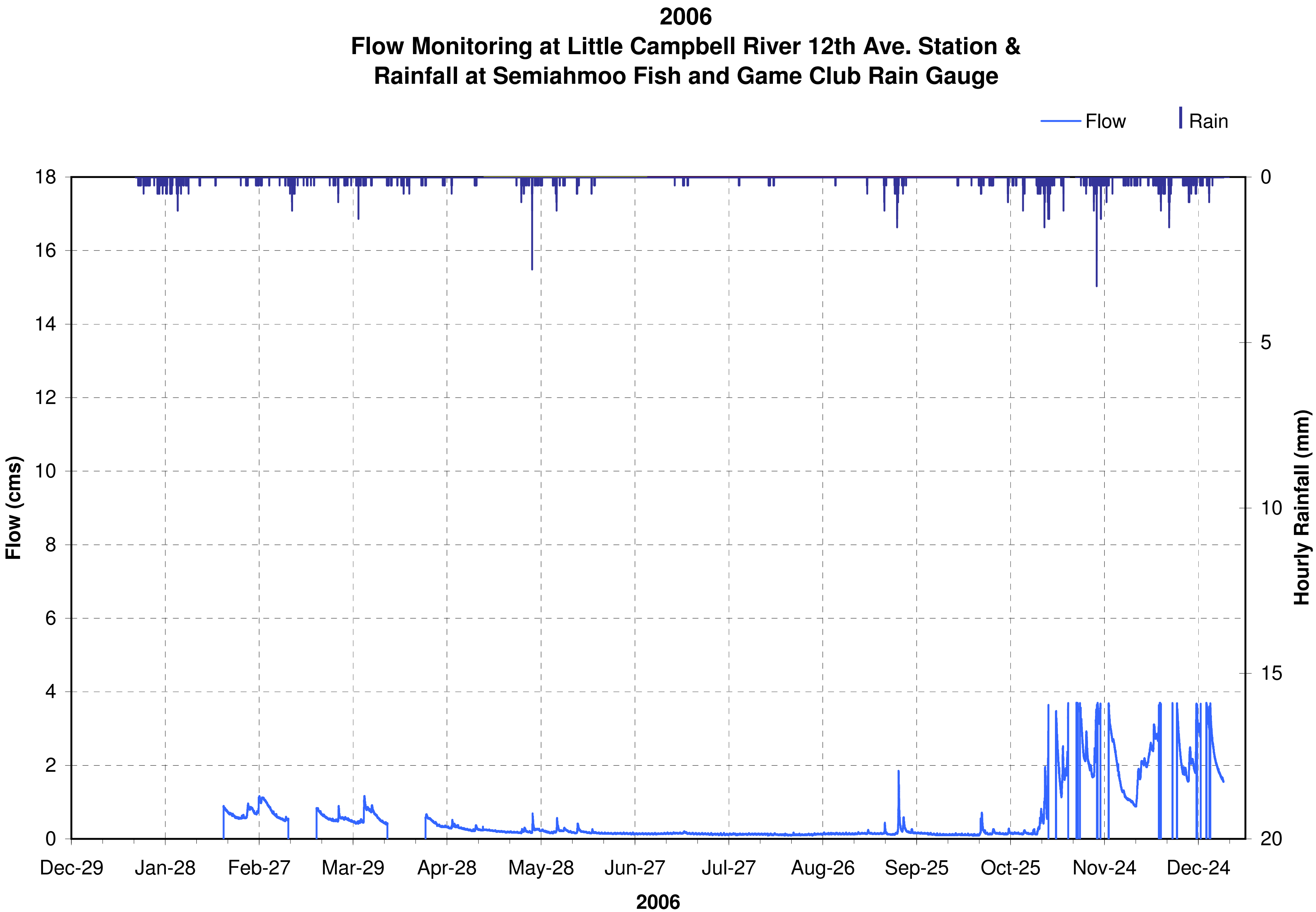

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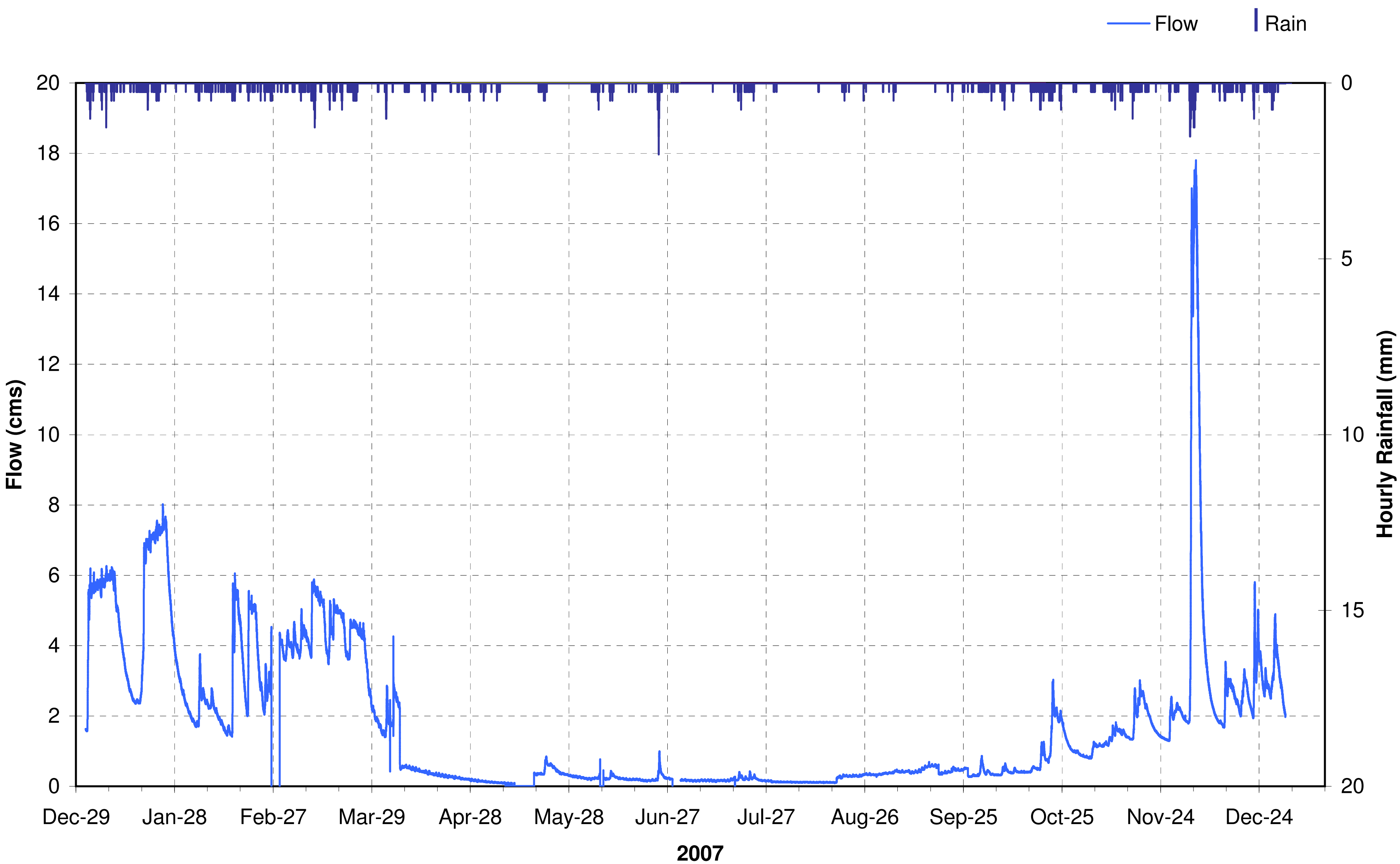

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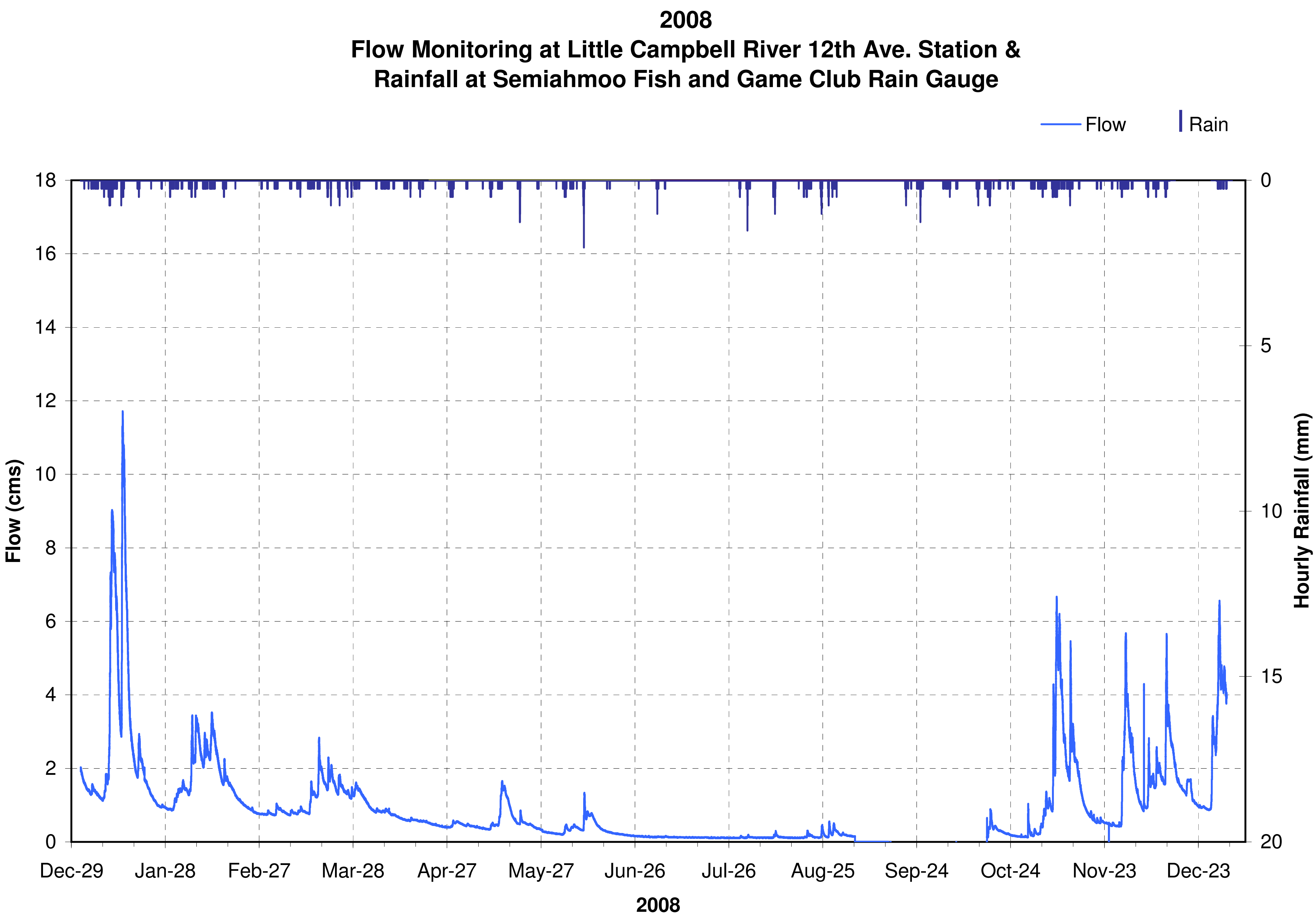

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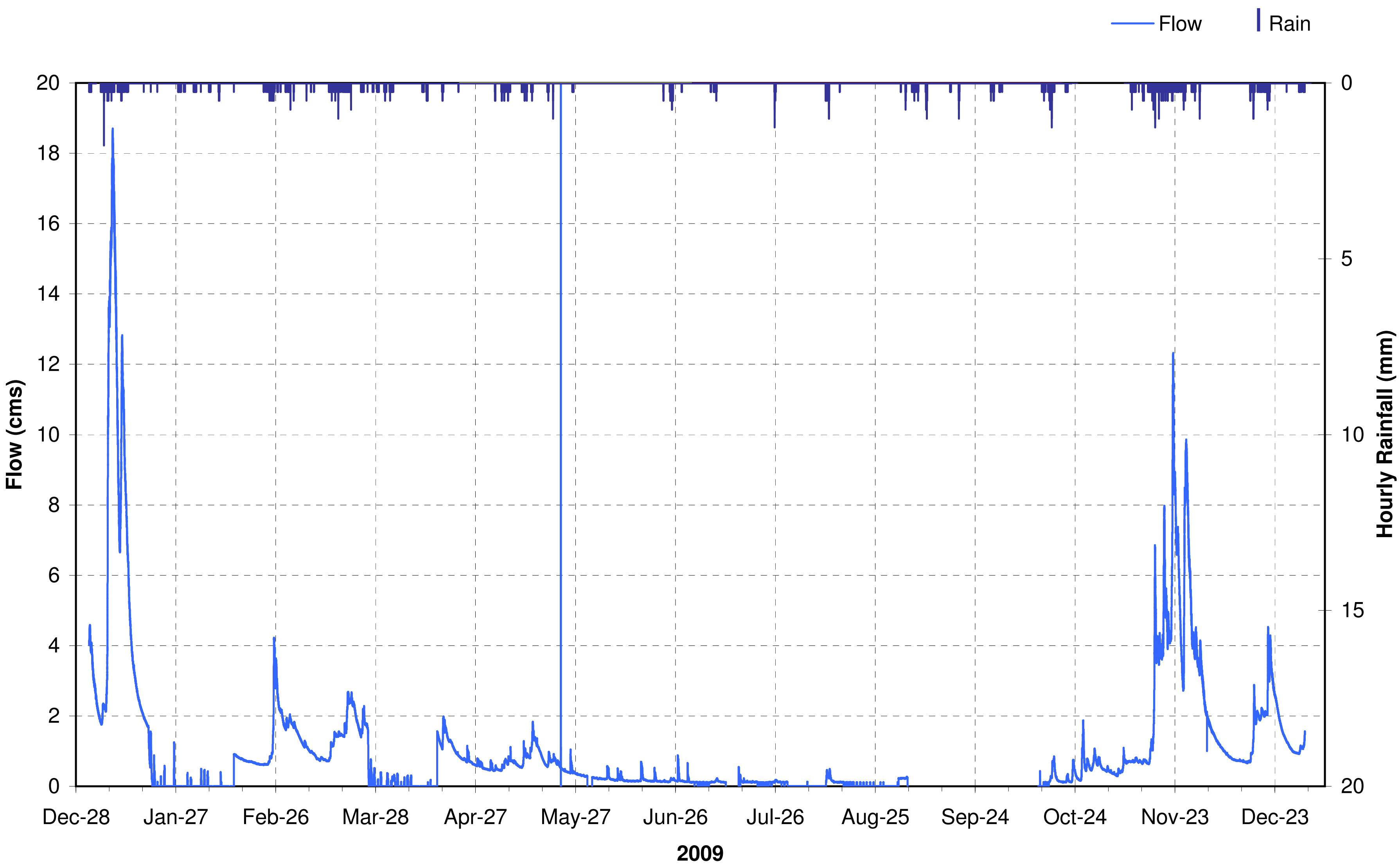

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Appendix C

Environmental Assessment Report

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

CONTENTS

FIGURES

TABLES

C1. WATER QUALITY AND BENTHIC INVERTEBRATES

The environmental assessment component of the Little Campbell River Integrated Stormwater Scoping Study is separated into three parts:

1. water quality and benthic invertebrates;
2. fish and fish habitat; and
3. biodiversity.

These reflect the direction and commitments under the Liquid Waste Management Plan (LWMP) and Metro Vancouver's *Template for Integrated Stormwater Management Planning 2005* (KWL 2005; called the "ISMP Template"), as well as broader environmental management goals of the City of Surrey and Township of Langley.

Each part is divided into five sections:

1. an introduction;
2. summary of existing information;
3. priority issues related to the development of Integrated Stormwater Management Plans (ISMPs);
4. ISMP-related management objectives; and
5. recommendations for the ISMP process in the Little Campbell River watershed.

It is important to note that not all aspects of water quality, fish habitat, and biodiversity are addressed in many current ISMP processes.

C1.1 INTRODUCTION

Assessing and minimizing impacts to water quality is a key component of ISMPs. The ISMP Template addresses water quality in Clauses 12 and 13 (KWL 2005). Clause 12 focuses on using benthic invertebrate communities to establish a baseline condition of stream health and monitor changes in conditions over time. Clause 13 proposes sampling of several water quality indicators (water temperature, specific conductivity, dissolved oxygen saturation, pH, fecal and total coliform, etc.) and suggests the sampling of additional parameters depending on the downstream water uses (KWL 2005).

Many watersheds in the Metro Vancouver region where ISMPs or other watershed-scale planning has been undertaken are relatively urbanized watersheds with limited water uses and little existing data on water quality. With respect to water quality, the Little Campbell River (LCR) is unique from most Metro Vancouver watersheds in several ways:

- **Detailed water quality data is available for a wide range of water quality parameters as a result of ongoing monitoring in the watershed.** This existing information provides a valuable tool with which to assess both past and existing conditions, identify known relationships between water quality effects and land uses, and observe trends over time to date.

- **Specific water quality issues have been identified by previous studies.** Several specific issues (e.g., fecal coliform) can be identified prior to the initiation of the formal ISMP process and specifically addressed during subsequent ISMP planning activities.

- **There are a larger number of potentially sensitive water uses in the LCR relative to most Metro Vancouver watersheds.** These include:

  - Recreational uses such as ***fishing*** and ***swimming*** (in both the LCR and Boundary Bay);
  - Agricultural uses for ***irrigation*** and ***watering of livestock***;
  - ***Shellfish harvesting*** (downstream in Semiahmoo Bay and Boundary Bay); and
  - Habitat for ***aquatic life*** and ***wildlife***.

  Protecting water quality for all of the uses within a watershed is an important objective of ISMPs and the LWMP for the region.

- **Specific water quality objectives have been previously set for the LCR watershed.** BC Ministry of Environment has developed province-wide Approved Water Quality Guidelines (criteria) to protect water quality based on broad categories of water uses. However, objectives specific to the LCR were developed for some parameters (e.g., nutrients) in 1988 to further protect the above water uses and the objectives of the LWMP while also recognizing unique watershed context and challenges (see Swain and Holms 1988 for more information).

- **There are a larger range of land uses and land use activities in the LCR than many Metro Vancouver watersheds that are potential sources of pollution.** These include urban (residential, commercial, and industrial), rural, and agricultural land uses.

- **Water quality impacts of the LCR to its receiving environment are an important international environmental protection and wildlife conservation issue.** Semiahmoo Bay is a transboundary waterbody shared between Canada and the US and part of the ecologically significant Boundary Bay ecosystem. Boundary Bay is a major stop-over on the Pacific Flyway for migratory bird species and a critical rearing habitat for fish, among other species.

These unique characteristics of the LCR are a result of the importance of downstream water uses that depend on adequate water quality (e.g., fisheries, shellfish harvesting, wildlife and aquatic life), longstanding concerns from several levels of government about water quality in the watershed, and the presence of several active stakeholder groups interested in water quality,

HISTORY OF WATER QUALITY MONITORING IN THE LCR WATERSHED

Historic interest in water quality in the LCR was initially motivated by fecal coliform contamination in Boundary Bay. Due to ongoing bacteriological contamination, valuable shellfish beds in the Canadian side of Boundary Bay have remained closed since 1972. Fecal contamination in Semiahmoo Bay, a sub-basin of Boundary Bay and the immediate receiving waters of the Little Campbell River, has been attributed to cumulative impacts of several upstream pollution sources: agricultural runoff, urban stormwater, and failing septic systems, as well as domestic pets and wildlife (Juteau and Krause 2007).

While fecal coliform contamination has maintained the highest profile of all water quality issues in the LCR to date, high turbidity and suspended solids, low dissolved oxygen levels and high water temperatures in the summer months, and nutrient loadings have also been identified as issues of potential concern in the LCR watershed (Drever and Brown 1999, Bull 2003, Fleming and Quilty 2006). Some of these effects have been attributed to acute and long-term impacts of increasing development and land use intensity in the watershed (Zevit et al. 2007, Juteau and Krause 2007).

To begin to address water quality concerns in the watershed, provisional water quality objectives were established for the LCR in 1988. These objectives were created to assist the Greater Vancouver Regional District (now Metro Vancouver) in the preparation of a Liquid Waste Management Plan for the Fraser-Delta area. Objectives were set to protect sensitive water uses: aquatic life and recreation in Boundary Bay (e.g., swimming, shellfish harvesting), and aquatic life, wildlife, irrigation and livestock watering in the tributaries (Swain and Holms 1988).

The Shared Waters Alliance (SWA) was formed in 1999 to provide a cooperative, coordinated approach to water quality in the Canadian-US shared waters of Boundary Bay. This international working group includes Canadian and US representatives from four levels of governments (federal, provincial/state, regional/county, and municipal/city), First Nations, and local community groups. The City of Surrey and Township of Langley are both partners of the SWA.

Since the creation of the SWA, several specific studies have been conducted to try to address the sources of fecal coliform contamination in Semiahmoo Bay. Studies have been undertaken or funded by Environment Canada (through the Georgia Basin Ecosystem Initiative; Hay & Co. 2003, Cheung 2003), BC Ministry of Environment (Bull 2003, Zevit et al. 2007, Juteau and Krause 2007), and the Little Campbell River Watershed Society with partners (Drever and Brown 1999, Fleming and Quilty 2006). Recent sampling by the City of Surrey and by A Rocha Canada and Environment Canada has used benthic invertebrate communities to characterize watershed health (Dillon 2005, Krause 2006).

SOURCES OF DATA

To date, water quality monitoring in the LCR watershed has taken the following forms:

1. **Water quality objectives attainment monitoring –** Attainment monitoring for both broad provincial and LCR-specific water quality objectives (see Swain and Holms 1988) was carried out annually from 1971–1992 at two sites (upstream station: LCR mainstem at 216th St; downstream station: LCR mainstem at 176th St) by BC Ministry of Environment but was discontinued in 1992 due to lack of funding. In 1999, 2000, 2002, and 2006/07, attainment monitoring was again undertaken at these sites and compared with available historical data (Drever and Brown 1999, Bull 2003, Juteau and Krause 2007).

2. **Spatial patterns in water quality parameters –** Spatially-extensive water quality sampling was carried out at various sites in the watershed by the Little Campbell Watershed Society and students from Kwantlen College from 2000 to 2002. In 2006, most of the existing water quality data for the watershed was collated and spatial patterns in the recent data (2000–2003) were analyzed and reported (Fleming and Quilty 2006). This report also included the modeling of climate effects on water temperatures in the LCR.

3. **Source tracking of fecal coliform contamination –** A circulation study of Semiahmoo Bay (Hay & Co. 2003) and a survey of freshwater outfalls along the Bay (Cheung 2003), completed by Environment Canada in 2003, indicated that the LCR and associated outfalls are the largest contributor of fecal contamination to the Bay. In 2006, BC Ministry of Environment commissioned a watershed characterization study to identify potential non-point sources of pollution, characterize the landscape processes that control and regulate water quality, and understand how human alterations to the watershed have degraded these functions (Zevit et al. 2007). Further fecal coliform sampling was carried by BC Ministry of Environment in 2006/07 to characterize the temporal and spatial dynamics of bacteriological contamination in the LCR watershed and assess relationships between fecal coliform loadings and potential sources of contamination. The contributions of different sub-watersheds to fecal coliform loading by season and the potential contributions of urban runoff, agricultural runoff, and on-site sewage disposal systems were assessed (Juteau and Krause 2007).

4. **Continuous monitoring using automated data collection –** Water temperature data loggers were installed along the mainstem and at locations within each of eight sub-watersheds in July 2005 and a Hydrolab automated water quality monitoring station was installed on the LCR mainstem in October 2005 (at the 12th Ave crossing) (Fleming and Quilty 2006, Juteau and Krause 2007). These stations are providing the first continuous water quality data for the watershed.

5. **Integrated monitoring using benthic invertebrates –** In 2005, four benthic invertebrate sampling sites (two in LCR mainstem and two in Fergus Creek) were established in the LCR watershed by the City of Surrey to provide baseline data in advance of ISMP initiatives (Dillon 2005). These sites were sampled in the spring of 2005, 2006, and 2007. Benthic invertebrates were also sampled at four sites (three in LCR mainstem and one in Fergus Creek) by A Rocha Canada and Environment Canada in the fall of 2004, 2006, and 2007 using an alternative benthic invertebrate sampling methodology (Krause 2006, Vinke 2008).

As a result of the above mentioned work, key water quality datasets and analysis are available from the following sources and the references listed at the end of this section. Table C1-1 summarizes water quality sampling programs conducted in the LCR by parameter and Figure C1-1 provides a summary of all locations where water quality and benthic invertebrates have been sampled in the watershed to date.

Table C1-1: Summary of Water Quality Sampling in the LCR Watershed

Parameter	Agency/ Group	Locations	Method	Frequency	Years
Bacteriological/fecal coliform	MOE	Attainment sites–216th St. (upstream) and 176th St. (downstream)	Grab	Annual	1971–1983, 1988–1990, 1999–2000, 2002
	LCWS and partners	Mainstem, tributary, and outfall stations throughout watershed	Grab	Periodic to monthly	2000–2003
	MOE	Mainstem, tributary, and outfall stations throughout watershed	Grab	Monthly, seasonal, and annual	2006–2007
Turbidity and suspended solids	MOE	Attainment sites–216th St. (upstream) and 176th St. (downstream)	In-situ	Annual	1971–1983, 1988–1990, 1999–2000, 2002
	LCWS and partners	Mainstem, tributary, and outfall stations throughout watershed	In-situ	Periodic to monthly	2000–2003
	MOE	12th Ave. Monitoring Station, east of 176th St.	Continuous (Hydrolab)	15 min	2005–2008
Dissolved oxygen (DO)	MOE	Attainment sites–216th St. (upstream) and 176th St. (downstream)	In-situ	Annual	1971–1983, 1988–1990, 1999–2000, 2002
	LCWS and partners	Mainstem, tributary, and outfall stations throughout watershed	In-situ	Periodic to monthly	2000–2003
	MOE	12th Ave. Monitoring Station, east of 176th St.	Continuous (Hydrolab)	15 min	2005–2008
Nutrients	MOE	Attainment sites–216th St. (upstream) and 176th St. (downstream)	Grab	Annual	1971–1983, 1988–1990, 1999–2000, 2002
	LCWS and partners	Mainstem, tributary, and outfall stations throughout watershed	Grab	Periodic to monthly	2000–2003
Water temperature	LCWS and partners	Mainstem, tributary, and outfall stations throughout watershed	In-situ	Periodic to monthly	2000–2003
	MOE	12th Ave. Monitoring Station, east of 176th St.	Continuous (Hydrolab)	15 min	2005–2008
	MOE	17 temperature loggers at eight mainstem and nine tributary stations	Continuous (thermistors)	15 min	2005–2010
pH	LCWS and partners	Mainstem, tributary, and outfall stations throughout watershed	In-situ	Periodic to monthly	2000–2003
	MOE	12th Ave. Monitoring Station, east of 176th St.	Continuous (Hydrolab)	15 min	2005–2007
Metals	MOE	Attainment sites–216th St. (upstream) and 176th St. (downstream)	Grab	Annual	1971–1983, 1988–1990, 1999–2000, 2002
	LCWS and partners	Mainstem, tributary, and outfall stations throughout watershed	Grab	Periodic to monthly	2000–2003
Persistent organic pollutants (POPs)	Not previously sampled				
Antibiotics/pharmaceuticals	Not previously sampled				
Benthic invertebrates	City of Surrey	2 sites in LCR mainstem, 2 sites in Fergus Ck.	Serber (Surrey protocol)	Annual (spring)	2005–2009
	A Rocha Canada	4 sites in LCR mainstem, 1 site in Fergus Ck., 1 site in 194th St. Channel	Kicknet (CABIN protocol)	Annual (fall)	2004, 2006–2009
Note: MOE=BC Ministry of Environment, LCWS= Little Campbell Watershed Society, LCR=Little Campbell River, CABIN=Canadian Aquatic Bio-monitoring Network					

C1.2 SUMMARY OF EXISTING WATER QUALITY INFORMATION

This section summarizes available information from the above sources (and others) on different water quality indicators relevant to watershed health in the LCR. First, it is explained how each indicator relates to watershed health and general factors that can affect that indicator's status. Using the above data and reporting, then each parameter's current status is assessed in the LCR (if known) relative to established water quality objectives, any observed trends over time, and any known or suspected relationships to land use in the watershed.

BACTERIOLOGICAL/FECAL COLIFORM

Fecal coliform (FC) bacteria originate in waste from warm blooded organisms including humans, cattle, birds, dogs, and wildlife. FC bacteria are not pathogenic but are an indicator of other enteric pathogens such as *E. coli* bacteria[1], protozoa, and viruses. These pathogens can cause gastro-intestinal illnesses in humans and farm animals. Contact can occur through recreation (swimming) and consumption of contaminated water or shellfish for humans, and by livestock watering. While the pathogens are not directly harmful to fish and other aquatic life, they are often indicators of conditions and pollution that can be directly harmful to fish, such as high biological oxygen demand (BOD) or ammonia (Nener and Wernick 1997).

Manure runoff is often the main source of bacteriological contamination to rivers and streams in agricultural watersheds. In urban areas, stormwater runoff can concentrate pathogens and deliver them to downstream receiving environments (Mallin et al. 2000). Potential sources of FC in urban areas include pets, wildlife (such as ducks and gulls), contaminated sediments, and sanitary sewer cross-connections. In rural areas, failure of on-site sewage disposal (e.g., septic) systems may also be a potential source of fecal contamination (Weiskel et al. 1996).

Current data suggests that FC concentrations frequently exceed water quality objectives for the LCR watershed, particularly in the lower watershed. The current objective for FC is a geometric mean[2] ≤200 MPN[3]/100 mL (five samples in 30 days) and a 90th percentile

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[1] *E. coli* bacteria can be measured directly but *E. coli* records for the LCR are sparse and have not been used as an indicator of bacteriological water quality in the watershed to date. Fecal coliform has been used as an indicator in the LCR watershed since 1973.

[2] A *geometric mean* is the average of the log10 transformed values converted to a base 10 number. The geometric mean can be used to reduce the effect of very high or low values which might bias the mean if a straight average or arithmetic mean was used. The *British Columbia Approved Water Quality Guidelines* (BCWQG) 2006 Edition uses a geometric mean based on at least 5 samples in 30 days.

[3] Fecal coliform concentrations are often reported in two types of units: the *most probable number (MPN)* per unit volume or the *number of colony-forming units (CFU)* per unit volume. The different units represent different laboratory methods for analyzing samples for FC bacteria. The MPN method provides estimates based on a multiple tube fermentation technique. In the Membrane Filtration (MF) method which reports concentrations in CFU

≤400 MPN/100 mL from April through October (Swain and Holms 1988). Monitoring has occurred at two attainment stations periodically since 1971 (upstream site at 216th St, downstream site at 176th St) with the most recent round of sampling in 2006/07. In 2006/07, attainment monitoring occurred three times over a 1-year period (April/May 2006, August 2006, and Dec/Jan 2006). Objectives were met two out of three times at the upstream station and one out of three times at the downstream station (Juteau and Krause 2007).

Historically, FC contamination peaked in the early 1970s and has steadily improved from 1983 to 2002 (objectives for FC were met at both stations in 2002). However, the 2006/07 results showed a marked increase in FC concentrations (Figure C1-2). Results suggest that FC bacteria concentrations are also highly variable during the year. In the past, FC levels have been greater at the downstream station by roughly an order of magnitude (Drever and Brown 1999).

The West Sub-watershed (the lower 16% of the LCR watershed, including City of White Rock) appears to be the greatest contributor of FC contamination across all seasons, but especially in the summer. Longitudinal monitoring of the four sub-watersheds of the LCR by Juteau and Krause (2007) found that FC loadings were consistently highest near the mouth. FC concentrations in the estuary frequently exceeded the BC Approved Water Quality Guideline for primary contact recreation of 200 MPN/100 mL (MOE 2006). Similar spatial patterns were found by Fleming and Quilty (2006) using 2000–2003 data. The West Sub-watershed is mainly urban (30% impervious area) and has a high number of on-site sewage disposal systems, mostly in the Fergus Creek catchment. FC levels were not linked to precipitation indicating that the majority of fecal coliform may be entering the LCR through routes other than storm event runoff (Juteau and Krause 2007). This includes direct deposition of fecal material into the mainstem or tributaries outside of precipitation periods, resuspension from contaminated sediments, failing on-site sewage disposal systems, and/or sanitary sewer cross-connections.

Urban runoff, agricultural (manure) runoff, and failing on-site sewage disposal systems have all been identified as potential sources of FC bacteria into the LCR. Of these three sources of FC contamination, urban runoff appears to be the most significant contributor to elevated fecal coliform levels during both the summer and winter months (Juteau and Krause 2007). High FC concentrations from several stormwater outfalls were first sampled in 2002 (Cheung 2003). Monitoring in 2006 found that the greatest contributions to FC load came from these stormwater outfalls and the most urbanized catchments. For example, the stormwater outfalls at Habgood Street (City of White Rock) contributed approximately 60% of total FC load at the LCR mouth in the summer of 2006 (Juteau and Krause 2007).

units, water samples are filtered through a sterile membrane filter, the filtrate is transferred to sterile medium, incubated, and generated colonies counted. The MF method is more rapid and considered more precise for freshwater samples than the MPN method but the results are not as reliable for samples that contain many non-coliform bacteria, high turbidity, algae, and/or toxic substances.

While FC levels from agricultural sub-watersheds containing high livestock densities consistently exceeded the approved BC guidelines for FC, contributions to overall FC load were limited and effects were largely localized. FC load from the upper LCR watershed did not reach the mouth of the river and a tributary from a cattle feedlot only contributed ~1.5% of FC load in fall 2006 when runoff would be most likely (Juteau and Krause 2007). However, local effects may be exacerbated by low flow conditions during the summer in the mainstem. The West Twin Creek sub-catchment appears to have had very high FC concentrations from 2001–2003 and tentative calculations of FC loadings suggest approximately 16% of the FC load at the LCR mouth is from West Twin Creek (Fleming and Quilty 2006). It is not known whether these high FC concentrations in West Twin Creek have been resolved as this watershed has not been specifically targeted in recent sampling.

During the winter of 2006/07, failing on-site sewage disposal systems were not a significant source of FC contamination (Juteau and Krause 2007), although this assessment was limited to a single catchment with a high number of such systems.

Key summary points:

- **Fecal coliform levels in the LCR watershed have improved compared to the 1970s but are still elevated and periodically exceed guidelines, particularly in the lower watershed.**
- **The West Sub-watershed (including City of White Rock) is the largest contributor of fecal coliforms to the LCR mainstem, especially but not exclusively in the summer months.**
- **Urban runoff from stormwater outfalls is the largest contributor to fecal coliform loadings at the LCR mouth.**
- **Agricultural runoff is a secondary source of fecal coliform contamination but effects are largely localized.**
- **Failing on-site sewage disposal systems do not appear to contribute to fecal coliform contamination at this time.**

TURBIDITY AND SUSPENDED SOLIDS

Turbidity is a measure of the amount of light intercepted by suspended particles in the water column, including sediments, microscopic organisms, and pollutants. It is typically measured in NTUs[4]. Total suspended solids (TSS) measures the amount of mass of suspended particles in a given volume of water. Turbidity and suspended solids are somewhat related, however, they often have different causes and effects. High turbidity is generally caused by very fine particles in the water column such as colloidal particles (e.g., clays) whereas high TSS is often caused by larger particles, such as silt and sand.

[4] NTU = Nephelometric Turbidity Unit. The term *nephelometric* refers to the way the instrument estimates how light is affected by suspended particulate material in the water. A nephelometer, also called a turbidimeter, uses a photocell to estimate scattered rather than absorbed light. This measurement generally provides a very good correlation with the concentration of particles in the water that affect clarity.

High turbidity can restrict light penetration affecting the primary production of aquatic flora. Depending on the duration of the turbidity event, this reduced productivity can impact insect populations and fish growth rates. Turbidity can also have indirect effects on water quality: for example, turbidity decreases the mortality of fecal coliform bacteria (Pommepuy et al. 1999) and can provide sites for metals or hydrocarbons to adhere to. Settling of larger suspended sediments can have detrimental effects on fish populations by degrading fish spawning gravels, aquatic insect habitat, and impairing fish egg survival. At very high levels, sediment can clog the gills and breathing structures of fish and benthic macroinvertebrates.

Some turbidity and suspended solids are a result of natural erosion and decay processes within aquatic ecosystems. However, human activities that remove riparian vegetation or change stream hydrology (i.e. through channelization or dyking) can disrupt natural patterns of sediment transport and increase erosion, which can substantially increase suspended solids. High turbidity or TSS can also result from the direct introduction of pollution or sediments from construction sites or gravel mining operations. Anthropogenic non-point sources of turbidity and suspended solids include urban development (land clearing, road runoff), agriculture (soil erosion, riparian removal), logging, and mining (Nener and Wernick 1997).

Both turbidity and suspended solids in the LCR frequently exceed the water quality objectives for these parameters. Overall, data suggests that turbidity is quite variable both within and between years. The current objective for turbidity is that induced turbidity should not exceed background levels by more than 5 NTU when background levels are ≤50 NTU and should not exceed background levels by more than 10% when background levels are >50 NTU. For suspended solids, the requirements are similar: suspended solids should not exceed background levels by more than 10 mg/L if background levels are ≤100 mg/L and should not be more than 10% of background levels if background levels are >100 mg/L in the LCR or its tributaries (Swain and Holms 1988). For attainment monitoring, the upstream station (216th St) is considered the background level and turbidity and suspended solids at the downstream station (176th St) are compared to this background level. Between 1988 and 1992, objectives for were not met for turbidity on 7 of 19 occasions and objectives for suspended solids were not met on 10 of 20 occasions (Drever and Brown 1999). All measurements took place September to November is this is when water flows are high and water quality is likely to be poorest. Suspended solids met objectives on all five sampling dates when measured in 2002 (Bull 2003). However, objectives were not met for both turbidity and suspended solids on at least one occasion in 2006 (Juteau and Krause 2007).

Periodic runoff events, most likely from active construction projects, are likely the largest contributor to high turbidity events in the watershed and suggest that sedimentation from construction projects is not being adequately managed. Continuous water quality monitoring from 2005-2007 at 12th Ave on the LCR mainstem found that the highest levels of turbidity in the LCR occur in the fall and winter months (Juteau and Krause 2007). Turbidity is substantially greater during the wet months than dry months of the year. This seasonal pattern may be the result of greater runoff from anthropogenic non-point turbidity sources during high rainfall periods or large volumes of runoff from point sources, such as active construction sites, overwhelming sediment control mechanisms. Channelization of some sections of the LCR mainstem has destabilized normal sediment movement and increased channel scouring and bank erosion (CMN 2008). However, during this period, there were also several moderate and extreme turbidity events, both in their magnitude, duration, and potential effects. These events were not linked to antecedent precipitation. Reports and investigation have attributed several of these turbidity events along the LCR mainstem to construction phase impacts from land development in the Campbell Heights area in Surrey (Phillip Milligan, pers. comm.) and the High Point development in Langley (Glen Carlson, pers. comm.).

Key summary points:

- **Both turbidity and total suspended solids regularly exceed guidelines in the LCR mainstem as measured at the 12th Ave monitoring station.**
- **Construction runoff has likely contributed to extreme turbidity events and large increases in sediment loading.**
- **Non-point turbidity and sediment sources (e.g., agriculture, riparian removal) may also increase turbidity and suspended solids during high rainfall periods.**

DISSOLVED OXYGEN

Dissolved oxygen (DO) is a measure of the amount of gaseous oxygen dissolved in water. In streams, oxygen enters the water through diffusion from the surrounding air, by aeration as water moves over substrates, and from photosynthetic activity. High and stable oxygen levels are important to maintaining suitable conditions for many aquatic biota, including spawning and rearing salmon, and benthic invertebrates. DO can be affected by many factors, including water temperature, pH, flow conditions, and the photosynthetic rates of algae and aquatic plants. Therefore, any human activities which impact these factors can alter DO. For example, removal of streamside vegetation can increase solar radiation and water temperatures, leading to a decrease in DO. Also, nutrients are often a limiting factor for aquatic algae therefore additions from agricultural runoff can increase biological oxygen demand (BOD) and lower DO when plants are respiring (Nener and Wernick 1997).

DO reaches extremely low levels (<2.0 mg/L) in the LCR in summer/early fall and is a serious issue for aquatic life in the upper reaches of the watershed, particularly for juvenile salmonid populations. The objectives for DO in the LCR are an instantaneous minimum of 6.0 mg/L (and long-term minimum objective of 8.0 mg/L) from June-October, or an instantaneous minimum of 11.0 mg/L when salmonid eggs, larvae or alevin are present (October-February) (Swain and Holms 1988). Over the years, regular monitoring has found that DO objectives are consistently not met in both summer and fall at both attainment monitoring stations, but particularly at the upstream site. For example, in August 2006, weekly measurements of DO levels ranged from 0.26–2.9 mg/L at the upstream site, and 2.54–9.26 mg/L at the downstream site (Juteau and Krause 2007). Sampling in October-November 2002 yielded comparable values at the upstream site (0.12–3.15 mg/L) when salmon were present. Oxygen levels below 1-2 mg/L can result in large fish kills. High levels of coho fry mortality have been observed in the upper reaches of the LCR mainstem during the summer months (J. Kambeitz, pers. comm.).

Continuous monitoring data from 2005–2007 confirmed the magnitude of DO problems in the LCR. Data from the 12th Ave Hydrolab station shows that oxygen levels in fall 2006 were below the instantaneous minimum DO objective of 11.0 mg/L (when salmonid eggs or alevin are present) for 100% of the time sampled in fall 2005 and 94% of the time sampled in fall 2006. DO levels reached as low as 5.5 mg/L in fall 2005 and 7.20 mg/L in fall 2006. Note that this is downstream from where DO levels are most problematic. Continuous monitoring also indicates that a diurnal cycle of primary productivity may be occurring during the summer months. Oxygen levels during the day increase as photosynthetic activity exceeds respiration, increasing DO levels as much as 3 mg/L over the course of the day. This oxygen is then used up at night by respiration when photosynthetic activity is absent (see Figure 49 in Juteau and Krause 2007).

Drever and Brown (1999) suggest that low DO in the LCR has different causes in summer and winter. In the winter months, increased surface runoff may increase nutrient and sediment loading leading to reduced DO levels. In the summer months, a combination of low stream flow and higher water temperatures may lead to lower DO levels. A portion of the upper reaches of the LCR mainstem (~1.5 km) becomes dewatered in summer, potentially for up to 5 months of the year (Juteau and Krause 2007). This is likely due to high levels of groundwater and surface water extraction (see Drever and Brown (1999) for more discussion of this issue). Further work is needed on the seasonal determinants of DO levels in the LCR.

Key summary points:

- **DO reaches extremely low levels in the upper reaches of the LCR in summer/early fall causing periodic mortality of coho fry.**
- **DO levels are also often below minimum objectives from October to February when salmonid eggs, larvae and alevin are present.**
- **Extremely low DO levels in the upper watershed in summer are likely caused by low flows and high water temperatures.**
- **Reduced DO levels in winter may be due to high BOD from nutrient and sediment loading in surface runoff.**

NUTRIENTS

Dissolved nutrients in streams occur naturally and are essential to the functioning of aquatic ecosystems. However, high levels of some nutrients, such as nitrogen (including ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-)) and phosphorus (e.g., orthophosphate) from anthropogenic sources can result in toxicity to fish or can cause eutrophication which lowers dissolved oxygen levels. Toxicity effects are interactive with other water quality parameters: toxicity can vary with specific conductivity, concentrations of other substances, and generally increase with water temperatures and pH (Nener and Wernick 1997). Nutrient enrichment in streams is often caused by sewage discharges, septic systems failures, and agricultural runoff (e.g., manure, application of fertilizers). Nutrient enrichment from excess application of manure or chemical fertilizers to agricultural fields is a concern to water quality worldwide.

LCR-specific water quality objectives for nutrients have been developed for ammonia and nitrite. These objectives have been met regularly since attainment monitoring began. Objectives change with temperature and pH for ammonia, and with chloride concentrations for nitrite so specific objectives are not outlined here (see Swain and Holms 1998 for details). Objectives for ammonia have been met at both the upstream (LCR mainstem at 216th St) and downstream (LCR mainstem at 176th St) attainment sites since 1971. Ammonia levels were low compared to the standard when last monitored (2002) and steadily improved since 1983 at the upstream site and since 1990 at the downstream site (Bull 2003). Nitrite objectives were not met in 1977, 1998, and 1989 at the downstream site but objectives have been met since 1990. Nitrite concentrations are generally higher at the downstream location.

It is unclear whether current objectives are stringent enough to maintain adequate water quality. It should be noted that ammonia objectives in the LCR are 123 times larger than the standard for ammonia set by the Canadian Council of Ministers on the Environment (CCME, 0.01 mg/L) and this more stringent objective is usually taken to indicate contamination from anthropogenic sources. The less stringent LCR-specific objective was set based on known background levels and to protect the most sensitive water use in the river, habitat for aquatic life (Swain and Holms 1988). Levels below the LCR-specific objective are not expected to cause harm to fish directly via toxicity effects. However, current guidelines do not take into account the potential effects of eutrophication on dissolved oxygen levels caused by nutrient enrichment (see previous section).

Nitrate and orthophosphate have been used in other Lower Fraser Valley watersheds as general indicators of nutrient increases due to population growth, land use changes, and accompanying commercial, industrial, and agricultural development (Schreier et al. 1999). However, nitrate and orthophosphate have been used minimally as indicators in the LCR. Both are commonly associated with agricultural runoff, but are also elevated by urban land uses (personal observation). Nitrate levels in the LCR mainstem at 172nd St from October 2005 to September 2006 ranged from 0.3–1.6 mg/L (Raincoast Applied Ecology, unpublished data), well below the recommended BC Approved and Canadian

Water Quality Guidelines of 10 mg/L (MOE 2006, CCME 2005). Orthophosphate levels ranged from 0.06–0.25 mg/L (Raincoast Applied Ecology, unpublished data). No specific objective currently exists for phosphorus (e.g., orthophosphate) because it is not thought to be limiting to algal growth in the watershed (Swain and Holms 1988). Currently, there are no provincial or federal guidelines for phosphorus to protect human health or aquatic life. Nitrate and orthophosphate were also comprehensively sampled throughout the LCR from 2000–2003. Twin Creeks, a largely agricultural catchment, was found to have fairly high levels of nitrate and orthophosphate (as well as fecal coliform). Given the potential for eutrophication, and the chronically low DO levels in the LCR, these conditions are higher than is desirable.

Key summary points:

- **Ammonia and nitrite levels consistently meet objectives in the LCR watershed and are consistent with low levels of anthropogenic enrichment.**
- **While nutrient objectives directly protect aquatic life against toxicity, it is unclear whether these objectives will protect against indirect effects, such as eutrophication in the LCR watershed.**
- **Nitrate and orthophosphate levels are well below national and provincial guidelines in the mainstem but may be higher than desirable within specific sub-catchments (e.g., Twin Creeks).**

WATER TEMPERATURE

Maintaining suitable water temperatures is important to the survival and growth of fish and other aquatic life in streams. Water temperatures can affect the development of fish eggs, rearing of juvenile fish, and the return of adult salmonids to spawn. Fish and invertebrate assemblages in the LCR watershed are generally adapted to cold water conditions. The preferred temperature range for juvenile Pacific salmonids broadly is approximately 5–13 ºC (Taccogna and Munro 1995). Slightly elevated temperatures (15–20 ºC) can be tolerated in the short-term but may adversely affect physiological functions in the long-term. Thermal stress can lead to increased susceptibility to parasites and disease. Changes in behaviour due to elevated water temperatures can also increase predation risk. Acute mortality for juveniles occurs in the range of 20–25 ºC. Adult mortality can occur at even lower temperatures. Effects can also be indirect: warm water contains less oxygen than cold water and can increase plant growth rates, which consumes more oxygen. Both effects can lead to anoxic conditions for fish.

Removal of streamside vegetation from logging, agriculture, and urbanization is a major contributor to altered temperature regimes in BC streams. Shading decreases the amount of solar radiation reaching the water, helping keep summer water temperatures low and stable. Low water flows due to water extractions can also contribute to problems with daily temperature fluctuation because there is less water to buffer the impact of high temperatures. Thermal pollution from industrial sources can also cause increased water temperatures. All effects are especially significant for small streams where small water volumes provide little capacity to buffer the effects of increased irradiation or industrial discharge.

Historical records of surface water temperatures in the LCR provide evidence that water temperatures likely often exceed the preferred range for fish, especially (but not limited to) during the summer months and in the upper portions of the watershed. Water temperature records at the two attainment sites exist intermittently from 1971–2002. The provincially recommended guideline for water temperature is + or - 1 degree Celsius beyond the optimum temperature range for the most sensitive fish species present (MOE 2006). Of the salmonids present in the LCR year-round (coho, cutthroat, and steelhead), coho has the most sensitive temperature range (9.0–16.0 ºC). From 1971–2002, maximum measured temperatures at the upstream site (LCR mainstem at 216th St) were above 17 ºC during at least four summers (July - October) and three winters (November–May). Temperatures were also above 17 ºC during the summer in at least two years at the downstream site (LCR mainstem at 176th St).

While it is known that water temperatures exceed suitable levels for salmonids, the magnitude and duration of temperature effects in the LCR is largely unknown. The historical data provides only a 'point-in-time' measurement at a specific day and time, but does not accurately assess mean and maximum values. Recently, continuous temperature monitoring has begun in the LCR using the Hydrolab station at 12th Ave and temperature loggers in eight different sub-catchments (Juteau and Krause 2007). However, due to problems with installation and calibration, the data record during 2006 and 2007 was intermittent. Results to date indicate that surface water temperatures exceeded 17 ºC during the early spring and late summer of 2006. Future continuous monitoring will provide data from which the magnitude and duration of effects can be assessed.

High temperatures in the LCR likely occur due to:

1. the lack of shading vegetation along some parts of the mainstem riparian corridor; and
2. low water levels during the summer months due to naturally low summer water levels exacerbated by ground and surface water extractions.

As a low-elevation surface and groundwater-fed stream, the LCR may also be naturally more susceptible to temperature effects than other coastal streams fed by alpine snowmelt. Fleming and Quilty (2006) found that mean daily LCR water temperatures were strongly correlated with mean daily air temperatures. As a result, they forecast that long-term impacts on growth rates from increased water temperatures will be an effect of future climate change.

Key summary points:

- **Water temperatures in the LCR periodically reach levels capable of inducing chronic effects on salmonid growth and survival, especially during the summer months in the upper reaches of the watershed.**
- **The magnitude and duration of these elevated temperatures is currently unknown but are being assessed.**
- **Increased water temperatures are likely caused by lack of riparian vegetation and low water levels due to ground and surface water extraction.**

pH

pH measures the relative acidity or alkalinity of a solution. The pH scale runs from 0 to 14 (i.e. very acidic to very alkaline), with pH 7 representing a neutral condition (pure water, for example). In unpolluted waters, pH is principally controlled by the balance between the carbon dioxide, carbonate, and bicarbonate ions as well as other natural compounds. Stream pH level depends on the geology of the surrounding area, and usually falls between 6.5 and 8.0. Streams that drain soils with high mineral content usually are alkaline, whereas streams that drain coniferous forests usually are acidic. Algal photosynthesis during a bloom can cause increased pH. Changes in pH can indicate the presence of particular effluents that may be detrimental to aquatic life, such as road runoff or a spill. Most aquatic organisms are sensitive to small pH changes and prefer a near-neutral pH.

pH objectives have been met historically and are met currently in the LCR watershed. The provincial approved freshwater guidelines for aquatic life recommend a pH range of 6.5 - 9.0 (MOE 2006). However, Swain and Holms (1998) recommended the more stringent guideline for drinking water of a pH range of 6.5 - 8.5 for use in the LCR. In 2006/07, pH ranged from 6.71 to 7.93 at the upstream attainment site (LCR mainstem at 216th St) and from 7.4 to 7.74 at the downstream attainment site (LCR mainstem at 176th St). Bull (2003) suggests that pH ranges have improved in recent years compared to historical data. pH in the LCR is generally lower in the lower mainstem and tributaries of the watershed (Fleming and Quilty 2006).

Key summary points:

- **pH is not a current water quality concern; pH objectives have been met historically and are currently met in the LCR watershed.**

OTHER CONTAMINANTS

Metals

Some trace elements are important to the ability of a stream to support aquatic life. For example, metals such as manganese, zinc, and copper, when present in trace concentrations, are important for the physiological functions of living tissue and regulate many biochemical processes. However, metals discharged at higher concentrations in stormwater, sewage, industrial effluents, or from mining operations can have severe toxicological effects on the aquatic ecosystem and humans. Most ecosystems lack natural elimination processes for metals so metals often persist in stream sediments and organisms. Metals can also move up the food chain and bioaccumulate at higher trophic levels, with potential toxicological risks to humans. Also, as a result of adsorption and accumulation, the concentration of metals in bottom sediments is much higher than in the water above and this sometimes causes secondary pollution problems.

Trace amounts of metals are usually due to weathering of rocks and soils. Higher concentrations often come from the transportation: from vehicle exhaust, brake linings, and tire and engine wear. These pollutants accumulate on roads and are washed into the stormwater system and streams with rainfall. Wastewater discharges from industry and mining are also major sources of metals. Some metals may reach streams through atmospheric deposition (e.g., lead).

Concentrations of several metals (iron, cadmium, lead, magnesium, manganese, zinc) were measured at several sites within the LCR watershed between 2000 and 2002. Because limited data is available on metal concentrations in the watershed and there is some uncertainty about the appropriate guidelines for these elements, it is difficult to accurately assess the extent of metal contamination with current data. Iron, cadmium, and possibly lead may exceed guidelines in parts of the watershed (Fleming and Quilty 2006). In general, metals are highest along the LCR mainstem in the West Sub-watershed suggesting that urban runoff is the largest source of these contaminants.

Persistent organic pollutants (POP's)

Many organic (carbon-based) compounds can enter watercourses from human activities and persist in aquatic ecosystems long after their introduction. Some examples of more common organic compounds with concerns to water quality include:

- **Hydrocarbons and vehicle byproducts –** these include petroleum products such as oil and grease as well as engine coolants and antifreeze which contain ethylene glycol and propylene glycol. These compounds may enter streams via stormwater runoff from normal vehicle use, leaks, and disposal directly into storm drains.

- **Polycyclic aromatic hydrocarbons (PAHs)** – these are a class of stable organic compounds that are formed during the incomplete burning of coal, oil and gas, garbage, or other organic substances like tobacco or charbroiled meat. These compounds are highly carcinogenic but also very common. Atmospheric deposition from vehicle exhaust is the largest source of PAHs in urban areas.

- **Pesticides –** these include insecticides, fungicides, and herbicides used in agriculture, urban gardens and lawns, and roadside maintenance. Many persist in the environment for long periods of time and, thus, can enter stormwater from leaching and erosion of soils over time. Many pesticides are toxic to wildlife and humans at high concentrations.

- **Polychlorinated biphenyls (PCBs)** – this class of compounds was used historically as coolants in transformers, and was added some PVC products, pesticides, paints, and hydraulic fluids. Production was banned in the 1970s but these compounds are highly persistent within the environment. Sources of PCBs include soil contamination beneath old power substations and other contaminated sites.

The potential effects of persistent organic pollutants on living organisms in aquatic ecosystems include cancer, as well as infertility and mutagenic effects. Some POPs may also be endocrine disrupting chemicals (EDCs) that mimic the action of hormones in living organisms, thereby disrupting the normal physiological function of naturally-occurring hormones. EDCs can cause disruption to the endocrine, reproductive, and immune systems of fish, wildlife, and humans. To our knowledge, no assessments of organic compounds in the LCR watershed have been carried out to date.

Antibiotics/pharmaceuticals

Antibiotics and other pharmaceuticals are used in some agricultural operations to protect animals against disease. They are either injected directly into livestock or added to their feed. Much of the antibiotics administered are excreted by animals and can remain functional in manure for many months giving potential for their introduction to streams through agricultural runoff. Another potential source of these contaminants is sanitary-storm sewer cross-connections. Growth of resistant bacteria may be promoted in watercourses with high levels of antibiotics (Jjemba 2002).

Current levels of antibiotics and other pharmaceuticals within watercourses of the LCR watershed are unknown.

Key summary points:

- **Other contaminants of potential concern in the LCR watershed include metals, persistent organic pollutants, endocrine disrupting chemicals, and antibiotics/pharmaceuticals but levels and effects are largely unknown.**
- **Some metals may exceed recommended guidelines at localized sites in the watershed and are generally associated with more urbanized catchments.**

C1.3 SUMMARY OF BENTHIC INVERTEBRATES INFORMATION

The ISMP Template emphasizes the use of benthic invertebrates to assess and monitor watershed health. Under the Template, benthic communities are assessed using the Benthic Index of Biological Integrity (B-IBI; Karr 1998, Karr and Chu 1999) score which ranges from 10 in highly degraded streams to 50 in pristine, old growth watersheds. Pristine, second growth watersheds in the lower mainland have scores of approximately 40. The B-IBI method uses predictable changes in the richness and composition of benthic invertebrate taxa along a defined gradient of anthropogenic stress, such as urbanization, to assess the biological condition of streams.

Through the City of Surrey's benthic invertebrate sampling program, four B-IBI sampling sites were established in the Surrey portion of the Little Campbell River watershed (see Figure C1-1) to provide baseline information in advance of ISMP planning initiatives (Dillon 2005). Sites are part of 25 sampling stations throughout Surrey. Two sampling sites were established along the LCR mainstem and first sampled in spring 2005. Also at this time, two sites were established in the Fergus Creek sub-catchment to assist with the specific ISMP process undertaken in this sub-watershed as part of the Highway 99 corridor - Grandview Heights development (see Figure 1-1 in main body of report and Table C1-2). To our knowledge, no benthic invertebrate sampling has occurred in the Township of Langley portion of the watershed.

Table C1-2: City of Surrey Benthic Invertebrate Sampling Sites in LCR Watershed

Site Code	Location Description	Sampling Dates	Pooled Sampled B-IBI Score
LCR-1	LCR mainstem (downstream site): north of 12th Ave. at 186th St. alignment, upstream of the weir	April 22, 2005	20
		Spring 2006	18
		May 10, 2007	20
		April 30, 2008	22
		May 4, 2009	18
LCR-2	LCR mainstem (upstream site): west of 194th St., upstream (north) of 16th Ave.	April 22, 2005	28
		Spring 2006	22
		May 10, 2007	20
		April 30, 2008	26
		May 4, 2009	28
F-1	Fergus Creek (upstream site): downstream of the driveway crossing at 16264 18th Ave.	April 22, 2005	14
		Spring 2006	14
		May 10, 2007	14
		April 29, 2008	14
		May 4, 2009	14
F-2	Fergus Creek (downstream site): downstream of 168th St., south of 12th Ave.	April 22, 2005	14
		Spring 2006	16
		May 10, 2007	14
		April 29, 2008	14
		May 4, 2009	14

Available sampling results to date indicate that B-IBI scores in the LCR mainstem range from 18 to 28 (see Table C1-2). Generally, stream conditions are better at the upstream site versus the downstream site. The Fergus Creek sites have a fairly consistent B-IBI score of 14. Stream conditions within the Fergus Creek tributary are substantially degraded compared with the mainstem sites. There is some variability between years at individual sites but the magnitude of variability within sites is much smaller than the differences between sites. Year-to-year changes in stream conditions do not appear to be correlated among the sampling sites.

Full benthic community data for these and other sites within Surrey are available from the City of Surrey (Dillon 2005 and others).

In addition to the City of Surrey's benthic monitoring program using the B-IBI methodology, benthic invertebrate sampling has also been undertaken using the reference condition approach (RCA) within the Surrey portion of the LCR watershed. Unlike the B-IBI method, which uses multiple samples collected with a Surber sampler and multimetric data analysis to summarize benthic community information[5], the RCA approach advocated by the Canadian Aquatic Biomonitoring Network (CABIN) uses a single sample collected with a kicknet sampler and multivariate data analysis that

[5] The City of Surrey's benthic sampling program uses the East Clayton Monitoring Protocol established in 1999. This protocol differs from the GVRD sampling protocol (EVS 2003) because the habitat characteristics of many Surrey streams (e.g., small size of riffle sections and lack of riffle sections) do not allow for multiple samples in the same riffle. Under the Surrey/East Clayton protocol, a total of three riffles are sampled at each site (using a 250 µM Serber sampler) and each sample is treated separately for taxonomic analysis.

compares community structure to a regional reference condition defined by reference sites (Page and Sylvestre 2006).

RCA-CABIN sampling was carried out by A Rocha Canada in partnership with Environment Canada in 2004, and from 2006–2009 (see Krause 2006 and Vinke 2008 for more info). In 2004, two sites were sampled along the LCR mainstem as well as one site in the Fergus Creek tributary (see Table C1-3). In addition to these existing sites, a third site along the LCR mainstem was added in 2006, and a fourth site in 2009. An additional site was also added in 2009 in the 194th St. Channel which connects Latimer Lake to the LCR mainstem through the Campbell Heights area (Figure C1–1).

Table C1-3: A Rocha Canada Benthic Invertebrate Sampling Sites in the LCR Watershed

Site Code	Location description	Sampling Date	RCA-CABIN Results
LCR01	LCR mainstem: approximately 100 m upstream from 172nd St., south of 8th Ave.	Sept 14, 2004	Unstressed
		Sept 15, 2006	Stressed
		Sept 14, 2007	Unstressed
		Sept 16, 2008	Stressed
		Sept 16, 2009	Not yet available
LCR02	LCR mainstem: at Semiahmoo Fish & Game Club, 1284 184th St., directly upstream of the footbridge in 2004, 5 m upstream in 2006	Sept 14, 2004	Potentially Stressed
		Sept 15, 2006	Potentially Stressed
		Sept 14, 2007	Potentially Stressed
		Sept 16, 2008	Stressed
		Sept 15, 2009	Not yet available
LCR03	LCR mainstem: immediately downstream of 16th Ave.	Sept 15, 2006	Unstressed
		Sept 14, 2007	Unstressed
		Sept 16, 2008	Potentially Stressed
		Sept 15, 2009	Not yet available
LCR04	LCR mainstem: west of 196th St., at 20th Ave. alignment, upstream of confluence with 194th St. Channel	Sept 16, 2009	Not yet available
FER01	Fergus Creek: approximately 60 m upstream of the driveway at 1177 168th Ave. in 2004, 25 m upstream of the driveway in 2006	Sept 14, 2004	Stressed
		Sept 15, 2006	Stressed
		Sept 14, 2007	Stressed
		Sept 16, 2008	Potentially Stressed
		Sept 15, 2009	Not yet available
CHC01	194th St. (Campbell Heights) Channel: approximately 50 m upstream from confluence with LCR mainstem	Sept 16, 2009	Not yet available

The RCA-CABIN results show that the status of invertebrate communities was consistent by both location and year, except at LCR01 (see Table C1-3). Also, results from 2008 show that some sites became more stressed in 2008. With the apparent exception of LCR01, sites further west within the watershed, with greater impacts from urban development, appear more stressed.

Krause (2006) tentatively attributed the inconsistency in assessments at LCR01 to differences in the taxonomic resolution used for certain taxa from year-to-year, rather than actual changes in conditions. Worms (Haplotaxida) were excluded in the analysis in

2004 and 2007 because this group was not identified to family level in these years despite their high counts in the samples. These taxa often indicate stressed conditions. Thus, LCR01 may actually be more stressed than the 2004 and 2007 assessments indicate without further taxonomy of this group. Community composition at sites showing stress indicates that DO and/or suspended sediments are the likely causes of degraded stream health (Vinke 2008). DO levels were much lower than the mean of the reference sites in 2006 and 2007.

C1.4 PRIORITY ISSUES

Several priority water quality issues have emerged from existing water quality and benthic invertebrate data that should be specifically addressed in ISMP planning:

1. **Fecal coliform from urban sources –** The largest sources of fecal coliform contamination to the LCR and the waters of Semiahmoo Bay appear to be urban runoff from stormwater outfalls near the LCR mouth. Many of these outfalls drain urbanized areas in the City of White Rock. Although the data suggests the fecal coliform is being introduced via stormwater, the specific upstream source of fecal coliform contamination of this runoff is unknown. It is possible that fecal coliform from urban catchments results from many diffuse sources. In any case, without a better understanding of the sources of fecal coliform to urban stormwater systems, increasing urbanization within the LCR watershed (even with current development plans which replace on-site sewage disposal systems with municipal sanitary sewage collection) will likely increase fecal coliform contamination.

2. **Low dissolved oxygen/high temperatures during summer months –** Low dissolved oxygen levels and high temperatures in the summer months, particularly in the upstream portions of the LCR mainstem, are a significant and ongoing threat to salmon and trout populations and other aquatic life in the watershed. The predominant cause of these conditions is likely low summer baseflows resulting from heavy surface water and groundwater extraction. As a low-elevation stream not fed by alpine snowmelt, the LCR is naturally susceptible to low flow conditions therefore the LCR is susceptible to even small water withdrawals and modifications to natural runoff patterns. Low flows can decrease aeration and increase the river's susceptibility to increases in water temperature. Warmer water temperatures decrease dissolved oxygen levels as warmer water holds less dissolved oxygen than cold water. Other potential contributing factors are nutrient enrichment from agricultural runoff (which increases BOD and lowers DO) and a lack of riparian vegetation (which increases solar radiation and water temperatures). Maintaining or improving DO and temperature conditions through the provision of adequate flows, remediation of runoff, and restoration of riparian vegetation should be a top priority to stormwater planning in the watershed. Involvement in the ISMP process from the provincial government, which regulates water withdrawals, is important to addressing this issue. Contributions from groundwater to LCR flows are also an important buffer against anticipated effects of climate change.

3. **Construction-phase turbidity from development –** Preliminary continuous monitoring data and anecdotal reports suggest that turbidity from the construction phase of large development projects at several locations in the watershed, including Campbell Heights and High Point, are increasing turbidity to levels detrimental to stream health. Management and control of sediment on these construction sites is not adequately preventing sediment from entering watercourses, despite better sediment and erosion control planning and municipal regulation.

4. **Bank erosion –** Riparian vegetation removal and channelization of sections of the LCR mainstem have destabilized stream banks and increased channel scouring and bank erosion (see also Section C2.4 for more information and specific locations). This increases turbidity and suspended sediment levels, particularly after heavy rainfall events. Future development has the potential to increase impervious area, increasing peak flows by replacing subsurface flow with more rapid surface flows. This will increase erosion problems in areas of the LCR mainstem.

C1.5 MANAGEMENT OBJECTIVES FOR WATER QUALITY IN ISMP PLANNING

The current ISMP Template requires consideration of water quality in stormwater management planning. However, the ISMP Template does not require that specific conditions be maintained, water quality objectives be met, or that watershed-specific objectives be set. Rather the Template focuses on general assessment of routine water quality parameters and the management of water quality using integrated or indirect indices of watershed health: the index of benthic invertebrate integrity (B-IBI), the amount of effective impervious area, and proportion of intact riparian corridor forest. Assessment is designed to provide an overview of water quality which may lead to further assessment if specific issues are identified.

With the above indices, assessing the condition of a watershed is done predominantly through comparisons to other Metro Vancouver watersheds with similar land use characteristics. Specific water quality issues are not generally identified. Such an approach could be necessary in watersheds that do not have comprehensive water quality data available and where issues are typical of other Metro Vancouver watersheds, but this is not the case in the LCR. The unique characteristics of the LCR – the presence of specific identified water quality issues, the number of important downstream water uses (e.g., fisheries, shellfish harvesting, wildlife and aquatic life), and the number of different land uses and land use activities that are potential sources of water pollution – suggest that ISMPs need to take a more specific issue-based approach to water quality in the LCR watershed.

COMPARISON OF PRIORITY ISSUES WITH CURRENT ISMP TEMPLATE

To assess the ability of the current ISMP Template to address priority water quality issues in the LCR, the individual water quality parameters were ranked by their current importance to overall stream health (low, medium, high) as assessed in previous sections. Then these rankings were compared with rankings of their relevance within the current ISMP Template, based on the known or potential sources of adverse effects, which are also listed (see Table C1-4). Ranking of water quality parameter importance to LCR and relevance to current ISMP Template were qualitatively assessed for summary purposes based on potential or known impacts in the watershed and the current minimum and maximum efforts outlined in the current ISMP Template. Also summarized are the landscape processes that should be preserved or remediated to promote good water quality.

Table C1-4: Comparison of Priority Water Quality Issues and Current ISMP Template

Water quality parameter	Importance to water quality in LCR	Relevance within current ISMP Template	Known or potential sources (in order of importance)	Landscape processes to preserve or remediate
Bacteriological /fecal coliform	High	Medium	Urban Agricultural runoff (localized)	Long water retention times, depressional wetlands with mineral soils
Turbidity and suspended solids	High	Medium	Construction Bank erosion First flush events	Intact riparian vegetation, reduced soil disturbance, natural hydrography
Dissolved oxygen	High	Low	Low water levels* High water temperatures ↑ BOD due to nutrient influx	Summer baseflow, riparian forest cover, nutrient removal (see Nutrients)
Nutrients	Medium	Medium	Agricultural runoff	Connected channel and floodplain, seasonal wetlands, wetlands with organic soils
Water temperature	High	Low	Low water levels Lack of riparian vegetation Climate change?	Groundwater supply to summer baseflow, riparian forest cover to provide shading
pH	Low	Medium	Spills	-
Other contaminants	Unknown	Medium	Road surfaces Industrial activity	Wetlands with organic soils
Water levels*	High	Low	Licenced surface water extraction Groundwater (aquifer) extraction Climate change?	Rainwater infiltration (low % EIA), high groundwater levels, forest cover
*see Section C1.4 for further details.				

This ranking shows that, for some of the priority water quality issues in the LCR, the current ISMP Template does not adequately address the source of those issues. For example, dissolved oxygen, water temperatures, and water levels are critical and interacting factors for salmon and trout populations and other aquatic life. However, the current ISMP Template prescribes only minimal monitoring that is not adequate to understand the factors driving such issues at the landscape scale, particularly riparian forest loss and declining baseflow caused by hydrologic disruption. Pollution from point and non-point sources (fecal coliform, turbidity, nutrients) are somewhat better addressed by monitoring but there is still a need to address appropriate mitigation of these parameters across different land uses. In both cases, landscape-level planning must consider the landscape features and processes that preserve or remediate these conditions.

It should be noted that, for some parameters, such as most urban contaminants (e.g., metals, contaminants), a lack of data preclude their inclusion as priorities at this time.

REGULATORY FRAMEWORK FOR WATER QUALITY AND ISMPS

Because the ISMP Template does not outline specific management objectives for water quality issues or a process for identifying them, this section reviews the regulatory framework for water quality in which the current ISMP Template was developed and the requirements for consideration of water quality in ISMPs.

Several acts, plans, and bylaws regulate the impacts of stormwater on water quality the LCR watershed:

- The Province of British Columbia's **Environmental Management Act (2003)** is the main anti-pollution law in B.C., regulating the introduction of waste into the environment. This replaced the previous Waste Management Act (1982, 1996). Through the ***Municipal Sewage Regulation (1999)***, the current Act generally prohibits the discharge of waste into aquatic environments without government approval, outlines long-term objectives for liquid waste management, and requires local governments to regulate liquid waste through area-based management plans. Thus, this Act provides broad objective and a legislative framework for regulation and enforcement by the Province but delegates responsibility for meeting objectives to regional and municipal levels.

- The Greater Vancouver Regional District's **Liquid Waste Management Plan (LWMP) (2001)** is the current provincially-approved waste management plan for liquid waste in the Metro Vancouver area. It provides sewerage and stormwater management policy and commitments to Metro Vancouver's member municipalities, though drainage and management may be regional or the responsibility of individual municipal governments. The LWMP is the current impetus for the ISMP process and the commitment that ISMPs be developed for all watersheds in Metro Vancouver by 2012.

  Generally, the LWMP views "stormwater as a resource". Resultingly, several policy statements promote the protection of water quality and are relevant for the LCR watershed at this early stage of the planning process:

- **Policy P2** states that environmental monitoring will be undertaken to "determine if, and where, wastewater or stormwater discharges are contributing to exceedances of water quality objectives". Exceedances can trigger an environmental risk assessment of particular discharges. Discharge indicators (***Commitment C3***) and monitoring programs (***Commitment C4***) are key fulfillments of this policy. This scoping study partially meets this commitment.

- **Policy P25** mandates a proactive integrated approach to stormwater management by integrating stormwater planning with relevant municipal planning processes (Official Community Plans, Neighbourhood Community Plans, Master Drainage Plans, etc.) in both urban and non-urban watersheds. Plans should specifically address the impacts of stormwater management on relevant community values, many of which depend on water quality (e.g., fisheries, environment). These impacts are currently addressed largely through the terms of reference template (***Commitment C39***) to guide watershed-scale stormwater management plans by municipalities (see next section).

  The LWMP also specifically addresses non-point source pollution management from non-urban areas (including agricultural runoff and on-site sewage disposal systems):

- **Policy P30** mandates that "municipalities will consider stormwater runoff from agricultural lands when undertaking integrated stormwater management planning for their municipality". Commitments that flow from this policy are based on monitoring and maintaining water quality in agricultural areas. ***Commitments C47-C49*** require the compilation of existing data on water quality from agricultural watersheds, ongoing monitoring and assessment (through the Fraser Basin Council), and identification of key water uses and water quality objectives.

Current water uses and water quality objectives for the LCR were developed to protect the most sensitive water uses to help meet the objectives of the current LWMP (Swain and Holms 1988).

- Some municipal bylaws offer additional environmental protection by providing enforcement mechanisms for non-compliance. These include:

City of Surrey:

- **Erosion and Sediment Control Bylaw (No. 16138)** – adopted in March 2007 to enforce compliance with best management practices for sediment and erosion control on any sites involving clearing, grubbing, excavating, grating, civil construction, or any activity which may cause sediment laden water to be discharged. An erosion and sediment control (ESC) permit is required for all construction projects on land of 2000 m^2 or larger.

- **Surrey Stormwater Drainage Regulation and Charges Bylaw (No. 16610)** – adopted in 2008 to regulate extensions, connections, and use of the stormwater drainage system, to impose connection charges to the stormwater drainage system, and to prohibit the fouling, obstructing, or impeding the flow of any stream, creek waterway, watercourse, ditch, or stormwater drainage system.

- **Waterways Protection Bylaw (No. 2659, amended as No. 12268)** – prohibits "the fouling, impeding, or obstructing of any stream, creek, waterway, watercourse, waterworks, ditch, drain or sewer within the City".

Township of Langley:

- **Erosion and Sediment Control Bylaw 2006 (No. 4381)** – similar to City of Surrey's ESC bylaw above.

- **Waterways Protection Bylaw 1991 (No. 3110)** – similar to City of Surrey's Waterways Protection Bylaw above.

- The Township of Langley's **Water Resources Management Strategy** was initiated in 1998. This strategy aims to balance "present and future water supply with demand for development while maintaining and maximizing opportunities to enhance the quantity and quality of surface water and groundwater" (Golder 1999, Golder 2002). The WRMS is intended to provide the township with a comprehensive and defensible framework for managing the quantity and quality of the local groundwater and surface water. The WRMS promotes a proactive approach to the management of water resources. A 20-year action plan outlines projects to address management goals. This action plan includes the requirement of ISMPs under the LWMP. Overall, the goals of this strategy are similar to those of the ISMP process and the LWMP for the region.

Several key points emerge from the above summary:

- ISMPs are required to address the impacts of stormwater management on relevant community values and water uses.

- Water quality objectives in the LCR under the LWMP were set to protect the most sensitive water uses.

- The current LWMP requires ongoing monitoring for exceedance of water quality objectives and an environmental risk assessment can be triggered by exceedance of objectives caused by stormwater (or other) discharges.

Thus, for ISMP in the LCR to remain relevant to water quality in this watershed and fulfill its obligations under the LWMP, the ISMP process used should address the most sensitive water uses and tie in to existing water quality objectives that are specifically aimed at protecting these objectives. This will require addressing the above identified water quality issues of concern in the watershed.

The current ISMP Template does not adequately meet the needs of planning in the LCR and the obligations under the LWMP with respect to water quality.

C1.6 RECOMMENDATIONS

Given the importance of maintaining specific water uses that depend on adequate water quality, the ecological significance of the LCR watershed and Boundary Bay ecosystem, and the specific regulatory requirements in the LWMP, the following recommendations are made to guide the development of ISMPs at the subwatershed scale.

Recommendations are divided into six components:

1. process-related recommendations that include broader questions for watershed management as part of ISMP planning;
2. assessment recommendations that provide direction on how watershed characteristics should be assessed during the development of ISMPs;
3. specific research and information gaps that should be addressed to assist in ISMP development;
4. implementation recommendations that summarize key topics that should be addressed as part of ISMPs; and
5. recommendations for monitoring environmental health and the success of ISMPs in managing the watershed.

1. ISMP Process

- Resolve the conflict between LWMP objectives and the current ISMP Template regarding water quality management, specifically the incorporation of different water uses. Consider inclusion of specific water quality objectives as criteria for management and using existing data to set specific targets for improvement over time.
- Incorporate the assessment, protection, and restoration of landscape-level watershed processes for water quality management into future ISMPs in the LCR (use Stanley et al. 2005 as template).

- Clarify the use and relevance of current MOE water quality objectives for the LCR in ISMP development.

- Consider an array of specific measures that address both point and non-point sources of water pollution, based on the best management practices available from other jurisdictions.

- Consider commencing of monitoring and assessing some aspects of water quality and benthic invertebrates in the overall LCR watershed ahead of initiating the ISMPs in order to have a longer record of data and simultaneous data from all parts of the watershed for comparison purposes.

2. Assessment

- Assess landscape processes that allow natural mitigation of non-point sources of pollution as part of ISMP assessment (using *Protecting Aquatic Resources using Landscape Characterization: A Guide to Puget Sound Planners* by Stanley et al. 2005 as template). This should include GIS-based assessment of terrestrial upslope forests, riparian forests, mineral wetlands (including seasonally flooded areas), and floodplains and periodically inundated areas.

- Assess infiltration and recharge at a subwatershed-scale and its role in maintaining water quality during summer baseflow.

- Because of the greater range of land uses, water uses, and environmental sensitivities within the LCR, it is recommended to expand the assessment of water quality beyond benthic invertebrate sampling (B-IBI) and collection of basic water quality data during summer baseflow (see Clauses 12 and 13 of the ISMP template) to include:

  1. more intensive seasonal sampling of water temperature, dissolved oxygen, fecal coliform, and other parameters within subwatersheds;

  2. fecal coliform source identification to both identify existing sources and to provide a baseline for comparing future concentrations in developing watersheds;

  3. continuous monitoring of temperature, dissolved oxygen, and turbidity during the development phase; and

  4. collection of sediment samples within developing catchments to track long-term changes to metal concentrations.

  To reduce costs, monitoring could be carried out at the watershed scale and in coordination with other agencies and groups conducting monitoring within the watershed, such as BC Ministry of Environment, the Little Campbell Watershed Society, and A Rocha Canada.

3. Research and Information Gaps

- Continue to identify sources of fecal coliform bacteria from urban areas such as cross-connections and domestic animal populations (pet feces), and identify options to mitigate the impacts.
- Improve the understanding how the combined hydrological effects of urbanization and agricultural water withdrawals exacerbate low dissolved oxygen and high water temperature problems in the LCR.
- Investigate the cause of low winter dissolved oxygen levels and their possible link to increased biological oxygen demand from nutrient-rich runoff.
- Investigate the possible interaction between elevated turbidity and fecal coliform concentrations; turbidity may reduce mortality of fecal coliform bacteria and fine sediment may provide sites for bacterial adhesion and transport.

4. Implementation

- Focus ISMP implementation on protecting and restoring natural watershed processes that regulate water quality such as denitrification and sediment removal in natural wetlands.
- Incorporate low impact development measures into new developments such as raingardens and seasonally flooded wetlands to emulate natural watershed processes and maintain predevelopment infiltration.
- Incorporate various measures to retrofit existing stormwater management systems to reduce non-point sources of pollution. Examples include catch basin inserts and oil/grease interceptors.
- Incorporate best management practices that target specific sources of stormwater and stream pollution. Examples include regular street sweeping and community spill prevention education programs (e.g., “All Drains Lead to Fish Habitat”).
- Protect and restore riparian forest along all sections of the Little Campbell River and tributary streams as an essential method for protecting stream health, including water temperature and dissolved oxygen. The highest priority area for restoration is the reach of the mainstem between 176 and 184th Avenue with intensive and historic riparian forest loss from agriculture.
- Recognize that the development phase is an important contributor to some forms of water quality impairment from suspended sediment and turbidity increases in

the LCR and that conventional sediment and erosion control measures have been unsuccessful. Incorporate more stringent sediment and erosion control measures including phasing for larger projects, winter construction halts, and better monitoring.

5. Monitoring

- Monitor the following water quality parameters at the subwatershed scale during the predevelopment, development, and early post-development (5 years) phase:

  1. monitoring of benthic invertebrates using the City of Surrey's collection and analysis methods;
  2. summer and winter measurement of fecal coliform concentrations in streamwater (at least 5 samples in 30 days to calculate geometric mean);
  3. continuous monitoring of water temperature, dissolved oxygen, and turbidity during the development phase; and
  4. collection of sediment samples within developing catchments to track long-term changes to concentrations of metals.

- Require fecal coliform concentrations in new stormwater systems be tested at least three times during the first year following construction to detect cross-connections; alternately, new developments should be dye-tested.

- Collaborate with MOE to continue to sample parameters specified in water quality objectives for the LCR (fecal coliform bacteria, dissolved oxygen, total suspended solids, water temperature, nitrite, ammonia, total lead, and pH) at 216th Street and 176th Street. Improve the consistency of this monitoring program by specifying that a minimum of five samples should be collected during baseflow conditions from August 15 to October 15 annually.

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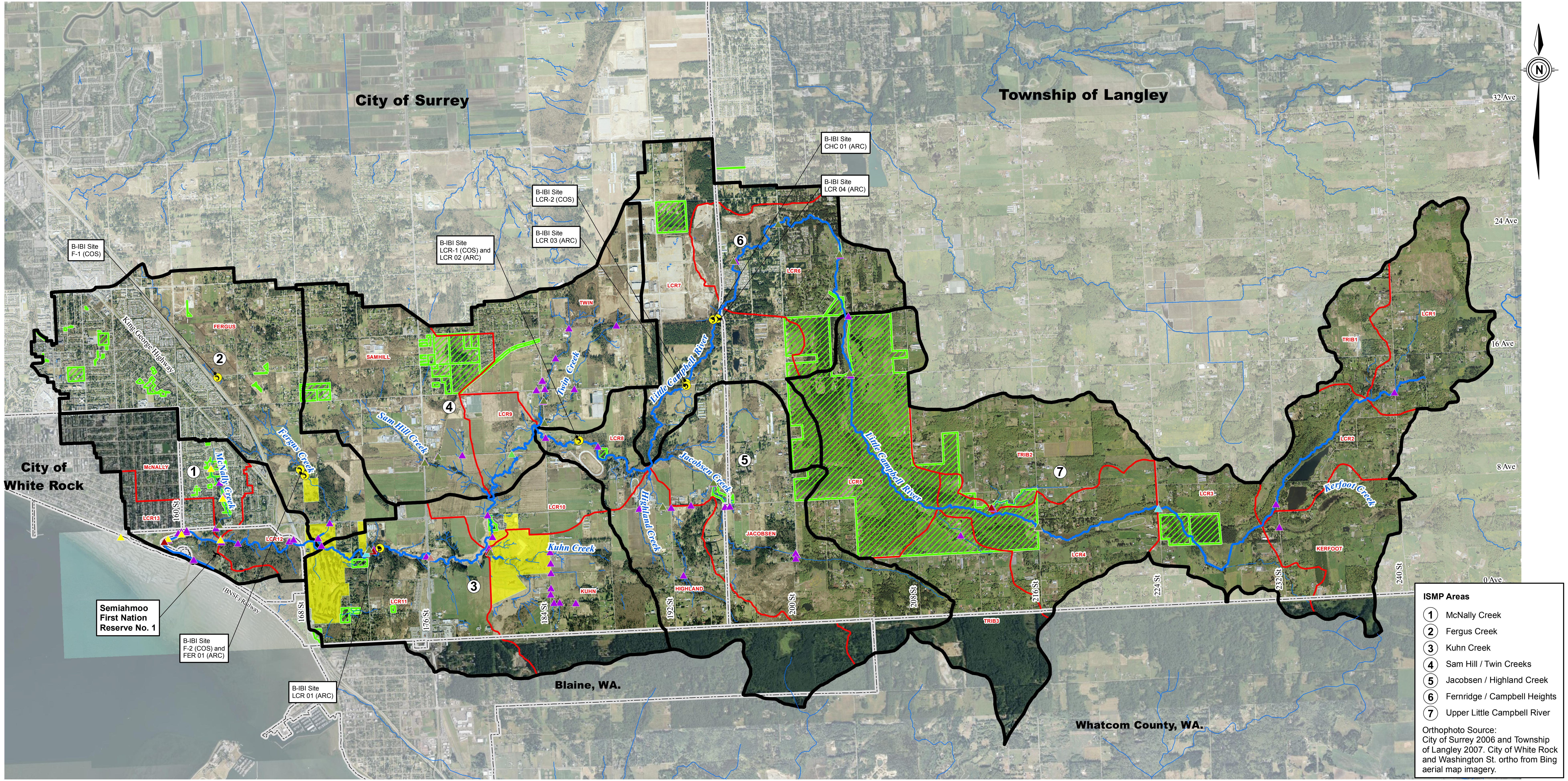

City of Surrey/Township of Langley
Little Campbell River ISMP
Scoping Study

Legend

- City/Township/US Boundary
- ISMP Area ID / ISMP Area Boundary
- Catchment ID / Major Catchment Boundary
- Watercourse
- Golf Course
- Parks
- Benthic Site

Water Quality Station

- Attainment Monitoring (1971-2007)
- Hydrolab Site (2005-2008)
- LCWS Study (2000-2003)
- Longitudinal Survey (2006-2007)
- Seasonal Monitoring - AgriculturalRunoff (2006)
- Seasonal Monitoring - On-site Sewage Disposal Systems (2006-2007)
- Seasonal Monitoring - Urban Runoff (2006-2007)
- Temperature Logger Sites (2005-2010)

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1 0.5 0 1
Scale in Kilometers

Project No.	Date
471-180	March, 2011

Water Quality and Benthic Invertebrate Sampling Locations

Figure C1-1

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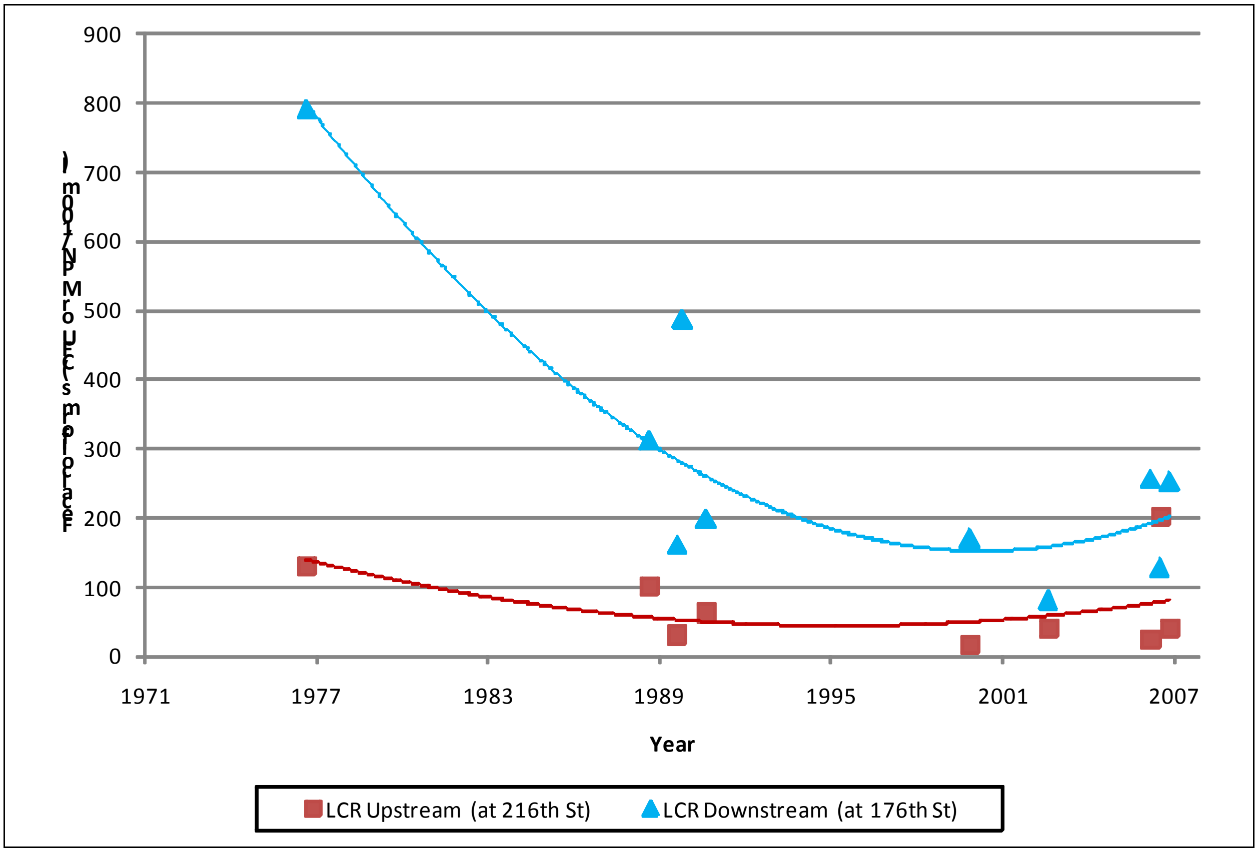

Figure C1-2: Fecal Coliform Concentrations (Medians or Geometric Means) at LCR Upstream (at 216th St.) and Downstream (at 176th St.) Attainment Sampling Sites, 1971-2007

C2. FISH AND FISH HABITAT

C2.1 INTRODUCTION

One of the drivers of stormwater management planning in Metro Vancouver is the protection of fish and fish habitat. This stems from the importance of the federal Fisheries Act in regulating both direct and indirect effects of urbanization on fish populations, but also the historical focus on fish, particularly salmonids, in environmental management in coastal BC.

Fish[6], in the context of Canadian environmental regulation, are interpreted to include all species with economic value for commercial, sustenance, or recreational fisheries including all life stages of salmonids (salmon and trout), game fish, shellfish, marine plants, and marine mammals. Endangered or threatened fish species are not necessarily protected under the Fisheries Act, although their protection and management is addressed by the Species at Risk Act. Fish that are not part of economic fisheries such as three-spine stickleback or western brook lamprey would not be protected specifically by the Fisheries Act.

Under the *Fisheries Act*, fish habitat[7] is defined as those parts of the environment "on which fish depend, directly or indirectly, in order to carry out their life processes". Activities that destroy or alter fish habitat[8] can result in charges under the Fisheries Act.

The City of Surrey, through its Natural Drainage Policy, and the Township of Langley have chosen to maintain and, where possible, enhance open watercourses. As a result, both municipalities have natural streams that are important spawning and rearing habitat for several species of salmonids. Fish and fish habitat are an important consideration in both the City of Surreys and the Township of Langley's stormwater management and overall planning.

The ISMP Template addresses fish and fish habitat in Clause 9. Clause 9 mandates the inventory of aquatic species and their habitat and the identification of opportunities for environmental enhancement. Emphasis in previous ISMPs completed in Metro Vancouver has been on protecting aquatic habitats for salmonids. Common foci of planning include removing barriers to fish migration within stream reaches (such as

[6] Fish: "includes parts of fish, shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals." (*Fisheries Act*, sec. 2).

[7] Fish habitat: "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes." (*Fisheries Act*, sec. 34(l)).

[8] Subsection 35(1) is a general prohibition of harmful alteration, disruption or destruction (HADD) of fish habitat. This means that any work or undertaking that results in HADD is a contravention of Subsection 35(1). The only relief from this general prohibition is when a Subsection 35(2) Authorization is issued for the HADD.

raised culverts), enhancing spawning and rearing habitat (e.g., cover, substrates), and protecting water quality and flow regimes (hydrology).

SOURCES OF DATA

A variety of existing sources of data on fish and fish habitat in the LCR were reviewed and supplemented with field collection or air photo analysis of new data. Existing data sources included:

- Species occurrence records from government and other databases including the Fisheries Information Summary System (FISS);
- Salmon escapement data provided by the Semiahmoo Fish and Game Club and historic records from DFO escapement monitoring;
- Habitat data collected using SHIM (Sensitive Habitat Inventory Mapping procedures) for portions of the LCR;
- Watershed-scale assessments such as Drever and Brown (1999) and Zevit et al., (2007);
- Site-specific stream inventories and habitat assessments such as the environmental assessment as part of the Fergus Creek ISMP;
- Survey data from local conservation, stewardship, and naturalist organizations; and
- Other undocumented professional and local knowledge.

C2.2 SALMON AND TROUT POPULATIONS

Presented in this section is existing information on salmon and trout populations in the Little Campbell River watershed. No new data collection, such as fish sampling, was undertaken. Additional information on the LCR's fish community is provided in the biodiversity portion of this report (Section C3).

The LCR is one of the most highly productive salmon rivers in the Lower Mainland relative to its size. Five species of salmonids[9], including four species Pacific salmon and one species of trout, have self-sustaining wild populations in the watershed (see Table C2-1). Records of sockeye and pink salmon also exist for the LCR but these occurrences are likely due accidental migrations of individual fish up the wrong home stream (Drever and Brown 1999). Several of the salmonid populations in the LCR have been or are currently augmented by regular hatchery releases of fry or smolts into the river by the Semiahmoo Fish & Game Club (as denoted in Table C2-1).

[9] According to current classifications by scientists, only chinook, chum, coho, pink, sockeye, and steelhead are considered to be true Pacific salmon species. Cutthroat trout are not considered true salmon. Together, Pacific salmon and trout species are called salmonids.

Table C2-1: Salmon and Trout Species in the LCR Watershed

Common name	Scientific name	Source	Status/comments
Chinook salmon	*Oncorhynchus tshawytscha*	SFGC, FISS 2008	Wild and hatchery pop'ns
Chum salmon	*Oncorhynchus keta*	SFGC, FISS 2008	Wild pop'ns[1]
Coho salmon	*Oncorhynchus kisutch*	SFGC, FISS 2008	Wild and hatchery pop'ns
Pink salmon	*Oncorhynchus gorbuscha*	FISS 2008	Unverified; accidental?
Sockeye salmon	*Oncorhynchus nerka*	FISS 2008	Unverified; accidental?
Steelhead/rainbow trout[1,2]	*Oncorhynchus mykiss*	SFGC, FISS 2008	Wild and hatchery pop'ns
Cutthroat trout	*Oncorhynchus clarki*	SFGC, FISS 2008	Wild and hatchery pop'ns

Abbreviations for sources: SFGC = Semiahmoo Fish & Game Club, FISS = Fisheries Information Summary System
[1]Approximately 500 hatchery-raised chum fry were released in 2009 from LCR wild stock taken in fall 2008. This was an initial trial by SFGC at hatchery raising this species. No other hatchery augmentation had occurred prior to this trial.
[2]includes both anadromous (sea-run) and non-anadromous (resident) forms.
[3]Steelhead are an anadromous form of rainbow trout that migrate to sea and return to their home streams to spawn.

Salmon and trout are widely distributed in the LCR mainstem and tributaries, although the gravel reaches from 184th to upstream of 200th Street are the most critical for spawning. The use of the mid-basin wetland complex by fish is poorly known, but does support juvenile coho rearing from spawning which occurs above 232 Street. Resident cutthroat trout are most widespread and occur in most permanent streams in the watershed.

The size of salmon and trout populations in the LCR is variable, but show some general trends and patterns (see Figure C2-1 for graphical depictions of long-term trends). A fish fence was installed on the Little Campbell River in 1982 and is operated by the Semiahmoo Fish & Game Club (Rempel et al. 1984). The fence has allowed accurate counts of salmonid returns to the middle and upper portion of the watershed. Coho salmon is the most abundant salmon species with a long term adult escapement of around 2,150 fish per year. Long-term average escapement for other species (wild and hatchery fish combined) are: chum (249); chinook (179), steelhead (147), and cutthroat trout (30). Steelhead and sea-run cutthroat trout populations have declined substantially since the 1980s (see Figure C2-1), and coho salmon have declined to less than half their long-term average since 2004. It is not known how changing freshwater conditions in the LCR have affected salmonid populations, although poor marine survival is likely the primary cause of recent coho population declines.

As described in Table C2-1, populations of coho salmon, chinook salmon, steelhead, and cutthroat trout are supplemented by the hatchery program run by the Semiahmoo Fish and Game Club. The hatchery program was not reviewed in terms of how it may affect influence salmon and trout populations in the river, including increasing distribution through releases of fry and smolts into inaccessible area. Overall, the hatchery production appears to be an important strategy for maintaining salmonid populations in the LCR.

However, wild fish populations may be affected negatively by interactions with hatchery produced smolts and fry.

C2.3 FISH HABITAT

Both the City of Surrey and Township of Langley have classified all watercourses within their boundaries using colour codes according to their potential to be salmon bearing. Anadromous[10] wild fish have access to at least 26 km upstream (240th St) on the Little Campbell River mainstem; to at least 1 km upstream of the mouth of McNalley Creek; to 14th Ave on Fergus Creek (where there is an impassable culvert); to the headwaters of Sam Hill Creek; and to the 8th Ave culvert on Jacobson Creek (CMN 2008). Good potential rearing habitat exists in the middle reaches of the watershed in the area of the mid-basin wetlands at Campbell Valley Regional Park but this potential is offset by low water flows during the summer months (CMN 2008).

Sensitive Habitat Inventory and Mapping (SHIM)[11] has also been used in the watershed to inventory and map fish habitat features and threats. In 2002, the LCR watershed was the first watershed in Surrey to undergo SHIM. Langley Environmental Partners Society (LEPS) has also used SHIM to map the Langley portion of the LCR. SHIM has identified that the best spawning and rearing habitat is currently found in the lower reaches of the watershed (CMN 2008).

C2.4 RIVER CHANNEL ASSESSMENT

Existing and newly collected data were used on channel conditions to describe general patterns of river channel characteristics in the LCR mainstem. The river's mainstem was divided into thirty 1 km long segments from the mouth to upstream of 240th St. which were used to characterize general channel conditions (see Figure C2-2). This is a different approach than most river and stream assessments which typically divide channels into reaches with consistent physical and hydrologic characteristics. The use of standardized river segments allows channel conditions to be more easily compared to riparian land cover data (see following section), as well as show more fine scale changes to channel conditions. From a perspective of reach characterization, the LCR has only five main reaches:

(1) tidal estuary;
(2) lowland agricultural reaches to 184th St;
(3) gravel reaches from 184th St to 24th Ave;

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10 Anadromous = describes fish which migrate from the ocean to fresh water to reproduce (spawn).

11 Sensitive Habitat Inventory and Mapping (SHIM) = a protocol for mapping watercourses with a Global Positioning System (GPS) unit and marking down the location of notable features such as culverts, obstructions, wetlands, erosion points, and fish sightings. See Mason and Knight (2001) for more info on the methods.

(4) mid-basin wetlands (to 232nd St), and
(5) low gradient headwater reaches (above 232nd St), which are likely too coarse for management planning.

Methods: For each 1 km river segment, key channel was summarized information using a combination of existing data (from SHIM and other sources) and newly collected field data. Field data was collected from intermittent stream walks in June 2007 and April 2008. Some orthophoto interpretation was used to measure bankfull channel width, % channelized, and % culverted.

1. Channel characteristics: bankfull width; channel gradient; % channelized; % culverted or bridged; channel form (% pool, % riffle, % glide); large woody debris (LWD) presence per 100 m of channel (<1, 1–3, 3–5, >5 pieces/100 m);

2. Erosion areas: qualitative description of erosion activity divided into no erosion, minor erosion, moderate erosion, and major erosion (note, this distinguished between natural erosion which is critical for river channel processes and anthropogenic erosion from anthropogenic influences); and

3. Substrate conditions: visual estimate of percent composition of boulder, cobble large gravel, small gravel, and fines (sand and silt).

Results: Representative photos of each river segment are included on Figure C2-2. The data are presented in Table C2-2. Figures C2-3 to C2-6 visually summarize key river channel characteristics.

Key observations on channel conditions include:

- **The LCR is a lowland river with average channel gradient under 0.5%** and rarely greater than 1%. This influences channel form (pools are dominant except in the gravel-bed segments) and substrate (gravel and finer sediment predominates) as well as affects the degree of tidal influence within the lower reaches. Boulder substrates are very rare which likely limits habitat for chinook and steelhead (note, that the Greater Georgia Basin Steelhead Recovery Plan states: "lack of large woody debris and extent of boulder reaches for parr[12] habitat" (online)). Therefore, wood debris has an essential role in influencing habitat complexity within the mainstem.

- **The mid-basin wetland complex is unique component of the LCR mainstem** and influences the movement of sediment, large wood, and other organic materials from the headwaters to the lower reaches. However, it is poorly accessible for assessment purposes and much of the information on channel conditions was obtained from air photo assessment.

[12] Parr are juvenile salmon, usually up to 2 years of age.

Table C2-2: Summary of Channel, Erosion, and Substrate Characteristics

Segment	Bankfull Width	Gradient	% channelized	% culverted	%Pool	%Riffle	%Glide	LWD / 100m	Erosion	%B	%C	%LG	%SG	%F
1	24.8	0.10	0.0%	0.0%	50	0	50	<1	minor	0	0	5	60	35
2	15.4	0.10	0.0%	0.0%	80	0	20	3 to 5	minor	0	0	0	20	80
3	11.3	0.07	0.0%	6.5%	80	0	20	<1	moderate	0	0	0	30	70
4	9.9	0.06	0.0%	3.0%	40	5	55	>5	minor	0	0	0	20	80
5	7.4	0.14	0.0%	4.5%	55	25	20	<1	major	0	0	0	25	75
6	7.5	0.09	0.0%	1.0%	50	25	25	<1	major	0	0	0	20	80
7	6.7	0.11	14.0%	2.0%	30	10	60	<1	major	0	0	0	20	80
8	5.8	0.24	0.0%	1.5%	45	25	30	<1	major	0	0	0	20	80
9	6.0	0.25	0.0%	2.0%	30	10	60	<1	major	0	0	40	40	20
10	6.2	0.40	3.5%	0.5%	50	40	10	1 to 3	moderate	0	5	40	40	15
11	8.4	0.40	0.0%	0.0%	40	40	20	>5	moderate	0	5	55	35	5
12	8.5	0.47	0.0%	0.0%	45	40	5	>5	moderate	0	25	50	20	5
13	11.5	0.57	0.0%	2.0%	40	45	15	1 to 3	minor	0	30	50	15	5
14	9.5	0.68	0.0%	0.0%	30	65	5	>5	minor	0	20	50	25	5
15	8.9	0.56	0.0%	2.5%	50	40	10	1 to 3	minor	0	30	50	15	5
16	8.5	0.57	14.5%	2.0%	50	40	10	<1	minor	0	30	50	15	5
17	9.0	0.39	29.0%	0.0%	60	30	10	<1	minor	0	30	45	30	5
18	8.3	0.11	32.5%	1.5%	65	15	20	<1	moderate	0	45	35	15	5
19	106	0.07	0.0%	0.0%	90	0	10	<1	none	0	0	0	10	90
20	92	0.13	5.5%	2.0%	90	0	10	<1	none	0	0	0	10	90
21	117	0.13	0.0%	0.0%	90	0	10	<1	none	0	0	0	10	90
22	115	0.12	0.0%	0.0%	90	0	10	<1	none	0	0	0	10	90
23	90	0.11	0.0%	0.0%	90	0	10	<1	none	0	0	0	10	90
24	93	0.08	0.0%	1.5%	90	0	10	<1	none	0	0	0	10	90
25	87	0.15	1.5%	4.5%	90	0	10	<1	none	0	0	0	10	90
26	84	0.15	0.0%	0.0%	90	0	10	<1	none	0	0	0	10	90
27	8.6	0.16	73.0%	3.0%	100	0	0	<1	none	0	0	0	5	95
28	16.5	0.17	0.0%	2.0%	85	5	10	>5	none	0	2.5	10	25	62.5
29	15.6	0.23	0.0%	0.0%	90	25	7.5	>5	none	0	0	10	40	50
30	14.5	0.23	0.0%	0.0%	90	5	5	1 to 3	none	0	0	5	45	50

Location of reaches shown on Figure C2-1.

- **Channelization and culvert or bridge installation has caused relatively little change to the LCR mainstem**. Segments 16–18 and 27 have been affected most by channelization; Segments 3–5 and 25 have been affected the most by culvert or bridge construction.

- **Much of the bank erosion observed in the watershed is considered a natural part of river channel processes**. The exceptions are erosion near buildings or other infrastructure which may pose a risk to property, and the extensive erosion between 176th and 184th Street associated with poor riparian conditions and cattle grazing. Bank erosion is expected to worsen if urbanization increases the intensity and frequency of storm flows.

- **The frequency of large woody debris (LWD) was extremely variable in river segments** but generally low. Lack of riparian forest cover in major segments is limiting wood debris recruitment. LWD is more abundant in forested river segments. Habitat quality for stream-dwelling salmonids, particularly coho salmon and steelhead, could be improved through the addition of LWD in many areas of the lower watershed. Based on the fact that the LCR catchment was mostly forested prior to settlement, LWD was likely 5–20 LWD per 100 m historically.

- **Stream bed substrates are predominantly gravel and sand** with increasing amounts of silt near the estuary. Sediment sources were not evaluated but are likely from tributary streams rather than the mainstem. (For example, Jenkins Creek has significant erosion that is apparently natural. The catchment has relatively low levels of development (C. Baron, pers. comm.).) No major natural or anthropogenic sediment sources were observed on the LCR mainstem and the mid-basin wetlands prevent the movement of coarse sediment from the headwaters.

C2.5 RIVER CORRIDOR ASSESSMENT

Riparian land cover has a critical function for fish habitat because of its influence on physical, biological and chemical processes in the river, as well as the degree which these processes are affected by anthropogenic activities. The typical area assessed by riparian assessments (typically 30–60 m from the river or stream) was expanded to encompass a larger area of floodplain and upslope areas; this area was termed the river corridor (see Figure C2-7 for an example).

Methods: To supplement the existing data sources on riparian habitat, land cover within 250 m of the LCR mainstem river channel from its mouth to 240th Street was mapped using 2005 orthophotos. This was undertaken to better understand the effect of adjacent land uses on riparian conditions, as well as identify sites where riparian restoration, particularly reforestation, could occur.

Land cover was divided into eight classes: agriculture, developed areas, sparse vegetation, landscaped areas, grassland (unmaintained), shrubland, forest, and wetland.

Some classes were subdivided based on vegetation composition: forest was mapped as deciduous, mixed, and coniferous forest) and agricultural land was divided into pasture, rough pasture, and forage crops. Reed canary grass areas were also mapped as a component of rough pasture or grassland because it is a distinctive plant community in many floodplain areas that are a high priority for reforestation.

The land cover data was analyzed within the whole river corridor, as well as within 1 km long segments starting at the river's mouth (see previous section for description). Analyses were undertaken for the full 250 m wide buffer and a 30 m wide corridor which is similar to the riparian forest integrity analysis described in the ISMP template.

Results: For the wider (250 m) buffer, land cover was predominantly forest (40.9%), agriculture (24.9%), and wetlands or river channel (9.5%), and developed areas such as roads and buildings (9.2%) (see Table C2-3 and Figure C2-8). The total area assessed was 123.75 ha with a mean polygon size of 0.041 ha (3,026 polygons; range of 0.001–1.529 ha).

Table C2-3: Land Cover within 250m (including 30m riparian corridor) of the LCR Mainstem

Habitat Class	Area (%)	Area (ha)
Agriculture	24.9%	30.8
Developed	9.2%	11.3
Forest	40.9%	50.6
Grassland	4.1%	5.1
Landscaped	7.0%	8.7
Shrubland	3.3%	4.1
Sparsely vegetated	1.1%	1.3
Wetland / River Channel	9.5%	11.8
Total	**100.0%**	**123.7**

For the narrow (30 m) buffer, land cover was dominated by forest (39.9%), wetland (31.5%), grass (9.5%), and agriculture (8.3%) (see Figure C2-9). There are only 2.3% developed areas within 30 m of the centreline of the river. The total area assessed was 17.04 ha with a mean polygon size of 0.016 ha (1,067 polygons; range of 0.001–0.401 ha).

The primary patterns of land cover in the river corridor are:

- Low levels of developed and agricultural land cover in the lower segments (1–4), particularly in Semiahmoo First Nation's lands.
- Rapidly increasing agriculture land cover through Segments 5–11 with over 85% of the river corridor used for agriculture in Segment 8. These segments are also associated with cattle grazing in some areas (e.g., upstream from 8th Ave), bank erosion, and reed canary grass in floodplain areas.
- Segments 9–17 have a high amount of forest cover; these areas, perhaps because of soil or topographic conditions, were not cleared as much for agriculture.
- Increasing wetland occurrence through the mid-basin area (Segments 19–25); and
- More agriculture in Segment 18, and in Segments 24–30.

C2.6 RECOMMENDATIONS

The following recommendations are made to guide the development of ISMPs at the subwatershed scale, with emphasis on fish and fish habitat components.

1. ISMP Process

- Review and refine the direction of Clause 9 of the ISMP Template to provide more specific direction on the consistent assessment of fish and fish habitat in all permanent, fish-bearing streams. This could include more emphasis on assessing structural habitat features such as large wood frequency, channel dimensions, and substrate characteristics. Non-permanent streams should be assessed for fish use and access.
- Review options for assessing sediment transport changes accompanying urbanization, with emphasis on maintaining predevelopment rates and volumes of coarse and fine sediment.
- Provide better direction in the ISMP Template for assessing natural vs. accelerated or anthropogenic bank and channel erosion.

2. Assessment

- Review and refine fish habitat mapping on a subwatershed basis to identify the spatial distribution of habitat use (spawning, rearing, and migration) by different species during different times of the year. Existing SHIM data likely includes most information needed for this task, although some new field assessment may be necessary. As part of this mapping, assess, and map the annual extent of dewatered stream reaches.

- Map substrate composition in subwatersheds undergoing ISMP planning as a component of fish habitat, as well as a monitoring tool.

- Map large wood frequency in fish bearing reaches as a measure of habitat quality and to assist in restoration planning.

- Avoid the use of detailed field inventories for ISMP planning unless they contribute to management of restoration goals or are useful for other purposes (e.g., hydraulic modelling). For example, detailed spatial information on small-scale channel obstructions, storm outfalls, pedestrian bridges, and other point features are not useful for fish habitat management.

3. Research and Information Gaps

- Assess fish use in the mid-basin wetlands.

- Identify juvenile rearing areas most affected by declining summer baseflows as a means of looking at temporary and long-term mitigation options.

4. Implementation

- Emphasize the protection of all components of fish habitat including water flows, water quality, sediment, structural channel features, natural disturbance processes, and off-channel habitats during ISMP planning. Consider the fish community and the habitat on which it depends to be temporally and spatially dynamic with some habitat features such as off-channel wetland being critical habitat only for a portion of the year.

- Protect the pre-development rate and volume of sediment (input, transport, and deposition) to the gravel reach of the LCR through the management of sediment transport in tributary streams.

- Restore large woody debris in the lower reaches of the LCR; combine with riparian restoration projects and bank stabilization.

- Work with the Semiahmoo Fish and Game Club, DFO, and MOE, A Rocha Canada, and other stakeholder groups to evaluate the hatchery program to ensure protection of wild stocks and other biodiversity values (e.g., amphibians).

5. **Monitoring**

- Support ongoing fish escapement monitoring by the Semiahmoo Fish and Game Club through continued in-kind assistance and suitable recognition of these efforts.

- Explore the usefulness of other forms of quantitative fish habitat monitoring, including monitoring using standard watershed assessment protocols (e.g., B.C. Forest and Range Evaluation Program), juvenile salmon abundance, and other ecological indicators of stream health (e.g., freshwater mussels). Consider engaging universities or other local research organizations to develop and implement these methods.

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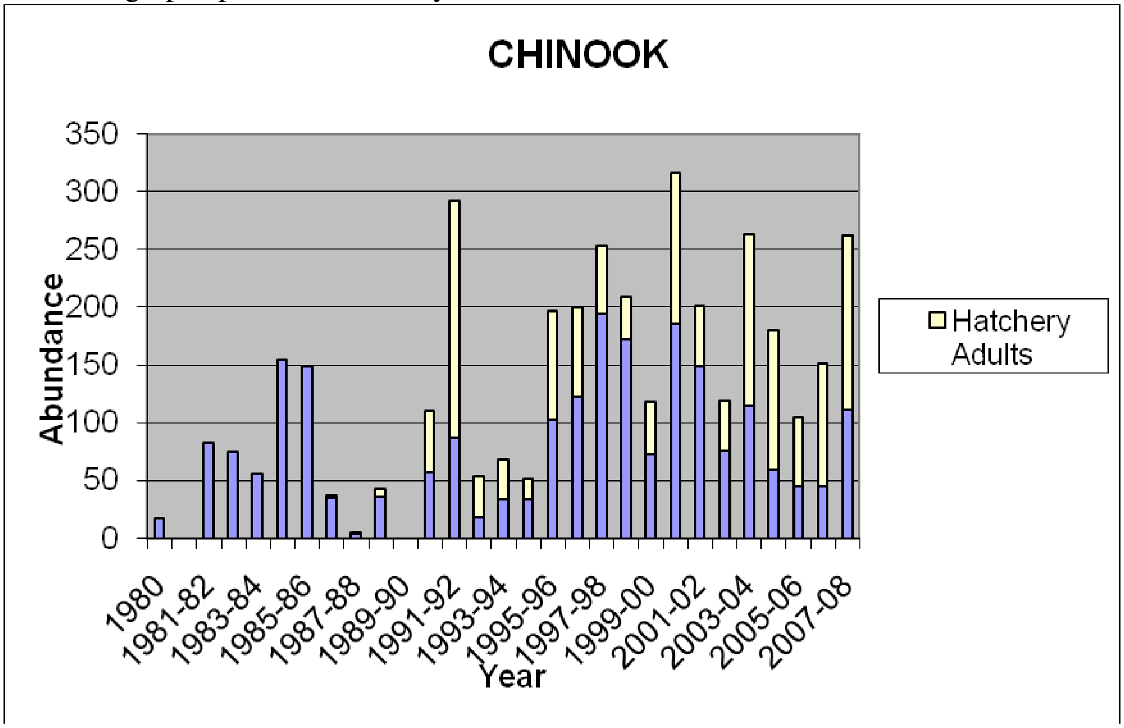
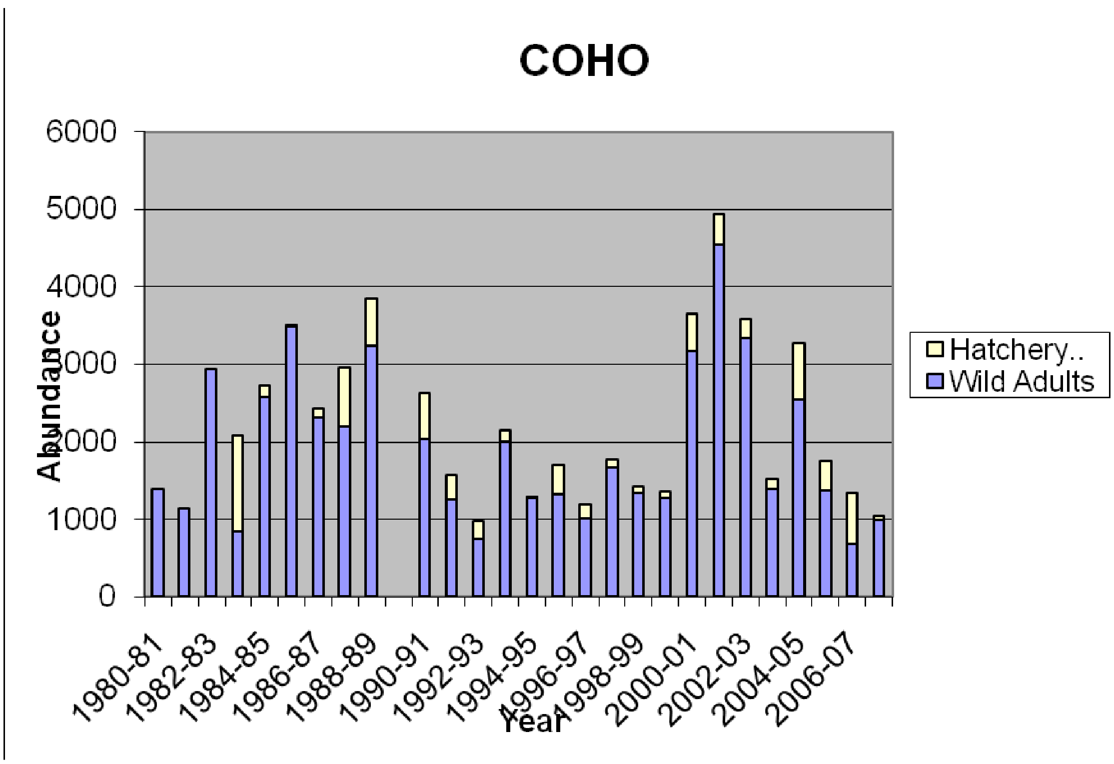
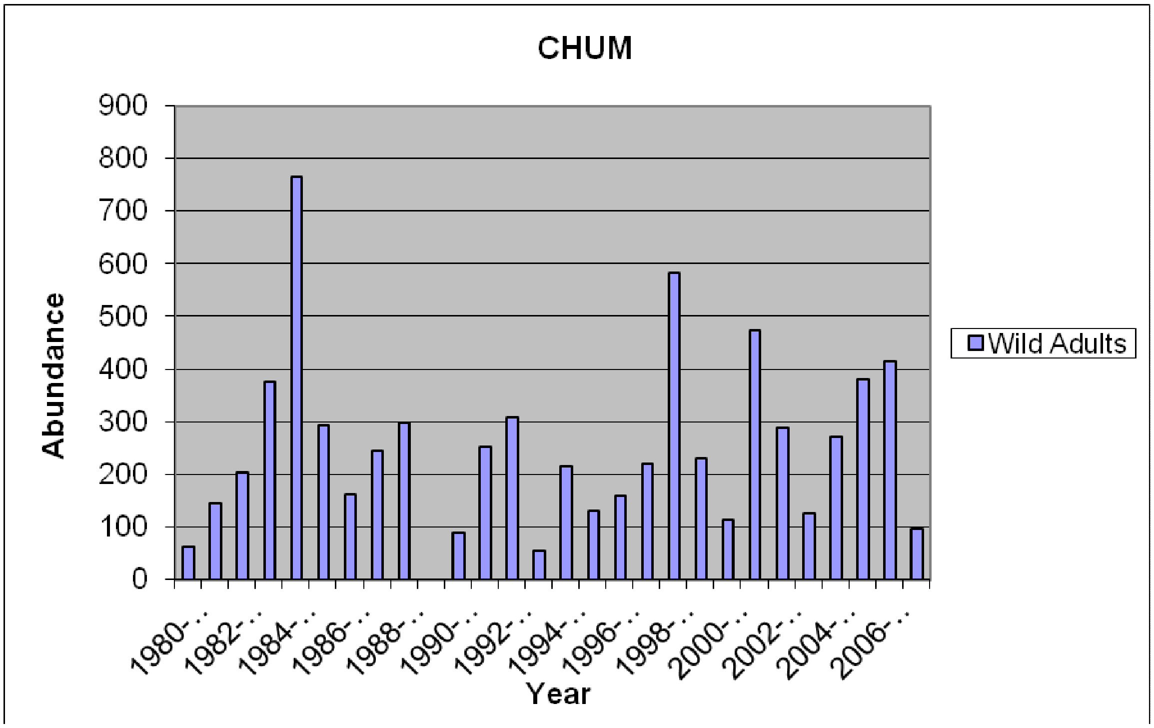
Figure C2-1: Returning Adult Spawner Counts (by Species) at LCR Fish Fence, 1980-2007

Data and graphs provided courtesy of the Semiahmoo Fish & Game Club.






CHUM
Abundance
900
800
700
600
500
400
300
200
100
0
1980-..
1982-..
1984-..
1986-..
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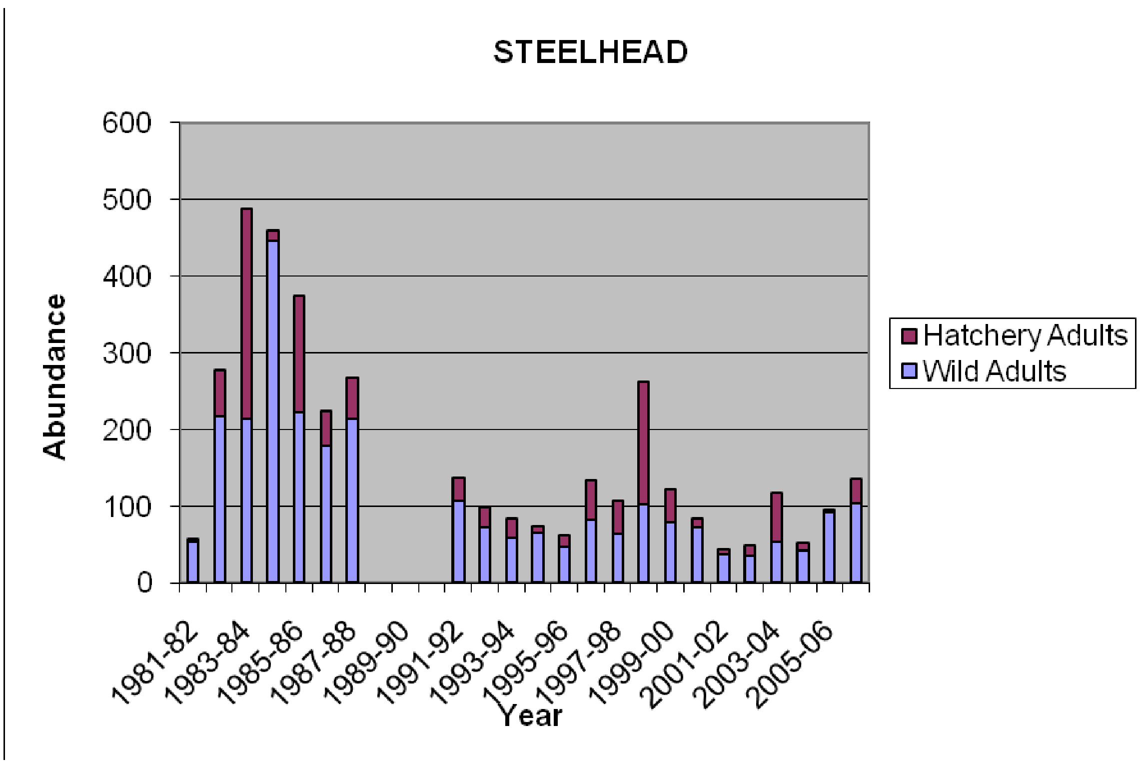
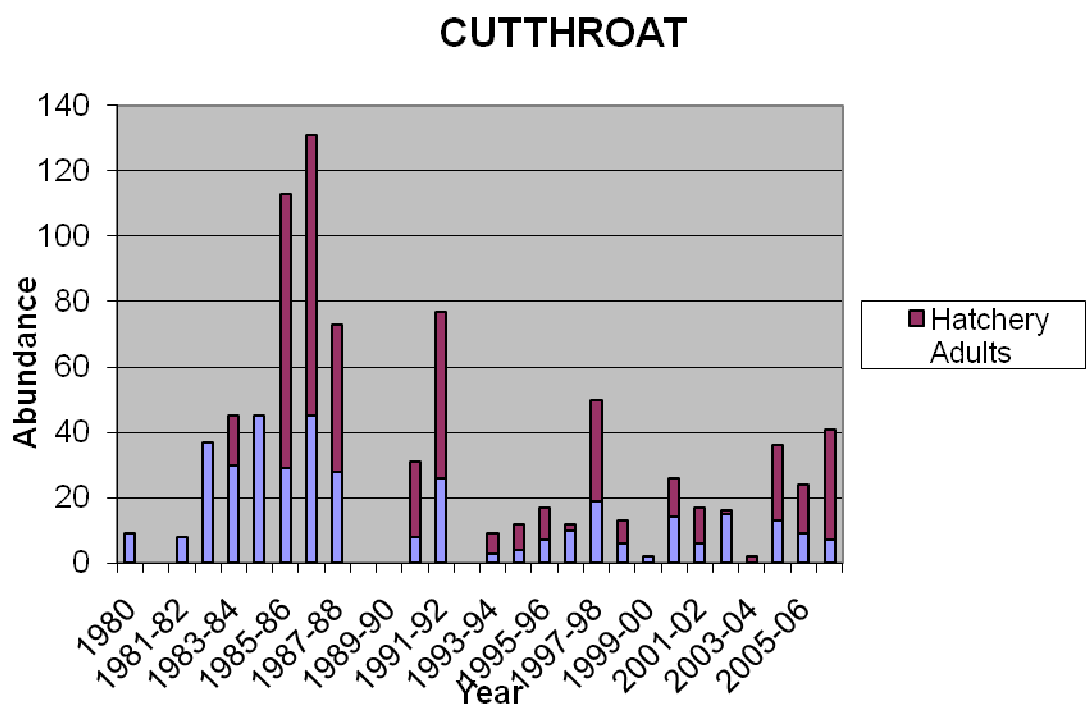
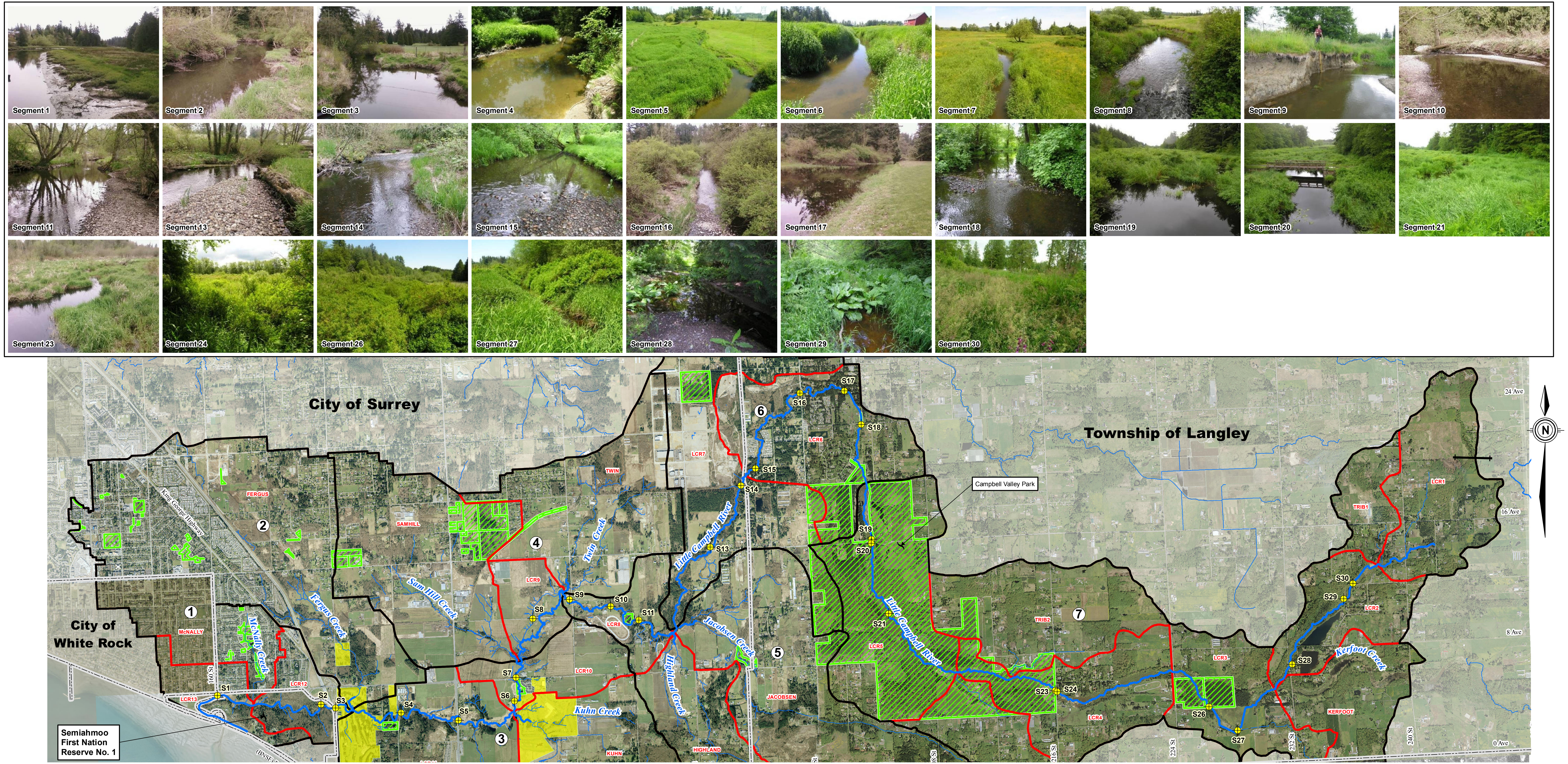
2004-..
2006-..
Year
Wild Adults


STEELHEAD
Abundance
600
500
400
300
200
100
0
1981-82
1983-84
1985-86
1987-88
1989-90
1991-92
1993-94
1995-96
1997-98
1999-00
2001-02
2003-04
2005-06
Year
Hatchery Adults
Wild Adults


CUTTHROAT
Abundance
140
120
100
80
60
40
20
0
1980
1981-82
1983-84
1985-86
1987-88
1989-90
1991-92
1993-94
1995-96
1997-98
1999-00
2001-02
2003-04
2005-06
Year
Hatchery
Adults

City of Surrey/Township of Langley
Little Campbell River ISMP
Scoping Study



Legend

- City/Township/US Boundary
- ISMP Area ID / ISMP Catchment Boundary
- Catchment ID (TRIB) / Major Catchment Boundary
- Watercourse
- Golf Course
- Parks
- River Segment
- Photo ID / Photo Location

ISMP Areas

1. McNally Creek
2. Fergus Creek
3. Kuhn Creek
4. Sam Hill / Twin Creeks
5. Jacobsen / Highland Creek
6. Fernridge / Campbell Heights
7. Upper Little Campbell River

Orthophoto Source:
City of Surrey 2006 and Township of Langley 2007.
City of White Rock and Washington St. ortho from Bing aerial map imagery.

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associates limited
CONSULTING ENGINEERS
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1 0.5 0 1
Scale in Kilometers

Project No.	Date
471-180	March, 2011

River Segments and Photo Locations

Figure C2-2

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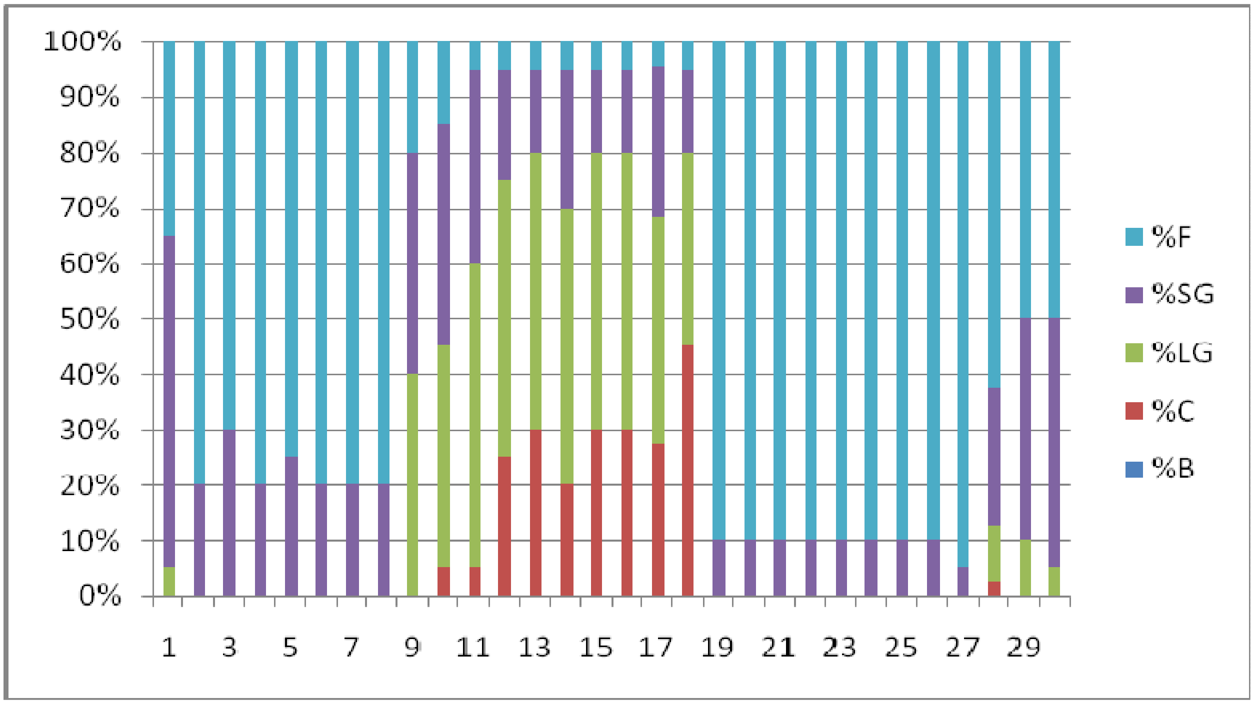

Figure C2-3: Substrate Composition in LCR River Segments
(% fines, small gravel, large gravel, cobble, and boulder)

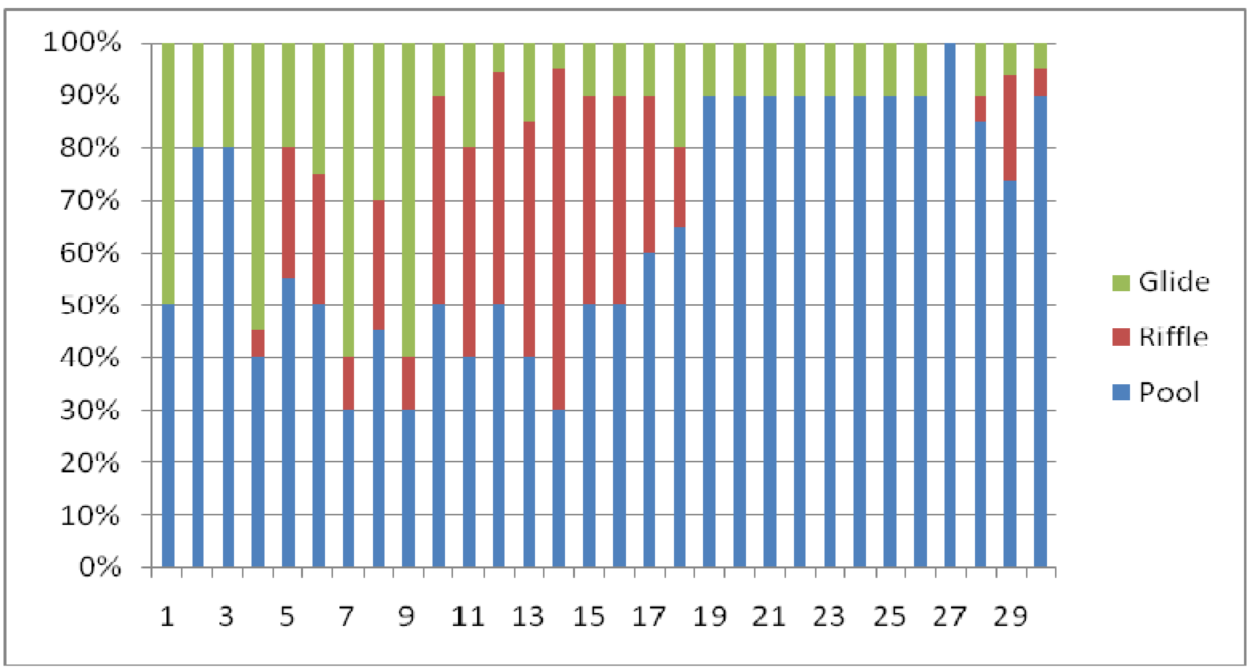

Figure C2-4: Hydraulic Habitats Within LCR River Segments
Salmonid Spawning is Associated with Riffle Habitats

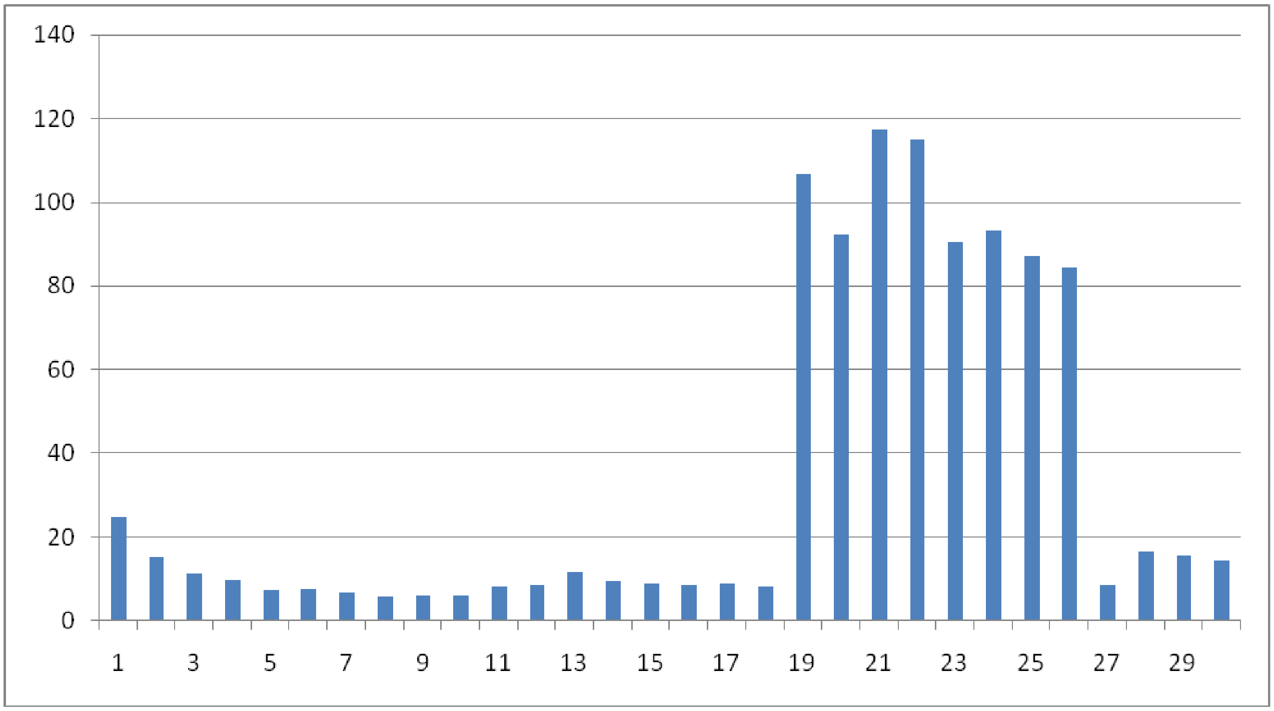

Figure C2-5: Bankfull Width (in meters) in LCR River Segments
The Mid-Basin Wetland Complex is clearly demarcated by bankfull width

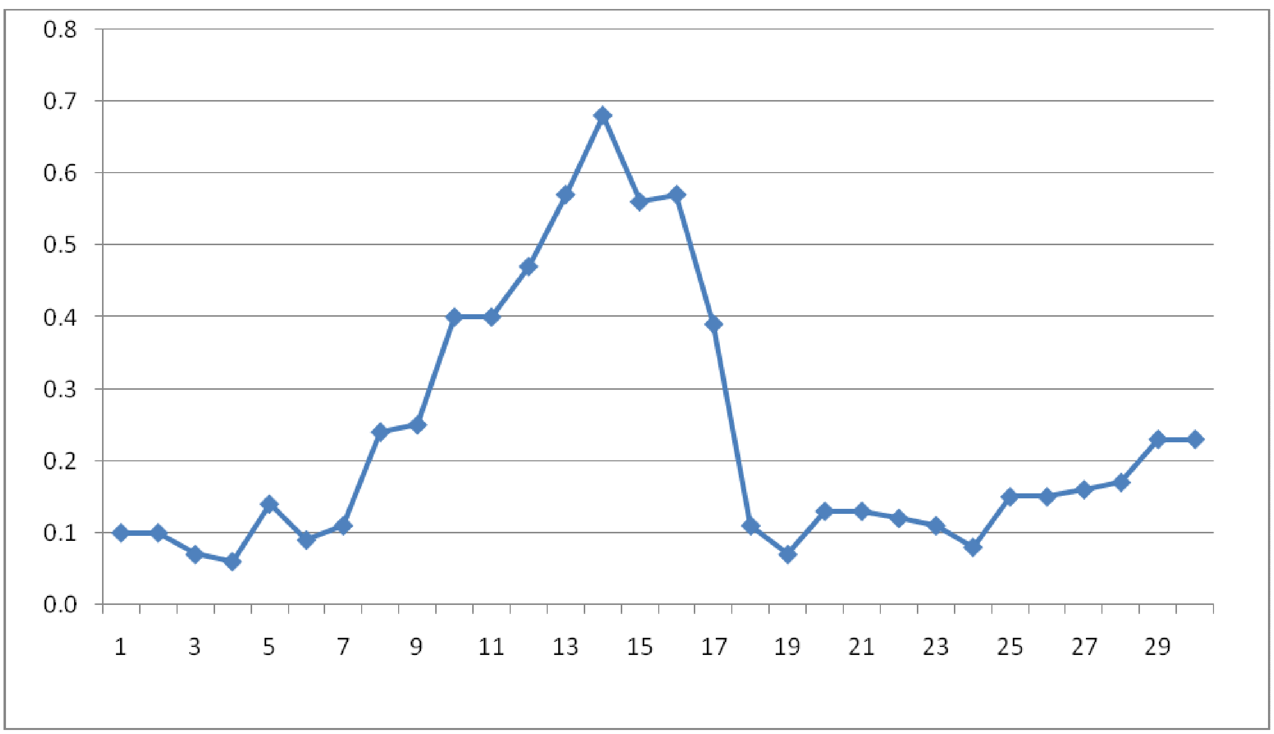

Figure C2-6: Percent Channel Gradient in LCR River Segments
The main salmonid spawning area likely occurs in gradients >0.3%

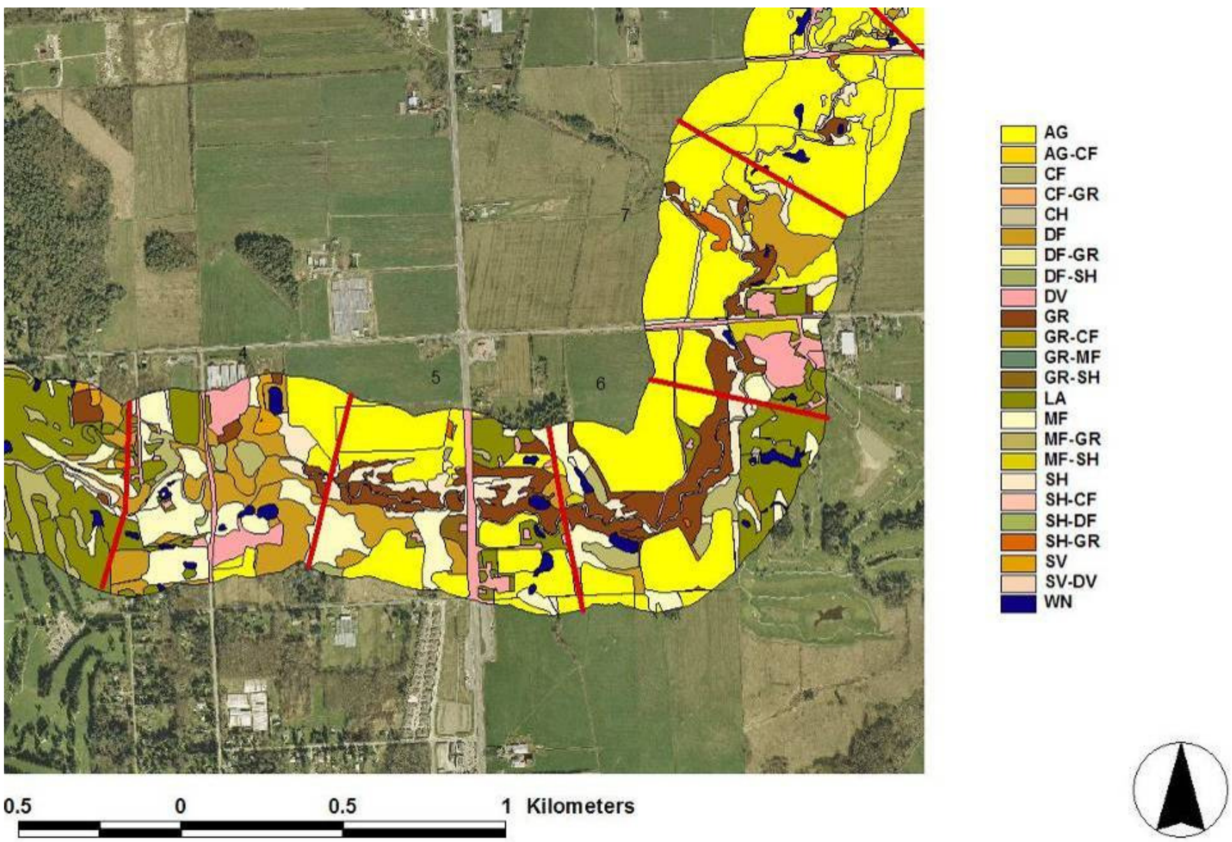

Figure C2-7: Example of Land Cover Mapping and 1 km Segment Breaks (red lines) in the lower portion of the LCR. Agricultural areas are shown in yellow

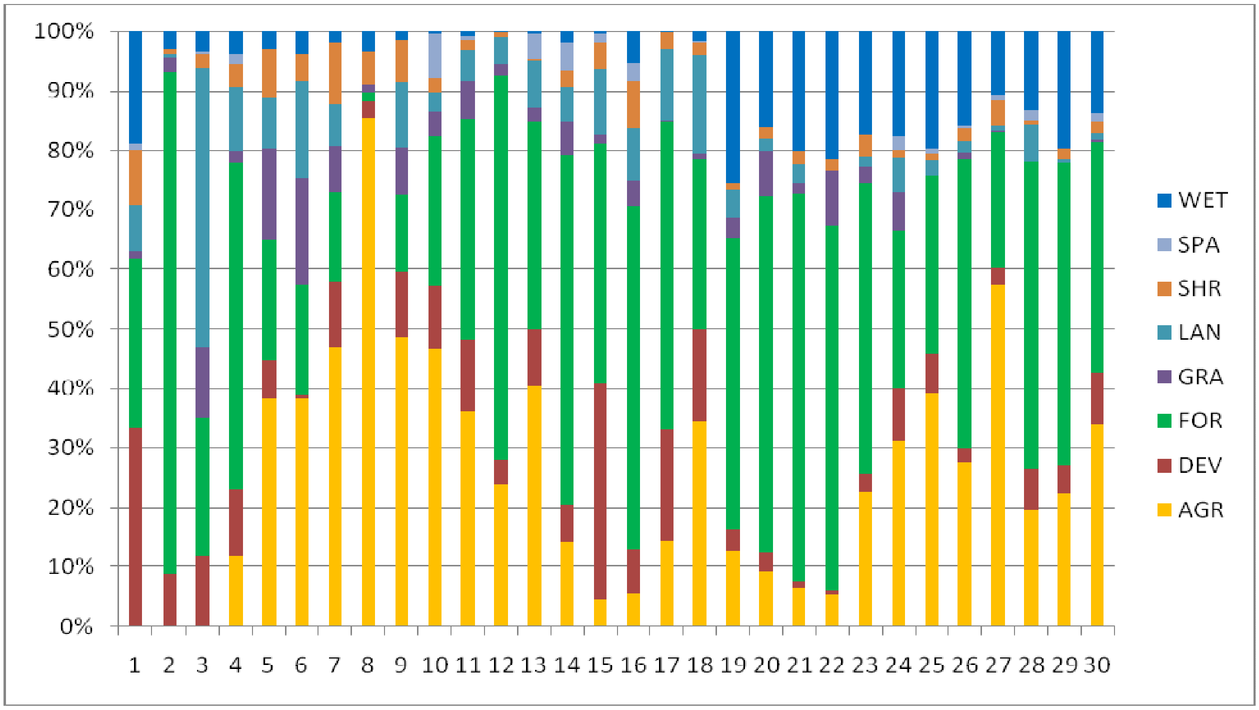

Figure C2-8: Distribution of Land Cover Types within 250 m of the River Channel in 1 km segments of the LCR. Segment 1 starts at the mouth

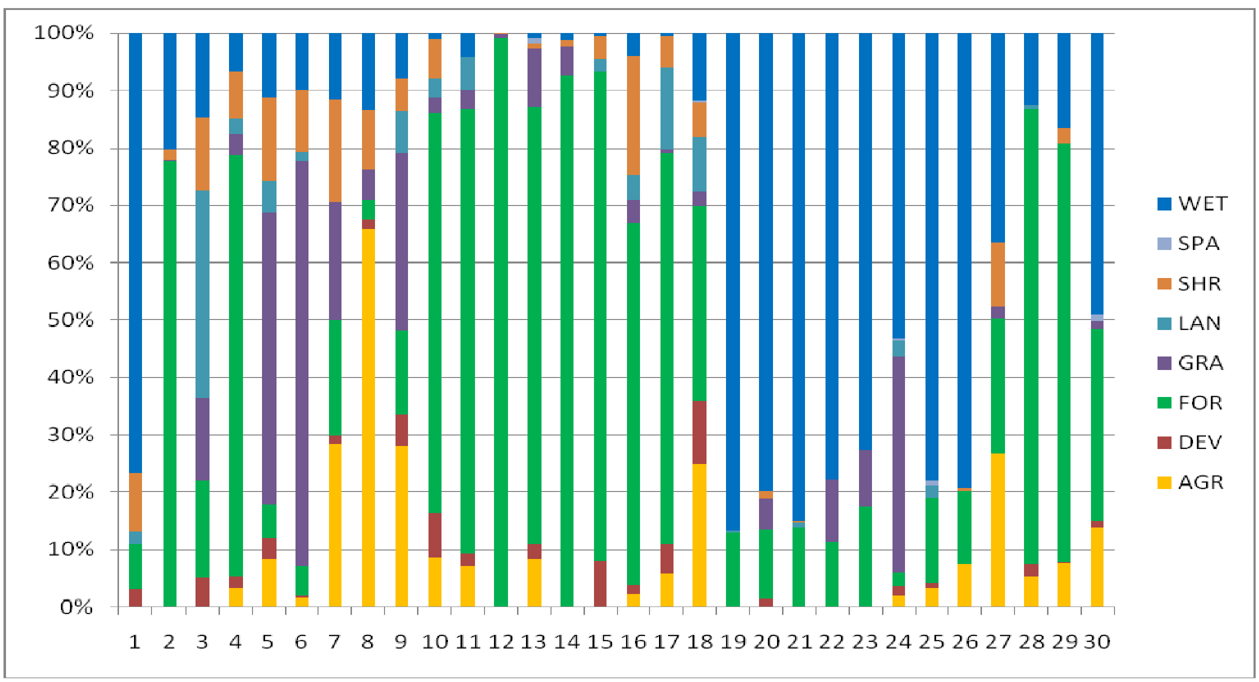

Figure C2-9: Distribution of Land Cover Types within 30 m of the River Channel in 1 km segments of the LCR. Segment 1 starts at the mouth

C3. BIODIVERSITY

C3.1 INTRODUCTION

The ISMP Template addresses some aspects of biodiversity in Clauses 9, 10, and 11 (KWL 2005). Clause 9 proposes the inventory of aquatic species and their habitat and the identification of opportunities for enhancement. Clause 10 focuses on assessment of the riparian corridor, including both its extent and quality. Together with impervious area, the amount of riparian forest (riparian integrity) is used as an indicator of watershed health in the ISMP Template's *Watershed Health Tracking System*. Clause 11 suggests the assessment of terrestrial species and their habitats. ISMPs should consider stormwater management alternatives that protect existing habitats in these three areas of the landscape and, if possible, enhance degraded habitats (KWL 2005).

Biodiversity (or biological diversity) is the variety and abundance of living organisms in a particular region. For this report, biodiversity was broadly defined to include both the diversity of animal and plant species as well as the diversity of ecosystems and habitats that sustain them. Biodiversity is an especially important consideration to planning initiatives in the LCR watershed for the following reasons:

- **The LCR watershed has regionally significant populations of several priority and at-risk aquatic and terrestrial species.** Stocks of five species of Pacific salmonids reproduce in the LCR and its tributaries. Several rare aquatic and terrestrial species are found in the watershed: for example, the endangered Pacific Water Shrew *(Sorex bendrii)* and the threatened Red-legged Frog *(Rana aurora)*.

- **The mid-basin wetland and associated riparian areas in Campbell Valley Regional Park and the marine foreshore on Semiahmoo Bay are regionally significant reservoirs for biodiversity.** A regional landscape assessment of habitats gave these habitats the highest relative biodiversity rating among all sites in the Greater Vancouver Region based on their habitat type, size, and quality (AXYS 2006). Secondary habitats in the LCR also important to biodiversity include smaller wetlands, older forest patches, and old field habitats.

- **The receiving waters of the LCR are an internationally recognized Important Bird Area (IBA).** Boundary Bay is a major stop-over on the Pacific Flyway for migratory bird species and was recently designated as a Western Hemispheric Reserve by the Western Hemisphere Shorebird Reserve Network.

- **The LCR is a relatively intact watershed.** The watershed currently has a large amount of undeveloped and semi-natural land, relatively to other Metro Vancouver watersheds. Land use is dominated by agriculture and urbanization is concentrated in the western and northern parts of the watershed. Furthermore, there are opportunities for habitat restoration and enhancement (e.g., riparian corridor) in many areas of the watershed.

- **Maintenance of biodiversity is an important part of community values and water uses.** Protection of biodiversity and the environment is an important community value. Protection of recreational and commercial uses of biological resources also requires protection of species dependent on overall ecosystem functioning, such as salmonid and shellfish populations.

Because of these values, it is suggested that biodiversity assessment and protection become a more important activity in future ISMPs in the LCR.

SOURCES OF DATA

While there is a large amount of pre-existing information on water quality within the LCR, there is much less current and comprehensive data on the status and distribution of species and habitats. With the exception of salmonids, most species populations have not been monitored in the LCR and more intensive biological inventories and habitat assessments have only been conducted at a handful of sites during the development process. Few documents provide a summary of biodiversity information although one of the best reviews for the LCR can be found in *An Overview Assessment of the Little Campbell River* by Drever and Brown (1999).

Existing biodiversity information was gathered from a variety of sources for this report. Types of information available include species' occurrence records (e.g., rare species records), site lists (e.g., bird and plant lists for Campbell Valley Regional Park), species- or site-specific projects focused on a particular location (e.g., more intensive inventories and assessments for development projects). Sources accessed include:

- Species occurrence records from government and other databases (e.g., Fisheries Information Summary System (FISS), BC Conservation Data Centre);
- Species' range and distribution maps;
- Site-specific biological inventories and habitat assessments;
- Academic research projects;
- Survey data from local conservation, stewardship, and naturalist organizations; and
- Other undocumented professional and local knowledge.

C3.2 SUMMARY OF EXISTING BIODIVERSITY INFORMATION

This section will briefly summarize existing knowledge on biodiversity within the LCR watershed. Because limited biodiversity monitoring has been carried out on a watershed-wide basis to date, available biodiversity information is summarized in two different ways:

1. **Rare species –** Rare species occurrences are of interest because they represent locations of species whose populations are of regional and global significance. Some are designated under the federal Species at Risk Act (SARA). In some cases, they have specific legal requirements for protection and management (see Section C3.4). Rare species are often targeted in management activities and can sometimes, but not always, act as appropriate surrogates for biodiversity more broadly.

2. **Review of important habitats** – Because information is not currently available to consider the status of most species individually, several habitat classes, subclasses, and types known to be important to biodiversity generally were reviewed. Different habitats often sustain different suites of species or have specific functions for groups of species. Thus, known species-habitat relationships can be used to infer a habitat's likely importance to biodiversity. Where habitat relationships for certain groups are well-defined, species lists associated with those habitats (e.g., fish, amphibians) are provided.

RARE SPECIES

Past surveys of habitats in the LCR have identified occurrences of several rare species in the watershed: one fish, three amphibians, three birds, two mammals, one terrestrial mollusc, and five plant species (BC CDC 2008; see Table C3-1). These species are: (a) currently listed under the federal Species at Risk Act (SARA)[13] and/or (b) on the provincial red or blue lists with the BC Conservation Data Centre (BC CDC)[14]. For some rare species, sightings in the LCR are recent, while for others, sightings are historical. For Salish Sucker *(Catostomus sp.)* and Oregon Spotted Frog *(Rana pretiosa)*, recent survey work associated with their status assessment for listing has not located the species making it likely that the species has been extirpated from the watershed.

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[13] The national status of species listed under Schedule 1 of SARA, the official list of wildlife species at risk in Canada, is initially assessed by an independent scientific panel, the Committee for the Status of Endangered Wildlife in Canada (COSEWIC). COSEWIC classifies assessed species according the following categories of risk of extinction:
Extinct (X) - A wildlife species that no longer exists.
Extirpated (XT) - A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E) - A wildlife species facing imminent extirpation or extinction.
Threatened (T) - A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC) - A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Data Deficient (DD) - A category that applies when the available information is insufficient (a) to resolve a wildlife species' eligibility for assessment or (b) to permit an assessment of the wildlife species' risk of extinction.
Not At Risk (NAR) - A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
COSEWIC then recommends species classified as XT, E, T, or SC for official listing by the Minister on Schedule 1.

[14] In British Columbia, species and ecological communities are assigned to one of three lists by the BC Conservation Data Centre, based on their provincial Conservation Status Rank (as assessed using methodology and standards established by NatureServe). **Red-listed** species are Extirpated, Endangered, or Threatened in British Columbia. **Blue-listed** species are Vulnerable and **Yellow-listed** species are secure.

Table C3-1: Occurrence Records of Rare, Threatened, and Endangered Species in the LCR watershed (Source: BC Conservation Data Centre 2008 and others)

Species	Listing	Source(s)	Known locations	Date of last recorded sightings	Current status in LCR*
Vertebrates					
Salish Sucker *(Catostomus sp.)*	Endangered (SARA, Schedule 1) Red-listed (BC)	FISS 2008, COSEWIC 2002	Unspecified	1976	Presumed extirpated
Red-legged Frog *(Rana aurora)*	Special Concern (SARA, Schedule 1) Blue-listed (BC)	Envirowest 2003, A Rocha Canada 2007, L. Englund, pers. comm., Burianyk 2010	Latimer Pond, Jacobsen Creek, Campbell Valley Regional Park, Douglas area, and others	2007–2010	Confirmed present
Western Toad *(Bufo boreas)*	Special Concern (SARA, Schedule 1)	Smith and Strix 2001, L. Englund, pers. comm., A Rocha Canada, pers. comm.	Horne Pit, Campbell Heights area	October 11, 2000	Confirmed present
Oregon Spotted Frog *(Rana pretiosa)*	Endangered (SARA, Schedule 1) Red-listed (BC)	Haycock 2000	Campbell Valley Regional Park	August 21, 1979	Presumed extirpated
Great Blue Heron *fannini* subspecies *(Ardea herodias* ssp. *fannini)*	Special Concern (SARA, Schedule 3)	A Rocha Canada 2007	LCR Estuary, Campbell Valley Regional Park, and others	2007–2010	Confirmed present (2010)
American Bittern *(Botaurus lentiginosus)*	Blue-listed (BC)	BC CDC 2008	Campbell Valley Regional Park	April 18, 1984	Likely present
Green Heron *(Butorides virescens)*	Blue-listed (BC)	BC CDC 2008	(1) LCR headwaters (2) Campbell Valley Regional Park	(1) May 20, 1987 (2) September 16, 2009	Confirmed present
Pacific Water Shrew *(Sorex bendrii)*	Endangered (SARA, Schedule 1) Red-listed (BC)	BC CDC 2008	Fergus Creek (2 records)	September 29, 1992	Confirmed present
Trowbridge's Shrew *(Sorex trowbridgii)*	Blue-listed (BC)	BC CDC 2008	Fergus Creek	September 29, 1992 2006	Confirmed present
Invertebrates					
Oregon Forestsnail *(Allogona townsendiana)*	Endangered (SARA, Schedule 1) Red-listed (BC)	BC CDC 2008	LCR mainstem near 172 St	March 6, 2006	Confirmed present

Table C3-1: Cont'd.

Species	Listing	Source(s)	Known locations	Date of last recorded sighting	Current status in LCR
Vascular plants					
Field dodder *(Cuscuta campestris)*	Blue-listed (BC)	BC CDC 2008	LCR mouth	August 3, 1989	Unknown
False pimpernel *(Lindernia dubia* var. *anagallidea)*	Red-listed (BC)	BC CDC 2008	(1) Latimer Pond (2) Gravel pit at end of 197A St (most likely Horne Pit)	(1) August 13, 1978 (2) August 13, 1978	Unknown
Water-pepper *(Polygonum hydropiperoides)*	Blue-listed (BC)	BC CDC 2008	Campbell Valley Regional Park	July 4, 1979	Unknown
Henderson's checkermallow *(Sidalcea hendersonii)*	Blue-listed (BC)	BC CDC 2008	Southeast of Grandview (vicinity of Hall's Prairie Rd)	June 27, 1955	Unknown
California-tea *(Rupertia physodes)***	Blue-listed (BC)	BC CDC 2008	Brookswood area (south of 196 St & 32 Ave)	July 9, 1975	Unknown

*Species are considered to be present in the watershed if there are recent occurrence records (<20 years old) or documented sightings with accurate location information that can be attributed to the LCR.
**Due to lack of detailed location information associated with this record, this occurrence may or may not be inside the boundaries of the LCR watershed.

Table C3-1 summarizes rare species known from the LCR including their ranking, known locations, dates sighted, and current status in the watershed. Rare species are distributed widely throughout the watershed although Campbell Valley Regional Park, several smaller wetlands (Latimer Pond, Horne Pit), and Fergus Creek are important habitats for multiple rare species. Occurrences, and especially multiple occurrences, of rare species 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.

The Pacific coastal subspecies of Great Blue Heron *(Ardea herodias* ssp. *fannini)* is currently listed as Special Concern under Schedule 3 of SARA but has been reassessed and recommended for listing under Schedule 1 (as of April 2008)[15]. Therefore, this species was included in the table. Western mannagrass *(Glyceria occidentalis),* and large Canadian St. John's-wort *(Hypericum majus)* were previously blue-listed species and found within the LCR watershed (the latter plant species at Campbell Valley Regional Park and Latimer Pond, respectively) but, due to revisions in their provincial Conservation Status Rank based on new information, these species have now been moved to the yellow list (not at risk) by the BC Conservation Data Centre.

REVIEW OF IMPORTANT HABITATS

The following review of important habitats in the LCR was completed using existing information, orthophotography, and mapping, as well as personal knowledge of the authors. New mapping of the riparian corridor and forest cover were undertaken as part of this study. For each habitat, several key locations in the watershed and any known or suspected threats from land use changes or potential effects of stormwater management actions were identified. As this report is a scoping study, identified habitats are only representative and do not represent all locations for that habitat in the watershed.

Table C3-2 shows the nested classification scheme developed to discuss habitat for biodiversity in the LCR. Note that the three broad classes of habitat are the same habitat types that currently define each of the biodiversity-related clauses of the current ISMP Template. This habitat classification may be suitable for future more detailed work.

[15] Schedule 2 and 3 of SARA include species that were initially assessed by COSEWIC prior to the creation of SARA. Once these species have been reassessed, they will either be added to Schedule 1 or not listed under SARA. Schedule 2 and 3 will eventually be eliminated.

Table C3-2: Classification Scheme for Habitats Important to Biodiversity in LCR Watershed

Habitat Class	Habitat Subclass	Habitat Type
Aquatic	Rivers and streams	LCR mainstem and larger tributaries Off-channel habitats Small tributaries/headwater streams
	Wetlands	Fluvial wetlands Ponds Seasonally-flooded fields LCR Estuary
Riparian		Riparian forest Non-forested riparian communities
Upland terrestrial	Forest	Large forest patches Small forest patches and isolated trees
	Agricultural-associated habitats	Old fields Hedgerows

Aquatic Habitats

Many species are dependent on aquatic habitats for all or a part of their life cycle. This includes all fish and amphibian species, some birds and mammals (for feeding), and many invertebrate species, such as dragonflies and freshwater molluscs. Water can be a medium for life and respiration, reproduction, juvenile growth and maturation, or a source of food. Because aquatic habitats are directly influenced by the quantity and quality of water entering from upstream sources, these habitats are the most sensitive to stormwater management decisions.

Rivers and Streams

Rivers and streams are defined channels that contain flowing water for all or at least part of the year. In Pacific Northwest watersheds, these watercourses provide important spawning and rearing habitat for salmonids and other fish as well as movement and migration corridors between other habitats (e.g., oceans and lakes). For streams to be suitable habitat for many fish species, important water characteristics must be maintained. These characteristics include access and connectivity, adequate flows, well-oxygenated water, low water temperatures from adequate riparian shading, and low levels of turbidity and other pollutants (see Section C1).

Unique components of LCR's watercourses used directly by wild salmonid populations at different life history stages are: (1) the LCR mainstem and larger tributaries, (2) off-channel habitats, and (3) small tributaries/headwater streams:

1. **LCR mainstem and larger tributaries –** The LCR mainstem and larger tributaries are the widest and deepest reaches of channel habitat in the LCR. In these areas, significant water volumes are maintained for most of the year. At some locations in these channels (e.g., 176th St to mid-basin wetlands), pool and riffle habitat with

adequate gravels provide spawning habitat for adult chinook, chum, steelhead, and some coho. These larger channels also provide rearing habitat for juvenile chinook and coho, species which spend significant time in freshwater before migrating to the ocean.

Major salmonid spawning zones along the LCR mainstem or in large tributaries include (more detailed locations in Drever and Brown 1999):

- **LCR mainstem from 184th St east to 20th Ave (chinook, chum, coho);**
- **LCR mainstem downstream of Campbell Valley Regional Park (between 204th St and 20th Ave) (coho);**
- **LCR mainstem in Campbell Valley Regional Park (24th Ave south to 8th Ave) (coho);**
- **Lower reaches of McNalley Creek (chum and coho), Jenkins Creek (chinook, chum, coho, steelhead), and Fergus Creek (chinook, chum, coho, steelhead).**

2. **Off-channel habitats –** Off-channel habitats are groundwater-fed pools and channels and floodplain areas away from the main channel of a river or stream. These areas are often only available during the wettest months of the year, such as in late fall, winter, and early spring. Off-channel areas provide spawning habitat for adult chum and over-wintering and refuge habitat for juvenile coho. Off-channel habitats are usually contained entirely within the floodplain.

   Areas of significant off-channel habitat can be found in **Campbell Valley Regional Park**.

3. **Small tributaries/headwater streams –** Where access is not limited by barriers to fish migration, very small tributaries and headwater streams at the upper reaches of the watershed provide spawning and rearing habitat for coho salmon and resident cutthroat trout.

   Examples of locations of small tributaries that provide spawning habitat for coho include (more detailed locations in Drever and Brown 1999):

- **Upper reaches of Fergus Creek (north of 14th Ave) and Sam Hill Creek (west of 176th St);**
- **Upper reaches of Jenkins Creek (east of 196th St) and Jacobsen Creek (east of 200th St);** and
- **Upper reaches of Kerfoot Creek (east of 236th St).**

Several non-salmonid anadromous and non-anadromous fish species depend on stream habitats in the LCR as well (see Table C3-3). Unlike salmonids which have been monitored continuously since 1982, records for non-salmonid species appear to be from a variety of small-scale inventories. Consequently, beyond the presence of these species in the watershed, the size and distribution of populations of most non-salmonid fish is largely unknown. Furthermore, for some species, records are not current.

The Salish Sucker (*Catostomus sp.)*, listed in Canada as Endangered (SARA, Schedule 1), has been found historically in the Little Campbell River but has not been seen since 1976 and is now considered extirpated from the watershed, although it is still found in the Bertrand Creek watershed immediately east of the LCR (COSEWIC 2002). The LCR is also the internationally recognized source population of Three-spine Stickleback *(Gasterosteus aculeatus)*, used as a model organism for academic research studies of evolution and speciation[16].

At least one freshwater mollusc *(Margaritifera falcata;* see below*)* and many benthic invertebrates have populations in stream habitats in the LCR. Benthic invertebrates are an important indicator of water quality (see Section C1.3) and a food source for many fish species.

Threats to Rivers and Streams: Rivers and streams and associated biodiversity are threatened by changes to the quality and quantity of runoff in developed areas. Fecal coliform contamination from urban areas is of ongoing concern in the LCR (see Section C1.2). Turbidity and sedimentation from the construction phase of development is also a problem in some areas (see Section C1.2). Decreased dissolved oxygen and increased water temperatures during the summer months may be a result of water withdrawals and the loss of riparian vegetation along sections of the LCR mainstem (see Section C1.2). Channelization, dyking, dredging, culverting, loss of woody debris, and changes in sediment transport patterns because of channel modifications or flow changes can all alter valuable fish habitat.

[16] For more information, see Chapter 14 in *The Evolutionary Biology of the Threespine Stickleback* (1994, Oxford University Press) by M.A. Bell and S.A. Foster (editors).

Table C3-3: Non-Salmonid Fish Species Records for the LCR Watershed

Common Name	Scientific Name(s)	Source(s)	Status/Comments
Bass/Sunfish (general)	*Micropterus spp.** *Lepomis spp.* *Pomoxis spp.*	FISS 2008	Some species in this group are introduced
Brassy Minnow	*Hybognathus hankinsoni*	Drever and Brown 1999	Unverified
Brown Catfish (formerly brown bullhead)	*Ameirus nebulous*	FISS 2008	Wild, indigenous
Coastrange Sculpin (formerly Aleutian sculpin)	*Cottus aleuticus*	FISS 2008	Wild, indigenous
Dolly Varden	*Salvelinus malma*	FISS 2008	Unverified, likely rare
Fathead Minnow*	*Pimephales promelas*	FISS 2008	Introduced
Flathead Chub	*Platygobio gracilis*	FISS 2008	Unverified
Pacific lamprey	*Lampetra tridentata*	UBC Fish Museum	One record from 1960
Lamprey (general) Western brook lamprey	*Lampetra spp.* *Lampetra richardsoni*	FISS 2008	Likely wild, indigenous populations of this species
Longnose Sucker	*Catostomus catostomus*	UBC Fish Museum	Two records from 1965, now considered to be records of the extirpated Salish Sucker?
Minnow (general)		FISS 2008	Wild, indigenous
Prickly Sculpin	*Cottus asper*	FISS 2008	Wild, indigenous
Pumpkinseed	*Lepomis gibbosus*	FISS 2008	Wild, indigenous
Salish Sucker**	*Catostomus sp.*	FISS 2008, COSEWIC 2002	Endangered (SARA, Schedule 1), red-listed in BC; likely extirpated from the LCR watershed
Slimy Sculpin	*Cottus cognatus*	FISS 2008	Wild, indigenous
Sturgeon (general) Green sturgeon	*Acipenser spp.* *Acipenser medirostris*	FISS 2008	Unverified[1]
Three-spine Stickleback[2]	*Gasterosteus aculeatus*	FISS 2008, UBC Zoology, UBC Fish Museum, Royal BC Museum	Wild, indigenous; anadromous form reaches 172nd St., resident form above 172nd St. (J. Courchesne, pers. comm.)

Abbreviations for sources: FISS = Fisheries Information Summary System (http://www.env.gov.bc.ca/fish/fiss/index.html)
*denotes introduced species.
**species is most likely extirpated.
[1]A captive sturgeon can be found in one of the ponds at the Semiahmoo Fish & Game Club and may represent the record for this species.
[2]includes both anadromous (sea-run) and non-anadromous (resident) forms.

Wetlands

Wetlands have distinctive soil and vegetation characteristics caused by standing or near-standing water present for at least part of the year. They often have unique vegetation adapted to wet conditions. After tropical rainforests, wetlands are among the most biodiversity-rich habitats in the world. Wetlands provide habitat to a wide variety of unique plants, invertebrates, fishes, amphibians, reptiles, and mammals, as well as both migratory and resident waterbirds. Wetlands meet essential breeding, nesting, nursery, and feeding needs for many species. Amphibians and dragonflies are examples of two species group which are dependent on freshwater wetlands. In addition to their value for biodiversity, wetlands are a part of key landscape processes important to water quality and quantity. Wetlands store surface water and release it gradually, reduce water velocity and erosion, and help to purify water by removing pollutants, such as nitrogen, phosphorus, and fecal coliform (Stanley et al. 2005).

Major wetland types in the LCR include: (1) fluvial wetlands, (2) ponds, (3) seasonally-flooded fields, and (4) the LCR Estuary:

1. **Fluvial wetlands –** Fluvial wetlands are wetlands formed by a river's floodplain. In fluvial wetlands, the stream channel is undefined and water spreads out across a wider area. Fluvial wetlands in the LCR are generally found along the mainstem of the river in the mid- and upper reaches of the watershed. Because of their size and adjacency to other natural habitats, the fluvial wetlands in Campbell Valley Regional Park are an important reservoir for biodiversity in the LCR watershed but also in the Metro Vancouver region more broadly (AXYS 2006). Upstream surface runoff inputs, groundwater inputs, direct rainfall, and evapotranspiration rates all have an effect on wetland's hydrologic cycle. Thus, the size and depth of these wetlands can vary dramatically with season, local weather, and is also affected by water withdrawals.

   In the LCR, fluvial wetlands have unique vegetation communities and are important overwintering habitat for juvenile coho and feeding habitat for blue-listed wading birds, such as American Bittern and Green Heron.

   Key locations of fluvial wetlands within the LCR watershed are:

   - **Mid-basin wetland complex in Campbell Valley Regional Park (along LCR mainstem, west of 216th St to 24th Ave);**
   - **Upper-basin wetlands (along LCR mainstem, east of 216th St to 226th St);** and
   - **Lower reaches of Kerfoot Creek (east from 232nd St to 242nd St).**

2. **Ponds –** Ponds (or lakes) are small, open, and usually permanent bodies of water. Ponds are generally smaller than lakes although the terms are often used interchangeably for small waterbodies. Despite their small size, these ponds are important habitat and water sources for biodiversity throughout the year. Many ponds

in LCR are man-made. Ponds in the LCR are important habitat for mammals, birds, amphibians, and dragonflies (Smith and Strix 2001, Envirowest 2003, A Rocha Canada 2007).

Significant ponds located in the LCR watershed are found at (with site-specific references are noted in brackets):

- **Latimer Pond/Lake (Stokes Pit, 192nd St at 28th Ave);**
  (References: Dillon 1999, 2000, 2002, Envirowest 2003)

- **Ponds at Horne Pit (between 196th and 200th St at 26th Ave);**
  (Reference: Smith and Strix 2001)

- **Meadow Lake (east of 232nd St at 8th Ave);** and

- **Ponds on private property (e.g., A Rocha Canada Field Study Centre).** *(Reference: A Rocha Canada 2007)*

3. **Seasonally-flooded fields –** Seasonally-flooded fields are agricultural fields which are covered in water at least for part of the winter season. They often form in areas with hydric soils where the water table is near or at the surface. These sites are often important feeding grounds for overwintering geese and ducks. The extent of seasonal flooding depends on local topography, whether natural patterns of drainage have been modified to discourage flooding, and weather.

   Key locations where seasonal flooding of fields is likely common due to the presence of flat topography and hydric soils include:

   - **Approximately 2 km on either side of the lower LCR mainstem between 192nd St and Highway 99;**

   - **Lower portions of Fergus Creek and Sam Hill Creek watershed, north of LCR mainstem;** and

   - **Most of the Twin Creek watershed.**

4. **The LCR Estuary –** The LCR Estuary is the near-coastal portion of the river at the mouth where freshwater and saltwater mix. These brackish waters trap nutrients coming from both the ocean and inflowing river resulting in a highly productive environment. Because estuaries are at the intersection between several habitat types and lie at the interface between the inland and marine environments, they support a large variety of biodiversity. Estuaries in the Pacific Northwest are important feeding grounds for resident waterbirds (waders, dabbling ducks, diving ducks), stopover habitat for migrating shorebirds, and gateway habitats for outmigrating and returning

Pacific salmon. Estuaries can also incorporate unique habitat types, such as salt marshes and scrub forests.

Because of the importance of estuaries and its position on the edge of Boundary Bay, the LCR estuary has been identified as having regional significance to biodiversity in Greater Vancouver (AXYS 2006). The zone of mixing in the LCR estuary extends 2.5 km upstream from the Burlington Northern-Santa Fe railway right-of-way up to the Highway 99 crossing. While other areas in Greater Vancouver have been subject to human modifications, the LCR Estuary is largely undeveloped. With the exception of its northwest portion, the estuary is buffered from human disturbance by forest on the Semiahmoo Indian Reserve, which is not open to the public. The LCR Estuary is also minimally used by recreational boaters. The LCR Estuary is an important feeding ground for Pacific coastal subspecies of the Great Blue Heron and nesting may occur nearby on the Semiahmoo Reserve (G. Carlson, pers. comm.). Water quality concerns in the estuary are an ongoing issue (see Section C1.2).

Amphibians as a group are largely dependent on wetlands for important breeding and rearing habitat. Red-legged Frog and Western Toad, federal species of Special Concern, rely on the presence of suitable wetland habitats in the watershed. The Oregon Spotted Frog, a federally-endangered species, was found within the fluvial wetland in Campbell Valley Regional Park but is now presumed extirpated from this site. It is still found in Bertrand Creek watershed east of the LCR (Haycock 2000). Table C3-4 summarizes the amphibian species known within the LCR watershed.

Threats to Wetlands: Wetlands and associated biodiversity in the LCR are threatened by the draining and infilling from urban development and agriculture. When wetlands are lost, their important functions in protecting aquatic resources are also lost or disrupted. Indirect impacts on wetlands can also occur from surrounding development through changes in water table infiltration from imperviousness or water withdrawals. Pollution and runoff from agriculture, such as pesticides and fertilizers, are also a concern. Invasive species are increasing in their distribution and abundance in the watershed. Invasive animal species, such as American Bullfrog and Green Frog, are known from the watershed (CMN 2008). Bullfrogs and Green Frogs have the potential to displace native frog species. Exotic plant species such as reed canarygrass *(Phalaris arundinecea),* purple loosestrife *(Lythrum salicaria),* and yellow flag iris *(Iris pseudacorus)* are also modifying the structure of wetland habitats.

Table C3-4: Amphibian Species Known Within Fluvial Wetlands and Ponds in LCR Watershed

Common Name	Scientific Name	Source	Status/Comments
FROGS			
American Bullfrog*	*Rana catesbeiana*	A Rocha Canada 2007, Frogwatch Sighting Mapping Tool (CMN), Envirowest 2003, Burianyk 2010	Present
Green Frog*	*Rana clamitans*	A Rocha Canada 2007	Present
Oregon Spotted Frog**	*Rana pretiosa*	Haycock 2000	Endangered (SARA, Schedule 1), red-listed in BC; historical population in Campbell Valley Regional Park, now locally extirpated.
Pacific Treefrog	*Hyla regilla*	A Rocha Canada 2007, Burianyk 2010	Present; common
Red-legged Frog	*Rana aurora*	A Rocha Canada 2007, Englund 2007 Burianyk 2010	Special Concern (SARA, Schedule 1), blue-listed in BC.
TOADS			
Western Toad	*Bufo boreas*	Smith and Strix 2001, Pers. obs.	Special Concern (SARA, Schedule 1), yellow-listed in BC.
SALAMANDERS			
Ensatina	*Ensatina eschscholtzii*	A Rocha Canada 2007	Present
Long-toed Salamander	*Ambystoma macrodactylum*	A Rocha Canada 2007, Burianyk 2010	Present
Northwestern Salamander	*Ambystoma gracile*	A Rocha Canada 2007, Frogwatch Sighting Mapping Tool (CMN), Burianyk 2010	Present; likely common
Rough-skinned Newt	*Taricha granulosa*	A Rocha Canada 2007, Burianyk 2010	Present
*denotes introduced species. **species is most likely extirpated.			

Riparian Habitats

Riparian habitats (also called the riparian zone) are the portion of land adjacent to the normal high water line in a stream, river, lake, or pond. It is the transition zone between aquatic and upland terrestrial habitats and can extend up to 100 m away from the waterbody. Because of their proximity to water, riparian zones have moist, rich soils that support unique riparian plants, such as skunk cabbage (*Lysichiton americanus)* and Indian-plum *(Oemleria cerasiformis).* Many riparian-specialist species depend on both the aquatic and terrestrial component of these habitats for different activities or life history stages. Riparian corridors along watercourses are important movement corridors for some species. Intact riparian zones can also stabilize streambanks subject to erosion, regulate water temperatures (see Section C1.2), and filter pollutants from surface runoff before they enter watercourses (Stanley et al. 2005).

Riparian habitats in the LCR can be divided into: (1) riparian forest and (2) non-forested riparian communities:

1. **Riparian forest –** Riparian forests support coniferous and deciduous tree species that prefer wetter conditions, such as cedar or black cottonwood. Riparian forests are usually structurally diverse, with a multi-layered, uneven-aged canopy. Riparian forests often have a dense understory of shrubs and ferns. Snags, downed logs, and coarse woody debris are common features. The variety of habitat niches makes them important habitat reservoirs. Along rivers, some riparian forests grow on flat areas above the edge of the floodplain while others are found on the side of steep ravines.

   Riparian forests are particularly important habitat for species which require the juxtaposition of aquatic habitat and moist, shaded forest with lots of available cover, such as amphibians and shrews. For example, the Red-legged Frog is more abundant where there is significant riparian forest near wetlands (Englund 2007). The federally-endangered Pacific Water Shrew is a very rare species and a habitat specialist on the moist, riparian forests near streams and marshes. The provincially blue-listed Trowbridge's Shrew is found in similar habitat as well as drier mixed and coniferous forest with significant coarse woody debris. Use of these habitats by these species is documented in the LCR along Fergus Creek (Zuleta and Galindo-Leal 1994) and on the LCR mainstem at 172nd St (A Rocha Canada 2007), respectively.

   The locations of the largest stretches of intact riparian forest along the LCR mainstem currently exist at (see Figure C3-1):

   - **LCR mainstem through the Semiahmoo Indian Reserve;**
   - **LCR mainstem from 171st St to 176th St;** and
   - **LCR mainstem through Campbell Valley Regional Park.**

   Drever and Brown (1999) identified several priority sites lacking riparian forest where habitat restoration activities could be undertaken. Some of these sites (such as the LCR Estuary) have been planted with native vegetation by the Little Campbell Watershed Society and others.

2. **Non-forested riparian communities –** Along sections of the LCR mainstem, such as the mid-basin wetlands in Campbell Valley Regional Park, non-forested natural plant communities can be found in the riparian area. These include shrub (such as hardhack) swamps and wet meadows. In these areas, because of seasonal fluctuations in water levels, there is not a clear boundary between the fluvial wetland and the riparian zone. In these areas, the vegetation communities are uniquely dominated by

species such as hardhack and willow. Because of the absence of a tree canopy in these areas, these areas are used by swallows and flycatchers to feed on flying insects.

The main sections of non-forested riparian habitat are **along the fluvial wetlands in Campbell Valley Regional Park**.

Threats to Riparian Habitats: Much of the riparian corridor in the LCR has been fragmented by road construction and land clearing for agricultural or rural development. This has resulted in loss of riparian forest and shifted some riparian areas from coniferous forest to more pioneering deciduous and herbaceous species. Riparian forest loss also causes increased soil erosion and higher stream temperatures, impacting the quality of aquatic habitats. In some areas, stream channelization and agricultural activities such as livestock watering have also impacted riparian habitats. Pollution, garbage, yard waste dumping, and introductions of invasive species are also detrimental to riparian habitats in the LCR.

Upland Terrestrial Habitats

Upland terrestrial habitats are natural or semi-natural habitats away from watercourses and other aquatic habitats. These habitats include areas of original or second-growth vegetation (such as coniferous and deciduous forests) or agricultural lands. At first, these habitats may appear unrelated to stormwater planning. However, considering protection of these habitats within ISMPs is important for two reasons. First, at the landscape scale, the presence of these natural habitats can serve important hydrologic functions. For example, forests intercept and transpire 20–40% of precipitation (Bauer and Mastin 1997). All vegetated areas allow for rainwater infiltration thereby reducing surface runoff and peak flows (Stanley et al. 2005). Groundwater recharge in pervious areas is important to maintaining groundwater levels necessary to supply groundwater-fed streams, especially during the summer months. Water transport by subsurface flow, rather than surface runoff, acts to filter out pollutants. Forested habitats in upland areas also stabilize slopes and decrease soil erosion. Second, natural upland areas are an important class of habitat and landscape-scale consideration for biodiversity. Thus, considering the connectivity and adjacency of these habitats to riparian and aquatic habitats is important. Landscape planning for biodiversity must consider these different habitat types collectively.

Forest

Forested habitats in the LCR can be divided into (1) large forest patches and (2) small forest patches and isolated trees:

1. **Large forest patches** – Large forest patches provide breeding and forage sites for many animal species and habitat for a wide variety of plants and invertebrates. Large patches are important because they can support animal species with large home range

or territory sizes. Large forest patches also contain more interior forest habitat. Unlike edge habitats, interior habitats are minimally affected by light and wind penetration and are less prone to human and weather-related disturbances (e.g., blowdowns). Bird species, such as Pileated Woodpecker (Dryocopus pileatus), Swainson's Thrush (Catharus ustulatus), and Brown Creeper (Certhia Americana) require interior forest for suitable nesting or foraging habitat. Birds nesting in the interior of patches are also less subject to predation from edge-dwelling predators, such as Raccoons (Procyon lotor) and Brown-headed Cowbirds (Molothrus ater). Large patches also generally contain greater diversity of habitats, such as both interior and edge habitats or coniferous and deciduous forest types.

Forest cover in the LCR was mapped by Zevit et al. (2007) using high-resolution orthophotos taken in 2004. Approximately 32% of the LCR was found to be forested (Figure C3-1). Forest cover was most prevalent in the Langley sub-watershed (44.0%) and least common in the West sub-watershed (16.3%). At the time of mapping, the largest patches of forest in the LCR were found:

- **in Whatcom County south of the Canada-US border (two patches > 140 ha);**
- **adjacent to Campbell Valley Regional Park (patches of 149.1 ha and 99.9 ha); and**
- **within the Semiahmoo Indian Reserve (62.8 ha).**

Forest patch size ranged from 0.01 ha to 151.2 ha with a mean patch size of 2.74 ha.

2. **Small forest patches and isolated trees** – Small forest patches can be defined as forest patches less than 30 m in width. These patches are entirely subject to edge effects and thus do not provide habitat for forest interior species. However, these habitats can be important for species which prefer edge conditions or depend on the structure trees provide (e.g. nesting, perching, cover) but also require proximity to open habitats. For example, some raptor species require mature trees for nesting and perching that are adjacent to old field habitats for hunting. Thus, even isolated trees can be important perching sites or 'wildlife trees' for some species which don't require dense forest cover. Small forest patches or linear strips of trees can be important for connectivity and movement between larger patches.

Threats to Forests: Fragmentation and clearing are the major threats to forests and forest-dependent species. Increasing edge and open areas lead to increased light and temperature and loss of moisture within the interior of the remaining patches. Forest dependent species then become vulnerable to introduced species and predators.

Agricultural-Associated Habitats

Important agricultural-associated habitats in the LCR include (1) old fields and (2) hedgerows:

1. **Old fields –** Old field habitats are decommissioned or abandoned agricultural lands overgrown with herbaceous and shrub species. They are often characterized by shrub patches and variable grass heights. These fields provide a critical stopover for some migratory birds and hunting habitat for raptors, such as Red-tailed Hawks *(Buteo jamaicensis)* and Short-eared Owls *(Asio flammeus flammeus)*. The old fields are suitable forage for the small mammal prey species that the raptors hunt, predominantly Townsend's Vole *(Microtus townsendii)*.

2. **Hedgerows –** Hedgerows are rows of trees and shrubs that are planted to provide a visual screen and divide fields and properties. Hedgerows provide a wind break, retaining soil moisture and reducing soil erosion. Hedgerows are often found associated with old field habitats. However, they are also found along active agricultural areas and in rural areas. They are valuable habitat and movement corridors for small mammals and songbirds, such as the Spotted Towhee *(Pipilo maculatus)* and Yellow Warbler *(Dendroica petechia)*.

The locations of important old field and hedgerow habitats in the LCR have not yet been assessed.

Threats to agricultural-associated habitats: Urban and industrial development of agricultural lands is a threat to the ongoing persistence of old field habitats. The Agricultural Land Reserve (ALR) currently protects against this conversion but land removal from the ALR, while rare, does occur. The return of old fields to active cultivation, or conversion to non-compatible agricultural uses, such as greenhouses, also threaten the habitat value of old fields. Off-road vehicle activity is also a problem in some areas.

C3.3 PRIORITY ISSUES

Several priority issues for biodiversity have emerged from existing information that should be specifically addressed in ISMP planning.

1. **Habitat impacts on fish populations –** Salmonid populations are under stress from the cumulative impacts of changes in water quality and quantity in the LCR mainstem and its tributaries, as well as changes to the physical structure of habitat. Of the earlier discussed water quality issues in the LCR (see Section 4), construction-phase turbidity and low dissolved oxygen and high water temperatures are likely to have the largest impacts on salmonid populations. Turbidity and sedimentation caused by inappropriately mitigated construction runoff can directly impact egg to smolt survival rates for all salmonids. Salmonid species which are resident (cutthroat) or spend significant time in freshwater as juveniles before migrating to the ocean (coho, chinook, steelhead) are most likely to be effected by low dissolved oxygen and high water temperatures during the summer months as a result of declining summer baseflow. In some reaches, channelization has destabilized the stream channel,

increasing scouring and erosion, and decreasing available spawning habitat. Dyking in some areas has reduced the amount of available off-channel habitat. Barriers to fish migration are present in the watershed.

Trends in returns of all salmon species to the counting fence are difficult to interpret because they represent the combined impacts of stressors in freshwater habitat and ocean survival. Returns of wild coho adults in the LCR declined dramatically in the 1990's (Drever and Brown 1999) but rebounded in 2001 to the highest numbers seen since 1980 (SFGC, unpublished data). Coho have again shown declines the last three years and chum returns were also much lower in 2007 (SFGC, unpublished data). While habitat impacts from development are suspected to have impacted recruitment recently (P. Milligan, pers. comm.), ocean survival rates for Lower Fraser coho have also remained low during the same period (DFO 2006). In any case, the current status of several stocks (coho, chum, chinook, steelhead) suggest that caution should be exercised in managing fish habitat. Furthermore, the current range of adult returns for most species is likely much lower than were seen in the watershed prior to settlement and clearing of the watershed in the early 1900's (beyond the range of available data).

2. **Encroachment into mid-basin wetlands –** The significance of the mid-basin wetlands within Campbell Valley Regional Park to biodiversity is partially dependent on its adjacency to intact riparian and upland forest habitats. Continued development in the Campbell Heights (Surrey), Fernridge (Langley), and High Point (Langley) areas of the watershed are decreasing natural habitats (wetlands, forest, old fields, etc.) in the vicinity of the park. This decreases the connectedness of these habitats to other areas of the watershed.

3. **Loss and fragmentation of riparian forest –** The riparian corridor along the LCR mainstem has been deforested along some key sections due to clearing for agricultural development. For example, the riparian corridor between 176th St and 184th St (Reaches 6 to 9) contains less than 10% forest cover and greater than 50% agricultural land (see Figure C2-8). Some riparian restoration has occurred but efforts to date have been largely volunteer-led and occurred at a small scale.

4. **Loss and fragmentation of upland forest –** Similar to the riparian corridor, land clearing for urban, rural, and agricultural development has reduced the amount and connectivity of forest cover in the upland portions of the watershed, especially in the lower portions of the watershed (west of 184th St.). However, even in the Langley portion of the watershed, which contains Campbell Valley Regional Park, less than 50% of forest cover remains. Moreover, the average patch size is less than 3 ha and only four patches are greater than 7.5 ha (see Figure C3-1). Thus, interior forest habitat is becoming extremely uncommon in the watershed.

5. **Exotic species introductions –** With increasing development in proximity to natural areas within the LCR watershed, exotic species are becoming more prevalent in key areas important to biodiversity in the watershed. Exotic plants are becoming more

common and can decrease habitat diversity and change the physical structure of habitats. For example, reed canary grass forms monocultures along the floodplain in many areas of the LCR and English ivy *(Hedera sp.),* if left uncontrolled, can kill trees. Non-native riparian invaders include Japanese knotweed (*Polygonum* spp.), giant hogweed (*Heracleum mantegazzianum*), and two touch-me-not species (*Impatiens glandulifera* and *Impatiens parviflora*). Key wetlands have also been found to contain introduced American Bullfrog and Green Frog, which have the potential to outcompete regionally-rare native amphibian species without active intervention. With the exception of Campbell Valley Regional Park, regular monitoring and control of invasive species is not occurring.

6. **Human disturbance –** Population growth is occurring rapidly in some parts of the LCR. This leads to increased pressure on natural areas to support human recreation, such as walking, biking, horse riding, and dog walking. Other uses may occur in areas where they are not unauthorized, such as the use of motorized recreational vehicles in natural areas (dirtbikes, ATVs, etc.). Uses may be incompatible with the presence of some species (e.g., nesting by herons) or may physically impact sensitive habitats (e.g., human trampling of salt marsh plant communities in the LCR Estuary).

C3.4 MANAGEMENT OBJECTIVES FOR BIODIVERSITY IN ISMP PLANNING

The ISMP Template focuses the majority of effort on gathering existing information, inventory of fish and fish habitat, and assessing the integrity of the riparian corridor. Typically, an assessment of aquatic and terrestrial habitats in ISMP planning includes the assessment of salmonid habitat and vegetation and wildlife inventories at a handful of representative sites. Common activities undertaken in ISMPs include:

- An inventory and classification of streams (focussing on salmonid access and use);
- Identification of key barriers to salmonid migration;
- Fish habitat descriptions by reach, including spawning and rearing habitat, stream width and depth, cover, and substrate;
- A GIS-based desktop assessment of riparian forest integrity;
- Listings of wildlife, plants, and species of conservation concern known or potentially found within study area; and
- Identification of opportunities for compensation and enhancement opportunities.

As mentioned earlier, some of these typical assessments have been already been carried out in the LCR (e.g. watercourse classifications, SHIM, forest cover mapping).

However, while the current ISMP Template suggests that important areas and values are identified for protection, the template does not prescribe methods for identifying these areas or values, particularly for non-stream habitats. Furthermore, in many cases, the scale or scope of habitat assessments already completed is not adequate to prioritize habitats for many species (e.g., birds, mammals, amphibians, invertebrates). Also, the

Template does not set out the goals or appropriate means of protection once they have been identified. With the exception of salmon habitat (see Section C2.3), which requires a "no net loss" approach under the federal *Fisheries Act*, specific management objectives for other aspects of biodiversity are not outlined. Currently, these objectives must be developed on a case-by-case basis with reference to other existing regulations.

REGULATORY FRAMEWORK FOR BIODIVERSITY AND ISMPS

This section reviews the regulatory framework for biodiversity and the protection of wildlife and wildlife habitat that apply to ISMP planning. Several acts, plans, and bylaws regulate or guide the impacts of development or stormwater specifically on biodiversity in the LCR watershed:

- Fish and fish habitat are protected under the federal **Fisheries Act**. The Act, among other things, requires that a person obtain approval from Fisheries and Oceans Canada (DFO) before taking any action that alters or destroys fish habitat and prohibits dumping anything that can harm fish into waters that contain fish. DFO generally strives to ensure "no net loss" of habitat, balancing unavoidable habitat losses with habitat replacement on a project-by-project basis. The Fisheries Act only protects habitat for species that are part of fisheries (e.g., salmon habitat) but does not protect aquatic habitat for other species.

- Migratory birds are protected under the federal **Migratory Birds Conventions Act (1994)**, which addresses a variety of issues related to migratory birds. The *Migratory Birds Regulations* include, but are not limited to:

  - A prohibition on disturbing the nests or eggs of migratory birds without a permit from the Minister; and

  - A prohibition against pollution (defined as the deposit of oil, oil wastes or any other substance harmful to migratory birds) in any waters or any area frequented by migratory birds.

- Canada's **Species at Risk Act (SARA) (2003)** aims to prevent rare wildlife species in Canada from becoming extinct or lost from the wild, and to help in the recovery of species that are at risk as a result of human activities. Species listed under SARA (Schedules 1–4) are recommended for listing by an independent scientific panel. Once listed, SARA includes general prohibitions against harming individuals of that species or their residences, protects critical habitat for that species, and requires recovery strategies and action plans that identify important actions and critical habitat needed to recover the species. SARA provides powers to the federal government to enforce protections on all lands, including privately-owned lands. However, stewardship on private land is strongly encouraged under SARA.

- British Columbia's **Wildlife Act** is the main provincial law for protecting wildlife, endangered species, and wildlife habitat. The Act has a number of provisions for protecting, managing, and purchasing habitat areas. Birds and bird nests, particular raptors, are protected under the Act. Species listed as endangered and threatened species are protected from hunting. However, currently, listing of species under the Act is discretionary and habitat is not automatically protected.

- Under British Columbia's **Fish Protection Act**, the **Riparian Areas Regulation (RAR)** requires local governments to protect riparian areas during residential, commercial, and industrial development by ensuring that proposed activities are subject to a science-based assessment conducted by a Qualified Environmental Professional. RAR is cooperatively administered by a joint agreement between the BC Ministry of Environment, DFO, and the Union of BC Municipalities. Municipalities can opt to enact a bylaw which meets or exceeds the requirements under RAR (e.g., Stream Protection Regulation). RAR provides some minimal protections to biodiversity values within the riparian corridor. In 2006, the Township of Langley amended its Official Community Plan to include specific provisions for streamside protection (Bylaw No. 4485).

- Municipal **tree protection bylaws** regulate and prohibit the cutting, removal, and damage of trees within public spaces and on private lands. The City of Surrey recently enacted a new tree protection bylaw: **Surrey Tree Protection Bylaw, 2006 (No. 16100).**

- Both the City of Surrey and Township of Langley aim to protect natural areas through policy documents. In Surrey, the new **Sustainability Charter** is an overarching policy document that guides Surrey's approach to social, cultural, environmental, and economic sustainability. Environmentally Sensitive Areas are designated under the **Official Community Plan** and Surrey's approach to ESAs is currently being refined as part of an **Ecosystem Management Study** currently in progress (being conducted by HB Lanarc with assistance from Raincoast Applied Ecology). Natural areas are addressed through the **Strategic Natural Areas Management Plan**, and the City's **10-Year Servicing Plan**. The Township of Langley is in the process of implementing its **Wildlife Habitat Strategy**, produced in partnership with Langley Environmental Partners Society (LEPS).

- The **Biodiversity Conservation Strategy for the Greater Vancouver Region** was produced under the Georgia Basin Action Plan as a partnership between federal, provincial and regional government agencies. The purpose of the project is to assess the network of areas contributing to the region's biodiversity and develop and implement coordinated strategies and actions to conserve biodiversity. The project has included consultation, research, case studies, and mapping. LEPS used the regional habitat and biodiversity mapping for the Wildlife Habitat Strategy being implemented in the Township of Langley.

Several important points emerge from the above summary:

- Consideration of biodiversity in ISMPs is a way of meeting both regulatory requirements and important local and regional biodiversity objectives. However, there is currently no established link between ISMP planning and these biodiversity objectives.

- Because comprehensive, landscape-scale information on biodiversity is largely lacking for the LCR watershed, further inventory and assessment will be required to set priorities for management and prescribe appropriate protection measures.

- Future assessment needs to occur at the landscape or watershed scale. Site-specific assessments do not provide scale-appropriate information useful for prioritization of habitats.

- While assessment methods must be comprehensive and broad in scale, they must also be cost-effective. Additionally, they should also provide a means of assessing the success of protection measures.

With these objectives in mind, Table C3-5 shows examples of (1) habitat attributes and (2) focal species that could be potentially used as assessment tools to prioritize and monitor sites for biodiversity in the LCR.

Table C3-5: Habitat Assessment including Potential Assessment & Monitoring Tools for the LCR Watershed

Habitat Class	Habitat Subclass	Habitat Type	Potential assessment and monitoring tools			
			Habitat attributes			Focal species (or group of species)
			Compositional (structural) attributes		Process (functional) attributes	
			Watershed-scale	Patch-scale		
Aquatic	Rivers and streams	LCR mainstem and larger tributaries Off-channel habitats Small tributaries/headwater streams	Location of streams	Watercourse classification Detailed SHIM mapping (e.g., fish barriers, erosion) Habitat quality (e.g., LWD, substrates)	Water quality Water levels/flow Nutrient inputs/flow Sediment transport Disturbance	Coho salmon Benthic invertebrates Western pearlshell mussel
	Wetlands	Fluvial wetlands Ponds Seasonally-flooded fields LCR Estuary	Location of wetlands Wetland sizes	Wetland class Vegetation type	Water quality Water levels Sediment quality Disturbance	Amphibians Great blue heron Marsh wren
Riparian		Riparian forest Non-forested riparian communities	Location of riparian forest Amount and % of intact riparian forest Riparian-upland connectivity	Tree age classes Deciduous/coniferous Tree species composition Structural features (e.g., CWD, snags) Soil type	Soil moisture Infiltration Disturbance	Amphibians Skunk cabbage
Upland terrestrial	Forest	Large forest patches Small forest patches and isolated trees	Location of forest patches Amount and % of forest cover Amount of interior and edge forest Forest patch sizes Patch connectivity	Tree age classes Tree species composition Structural features (e.g., CWD, snags)	Successional processes Disturbance	Pileated woodpecker Brown creeper
	Agricultural-associated habitats	Old fields Hedgerows	Location of old fields Amount and % of old fields Size of old field patches	Vegetation structure Vegetation composition Adjacency of raptor nesting and perching sites	Successional processes Disturbance	Raptors (e.g., Short-eared owl) Townsend's vole

1. **Habitat attributes –** these can be divided into two types:

   - **Structural (compositional) attributes** – assess the quantity (amount, distribution) and quality (size, connectivity, composition) of existing habitats. Some attributes are best assessed at the **watershed-scale** while others would be measured at the **scale of individual habitat patches**. Maps typically capture compositional attributes well.

   - **Functional (process) attributes –** assess flows of water, energy, and nutrients within and between habitats important to biodiversity. These processes are particularly relevant to stormwater as water is often a medium for life but also for flow of energy, nutrients, and pollutants within ecosystems.

2. **Focal species (or groups of species) –** these species represent potential surrogates for broader sets of species possibly affected by land use change and targets for management in ISMP planning activities. They can be used as indicators of habitat integrity and change in biodiversity in the watershed more broadly. Assessment of these species and their expected responses to alternative management strategies provides one way to predict or monitor the effects of management alternatives on biodiversity more broadly.

While some of these tools are not new, this habitat assessment framework unifies existing tools (such as riparian corridor assessment and benthic invertebrates) and adds important aspects of habitat not assessed in most ISMP planning processes but that are very relevant to biodiversity, such as habitat connectivity, forest structure, and disturbance.

C3.5 RECOMMENDATIONS

Because of the significance of habitats in the LCR watershed and the adjacent Boundary Bay ecosystem for biodiversity and the potential for effects of stormwater on these habitats, the following recommendations are provided to guide the biodiversity aspects of ISMPs at the subwatershed scale.

1. **ISMP Process**

   - Review the ISMP Template and incorporate biodiversity more explicitly into stormwater planning activities.

   - Better integrate the biodiversity aspects of ISMPs with current local (municipal) and regional biodiversity objectives, including the City of Surrey's Ecosystem Management Study which is currently in progress.

- Review the effectiveness of current tools typically used to assess biodiversity and their habitats in ISMPs and consider incorporating landscape- or regional-scale approaches to biodiversity and habitat assessment for future ISMPs in the LCR.

- Consider developing sub-watershed or watershed-wide goals for maintaining habitat for biodiversity on developed and undeveloped land (i.e., amount of forest, distribution of forest patch sizes), during ISMP processes or as part of Official Community Plans (OCPs).

2. Assessment

- Use the results of the current Ecosystem Management Study to identify undeveloped and other lands in the LCR most critical to the watershed's long-term ecological health. The Ecosystem Management Study includes a GIS-based "Green Infrastructure Assessment" based on the principles of landscape ecology and conservation biology which systematically assesses both structural and functional habitat attributes to identify the most important hubs and corridors for biodiversity. During the ISMP process, the analysis should be examined at the watershed scale and sub-watershed scale and includes the Township of Langley as well. Important attributes for biodiversity include:

  1. distribution of different habitat types, such as upland forest cover, riparian forest cover, wetlands, and old fields;
  2. amount of interior and edge forest;
  3. size distribution of habitat patches; and
  4. connectivity of habitat patches.

- Identify potential habitat for rare species likely to occur in the watershed (e.g., Pacific Water Shrew, Western Toad, and Red-Legged Frog) based on known habitat requirements and preferences. Apply habitat suitability or capability models, where available. Conduct surveys at high priority sites to identify occupied sites for protection and stewardship.

- Establish one or more focal species or species groups (both aquatic and terrestrial) to use as indicators of the status of biodiversity across different habitat types in the watershed. Table C3-5 provides recommendations of suitable focal species. Establish standardized methodology and monitoring sites for these species based on the above habitat assessment.

3. Research and Information Gaps

- Investigate the habitat requirements for species at risk which depend on habitats in the LCR watershed (e.g., minimum patch sizes, habitat attributes within patches, etc.).

- Promote the use of the LCR watershed among universities, colleges, conservation organizations, and other researchers as a research site for biodiversity studies, specifically habitat–species relationships.

4. Implementation

- Protect all large forest patches and wetlands for their important hydrologic functions and biodiversity value. One of the environmental goals in Surrey's Sustainability Charter (2008) is to retain natural areas such as existing forests and other natural vegetation, and maximize the City's tree canopy. An interconnected ecological network for protection and enhancement has also been defined in Surrey's Ecological Management Study (in progress). Consider setting goals for forest cover retention within the LCR and restoring forested areas in key locations of the network.

- Establish an "ecological buffer zone" to limit further encroachment into the undeveloped lands surrounding the mid-basin wetlands and Campbell Valley Regional Park.

- Minimize stormwater impacts on the quality of aquatic habitat by adopting policies to reduce point and non-point source pollution and reduce the effective impervious area of developments.

- Protect and restore important wildlife corridors to retain and enhance habitat connectivity for wildlife using the results of Surrey's Ecological Management Study (in progress).

- Encourage adoption of provincial Best Management Practices (BMP's) for known habitat for rare and other species (e.g., raptors) found in the watershed. Encourage implementation of BMP's for high priority potential habitat, where possible.

- Take measures to actively improve the value of existing protected habitats by restoring portions of riparian corridor and actively managing exotic species.

- Continue to support the work of the Salmon Habitat and Restoration Program (SHaRP) and Langley Environmental Partners Society (LEPS) as well as local naturalist and stewardship groups to encourage stewardship on private land (only 12% of the watershed is currently protected).

5. Monitoring

- Support City-wide GIS-based monitoring of habitat attributes at the watershed and subwatershed scale as an important resource for ISMP planning. Include attributes such as:

1. distribution of upland forest cover, riparian forest cover, wetlands, and old fields;
2. amount of interior and edge forest;
3. size distribution of habitat patches; and
4. connectivity of habitat patches.

Data from the Ecosystem Management Study represents baseline data for this work and updates are recommended to occur every 5 years. Ongoing monitoring may be best carried out at a broader scale as part of City-wide biodiversity initiatives.

- Collaborate with local stewardship, naturalist, and streamkeeper groups to carry out the monitoring of focal species on an annual basis (e.g., through annual bird counts, amphibian surveys).

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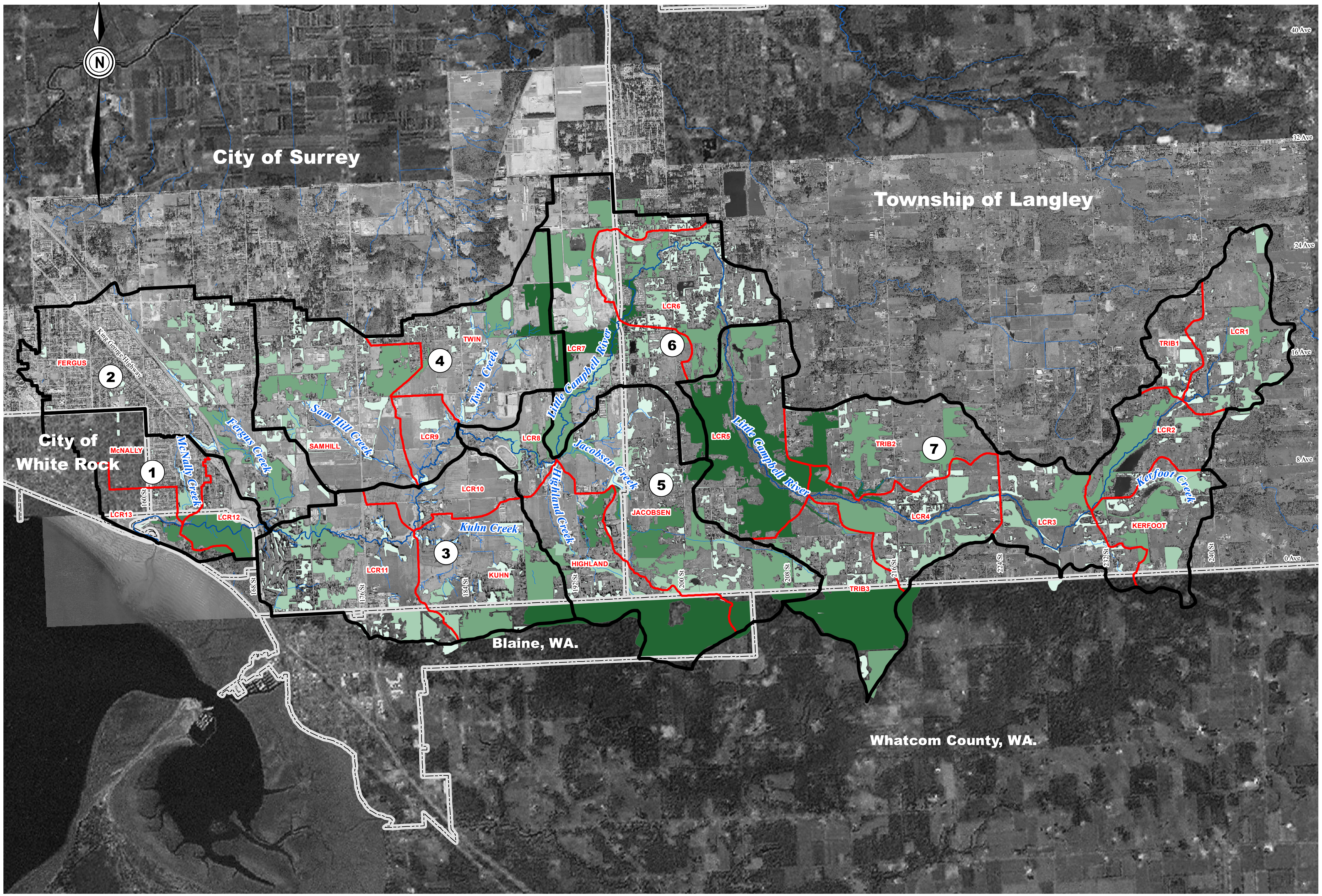
City of Surrey/Township of Langley
Little Campbell River ISMP
Scoping Study



Legend

- City/Township/US Boundary
- ISMP Area ID / ISMP Area Boundary
- Catchment ID (TRIB) / Major Catchment Boundary
- Watercourse

Riparian Forest (Hectares)

- < 0.5
- 0.5 - 1.5
- 1.5 - 5.0
- 5.0 - 7.5
- > 7.5

ISMP Areas

1. McNally Creek
2. Fergus Creek
3. Kuhn Creek
4. Sam Hill / Twin Creeks
5. Jacobsen / Highland Creek
6. Fernridge / Campbell Heights
7. Upper Little Campbell River

Orthophoto Source:
City of Surrey 2006 and Township of Langley 2007.
City of White Rock and Washington St. ortho from Bing aerial map imagery.

KERR WOOD LEIDAL associates limited
CONSULTING ENGINEERS

1 0.5 0 1
Scale in Kilometers

Project No.	Date
471-180	March, 2011

Distribution of Forest Cover in the LCR Watershed

Figure C3-1

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