FINAL REPORT

City of Campbell River

Integrated Stormwater Management Plan

Nunns Creek Watershed

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1479.0005.01 / May 25, 2005

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May 26, 2005

File: 1479.0005.01 - C1

City of Campbell River
301 St. Ann's Road
Campbell River, BC V9W 4C7

Attention: **Mr. Michael Roth**
Environmental Coordinator

RE: NUNNS CREEK INTEGRATED STORMWATER MANAGEMENT PLAN
FINAL REPORT

We are pleased to submit to you this Final Report for the Nunns Creek Integrated Stormwater Management Plan. We are enclosing 15 copies of the report, along with a CD-ROM containing the complete electronic file of the report. In order to reduce paper usage, several of the appendices are being provided in electronic format only, on a CD-ROM in the back of each copy of the report; the Table of Contents indicates which appendices are affected.

We will provide you with appropriate GIS electronic files within the next week.

Thank you for this opportunity to work with you to protect and enhance this natural community asset. We believe that the results of our consultations and technical work have produced a practical plan that embraces the best sustainable stormwater management approaches available at this time while recognizing the development values important to the City and building in flexibility now and in the future.

If you have questions, please call us.

Yours truly,

URBAN SYSTEMS LTD.

5/26/05

Jeffrey M. Rice, P.Eng.
Senior Water Resources Engineer

Samantha Ward, P.Eng.
Project Engineer

Enclosures (15 copies of report; CD-ROM)

/jmr

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integrity. longevity. diversity.

TABLE OF CONTENTS

APPENDICES

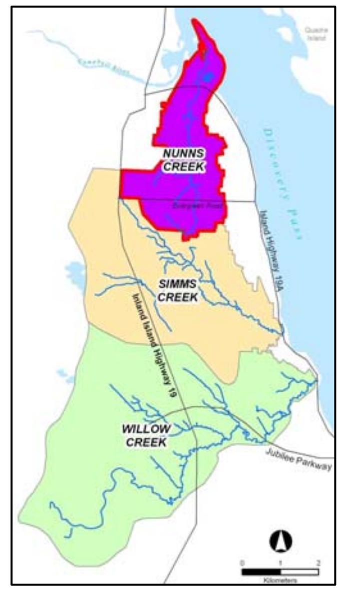
LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The City of Campbell River has embarked on a process to address stormwater issues within the City, which is consistent with current guidelines published by the Province for integrated stormwater management planning (ISMP). This effort will eventually encompass the entire City, though this study addresses the Nunns Creek Watershed only. The watershed covers about 760 hectares in Campbell River (see map). The City is responsible for the construction, operation, maintenance and enhancement of stormwater systems in the watershed.

The goals of the City-wide stormwater management planning effort are:



- Develop stormwater management solutions and policies that maintain, restore and enhance the watershed and meet engineering, environmental and land use needs
- Protect the community from flooding, erosion and destruction of private and public property
- Promote community development while recognizing neighbourhood values and unique characteristics of the area
- Integrate engineering, planning and environmental solutions for the benefit of the Campbell River

The Project Team for this ISMP included engineers, planners, biologists and hydrogeologists. The process included technical assessments by the Project Team as well as direct consultation with local stakeholders. A Stakeholders Working Group, that included the Nunns Creek Stewards, the local Development Liaison Group and senior environmental agencies, met three times to discuss the issues facing the watershed, review options presented by the Project Team and provide input to the plan. Two Open Houses were held during the project to provide for general public consultation as well.

Six main tasks or objectives were addressed in this plan:

- Document existing stormwater, biophysical and land use conditions
- Identify required stormwater infrastructure and land use policies to ensure protection of residents and property as well as protection of aquatic habitat

- Ensure that stakeholder interests and senior environmental agency support for recommendations is balanced with social and economic interests of the community
- Develop decision matrices that allow the City to analyze and evaluate options
- Recommend an integrated approach to achieving cost effective solutions
- Provide City with evaluation and recommendations that will lead to the development of sustainable financial tools for implementation

Nunns Creek is a fish-bearing stream that will continue to degrade if stormwater management is not brought to bear on the development that is expected to occur within the watershed. Healthy watersheds in Southwestern British Columbia, including Vancouver Island, are typified by having greater than 65% forested land and less than 10% impervious surfaces (buildings, roads, parking lots and other hard surfaces). Nunns Creek watershed currently has about 32% currently forested area with another 0.7% still regenerating, and 16.5% of impervious surface. Healthy watersheds are also typified by the presence of significant riparian corridors and wetlands. While Nunns Creek retains about 3.3% of its land base in wetlands, it has lost significant wetland areas over the years. The watershed, however, does retain significant areas of riparian vegetation.

A hydrologic and hydraulic model was developed to assist with the evaluation of the existing storm sewer system. Using this model, several existing storm drains were identified for improvement to alleviate nuisance flooding. The model was also used to test alternative management approaches, including traditional storm trunk systems, use of detention ponds and implementation of various low impact, sustainable stormwater controls.

Other specific issues that were identified for the watershed are:

- Extensive existing development (mostly residential), particularly within the eastern part of the watershed
- Loss of forested areas throughout the watershed
- Loss of historical wetlands throughout the watershed
- Low base flows in summer, likely a result of heavy reliance on storm sewers in the eastern part of the watershed and ditches that have drained adjacent soils in the western part of the watershed
- Erosion concerns at existing storm sewer outfalls to creek
- Water quality concerns at existing storm sewer outfalls from industrial and commercial areas in the lower reaches of the creek

- Pressure to continue developing portions of the watershed in the near-term (1-10 year horizon), including both new development and infill / redevelopment of existing parcels
- Degraded fish habitat in a several reaches of the creek and its tributaries, including lack of LOD and sedimentation
- Tidal influences of the Campbell River estuary and Discovery Passage on the lower reaches of the creek

To address these issues two guiding principles for stormwater management in Nunns Creek watershed were formulated:

- No further degradation in the Nunns Creek system
  - Maintain base flows within the creek
  - Avoid inducing any new flooding or creek erosion
  - Apply sustainable stormwater controls on all new development
- Enhance the Nunns Creek system where possible
  - Move towards establishing a "pre-development" hydrologic cycle throughout the catchment
  - Retrofit sustainable stormwater controls in existing development areas, where feasible
  - Construct in-stream habitat improvements as resources become available

The overall intent is to preserve and enhance the significant resource that is Nunns Creek, accommodate the demand for growth in the community and preserve the generally residential character of the current watershed.

Performance targets for stormwater control are recommended that will implement these guiding principles:

- *Small storms* – No discharge of runoff from new impervious areas
- *Medium storms* – Limit post-development runoff to the following pre-development levels in new areas of development:
  - 50% of the 2-year event
  - 100% of the 5-year event
- *Big storms* – Safe conveyance of runoff
- *Water quality* – Provide treatment of runoff from new impervious areas for all storm events less than 55 mm in 24 hours, with specific targets for:
  - Total Suspended Solids – Remove 80% of the annual average load

- o Oil & Grease – Remove from runoff from commercial and industrial areas

The following table lists and prioritizes the range recommendations for this ISMP study, grouped as follows:

- Municipal drainage system
- Environmental
- Pilot Projects
- Data Management
- Policy
- Public Education

We recommend that the City take an adaptive approach to stormwater management. This includes:

- Regular updates of the plan, at 5-year intervals
- Make use of pilot projects to test and provide a basis for design of new sustainable stormwater control methods
- Allow flexibility on the part of developers to prepare plans that meet the basic performance targets for stormwater volume, peak and water quality control

The estimated capital cost for recommended system improvements is $5.74 million with annual maintenance costs of approximately $164,000. These improvements are for storm drains and detention ponds.

Financing for these improvements can be through DCCs, however we strongly recommend that the City consider establishing a community-wide stormwater utility which can collect user fees and charges. Such a utility can provide a long-term, sustainable source of funds for both capital improvements as well as for on-going operation and maintenance of the stormwater system.

Table ES-1
Nunns Creek Watershed Recommended Works

Category	Recommendation	Priority Level		
		1	2	3
Municipal Drainage System	Upgrade deficient municipal drainage infrastructure	X		
	Replace culverts at 16th Avenue, Old Island Highway and Island Highway with open bottom arch culverts or bridge structures		X	
	Prepare operations and maintenance schedule for stormwater system		X	
Environmental	Survey erosion sites in all watercourses (location, extent, etc.)	X		
	Undertake a wetlands inventory (historical location, extent, etc.)	X		
	Prepare a wetland management plan	X		
	Prepare a beaver management plan		X	
	Consider instream boulder / gravel recruitment between 16th Avenue and 9th Avenue		X	
	Install water quality units at existing storm sewer outfalls from industrial / commercial sites (Nunns Creek Park)	X		
	Verify connections from ERT ditches to Nunns Creek; revegetate / enhance ditches where possible		X	
	Add detention facilities, water quality treatment at 2nd Avenue and 4th Avenue storm sewer outfalls	X		
	Construct check dams / rock liners / pool riffles and LOD's in ravines / ditches downstream of 2nd Avenue and 4th Avenue outfalls to address erosion concerns and enhance habitat value	X		
	Consolidate Willis Road ditches into one swale / ditch system in conjunction with road widening program, enhance swale with native plantings, boulder / gravel recruitment, detention / water quality treatment where possible, lower existing road culverts where needed for fish access	X		
	Address erosion in Evergreen Road ditch with riffle / pools, riprap and bioengineering	X		
	Add ponds / rock weirs / native plantings to ditch above Evergreen Road for water quality treatment		X	
	Divert upper creek to Petersen Road and Merecroft Road right-of-ways and enhance for habitat / water quality treatment / baseflow restoration	X		
	Install check dams in ditch system at Pinecrest Road / Petersen Road and plant with native vegetation for water quality / erosion control		X	
	Define Trask Road channel, install culvert at road crossing, enhance with riparian plantings		X	
	Conduct water quality monitoring program (one year minimum)			X
	Verify soil infiltration properties throughout the watershed (test pit program)		X	
Pilot Projects	Roof Leader Disconnection Program	X		
	Sustainable Roads Design and Construction	X		
	Porous Pavement		X	
	Shallow infiltration trenches in existing roadside ditches west of Nunns Creek		X	
	Deep Infiltration Wells			X
Data Management	Conduct flow monitoring program (one year minimum)	X		
	Obtain detailed cross section and profile survey of creek	X		
	Obtain updated, detailed aerial contour mapping of watershed		X	
	Re-establish digital recording of continuous rainfall measurements at the airport rain gauge	X		
	Compile manhole rim data throughout the area		X	
	Refine the current XP-SWMM model to perform extended period (continuous) simulations		X	
	Update GIS database		X	
Policy	Consider requiring the use of LID techniques (where appropriate and feasible) for new development (as described in Section 9)	X		
	Develop and adopt an Erosion and Sediment Control Bylaw		X	
	Prepare and distribute an Erosion and Sediment Control Brochure to builders		X	
	Adopt performance targets for stormwater volume, peak and quality	X		
	Adopt a single, consistent 5-year level of service for minor conveyance systems	X		
	Require specific stormwater quality treatment for all new commercial and industrial sites	X		
	Adopt measurable targets in OCP for preserving tree cover and limiting impervious area	X		
	Update zoning bylaw to include maximum parking space and impervious area limits, encourage vegetation retention and native species plants, and encourage cluster development		X	
	Develop and adopt a tree retention bylaw		X	
	Update Engineering Standards / Specifications to include BMP's which promote integrated stormwater management practices		X	
	Develop and adopt a stormwater utility to finance all aspects of the stormwater system		X	
Public Education	Conduct a long term public education and outreach program	X		
	Undertake a native planting program with private landowners within riparian corridor		X	
	Develop a stewardship award for the development community		X	

Level 1 is highest priority, Level 3 is lowest priority

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1.0 INTRODUCTION

1.1 Vision for the Watershed

The City of Campbell River (the City) desired to review and update its stormwater controls in three watersheds, to better emphasize an integrated approach that applies with current understandings of urban hydrologic processes. In particular the City wished to incorporate policies and practices that emphasize sustainability with community acceptance and that harmonize environmental stewardship with flood control and erosion protection. This integrated approach combines the expertise of engineers, planners, habitat biologists and hydrogeologists to develop a comprehensive set of tools which can be implemented on a watershed-wide scale for stormwater management. The result of this collaboration is commonly known as an Integrated Stormwater Management Plan (ISMP).

The City is in the midst of implementing a 5-year program to develop ISMP's for several watersheds within their jurisdiction. ISMP's for the Holly Hills and Perkins Road watersheds were completed in early 2004. The focus of this current study is on the next phase of ISMP's, which includes the Nunns Creek, Simms Creek and Willow Creek watersheds. These watersheds encompass a significant portion of the City, including a portion of its downtown core, the municipal airport and the majority of its residential, commercial and industrial development. Large tracts of agricultural and forestry land are also present in these watersheds.

It is the vision of both the City and the project team to ultimately create a living document for each watershed, which is expected to be updated and revised, as necessary, as the recommendations described herein are implemented and monitored. The primary goal is to recommend stormwater management solutions for these watersheds which are realistic and practical to achieve, and which are adaptable should conditions change as future information on each watershed is obtained.

While the three watersheds have several commonalities, separate ISMP studies will address issues that are specific to each watershed. Thus, this report is for the Nunns Creek watershed only.

1.2 Goals and Objectives of the ISMP Studies

The Terms of Reference issued by the City for the Nunns Creek, Simms Creek and Willow Creek ISMP's identified four main goals:

I. To establish an achievable and supportable vision for each watershed that will result in the development of stormwater management solutions and policies that maintain, restore and enhance the natural watershed characteristics while meeting engineering, environmental and land use needs.
II. To protect the community from flooding, erosion and destruction of private and public property.
III. To promote community development while recognizing neighbourhood values and unique characteristics of the area.
IV. To integrate engineering, planning and environmental solutions to the benefit of each watershed.

To achieve these goals, the City outlined six main objectives, or tasks, to be undertaken as part of the ISMP studies:

I. To document the existing condition of each watershed including the stormwater infrastructure, biophysical inventory, and existing and future land use patterns.
II. To identify the required stormwater management infrastructure and land use policies necessary to ensure the protection of residents and property with protection of the aquatic habitat.
III. To ensure that stakeholder interests and senior environmental agency support for the study recommendations is balanced with the social and economic interests of the community.
IV. To develop decision matrices that will allow the City to analyze and evaluate options that meet the multiple needs of the community.
V. To recommend an integrated approach to achieving cost effective solutions which will assist the City and its partners in establishing watershed based stormwater policies, a stormwater infrastructure program.
VI. To provide the City with an evaluation and recommendation(s) that will lead to the development of sustainable financial tools that support the City's land use plan and

capital works program, including but not limited to the establishment of a stormwater utility and development cost charges.

1.3 Communications Strategy

To ensure that the ISMP process is a successful one, involvement and support from a variety of interest groups is essential. Over the course of the project, the following groups were consulted.

1.3.1 City of Campbell River

A series of meetings were held with City staff over the project duration to define and address several issues, such as the scope of work, schedule and associated milestone dates, review of submissions, public and stakeholder consultation, etc. City staff from the Engineering, Planning and Public Works departments participated in the meetings. The project team worked closely with City staff throughout the project to ensure that the ISMP studies ultimately reflected the vision that the City has for these watersheds.

Council was kept informed on the status of the project via discussions with City staff, announcements in the Council's newsletter and project summary statements, which will be presented to Council at the conclusion of the project.

1.3.2 Stakeholders Working Group

One of the objectives of the ISMP study was the formation of a stakeholders working group. This group included representatives from a variety of interest groups in the watersheds, including provincial and federal environmental agencies, major landowner spokespersons, Ministry of Transportation, local stewardship groups, non-government organizations, area residents, local businesses and City staff. The main purpose of the group was to provide background information on each of the watersheds, as well as to review and comment on recommendations from the ISMP studies. The group met three times over the course of the project. Table 1.1 lists the members of the stakeholders working group. Additional information related to the group can be found in Appendix E.

Table 1.1
Stakeholders Working Group Participants

Name	Organization
Michael Roth	City of Campbell River
Ron Neufeld	City of Campbell River
Graham Stewart	City of Campbell River
Phil Skognes	City of Campbell River
Sean Roy	City of Campbell River
Barbara Phipps	Nunns Creek Stewards, Greenways Land Trust
Tom Easton	Simms Creek Stewardship Society
Ian McDougall	Simms Creek Stewardship Society
Chuck DeSorcy	Willow Creek Watershed Society
Barry Peters	Fisheries and Oceans Canada
Shannon Anderson	Fisheries and Oceans Canada
Peter Law	Ministry of Water, Land and Air Protection
Andy Telfer	Greenways Land Trust, Development Liaison Group
Bob Hall	Ministry of Transportation
Dan Berkshire	Development Liaison Group
Jim Dobinson	Development Liaison Group
RK Stephens	Development Liaison Group
Tim Ennis	Nature Conservancy of Canada

Representatives from the Ministry of Forests, Nature Trust and the Advisory Planning Commission were invited to participate in the stakeholders working group but ultimately did not contribute to the group.

The Campbell River and Homalco First Nations were also invited to participate in the group, as they are located within the limits of the overall study area. Both parties, however, preferred to discuss their particular issues and concerns with the project team outside of the stakeholders working group.

1.3.3 General Public

Contact with the general public was primarily made through media releases and public open houses. Four separate media releases were published in the local newspapers as well as posted on the City's website over the project duration. These media releases provided updates on the project status, contact information for City staff and the project team, and dates and times for upcoming public open houses. Media releases can be found in Appendix F.

Two public open houses were hosted by the City to summarize the progress to date on the ISMP's and to allow the general public an opportunity to comment and provide input into the studies. The public open houses were held on Tuesday January 11, 2005 and Tuesday March 15, 2005. A brief presentation was given by the project team at the start of each open house, which was then followed by an open discussion and question period. Presentation materials, sign-in sheets and feedback forms for both open houses are located in Appendix F.

1.4 Background Studies and Reports

Several background studies and documents relating to all three watersheds were provided to the project team at the project initiation meeting with City staff. Additional reports and anecdotal information were also obtained from several of the stakeholder group members, including the Nunns Creek Stewards, Fisheries and Oceans Canada (DFO) and the Ministry of Transportation (MoT). A comprehensive list of the documents which were reviewed by the project team is attached in Appendix A.

Background materials were reviewed by all members of the project team for relevant information in their respective fields. The habitat biologist reviewed existing data as to its environmental attributes and assessed the data using ecological principles including in-stream fish habitat, riparian fish habitat and water quality. They proceeded to meet with City staff and the stakeholder working group to further identify critical habitat issues and areas. Candidate critical habitat areas were then assessed and confirmed in the field, and recommendations for critical habitat restoration and enhancement opportunities were subsequently developed and prioritized. "Critical" in this context is not intended as a legal or regulatory definition, but as a category used for the purposes of this study, as required by the Terms Of Reference.

The geotechnical engineer reviewed reports which had the most relevant information relating to the local area groundwater resource, including those with information on: soils, geology, stream low flows, water temperature and chemistry. They also reviewed information on land cover, land use and types of vegetation to assess past and present groundwater recharge and discharge areas, as well as the BC Ministry of Water, Land and Air Protection's database for water well records and locations in the area.

Past hydrologic / hydraulic studies, master drainage plans, stream flow data and relevant City documents were reviewed by the stormwater engineer to obtain a comprehensive understanding of the condition of each watershed and water related issues. Other policy documents, bylaws and the official community plan were reviewed by the planner to understand various land use issues and future development and re-development potential.

1.5 Project Team

A comprehensive project team was assembled for these ISMP studies, including representatives with engineering, planning and environmental perspectives. Each team member has extensive experience in their related field and has prior experience in developing ISMP's. Team members and contact information are provided in Table 1.2.

Table 1.2
ISMP Project Team Members

Area of Expertise	Company	Contacts	Phone Number
Stormwater Management	Urban Systems	Jeffrey Rice, P.Eng., Project Manager Samantha Ward, P.Eng. Andrew Ling, EIT	604-273-8700
GIS	Urban Systems	Craig Polzen, GIS Specialist	604-273-8700
Planning / Land Use	Urban Systems	Andrew Baigent, M.C.I.P. Sara Stevens, M.Pl.	604-273-8700
Habitat Biologist	TERA Planning	Helmut Urhahn Nadia Baker	604-222-8372
Hydrogeological	Piteau Associates	Allan Dakin, M.Sc., P.Eng.	604-986-8551

2.0 STORMWATER

There was a time when people tended to think publicly about water only during two periods: When there was too little of it (drought) or when there was too much of it (flood). When it came to drinking water, the former was most on people's minds, but when it came to urban drainage, the latter tended to rule. Since the focus was on preventing flooding and thus protecting people and their property, efficiency in removal was the goal. The faster water could be moved away from flood-threatened areas, the sooner people could forget about it.

For centuries, with respect to water supply, water has been treated as a resource, that is, as something to protect and maintain. But in the latter part of the 20th century, many people began to recognize that stormwater represents a resource as well. If treated wisely, stormwater contributes to the well-being of the natural environment, including fish-bearing water-bodies and groundwater resources. But if treated unwisely, stormwater can become a nuisance at best or a serious factor in environmental degradation at worst.

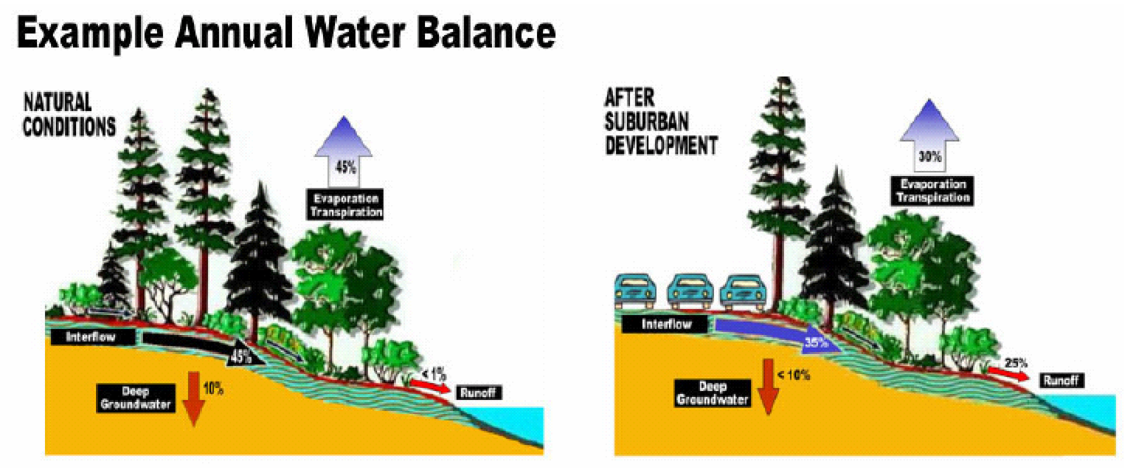
2.1 The Hydrologic Cycle

Rain that falls on any piece of land, whether natural or built, can basically move in only four directions:

- Back into the air via evaporation from surfaces and transpiration from leaves (evapotranspiration)
- Into the surface soils via soaking where it can move slowly to streams (interflow)
- Into deep groundwater aquifers via seepage (groundwater recharge)
- Directly into streams via the land surface or built structures (surface runoff, or stormwater)

Surface runoff from a forested or naturally vegetated watershed is very small, representing 10% or less of rainfall volume in many cases. Except during occasional extreme rainfall events, the flow that is observed in streams (commonly called *base flow*) is actually a product of *interflow,* the slow movement of water through soils into streams. Land development alters this natural water balance. When natural vegetation and soils are replaced with roads and buildings, less rainfall infiltrates into the ground, less is taken up by vegetation and more becomes direct surface runoff. Runoff volumes increase in direct proportion to impervious area – land uses with extensive roof and paved area create more runoff than land uses with extensive areas of absorbent soils and forest cover (see Figure 2.1).

Figure 2.1
Typical Annual Water Balance for the Lower Mainland British Columbia



(Source: BC Guidebook)

2.2 Land Use Characteristics of a Healthy Watershed

From a stormwater management perspective, two of the most significant land use factors to consider in defining a healthy watershed are wooded (forest) area and impervious area. Recent studies consistently show that healthy watersheds in this region of North America are characterized by high percentages of forest area (generally >65%) and low percentages of impervious area (generally <10-15%). Outside these ranges, streams tend to exhibit a host of "unhealthy" conditions that are attributable to the process of urbanization, as described in the next section.

2.3 Impacts of Urban Development

Work at the Center for Urban Water Resources[1] (University of Washington) clearly demonstrates that the most important impacts of development (urbanization) on streams, in order of importance, are:

- Changes in hydrology
- Disturbance of the riparian corridor
- Deterioration of water quality
- Disturbance of the physical habitat within the stream

[1] Integrated Stormwater and Stream Corridor Management forums, 2001

In addition, if these impacts are not avoided, there can also be serious legal, financial and political implications. These impacts are discussed in more detail in the paragraphs that follow.

2.3.1 Hydrology

One of the major impacts of urbanization on streams is its effect on stream hydrology. Hydrology is defined as the study of the movement (or flow) of water in all its phases. Understanding the water balance is essential to understanding the impact of development on the hydrology of streams.

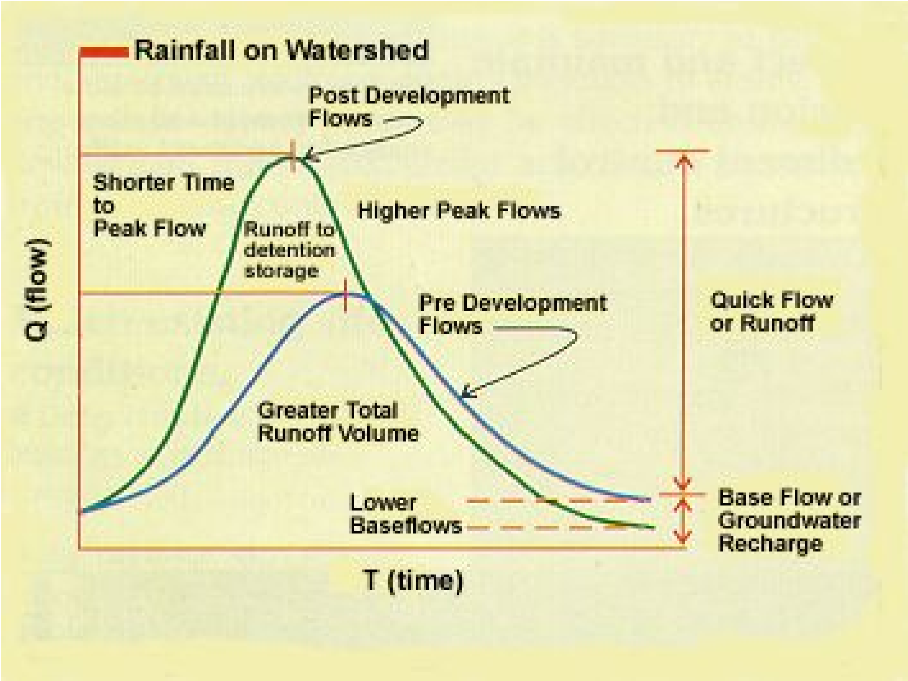
The water balance, as shown in Figure 2.1, is the concept that the sum total of rainfall is equal to the amount of rain infiltrated (interflow), absorbed (deep groundwater), and evapotranspired, plus the volume of runoff generated from the watershed. In a pre-developed setting, much of the rainfall is absorbed by the surrounding vegetation, soil and ground cover. In a developed setting, the water balance changes and a disproportionate amount of rainfall becomes surface runoff.

Changes in the water balance in urban streams are exemplified by increased flood peaks, increased frequency of bankfull flows, widening of the floodplain and decreased dry weather flows (see Figure 2.2). Bankfull flows are simply runoff events that fill the normal channel of a stream to the top of the banks. Bankfull flows are significant because they are the channel forming flow condition in a stream and they are highly erosive, turbid ("cloudy") and damaging to the natural morphology of the stream.

Further, traditional pipe and ditch systems were designed to remove runoff from impervious surfaces as quickly as possible and deliver it to receiving waters. With increased land development, stormwater arrives at the receiving waters much faster, which in turn increases the peak rate of flow.

By the time a watershed is fully developed with buildings, roads and parking lots, 15 to 20 times more runoff can occur as compared to conditions prior to development.

Figure 2.2
Change in Streamflow with Urban Development



2.3.2 Disturbance of Riparian Corridor

Generally, most streams begin to enlarge as impervious cover exceeds 10-15% in the watershed. The enlargement process may take up to 50 years to fully occur, but urban streams in watersheds with more than about 10-15% impervious cover are characterized by various degrees of stream enlargement and widening, erosion, downcutting, decreased channel stability and embeddedness. An undeveloped watershed with less than about 5% impervious cover is characterized by excellent stream conditions — good riparian cover, high quality substrate (stream bottom) and wetted perimeter during low flow conditions.

Even though a developed area does not entirely encompass a watershed, the sections of a stream that are located downstream are likely to experience these changing conditions.

2.3.3 Deterioration of Water Quality

In addition to hydrologic changes and changes to the riparian corridor of the stream, urbanization directly impacts the quality of the receiving water. Some of the indicators of the impact of urbanization on water quality include increased stream temperature and pollutants.

Stream temperature is a very important habitat parameter for fish and insects, and temperature variability can dictate the growth of aquatic insects and timing of migration and molts. Impervious cover increases air and soil water temperatures and can create an increase of 3-6°C in urban streams.

In addition to increased stream temperature, urbanization can increase the amount of pollutants entering water bodies, such as sediment, nutrients, organic matter, trace metals (copper, cadmium, lead), pesticides, herbicides and hydrocarbons, and others. During storm events, the quality of urban stormwater declines sharply which adversely affects human and aquatic uses of downstream waters.

The sources of pollutants in stormwater are predominately associated with impervious areas. Impervious areas act as a collector and conveyor for pollutants that arrive from many pathways. Pollutants can fall out of the sky during dryfall. They may also arrive in rain or snow as wetfall. Automobiles are also sources of pollutants. Wear of tires (a known source of zinc), deteriorating brake pads, or just leaks, drips and spills of oil and other pollutants from the car can accumulate on impervious surfaces. Pollutants can also be blown in from adjacent pervious areas. Pollutants land on the street where they often stay in curbs, cracks and other areas until the next rain storm where they are washed off the surface and into the storm drain system and ultimately to receiving streams.

Excess nutrients (such as nitrogen and phosphorous) can create eutrophic conditions that can lead to uncontrolled algal growth that consumes oxygen in shallow, slow-moving waters and may create fish kills, odours and other problems.

Another common pollutant in urban stormwater is sediment. Sediment can smother bottom organisms and it can clog gills of fish and aquatic insects when it is in the water column. Sources of sediment include streambank erosion, construction sites and the wash off from paved surfaces.

Fecal coliform levels in urban stormwater runoff are typically 15 to 50 times the standard set for water contact recreation. Fecal coliform can be derived from human and nonhuman sources. In fact, research indicates that much of the fecal coliform in urban runoff is from nonhuman sources such as dogs, cats, cattle, horses, squirrels, geese, pigeons and ducks. However, very high levels of bacteria may also be due to leaks of human sewage from sanitary sewer overflows, leaking septic systems, combined sewers or illicit discharge of sewage.

Stormwater hotspots are areas that produce higher concentrations of pollutants than normally found in urban runoff. Certain areas of the urban landscape are known to be hotspots of stormwater pollution. Examples include gas stations, parking lots and auto recycling facilities. Generally, stormwater hotspots contribute 5 to 10 times higher concentrations of trace metals and hydrocarbons in stormwater runoff. These hotspots merit special management and pollution prevention activities.

Trace metals are frequently found in urban stormwater and sometimes at concentrations that can be acutely toxic to aquatic life. In nearly every stormwater sample, one generally will find zinc, copper and lead. Hydrocarbons, zinc, copper, cadmium, and lead are known to accumulate in the tissue of fish. In some cases, this may make the fish unsuitable for human consumption.

2.3.4 Disturbance of the Physical Habitat within a Stream

Along with changes in hydrology, riparian corridor and water quality, the habitat value of urban streams diminishes with increased impervious cover. There are numerous impacts to the aquatic habitat as well as the riparian corridor, particularly along the stream side zone.

The creation of fish barriers is another impact of urban development. Barriers can prevent the movement of fish. In some cases, the fish barriers are created by culverts that are put in stream crossings for roads and other urban infrastructure. As the stream erodes down with increasing urban development, vertical barriers to fish movement are created that cut off spawning areas. Fish that are trying to move up stream to spawn in spring will likely encounter fish barriers that they cannot surmount.

Pipes such as culverts and storm sewers are typically much smoother than a natural stream. Thus, they tend to produce higher velocities of water flowing through them. Further, long culverts and storm sewers do not provide natural resting areas and cut off access to natural light. All of these effects tend to act as barriers or restrictions to fish movement.

2.4 Integrated Stormwater Management

Integrated stormwater management is comprehensive and ecosystem-based; it attempts to take into account the scientific and technical knowledge that has been gained over the last 40 years concerning the impacts of land development on watersheds. As a result, stormwater management has undergone evolutionary growth in its scope and in its perspectives. At first focusing almost exclusively on removing runoff from developed areas quickly and efficiently, we are now coming to know the importance of considering all aspects of the hydrologic cycle, including understanding how land use development decisions can lead to disruption of that cycle.

Further, we are beginning to see the value of eliminating causes of stormwater problems, rather than dealing only with the consequences of our land use decisions.

The recently released provincial guidelines for stormwater control represent one approach to integrated stormwater management planning. The guidelines are consistent with recent thinking across North America about urban drainage. As noted in Section 1, the City views the current planning for the Nunns Creek watershed in the context of these provincial guidelines, which offer the following guiding principles for integrated stormwater management:

1. **A**gree that stormwater is a resource
2. **D**esign for the complete spectrum of rainfall events
3. **A**ct on a priority basis in at-risk drainage catchments
4. **P**lan at multiple scales – regional, watershed, neighbourhood and site
5. **T**est solutions and reduce costs by adaptive management

With respect to the second principle, the general approach is to:

- Capture rainfall from small storms (runoff volume reduction and water quality control)
- Control runoff from larger storms (runoff rate reduction)
- Manage flood risk for extreme storms (peak flow conveyance)

In the past stormwater management has focused almost exclusively on this final item, extreme event risk management. But from the standpoint of, for example, fisheries, it is the small, frequent storms and water quality that are of much more interest.

Regardless of how "pristine" or how "degraded" a watershed may be initially, steps can be taken to improve urbanizing conditions by treating stormwater as a resource. However, communities can choose when it is best to take these steps, what level of commitment to make towards protecting, enhancing or restoring a stream, and how to use the various management tools that are available.

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3.0 WATERSHED DESCRIPTION

3.1 Available Information on the Watershed

Extensive background information is available for the Nunns Creek watershed. The City provided the project team with GIS and AutoCAD data for relevant features in the watershed, including watershed boundaries, contour information, elevation points within developed areas, some storm sewer and culvert locations / properties, watercourse locations, wetland and ditch locations, OCP and zoning designations, Agricultural Land Reserve lands, legal boundaries, street configurations and aerial photography. Much of this information was used to complete hydrologic / hydraulic modeling for the watershed, as discussed in Section 7. Several background studies and reports pertaining to the Nunns Creek watershed were also obtained from the City. The Public Works department also forwarded flooding complaint summary spreadsheets, which summarized resident drainage complaints between the years 2000 to 2004. The drainage complaint summary spreadsheets are attached in Appendix H.

A number of background studies and documents were also obtained from the Stakeholders Working group. In addition to these documents, the stakeholders were asked to provide the following information, if available:

- Anecdotal information, for example:
  - historical flooding along creeks
  - historical seasonal dry-up on creeks
  - records of past road and property flooding
  - erosion concerns
  - rain gauge data
  - flow or water stage monitoring results (staff gauges noted on all creeks)
  - development levels and/or areas scheduled for future development (type of development and density)
  - setback limits and encroachment areas
  - presence of beaver dams
  - number of fish sampled in a given year
  - personal impressions of issues, etc.
- Record of past activities or improvements undertaken by watershed groups
- Stream cross sections
- Video surveys
- Photo inventories
- Correct nomenclature for tributaries of each creek
- Sub-watershed boundaries

A hydraulic model (HEC-RAS) prepared as part of the 2004 Nunns Creek Lower Watershed Management Study was also obtained and reviewed. Geometric data, including creek cross sections, Manning's n values and related hydraulic parameters for Nunns Creek between Homewood Road and the Campbell River estuary was then used in the current modeling effort.

Rainfall information was obtained for the Campbell River Airport and Campbell River Sewage Treatment Plant stations, both of which are located within the overall study area and are the closest complete meteorological stations. While the Campbell River Airport rain gauge station is still active, the Sewage Treatment Plant rain gauge station was shut down several years ago. All of the above information was reviewed and incorporated, where relevant, into the context of this report. A summary of the documents reviewed can be found in Appendix A.

Existing conditions for the context of this report is based on 2002 aerial photography or GIS information, except were more current as-built drawings were available.

3.2 Field Verification

While the existing documents and data available for the Nunns Creek watershed are extensive, some critical data was missing which was required in order to fully understand the hydrologic / hydraulic regime of the watershed. As such, additional site investigations and field work were needed.

A site reconnaissance and detailed survey was undertaken during the week of December 6-10th, 2004, to verify conflicting information in the City's existing GIS database and to supplement our knowledge of the watershed. Several tasks were completed during the site reconnaissance, including:

- Measuring culvert sizes under roads
- Surveying invert elevations of culverts
- Surveying manhole rims at critical locations
- Measuring creek cross sections and surveying creek invert elevations at various locations
- Measuring roadside ditch cross sections and surveying invert elevations at various locations
- Completing a photo inventory of the watershed
- Obtaining a general overview of land use in the watershed
- Visually observing tidal influences on the watercourse

- Gaining an understanding of the overall configuration of the watercourse and how runoff is conveyed to it
- Identifying significant areas of erosion concern within the creek

A second site reconnaissance on January 25th, 2005 concentrated on observing drainage patterns within Nunns Creek Park and the Campbell River First Nations lands, as both sites have locations where the watercourse is poorly defined. This reach of the watercourse is also tidally influenced by the Campbell River estuary. Flooding, poor overland drainage conveyance and frequent overtopping of adjacent roads and properties are the main complaints in this area.

3.3 Catchment Area and Composition

The Nunns Creek watershed is located immediately south of the Campbell River, as shown in Figure 3.1. The watershed is oriented in a north-south direction, with the upland portion of the watershed located at the southern end. The watershed is bounded by the Kingfisher Creek watershed to the west, the Campbell River watershed to the north, the Foreshore area to the east (which drains directly to Discovery Passage) and the Simms Creek watershed to the south.

Topography within the Nunns Creek watershed is varied. A plateau, running roughly parallel with Dogwood Street, separates the watershed from the Foreshore area. From Dogwood Street, the topography dips west at a moderate grade down towards Nunns Creek. The topography rises up again west of the creek until around Petersen Road, where the slope then flattens out. The headwaters of the creek originate on a gently sloped bench at the south end of the watershed. North of Homewood Road, the topography again flattens out as the lower reaches of the creek discharge to the Campbell River estuary. This lower section of the watershed is heavily influenced by the tidal conditions of the Campbell River and Discovery Passage.

The Nunns Creek watershed boundary was established based on the existing contour and storm sewer configuration information supplied by the City. The existing contour information was supplemented in the upper watershed area by 20-meter contour TRIM mapping where necessary. The resultant watershed boundary was slightly different than the one currently available in the City's GIS database, however, as it was not known how the original boundary was developed, the revised watershed boundary was used for the purposes of this study. The total area of the revised Nunns Creek watershed boundary is 762 hectares (ha). Sub-catchment boundaries were then established based on the storm sewer and ditch network configuration and contour information for Nunns Creek.

The Nunns Creek watershed already has a fair amount of existing development, particularly east of the creek. There are several different types of land uses present in the watershed, including residential, commercial, light industrial, agricultural, First Nations lands, schools and parks. Most of the urban development is concentrated on the east side of the watershed, whereas rural development is mainly situated on the west side of the watershed. The Nunns Creek watershed also encompasses a significant portion of Campbell River's downtown core, which is located in the northeast section of the watershed.

Table 3.1 summarizes several basic parameters which are useful in measuring the extent of urban disturbance and its associated risk within a watershed. These parameters are also shown graphically in Figure 3.2. The parameters were calculated based on the 2002 aerial photography supplied by the City.

Table 3.1
Hydrologically Significant Land Use Features in the Nunns Creek Watershed (Existing Conditions)[2]

Parameter		% of Watershed
Total Area	762 ha	n/a
Impervious Area	126 ha	16.5%
Developed Area	477 ha	62.5%
Replanted / Regenerating Forest Area	5.7 ha	0.7%
Mature Forest Area	243 ha	32%
Riparian Area	47.5 ha	6.2%
Wetland Area	25 ha	3.3%
Length of Open Channel Watercourses	14.1 km	n/a
Length of Closed Channel Watercourses (Storm Sewers)	19.8 km	n/a
Length of Ditches	21.1 km	n/a

The basis for delineating the areas shown on Figure 3.2 is as follows:

2 These parameter values were prepared for the purposes of this planning study and are provided for general reference only. Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

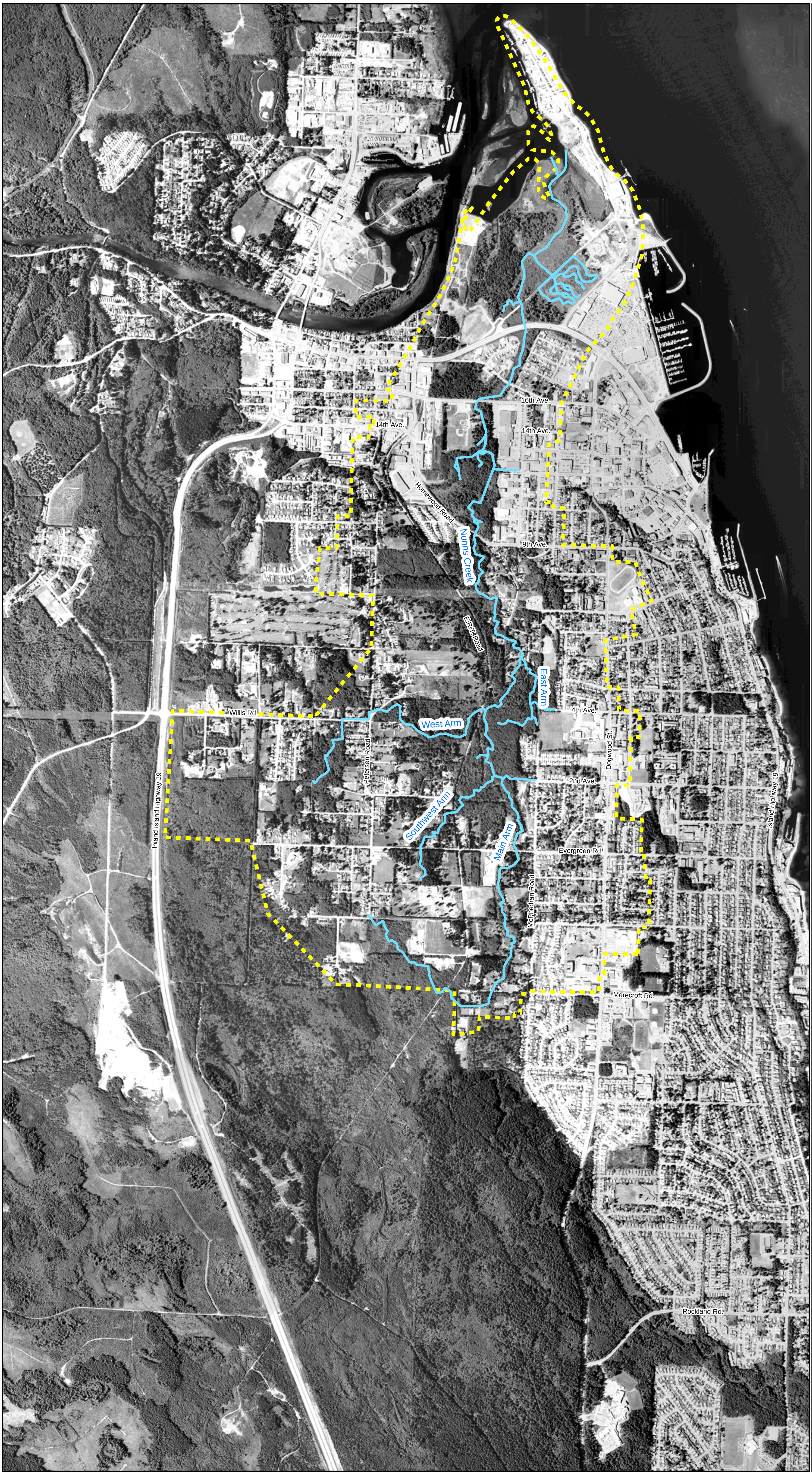

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Figure 3.1

Nunns Creek Watershed Boundary

Nunns Creek

Nunns Creek Watershed

0 200 400

Metres

Scale 1:20 000

Source: City of Campbell River
2002 Aerial Photography

This map was prepared for the purposes of this planning study and are provided for general reference only.
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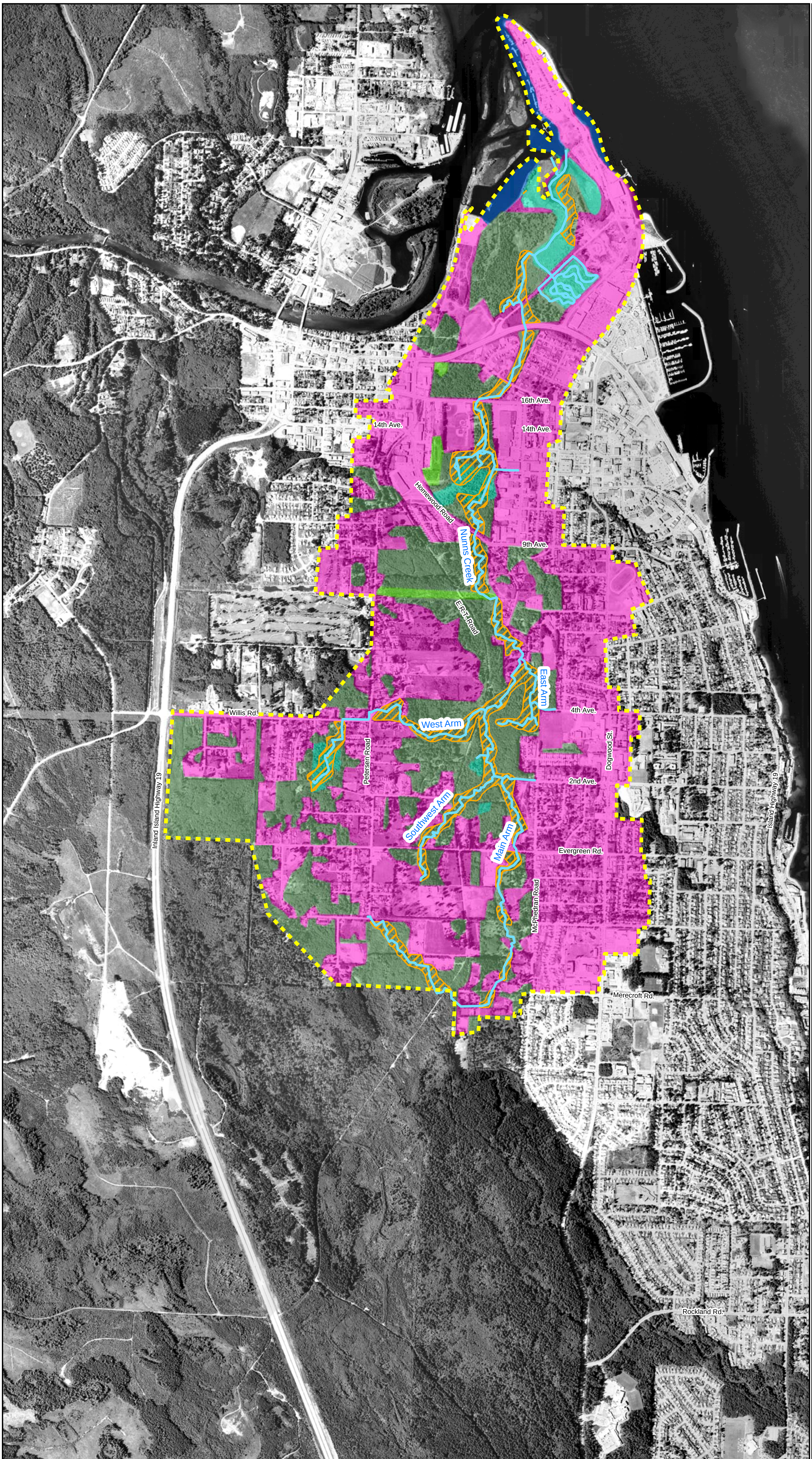

City of Campbell River

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Figure 3.2

Hydrologically Significant Land Use Features in the Nunns Creek Watershed (Existing Conditions)

Nunns Creek
Nunns Creek Watershed
Forest - Mature
Forest - Regenerating
Developed Area
Wetland Area
Water
Riparian Area

0 200 400
Metres

Scale 1:20 000

Source: City of Campbell River 2002 Aerial Photography

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Impervious Area – Representative "blocks" of properties were randomly chosen within the developed portion of the watershed for each land use type (residential, commercial, industrial, etc). The total impervious area was calculated for each representative block (impervious area included roofs, driveways, roads, sidewalks, etc). These impervious values were extrapolated for each land use type over the entire developed area and then added together to calculate the total impervious area for the watershed. Existing impervious areas in the Nunns Creek watershed are mainly concentrated to the east of the creek in residentially and commercially developed areas.

Developed Area – Includes all impervious areas, as well as the pervious areas which are in direct relation, such as grassed areas (lawns), fields, parks, school yards, etc (based on the 2002 aerial photography).

Cleared Forest Area – Includes all areas which appear to have been recently cleared of vegetation (based on the 2002 aerial photography).

Replanted / Regenerating Forest Area – Includes all areas which appear to have been cleared of vegetation in the past, but the areas were recently replanted or appear to have young trees / low vegetation growing (based on the 2002 aerial photography).

Mature Forest Area – Includes all areas where trees appear to have developed an extensive canopy (based on the 2002 aerial photography). Mature forested areas which also fell within a riparian corridor (see description below) are included in the mature forest area calculation.

Riparian Area – Includes all areas along watercourse corridors where the corridor appeared to be extensively vegetated (based on the 2002 aerial photography). Limits of the riparian areas were set based on a noticeable change in vegetation type.

Wetland Area – Includes areas which were deemed to be wetland areas based on previous studies supplied by the City and the Nunns Creek Stewards.

As discussed in Section 2.2, healthy watersheds are typically characterised as having less than 10-15% of impervious area and greater than 65% of forested area. The Nunns Creek watershed has passed the 16.5% impervious level, meaning that development in the watershed has likely already impacted the watercourse. The total forested area is also well below the 65% threshold. This does not mean, however, that the watershed on a whole is not functioning. Rather, this indicates that greater attention should be given to how future development proceeds in the watershed and that further discussion should take place on what can be done to mitigate stormwater issues on a total watershed level.

There are various parts of the watershed which have experienced a significant reduction in forested area as a result of recent logging activities. Based on the aerial photography, areas that have been previously logged appear to be in various stages of regeneration; however, it also appears that there may be some areas which have not been replanted. The loss of forested areas does have a detrimental impact on the overall health of the watershed.

The percentages outlined in Table 3.1 indicate that greater attention should be given to how future development proceeds in the watershed and that further discussion should take place on what can be done to mitigate stormwater issues resulting from existing development and logging activities on a total watershed level.

3.4 Historical Background

The lower Nunns Creek watershed was one of the first sites in Campbell River to be settled by Europeans almost 120 years ago. Prior to that the area was home to First Nations people for extended periods. Over time lowland areas were infilled for roads and other lands were cleared for buildings. This development has had a direct impact on the watershed, changing its hydrologic characteristics significantly. The City of Campbell River also has a past which is deeply routed in the forestry industry. The area has been extensively logged over the past several decades, with many of the current forested areas being second or third generation forests. Past logging activities have also had an impact on the hydrologic regime of the watershed.

Research to date has suggested that one of the primary goals of integrated stormwater management should be to mimic the "pre-development" hydrologic conditions of the watershed to the maximum extent possible. It should be noted however, that given the history of logging in the area, the assumed "pre-development" condition of this watershed should not be considered to be a mature and pristine forested area. Past logging activities, such as clearing trees, stripping surficial organics and compacting the ground with logging equipment, should be taken into consideration when trying to establish a "pre-development" condition for the watershed.

3.5 Watercourse Characteristics

Nunns Creek main branch can be separated into four main reaches: south of Second Avenue, between Second Avenue and Homewood Road, between Homewood Road and 16th Avenue, and between 16th Avenue and the outlet of Nunns Creek into the Campbell River estuary. The four principle branches of Nunns Creek are known as the Main Arm, the Southwest Arm, the West Arm and the East Arm. These branches are shown in plan view on Figure 3.3.

The upper portion of the Nunns Creek watershed, south of Second Avenue, is the headwater area for the Main Arm, the Southwest Arm and the West Arm of the creek. These branches are somewhat unconfined in localized areas in the upper watershed area and are fed primarily by roadside ditches. The gradient in each branch is gently sloping and some meandering is present. A typical cross section of a branch in this area would include a 2 metre bottom width with 2:1 side slopes.

The confluence of the Main Arm and the Southwest Arm occurs just north of Second Avenue. From this point the gradient of the creek steepens and subsequently converges with both the West and East Arms of the creek. The creek is somewhat confined within localized areas in this reach due to the encroachment of adjacent development and the realignment of the creek within private property by some residents. The base width of the creek in this reach is approximately 4 metres, with 2:1 side slopes.

North of Homewood Road, the creek gradient flattens out through Nunns Creek Park. The creek is somewhat undefined within the park and there are several backwater areas which are offline from the main channel. Where the channel is defined, it has an average bottom width of about 4 metres and a top of bank height of 1m. The adjacent land is level with the top of the creek banks therefore overland flooding can be quite extensive when the bankfull capacity of the creek is exceeded in this reach. Beavers are active in the park near Homewood Road, which may be contributing to the generation of backwater and offline storage areas in the park.

North of 16th Avenue, the creek enters the Campbell River First Nations reserve. The creek meanders through this region within a wide, marshy floodplain which is heavily vegetated in some locations. Some filling within the floodplain has taken place to accommodate residential housing for the reserve and flooding on reserve lands continues to be an issue.

Culverts are used for all road crossings of Nunns Creek. In the past, bridges were used for road crossings within the lower reaches of the creek, however, as these roads were upgraded the bridges were replaced with culvert structures. According to local reports, 16th Avenue is usually overtopped at least once a year and the road crossing further downstream at the Old Island Highway also experiences overtopping. The Nunns Creek Stewards group and the Campbell River First Nations both noted that the frequency of overtopping on these road crossings appears to have increased since the bridges on these roads were replaced with culverts.

3.6 Hydrologic Conditions

The most recent study on the Nunns Creek watershed is the Nunns Creek Lower Watershed Management Study, completed by McElhanney Consulting Services in February 2004. This study specifically looked at flood protection and habitat restoration works in Nunns Creek downstream of Homewood Road. The study used peak flows from a Ministry of Environment (MoE) design brief completed in 1984. The peak flows from the MoE study were based on the U.S. Soil Conservation Service (SCS) method, assuming Group A soils, a curve number of 60 and a Level III antecedent soil moisture condition. The MoE study used rainfall data from Chatham Point and Strathcona Dam since rainfall information was not available for Campbell River for their study. Although not stated explicitly in the report, presumably a Type IA 24-hour SCS rainfall distribution was used in conjunction with the available daily rainfall data. Peak flows at the Island Highway for the 24-hour duration in Nunns Creek from the MoE study are presented in Table 3.2 below.

Table 3.2
Peak Flows in Nunns Creek at the Island Highway Crossing

Storm Event	5 Year	10 Year	25 Year	50 Year
Peak Flow (m^3/s)	7.4	10.2	15.9	20.4

(Source: MoE, 1984)

These flows were also used for the proposed restoration works outlined in the 2002 Fish Habitat Restoration Prescriptions and Cost Summary for Nunns Creek by Komori Wong Environmental.

A different set of peak flows for Nunns Creek were used in the 1995 Master Drainage Plan. This study used rainfall data from the nearby Campbell River sewage treatment plant rather than the stations used in the 1984 MoE study and the data was translated into "design storms" using the "Chicago storm" method. The 2-year recurrence design event was the focus of the Master Drainage Plan. Modeling completed in this study indicated a natural, or "pre-development", flow rate of 3.9 m^3/s and an existing conditions flow rate of 4.6 m^3/s, reported for the Homewood Road crossing.

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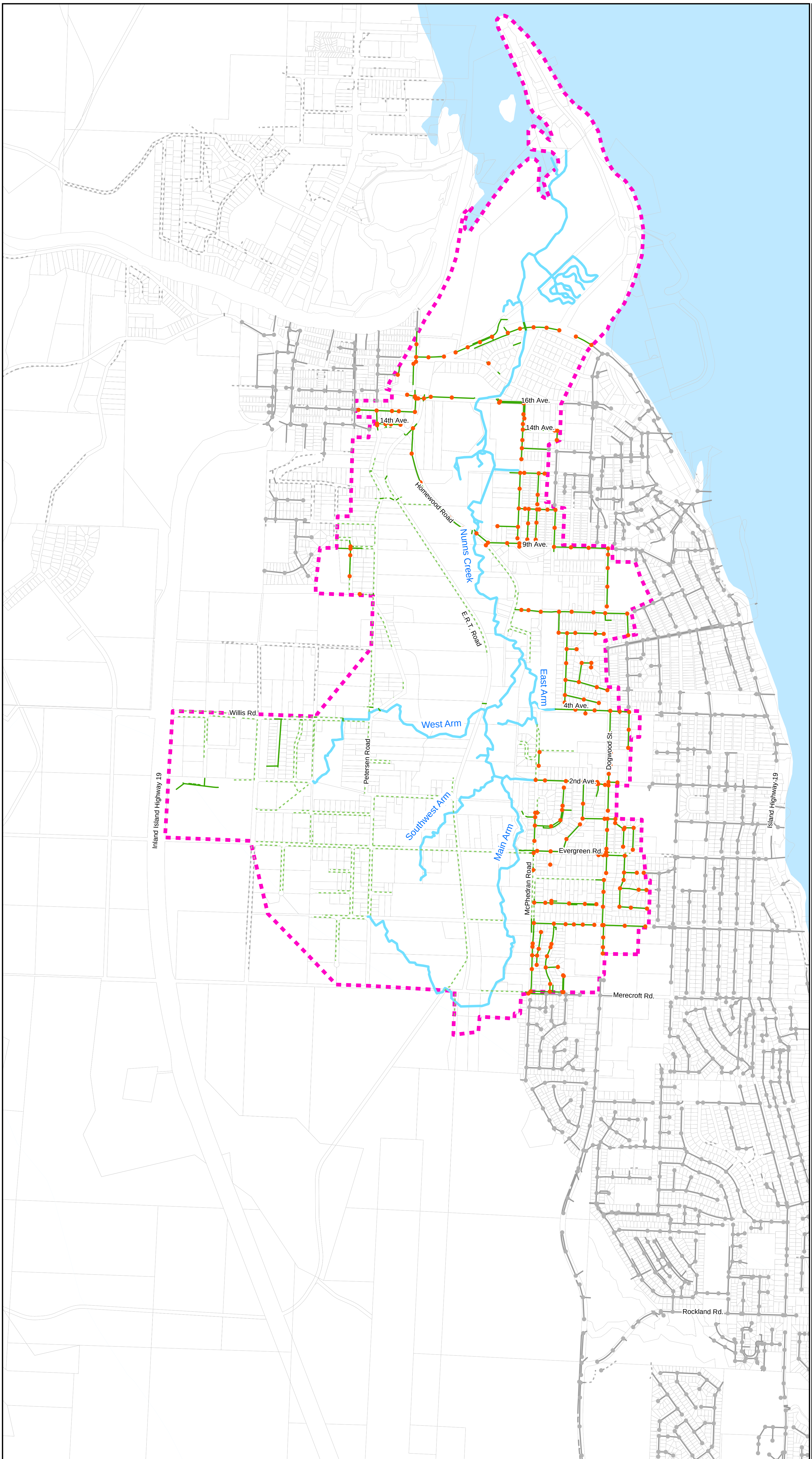

Figure 3.3

Nunns Creek Watershed Municipal Drainage System

- Storm Manhole Within Watershed
- Storm Main Within Watershed
- Storm Manhole Outside Watershed
- Storm Main Outside Watershed
- Ditches Within Watershed
- Ditches Outside Watershed
- Nunns Creek
- Nunns Creek Watershed

0 200 400
Metres

Scale 1:20 000

Source: City of Campbell River

This map was prepared for the purposes of this planning study and are provided for general reference only. Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

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3.7 Tidal Conditions

The lower reaches of Nunns Creek, from approximately Nunns Creek Park to the Campbell River estuary, are tidally influenced. Table 3.3 summarizes tide data for Campbell River, as adapted from the 2004 Nunns Creek Lower Watershed Management Study.

Table 3.3
Tidal Heights, Extremes and Mean Water Level for Campbell River

DATUM	HEIGHTS (m)				RECORDED EXTREMES (m)		MEAN WATER LEVEL (m)
	Higher High Water		Lower Low Water		Highest High Water	Lowest Low Water	
	Mean Tide	Large Tide	Mean Tide	Large Tide			
Hydrographic Datum	4.0	4.8	1.3	0.2	5.4	-0.2	2.9
Geodetic Datum	1.1	1.9	-1.6	-2.7	2.5	-3.1	0.0

(Source: McElhanney, 2004)

The combination of tidal backwater from the estuary, runoff conveyed in the creek from upstream areas and the flat terrain within the lower sections of the Nunns Creek make this part of the watershed vulnerable to flooding, particularly north of Homewood Road. The lower portion of the watershed is especially at risk when high tides coincide with a rainfall event. Downstream of Homewood Road the overbank areas are fairly flat and not much higher than the top of bank elevations, therefore flooding may be extensive should the creek overtop its banks.

3.8 Biophysical Inventory

Nunns Creek has high fish production value for Coho (*Oncorhynchus kisutch*), Cutthroat trout (*Oncorhynchus clarki*) and Steelhead/Rainbow Trout (*Oncorhynchus mykiss*). Pinks (*Oncorhynchus gorbuscha*) have been in the system historically. The watershed supports many birds and small mammals, with large mammals located in the upper watershed (KWL 1995).

The lower watershed, from the Campbell River estuary to 16th Avenue, forms part of the inter-tidal zone. The channel is well established and flows through a tidal marsh. This area has been impacted by urban development and road construction. A large freshwater marsh delineates the upper limit of extreme tides. Upstream of Homewood Road the creek is confined and has changing gradients characteristic of Coho / Cutthroat streams on Vancouver Island's east coast. This area is composed of rural residential lots with good riparian cover to the headwaters of Nunns Creek.

3.9 Geology

The watershed lies in a geologic region characterized by silty sand and pebbly sand near the ground surface, with silts and clay below that. In areas along major drainage channels, veneers of alluvial and colluvial deposits have accumulated. Underlying the silts and clays there is typically either sedimentary bedrock or glacial outwash sand (called the Quadra Sand). The glaciomarine deposits of silt and clay generally have low permeability while the underlying Quadra Sand is more moderately permeable.

Although there are a number of shallow dug wells in the area, there are no deep drilled wells from which to develop a more complete picture of the geology of the watershed. Nearby deep drilled wells are south, in the Willow Creek watershed, while geotechnical bore hole logs (<3 m deep) can be found across the River, in North Campbell River. Based on the available information, many areas of the Nunns Creek watershed consist of a 0.5 to 3 m thick layer of marine silt or sand, and/or weathered till, which overlies glacial till (typically a dense silty clay). The upper layers tend to be moderately permeable, but the underlying glacial till has low permeability.

From the available well records, supplemented by extensive well records in geologically similar Quadra Island, the underlying Quadra Sand unit becomes increasingly thin towards the south. While mostly consisting of sands, this unit also displays beds of clay, silt and gravel. Typically the silts are on the lower parts of the unit, while gravels lie towards the upper parts.

Appendix C contains additional detail in the complete hydrogeological report.

3.10 Soil and Groundwater Conditions

3.10.1 Surficial Soils

The dominant soil types found in roughly equal mix in the upper watershed are the moderately well drained Dashwood gravelly loamy sand unit, the more moderately drained Fairbridge and Puntledge units and the poorly drained Tolmie unit. The Dashwood unit is typically located in the sloping upland areas of the watershed, to the east of the creek, while the others lie along the creek and throughout the uplands to the west.

The lower watershed, from Homewood Road to the Campbell River estuary, is about equally divided between the variably drained Cassidy unit, consisting of gravely loamy sand or sandy loam, and the Coastal Beach unit, consisting of sands and gravels. Being at very low elevation, these areas tend to have a high water table.

Only one of these soils appears to have long-term potential for stormwater infiltration. The Dashwood unit has a long-term saturated infiltration potential of about 250 mm/hr. Fairbridge, Puntledge and Tolmie units all have long-term saturated infiltration potentials of under 3 mm/hr. A small area of Bowser loamy sand, lying along the boundary with the Simms Creek watershed, has a somewhat higher infiltration potential of about 8 mm/hr. These estimates are based on soil granular size descriptions, depth of the soil horizon and experience with similar types of soils. Detailed design of infiltration systems will require site-specific percolation testing.

Figure 3.4 shows the areas within the watershed with high and low potential for long-term stormwater infiltration.

Appendix C contains additional detail in the complete hydrogeological report.

3.10.2 Creek Base Flows

Base flow in a stream is in part a measure of the soil and groundwater conditions within the watershed as well as an indicator of the extent that urban development has impacted stream hydrology. For Nunns Creek, there is only very limited data on base flows. Values measured in various reaches of the creek in July and August 1998 are generally low and vary little throughout the basin, but many reaches show no flow at all. When expressed as a flux (flow per unit catchment area, in L/s/km^2), the Nunns Creek value of 4 L/s/km^2 is low compared with other regional rivers, which are typically greater than 8 L/s/km^2 (see Table 3.3).

Table 3.3
Nunns Creek Mean Annual and Summer Low Flows

Name	Period of Record	Area (km^2)	Mean Annual Discharge (MAD) (m^3/s)	MAD Flux (L/s/km^2)	Mean Summer Discharge (MSD) (m^3/s)	MSD Flux (L/s/km^2)
Oyster River below Woodhus Creek	1973-1999	298	14.20	47.7	9.10	30.5
Hyacinthe Creek on Quadra Island	1990-1999	7.68	0.28	35.8	0.02	3.1
Tsable River near Fanny Bay	1960-1999	113	7.99	70.7	3.48	30.8
Browns River near Courtney	1960-1999	86	5.78	67.2	2.86	33.3
Dover Creek near the Mouth	1985-1999	41.1	1.93	47.0	0.34	8.3
Nunns Creek above 16th Avenue	Aug 1998	12.5	Not available	Not available	0.05	4.0

As discussed in more detail in the hydrogeological report, the data shows that overall the groundwater contribution to Nunns Creek is not very significant. This is likely a consequence of extensive urban development in the east side of the watershed and the semi-rural development in the south and western areas of the watershed. The former area has significant impervious surface coupled with storm sewer systems that limits or truncates interflow processes which normally support base flow; the latter area is characterized by numerous ditches that tend to drain adjacent areas which would otherwise store water in the upper soils.

Appendix C contains additional detail in the complete hydrogeological report.

3.10.3 Groundwater Flow Systems

Some of the precipitation falling on the upland areas in the study area seeps into the ground and likely flows along the surface of the marine clay unit. The flow will either find a place where it can seep through the cap into the underlying Quadra Sand unit, or discharge into nearby stream channels and ditches.

Ground infiltration of stormwater runoff will only be practical in parts of the watershed, due to low permeability soils and/or high water tables. However, in some areas, the construction of ditches and services trenches will have lowered the water table and actually created the potential for subsurface storage capacity in adjacent drained soils. For example, soak-away pits for roof and drive runoff could possibly become viable in areas where the water table was relatively shallow prior to development. The drained soils could then be utilized for temporary storage of runoff which would become available for slow release during the ensuing dry season.

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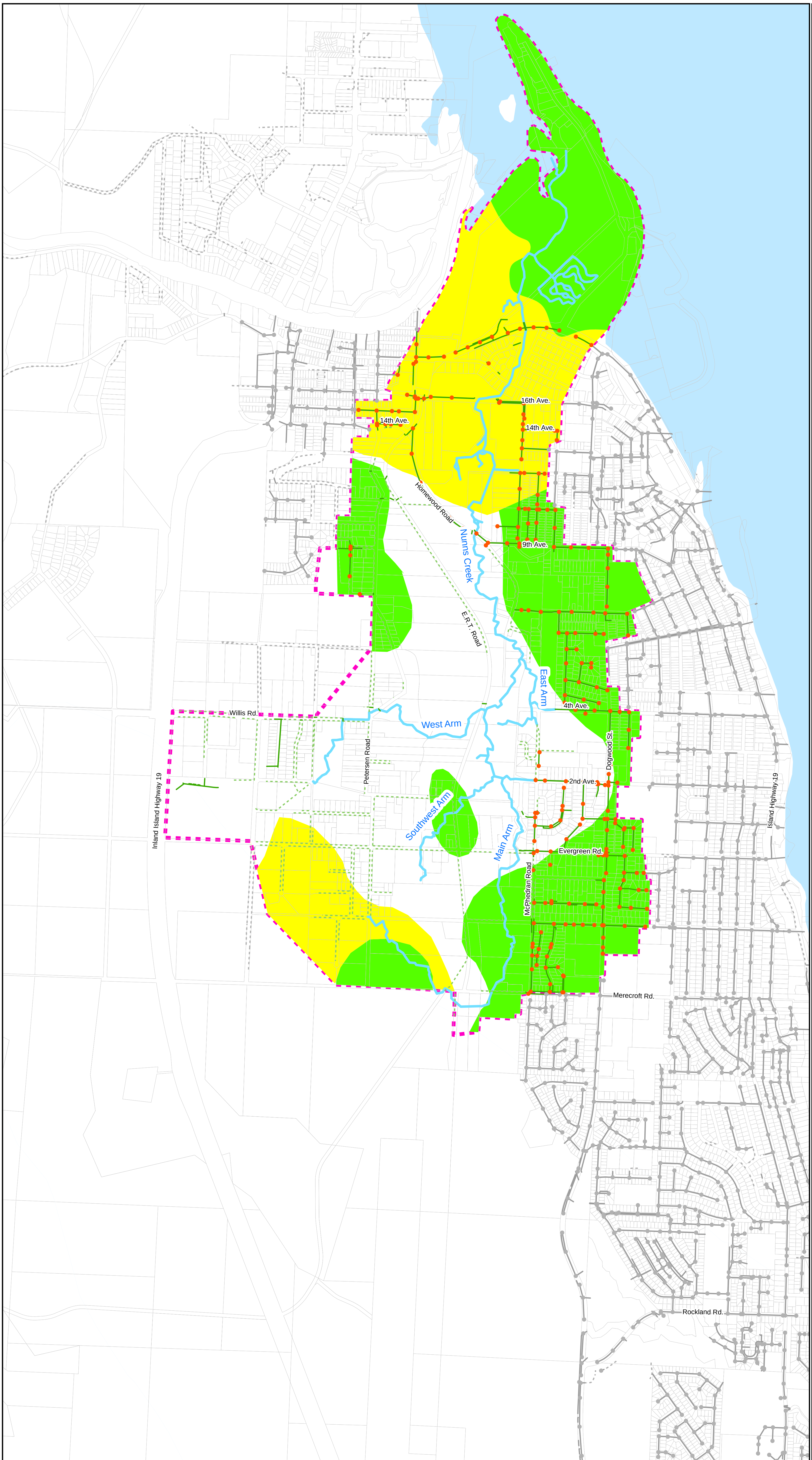
Figure 3.4

Nunns Creek Watershed Potential Locations for Long-Term Stormwater Infiltration



Highest Potential
Possible Potential
Storm Manhole Within Watershed
Storm Main Within Watershed
Storm Manhole Outside Watershed
Storm Main Outside Watershed
Ditches Within Watershed
Ditches Outside Watershed
Nunns Creek
Nunns Creek Watershed

0 200 400
Metres

Scale 1:20 000

Source: City of Campbell River

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3.11 Municipal Drainage Infrastructure

The eastern half of the watershed is essentially fully serviced by a municipal storm sewer system, although some localized areas exist which are serviced by roadside ditches. Storm sewers discharge into Nunns Creek at several locations along its reach, as indicated on Figure 3.3. According to the as-built drawings obtained from the City, there is only one stormwater detention facility in the watershed. This facility is located in the southeast portion of the watershed and only services the immediate area. Therefore, most of the stormwater runoff captured by the storm sewer system within the east half of the watershed is discharged directly to the creek without attenuation or water quality treatment.

The western half of the watershed is predominantly serviced by a network of roadside ditches and culverts, although there are some storm sewers present within the lower watershed area. These ditches and culverts also discharge to the creek in several locations. It is expected that the municipal storm sewer system will expand in the western half of the watershed over time as future development is implemented in this area over the next several years. It is also anticipated that infill and redevelopment of smaller parcels in the eastern half of the watershed will occur in the future, which will have a direct impact on the watercourse if runoff is not properly captured, detained and treated prior to discharge into Nunns Creek.

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4.0 LAND USE

4.1 Existing Land Use Pattern

The existing land use pattern within the Nunns Creek Watershed is largely determined by the City of Campbell River's Zoning Bylaw No. 2700, which regulates the use of land and structures in the City. As shown on Figure 4.1, significant portions of the Nunns Creek Watershed have already been developed for residential use, and fall within the following zones:

- **Residential One Zone:** The majority of the eastern half of the watershed is already developed and zoned for residential use. The Residential One (R-1) Zone permits one single-family residence per lot. The minimum lot size in the R-1 Zone is 450 square metres, and the maximum lot coverage of all buildings is 35%.

- **Residential Infill One Zone:** This zone is intended to reserve land for future urban residential development, while allowing for cluster development. The maximum density is generally 5 units per hectare, but can be as high as 25 units per hectare for lots with indefeasible title or bareland strata lots. The permissible maximum lot coverage ranges from 20% to 65%.

- **Residential Infill Two Zone:** This zone permits low density residential infill to complement existing single and two-family residential areas. The maximum unit density is 25 units per hectare, and the maximum lot coverage is 65% of the total lot area. This zone also includes a provision regarding open space, which is defined as an open area not occupied by any buildings or structures or impervious surfaces, and may include recreational areas, paths, landscape areas and features. A minimum 15% of the lot area must be usable open space.

- **Residential Infill Three Zone:** This zone permits medium density residential infill to complement existing medium density residential development. Infill is intended to be within walking distance of neighbourhood commercial centres. The maximum unit density is 60 units per hectare, and the maximum lot coverage is 65%. As well, a minimum 15% of the lot area must be preserved as usable open space.

In addition to those listed above, the Nunns Creek Watershed includes a number of other land uses such as a First Nation Reserve (Campbell River Indian Reserve), parks, public assembly land uses, and industrial uses (particularly west of Nunns Creek Park). The Nunns Creek Watershed also includes a substantial amount of commercial development located east of Nunns Creek Park and along Dogwood Street at 2nd Avenue and Merecroft Road. Much of the commercial and industrial areas north of Homewood Road are susceptible to flooding from the tidally-influenced creek.

4.2 Future Land Use Pattern

The watershed's future land use pattern is primarily determined by the City's Official Community Plan, which provides the overall direction for future development in the City[3]. The future land use designations (OCP designations) are shown on Figure 4.2. The majority of land within the Nunns Creek Watershed is designated for the following type of development.

- **Residential:** Most of the Nunns Creek Watershed is already developed for residential uses. The Residential OCP designation encourages residential infill, and supports cluster housing near Environmentally Sensitive Areas. The residential area within the Nunns Creek Watershed is designated for low density residential development (up to 30 dwelling units per hectare) as well as medium density residential development (31 to 65 dwelling units per hectare) in the central area of the watershed near the intersection of Willis Road and Petersen Road.

The Nunns Creek Watershed also includes a number of other land use designations to provide for industrial land uses, institutional land uses (e.g. schools, churches, hospitals, and medical facilities, etc.), parks and natural areas, rural land uses, and commercial areas (Figure 4.2).

Urban Residential Containment Boundary

The Draft OCP contains an Urban Residential Containment Boundary (URCB) to control residential development and prevent urban sprawl. As shown on Figure 4.2, all of the Nunns Creek Watershed lies within the Urban Residential Containment Boundary, which means the City plans to direct future residential development to this area.

Nunns Creek Area Road and Greenways Plan

The Draft OCP also includes a more detailed neighbourhood plan for the Nunns Creek area, which stretches north-south from Evergreen Road to 14th Avenue, and east-west from McPhedran Road to Peterson Road (330 ha) (Figure 4.2). While this area is currently sparsely developed with large, semi-rural type lots, the area is expected to accommodate significant population growth in the future. This neighbourhood encompasses nearly all the upland open channel reaches of Nunns Creek.

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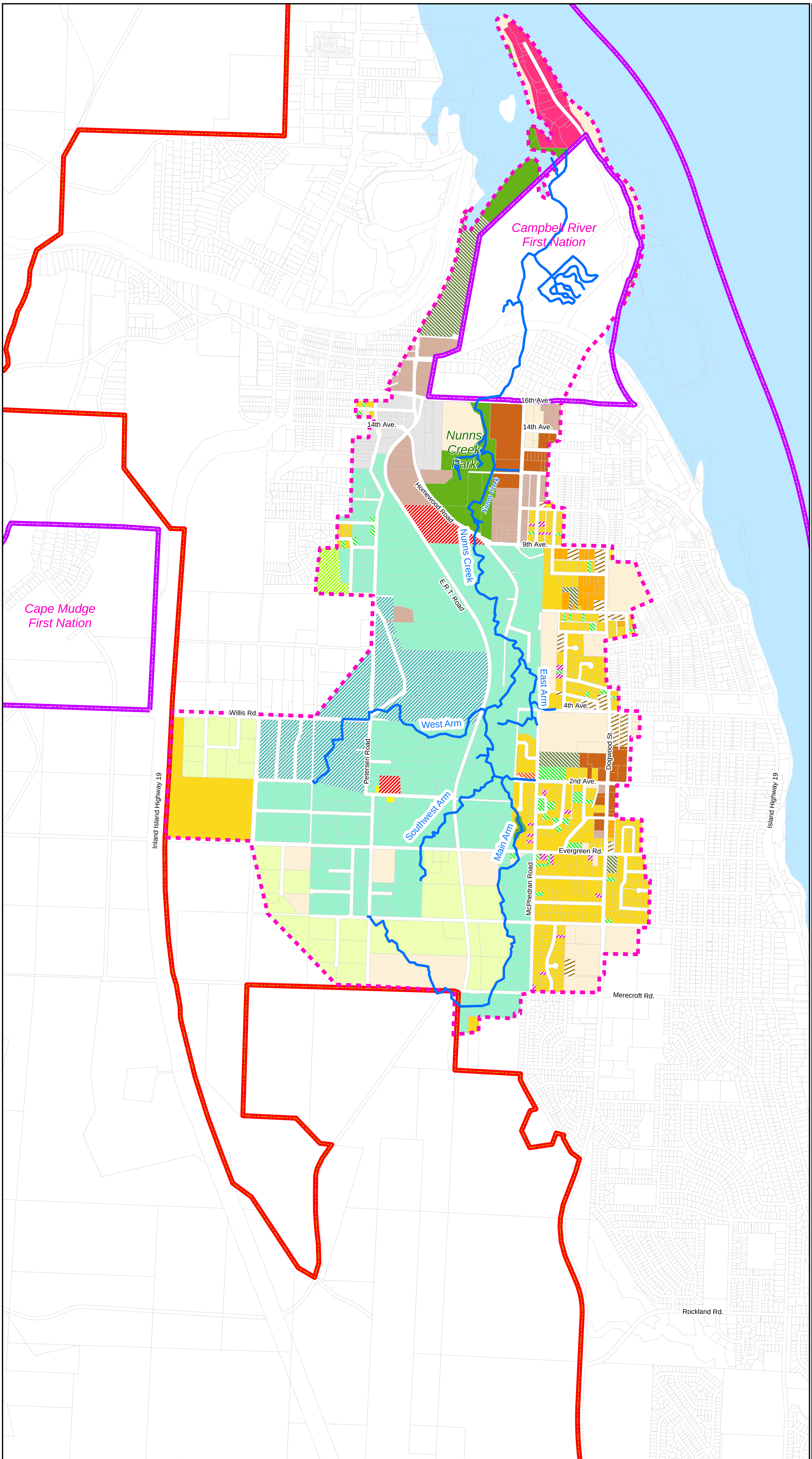
3 At the direction of the City, the Draft OCP rather than the current OCP was used as the basis for this study.

City of Campbell River

Integrated Stormwater Management Plan

Figure 4.1

Nunns Creek Watershed Zoning



Nunns Creek
Nunns Creek Watershed
District Boundary
C-1 Commercial One
C-2 Commercial Two
C-3 Commercial Three
C-4 Commercial Four
CD-2 Comp. Dev. Two
G-1 Greenways
I-1 Industrial One
MH-2 Mobile Home Two
PA-1 Public Assembly
R-1 Residential One
R-1A Residential One A
R-2 Residential Two
R-4 Residential Four
RM-1 Residential Multiple One
RM-2 Residential Multiple Two
RM-3 Residential Multiple Three
RR-1 Rural Recreation
RI-1 Residential Infill One
RI-2 Residential Infill Two
RI-3 Residential Infill Three
Urban Containment Boundary

0 195 390
Metres

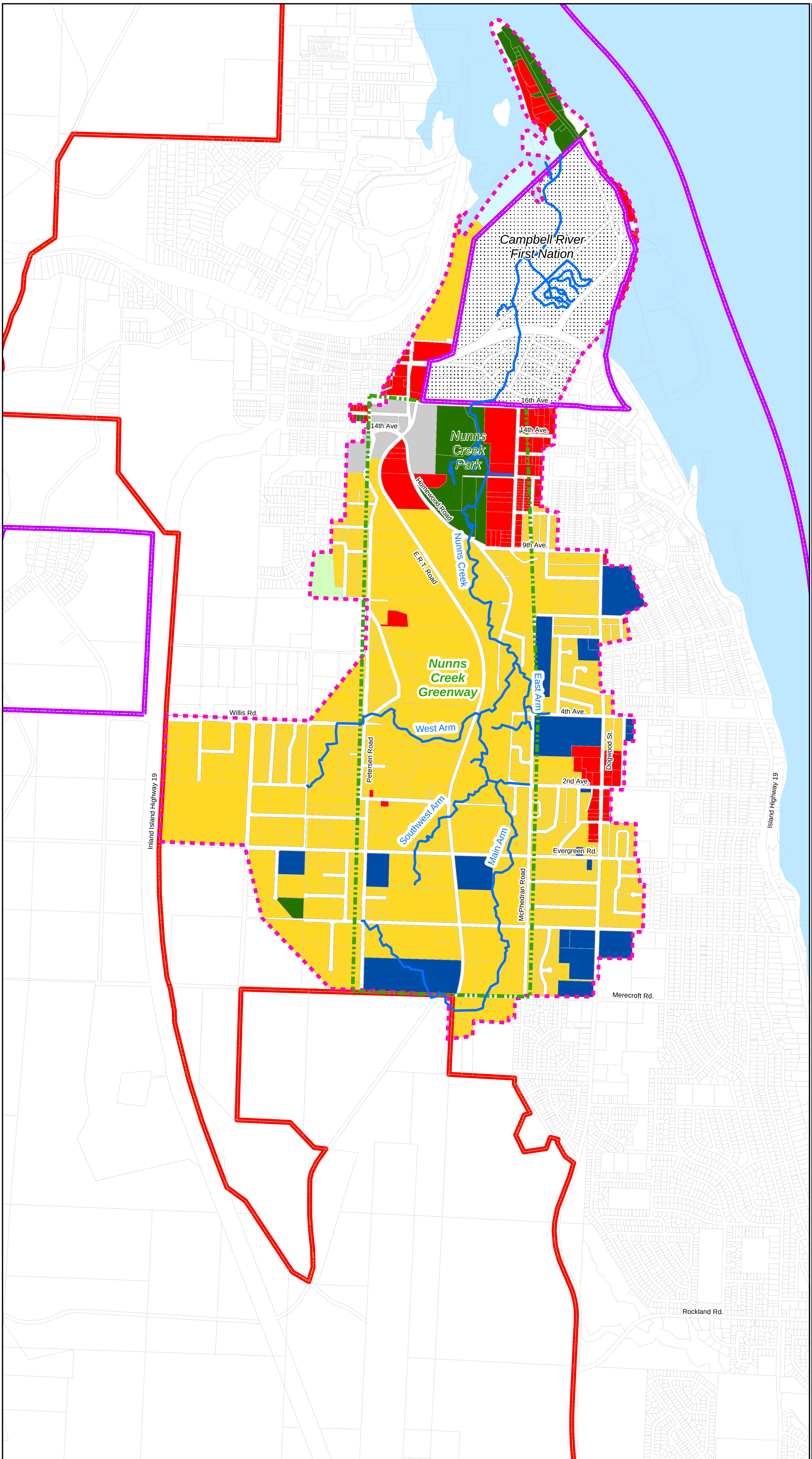
Scale 1:20 000

Source: City of Campbell River

This map was prepared for the purposes of this planning study and are provided for general reference only. Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

URBANSYSTEMS.
PLANNERS • ENGINEERS • LANDSCAPE ARCHITECTS

1479.0005.01 May 2005



City of Campbell River

Integrated Stormwater Management Plan

Figure 4.2

Nunns Creek Watershed Future Development Based On Draft OCP

- Commercial
- Industrial
- Institutional
- Residential
- Park / Natural Areas
- Rural
- Federal Indian Reserve
- Water
- Road
- Nunns Creek
- Residential Containment Boundary
- Nunns Creek Greenway
- Nunns_Watershed_Finall
- District Boundary

0 200 400
Metres

Scale 1:20 000

Source: City of Campbell River

This map was prepared for the purposes of this planning study and are provided for general reference only.
Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

URBAN SYSTEMS

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The plan advocates cluster development to intensify development on lands most suitable for development and to protect sensitive lands less suitable for development. Density averaging is permitted on strata lots, but would require rezoning on fee simple subdivisions. Density averaging would likely be exchanged for enhanced protection of environmentally sensitive areas such as streams, wildlife habitat, as well as open space, views, and hazard areas. Cluster development is also encouraged on lands fronting the Elk River Timber (ERT) Alignment.

While cluster development is supported by the Nunns Creek Area Road and Greenways Plan, current zoning effectively prevents the implementation of cluster development on fee-simple land. The City plans to revisit the Nunns Creek Area Road and Greenways Plan to address this issue.

Environmentally Sensitive Areas

The Draft OCP includes a chapter on Environmentally Sensitive Areas (ESAs), which puts forward policies to protect the environment, minimize pollution, and conserve the quality and quantity of groundwater and surface water. ESAs are defined as "any parcel of land, large or small, under public or private control, that provides, contains, or includes productive, rare or sensitive habitat, ecosystems or landforms", which includes watersheds, watercourses and their associated aquatic habitats. To control development in these areas, the Draft OCP designates these areas as Environmental Development Permit Areas. All lands within 30 metres from the top of the bank of any watercourse fall within the Environmental Development Permit Area (DPA), and therefore proposed development within this zone triggers the DPA process; however, actual setbacks are determined by the Zoning Bylaw.

The development permit guidelines for streamside areas protect waterways, drainage areas, and wetlands through a variety of policies, including:

- Requiring development setbacks from watercourses (as identified in the Zoning Bylaw)
- Encouraging the planting of appropriate vegetation to restore riparian areas
- Encouraging the registration of covenants to protect streamside areas
- Requiring (in some cases) the provision of works (e.g. fencing) to protect or enhance environmentally sensitive areas
- Requiring that the discharge of stormwater not negatively impact adjacent water quality

4.3 Special Land Use Designations

In general, local governments have the authority to regulate land use through their Official Community Plan and Zoning Bylaw. However, local governments must respect special land use designations imposed by the provincial and federal governments. As such, the City cannot regulate development (or in some cases has only limited ability to do so) on land within these special land use designations. Identification of these special types of land use is important because each designation has a different impact on stormwater management. The Nunns Creek Watershed includes the following special land use designation:

- **First Nations Reserves** – development on First Nations Reserves is governed by federal legislation (the *Indian Act* and the *First Nations Land Management Act*) and corresponding bylaws adopted by the First Nation. Local governments have no authority over land use on Indian Reserves. There is one First Nations Reserve located within the Nunns Creek Watershed, the Campbell River Indian Reserve, which totals 115.3 ha. This Reserve is mostly undeveloped, but does have significant residential and commercial (including the Discovery Harbour Shopping Centre) development in its southern portion. Due to increasing demand for Band housing, the Campbell River Band has plans to develop additional housing along 16th Avenue and north of Spit Road. The Band is also considering "big box" type commercial development along the Island Highway.

The specific impacts of the Reserve on stormwater are uncertain, since future development on Reserve is not yet well defined. While the Campbell River Band is pursuing large-scale commercial development as well as residential development, at the time this study was underway plans had not been finalized for either.

Table 4.1
Special Land Use Designations within the Nunns Creek Watershed

Land Use Designation	Description	Jurisdiction	Impact on Integrated Stormwater Management
First Nations Reserves	Federal land reserved for First Nations under the *Indian Act*	Federal – municipality has no jurisdiction over land use on Indian Reserves	Impact on ISMP is determined by each First Nation's land use plan – depending on the scale and type of development, impact could be positive or negative.

4.4 Short Term Future Development Potential

Because most of the watershed has already been developed, there is only limited land available for future development within the Nunns Creek Watershed. As shown on Figure 4.3, which identifies the more significant developments that are anticipated within the next 10 years, most

City of Campbell River

Integrated Stormwater Management Plan

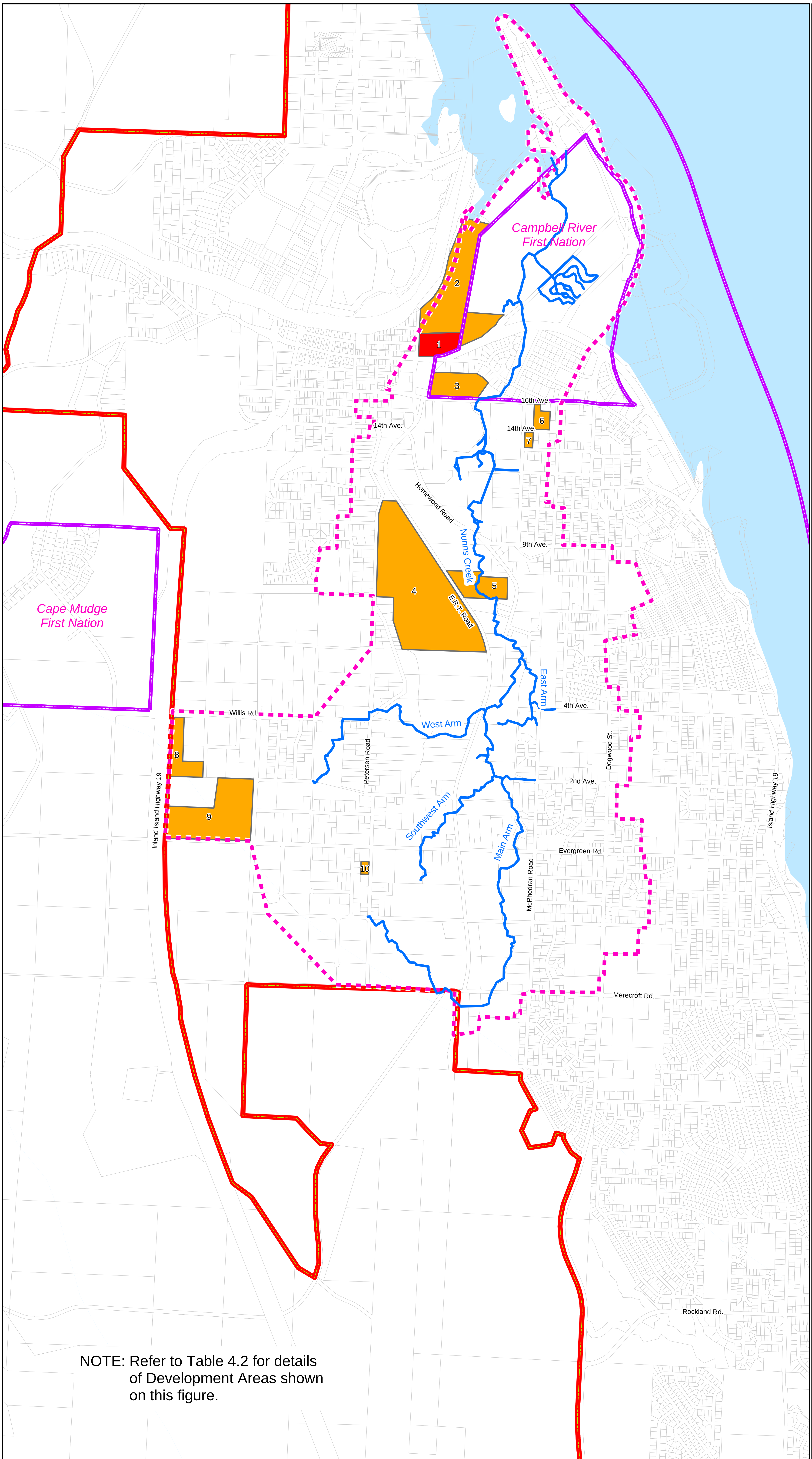

Figure 4.3

Nunns Creek Watershed

Probable Short Term Future Development

Commercial Dev.
Residential Dev.
Nunns Creek
Nunns Creek Watershed
District Boundary
Urban Containment Bdy.

0 200 400
Metres

Scale 1:20 000

Source: City of Campbell River

This map was prepared for the purposes of this planning study and are provided for general reference only. Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

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of the new development in the watershed will be residential[4]. In total, the watershed will likely need to accommodate an additional 64 ha of residential development and 9 ha of new commercial development in the short term (Table 4.2). In addition, the Nunns Creek Watershed is expected to experience infill development and re-development, which could also increase the overall density of development in the watershed.

Table 4.2
Areas of Short Term (1-10 years) Future Development Potential in the Nunns Creek Watershed

Development Area	Development Type	Total Area (ha)	Location
1	Commercial	2.89	1498 Island Highway
2	Residential	14.34	Along Campbell River, N. of 20th Ave.
3	Residential	4.18	16th Ave at Maple St.
4	Residential	29.18	Between Petersen & Elk River Rd.
5	Residential	4.04	Between Elk River Rd. & Homewood
6	Residential	1.09	840 14th Ave. and 1449 16th Ave.
7	Residential	0.40	1351 Ironwood St.
8	Residential	3.40	Inland Island Highway 19 at Willis Rd.
9	Residential	12.40	Inland Island Highway 19 at Evergreen
10	Residential	0.32	50 Peterson Rd. South

This short-term development will contribute an additional 30 ha of impervious area to the watershed (Table 4.3), which will represent an increase of 24% over the watershed's current total amount of impervious area (see Table 3.1).

4 Areas assignated for short-term development potential were established with input from the City's Development Liaison Group.

Table 4.3
Impervious Areas for Short Term Future Development

Development Type	Total Area (ha)	% Impervious*	Impervious Area (ha)
Residential	69.35	40	27.74
Commercial	2.89	90	2.60
		Total	**30.34**

** As per City of Campbell River design standards.*

4.5 Gaps in Land Use / Development Policy

To be most effective, integrated stormwater management policies should be implemented at regional, watershed, neighbourhood, and site planning scales. The City's Official Community Plan oversees development on a neighbourhood level and at times even at the regional and watershed levels, while the Zoning Bylaw controls development at the site level. To support an Integrated Stormwater Management Plan, the OCP and Zoning Bylaw should include provisions to:

- Limit sprawl
- Protect natural areas
- Reduce and/or disconnect impervious area
- Protect environmentally sensitive areas

This section reviews the City's Draft OCP and Zoning Bylaw to identify land use policy gaps relevant to stormwater management.

4.5.1 Official Community Plan

In general, the City's Draft OCP policies for the Nunns Creek Watershed reflect integrated stormwater management principles. The Draft OCP includes provisions to protect Environmentally Sensitive Areas by requiring Development Permits in specified Environmental Development Permit Areas, which include areas along watercourses and wetlands. As well, the Draft OCP's Nunns Creek Area Road and Greenways Plan supports infill and cluster development (though implementation on fee-simple land is effectively limited by current zoning), as well as medium density residential development. Together, these policies help limit impervious area, preserve natural areas, and protect environmentally sensitive areas, all of which are vital to the health of the watershed.

The City's Draft OCP also includes an Urban Residential Containment Boundary (URCB) to limit sprawl and concentrate residential development in areas within close proximity to public services. While the URCB will benefit other watersheds by limiting development in rural areas, because the Nunns Creek Watershed falls almost entirely within the boundary, the URCB will not protect the Nunns Creek Watershed from development pressures. However, the Draft OCP does designate most of the Nunns Creek Watershed for low density residential development, which should ensure development is somewhat limited.

While the Draft OCP is, in general, supportive of integrated stormwater management practices, the document fails to include measurable targets for preserving open space or limiting impervious area. The introduction of more specific measures (e.g. percentage of impervious area targets) could promote better stormwater management practices within the Nunns Creek Watershed.

4.5.2 Zoning Bylaw

Like the Draft OCP, in general, the City's Zoning Bylaw supports integrated stormwater management principles. The Zoning Bylaw helps limit impervious area by setting maximums for lot coverage and, in some zones, requiring a minimum amount of open space (which must be pervious). In terms of parking requirements, the City requires only one off-street parking space for single-family residences, which is a relatively low requirement and should help minimize impervious area. In addition, the Zoning Bylaw protects ESAs by prohibiting development within any streamside protection or enhancement area.

While the Zoning Bylaw includes several provisions that support integrated stormwater management, the City may consider improving its Zoning Bylaw by imposing more specific requirements to limit impervious area and protect open space. For example, the City could set maximums as well as minimum parking standards to limit the amount of impervious area, or require the use of pervious materials for off-street parking. The Zoning Bylaw could also extend impervious area limitations to all zones by including impervious areas in the calculation of lot coverage. Landscaping requirements could also be more specific regarding the use of pervious materials or could require more trees to be planted. The Zoning Bylaw could also specify density averaging options within select zones to promote cluster development. Furthermore, the Zoning Bylaw could be amended to enable cluster development for the area governed by the Nunns Creek Area Road and Greenways Plan.

Table 4.4 provides a summary of the City's OCP and Zoning Bylaw and identified gaps related to stormwater management within the Nunns Creek Watershed.

4.5.3 Other Bylaws

As permitted by the *Community Charter*, municipalities have the power to adopt a bylaw to regulate, prohibit and impose requirements in relation to trees. While these powers are subject to certain limitations, a tree protection bylaw can be an effective component of an integrated stormwater management plan. Protecting trees can prevent increases in stormwater flow, flooding, and erosion due to development. In general, a tree protection bylaw specifies circumstances in which trees may not be removed, and typically sets out requirements for obtaining a tree cutting permit. The City may consider adopting a tree protection bylaw to support their integrated stormwater management plan.

Table 4.4
Nunns Creek Watershed Land Use Policies and Gaps

Bylaw	Purpose	Provisions Supportive of Stormwater Management (applied within the Nunns Creek Watershed)	Identified Policy Gaps (recommended improvements)
Official Community Plan (Draft)	To direct future development in the watershed.	• Designation of residential densities discourages intense residential development. • Designation of Development Permit Areas for streamside areas protects ESAs – development permits require setbacks, planting of vegetation, registration of restrictive covenants, provision of works to protect ESAs, and requirement that discharge of stormwater not negatively impact adjacent water quality. • Residential land use designation supports cluster development. • The residential land use designation permits some medium density development and infill development. • The Nunns Creek Area Road and Greenways Plan encourages cluster development and density averaging as well as protection of ESAs.	• OCP does not include measurable targets for preserving open space or limiting impervious area.
Zoning Bylaw	To regulate the current use of land, at the site level, within the watershed.	• Most zones set maximums for lot coverage of all buildings. • Some zones include minimum requirements for usable open space. • Parking requirements – one off-site space for each single-family residence (low requirement decreases impervious area). • Prohibits development within any streamside protection and enhancement area – required streamside setbacks.	• No maximums on parking requirements. • Impervious area measures should extend to all zones. • Landscaping requirements (including tree protection provisions) could be more specific to support stormwater management principles. • Not all zones directly encourage cluster development. • Calculation of lot coverage should extend to impervious areas.

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5.0 CURRENT STORMWATER MANAGEMENT TOOLS

The City currently has a number of policy, management and regulatory "tools" available to address stormwater issues in the Nunns Creek watershed. These include the broad principles adopted in the Official Community Plan (OCP), as well as the City's various land use and development bylaws and engineering standards. In addition, management of stormwater is also addressed in and through provincial and federal laws and guidelines. In the following paragraphs, some of these tools are briefly discussed, highlighting potential avenues for better stormwater resource management. Of particular interest in this regard is the provincial "Environmental Best Management Practices" document described in Section 5.2.4; this document provides a much fuller and more complete discussion than can be provided in this brief chapter.

5.1 Municipal Level

5.1.1 Bylaws

Through its authority under the *Local Government Act* (see next section), the City has adopted a number of bylaws which have a direct impact on stormwater. While the OCP provides a framework for some aspects of stormwater management within the City, these bylaws regulate implementation on a routine basis. Critical bylaws include:

- **Building Bylaw** – regulates design and construction of structures within the City
- **Subdivision Bylaw** – regulates development within the City
- **Zoning Bylaw** – regulates the use of land and structures within the City
- **Frontage Improvement Bylaw** – Requires certain improvements to serve developments
- **Storm Drain System Connections Bylaw** – requires connection to storm drains, where available

The financing of stormwater improvements such as storm drains and regional detention ponds is also addressed in several City bylaws:

- Development Cost Charges Bylaw
- Frontage Improvement Bylaw
- Stormwater Management Parcel Tax Bylaw
- Local Improvement Charges Bylaw

The Stormwater Management Parcel Tax is an especially important tool for the City as it generates revenue that is designated exclusively for use in stormwater management. The tax is $12 per non-exempt parcel and is being assessed for only five years (2001-2005). With approximately 10,000 parcels in the City, the tax generates about $120,000 per year for stormwater management purposes.

5.1.2 Land Use Policies

The previous section of this report discussed the OCP in detail. One basic environmental principle is that in order for the "natural life support systems to remain healthy [the City] must reduce [its] negative impact on them." Several guiding principles for general community decision-making and governance outlined in the OCP may impact the way stormwater planning is approached:

- Balance between development and conservation
- cooperation between public and private sectors
- Proactive management of change
- Involved citizenship

5.1.3 Design Standards and Specifications

The City's Engineering Design Standards and Specifications are appendices to the Subdivision and the Frontage Improvement Bylaws. Together, they set standards for design and construction of infrastructure including roads and storm drains. For example, new roads in residential areas must have minimum pavement widths of 9.0 metres.

In addition, the City maintains a list of "approved products," such as manholes, catch basins and pipe that can be used to meet storm drainage needs of the area.

5.2 Provincial Level

5.2.1 Riparian Areas Regulation

The Provincial Riparian Area Regulation (RAR), enacted in July 2004, calls for local governments to protect riparian areas during urban development by ensuring that proposed activities are subject to a science-based assessment. The assessment is to be conducted by a Qualified Environmental Professional (QEP), serving as the consultant for the land developer. RAR is managed by the Ministry of Water, Land and Air Protection (MWLAP).

The RAR is intended to provide protection for the features, functions and conditions that are vital to the natural maintenance of stream health and productivity. This includes such things as:

- Large organic debris (fallen trees and tree roots)
- Areas for stream channel migration
- Vegetative cover to moderate stream temperature
- Provision of food, nutrients and organic matter to the stream
- Stream bank stabilization
- Buffers to prevent excessive introduction of silt and runoff pollution

The assessment methodology for streamside protection and enhancement areas are set forth in the RAR. The RAR does not apply to agriculture, mining or forestry-related land uses. Riparian protection for these activities is under separate initiatives.

Currently in Campbell River, a Memorandum of Understanding (MOU) among the City, MWLAP, and Fisheries and Oceans Canada (DFO), deals with activities in the riparian area. Since this MOU was signed under previous provincial streamside protection regulations, RAR has not been fully incorporated into the agreement.

5.2.2 Stormwater Guidelines

The Province recently released guidelines for stormwater control that encourages the use of an integrated approach to management planning. The guidelines are consistent with recent thinking and practice across North America about urban drainage. The guiding principles for integrated stormwater management, as set forth in the document "Stormwater Planning: A Guidebook for British Columbia" (May 2002), are:

- Agree that stormwater is a resource
- Design for the complete spectrum of rainfall events
- Act on a priority basis in at-risk drainage catchments
- Plan at multiple scales – regional, watershed, neighbourhood and site
- Test solutions and reduce costs by adaptive management

With respect to the second principle, the general approach advocated by the Guidelines is to:

- Capture rainfall from small storms on site for surface runoff volume reduction and water quality control
- Control runoff from larger storms to provide surface runoff rate reduction
- Manage flood risk from extreme storm events by providing peak flow conveyance

In the past stormwater management has focused almost exclusively on this final item, extreme event risk management. But from the standpoint of fisheries, for example, it is the small, frequent storms and water quality that are of much more interest.

One of the tools subsequently developed by the province (in partnership with the Fisheries and Oceans Canada and private sector participants) to assist with implementation of the guidelines is the so-called "Water Balance Model."

5.2.3 Local Government Act and Community Charter

In British Columbia, local governments acquire their powers from two pieces of provincial legislation: the *Local Government Act* and the recently introduced *Community Charter*. The *Community Charter*, which came into force on January 1, 2004, is intended to eventually replace the *Local Government Act*. However, at this time, the *Community Charter* contains only the core municipal provisions, while other provisions such as those related to planning and land use remain within the *Local Government Act*.

The *Local Government Act* allows local governments to enact various bylaws and policies that can affect stormwater management. Under the *Local Government Act,* municipalities have the power to enact the following types of policies:

- Regional growth strategies
- Official Community Plans
- Policies to prohibit pollution
- Soil deposit and removal controls (erosion control)
- Zoning
- Environmental policies
- Runoff controls
- Landscaping requirements
- Development permit area policies
- Subdivision servicing requirements

The *Local Government Act* also gives municipalities a number of other powers to manage stormwater less directly, through a variety of regulatory tools and policies such as building standards, development cost charges, development works agreements and tree protection bylaws.

5.2.4 Environmental Best Management Practices

In June 2004, MWLAP published a comprehensive guide to environmental practices for land development in British Columbia. The document, "Environmental Best Management Practices for Urban and Rural Land Development," is intended to provide guidance for sustaining environmental values during the land development process throughout the province. In overview, it discusses and provides links to the full range of provincial resource and environmental laws, regulations and guidelines for planning, implementing, reviewing and approving land development in BC. In addition, it also cross references many related federal level laws, regulations and guidelines.

Taking both a community and site level perspective, "Environmental Best Management Practices" describes objectives, requirements and best management practices for development with respect to such topics as:

- Environmentally sensitive areas
- Special wildlife and species at risk
- Aquatic and riparian ecosystems
- Pollution prevention

The section on pollution prevention includes discussions of water quality, spill containment and reporting, liquid waste, pesticides and groundwater, all of which have application to stormwater management.

Special areas of land development – mining, forestry and commercial agriculture in Agricultural Land Reserves – are specifically not covered, although many of the BMP's discussed in the document can also apply in these areas.

5.3 Federal Level

5.3.1 Land Development Guidelines

Fisheries and Oceans Canada (DFO) has recently updated their previous "Land Development Guidelines for the Protection of Aquatic Habitat" (originally issued in 1992 jointly with the BC Ministry of Environment, Lands and Parks, now MWLAP), with a guidelines document entitled "Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat" (draft, October 2004). Issued within DFO's broader mandate under the Federal *Fisheries Act*, these guidelines emphasize the critical role of source control and runoff reduction on protecting fish and fish habitat. It specifically notes the roles of several mechanisms for reducing the impact of urban runoff:

- Minimizing impervious areas
- Retaining runoff by infiltration (or long-term storage)
- Encouraging evapotranspiration through vegetation

It also notes the importance of minimizing or removing contaminants and pollutants from runoff.

To this end the DFO recommends a hierarchy of three site-based BMPs:

- *Reduce the volume of runoff* – Impervious area runoff from the 6-month 24-hour post-development storm event is not to be discharged; can be accomplished by:
  - Minimizing impervious area
  - Infiltration to ground
  - Evapotranspiration via vegetation, and/or
  - Long-term storage
- *Improve water quality of runoff* – Collect and treat the volume of the 24-hour precipitation equalling 90% of the total rainfall runoff from impervious areas; can be accomplished by:
  - Infiltration to ground, and/or
  - Treatment in constructed wetlands
- *Control runoff from larger storm events* – Restrict runoff from developed areas to match the volume, shape, and peak instantaneous rates of pre-development runoff for the 6-month, 2-year and 5-year 24-hour recurrence storm events; can be accomplished through detention and controlled release

Though site-based, DFO recognizes that all site-based BMP implementation must be placed in the context of watershed-wide planning in order to maintain and enhance overall watershed health.

5.3.2 Fisheries Act

The *Federal Fisheries Act* provides the basis for Fisheries and Oceans Canada (DFO) to carry out protection of fish and fish habitat. The *Act* itself addresses three primary areas of concern:

- Management and control of fisheries
- Conservation and protection of fish and protection of fish habitat
- Prevention of pollution

The *Act* applies to all fisheries waters throughout Canada, including private property in every province and territory. The *Act* applies both to waters with fish present as well as those that provide food and nutrients to fish-bearing streams. Specifically, Section 34 defines fish habitat as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly to carry out their life processes."

The key habitat protection provision of the *Act* (Section 35) states that "[n]o person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat" without proper authorization. Authorization can be given by the Minister or through regulations under the *Act*.

Clearly, urban development that impacts streams by, for example, altering flow regimes, introducing pollutants to streams or causing significant stream siltation fall could generate concern from the perspective of the *Fisheries Act*. For that reason alone, stormwater management takes on a critical function within local development process. The BMP guidelines described in Section 5.3.1 were developed as part of DFO's mandate under the *Act*.

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6.0 APPROPRIATE BEST MANAGEMENT PRACTICES

Communities and regions around North America have increasingly applied stormwater "best management practices" (BMP's) to mitigate the potential effects of land development on watersheds. Initially this was primarily done to reduce stormwater runoff peak rates, generally to a level occurring prior to development. Over the years, broader objectives have been assigned to BMP's. Specifically, the current ideal is to fully mimic the natural hydrology of an area and protect water quality as well. Thus BMP's may serve to reduce the peak rate of stormwater runoff, reduce the total volume of stormwater runoff, improve the water quality of the stormwater runoff or, typically, meet more than one of these objectives.

The realization among stormwater practitioners that it is important to control runoff at its source as well as deal with consequences of runoff has led to the development of a philosophy called Low Impact Development (LID). Although sometimes used nearly interchangeably, LID and BMP are not quite the same thing. They can, however, be complementary ways to address stormwater management. Some BMP's fit well within an LID approach and use of LID can reduce the size or need for large, often public, BMP's such as regional detention ponds. For purposes of this discussion, LID methods are included within the list of BMP's discussed below.

BMP's can generally be divided into three broad categories:

- Structural
- Non-structural / land use-oriented
- Operation and maintenance (O&M)

Structural BMP's are probably the most well-known type of stormwater treatment practices. Underground oil and grease traps, detention ponds and constructed wetlands are examples of structural BMP's. A properly designed and constructed roadside ditch, called a vegetated or bio-filter swale, can also be considered a structural BMP.

Non-structural BMP's generally do not involve such visible mechanisms but can be no less effective in addressing stormwater issues. They can range from providing land buffers around developed areas, to reducing the total allowed impervious area in developing areas, to public education.

Finally, O&M BMP's focus both on maintaining the long-term usefulness of structural BMP's as well as reducing the likelihood of stormwater causing problems. O&M BMP's include street cleaning, detection of contaminant spills, maintenance of vegetation in swales and catch basin cleaning.

BMP's can also be considered either temporary or permanent. Temporary BMP's are used during construction to control the acute conditions that occur when vegetative cover is removed and large areas of soil are directly exposed to rainfall. These BMP's generally focus on controlling soil erosion at the site and preventing subsequent downstream deposition of the sediments. Permanent BMP's are intended to remain in working condition for extended periods of time. They can fulfill multiple functions including reducing the rate and volume of runoff as well as improving the quality of the runoff.

There are also several types of in-stream BMP's that are useful for mitigating negative effects on the creek. Placing large woody debris in the channel corridor, establishing a riffle/pool configuration to reduce flow velocities or creating off-channel spawning areas are all examples of in-stream BMP's.

The following section discusses the types of BMP's that may be suitable for the Nunns Creek watershed on a watershed level approach. The remainder of the chapter outlines how the City could proceed with incorporating BMP's into the watershed and the types and sizes of BMP facilities that may be required.

6.1 Watershed Wide

The City's current engineering design standards indicate a preference for the use of regional wet detention ponds, designed in accordance with stormwater management plans. Where such facilities (existing or proposed) are unavailable, dry detention ponds, pipe-based detention or parking area and roof-top detention may be used. As an alternative to, or in conjunction with these traditional types of facilities, various BMP's could be used. Table 6.1 outlines some of the different BMP options which are available to address stormwater issues for various land use types.

Some of these BMP options are explained in further detail below.

Table 6.1
Potential Stormwater Issues and BMP Options for Various Land Uses

Best Management Practice	Scale				Primary Issue(s) Addressed			
	Site Level	Neighborhood Level	Watershed Level	Regional Level	Volume Control	WQ Control	Peak Control	Erosion Control
Structural BMPs								
Bioengineering Techniques	X							X
Biofiltration Swale (Bioswale)		X						
Constructed Wetlands		X	X		X	X		
Disconnect Impervious Areas	X	X			X			
Downspout Splashpads	X				X			
Dry Detention Pond		X	X				X	
Engineered / Amended Soils	X				X			
Grass Swale		X			X			
Green Roof	X				X		X	
Green Street		X			X	X		
Infiltation Trench	X	X						
Infiltration Basin	X	X			X	X		
Infiltration Basin		X			X	X		
Infiltration Swale		X						
Minimum Lawn Soil Depth	X				X	X		
Narrow Pavement Street		X			X		X	
Oil / Grit Separator	X					X		
Perforated Storm Sewer		X			X		X	
Planter Boxes	X				X			
Porous Pavement	X	X			X			
Porous Pavement	X	X			X			
Rain Barrel	X				X			
Rain Garden	X				X			
Rip Rap	X							X
Rock / Soakaway Pit	X							
Turf Reinforcement Mats	X							X
Underground Infiltration System	X				X			
Underground Tank / Vault	X						X	
Wet Detention Pond		X	X			X	X	
Non-Structural BMPs								
Early Revegetation of Cleared Sites	X							X
Maintain Riparian Corridors			X	X		X		X
Minimize Soil Compaction	X				X			X
Preserve Natural Drainage Features	X	X	X					
Protect / Retain Wetlands		X	X		X	X	X	
Public Education Programs			X	X	X	X	X	X
Retain trees at building sites	X				X			
Street Sweeping			X	X		X		

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6.1.1 Alternative Road Design Standards

The City's current practice for roadway urbanization is to infill the existing roadside ditches and install a storm sewer system. Runoff generated on the road surface is directed to the curb and gutter, where it then flows into a catch basin which is connected to the new storm sewer. The underlying intent of an urbanized roadway design is to convey runoff away from the road as soon as possible. This efficient method of drainage capture and conveyance has a detrimental impact on downstream watercourses, as both peak flows and volumes of runoff are significantly increased over the un-urbanized condition, where runoff had an opportunity to infiltrate or be attenuated in the roadside ditches. Stormwater quality also suffers as plants and soil no longer have an opportunity to filter out contaminants prior to discharge of runoff offsite.

A significant number of the roads in the Nunns Creek watershed have already been constructed with an urbanized cross section. However, there are opportunities to convert an existing urbanized road to a road using alternative standards, or to incorporate an alternative road design in future developments.

Rather than upgrading a road section to a typical urbanized section with curbs, gutters, catch basins and storm sewers, there may be an opportunity to implement alternative roadway design options for stormwater control, through the use of components such as porous pavements, vegetated swales, infiltration facilities and reduced impervious areas. These features have been used in other areas of the Pacific Northwest, most notably in Seattle, Washington as part of the Street Edge Alternative (SEA Street) program (photo above). However, some British Columbia municipalities are now trying these new techniques. For instance, the City of Vancouver is currently re-constructing a road using alternative design components in an area near the University of British Columbia (photo below right). This design includes extensive use of vegetated swales, infiltration facilities, landscaping features and offline detention / attenuation areas. Designs like this not only provide

an opportunity to mimic the natural hydrologic regime of the site, they are also aesthetically pleasing, provide traffic calming measures and are promoted as a community amenity.

Similar opportunities for infiltration and attenuation of flows can be implemented in higher density areas, such as in parking lots, multi-family residential or commercial areas. This parking lot at UBC incorporates an underground infiltration gallery with perforated pipe system to promote infiltration into the native subgrade below prior to discharge to the offsite storm sewer system (photo at left). Surface runoff flows overland to the vegetated swale, where water then seeps into the infiltration gallery below. Another option is the use of porous paving materials, such as porous asphalt, porous concrete or porous paver block systems. All three types of materials allow stormwater to seep through the pavement structure into the underlying native subgrade or infiltration gallery beneath. Currently, only limited use of porous pavements has been seen in British Columbia, however, the City of Portland, Oregon has been using porous pavements extensively for several years (photo below). Both the City of Burnaby and the City of White Rock are currently in the process of designing roads which incorporate porous pavements, along with some of the other features discussed above.

Overall, the application of alternative roadway components mainly depends on the characteristics of the site and local soil conditions. However, even if infiltration is not possible due to poor soil conditions, stormwater attenuation and water quality treatment through the use of alternative roadway design components can still go a long ways towards improving the health of the downstream watercourse.

6.1.2 Water Quality

Water quality in the Nunns Creek watershed is of particular importance as there are several storm sewer outfalls which convey runoff from developed areas directly to the creek with no opportunity for water quality treatment prior to discharge. This is especially an issue in the lower reaches of the watershed, where most of the existing development is situated. There are opportunities to retrofit existing storm sewer outfalls with water quality treatment devices to remove sediments, oils and grease, before runoff is discharged to the creek. There are also other non-structural techniques which could be implemented for water quality improvement, such as the construction of bioswales at storm sewer outfalls which could incorporate native plantings and/or soil amendments to encourage plant and soil uptake of pollutants.

6.1.3 Erosion and Sediment Control Practices

The current state of erosion and sediment control (ESC) practices on construction sites has been a recurring topic mentioned by the City, the stakeholders and the public throughout the ISMP process. While, in general, developers are fairly diligent about implementing and operating ESC works, the function of these facilities tends to diminish once the land has been transferred to individual builders. The City has some grounds to enforce ESC on the developer through the maintenance period in their contract, however, it is often difficult to enforce to the same standard on the builders themselves. Long-term maintenance of ESC works, restoration of disturbed areas and lack of enforcement appear to be the main issues and minimization of cleared areas, source control measures and timing of implementation of ESC works within the construction framework should be stressed by the City.

6.2 Strategy for Incorporation of Best Management Practices

In addition to the action options that can generally be implemented by the City now, there are a number of management and policy options that could be adopted as well. These would focus on avoiding and mitigating future impacts of new development (including redevelopment) on the drainages and the fish habitat within them. They range from the fairly common (e.g., establishing a ditch maintenance program) to the more progressive (e.g., capturing on site the total volume of rainfall from the Mean Annual Rainfall event).

The City currently has obligations to maintain various drainage facilities. But shifting from a flood and erosion avoidance mode of drainage control to an integrated stormwater approach will require more attention to management issues and finding dedicated funds to pay for public stewardship of the stormwater systems. Many municipalities in North America have adopted a stormwater utility approach to handling these issues. Among other things, this typically requires identifying which aspects of an area's stormwater systems are to be included in public care and then establishing a mechanism for generating funds.

6.3 Public versus Private Facilities

Some BMP's are best owned and maintained by the public, that is, the City. This can guarantee that the facility is properly maintained, repaired or upgraded as needed. Detention ponds serving large tracts of land are an example of a publicly-owned stormwater facility. Similarly, street sweeping is an activity generally suited for handling by a public agency (e.g., public works department).

Other BMP's are better suited for private construction and ownership, often because they are located on private property or are designed to serve only a small land area. Examples include roof-top gardens and bioretention areas. Sometimes a combination works, for example, a pond may be built by a private developer, but later maintained by the City.

6.4 Large Scale versus Small Scale Facilities

BMP's can be either large in scale (e.g. regional detention facility) or small in scale (e.g. onlot infiltration basin). A concentration of several small scale BMP's can also be considered equivalent in effectiveness and impact to a large scale BMP. While both small and large scale BMP's can be effective in controlling stormwater, the point at which they contribute to the drainage system usually differs. Often, a small scale BMP can be considered as an "at the source" application whereas a large scale BMP is often an "end of pipe" application.

Large scale BMP's are often publicly owned and tend to have a better history of long-term maintenance, partly because municipalities have more experience in maintaining large scale facilities and partly because they are more "visible" to the public, thus complaints are more frequent. Since small scale BMP's tend to be privately owned, long-term maintenance can be difficult for the City to control. On the other hand, the impact that BMP's have on the watershed if they fail can be vastly different. For example, a regional detention facility failure can have serious implications on the entire watershed, however, if an infiltration basin on one property fails, the overall impact to the watershed is likely to be fairly minimal. In addition, consistent with the general objective of mimicking natural hydrology, numerous small scale systems are more diffuse and thus avoid concentrating infiltration and runoff.

Large scale facilities need to be evaluated carefully, since there may be negative synergies among several facilities within the same watershed. For example, by delaying the time to peak flows, detention ponds may inadvertently yield worse floods below unregulated tributaries. This highlights the importance of watershed-scale continuous modeling in order to effectively locate and size detention facilities.

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7.0 HYDROLOGIC / HYDRAULIC MODELING AND ANALYSIS

7.1 Rainfall Analysis

The following rainfall analysis was previously completed as part of the ISMP studies prepared by Urban Systems in 2004 for the Holly Hills / Perkins Road drainages in North Campbell River. This rainfall analysis is also valid for the Nunns Creek ISMP.

Precipitation in Campbell River is typical of the area, with most falling in the form of rain. The average annual rainfall is 1335 mm per year, with snowfall averaging only about 110 mm/year. The monthly distribution of this rainfall over the course of a year is shown below in Figure 7.1. From 36 years of record at the Campbell River Airport (1965 through 2000), the Mean Annual Rainfall (MAR) storm event is 55 mm per day. Rainfall events tend to be of long duration but relatively low intensity. Over the period of record, about 95% of all rainfall events in the City yielded total rain amounts of less than half the MAR, or 27.5 mm, while only 0.4% exceeded the MAR. This is typical for areas within coastal British Columbia (See Figures 7.2 and 7.3).

Figure 7.1
Typical Annual Rainfall Pattern

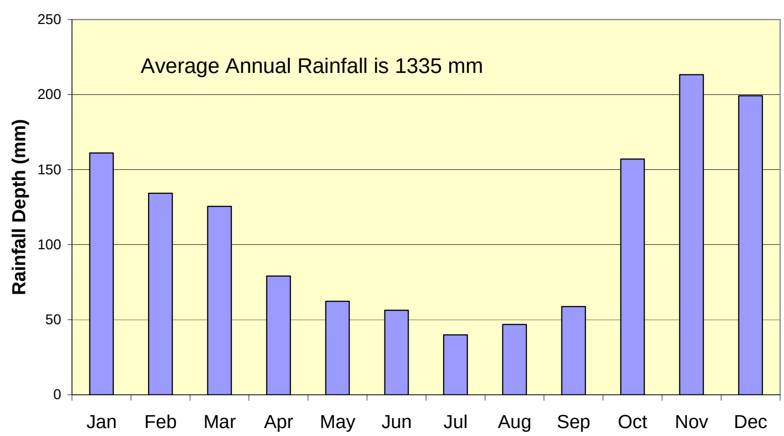


Figure 7.2
Typical Annual Volume Distribution of Rainfall

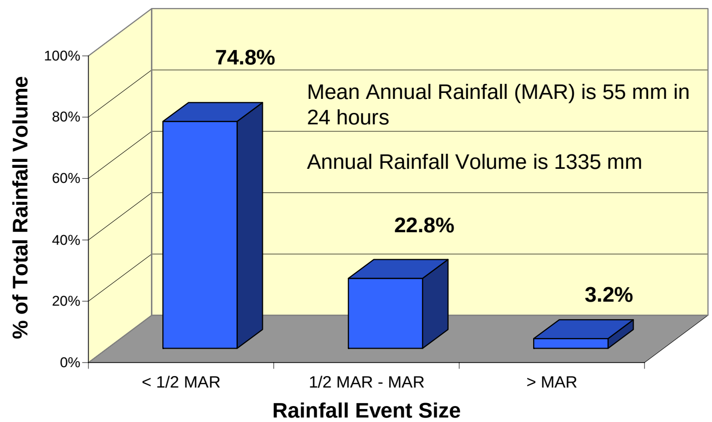
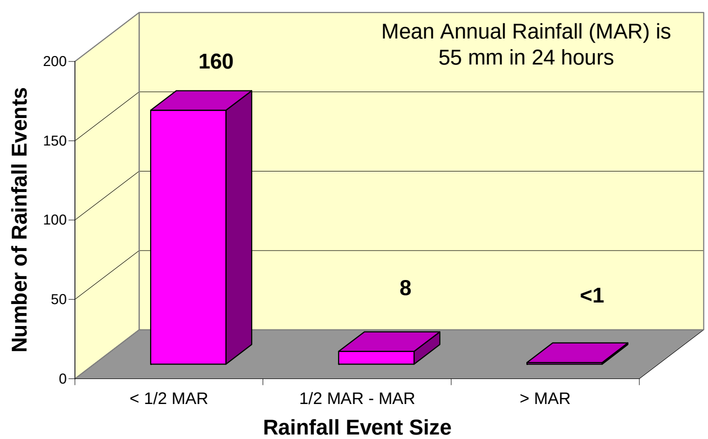


Figure 7.3
Typical Annual Frequency Distribution of Rainfall



The rainfall record is of insufficient length to firmly estimate the most extreme storm event conditions, such as the 100-year recurrence storm[5]. However, based on the records at the airport, Table 7.1 shows the estimated peak 12-hour and 24-hour rainfall depths for various recurrences:

5 The 100-year recurrence event is a storm anticipated to occur on average once in 100 years or, put another way, it is a storm with a 1% chance of occurring in any year. Similarly the 2-, 5- 10- and 25-year recurrence events have 50%, 20%, 10% and 4% chances, respectively, of occurring in any year.

Table 7.1
Design Storm Rainfall Depths

Recurrence (Year)	12-Hour Rainfall Depth (mm)	24-Hour Rainfall Depth (mm)
2	44	52
5	53	65
10	59	74
25	64	84
100	78	100

One of the concerns expressed by the Stakeholders Working Group and by City staff was the potential variation in rainfall patterns within the extent of the overall study area. This is commonly known as a "micro-rainfall" climate. In response to this, rainfall information from the Campbell River Airport and Campbell River Sewage Treatment Plant stations was obtained and reviewed. The Campbell River Airport station is located in the Willow Creek watershed at an elevation of 103.0 metres, whereas the Sewage Treatment Plant station was located in the downtown harbour area at an elevation of 3.0 metres. Rainfall data from the Campbell River Airport is typically used for estimating peak flows within the city, however, most of the development in the region is situated at a lower elevation than the airport station. Our review of the rainfall data (daily precipitation depths as well as IDF curves prepared by Environment Canada) indicated that there was no appreciable difference in the rainfall data between the two stations. As such, the Campbell River Airport rainfall data was used exclusively in the hydrologic modeling for this study, as it has a longer and more current period of recorded data than the sewage treatment plant.

7.2 Model Development

The hydrologic and hydraulic modeling for this study was performed using the XPSWMM software package. This package is capable of incorporating infiltration and groundwater recharge conditions within it, as well as modeling the hydraulic conditions of both closed pipes and open streams. XPSWMM models can be calibrated to available pipe and stream flow data, as well as simulate both "event storms" and "extended period" conditions[6]. At this time, modeling is being performed on "event storms" only in Nunns Creek. While continuous modeling is possible, it was the project team’s assessment that the lack of continuous rainfall data (i.e. rainfall in increments of 1 hour or less) and of corresponding field measured continuous flow data would limit the value of such simulations.

Hydrologic parameters, such as sub-catchment areas, widths and slopes, were calculated using available contour information and TRIM mapping. Levels of imperviousness in each sub-catchment were estimated from the 2002 aerial photographs supplied by the City. Impervious levels were calculated for representative "blocks" of each type of land use in the catchment, which were then extrapolated to cover the entire watershed area.

Infiltration parameters were based on either a well drained clay loam or poorly drained silty clay soil type. The locations of both types of soils in the watershed were based on the hydrogeological results from this IMSP study. A nearly saturated soil state was entered as the initial condition in the model to simulate winter conditions. The groundwater module in XPSWMM was not used in the simulation, as there are several parameters in the groundwater module which require extensive monitoring and testing to ascertain.

Information related to the municipal drainage infrastructure was obtained from the City in order to establish hydraulic parameters. Data provided included:

- Sizes, slopes, lengths, invert elevations, material types and locations for most existing storm sewers
- Locations and invert elevations of manholes
- Locations of culverts
- Locations of roadside ditches
- Locations of watercourses and tributaries
- Available as-built information for existing ponds and detention facilities

The following data was missing from the City's database:

- As-built information for some existing storm sewers
- Manhole rim elevation
- Creek cross sections, invert elevations and Manning's roughness factors
- Culvert sizes and invert elevations
- Wetland locations and capacities
- Some as-built information for existing ponds and detention facilities

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[6] Event modeling is based on a simulation with a prescribed rainfall depth, storm duration and rainfall distribution, whereas extended period is based on a real-time set of continuous rainfall data obtained from a local rain gauge.

A skeletonized, or simplified, model was developed for the watershed. This process simplifies the system sufficiently for modeling purposes by eliminating smaller pipes and channels from the model without compromising the results. The main criteria used for skeletonizing the model are summarized below:

1. Storm sewers which were 300mmØ or smaller were not modeled.
2. All of the storm sewer outfalls shown on City's database to the creek were modeled.
3. Detention ponds were modeled based on as-built drawings.
4. Creek cross-sections were modeled where surveyed data was available (e.g. 2004 HEC-RAS model for the Lower Nunns Creek).

A plan view of the XPSWMM model schematic for the Nunns Creek watershed is shown in Figure 7.4.

As noted earlier, there may be some existing detention facilities in the watershed which were not included in the model as there was insufficient as-built information available. Table 7.2 lists the known detention facilities in the watershed and indicates whether they have been included in the model.

Table 7.2
Existing Stormwater Detention Facilities in the Nunns Creek Watershed

Detention Facility ID	Location	Comments	Modelled?
4	S. McPhedran / Merecroft	As-built drawings provided	Yes

Other small ponds and wetlands-like areas may still be scattered around the watershed on individual lots[7]. For example, one member of the Stakeholders Working Group noted that her property has just such a private pond and wetland complex. These small pond/wetland features are important to the overall health of the watershed. However, there was insufficient data to include them in the modeling performed for this report.

Table 7.3 shows the inventory of culverts that were used in the XPSWMM model.

[7] An inventory of these small, privately owned features was beyond the scope of this project.

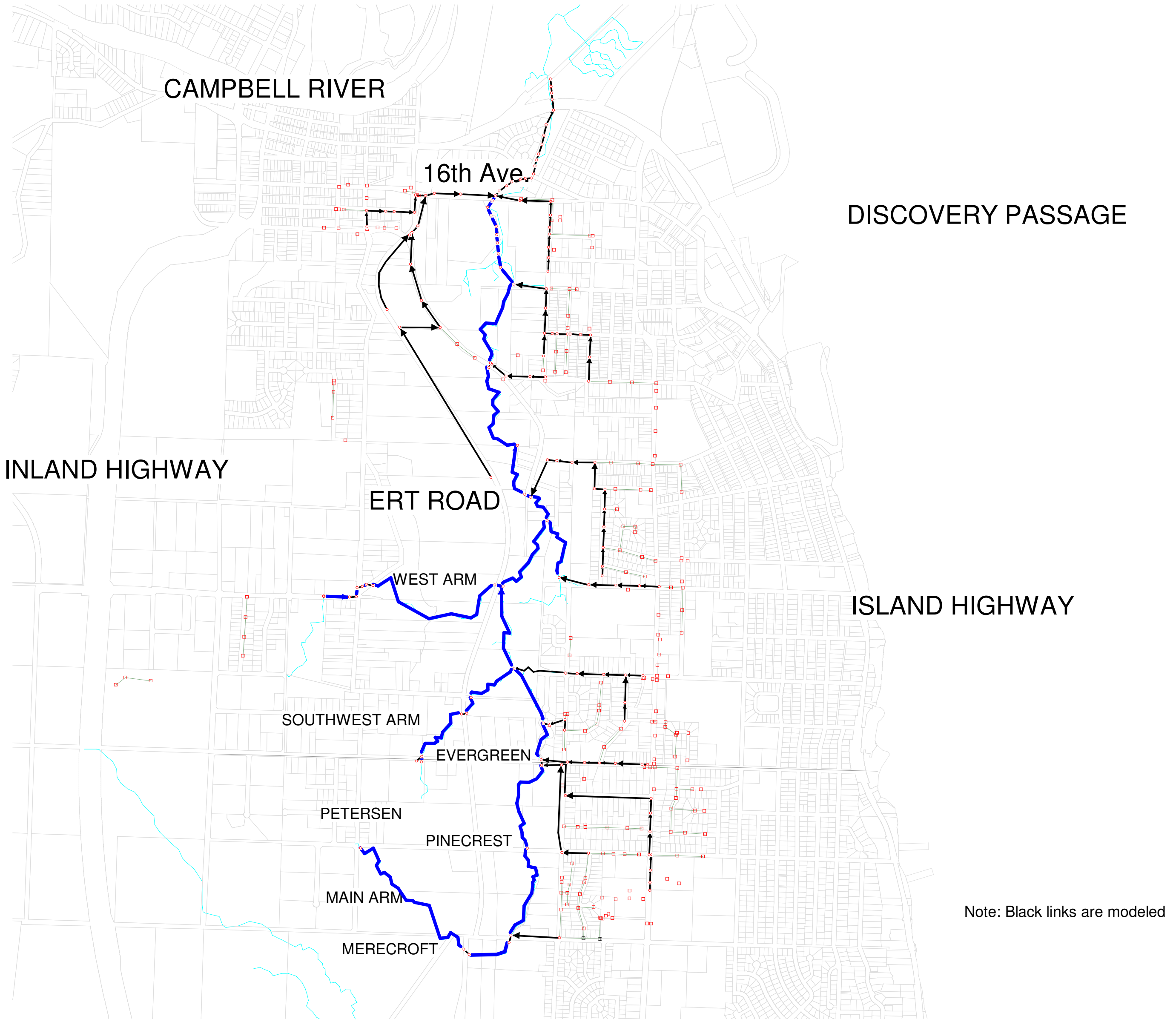
Table 7.3
Modeled Culverts in the Nunns Creek Watershed

Model Link ID	Location	Size (mm) / Type
192	Trask Road	300 PVC
194	Merecroft Road	2 – 750 CSP
137	Evergreen Road – east	1500 CSP
176	Evergreen Road – west	450 CSP
209	Evergreen Road – west	600 CSP
178	ERT Road – south	2 – 900 CSP
206	Willis Road – north	900 PVC
172	Petersen Road	1200 CSP
204	Old Petersen Road	1800 CSP
168	ERT Road – north	2000 x 1000 Steel Box
162	Homewood Road	900 & 1300 CSP
201	16th Avenue	2 – 1800 x 1200 Conc. Box
236	Old Highway	2 – 2000 x 1600 CS Arch
239	Inland Highway	2 – 1820 Conc.

7.3 Model Assumptions

The following is a list of the assumptions that were made in the development of the XPSWMM model:

- Manhole rim elevations were estimated based on one of the following methods: contour mapping, field survey or were assumed to be 2 metres above the storm sewer invert at the manhole junction
- Creek cross-sections were based on the 2004 Lower Nunns Creek HEC-RAS model or on field measurements done for this project
- The creek profile slope was assumed to be linear between the upstream and downstream culvert invert elevations (culvert invert elevations were surveyed)
- Culvert sizes at road crossings were based on field measurements
- Manning's roughness factors were estimated based on visual observations and photographs



SWMM	Figure 7.4 - Nunns Creek XPSWMM Model Schematic	05/24/05
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- Wetland areas were approximated based on the GIS wetland layer and aerial photography and were accounted for in the hydrologic model as a storage node with a high pervious Manning's roughness factor to simulate attenuation
- Multiple wetlands in any given sub-catchment were modeled as a single wetland with a total area equal to the sum of the multiple wetland areas
- Existing ponds and other detention facilities with insufficient as-built information were assumed not to exist or otherwise not be functional
- Sub-catchment boundaries were based on available contour information and ditch locations in rural areas, or on the storm sewer configuration in urban areas

7.4 Sensitivity Analysis

The sensitivity analysis is a tool used to understand the reliability of the model output and to identify those parameters most critical to the modeling process. The former is especially important since at this time we are not building calibrated models and are only using "event storm" simulations, not "continuous" modeling.

For the sensitivity analysis, both hydrologic and hydraulic parameters were varied by plus and minus 20%. Each parameter was varied in isolation (i.e. all of the other parameters were kept constant) so that the true sensitivity to each individual parameter could be determined. The hydrologic parameters were varied under both "summer" and "winter" regimes, assuming that the soils were fully available for infiltration during summer conditions and were essentially saturated under winter conditions. This was done to better understand the degree of sensitivity of other hydrologic parameters if the soil conditions were already saturated at the start of a rainfall event during the winter season.

The base conditions values, where applicable, for some of the hydrologic and hydraulic parameters are summarized in Table 7.4. The sensitivity analyses for hydrologic parameters are shown in Table 7.5 and Table 7.6 for summer and winter conditions, respectively. Table 7.7 summarizes the sensitivity analysis for hydraulic parameters.

Table 7.4
Base Condition Values of Hydrologic / Hydraulic Parameters

Hydrologic Parameter	Base Value	Hydraulic Parameter	Base Value
Impervious Depression Storage (mm)	0.5	Pipe Roughness Coefficient (Concrete)	0.013
Pervious Depression Storage (mm)	5.0	Open Channel Roughness Coefficient	0.045
Impervious Manning's "n"	0.011	Contraction / Expansion Loss Coefficient	0.2
Pervious Manning's "n"	0.18	Entrance / Exit Loss Coefficient	0.5 / 1.0
Average Capillary Suction (mm)	250	Boundary Water Surface Condition at Discovery Passage (m)	1.4
Initial Moisture Deficit (m/m)	0.005	-	-
Saturated Hydraulic Conductivity (mm/hr)	1.5	-	-

Table 7.5
Sensitivity Analysis on Hydrologic Parameters (Summer Conditions)

Parameter	Change to Peak Flow		Degree of Sensitivity	Change to Volume		Degree of Sensitivity
	+20%	-20%		+20%	-20%	
Total Area (ha)	+20.7%	-20.8%	High	+20.5%	-20.4%	High
Impervious Area (%)	+9.1%	-9.5%	Medium	+16.0%	-16.2%	High
Catchment Width (m)	+0.6%	-1.0%	Low	+0.4%	+0.6%	Low
Catchment Slope (m/m)	+0.3%	-0.5%	Low	+0.2%	-0.3%	Low
Impervious Depression Storage (mm)	0.0%	0.0%	Low	-0.9%	+0.9%	Low
Pervious Depression Storage (mm)	-5.4%	-0.1%	Medium	-4.4%	+4.5%	Medium
Impervious Manning's "n"	0.0%	0.0%	Low	0.0%	0.0%	Low
Pervious Manning's "n"	-0.8%	+0.7%	Low	0.0%	0.0%	Low
Average Capillary Suction (mm)	-12.5%	+6.2%	High	-6.7%	+8.1%	Medium
Initial Moisture Deficit (mm)	-27.8%	+15.6%	High	-10.7%	+15.2%	High
Saturated Hydraulic Conductivity (mm/hr)	-12.5%	+6.3%	High	-6.7%	+8.1%	Medium

Table 7.6
Sensitivity Analysis on Hydrologic Parameters (Winter Conditions)

Parameter	Change to Peak Flow		Degree of Sensitivity	Change to Volume		Degree of Sensitivity
	+20%	-20%		+20%	-20%	
Total Area (ha)	+22.8%	-22.9%	High	+21.3%	-21.2%	High
Impervious Area (%)	0.0%	-1.2%	Low	+0.8	-1.2%	Low
Catchment Width (m)	+2.4%	-3.6%	Medium	+1.1%	-1.5%	Low
Catchment Slope (m/m)	+1.3%	-1.7%	Low	+0.6%	-0.7%	Low
Impervious Depression Storage (mm)	0.0%	0.0%	Low	-0.7%	+0.7%	Low
Pervious Depression Storage (mm)	-2.5%	+2.0%	Medium	-3.7%	+3.7%	Medium
Impervious Manning's "n"	0.0%	0.0%	Low	0.0%	0.0%	Low
Pervious Manning's "n"	-2.8%	+2.8%	Medium	-1.2%	+1.3%	Low
Average Capillary Suction (mm)	-0.8%	+0.8%	Low	-1.1%	+1.2%	Low
Initial Moisture Deficit (mm)	-3.9%	+3.8%	Medium	-5.5%	+5.8%	Medium
Saturated Hydraulic Conductivity (mm/hr)	-0.8%	+0.8%	Low	-1.1%	+1.2%	Low

Table 7.7
Sensitivity Analysis on Hydraulic Parameters

Parameter	Change to Peak Flow		Degree of Sensitivity	Change to Volume		Degree of Sensitivity
	+20%	-20%		+20%	-20%	
Pipe Roughness Coefficient	-2.1%	+1.9%	Low	-1.1%	+0.4%	Low
Open Channel Roughness Coefficient	-1.4%	+1.8%	Low	0.0%	0.0%	Low
Contraction / Expansion Loss Coefficient	0.0%	0.0%	Low	0.0%	0.0%	Low
Entrance / Exit Loss Coefficient	-0.4%	+0.4%	Low	-0.1%	+0.1%	Low
Detention Volume (m^3)	-0.2%	0.0%	Low	0.0%	0.0%	Low
Boundary Water Surface Condition (m)	-0.2%	0.0%	Low	0.0%	+3.8%	Low

As indicated in Table 7.5, besides the obvious parameters of total area and impervious area, there are several hydrologic parameters which exhibit a high degree of sensitivity under summer conditions. However, if saturated soil conditions are assumed for winter conditions, the degree of sensitivity of some hydrologic parameters decreases, as shown in Table 7.6. This is due to the fact that pervious areas in the watershed are now functioning essentially as impervious areas, as the soils are no longer available for infiltration.

While the summer condition scenario is useful for evaluating sensitive parameters for base flow conditions and fisheries purposes, a winter condition analysis is generally more useful for sizing drainage infrastructure and determining detention requirements. Further monitoring and analysis on hydrologic parameters that exhibit a medium or high degree of sensitivity should be undertaken in the future as they will have an appreciable impact on the overall model results. In general, model response to hydraulic parameters does not appear to be critical for estimating runoff peaks or volumes.

7.5 Existing Conditions Hydrology

Using the "base condition" hydrologic and hydraulic parameter values, the XPSWMM model was run under a variety of storm events to establish existing peak flows at several locations in the watershed. The locations were generally chosen to coincide with confluences of tributaries or with major road crossings. Table 7.8 summarizes peak flows in the Nunns Creek watershed based on the XPSWMM model results.

Table 7.8
Peak Flows in Nunns Creek for Existing Development Conditions

Location	Peak Flow (m^3/s) *				
	2 Year	5 Year	10 Year	25 Year	100 Year
Evergreen Road	1.35	1.92	2.24	2.64	3.14
2nd Avenue	2.07	3.13	3.71	4.50	5.40
4th Avenue	2.48	3.79	4.54	5.55	6.81
Otter Road	3.11	4.61	5.43	6.47	7.75
Homewood Road	3.28	4.90	5.79	6.42	6.97
16th Avenue	4.29	5.77	6.50	7.22	7.66
Island Highway	4.03	5.28	5.91	6.66	7.18

* Based on a 4-hour storm duration

Peak flows below Homewood Road fluctuate for larger storm events because the model indicates that flooding will occur downstream of this location beyond the 2-year storm event. The model has not been configured to reintroduce this lost water back into the drainage system.

7.6 Impacts of Unmanaged Future Development

In order to simulate short-term future development conditions, the project team met with City staff and the Development Liaison Group to determine which areas in the watershed were most likely to develop over the next ten-year period. These areas are shown in Figure 4.3. For the purposes of this study, it was agreed that the ten-year period would be used to represent future short-term development conditions.

Short-term future potential development areas were added to the XPSWMM model and the design storm events were rerun to determine the impact on peak flows in Nunns Creek. The development areas were added to the model with no effort to increase attenuation or infiltration of runoff, or to address hydraulic capacity issues in the municipal storm sewer system. These simulations represent an "unmanaged", or worst case, future condition. Resultant peak flows are summarized in Table 7.9.

Table 7.9
Peak Flows in Nunns Creek for Short-Term Future Development Conditions (Unmanaged)

Location	Peak Flow (m^3/s) *									
	2 Year	% Incr.	5 Year	% Incr.	10 Year	% Incr.	25 Year	% Incr.	100 Year	% Incr.
Evergreen Road	1.35	0.0	1.92	0.0	2.25	0.0	2.64	0.0	3.14	0.0
2nd Avenue	2.24	8.2	3.36	7.2	4.01	8.2	4.83	7.4	5.62	4.0
4th Avenue	2.70	8.8	4.08	7.7	4.92	8.4	5.98	7.9	7.16	5.0
Otter Road	3.32	6.8	4.94	7.1	5.90	8.6	7.08	9.3	8.26	6.6
Homewood Road	3.51	6.9	5.24	7.0	6.17	6.5	6.64	3.5	6.98	0.2
16th Avenue	4.52	5.4	6.09	5.6	6.96	7.0	7.46	3.3	7.83	2.1
Island Highway	4.29	6.5	5.63	6.7	6.34	7.3	7.01	5.2	7.40	3.2

* Based on a 4-hour storm duration

As shown in Table 7.10, increases in peak flows at the Island Highway are expected to range from 3.2% to 7.3% if the short-term future development is implemented and not managed properly. Modeling results indicate that the magnitude of the peak flow decreases slightly for the 100-year event. The decrease is likely due to the fact that the model has insufficient detail to accurately track water over the entire simulation and therefore minor inaccuracies are introduced in the results. This typically only occurs during extreme rainfall events, such as the 100-year storm.

For comparison purposes, the XPSWMM model was then used to simulate full build-out conditions, as designated by the OCP. As indicated on Table 7.10, this level of development will have a significant impact on the watershed if development is allowed to proceed in an unmanaged fashion.

Table 7.10
Peak Flows in Nunns Creek for Full Build-out Conditions (Unmanaged)

Location	Peak Flow (m^3/s) *									
	2 Year	% Incr.	5 Year	% Incr.	10 Year	% Incr.	25 Year	% Incr.	100 Year	% Incr.
Evergreen Road	1.81	34.6	2.36	22.9	2.65	18.1	2.98	12.8	3.36	7.0
2nd Avenue	3.11	50.5	4.3	37.3	4.95	33.4	5.5	22.3	6.06	12.2
4th Avenue	4.09	65.1	5.66	6.6	6.57	44.9	7.42	33.8	8.13	19.3
Otter Road	4.88	56.8	6.66	34.1	7.63	40.5	8.53	31.8	9.24	19.3
Homewood Road	5.09	55.1	6.35	29.7	6.77	16.8	6.97	8.7	6.98	0.2
16th Avenue	5.83	35.8	7.15	24	7.54	15.9	7.8	8.1	7.89	2.9
Island Highway	5.4	34	6.64	25.8	7.07	19.7	7.35	10.4	7.56	5.4

Any increase in peak flows, regardless of the magnitude, from current to future conditions will have a detrimental impact on both the stability of the creek itself as well as its fisheries habitat. Some localized sites within the creek would likely be harder hit than others, particularly if those sites are already showing signs of degradation under current conditions.

7.7 Impacts of Management Strategies

There are a variety of management strategies that can be implemented to mitigate the effects of future development in the watershed. The results of implementing strategies such as improvements to the municipal storm sewer system, providing additional detention facilities and incorporating best management practices are discussed in Section 9.

8.0 ISSUES AND CHALLENGES

8.1 Identification Criteria

Information provided by the City and the stakeholders working group, together with the modeling results, were used as the primary means of identifying issues in the watershed. These issues were considered to be of utmost importance to address in the ISMP study. Other anecdotal information and complaints from residents were viewed as a secondary source for identification of issues.

Through consultation with the City and the stakeholders working group, the project team identified the following issues to address in the Nunns Creek watershed:

a) Establishment / maintenance of year-round baseflows

b) Maintenance / enhancement of existing upland wetland areas

c) Lack of detention facilities (particularly in areas of existing development and in lower reaches)

d) Performance of the existing detention facility (flow-thru time, volume capacity)

e) Localized erosion issues due to watercourse constrictions and realignments;

f) Locations and conditions of existing outfalls to creeks

g) Long-term maintenance of municipal drainage infrastructure

h) Long-term degradation of riparian corridors (loss of large woody debris and instream cover, encroachment by development)

i) Barriers to fish passage (e.g. culvert restrictions) and degradation / absence of spawning areas (e.g. siltation in lower reaches)

j) Presence of native species, such as birds, frogs and beavers

k) Mitigation of invasive plant species

l) Vegetation retention during development

m) Sediment control practices on construction sites and rate of vegetation re-establishment

n) Water quality

o) Establishment of a practical and effective flow monitoring program

p) Public education, outreach and support mechanisms

q) Undefined floodplains resulting in flooding in lower reaches;

r) Tidal influences on the watercourse

s) How to address future development in each watershed (e.g. use of best management practices and/or low impact development techniques)

t) How to implement / enforce recommendations from ISMP (e.g. new / revised bylaws and municipal standards, staffing implications for City for monitoring / inspection / enforcement, funding sources, etc)

Modeling results also identified several areas of the municipal drainage system which were undersized based on the City's design criteria. Municipal system deficiencies are described in further detail below.

8.2 Municipal System Deficiencies

The municipal drainage system is based on two levels of design criteria. Municipal storm sewers which service residential areas must be designed to safely convey the 5-year rainfall event, whereas commercial and industrial areas require a 10-year level of service.

Based on this design criteria, the model indicates that there are several storm sewers in the Nunns Creek watershed which are undersized for the 5-year design event. When the 10-year event was run, the magnitude of surcharging and flooding in these sewers increased, however, there were no additional pipes identified within commercial and industrial areas beyond those already shown under the 5-year event. Table 8.1 lists the municipal storm sewers which appear undersized for existing development conditions in the Nunns Creek watershed. The locations of these pipes are also shown graphically in Figure 8.1. If the flooded sewers shown in Table 8.1 are upgraded, in many cases the downstream sewer then becomes a bottleneck, resulting in additional flooding downstream. Thus, if the City wishes to upgrade flooding sewers in the watershed, it should be noted that there will be additional sewers to upgrade beyond those shown on Table 8.1. These additional sewers are shown on Table 10.1.

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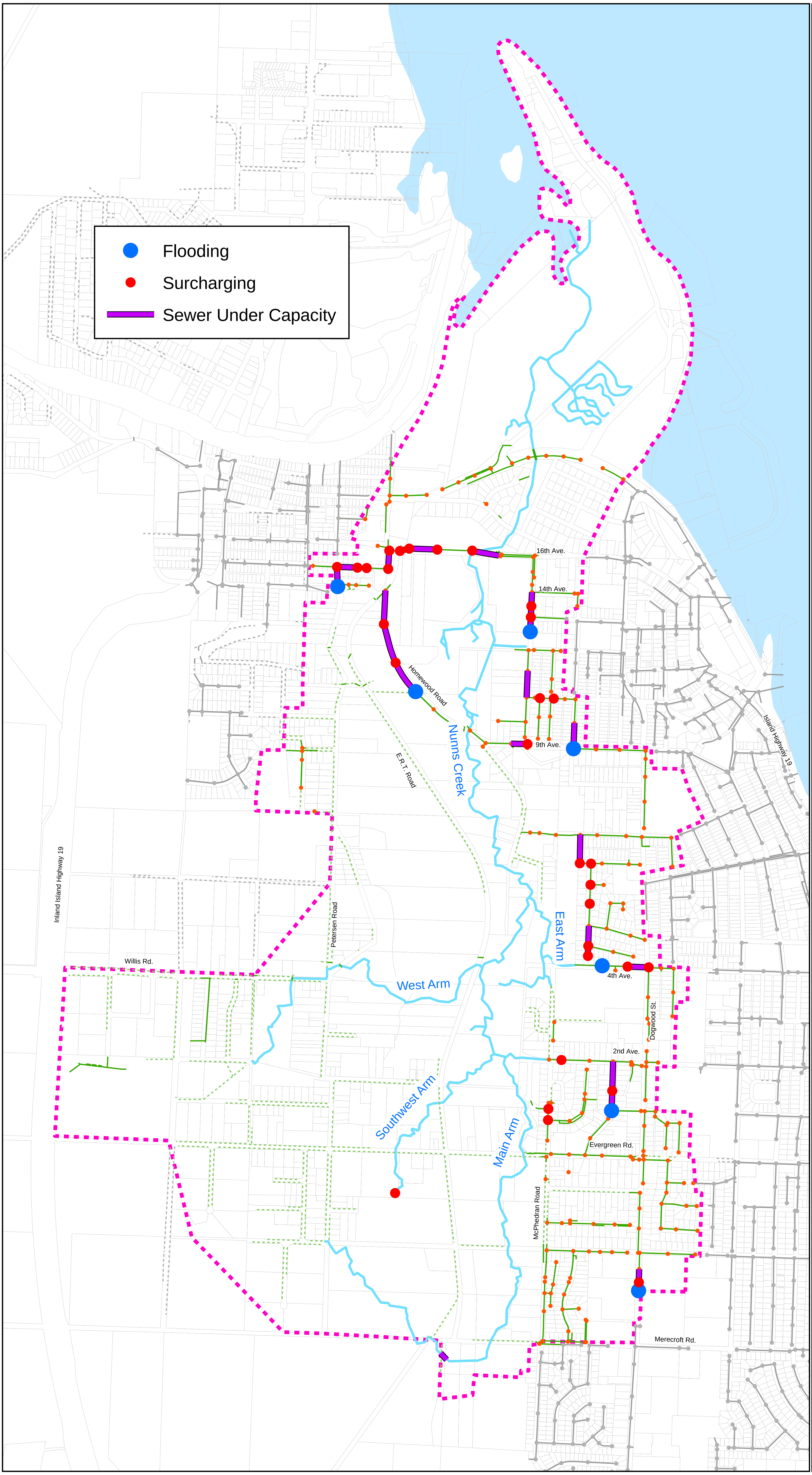
Integrated Stormwater Management Plan

Figure 8.1

Nunns Creek Watershed Municipal Drainage System Modeled Deficiencies (Existing Conditions)



Storm Manhole Within Watershed
Storm Main Within Watershed
Storm Manhole Outside Watershed
Storm Main Outside Watershed
Ditches Within Watershed
Ditches Outside Watershed
Nunns Creek
Nunns Creek Watershed

0 150 300
Metres

Scale 1:15 000

Source: City of Campbell River

This map was prepared for the purposes of this planning study and are provided for general reference only.
Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

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1479.0005.01 May 2005

Table 8.1
Municipal System Deficiencies (Existing Conditions)

Model Link ID	Location	Pipe Size (mmØ)	Type	Surcharged[8]	Flooded[8]
1566	Ironwood Street / 10th Avenue	600	Sewer	√	
1546	Greenwood Street / 9th Avenue	375	Sewer		√
1352	Ridge Rd / Elkhorn Road	375	Sewer	√	
1343	Ridge Road / 4th Avenue	375	Sewer	√	
1755	Homewood Road	525	Sewer	√	
1756	Homewood Road	525	Sewer		√
1754	Homewood Road	600	Sewer	√	
1561	Homewood Road / 9th Avenue	300	Sewer		√
210	Hemlock Street / 10th Avenue	450	Sewer	√	
1358	Ridge Road / 7th Avenue	600	Sewer	√	
1338	Dogwood Street / 4th Avenue	375	Sewer	√	
202	Ridge Road / 4th Avenue	375	Sewer		√
1283	Munson Road	525	Sewer		√
1282	Munson Road	525	Sewer		√
192	Trask Road / Merecroft Road	300	Culvert		√
217	S. Dogwood Street / Pinecrest Road	375	Sewer	√	
215	S. Dogwood Street / Pinecrest Road	375	Sewer		√

According to the drainage complaint summary spreadsheets attached in Appendix H, residents on Greenwood Street, 4th Avenue, Homewood Road, South Dogwood Street and Trask Road have all contacted the City in the past regarding flooding issues, therefore it appears that the model is reasonably predicting areas with poor drainage service. While it does not appear that residents on Munson Road have called in regarding flooding issues, several calls have been received from

[8] In a surcharged sewer, the hydraulic gradeline is above the top of the pipe but water is still contained within the pipes. In a flooded sewer, the hydrualic gradeline has reached the ground surface and water is being lost from pipes via overland flow.

residents at the Evergreen Road and South Dogwood Street intersection, which is only one block south of Munson Road.

The pipes listed below in Table 8.2 were also identified in the model as being undersized for the 5- and 10-year events, however, all of these pipes are in the lower watershed and are likely impacted by tidal fluctuations in the Campbell River estuary. Due to the backwater conditions, upgrading these sewers would likely not eliminate the surcharging and flooding in these areas, therefore upgrades to these sewers are not considered to be as high a priority. Pipes listed in Table 8.2 are also shown graphically on Figure 8.1.

Table 8.2
Municipal System Deficiencies within the Tidal Zone (Existing Conditions)

Model Link ID	Location	Pipe Size (mmØ)	Type	Surcharged[8]	Flooded[8]
1949	Ironwood Street / 14th Avenue	375	Sewer	√	
1633	Ironwood Street / 14th Avenue	375	Sewer	√	
1631	Ironwood Street / 14th Avenue	375	Sewer	√	
1630	Ironwood Street / 13th Avenue	375	Sewer		√
253	16th Avenue / Nunns Creek	600	Sewer	√	
240	16th Avenue / Nunns Creek	920	Sewer	√	
1733	16th Avenue / Nunns Creek	920	Sewer	√	
1732	16th Avenue / Maple Street	920	Sewer	√	
243	16th Avenue / Maple Street	610	Sewer	√	
242	Maple Street	610	Sewer	√	
241	Maple Street / 15th Avenue	610	Sewer	√	
1744	Maple Street	610	Sewer	√	
1743	Maple Street / Petersen Road	610	Sewer	√	
244	Petersen Road / 15th Avenue	460	Sewer		√

The City has received calls from people regarding drainage issues on all the streets mentioned in Table 8.2.

The magnitude of these deficiencies could be mitigated through the use of appropriate best management practices to reduce peak flow and volume of stormwater runoff to the municipal drainage system, as discussed previously in Section 6.

8.3 Detention / Attenuation of Flows from Developed Areas

Currently, there is only one detention facility in the Nunns Creek watershed. The detention facility is located east of the creek on McPhedran Road near Taylor Way and only services the immediate area. Land use in this area is single family residential. Peak flows from the remaining developed areas in the watershed discharge to Nunns Creek without any detention or attenuation.

As most of the eastern half of the watershed is already developed, there is limited opportunity to provide stormwater detention and attenuation before runoff reaches the creek. There may be some opportunity to provide future detention at outfall locations where there is sufficient land available and no topographical constraints. Potential detention facilities could be located at the 2nd Avenue and 4th Avenue storm sewer outfalls. However, it is more likely that onsite detention will be required in the eastern half of the watershed for any new development or re-development of existing parcels. Implementation of appropriate onsite Best Management Practices (BMP's) will also assist in reducing the volume and peak levels of stormwater runoff from existing development, which would have a beneficial impact on the creek. Additional information on BMP's is included in Section 6.

The western half of the watershed is more sparsely developed. While runoff from existing developed areas is currently not detained, there are opportunities to implement facilities to attenuate these flows. Future development in the western half of the watershed could also be serviced with detention facilities. As development proceeds in the western half of the watershed, it will be important to ensure that flows are detained appropriately and that attenuated flows are discharged to the creek as far upstream as possible to retain and enhance base flow levels in the creek.

We understand that there are two future detention ponds proposed in conjunction with the expansion of the Willis Road. At the time of the preparation of this report, however, detailed design drawings were not available to assess the catchment area or performance characteristics of these ponds.

8.4 Development Encroachment

Development ranges from mostly residential in the upper watershed, to a mix of commercial, light industrial and residential in the lower watershed. In several instances, development is situated in close proximity to the creek, particularly through Nunns Creek Park on the east side of the creek and within the Campbell River Indian Reserve between 16th Avenue and the Island Highway. Some encroachment has also occurred in the Homewood Road / Otter Road area where the creek runs through private residential properties, although most homeowners appear to have maintained an appropriate setback from the creek for major structures. Finally some portions of the West Arm of the creek appear to have been channelized into roadside ditches to accommodate adjacent development.

While there is limited opportunity to correct development encroachments on the creek that have already occurred, the City can continue to strengthen the application of its Environmental Development Permit Area requirements along watercourses. This permit process is now also paralleled by the new provincial Riparian Area Regulations, which have recently come into effect. The City may wish to develop "best management practice" guidelines for use along watercourses to preserve and protect the ecological functions provided by this zone. The City could encourage property owners by working with them to develop remediation plans on previously developed properties where minimal setbacks now exist. This might include such things as tree planting, removing existing small structures and stream bank protection measures.

8.5 Critical Habitat Protection Areas

Watershed matrices were developed for Nunns Creek which outline the environmental attributes of each reach based on a review of the available studies (refer to Appendix B). These watershed matrices provide detailed fish and riparian habitat descriptions. It was assumed that the riparian and wetland habitat descriptions reflect wildlife habitat values as well.

Summary tables were then created for each reach of the watershed which indicate limiting factors, Urban Salmon Habitat Program (USHP) habitat rating, and the USHP riparian rating. The USHP habitat and riparian ratings are determined using the Urban Salmon Habitat Program Assessment Procedures (Michalski et. al, 2001). Habitat rating values are determined by comparing habitat values collected during an instream habitat assessment to habitat standards for undisturbed streams, whereas riparian ratings are based on the comparison of riparian values collected during a riparian assessment with standards for healthy riparian systems. These ratings can be used to help identify restoration priorities, as a higher rating indicates a greater number of limiting factors. Ratings were adapted from USHP Assessments conducted by Roth (1998 and 1999) and Urchuck et al. (1997). Habitat parameters that were rated as poor or fair were included in the summary table. For more information refer to the Urban Salmon Habitat Program Assessment Procedures for Vancouver Island (Michalski et. al, 2001).

There are three components to the reach identification code used in the matrices and summary tables: creek name, tributary (if applicable), and reach number. The creek is identified by the first letter of the creek name. The tributary is identified as "Trib #". The reach is identified by the letter R followed by the reach number. For example, Nunns Creek Tributary 1 Reach 1 would be expressed as "N Trib1. R1". Reaches are numbered from the Campbell River estuary to the headwaters of the creek, in ascending order.

The terms large woody debris (LWD) and large organic debris (LOD) are used throughout this report. A LWD is a large tree part, conventionally a piece greater than 10 cm in diameter and 1 m in length. A LOD refers to entire trees or large pieces of trees that provide channel stability or create fish habitat diversity in a stream channel.

8.5.1 Methodology for Identifying Critical Habitat Concerns

As noted earlier, "critical" in this context is not intended as a legal or regulatory definition, but as a category used for the purposes of this study, as required by the Terms Of Reference. The following methodology was used to identify areas of critical fish and wildlife habitat concern:

1. Limitations of the overall stream system to fish and wildlife carrying capacity were determined as follows:

   - Tributaries with salmonid numbers below the carrying capacity of the system indicated the presence of habitat limitations.
   - Riparian and wetland degradation indicated a limitation to other vertebrates.

   Mitigation of these limiting factors has the potential to increase the habitat function and value of these areas.

2. Limitations (on a reach by reach basis) have been summarized in the watershed matrices and summary tables (refer to Section 8.5 above and Appendix B).

3. Reaches with limitations which coincided with the overall system limitations were considered to be candidate critical habitat areas, as they have limiting factors which reduce the fish and wildlife carrying capacity of the system.

4. Reaches with erosion sites and extensive physical alteration are also considered to be critical habitat areas because of the impact that sedimentation, erosion, and lower water quality has on spawning and rearing habitat.

8.5.2 Limiting Factors

The 1999 USHP Assessment identified the following potentially limiting factors to fish production in Nunns Creek (Roth 1999):

- Lack of natural riparian structure, function and diversity
- Lack of high water refuge habitat for rearing juvenile coho and steelhead
- An overall lack of LWD complexity, particularly in the form of pool forming scour features
- Lack of stable off channel winter rearing habitat for juvenile coho and steelhead
- Limited percent pool area
- Limited instream cover
- Increased percent fines in sediment

As noted above, limitation factors on a reach by reach basis are included in Appendix B.

8.5.3 Areas of Critical Habitat Concern

Based on the watershed matrices and the habitat / riparian rating tables for the Nunns Creek watershed, eight (8) reaches were identified with limiting factors which affect the overall system to salmonid carrying capacity (refer to Table 8.2 and Figure 8.2). These are listed below:

- Mainstem Tributary 1 (four reaches)
- Tributary 2a (one reach)
- Tributary 3 (two reaches)
- Triburary 4 (one reach)

All reaches fall into rearing limitations of the system including limited LWD, instream cover, percent wetted area and high percentage of fines. In addition to the limiting factors of the system, the following reaches are also impacted by altered sites: Tributary 1 reach 3 and Tributary 4 reach 3.

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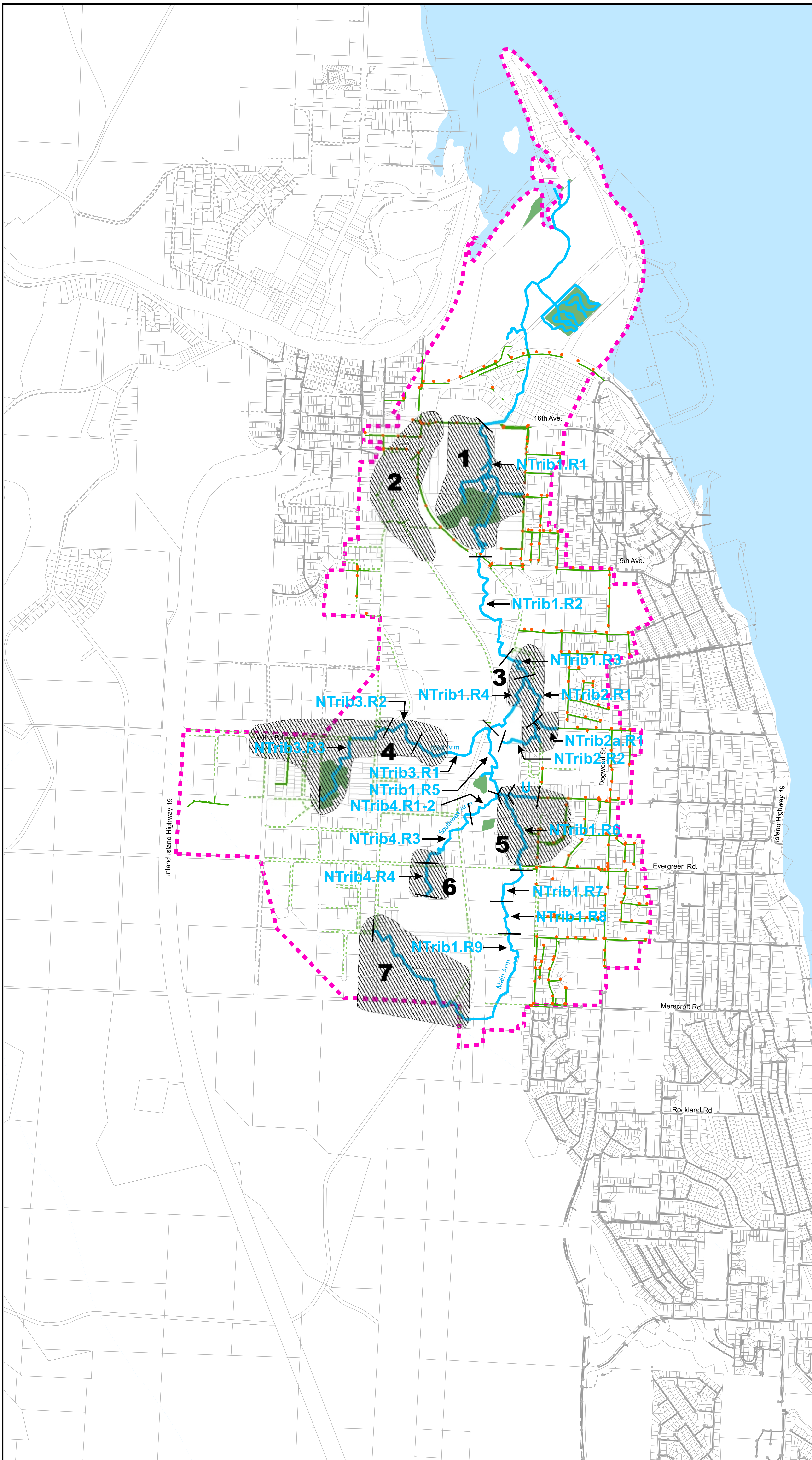

Figure 8-2
Nunns Creek Watershed Reach Identification and Critical Areas

/ = boundary of reach break with reach identifier
U = un-named

critical area

Note:
- reach breaks are approximate
- for description of reaches or critical areas refer to report

- Storm Manhole Within Watershed
- Storm Manhole Outside Watershed
- Storm Main Within Watershed
- Storm Main Outside Watershed
- Nunns Creek
- Ditches Within Watershed
- Ditches Outside Watershed
- Nunns Creek Watershed
- Wetlands

0 250 500
Metres

Scale 1:20 000

Source: District of Campbell River

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In Tributary 3 reach 1, five log weirs with insufficient flow to allow fry movement upstream were observed in the 1999 USHP assessment (Roth 1999). Tributary 3 suffers from low summer flows. During the 1999 USHP assessment, flow was observed in July but the tributary had completely dried up in August (Roth 1999). The long-term viability of this tributary is dependent on securing water storage in the upper reaches (Roth 1999). It is important to note that beyond reach 3 the system enters a series of road ditches. Low summer flows would allow access to an additional 906 m (reaches 1 to 3) providing good spawning and rearing habitat (Roth 1999).

Table 8.3
Preliminary List of Areas with Critical Habitat Concern

Reach #	USHP* Habitat Rating	USHP Riparian Rating	Limiting Factors
Tributary 1 (Mainstem			
N Trib1.R1	24	40	High incidence of sediment deposition. Other limiting factors are LWD and boulder cover.
N Trib1.R3	28	22	LWD, boulder cover, altered stream sites, % wetted area.
N Trib1.R4	31	46	LWD, boulder cover, % wetted area.
N Trib1.R9	29	20	LWD, boulder cover, % fines, % wetted area.
Tributary 2			
N Trib2a.R1	17	14	Sources of non point pollution and sediment. Erosion concerns due to high peak flows. Other limiting factors are % pool area and instream cover.
Tributary 3			
N Trib3. R1	42	58	Five potential barriers throughout this reach. Limited summer flows. Percent pool area, LWD, boulder cover, % fines, % wetted area.
N Trib3. R2	31	32	Limited summer flows. LWD, boulder cover, % fines, % wetted area.
Tributary 4			
N Trib4. R3	39	38	LWD, boulder cover, 100% fines, altered stream sites, % wetted area.

* USHP= Urban Salmon Habitat Program

8.6 Flooding

Flooding in the lower reaches of Nunns Creek can be attributed to several factors. The gradient of Nunns Creek is quite flat north of Homewood Road and is influenced by tide levels in the Campbell River estuary. During high tide, water from the estuary flows into Nunns Creek, often surcharging the culverts under the Island Highway, Old Island Highway and 16th Avenue. When a high tide corresponds with significant rainfall, the combination of high backwater levels from the estuary with increased flows from the upper watershed often causes the creek to overtop its banks in the lower reaches. This results in the flooding of adjacent properties and parks and overtopping of roads crossing the lower sections of the creek.

The capacity of the creek itself in the lower reaches is further reduced by the high rate of sediment deposition that tends to occur at the gradient change in the creek near Homewood Road. Sediments also continue to settle out in the lower reaches downstream of Homewood Road as the water velocity slows and water from the upper watershed meets the tide level in the estuary.

Beavers are known to be active in Nunns Creek Park and it appears that they have created a series of small ponds at the south end of the park. Their activities for the most part appear to be offline of the main channel, however, they are retaining water in the park that could ultimately impact the usage of the parks facilities or contribute to the flooding issues downstream should the dams fail.

The culvert crossings under the Island Highway, Old Island Highway and 16th Avenue have also been linked to the flooding issues in the lower reaches by both the Campbell River First Nations and the Nunns Creek Stewards. Both groups feel that flooding in the lower watershed increased when the original bridges for these roads were replaced with the current culvert structures. The Campbell River First Nations have stated that they had to relocate several homes on their lands eight years ago due to the flooding issues north of 16th Avenue. They also suggested that the dense vegetation in the creek downstream of 16th Avenue is impacting the creek's capacity, which in turn is causing more frequent flooding on reserve lands.

A study completed in early 2004 investigated flooding at the three lower Nunns Creek culvert crossings[9]. The basic conclusions of the study were:

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[9] "Nunns Creek Lower Watershed Management Study," February 2004, McElhanney Consultants and Komori Wong Environmental

- The culverts at the Island Highway, the Old Island Highway and 16th Avenue are significant constrictions to stream flow
- Consequent raised water levels upstream of the culverts from these constrictions has changed the riparian and geomorphologic characteristics of the stream
- There is limited opportunity for increasing channel capacity between the crossings

The study recommended replacing the three culverts with longer-span, open-bottom structures (bridges or bottomless arch culverts) and removing accumulated sediments from specific creek reaches. These recommendations were intended to enhance habitat as well as address flooding concerns. We are in basic agreement with these conclusions and recommendations and no further study was undertaken for this integrated stormwater management plan.

8.7 Erosion and Sedimentation

Three sites were noted in the Nunns Creek watershed as being of particular concern for erosion. The southern roadside ditch on Evergreen Road, between Petersen Road and the outfall to the Southwest Arm of Nunns Creek, is fairly steep with an average profile gradient of approximately 4% (see photo at left). The ditch along this section is also quite deep relative to the road and the adjacent property to the south and has average bank slopes of 1:1. It appears that erosion has been an issue at this location in the past, as riprap can be seen on the bank slope adjacent to the road shoulder, presumably to stabilize the road edge from slipping into the ditch and to prevent toe erosion along the northern bank. However, riprap was not extended to the south toe of the ditch bank and now the south bank is showing significant signs of toe erosion and slumping of the bank face. Vegetation on the south bank has not been successful in stabilizing the bank slope and large sections of exposed earth can be seen.

Erosion and oversteepening of the existing ravine banks at the 4th Avenue storm sewer outfall was also noted. This outfall provides the majority of flow to the East Arm of Nunns Creek. As this storm sewer outfall services a fully developed area in the eastern half of the watershed, the developed area provides a flash response which delivers high peak flows over a short duration to the East Arm. This rush of water is what has likely caused the downcutting of the creek invert and the bank erosion at this location.

A similar situation is also occurring at the 2nd Avenue storm sewer outfall, which feeds the main arm of the creek just upstream of its confluence with the southwest arm. The storm sewer on 2nd Avenue outfalls to a ditch located in the 2nd Avenue right-of-way just west of McPhedran Road, which in turn flows to Nunns Creek. This ditch is also experiencing significant erosion due to the flash response of the upstream catchment area.

Sedimentation is mainly occurring in the lower reaches of Nunns Creek where the gradient changes from a moderate slope south of Homewood Road to a fairly flat slope through Nunns Creek Park. Sediment deposits are restricting the capacity of the main channel which may be contributing to the flooding issues in the lower reaches of the watershed. Deposits are also impacting instream habitat in the lower reaches due to the composition of instream substrate and the lack of boulders and cobbles.

8.8 Loss of Wetlands and Tree Cover

There is insufficient data available to quantitatively assess the extent of the loss of wetlands and tree cover that has occurred in the watershed since intensive urban development began. Nonetheless, since most of the area would likely have been forested at some point in the past, it can be surmised that the loss of trees has been great. Even the less developed areas on the west side of the watershed, though only partially developed with low density residential housing, exhibit significant parcels with few trees (see Figure 3.2).

Neighbouring Willow and Simms Creek watersheds are (or were at one time) dotted with wetlands in the upper reaches along and west of what is now the Inland Island Highway; it is likely that Nunns Creek had similar features. Members of the Stakeholders Group noted, for example, that historical wetlands near Willis Road have since disappeared. Again, though the west side of the watershed is only partially developed, extensive open ditching has drained surrounding soils and local wetlands that may have been present. The result is faster peaking and greater volumes of runoff during storms and little soils and wetlands detention capacity to maintain base flows between storms.

8.9 Construction Practices

We understand that, in general, while the City requires that construction activities include the implementation of an erosion and sediment control (ESC) plan, ongoing maintenance of ESC facilities and enforcement practices by the City could be improved. Often a significant portion of the site is cleared and then not developed right away. If work on the site does commence, ESC facilities are not always in place and operational beforehand. Exposed soil is easily eroded and carried in the runoff exiting the site. Hydroseeding and re-vegetation is often not completed until late in the season and therefore does not have an opportunity to fully establish and prevent sediment from entering the downstream drainage system. Sediment continues to be discharged from the site until vegetation has re-established, which can be upwards of a year later.

Defined enforcement policies and triggering actions for ESC within the development and building processes could assist the City in improving construction practices in the watershed.

8.10 Long Term Maintenance

The City currently has a maintenance program which outlines the level of effort and frequency of maintenance on the traditional components of the municipal drainage system, such as storm sewers, catch basins, roadside ditches and culverts. However, non traditional drainage features like detention facilities and wetland complexes should also be considered as part of the municipal drainage system and should be maintained. While these features typically only require infrequent maintenance, they are extremely important to the overall health and function of the watershed. They are also environmentally sensitive areas as they tend to evolve into excellent habitat refuges, so education of maintenance staff is crucial to ensure that they are properly maintained and not destroyed in the process.

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9.0 FORMULATION AND EVALUATION OF ALTERNATIVES

9.1 Selection Criteria

A primary consideration in evaluating the many alternatives that can be applied to stormwater management is how well the options address the critical issues. When formulating solutions to address stormwater management issues in the Nunns Creek watershed, the following things must be considered:

1. Certainty in development process
2. Cost (both capital and operation/maintenance)
3. Financial impact (taxes, DCC's)
4. Public versus private ownership and maintenance
5. Sustainability
6. Hydrologic / hydraulic impact
7. Fish habitat impact
8. Benefit to community (amenities)
9. Improvement to health of watercourse

9.2 Existing Development Scenarios

9.2.1 Roof Leader Disconnection

The soils mapping provided by the hydrogeological report indicates that infiltration of stormwater runoff may be possible in the watershed, particularly in areas east of the main arm of Nunns Creek. In an effort to reduce the amount of runoff reaching the municipal storm sewer system, a model simulation was run assuming that all roof leaders from the majority of existing and proposed developments could be redirected to pervious areas for infiltration purposes. For example, roof downspouts from individual homes would be discharged onto splash pads and grassed areas rather than be connected directly to the municipal storm sewer system, which is the City's current standard.

This simulation was run in conjunction with redirection of roof leaders for future developments in the watershed and the results are discussed in Section 9.3.6.

9.3 Short-term Future Development Scenarios

Six different scenarios were run using the XPSWMM model to understand how short-term future development would impact the watershed. Short-term future development areas were based on the level of development that is expected to occur in the watershed over the next ten years, as discussed with the City and the Development Liaison Group. These development areas were shown in Figure 4.3.

9.3.1 Unmanaged Development

A future conditions baseline model was established by adding the probable future development areas shown on Figure 4.3 to the existing conditions model. The model was then run without any upgrades to the municipal storm sewer system to determine the impacts resulting from future development.

The model indicated that, in addition to the storm sewer deficiencies listed in Table 8.1 for existing conditions, a 136 metre reach of 350mmØ storm sewer at Milford Road and Goodwin Road would flood under future development conditions. The magnitude of surcharging and flooding would also increase in the sewers listed in Table 8.1 under a future unmanaged condition scenario over the levels indicated for existing conditions. Under a 5-year event, this first scenario would increase the peak flow in Nunns Creek at the Island Highway (Hwy 19A) from 5.28 m^3/s under existing conditions to 5.63 m^3/s.

9.3.2 Municipal Infrastructure Upgrades

A second scenario was modeled to determine the necessary upgrades to existing drainage infrastructure to eliminate flooding under future unmanaged development conditions. Using the future baseline model from the scenario above as a starting point, the model was run to establish necessary pipe upgrades based on insufficient hydraulic capacity. The model was run under both the 5-year and 10-year design events to correspond with residential and commercial / industrial land uses, respectively. It was assumed that surcharging in the storm sewers at any point in the system would be considered acceptable, as the relationship between the storm sewer system and service connections is not known.

Table 9.1 summarizes the municipal infrastructure upgrades required to eliminate flooding conditions under a future unmanaged development scenario.

Table 9.1
Required Municipal Infrastructure Upgrades (Future Unmanaged Conditions)

Model Link ID	Location	Design Event (yr)	Existing Pipe Size (mmØ)	Proposed Pipe Size (mmØ)	Length (m)	Still Surcharged?
253	16th Avenue / Nunns Creek	10	600	900	25	√
252	16th Avenue / Ironwood Street	10	600	900	140	√
251	16th Avenue / Ironwood Street	10	450	600	63	√
1637	16th Avenue / Ironwood Street	10	450	600	56	√
1949	Ironwood Street / 14th Avenue	10	380	600	30	√
1633	Ironwood Street / 14th Avenue	10	380	600	47	√
1631	Ironwood Street / 14th Avenue	10	380	600	47	√
1630	Ironwood Street / 13th Avenue	10	380	600	64	√
240	16th Avenue / Nunns Creek	10	920	1200	140.5	√
1733	16th Avenue	10	920	1200	120	√
1732	16th Avenue	10	920	1200	40	√
246	Petersen Road / 10th Avenue	10	920	1200	143	√
249	Petersen Road	10	920	1200	50	√
245	Petersen Road	10	920	1050	32	√
1754	Homewood Road	10	530	1050	87	√
1755	Homewood Road	10	530	1050	186	√
1756	Homewood Road	10	530	1050	150	√
1567	Ironwood Road / 11th Avenue	10	685	900	87	
1566	Ironwood Road / 11th Avenue	10	600	1050	111	
1557	Ironwood Road / 10th Avenue	5	690	900	33	
210	Hemlock Street / 10th Avenue	5	450	600	21	√
1553	Hemlock Street / 10th Avenue	5	450	600	65	√
1947	Hemlock Street / 10th Avenue	5	450	600	12	√
1549	Hemlock Street / 10th Avenue	5	450	600	47	
1548	Greenwood Road / 10th Avenue	5	450	600	46	
1547	Greenwood Road / 10th Avenue	5	380	600	102	
1546	Greenwood Road / 9th Avenue	5	380	600	109	
202	4th Avenue	5	375	450	123	√
1283	Munson Road	5	530	600	150	
1282	Munson Road	5	530	600	150	√
217	S. Dogwood Street/Pincrest Road	5	375	450	56	√
215	S. Dogwood Street/Pincrest Road	5	375	450	36	√
192	Trask Road / Merecroft Road	5	300	600	10	
1561	Homewood Road / 9th Avenue	5	300	450	69	

The storm sewer upgrades listed above would increase the 5-year peak flow at the Island Highway from 5.28 m^3/s under existing conditions to 6.04 m^3/s.

9.3.3 Detention Facilities

This scenario examined whether detention facilities could be used to attenuate peak flows from future development in the watershed. Starting with the future baseline model from the first scenario, it was assumed that each of the major developments proposed in the western half of the watershed (shown in Figure 4.3) would have its own detention facility. In addition, two new detention facilities were proposed in the eastern half of the watershed at the 2^{nd} Avenue and 4^{th} Avenue storm sewer outfalls. While the two detention facilities in the east are proposed mainly to address downstream erosion concerns, the three detention facilities in the west are for the purpose of servicing future short-term developments. The following detention criteria were applied for the 5 proposed detention facilities:

- Post-development 2-year flow rate to match 50% of the 2-year existing conditions flow rate
- Post-development 5-year flow rate to match the 5-year existing conditions flow rate

Table 9.2 summarizes the required storage volumes for each proposed detention facility in the watershed based on the model results.

Table 9.2
Required Storage Volumes for Proposed Detention Facilities

Development	Location	Area (ha)	Required Storage Volume (m^3)
4/5	Petersen Road	33.22	4,100
8	Willis Road / Inland Island Highway	3.40	440
9	Evergreen Road / Inland Island Highway	12.40	1,500
2^{nd} Ave Outfall	2^{nd} Avenue / McPhedran Road	23.04	2,300
4^{th} Ave Outfall	4^{th} Avenue / McPhedran Road	20.37	2,400

It was assumed that the proposed detention facility for development 8 would discharge to Willis Road and ultimately into the west arm of Nunns Creek at Petersen Road. It was also assumed that the existing roadside ditches on Willis Road would likely be replaced by a storm sewer once the development on Willis Road proceeded. Based on the modeling results, a 525mmØ storm sewer would be required on Willis Road.

Similar assumptions were mode for development 9 which was assumed to discharge to the southwest arm of Nunns Creek. In this case, it is assumed that the ditches along Evergreen Road would be enclosed. Based on the modeling results, a 525mmØ storm sewer would be required on Evergreen Road.

Due to their small size, future developments labelled as 6, 7 and 10 on Figure 4.3 will not be able to provide onsite detention. Other onsite BMP's should be examined for stormwater control on these sites. Future developments labelled 1, 2 and 3 on Figure 4.3 were also not assessed as they are either partially or fully within the Campbell River First Nations lands and were also outside of the area included in the XPSWMM model.

The addition of five detention facilities in the Nunns Creek watershed changed the 5-year peak flow at the Island Highway from 5.28 m^3/s under existing conditions to 4.98m^3/s.

9.3.4 Trunk Sewer with Pond Upgrade

As an alternative to providing onsite detention facilities for short-term future development, this scenario assumes that trunk storm sewers would be constructed to service future developments labelled 4, 8 and 9 on Figure 4.3. This scenario assumes that development 6 and 7 would still require onsite detention, and that development 5 would discharge directly to Nunns Creek using onsite detention and/or appropriate BMP's.

The trunk sewer to service Development 8 would run east along Willis Road and outlet to the west arm of Nunns Creek at Old Petersen Road. This trunk sewer would essentially be enclosing the open ditches along Willis Road. Based on the City's 5-year criteria, a 600mm∅ would be required to service the development 8.

The trunk sewer to service Development 9 would run east along Evergreen Road and outlet to the southwest arm of Nunns Creek at Evergreen Road. This trunk sewer would essentially be enclosing the open ditches along Willis Road. Based on the City's 5-year criteria, a 600mm∅ would be required to service the development 9.

Finally, the trunk sewer to service Development 4 would run along the ERT to Maple Street, where it would follow the right-of-way and discharge directly into the Campbell River estuary. Based on the City's 5-year criteria, a 600mm∅ would be required to service the development 4.

9.3.5 Low Impact Development

The underlying intent of Low Impact Development (LID) techniques is to mimic the natural hydrologic regime of the site through infiltration and retention of runoff onsite. The amount of infiltration is typically based on provincial guidelines which is based on a parameter called the Mean Annual Rainfall (MAR). The MAR is essentially equivalent to the 24 hour rainfall event that maintains the wetted perimeter of a channel. For Campbell River, the MAR is 55 mm.

The guidelines for running an LID scenario for future development were as follows:

- Up to half of the Mean Annual Rainfall (MAR) – runoff retained on site and infiltrated or evapotranspired
- ½ MAR to MAR – runoff detained on site and discharged at existing conditions flow rates
- Above the MAR – runoff safely conveyed overland to the receiving body

To simulate these conditions in the model, a depression storage value equal to ½ the MAR was assigned to impervious and pervious areas in the future development. The infiltration files were also set equal to zero to ensure that all of the initial rainfall was held as depression storage. These conditions essentially prevent the model from generating runoff from the future development areas until a rainfall depth equal to ½ the MAR is reached.

Table 9.3 lists peak flows in the watershed under an LID approach.

Table 9.3
Peak Flows for Future Conditions using an LID Approach

Location	2 Year	5 Year	10 Year	25 Year	100 Year
Evergreen Road	1.33	1.91	2.24	2.63	3.13
2nd Avenue	2.04	3.09	3.68	4.35	5.36
4th Avenue	2.48	3.74	4.44	5.27	6.5
Otter Road	3.1	4.59	5.42	6.35	7.59
Homewood Road	3.26	4.87	5.76	6.35	6.87
16th Avenue	4.25	5.75	6.49	7.22	7.71
Island Highway	4.02	5.35	5.99	6.77	7.29
Evergreen Road	1.33	1.91	2.24	2.63	3.13

Infiltrating and retaining up to ½ the MAR onsite is highly dependent on local soil conditions. Furthermore, during winter conditions with nearly saturated antecedent moisture conditions, the soil's capacity to infiltrate additional runoff is compromised. LID techniques cannot be expected to mitigate runoff volumes and/or peak flow rates throughout the year since its operation is dependent on antecedent moisture conditions, which vary from very dry during the summer months to nearly saturated during the winter. Therefore detention ponds, such as those outlined under Section 9.3.3, may still be required even if an LID approach was implemented. Additional experience with LID approaches and availability of a full-calibrated extended period simulation model are needed to adequately assess and realize the benefits of LID. The benefit, and reason for incorporating an LID approach, is to mimic the natural hydrologic regime of the watershed. By allowing stormwater runoff to infiltrate (where appropriate and subject to antecedent moisture conditions), year-round base flows to the creek will be sustained and runoff will be treated (through pollutant removal from soils / plants, lowered water temperature, etc), which will result in significant benefits for fisheries resources and other habitat communities.

9.3.6 Roof Leader Disconnection

As mentioned in Section 9.2.1, infiltration of stormwater runoff appears to be a possibility in areas east of the Creek. This final model simulation examined the impacts of redirecting roof leaders from most of the existing development draining to the main branch of Nunns Creek as well as future development areas in the lower watershed. Table 9.4 summarizes the resultant impacts to peak flows under this scenario.

Table 9.4
Future Peak Flows using Roof Leader Disconnections

Model Catchment ID	Location	Area (ha)	Land Use	2-Year 24-Hour Peak Flow (m^3/s)		
				Existing	Future Unmanaged	Future Unmanaged w/ Disconnections
1208	Pinecrest / Merecroft	22.74	Res	0.090	0.090	0.070
1271	Evergreen/ S.Dogwood	25.01	Res	0.153	0.153	0.119
1400	Taylor Way	9.85	Res	0.078	0.078	0.062
1396	2nd Ave / S.Dogwood	17.84	Res	0.161	0.161	0.100
1415	4th Ave / S.Dogwood	20.38	Insti/Comm	0.169	0.169	0.134
1421	Westmere / S.Dogwood	20.37	Res	0.153	0.153	0.115
1524	7th Ave / S. Dogwood	20.38	Res	0.160	0.160	0.124
1741	9th Ave / Homewood	18.31	Res	0.095	0.095	0.080
1137	Development 8	3.4	Res	0.009	0.030	0.025
1139	Development 9	12.4	Res	0.010	0.094	0.054
1124	ERT Road / 7th Ave	33.22	Res	0.017	0.260	0.203

Roof leader disconnections can lead to a significant reduction in peak flows from a site provided that the soil conditions are favourable to infiltrate the redirected runoff under a 2-year event or that significant numbers of homes reconnect to rain barrels instead. Even under saturated antecedent moisture conditions, roof leader disconnections can be used to increase the overland flow path to the downstream drainage system, which has the effect of attenuating peak flows within the watershed. Thus, they still provide a benefit. The average reduction in peak flow for the above locations was 25%.

9.4 Long-term Future Development (OCP)

Long-term "full build out" conditions based on the Draft OCP were only simulated for unmanaged conditions, that is, without application of any specific stormwater management controls. Thus, stormwater infrastructure capital improvements to service future development beyond the near term (1 to 10-year) horizon have not been assessed at this time. Until the watershed model is upgraded to perform extended period simulations and until the sustainable stormwater measures recommended in this plan can be implemented and assessed, such recommendations are premature. Increases to peak flows at various locations in the watershed for full build out conditions were previously shown in Table 7.10.

9.5 Assessment of Critical Habitat Areas

Critical habitat limitations in the Nunns Creek watershed are primarily based on rural and urban encroachment in the watershed. Healthy watersheds are defined as having less than 10-15% impervious surface and greater than 65% forested area. The impervious area in the Nunns Creek watershed currently stands at 16.5% and the mature forested area has been reduced to 32%.

Specific development impacts include the construction of roadside ditch systems for the ERT, Willis Road and Petersen Road areas, as well as at the headwaters of Nunns Creek. These ditch systems have impacted base flows and peak flows. Existing stormwater outfalls located in the Ironwood area, as well as the 4th Avenue and 2nd Avenue right-of-way extensions, are sources of water pollution and/or sediment release. In general, there is a lack of riparian vegetation in the watershed due to urban encroachment.

The following critical habitat areas were assessed in the field with the creek stewards. These areas are described below and are shown on Figure 8.2.

1) **Nunns Creek reach between 16th Ave and 9th Ave –** This reach has a significant gradient change and is within the tidal influence of Discovery Passage and the Campbell River estuary. Critical limitations for this reach are:

a) High sediment deposition has impacted the main channel. There is a lack of boulders and cobbles for instream habitat therefore boulder and gravel recruitment should be considered. Instream habitat could be enhanced by encouraging beaver activity through riparian planting of willow species. Maintain downed trees or unsafe trees as wildlife trees and/or drop to create LOD.

b) Flooding impacts this area. The two box culverts at the 16th Avenue road crossing are back watered to the top of the culverts at high tide. There is a fine silty sandy substrate in the tidal reach and the wetland. These culverts need repair.

c) There is industrial contamination in the eastern tributary which originates in the Ironwood area. At 12th Avenue, a sediment trap with a clean out and access should be installed in case of a spill.

2) **Along ERT Road** including ditch and stormwater flow and separate outflow into Campbell River – This reach is connected at its upper reaches to Nunns Creek, but it subsequently forms a separate creek into the Campbell River. It may have been historically connected to Nunns Creek. Critical limitations are:

a) Ditches and stream alterations from the ERT road have impacted Nunns Creek.

b) The connections of these ditches to Nunns Creek are not clear and need to be determined.

c) The remaining ditches which discharge to the creek from the ERT and Maple Street stormwater system into Campbell River have coho and other salmonid accessible habitat and should be protected.

d) Evaluate the possibility of directing the upper ERT ditches into this system through comprehensive ditch consolidation and channel reconstruction. Vegetate ditches wherever road construction has denuded them.

3) **Eastern tributary to Nunns Creek, located at Homewood Rd cul-de-sac and the westernmost extension at 4th Avenue.** All sites are significantly impacted by stormwater, ditch construction and other human alterations.

a) Water pollution and sediment release from the municipal storm sewer system has impacted this tributary. Recommend infiltration at the source, such as directing roof and driveway drainage into soils and swales on lot for significant renovations and new construction (if feasible based on sited conditions).

b) The storm sewer system has caused changes to flow regime.

c) Peak flows from the stormwater outfall on 4th Avenue have over-steepened the existing ravine. Significant erosion needs to be managed (i.e. check dams and/or rock liners). There may be limited room for treatment at this location.

d) The lower reaches of tributaries with salmonid habitat could be enhanced with pool/ riffle construction and placement of LODs.

4) **The reach connected to Willis Road and its ditch system which crosses Petersen Road** has the following critical limitations:

a) The existing ditches on Willis Road have impacted base flows and peak flows and should be made into swales.

b) The current proposal to widen Willis Road offers an opportunity to consolidate the roadside ditches into a main channel, rehabilitate the ditches into wider stream systems, lower and enlarge the culvert crossing at Petersen Road and lower the culvert at Willis Road. An opportunity to direct drainage from the south ditch and culvert into this tributary (tributary 3) instead of down Croatian Road should also be investigated.

c) Install large detention pond (Stevens, Rich. 2005, personal communication). Negotiate with the owner of the rock wall at Petersen Road and Old Petersen Road to replace the rock wall with a coarse rock liner. Place a small detention facility at the outlet of Old Petersen Road to treat drainage originating at Willis Road.

d) Instream substrate, including a high percentage of fines and low percentage of coarse substrate, has limited instream fish habitat. Gravel and cobble recruitment should be considered.

e) There is a reduction of riparian cover at the headwaters. The lack of riparian vegetation due to urban encroachment should be managed by encouraging landowners through active programs to contribute some native planting if possible. Vegetate ditches with grass and wetland species which can withstand some ponding while providing source control treatment.

f) Recommend infiltration at the source, such as directing roof and driveway drainage into soils and swales on lot for significant renovations and new construction (if feasible based on sited conditions).

5) **Reach of mainstem of Nunns Creek between 2^nd^ Avenue and Evergreen Road** – This reach was added because of stormwater related issues at 2^nd^ Avenue and its small tributary. Critical limitations include:

a) The most significant problem is channelization due to the storm sewer outfall on 2^nd^ Avenue. Erosion along the existing ditch in the 2^nd^ Avenue right-of-way is significant and should be addressed with a rock liner and/or check dams along its length, as well as storm drain outlet protection.

b) Stormwater quality should be addressed through potential sediment trap and small detention pond (already designed, Stevens, Rich. 2005, personal communication) in right-of-way. Explore the possibility of constructing a detention facility at the outfall on 2nd Avenue. General cleanup of the lower tributary in rearing habitat and potential enhancement by introduction of LODs is recommended.

c) Recommend infiltration at the source, such as directing roof and driveway drainage into soils and swales on lot for significant renovations and new construction (if feasible based on sited conditions).

6) **Western tributary to Nunns Creek above Evergreen Road** – This reach was added because of the significant discoloration of water in the stream due to fill (soil) leachate and iron bacteria from adjacent properties. Critical limitations are:

a) Discoloration of water impacts water quality. This reach should have a series of ponds with rock weirs to treat and detain the water before it enters the culvert at Evergreen Road. Replant within 15 metres from the top of bank with native riparian vegetation.

b) Recommend infiltration at the source, such as directing roof and driveway drainage into soils and swales on lot for significant renovations and new construction (if feasible based on sited conditions).

7) **Headwaters of Nunns Creek** – This reach of Nunns Creek is fed by a series of ditches from rural areas and is under development pressure for diversion (DFO in agreement, Roth. M. 2005, personal communication). Critical limitations are:

a) Lack of base flow and poor water quality impacts this reach of Nunns Creek. Review the ditch system flowing into the stream at Pinecrest Road and Petersen Road. Consider swales and check dams to allow for source control or treatment and revegetate throughout to avoid erosion issues.

Recommend infiltration at the source, such as directing roof and driveway drainage into soils and swales on lot for significant renovations and new construction (if feasible based on sited conditions).

b) Consider a diversion along the Petersen Road right-of-way and Merecroft Road right-of-way. Construct an in-line pond and wetland complex in the low lying area at Trask Road and Merecroft Road for detention and treatment.

c) Erosion of the poorly defined channels on Trask Road should include rebuilding the wetland pond outlet, installing a culvert at Trask Road, and defining the channel at the culvert outlet at Trask Road. Replant riparian vegetation at all disturbed areas.

d) The lack of riparian vegetation due to urban encroachment should be managed by encouraging landowners through active programs to contribute some native planting if possible.

9.6 Infiltration / Recharge Potential

9.6.1 Design Concepts and Justification

In many parts of the study area, ground infiltration systems could be incorporated into landscaping and engineering plans, to direct water towards points where ground infiltration is feasible. The infiltration rating numbers presented on Figure 2 in Appendix C are intended to indicate the relative capacities of soils to absorb storm water runoff. This indicates Dashwood soils (Rank 1) have the greatest potential and Arrowsmith soils have the lowest potential (Rank 13).

Systems that collect stormwater runoff need to have a number of considerations, including: landscaping to channel water to the infiltration system, an adequate storage compartment to hold the required amount to be slowly infiltrated after the rainfall event, and a clarification system to eliminate suspended sediments and floating detritus. A regular (annual or 10-year) clean out of some structures should be anticipated.

Improving water quality is important to maintaining the lifetime of the infiltration system that would be reduced due to clogging, which is the cause of most failures. Measures that can be taken to improve water quality include a flotation (for oily water) and settlement chamber that allows carried material to settle, filter cloth that can be periodically replaced, a detention pond for settlement, or a filter chamber with sand that can remove fine silts and clays from stormwater.

9.6.2 Shallow Infiltration Systems

Shallow infiltration systems could be designed to infiltrate water into some areas within the well drained Dashwood soil. Dashwood soils are present in about 15% of the Nunns Creek drainage basin. In addition, as discussed in Section 3.10.3, it may be possible to make use of these same shallow infiltration systems in areas now drained by the presence of ditches and service trenches.

Examples of shallow infiltration enhancement systems include: soak-a-way pits, seepage basins, shallow infiltration wells and seepage trenches.

The hydraulic conductivity of the subsurface soils in the study area is likely quite variable, due to the presence of localized permeable sand and/or gravel seams, or interbeds, in the middle of relatively low permeability loamy soils. For this reason performing infiltration tests in linear trenches in representative areas will be required, prior to development of more detailed plans for stormwater infiltration. For example, infiltration tests performed in soils similar to Dashwood indicated infiltration rates to a 0.6m wide trench in the range from about 2 to 4 L/s/km length of trench.

It is better to have a wide distribution of infiltration systems introducing the water into different areas and strata, rather than a few concentrated areas discharging into one strata. This will reduce the potential for water table mounding, and in some areas, the potential for slope instability.

9.6.3 Vertical Infiltration Wells

Clean stormwater that cannot infiltrate into shallow soils in the upland areas could be discharged into the Quadra Sand Unit below the low permeability till-like unit. The concept for this method is illustrated on Figures 4 and 5 in Appendix C.

As indicated on the hydrogeologic profile provided on Figure 3 in Appendix C, the depths to the top of the deep Quadra Sand aquifer units range from about 4 to 7m below ground. While no tests have been conducted in the study area, the results of tests run in hydrogeologically similar areas (such as the Point Grey peninsular and at Cape Mudge) suggest that short-term inflow rates of between 0.5 to 2 L/s per well may be feasible in the upland parts of the study area. The actual infiltration rate for an individual well will depend on a number of factors including: well depth, depth to static water level, formation permeability and continuity of the aquifer. Infiltration wells are apparently being constructed at a commercial site along Merecroft Road, but details were not available at the time of completion of this study.

It is important to appreciate that all ground infiltration systems will not be effective for very long if suspended solids and bacteria are not adequately removed from surface runoff, prior to discharge into the ground. This can be accomplished with properly designed, constructed and maintained vegetated swales or other similar stormwater "best management practices."

9.7 Sustainability and Impact

Each of the above future development scenarios offer different levels of sustainability and positive impacts for stormwater management, generally ranging from bad (unmanaged) to good

(LID approach). Simply allowing future development to occur in an unmanaged fashion would have the hardest impact on the health of the watershed. Even if the municipal storm sewer system was upgraded to eliminate flooding, the creek would still see an appreciable increase in both peak flow and volume, and a corresponding increase in the time of concentration. This is not a sustainable approach.

By requiring future development to have detention facilities to attenuate flows back to existing rates, the watershed would at least have an opportunity to stabilize and maintain its current status. However, the most sustainable approach would be to implement low impact development techniques in the watershed, as this would most closely mimic the natural hydrologic and hydraulic regime of the watershed.

9.8 Operation and Maintenance

In general, municipalities in the past have leaned towards implementing more traditional drainage infrastructure, such as storm sewers, ditches and regional detention ponds. Unfortunately, these types of drainage infrastructure also tend to be less sustainable. Many sustainable stormwater management approaches have been introduced over the past 10 to 15 years and there is not a lot of consistent information available with regards to long-term operation and maintenance.

Education is particularly important to ensure that long-term maintenance on sustainable facilities is undertaken. In this respect, it is likely that the City will have to maintain ownership of any new facilities at the outset and be responsible for maintenance. Costs related to maintenance can be addressed through various means, including a stormwater utility. Once the City's staff is clear on the procedures for maintaining these types of facilities, private ownership of operation and maintenance could take place and the City could move into a monitoring and enforcement role.

10.0 RECOMMENDATIONS

10.1 Guiding Principles

It is the vision of both the City and the project team to ultimately create a living document for the Nunns Creek watershed, which is expected to be updated and revised, as necessary, as the recommendations described below are implemented and monitored. The primary goal is to recommend stormwater management solutions for the watershed which are realistic and practical to achieve, and which are adaptable should conditions change as future information on the watershed is obtained.

Over the next ten years, new development is expected to focus primarily on residential uses, with some in-fill type development scattered around the watershed. Therefore it is critical that guidelines for future development be firmly in place to manage the impact on the watershed from this development. In addition, there may be opportunities to counteract the effects of existing development and to enhance the current information database on the watershed.

As a filter for formulating, evaluating and implementing stormwater management options within the watershed, we have used the following guiding principles:

- No further degradation in the Nunns Creek system
    - Maintain base flows within the creek
    - Avoid inducing any new flooding or creek erosion
    - Apply sustainable stormwater management controls on all new development
- Enhance the creek resource where possible
    - Move towards establishing a "pre-development" hydrologic cycle throughout the catchment
    - Retrofit sustainable stormwater controls in existing development areas, where feasible
    - Construct in-stream habitat improvements as resources become available

10.2 Municipal System Upgrades for Existing Conditions

As noted in Table 10.1 below, there are several storm sewers that flood under existing conditions for their relevant design event. We recommend that the City upgrade these sewers to provide an appropriate level of service to the community. Cost related to these upgrades can be found in Section 11.

Table 10.1
Required Municipal System Upgrades (Existing Development Conditions)

Model Link ID	Location	Existing Pipe Size (mmØ)	Proposed Pipe Size (mmØ)	Length (m)
1754	Homewood Road	530	1050	87
1755	Homewood Road	530	1050	186
1756	Homewood Road	530	1050	150
1567	Ironwood Road / 11th Avenue	685	900	87
1566	Ironwood Road / 11th Avenue	600	1050	111
1557	Ironwood Road / 10th Avenue	690	900	33
210	Hemlock Street / 10th Avenue	450	600	21
1553	Hemlock Street / 10th Avenue	450	600	65
1947	Hemlock Street / 10th Avenue	450	600	12
1549	Hemlock Street / 10th Avenue	450	600	47
1548	Greenwood Road / 10th Avenue	450	600	46
1547	Greenwood Road / 10th Avenue	380	600	102
1546	Greenwood Road / 9th Avenue	380	600	109
202	4th Avenue	375	450	123
1283	Munson Road	530	600	150
1282	Munson Road	530	600	150
217	S. Dogwood Street/Pincrest Road	375	450	56
215	S .Dogwood Street/Pincrest Road	375	450	36
192	Trask Road / Merecroft Road	300	600	10
1561	Homewood Road / 9th Avenue	300	450	69

We have not accounted for upgrading any existing sewers which are surcharging under the design event, as it is not clear from past discussions with the City or from the drainage complaint summaries whether these surcharging sewers are an issue for the City or its residents. We have also not recommended upgrades for flooding sewers in the lower reaches of the watershed at this time. The complexities of tidal conditions and runoff events will require the use of calibrated extended period simulation model to make a full assessment of conditions.

We also recommend that the City look for opportunities, possibly through a pilot project application, to disconnect roof leaders from existing homes located in the lower watershed. Based on soils suitability, several areas may be promising in this regard due the presence of some soils with high conductivity.

There are a number of factors affecting fish passage at culverts, including age and size of fish, culvert and stream geometry, and timing. However, in general, velocities greater than about 1.2 m/s can present difficulties for fish passage. Simulated velocities in the main culverts at road crossings in the watershed were in the range 0.4 to 2.6 m/s (2-year recurrence condition). Thus, the City may wish to investigate replacing some culverts and/or providing backwater through the culverts as opportunities arise. If a replacement culvert is proposed, it will be important to use a calibrated model (see Section 10.9) in setting design velocities and to coordinate the design with a fisheries expert.

10.3 Municipal System Upgrades for Future Conditions

Based on the future development scenarios outlined in Section 9, we recommend that the City require the use of LID techniques, where appropriate, for future development in the watershed. The City must first require that development applicants submit a detailed hydrogeological report on the development site, prepared by a qualified professional, which outlines the infiltration capacity of the soils, determines whether the soils are capable of infiltrating runoff up to ½ of the MAR and outlines any additional detention requirements to match post development flows up to the MAR to existing condition levels. Alternatively, if the soil conditions are not well suited for infiltration, we recommend that the City require that all future development, particularly on the west side of the watershed, provide onsite detention facilities to attenuate flows to existing condition levels prior to discharge to Nunns Creek.

The approach to stormwater management for future development sites will need to be evaluated on a development by development basis, where the development's proposed stormwater management concept can be entered into the model and the City can determine the concept's suitability based on model results. The City will then be able to confirm whether LID or detention is the preferred approach and whether any offsite improvement works would be required to service the proposed development (a cost which would then be borne by the developer). An example of offsite improvement works could include road improvements for site access to accommodate increased vehicle demand.

10.4 Culvert Replacements in Lower Nunns Creek

We recommend implementation of the recommendations presented in the 2004 Nunns Creek Lower Watershed Management Study that the culverts at the Island Highway, the Old Island Highway and 16th Avenue be replaced with longer span, bottomless structures. The final design of structure opening geometries and of any related channel improvements (including placement of LWD, sediment removal and channel shaping) should use an updated, calibrated Nunns Creek hydrologic and hydraulic model (see Section 10.9) in order to optimize the design. Cost estimates were included in the original study and thus are not reiterated in this study.

10.5 Erosion Sites

We recommend that the City address the erosion and bank instability in the roadside ditch on Evergreen Road. The southern bank is very steep, however, there does not appear to be much opportunity to flatten this slope as the property line for the adjacent school is located near the top of bank. Rather, we recommend that the ditch profile slope be flattened using a series of riffle pools, which will also slow the water velocity. This will also reduce the depth of the ditch invert relative to the road and the adjacent property, which may provide an opportunity to flatten the southern bank slope within the municipal right-of-way. The invert of the ditch should be armoured with riprap across the bottom and partially up the side slopes, at least to its bankfull condition. Bioengineering could be used to stabilize the bank slopes above the riprap. Vegetation should be properly keyed into the slope as surface planting does not appear to be successful at the site.

We recommend that the City examine the feasibility of constructing detention facilities at the 2nd Avenue and 4th Avenue storm sewer outfalls to Nunns Creek to address erosion concerns downstream of the outfall locations. The City should also address the existing erosion conditions downstream of these outfalls through the placement of riprap along the creek invert, reconstructing the creek invert to construct a riffle pool configuration to slow flow velocities and using bioengineered slopes to stabilize the bank slopes.

10.6 Future Survey Work

We understand that the Nunns Creek Stewards group is planning to conduct a creek survey in the summer of 2005. We recommend that the City work with the Nunns Creek Stewards to conduct a creek survey that would assist the steward group with their work as well as provide relevant information to update the City's XPSWMM model. Relevant survey data includes:

- A full surveyed cross section of the creek at 100 metre intervals using Total Station equipment. Points surveyed would include the bottom width of the creek bed, creek invert, top of bank on main creek channel, bottom of floodplain slope and top of bank of floodplain
- Additional ground elevation shots within the floodplain if the floodplain is wide (e.g. Nunns Creek Park)

- A full surveyed cross section immediately upstream and downstream of all culvert crossings under roads, including the culvert invert elevations and measurements of the culvert and end walls (if present)
- Surveyed information should be tied into legal monuments and geographically referenced to the Universal Transverse Mercator (UTM Zone 10) Projection using the North American Datum of 1983 (NAD83) with units set as metres
- Notes on bed and bank materials (particle size testing)

As noted earlier, there may be existing detention ponds in the watershed which were not modeled as there was insufficient as-built information available. If there are additional detention ponds in the watershed besides the pond on McPhedran Road, we recommend that these ponds be surveyed and added to the XPSWMM model. The survey should include the following information:

- Perimeter of the pond
- Approximate depth of the pond
- Invert elevations and sizes of inlet and outlet pipes
- Configuration of any outlet structures (e.g. overflow weirs, orifice plates), including elevations and sizes

Finally, we recommend that the City conduct a long term program to review storm sewer as-built information and compile manhole rim elevation data. Manhole rim elevation data found to be missing should then be surveyed in the field and all rim elevation data should be updated accordingly in the model and in the City's GIS database.

10.7 Flow Monitoring Program

We recommend that the City implement a flow monitoring program for the Nunns Creek watershed, in order to more fully understand the long-term hydrologic and hydraulic responses of the watershed. Results from the flow monitoring program can be used as a basis to convert the current event-based XPSWMM model to a continuous model to perform continuous simulations which can assist in refining and calibrating several model parameters. A calibrated model will then be more effective in analysing the impacts on the watershed from future development proposals.

A flow measurement device should be installed on the main arm of the creek at Homewood Road to measure flow. The flow measurement device should not be installed further downstream within the tidal influenced zone of the creek, as flow information could be affected by backwater conditions at high tide. A data logger should be included with the flow measurement device to record water depths, velocities and flow at 5-minute intervals. Data should be downloaded once a month and analyzed for completeness and accuracy, then incorporated into the XPSWMM model for use in model calibration. Staff gauges should also be installed further upstream in the watershed to estimate flows from the main tributaries to Nunns Creek. Water levels at the staff gauges should be read once a week during the winter months and once a month in the summer. Six staff gauges should be sufficient to obtain a comprehensive understanding of flows from the tributaries.

We recommend that the flow monitoring program be conducted over the course of at least one year, so that a continuous record of flow information could be obtained through both the wet and dry seasons. Dry season flows will be useful in determining base flows in the creek for fish habitat purposes and to assess groundwater recharge to the creek, which may ultimately allow for the inclusion of groundwater characteristics into the XPSWMM model. The City may wish to partner with the Nunns Creek Stewards in this effort, where the stewards group could be responsible for downloading the flow data and notifying the City if maintenance or debris removal is required at the structure, and the City could be responsible for the overall maintenance of the structure on an as-needed basis as well as the analysis of the flow data. Initial set-up and calibration of the flow measurement device and data logger should be undertaken by a company experienced in this field.

As mentioned earlier, our analysis of the rainfall distribution at both the Campbell River Airport station and the Sewage Treatment Plant station indicated that there may be no appreciable difference between the two to suggest that a micro-rainfall climate exists in Campbell River. Therefore, we recommend that the rainfall data from the Campbell River Airport rain gauge be used in conjunction with the flow information obtained through this flow monitoring program for the XPSWMM model. The City will need to arrange to obtain raw rainfall data in 5-minute intervals for the Campbell River Airport rain gauge through the Atmospheric Environment Service department of Environment Canada.

We also recommend that the City consider measuring other water quality parameters in conjunction with the flow data for fisheries habitat purposes. Measuring parameters such as water temperature, pH, dissolved oxygen and total suspended solids would assist the City in further defining limitations for fish habitat in the creek.

10.8 Field Verification of Soil Infiltration Properties

In addition to the creek / pond surveys and flow monitoring program, we recommend that the City undertake further field verification of soil infiltration properties. As noted in Table 7.5, the infiltration parameters used in the XPSWMM model are quite sensitive and have a significant impact on both peak flows and volumes predicted by the model.

Field verification of infiltration parameters would likely include requiring a soils report to be submitted with a development application which discusses in-situ testing undertaken at the site to establish infiltration rates. This report would assist both the developer and the City in selecting and evaluating different types of best management practices which may be appropriate for that particular site to mitigate the impacts of the development. Over time, the City should also use this information to build a database of soil infiltration properties for the watershed which could then be used to refine the infiltration parameters used in the model.

Alternatively, if the rate of future development applications is slow, we recommend that the City implement a test pit program in the watershed to obtain the necessary soils information for the model. A total of six to twelve test pits could be dug at various locations in the watershed to confirm soil infiltration properties. Preliminary costs for infiltration tests and test pitting are included in Section 11.

10.9 Continuous Modeling

We understand that it is the City's intent to use the XPSWMM model prepared for this study as a base model, which will be developed and refined over time as additional information on the watershed becomes available. We recommend that the City implement the recommendations listed in Sections 10.6 to 10.8 above so that the XPSWMM model can be expanded from an event based model to a continuous simulation model.

There are several benefits for the City in moving from an event based model to a continuous simulation, besides sizing municipal drainage infrastructure and determining detention requirements. A continuous simulation provides an indication of the magnitude of baseflows that are in the creek which can then be correlated to fisheries habitat. Continuous simulations also allow the City to model infiltration, evapotranspiration and groundwater recharge processes more accurately, so that their benefits can be accounted for when designing BMP / LID facilities.

A model which is calibrated based on actual data can be used to more accurately understand the response of the watershed to rainfall and interstorm events, as well as to evaluate the impact of potential development proposals. This type of analysis will assist the City when providing direction to developers on the stormwater management requirements for their site, as well as the types of features that would be well suited to the individual characteristics of their site.

10.10 Baseflow Restoration Measures

Of the three watersheds studied in the overall project (Nunns, Simms and Willow Creeks), Nunns Creek exhibits the impacts of urban development most fully. One particularly visible impact is dry stream beds during summer months. Regardless of whether future development is extensive, there are measures that can be further investigated that may mitigate the effects of past development and at least partially restore base flows in Nunns Creek.

First, opportunities for disconnecting existing roof leaders from storm sewers systems in areas east of the creek should be explored. As noted earlier, the Dashwood soils in the watershed show promise for long-term infiltration of runoff; this will first need to be confirmed with further soils testing work. Other issues that would have to addressed include:

- Slope stability
- Potential basement flooding in downslope houses
- Alternate methods such as splash pads to yards, to rain barrels or to underground infiltration systems
- Need for additional topsoil in yards in conjunction with leader disconnection
- Resident acceptance

A pilot project in one subdivision or block could be an excellent way to test this.

As noted previously, in areas west of the creek, the presence of ditches has likely caused a lowering the local water table. This opens the possibility for exploring shallow infiltration systems in these areas. This could be done either on individual lots in order to disperse the infiltration around the watershed (thus mimicking pre-development conditions) or within the ditches themselves (thus putting the "facilities" directly into City control). The latter method could be accomplished by excavating below ditch grade, placing a rock trench or similar system below the ditch, backfilling, placing low weirs along the length of ditch and replanting with native vegetation. Again, a pilot project in one or more areas could be used to determine viability and test design criteria for future expansion of the program.

10.11 Operations and Maintenance Schedule

The City's council policy manual has a chapter which outlines the Public Works department's operation and maintenance schedule. The manual outlines a timeline for inspection and maintenance, as well as recording and action procedures to rectify inadequacies, for several types of drainage facilities in the City including roadside ditches, catch basins and storm sewers. The manual, however, does not include timelines for inspection and maintenance of other types of facilities which currently exist in the City, such as detention ponds and wetland complexes.

We recommend that the City expand their current documentation to include detention ponds and wetlands in their maintenance schedule. The City may consider a yearly inspection for detention ponds, where public works staff could inspect the condition (and potential blockage) of the inlet and outlet structures of the pond, as well as the presence and health of vegetation around the pond perimeter. The City may also wish to take turbidity samples on a more frequent basis at the pond inlet and outlet locations to verify the performance of the pond. Regional detention ponds typically also require more rigorous maintenance on an infrequent basis (every 10-15 years), such as dredging of sediments from the bottom of the pond. Wetlands should also be inspected yearly for presence and health of native vegetation, presence of invasive plant species, beaver activity and condition of man-made flow control structures (e.g. rock weirs, check dams) or beaver dams. Eventually, as LID techniques are implemented in the watershed, the operation and maintenance schedule will need to be modified to suit.

10.12 Critical Habitat Protection, Restoration and Enhancement Opportunities

General recommendations include:

1. The biophysical information for the stream system should be brought up to the same data standard and level as the adjacent watersheds. For Nunns Creek, some of the remnant wetlands could be identified by soil auger tests and the historical extent of the Nunns Creek wetlands at its headwaters established.

2. An overall wetland management plan for the system would be appropriate, this should include an assessment of the wetland's contribution to the system and a management plan including enhancement of the remnant wetland complexes.

3. A beaver management plan would identify areas where beavers can be encouraged and where they should not be encouraged. In particular, riparian management in the light of riparian species palatable and non-palatable to beavers and where they should be planted would be useful. Other recommendations include beaver-proof ponds and

wetlands where beavers are discouraged. Beavers quickly exhaust their food supply and move on, but should be encouraged to sustainable levels in those portions of the watersheds where they are of benefit to other terrestrial and aquatic organisms.

Nunns Creek has been signficantly encroached by urban development. It has lost most of its headwater wetlands, which have been ditched to give way to rural development. Further rural and infrastructure developments are planned and these may provide opportunities to remedy some of the limitations within the systems. These are, in order of priority:

1. The Willis Road expansion would allow the establishment of further detention and treatment within Tributary 3. This can be attained thorugh source control, provision of swales to wider ditch system further downstream, and placing in-line detention ponds in strategic locations within Tributary 3. Ditches and some of the detention structures could be enhanced through marsh and riparian planting to make them into viable terrestrial and aquatic systems. The cost of such improvements could be borne by the Willis Road expansion.

2. Above Trask Road, a headwater diversion could be accomplished by enhancing the system as follows:
   - headwater ditches, swaling and ditch widening
   - diversion along property lines in road right-of-ways to Trask Road
   - installation of a wetland complex and detention pond upstream of Trask Road
   - all systems should be planted with marsh and riparian vegetation

   The cost of this system could be borne by the development application of the adjacent landowner to achieve a habitat balance under the Fisheries Act using Section 32.

3. The third critical item for Nunns Creek is to address the erosion issues at the storm sewer outfalls at 2nd Avenue and 4th Avenue, starting with the provision of:
   - an outlet pond with proper erosion control
   - a rock liner within the ditches to prevent erosion and bank cutting
   - wetland and riparian plantings at the stormwater outlets to provide nutrients and shading

This stormwater program could be managed by phasing the project and implementing a charge against major development proposals in this part of the watershed which encroach on fish habitat or incur poor stormwater water quality.

10.13 Erosion and Sediment Control Practices on Construction Sites

To address erosion and sediment control practices on construction sites, we recommend that the City prepare a detailed ESC brochure or pamphlet that would be distributed with every building permit application. The brochure would outline the City's expectations for ESC on construction sites as well as a discussion on the impacts to local watercourses and fish habitat if proper ESC practices are not followed. Source control practices such as minimizing cleared areas, timing clearing activities to correspond to actual construction windows, retaining vegetation as much as possible and covering / re-vegetating exposed areas quickly, would be encouraged over end-of-pipe solutions such as sediment control fences and sediment ponds (although these may ultimately still be required). The DFO Land Development Guidelines could also be referenced to assist the applicant with design information for ESC facilities, along with stating the required site runoff water quality requirements to provide grounds for enforcement for the City.

If the City would like to take a more definitive stance on the issue, then we recommend that the City implement a new Erosion and Sediment Control Bylaw. This bylaw would clearly outline the City's requirements for ESC practices on construction sites and would also state the penalties and/or fines for not meeting the requirements of the bylaw. A comprehensive ESC bylaw may require that the applicant do one or more of the following:

- Prepare and submit an ESC plan for the site prior to the start of construction, which would indicate the location and function of all proposed ESC facilities, as well as the location of any nearby watercourses or other sensitive areas
- Designate an ESC supervisor for the site, who would be responsible for the construction, operation and maintenance of onsite ESC facilities

- Outline a reporting structure for the ESC supervisor on their inspection of ESC facilities, where the reports may or may not need to be submitted to the City
- Outline a timeline for inspections by the ESC supervisor, which may be weather dependent
- Establish the City's right to enter the site at any time to inspect ESC facilities and issue warnings / fines for non-compliance as necessary
- Allow the City to undertake any remedial works necessary to correct non-compliance issues and bill the applicant
- Limit the times of year when certain construction activities could take place, or require more stringent controls during the winter season
- Limit the amount of area that can be cleared at any one time

If the City chooses to implement a new ESC bylaw, it should be recognized that additional staff and or re-training of existing staff may be necessary to ensure that the bylaw is properly enforced.

10.14 Performance Targets

We recommend that the City adopt stormwater performance targets for runoff volume, quality and peak that are generally consistent with Provincial and Federal guidelines and that will support the City's desire to continue to provide a consistently high level of service throughout the community. We recommend the following specific performance targets:

- **Small Storm Goal:** No discharge from impervious areas for storm events with rainfall depths up to one half the 24-hour Mean Annual Rainfall (MAR)[10]
- **Medium Storm Goal:** The post-development runoff for the 2-year recurrence 24-hour storm shall be 50% of the pre-development runoff and the post-development runoff of the 5-year recurrence 24-hour storm shall not exceed the pre-development runoff
- **Large Storm Goal:** For storm events exceeding the 5-year recurrence, safe conveyance of runoff
- **Water Quality Goal:** Treat runoff from impervious areas for all storm events less than or equal to the MAR, with a minimum 80% annual average removal of Total Suspended Solids (TSS); for commercial and industrial developments, oil and grease shall also be removed

[10] The Mean Annual Rainfall (MAR) is 55 mm in 24 hours.

While these targets will be generally applicable to individual residential sites, in some or even many cases it will not be feasible to meet them. Thus the targets should be applied more strictly to entire developments (or phases of development) with developers and builders given the option of finding an appropriate mix of onsite and neighbourhood best management practices for each development. The targets should however be applied to all commercial and industrial development.

In conjunction with this, we recommend the City revise its current design frequency for minor storm conveyance systems to provide the same level of service to all areas, regardless of land use. We recommend that the level of service be the 5-year recurrence runoff event, after taking account of the on-site performance targets noted above, if applicable. The major storm conveyance system level of service should remain the same, namely the 100-year recurrence runoff event.

With respect to stormwater quality, as listed above, we recommend that City require removal of 80% of the annual average Total Suspended Solids (TSS) load conveyed by runoff from all new development. This standard would be supplemented during construction by application of an approved ESC plan (see Recommendation 10.13). Further, properly installed and maintained BMP's or the use of low impact development methods will be presumed to satisfy this target when approved as part of a development application / building permit process. For commercial and industrial development, we also recommend requiring removal of oil and grease before discharge to storm systems or the creek.

With respect to infill development, we recommend that the City consider each development application on a case by case basis to determine the need for rigid application of these performance targets. At the least, residential in-fill development must attempt to include on-site BMP's or low impact methods and commercial / industrial redevelopment must incorporate measures to control runoff water quality.

10.15 Public Outreach and Education Initiatives

The City should continue to foster a positive relationship with the Nunns Creek Stewards. Both the City and the stewardship group should actively seek opportunities to work together to achieve common goals for the watershed.

We understand that the City currently has a program in place to recognize the positive actions of stewardship groups in the watersheds through a stewardship award. We recommend that the City also implement a similar type of award for developers who recognize the importance of proper and innovative stormwater management in the watershed. Developers who exert a high level of effort to mitigate the impacts of development on stormwater runoff, either through excellent erosion and sediment control practices during construction or through the implementation of alternative design standards and low impact techniques, should be recognized publicly by the City. Public recognition may provide an incentive for developers to work with the City on testing new stormwater methodologies or enter into partnerships with the City for the design and construction of the pilot projects outlined in the next section.

There are also several things that the City can do to educate the general public. Many residents understand the detrimental impacts that both people and development can have on a watercourse, but are often unaware about what they can do as individuals to help out. We recommend that both the City and the stewardship group strongly encourage participation in the local stewardship group and advertise events, such as creek clean-ups or planting activities, on the City's website and through stewardship newsletters. The stewardship group may also consider going door-to-door once a year to outline their proposed activities for the coming year and to encourage residents to volunteer.

We also recommend that the City prepare a brochure outlining measures that could be undertaken by individual homeowners on their property. This brochure could be posted on the City's website as well as be available in hard copy at the front desk at the municipal hall. The brochure could describe activities such as:

- Water conservation, by capturing water from roof downspouts in a rain barrel and using for irrigation of on-lot landscaping and grassed areas
- Retaining as much native vegetation as possible on their property
- Amending soils in landscaped areas with additional organics and topsoil to encourage retention of water
- Purchasing only native species of plants from local garden centres to plant in their yards
- Cleaning up garbage and debris from the roadside ditch or curb / gutter in front of their home
- Reducing or eliminating the use of herbicides and pesticides on grassed areas
- Using environmentally friendly waxes and soaps if washing vehicles on the driveway

Other City led activities, such as painting fish symbols on catch basin and manhole lids, can also be an effective public education tool. The City should post periodic bulletins on their website or in local newspapers to update the public on the implementation of any of the ISMP recommendations and future stormwater work proposed in the future.

10.16 Pilot Projects

In general, pilot projects are a great way to test out new stormwater concepts before they are permitted City-wide, but the City has to first be willing to test out these new concepts in the field and realize that there may be a period of trial and error involved. Monitoring of constructed works and analysis of measured data are critical to the success of any pilot project. More often than not, constructed works need to be refined or even replaced over time in order for them to be completely successful, however, once issues are worked out, these types of projects will provide great benefits and represent a step towards mimicking the natural hydrologic and hydraulic response of the watershed.

We recommend that the City consider implementing the following pilot projects in the Nunns Creek watershed:

Sustainable Roadway

The City could test out the use of several sustainable stormwater management concepts by constructing a sustainable roadway design. The road could incorporate features such as porous pavement, infiltration galleries, vegetated swales, reduced impervious areas through narrowed road and sidewalk widths, etc. The sustainable road could then be monitored against an urbanized road with similar land use characteristics in the vicinity to determine the reduction in runoff peaks and volumes due to the alternative design. Temperature, pH, TSS and DO could also be measured at the downstream end of the street to assess the design's benefit to water quality.

Selection of an appropriate site will depend on soil conditions, location in the watershed, type of land use, level of support from adjacent landowners and the presence of existing municipal drainage infrastructure and underground utilities.

Deep Infiltration Wells

Results from the hydrogeological study suggest that vertical infiltration wells may be a possible method of infiltrating stormwater. Installation of vertical infiltration wells in the upland areas of the watershed could assist groundwater recharge to the creek, which would help to maintain a more consistent level of base flow. As noted previously, this method of infiltration is currently being implemented at a development along Merecroft Road (details were not available at the time of study completion). We recommend that the City approach the developer jointly implement monitoring of the project, to test performance and assess the impact of the system.

Porous Pavement

Porous pavement could be implemented on a smaller scale in commercial areas, on-street parking areas or driveways. This would provide a good opportunity for the City to work in partnership with a local developer or a group of homeowners. The extent of the area to be replaced by porous pavement could be selected by the City and an emergency overflow to the municipal storm sewer system would likely be simple to include if desired, as the site was likely already serviced by catch basins and storm sewers. If the City wishes to try porous pavement in a pilot project, we recommend that porous asphalt or paver blocks be used, as the mixing and installation process for porous concrete is more complex and pilot projects conducted in other areas suggests that prior experience with the material is important for the overall success of the installation.

Disconnect Roof Downspouts

The City's current standards require that all roof downspouts be tied into the municipal storm sewer system. Water generated from rooftops accounts for an appreciable volume of the water that reaches a downstream watercourse. It would be an interesting pilot project to quantify the volume of water from this source by monitoring peak flows from two similar residential areas where one area maintains downspout connections to the municipal sewer whereas the other disconnects their downspouts. The City could also monitor how the redirection of roof water to pervious surfaces affects surface drainage in the second neighbourhood, i.e. is the water infiltrating or creating nuisance ponding. Again, success of this project will depend partially on soil conditions and the location in the watershed. The hydrogeological report suggests that this type of pilot project would be best suited in areas east of Nunns Creek. The two residential areas should be at the upstream end of the municipal system so that peak flows in the sewer are not affected by offsite areas.

Both Seattle, WA and Portland, OR have roof leader disconnection programs in place, where residents are encouraged to disconnect their roof leaders through tax credits or monies paid directly to the resident for each roof leader disconnected. Both programs have been quite successful. Further details on these programs can be found on the websites for those cities.

10.17 GIS Database

Several new GIS layers were created during the ISMP study to assist the project team in their analysis of the watershed. We recommend that the City incorporate the following new layers into their GIS database:

- Revised watershed boundary

- Sub-catchment boundaries within the watershed (used for model development)
- 5m contours for partial project area
- Forested area delineation (based on aerial photo interpretation)
- Riparian area delineation (based on aerial photo interpretation)

We also recommend that the City continue to expand and supplement their GIS database as more information becomes available. Other parameters that would also be useful to reference in the GIS database include:

1. **Creek Attributes** – each reach of creek could have attributes associated with it, such as surveyed cross sections, Manning's roughness coefficient, photos of the reach and any related erosion or fisheries habitat improvement works completed or scheduled for future.
2. **Soils Attributes** – a new soils layer could be developed based on the hydrogeological information from this ISMP study, which could then be refined in the future as additional in-situ and drill testing is conducted and as new development provides additional data.
3. **Rainfall Data** – the Campbell River Airport rain gauge location and associated rainfall data (including the IDF curve) could be added to the GIS database.

10.18 City Bylaw and Policy Revisions

As noted in Section 4.5 on Land Use Policy Gaps, the City's land use bylaws (the Draft Official Community Plan and Zoning Bylaw) are, in general, supportive of integrated stormwater management. However, as outlined in Table 4.4, a number of land use policy gaps remain. The City may wish to consider the following revisions to ensure its land use policies fully promote integrated stormwater management within the Nunns Creek Watershed:

Official Community Plan – the OCP could be revised to include measurable targets for preserving open space or limiting impervious area. While the OCP already includes provisions to encourage the preservation of open space, setting well-defined targets would help the community more accurately determine whether broader goals are actually being met. For instance, the City may consider setting a goal to preserve a certain percentage of the City for open space. The OCP could also support policies to obtain open space (e.g. policies to support reclaiming brownfield lots for greenspace). This would allow the City to consider the cumulative impact of all types of development as opposed to the impact of each type of development separately, which is addressed in the Zoning Bylaw.

Zoning Bylaw – the City could make its Zoning Bylaw more supportive of integrated stormwater management principles by:

- Introducing maximum parking requirements (in addition to the existing minimum requirements)
- Extending maximum impervious area limitations to all zones
- Encouraging the use of native species of vegetation and Best Management Practices, where appropriate, to support integrated stormwater management
- Directly encouraging cluster development by allowing density averaging in all residential zones
- Revisiting zoning for the area governed by the Nunns Creek Area Road and Greenways Plan to enable cluster development
- Including impervious areas such as driveways, sidewalks, and any other hard surfaces in the calculation of lot coverage to limit impervious area

Tree Protection Bylaw – The City should consider adopting a tree protection bylaw, which could specify retention and planting requirements for both new development and re-development of existing parcels in the City.

10.19 Updates to City Engineering Standards and Specifications

We recommend that the City revise its Engineering Design Standards and Specifications to include best management practices that are consistent with the goals, objectives and guiding principles of this ISMP. The City's alternate design standards initiative, which is currently in a consultative phase, will meet this recommendation.

10.20 Public / Private / NGO Partnerships

We recommend that the City seek ways to creatively engage private and non-government organizations (NGOs) in partnerships to implement the ISMP recommendations and further improve watershed health. Pilot projects may be particularly fruitful for such partnerships. Some examples are:

- **Large Woody Debris** – As site clearing progresses in a new development, the cut trees could be used by the Nunns Creek Stewards for placement as LWD / LOD in local streams. Developer would provide the raw materials at no cost while the City could assist with handling.
- **Monitoring** – Enlist Nunns Creek Stewards' help with reading staff gauge levels, downloading digital rainfall and/or flow metering data, perform visual assessments of erosion sites and public education programs

10.21 Funding Mechanisms

We recommend that the City establish a stormwater utility as a mechanism to generate dedicated funds for construction, operation, maintenance and administration of all publicly-controlled components of the stormwater system. The stormwater system would likely include:

- Streams and ditches
- Culverts
- Storm sewers and appurtenances
- Regional detention ponds, wetlands and infiltration facilities
- Regional "engineered" water quality structures (such as oil / sediment removal systems)

The utility would have enforcement authority to require, for example, stormwater management plans from new development. Further, the utility would be able to collect stormwater user charge fees on a common and fair basis.

While there are many methods of determining user charge rates, we recommend adoption of the fairly simple approach of basing rates on either land use classes or on actual impervious area on each property. The latter is preferred, as it is the single most important determinant of runoff peak and volume from any developed property in an urban area. However, establishing actual impervious area is not always straightforward or easy. In any case, the basis must be fair and must be based on the actual service provided, in this case stormwater removal and stream protection. Credit could be given for the upkeep and use of approved runoff reduction methods (BMP's / LID methods) on existing properties. Consideration may also be required for new development which is required to meet the recommended performance targets for stormwater control.

Table 10.2 summarizes the recommendations of the Nunns Creek ISMP study and assigns priority levels for each activity, with Level 1 being the highest priority and Level 3 being the lowest priority. Some of the recommendations are also shown graphically on Figure 10.1.

Table 10.2
Summary of Recommended Works

Category	Recommendation	Priority Level 1	Priority Level 2	Priority Level 3
Municipal Drainage System	Upgrade deficient municipal drainage infrastructure	X		
	Replace culverts at 16th Avenue, Old Island Highway and Island Highway with open bottom arch culverts or bridge structures		X	
	Prepare operations and maintenance schedule for stormwater system		X	
Environmental	Survey erosion sites in all watercourses (location, extent, etc.)	X		
	Undertake a wetlands inventory (historical location, extent, etc.)	X		
	Prepare a wetland management plan	X		
	Prepare a beaver management plan		X	
	Consider instream boulder / gravel recruitment between 16th Avenue and 9th Avenue		X	
	Install water quality units at existing storm sewer outfalls from industrial / commercial sites (Nunns Creek Park)	X		
	Verify connections from ERT ditches to Nunns Creek; revegetate / enhance ditches where possible		X	
	Add detention facilities, water quality treatment at 2nd Avenue and 4th Avenue storm sewer outfalls	X		
	Construct check dams / rock liners / pool riffles and LOD's in ravines / ditches downstream of 2nd Avenue and 4th Avenue outfalls to address erosion concerns and enhance habitat value	X		
	Consolidate Willis Road ditches into one swale / ditch system in conjunction with road widening program, enhance swale with native plantings, boulder / gravel recruitment, detention / water quality treatment where possible, lower existing road culverts where needed for fish access	X		
	Address erosion in Evergreen Road ditch with riffle / pools, riprap and bioengineering	X		
	Add ponds / rock weirs / native plantings to ditch above Evergreen Road for water quality treatment		X	
	Divert upper creek to Petersen Road and Merecroft Road right-of-ways and enhance for habitat / water quality treatment / baseflow restoration	X		
	Install check dams in ditch system at Pinecrest Road / Petersen Road and plant with native vegetation for water quality / erosion control		X	
	Define Trask Road channel, install culvert at road crossing, enhance with riparian plantings		X	
	Conduct water quality monitoring program (one year minimum)			X
	Verify soil infiltration properties throughout the watershed (test pit program)		X	
Pilot Projects	Roof Leader Disconnection Program	X		
	Sustainable Roads Design and Construction	X		
	Porous Pavement		X	
	Shallow infiltration trenches in existing roadside ditches west of Nunns Creek		X	
	Deep Infiltration Wells			X
Data Management	Conduct flow monitoring program (one year minimum)	X		
	Obtain detailed cross section and profile survey of creek	X		
	Obtain updated, detailed aerial contour mapping of watershed		X	
	Re-establish digital recording of continuous rainfall measurements at the airport rain gauge	X		
	Compile manhole rim data throughout the area		X	
	Refine the current XP-SWMM model to perform extended period (continuous) simulations		X	
	Update GIS database		X	
Policy	Consider requiring the use of LID techniques (where appropriate and feasible) for new development (as described in Section 9)	X		
	Develop and adopt an Erosion and Sediment Control Bylaw		X	
	Prepare and distribute an Erosion and Sediment Control Brochure to builders		X	
	Adopt performance targets for stormwater volume, peak and quality	X		
	Adopt a single, consistent 5-year level of service for minor conveyance systems	X		
	Require specific stormwater quality treatment for all new commercial and industrial sites	X		
	Adopt measurable targets in OCP for preserving tree cover and limiting impervious area	X		
	Update zoning bylaw to include maximum parking space and impervious area limits, encourage vegetation retention and native species plants, and encourage cluster development		X	
	Develop and adopt a tree retention bylaw		X	
	Update Engineering Standards / Specifications to include BMP's which promote integrated stormwater management practices		X	
	Develop and adopt a stormwater utility to finance all aspects of the stormwater system		X	
Public Education	Conduct a long term public education and outreach program	X		
	Undertake a native planting program with private landowners within riparian corridor		X	
	Develop a stewardship award for the development community		X	

Level 1 is highest priority, Level 3 is lowest priority

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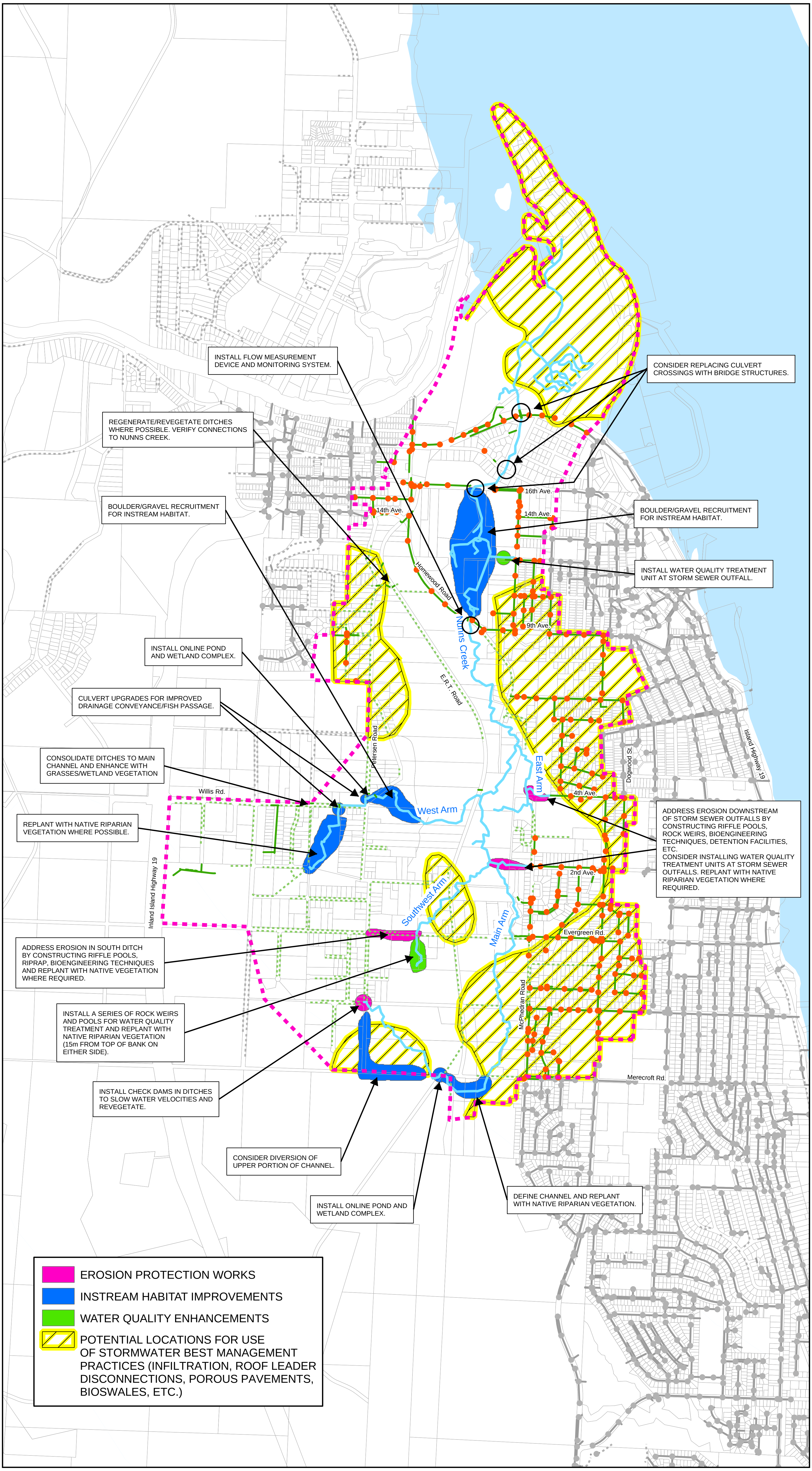

City of Campbell River

Integrated Stormwater Management Plan

Figure 10.1

Nunns Creek Watershed Recommended Works

- Storm Manhole Within Watershed
- Storm Main Within Watershed
- Storm Manhole Outside Watershed
- Storm Main Outside Watershed
- Ditches Within Watershed
- Ditches Outside Watershed
- Nunns Creek
- Nunns Creek Watershed

0 200 400
Metres

Scale 1:20 000

Source: City of Campbell River

This map was prepared for the purposes of this planning study and are provided for general reference only. Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

URBANSYSTEMS
1479.0005.01 May 2005

11.0 COST ESTIMATES

Several recommendations for the Nunns Creek watershed were presented in Section 10, however, some of these recommendations are policy related (e.g. bylaw amendments) or "soft" solutions (e.g. public outreach and education), therefore it is difficult to assign a cost to them. Thus, the costs outlined in this section are related to "well-defined" recommendations presented in the previous section, namely:

- Municipal storm sewer upgrades to service existing development conditions
- Detention facilities to service future development conditions
- Trunk storm sewers to service future development conditions
- Topographic mapping and aerial photography updates
- Flow monitoring program and water quality sampling
- Infiltration test pit program

Costs outlined in this section are representative of a Class D cost estimate and include a 35% contingency and 15% engineering allowance. Details on the cost estimates can be found in Appendix I. GST has not been included in these estimates.

11.1 Municipal Storm Sewer Upgrades

Municipal upgrade requirements to service existing development conditions were summarized in Section 10.2. Table 11.1 itemizes the costs associated with these upgrades (including capital costs and operations / maintenance costs). Costs assume that any existing manholes will not require replacement.

Table 11.1
Municipal Sewer Upgrade Costs to Service Existing Development

Model Link ID	Location	Ex. Size (mmØ)	Proposed Size (mmØ)	Length (m)	Capital Cost ($)	O & M Cost ($/yr)	Present Value of O & M Cost
1754	Homewood Rd	530	1050	87	$ 75,760.00	$ 800.00	$ 11,700.00
1755	Homewood Rd	530	1050	186	$ 161,880.00	$ 1,700.00	$ 24,800.00
1756	Homewood Rd	530	1050	150	$ 130,500.00	$ 1,400.00	$ 20,400.00
1567	Ironwood Rd / 11th Ave	685	900	87	$ 67,060.00	$ 700.00	$ 10,200.00
1566	Ironwood Rd / 11th Ave	600	1050	111	$ 96,580.00	$ 1,000.00	$ 14,600.00
1557	Ironwood Rd / 10th Ave	690	900	33	$ 25,440.00	$ 300.00	$ 4,400.00
210	Hemlock St / 10th Ave	450	600	21	$ 12,080.00	$ 200.00	$ 3,000.00
1553	Hemlock St / 10th Ave	450	600	65	$ 37,200.00	$ 400.00	$ 5,900.00
1947	Hemlock St / 10th Ave	450	600	12	$ 6,860.00	$ 100.00	$ 1,500.00
1549	Hemlock St / 10th Ave	450	600	47	$ 26,860.00	$ 300.00	$ 4,400.00
1548	Greenwood Rd / 10th Ave	450	600	46	$ 26,280.00	$ 300.00	$ 4,400.00
1547	Greenwood Rd / 10th Ave	380	600	102	$ 58,260.00	$ 600.00	$ 8,800.00
1546	Greenwood Rd / 9th Ave	380	600	109	$ 62,320.00	$ 700.00	$ 10,200.00
202	4th Ave	375	450	123	$ 57,240.00	$ 600.00	$ 8,800.00
1283	Munson Rd	530	600	150	$ 85,700.00	$ 900.00	$ 13,100.00
1282	Munson Rd	530	600	150	$ 85,700.00	$ 900.00	$ 13,100.00
217	S.Dogwood St/Pincrest Rd	375	450	56	$ 26,080.00	$ 300.00	$ 4,400.00
215	S.Dogwood St/Pincrest Rd	375	450	36	$ 16,780.00	$ 200.00	$ 3,000.00
192	Trask Rd / Merecroft Rd	300	600	10	$ 5,800.00	$ 100.00	$ 1,500.00
1561	Homewood Rd / 9th Ave	300	450	69	$ 32,120.00	$ 400.00	$ 5,900.00
Total					$1,096,500.00	$ 11,900.00	$ 174,100.00
+35% Contingency					$ 383,800.00	$ 4,200.00	$ 61,000.00
+15% Engineering					$ 164,500.00		
Total (Capital)					$1,644,800.00	$ 16,900.00	$ 235,100.00

11.2 Detention Facilities

Detention requirements to service future development are based on the short-term future development areas indicated in Figure 4.3. Table 11.2 summarizes the cost associated with the proposed detention facilities (including capital costs and operations / maintenance costs):

Table 11.2
Detention Facility Costs to Service Future Development

Development	Location	Required Active Storage Volume (m^3)	Capital Cost ($)	O & M Cost ($ / yr)	Present Value of O & M Cost
4/5	Old Petersen Road	4,100	$1,037,750.00	$ 41,600.00	$ 604,700.00
8	Willis Road / Inland Highway	440	$ 114,500.00	$ 4,600.00	$ 66,900.00
9	Willis Road / Inland Highway	1,500	$ 382,500.00	$ 15,300.00	$ 222,400.00
2nd Ave	2nd Ave / Nunns Creek	2,300	$ 584,750.00	$ 23,400.00	$ 340,100.00
4th Ave	4th Ave / Nunns Creek	2,400	$ 609,750.00	$ 24,400.00	$ 354,700.00
Total			$2,729,250.00	$ 109,300.00	$1,588,800.00
+35% Contingency			$ 955,300.00	$ 38,300.00	$ 556,100.00
+ 15% Engineering			$ 409,400.00		
TOTAL (Capital)			$4,093,950.00	$ 147,600.00	$2,144,900.00

11.3 Trunk Storm Sewers

Trunk storm sewers were sized to service future development areas labelled 4, 8 and 9 on Figure 4.3. Table 11.3 summarizes the cost associated with the trunk sewers (including capital costs and operations / maintenance costs):

Table 11.3
Trunk Storm Sewer Costs to Service Future Development

Location	Proposed Size (mmØ)	Length (km)	Capital Cost ($)	O & M Cost ($ / yr)	Present Value of O & M Cost
ERT Rd to Campbell River	600	2.2	$1,311,200.00	$13,200.00	$191,900.00
Willis Road to Nunns Creek West Arm	600	0.95	$ 566,200.00	$ 5,700.00	$ 82,900.00
Evergreen Rd to Nunns Creek SW Arm	600	1.4	$ 834,400.00	$ 8,400.00	$122,100.00
Total			$2,711,800.00	$27,300.00	$396,900.00
+35% Contingency			$ 949,200.00	$ 9,600.00	$139,000.00
+ 15% Engineering			$ 406,800.00		
TOTAL (Capital)			$4,067,800.00	$36,900.00	$535,900.00

11.4 Topographic Information and Aerial Photography

As noted previously, topographic information on the watershed consists of 5-metre contour intervals in the lower watershed and 20-metre TRIM mapping for the upper watershed. Due to the nature of the terrain in the watershed, a refined contour interval would be desirable in order to verify the watershed boundaries. Contour intervals of 1 to 2 metres can be prepared through an aerial survey of the watershed.

For ease of discussion, costs to update topographic information and aerial photography were prepared assuming that this work would be undertaken for the Nunns Creek, Simms Creek and Willow Creek watersheds at the same time. A fee estimate was obtained from the survey division of McElhanney Consulting Services Ltd. and is summarized below:

Table 11.4
Topographic Information and Aerial Photography Costs

Item	Cost ($)
Topographic Mapping with 1 metre contours for select areas, including photo targeting and GPS control survey.	$19,800.00
Topographic Mapping with 1 metre contours for all three watersheds done at once, including photo targeting, GPS control survey, and colour air photo.	$42,900.00
Colour orthophoto with 20 cm pixel resolution for all three watersheds.	$4,800.00

11.5 Flow Monitoring Program

Flow monitoring costs are based on a one year flow monitoring program and assume that rainfall information will be obtained from the Campbell River airport rain gauge (i.e. a new rain gauge would not be installed at the flow monitoring site). Table 11.5 provides preliminary costs to implement a flow monitoring program in the Nunns Creek watershed. Water quality sampling and staff gauges could be added as needed and as desired by the City. Note that these costs would be somewhat lower should a volunteer program be implemented to download data and maintain the equipment.

Table 11.5
Flow Monitoring / Water Quality Monitoring Costs

Item	Cost ($) / year
Flow Meter	$25,000
Water Quality Sampling	$4,000 per site
Staff Gauges	$3,000 per gauge

11.6 Infiltration Test Program

Conducting one infiltration test per soil type per 5 hectares could be used as a guide for preliminary planning. This program could be modified if the results show a relatively high degree of consistency. A typical cost for constructing a test trench, running an infiltration test, analyzing the results and preparing a report for ten pits typically costs between $400 and $600 per pit.

Two to three 30-metre deep test holes could also be drilled to assess the feasibility of the deep infiltration method. A well typically costs about $9,000 and an infiltration tests cost in the range $1,800 to $3,500 depending of the availability and cost of a water source, such as a fire hydrant or tanker truck. Engineering and interpretation costs would typically cost an additional $4,000 to $5,000 per well. These well should be located in areas where development is planned, and where there is not much data on deep drilled wells. Selected wells can also be used for long term monitoring of groundwater levels and water quality. Water level monitoring is best performed using an electronic data logger that can be set to record water levels at intervals such as 15 minutes and run off a battery for several months. A data logger costs about $1,000 and typically runs for about seven years on a non renewable battery.

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12.0 IMPLEMENTATION

12.1 Enforcement of Policies and Standards

For the recommendations outlined in this report to be successful, three elements must be present:

- **Education** – For both the City and developers, so that the development process and expectations for stormwater management in the watershed are clearly defined and understood by both parties
- **Enforcement** – Of new policies and standards by the City, particularly in the area of erosion and sediment control
- **Dedication** – By the City, to be willing to test out innovative techniques which may not always be entirely successful

Most importantly, support from all parties (City, stewardship groups, development community, environmental agencies) is needed for the ISMP process and its outcomes to be a true success.

12.2 Measuring Success

At one of the stakeholders working group meetings, the project team asked the group how they would determine whether recommendations implemented from this ISMP study were working in the field. The following mechanisms were suggested by the group:

- Biodiversity (current versus future levels)
- Decrease in number of flooding events
- Adaptability
- Decrease in siltation in the stream
- Changes to stream morphology, natural obstructions
- Maintenance of riparian corridors
- Water quantity and quality (e.g. temperature)
- Measure flow rate from traditional lot versus lot which implements Best Management Practices

The recommendations outlined in this report should provide an opportunity to determine changes to the above noted mechanisms, either anecdotally or through actual field measurements.

12.3 Future Adaptation

As mentioned previously, it is the intent of both the City and the project team to ultimately create a living document for the Nunns Creek watershed, which is expected to be updated and revised, as necessary, as the recommendations described below are implemented and monitored. The primary goal is to recommend stormwater management solutions for the watershed which are realistic and practical to achieve, and which are adaptable should conditions change as future information on the watershed is obtained.

With that said, the City will need to be diligent in monitoring the impacts of any implemented works so that the true effect of that improvement is known. The City may wish to pass monitoring duties to the developers, however, the City must have the appropriate number of staff with adequate training to ensure that monitoring is in fact being done and that accurate results are being produced. The City should also review the flow monitoring program on a frequent basis and ensure that the program is refined as necessary so that a true continuous model for the watershed can be developed. The City should also make a conscientious effort to obtain relevant data and add it to the model on a continuous basis.

Finally, as this ISMP study is meant to be a living document, the City should review and update it in five (5) years time.

APPENDIX A

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APPENDIX B

HABITAT / FISHERIES REPORT

CAMPBELL RIVER
WATER QUALITY, WATER QUANTITY AND FISH HABITAT IN NUNNS, SIMMS, & WILLOW CREEK WATERSHEDS

April 22, 2005

prepared for
Urban Systems Ltd
and
The City of Campbell River

prepared by

tera
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Table of Contents

List of Tables

List of Appendices

1 INTRODUCTION

In November of 2004, Jeff Rice, PEng., of Urban Systems Ltd, retained TERA Planning Ltd (TERA) to conduct the environmental and fisheries assessment of the Integrated Stormwater Management Plan for Nunns, Simms, and Willow Creek Watersheds for the City of Campbell River, B.C. The objective of this study is to confirm and identify priorities for critical habitat management and integrate restoration and enhancement opportunities with stormwater management in these watersheds.

2 METHODS

Existing Stormwater Management Plans and Fisheries studies and data were reviewed to establish the ecological information for each watershed. Meetings and discussions with District staff and the stakeholder working group further helped to identify critical habitat issues and areas. Candidate critical habitat areas were assessed and confirmed in the field. Recommendations for critical habitat restoration and enhancement opportunities were developed and prioritized. The level of scope for instream and riparian enhancement work as well as best management facilities have been provided to Urban Systems for their engineering evaluation to allow preliminary engineering parameters and costing. ACritical@ in this context is not intended as a legal or regulatory definition, but as a category used for the purposes of this study, as required by the Terms Of Reference.

2.1 Data Review Methodology

Existing data was reviewed as to its environmental attributes and assessed as to habitat value and function including instream fish habitat, riparian habitat, and water quality. Watershed matrices of environmental attributes of each reach were developed for Nunns, Simms, and Willow Creeks based on review of the available studies (refer to Appendices 1-3). The watershed matrices identify fish habitat and riparian habitat by tributary and reach for habitat alteration and encroachment as well. It is assumed that the riparian and wetland habitat reflect wildlife habitat values as well.

Summary tables were created for each watershed showing the limiting factors, Urban Salmon Habitat Program (USHP) habitat rating, and USHP riparian rating for each reach. Summary table information including habitat and riparian ratings were adapted from USHP Assessments conducted by Roth (1998 and 1999) and Urchuck et al. (1997). Habitat parameters that were rated as poor or fair were included in the table.

The USHP habitat and riparian ratings are determined using the Urban Salmon Habitat Program Assessment Procedures (Michalski, et. al, 2001). Habitat rating values result from the comparison of habitat values collected during an instream habitat assessment to habitat standards for undisturbed streams. Riparian ratings are based on the comparison of riparian values collected during a riparian assessment with standards for healthy riparian systems. These ratings can be used to help identify restoration priorities. The higher the rating the greater the number of limiting factors. For more information refer to the Urban Salmon Habitat Program Assessment Procedures for Vancouver Island (Michalski, et. al, 2001).

There are three components to the reach identification code used in the matrices and summary tables: creek name, tributary (if applicable), and reach number. The creek is identified by the first letter of the creek name. The tributary is identified as >Trib#.@ The reach is identified by the letter R followed by the reach number. For example Willow Creek Tributary 1 Reach 1 would be expressed as >W Trib1. R1'. Reaches are numbered from estuary to headwater in an ascending order.

The terms large woody debris (LWD) and large organic debris (LOD) are used throughout the report. LWD is a large tree part, conventionally a piece greater than 10 cm in diameter and 1 m in length while LOD refers to entire trees or large pieces of trees that provide channel stability or create fish habitat diversity in a stream channel.

2.2 Identification of Critical Habitat Concerns Methodology

The following methodology was developed to identify areas of critical fish and wildlife habitat concern:

1) Determine the limitations of the overall stream system to fish and wildlife carrying capacity. Tributaries with salmonid numbers below the carrying capacity of the system indicate the presence of habitat limitations. Riparian and wetland degradation indicate limitation to other vertebrates. Mitigation of these limiting factors has the potential to increase the habitat function and value of these areas.

2) The determination of limitations on a reach by reach basis has been summarized in the watershed matrices and summary tables.

3) Reaches with limitations coinciding with overall system limitations are candidate critical habitat areas because they have limiting factors which reduce the fish and wildlife carrying capacity of the system.

4) Reaches with erosion sites and extensive physical alteration are also critical habitat areas because of the impact of sedimentation, erosion, and lower water quality on spawning and rearing habitat.

Preliminary areas of critical habitat concern were identified using this methodology (refer to Sections 3.1.3, 3.2.3, and 3.3.3).

2.3 Field Assessment Methodology

On Monday February 7, 2005, Helmut Urhahn of TERA Planning Ltd met with Michael Roth to review candidate areas of critical habitat concern within the three watersheds. At that time, it was decided to add to critical candidate areas in light of existing alteration and development pressure in these watersheds. In the afternoon, Helmut Urhahn met with the stewards of the three watersheds and requested input to further refine candidate sites. Once the list of areas of critical habitat concern were finalized with District staff and stakeholders, each site was assessed in the field to confirm previous findings. On Thursday February 10, 2005, Simms Ck and Nunns Ck were visited and on Friday February 11, 2005, Willow Ck was visited with the creek stewards. Because of the multiplicity of limitations in each of the critical sites, it was decided to expand the geographic boundary of each critical site to include an assessment of each of those issues in general and then focus on the Ahot spots@ in each of the critical habitat areas. Sections 3.1.4, 3.2.4, and 3.3.4 describe the results of our field assessment of the areas of critical habitat concern.

3 BIOPHYSICAL INVENTORY AND ASSESSMENT

This report describes three watersheds in the City of Campbell River, B.C.: Nunns, Simms, and Willow Creeks. It is a compendium of other studies such as the geology, hydrology and land use by others. This report sets out the biophysical conditions of aquatic and terrestrial resources and their limitations to maintain sustainable ecology.

3.1 Nunns Creek Watershed

3.1.1 System Profile

Biophysical Setting

The Nunns Creek Watershed is one of several creeks which drains the area between the Oyster River Watershed and the Campbell River/ Quinsam River Watershed. This creek has high fish production value for Coho (*Oncorhynchus kisutch*), Cutthroat trout (*Oncorhynchus clarki*) and Steelhead/Rainbow Trout (*Oncorhynchus mykiss*). Pinks (*Oncorhynchus gorbuscha*) have been in the system historically. The watershed supports many birds and small mammals, with large mammals located in the upper watershed (KWL 1995).

Soils

The Watershed lies within the Coastal Western Hemlock (CWHxm) Biogeoclimatic zone. Soils within this region are humo-ferric podzols, imperfectly drained and leached soils. With a mixture of dry brunisols, rapidly draining brown soil (Valentine et al, 1986).

Climate

Average winter temperatures range from 0.9 C to 2.7 C. Average summer temperatures are 16.7 C (C.R. Climate station). The prevailing wind is from the southeast, especially during the winter months, and westerly during the summer months.

Land Use

The lower watershed, from the Campbell River estuary to 16th Street, forms part of the inter-tidal zone. The channel is well established and flows through a tidal marsh. This area has been impacted by urban development and road construction. A large freshwater marsh delineates the upper limit of extreme tides. From 16th Street to Homewood Road the low gradient system continues through a municipal park with commercial development along the north and south edges of the park. Upstream of Homewood Road the creek is confined and has changing gradients characteristic of Coho/ Cutthroat streams on Vancouver Island=s east coast. This area is composed of rural residential lots with good riparian cover to the headwaters of Nunns Creek..

3.1.2 Limiting Factors

The 1999 USHP Assessment identified the following potentially limiting factors to fish production (Roth 1999):

$ Lack of natural riparian structure, function and diversity.
$ Lack of high water refuge habitat for rearing juvenile coho and steelhead.
$ An overall lack of LWD complexity, particularly in the form of pool forming

scour features.

- $ Lack of stable off channel winter winter rearing habitat for juvenile coho and - steelhead.
- $ Limited percent pool area.
- $ Limited instream cover.
- $ Increased percent fines in sediment.

Table 1 is a summary of limiting factors and USHP habitat and riparian ratings by tributary and reach. Habitat parameters that were rated as >poor= or >fair= have been included in the table. Higher rating values indicate reaches with a greater number of limiting factors.

3.1.3 Areas of Critical Habitat Concern

Based on the data matrices and habitat and riparian rating tables for Nunns Creek Watershed, eight reaches were identified with limiting factors affecting the overall system to salmonid carrying capacity (refer to Table 2 and Figure 1).

Four reaches were identified in the mainstem Tributary 1 (reaches 1, 3, 4, and 9), one reach in Tributary 2a (reach 1), two reaches in Tributary 3 (reaches 1 and 2), and one reach in Tributary 4 (reach 3). All reaches fall into rearing limitations of the system including limited LWD, instream cover, percent wetted area, and high percentage of fines. In addition to the limiting factors of the system, the following reaches are also impacted by altered sites: Tributary 1 reach 3 and Tributary 4 reach 3.

In Tributary 3 reach 1, five log weirs with insufficient flow to allow fry movement upstream were observed in the 1999 USHP assessment (Roth 1999). Tributary 3 suffers from low summer flows. During the 1999 USHP assessment flow was observed in July, but the tributary had completely dried up in August (Roth 1999). The long term viability of this tributary is dependent on securing water storage in the upper reaches (Roth 1999). It is important to note that beyond reach 3 the system enters a series of road ditches. Low summer flows would allow access to an additional 906 m (reaches 1 to 3) providing good spawning and rearing habitat (Roth 1999).

3.1.4 Assessment of Areas of Critical Habitat Concern

Critical habitat limitations in the Nunns Creek watershed are primarily based on rural and urban encroachment in the watershed. Healthy watersheds are defined as having less than 15% impervious surface and greater than 65% forested area. The impervious area of Nunns Creek watershed has been reduced to 15% and the forested area to 11% (Urban Systems, 2005).

Specific development impacts include the ditch systems of the ERT, Willis Road, Petersen Road, and at the headwaters of Nunns Creek which have all impacted base flows and peak flows. Stormwater outfalls located in the Ironwood area, 4th Avenue extension, and 2nd Avenue extension are sources of water pollution and/or sediment release. Generally, there is a lack of riparian vegetation due to urban encroachment.

Nunns Creek Watershed areas of critical habitat concern were assessed in the field with the creek stewards. These areas are described below and are shown on Figure 1.

1) Nunns Creek Reach between 16th Ave and 9th Ave - This reach has a significant gradient change and is within the tidal influence of Discovery Channel. Critical limitations for this reach are:

    a) High sediment deposition has impacted the main channel. There is a lack of boulders and cobbles in instream habitat. Consider boulder and gravel recruitment. Instream habitat could be enhanced by encouraging beaver activity through riparian planting of willow species. Maintain downed trees or unsafe trees as wildlife trees and/or drop to create LOD.

    b) Flooding impacts this area. The two box culverts at 16th Avenue are back watered to top of culvert at high tide. There is a fine silty sandy substrate in tidal reach and wetland. These culverts need repair.

c) There is industrial contamination from the eastern tributary in the Ironwood area. At 12th Avenue install a sediment trap with clean out and access in case of spill.

2) Along ERT Road including ditch and stormwater flow and separate outflow into Campbell River - This reach is connected at the upper reaches to Nunns, but forms a separate creek into the Campbell River. Its relationship is that it may have been previously connected to Nunns Creek. Critical limitations are:

a) Ditches and stream alterations from the ERT road impact Nunns Ck.

b) The connections of ditches to Nunns Ck are not clear and need to be determined.

c) Remaining ditches in creek from ERT to Maple Street stormwater system into Campbell River has coho and other salmonid accessible habitat and should be protected.

d) Evaluate the possibility of directing the upper ERT ditches into this system through comprehensive ditch consolidation and channel reconstruction. Vegetate ditches wherever road construction has denuded.

3) Eastern tributary to Nunns Creek located at Homewood Rd cul-de-sac and the westernmost extension at 4th Ave. All sites are significantly impacted by stormwater, ditches and other human alterations.

a) Water pollution and sediment release from stormwater system impact this tributary. Recommend infiltration at source such as roof and driveway drainage into soils and swales on lot, if feasible based on site conditions.

b) The stormwater system has caused changes to flow regime.

c) The stormwater outfall from 4th Avenue over-steepened the existing ravine. Significant erosion needs to be managed (i.e. check dams and/or rock liners). There may be limited room for treatment at this location.

d) Lower reaches of tributaries with salmonid habitat could be enhanced with pool/ riffle construction and placement of LODs.

4) The reach connected to Willis Rd and its ditch system which crosses Petersen Rd has the following critical limitations:

a) The existing ditch at Willis Road impacts base flows and peak flows and should be made into swales.

b) Proposal to enlarge Willis Rd offers opportunity to consolidate ditches to main channel, rehabilitate ditches into wider stream systems, lower and enlarge culvert at Petersen Rd, and lower culvert at Willis Rd. Investigate directing drainage from south ditch and culvert into this tributary (tributary 3) instead of down Croatian.

c) Install large detention pond (Stevens, Rich. 2005, pers. comm.) Negotiate with owner of rock wall at Petersen and Old Petersen Road to replace with coarse rock liner. Place a pool at the outlet of Old Petersen Road for treatment of drainage at Willis Road.

d) Instream substrate, including high percentage of fines and low percentage of coarse substrate, limits instream fish habitat, gravel and cobble recruitment should be considered.

e) There is a reduction of riparian cover at the headwaters. Lack of riparian vegetation due to urban encroachment should be managed by encouragement and active programs with landowners to contribute some native planting if possible. Vegetate ditches with grass and wetland vegetation to withstand some flooding and provide some source control treatment.

f) Recommend infiltration at source such as roof and driveway drainage into soils and swales on lot for significant renovations and new construction, if feasible based on site conditions.

5) Reach of mainstem of Nunns Ck between 2^{nd} Ave and Evergreen Rd - This reach was added because of stormwater problems at 2^{nd} Ave and its small tributary. Critical limitations include:

a) The most significant problem is channelization due to stormwater outfall on 2^{nd} Ave. Erosion of ditch along 2^{nd} Ave right of way is significant and should be addressed with rock liner and/or check dams along its reach as well as storm drain outlet protection.

b) Stormwater water quality including first flush and sediment should be addressed through potential sediment trap and small detention pond (already designed, Stevens, Rich. 2005, pers. comm.) on right of way. Explore possibility of detention of outfall at 2^{nd} Ave. General cleanup of the lower tributary in rearing habitat and potential enhancement by introduction of LODs is recommended.

Recommend infiltration at source such as roof and driveway drainage into soils and swales on lot for significant renovations and new construction, if feasible based on site conditions.

6) Western tributary to Nunns Ck above Evergreen Rd - This reach was added because of significant discoloration in stream due to fill (soil) leachate and iron bacteria. Critical limitations are:

a) Discoloration of water impacts water quality. Reach to headwall should have a series of ponds with rock weirs to treat and detain water before entering culvert at Evergreen. Replant 15 m top of bank setback area with native riparian vegetation to introduce nutrients to lower reaches.

b) Recommend infiltration at source such as roof and driveway drainage into soils and swales on lot for significant renovations and new construction, if feasible based on site conditions.

7) Headwaters of Nunns Ck - This reach of Nunns Ck is fed by a series of ditches from rural areas and is under development pressure for diversion (DFO in agreement, Roth. M. 2005, pers. comm.). Critical limitations are:

a) Lack of base flow and poor water quality impacts this reach of Nunns Ck. Review ditch system flowing into stream at Pinecrest and Petersen Road. Consider swales and check dams to allow for source control or treatment and revegetate throughout to avoid erosion.

Source control such as infiltration of roof and driveway drainage into soils and swales on lots for significant renovations and new construction is recommended if feasible based on site conditions.

b) Consider diversion along Petersen Road right of way and Merecroft Road right of way. Install in-line pond and wetland complex in wet area at Trask and Merecroft for detention and treatment.

c) Erosion of poorly defined channels at Trask should include rebuilding of wetland pond outlet, culvert at Trask, and outlet of culvert at Trask to define channel. Replant riparian vegetation wherever disturbed and possible.

d) Lack of riparian vegetation due to urban encroachment should be managed by encouragement and active programs with landowners to contribute some native planting if possible.

3.2 Simms Creek Watershed

3.2.1 System Profile

Biophysical Setting

The Simms Creek Watershed drains the area between the Nunn=s Creek Watershed to the north, the Quinsam River Watershed to the west, and the Willow Creek Watershed to the south. The creek has a north and south arm which join below Rockland Road. The watershed is an important fisheries and wildlife resource, whose lower reaches have been impacted by urban development and construction including sedimentation and possible stormwater quality degradation. It has good rearing and spawning habitat and high fish production value for Coho and Cutthroat trout. The Department of Fisheries and Oceans (DFO) regularly release fish into this creek. Wetland and forested areas are important habitat for birds, small mammals, and large mammals like deer, bear and cougar. Beavers are active in the system. The red legged frog has been recorded in the middle reach of Simms system.

Soils

The Watershed lies within the Coastal Western Hemlock (CWHxm) Biogeoclimatic zone. Soils within this region are humo-ferric podzols, imperfectly drained and leached soils. With a mixture of dry brunisols, rapidly draining brown soil (Valentine et al, 1986).

Climate

Average winter temperatures range from 0.9 C to 2.7 C. Average summer temperatures are 16.7 C (C.R. Climate station). The prevailing wind is from the southeast, especially during the winter months, and westerly during the summer months.

Land Use

The Simms Creek Watershed is built-out in north eastern areas. The south-eastern area is a working forest. There are three main areas: the upper watershed, the Beaver Lodge Trust Lands, and the developed lands. The upper watershed is located west of the inland Island Highway and outside of the District boundary. It is impacted by the new Inland Island Highway with the remainder part a working forest. Both the north and south arms originate in the upper watershed.

The Beaver Lodge Trust Lands are protected from development by the Beaver Lodge Lands trust agreement (see Figure 2 for location). The north arm has some wetlands, on-line ponds, and storm sewer outfalls from the McPhedran Road and South McPhedran Road storm sewer.

There are no major storm sewer outfalls to the south arm, and it can be considered to be managed in a semi-natural state.

Land use is mainly composed of single family residential, with one park (Willow Point). There are trails on the south side of the creek from South Alder Road to above Rockland Road. Storm sewer outfalls from the northeastern residential area discharge directly into the creek, however there is only one small stormwater detention ponds within this area. There is a permanent stormwater detention pond associated with the new development site off McPhedran. There are also stormwater detention ponds associated with Dogwood and Rockland crossings.

3.2.2 Limiting Factors

Fish production of the Simms Creek watershed is potentially limited by the following factors (Urchuck et al 1997and Campbell 2003):

$ Siltation of spawning and rearing areas.
$ Lack of spawning habitat.
$ Low water levels.
$ Limited percent pool area and wetted area.

- $ Limited summer rearing habitat.
- $ Obstructions to fish passage.
- $ Altered sites.

Table 3 is a summary of the limiting factors and UHSP habitat and riparian ratings by tributary and reach. Habitat parameters that were rated >poor= or >fair= have been included in the table. Higher rating values indicate reaches with a greater number of limiting factors.

3.2.3 Areas of Critical Habitat Concern

Based on the data matrices and habitat and riparian rating tables for Simms Creek Watershed, four reaches were identified with limiting factors affecting the overall system to salmonid carrying capacity (refer to Table 4 and Figure 2). Two reaches, 3 (South Simms) and 5 (North Simms) fall into rearing limitations of the system and coincide within the individual reach to suggest pool habitat creation, structure and cover. The other critical reaches are reach 1 (mainstem) and reach 6 (North Simms Tributary 1). Reach 1 falls into spawning limitation of the system and has extensive habitat alteration and erosion. All four identified reaches are limited by erosion, obstructions and altered sites. In addition, the stormwater system drains into reach 6 from urban areas.

Good winter rearing habitat exists in the upper watershed, but low summer flows restrict migration above Galerno Road (Campbell 2003). Fall rains provide water levels allowing returning salmon to access habitat upstream of the Galerno Road culvert. Summer rearing habitat availability decreases in the upper watershed as the system dries up. Both North and South Simms Creek have very low water levels from May to October, and much of the upper watershed is dry from July to September (Campbell 2003). Every year there are reports of coho and cutthroat trout in Simms Creek (Campbell 2003).

Spawning success is limited by a lack of gravel in the lower reaches of the stream (Campbell 2003).

3.2.4 Assessment of Areas of Critical Habitat Concern

The critical habitat limitations of Simms Creek are primarily based on urban encroachment and the construction of the Inland Island Highway. Healthy watersheds are defined as having less than 15% impervious surface and greater than 65% forested area. Simms Creek watershed is below the 15% impervious level at 6.6%, however it has been logged extensively with 21.5% of forested area remaining.

The lower mainstem and headwaters of Simms Creek are impacted by erosion, sedimentation, and altered stream sites. Stormwater oufalls from the Springbok Road subdivision and Cortez-McPhedran subdivision have impacted the creek. The Inland Island Highway impacts both the North and South branches of Simms. Impacts include reduction in base flows, channelization leading to erosion, sediment accumulation, and isolation of wetlands.

Simms Creek Watershed areas of critical habitat concern were assessed in the field with the creek stewards. These areas are described below and are shown on Figure 2.

1) Lower mainstem of Simms Creek between Alder and the extension of Nunns Rd has 34 erosion sites, sedimentation and 33 altered stream sites. Critical limitation issues:

    a) Below Alder the Simms Creek channel is clay lined with significant erosion along cutbanks and fines in the channel. This reach lacks boney instream material, pools and pool/riffle. Introduction of gravel and cobble substrate for recruitment in different areas is recommended. Major erosion features should be rock lined or flow deflectors directing flow away from cutbanks should be installed in strategic places. Rock weirs should be installed where appropriate to get pool/riffle. LOD introduction is also recommended.
    At Galerno, different methods of erosion control for cutbanks include slowing down flow in the Galerno culvert with baffles or rocks, further rock material in

outlet pool of culvert directing flow away from cutbank, and placing large rip rap material on cutbank with large interstitial spaces to create refugia for fish.

Each culvert should be checked for inlet and outlet pool. Should have the ability to backwater into the culvert to create a splash pool.

Opportunity for a side channel upstream of Alder should be investigated.

b) Lack of riparian vegetation due to urban encroachment should be managed by encouragement and active programs with landowners to contribute some native planting if possible.

c) Recommend infiltration at source such as roof and driveway drainage into soils and swales on lot for significant renovations and new construction, if feasible based on sited conditions.

2) Area between Rockland Road and Dogwood Street - This area has been added to the critical habitat area because of impacts relating to stormwater outfalls into the system.

a) Impact of Springbok Road subdivision stormwater outfalls, foundation drainage and yard drainage into Simms wetland complex. Southern outfall seems to work. In contrast the northern outfall through small pond needs to be retrofitted with better drainage system from pond to creek. Water is discolored by iron and iron loving bacteria for ~30 m in ditch along trail. Channel should have check dams to slow down the water and be re-directed into a large pond before draining into the creek.

Many of the smaller uncontrolled drainages from the backs of the lots should be controlled by having gravel put into the wet spots of the trail over top of the sanitary sewer line so that fines are not washed from the trail into the system. Retrofit splash plates for roof drainage and yard swales for significant renovations and new construction.

b) Flow regime to this reach of Simms Ck is impacted by beaver which benefit fish habitat. Hydraulicly separated wetland could benefit the red legged frog and other amphibians.

Riparian enhancement would be considered for better drained areas within and adjacent to the wetlands. Riparian species which are not palatable to beavers should be considered.

3) Small tributary to north branch of Simms Creek at McPhedran Rd. Critical limitations are:

a) The Cortez-McPhedran stormwater system drains to this small tributary contributes poor water quality and sediment release into the large wetland complex of the tributary. The pond at this outfall should be cleaned out and flowering bullrush should be used as donor stock for other sites. The remaining wetland can be further charged by stormwater through LOD weirs and will treat and detain it. The existing subdivision of McPhedran should not be allowed to flow into pond, but be maintained to flow into wetland. The new pond and outlet of the new subdivision should be planted.

Recommend infiltration at source such as roof and driveway drainage into soils and swales on lot for significant renovations and new construction, if feasible based on site conditions.

b) Headwaters impacted by erosion sites, obstructions and altered streams should be further managed by maintaining existing wetland pond complex.

c) Because of high temperatures measured in this tributary (Myers, R. 2005, pers. comm.), riparian setbacks and planting of denuded areas is recommended.

4) North Simms Creek at Inland Island Highway 19 - This reach focuses on the impacts of the Inland Island Highway on the headwaters of the North Simms Ck. Critical limitations are:

a) Impacts to headwaters of North Simms by the Inland Island Highway include reduction in base flows, channelization leading to erosion, sediment accumulation along 2 culverts, and isolation of some of the wetlands with same impact.

All wetland area in upper reaches of North Simms should be identified on each side of the highway and small weirs could be installed in strategic lowland areas to renovate wetlands to a wetter status.

Each culvert should be checked for inlet and outlet pool. Should have the ability to backwater into the culvert to create a splash pool.

b) Changes to ditches adjacent to the Inland Island Highway with check dams and 2:1 slopes and by directing them into depressions or wetlands or ponds will insure water detention and filtration. Vegetate ditches wherever highway construction has denuded ditch banks.

5) Headwaters of South Simms Creek at Inland Island Highway 19

a) Impacts to headwaters of South Simms by the new Island Highway include reduction in base flows, channelization leading to erosion, sediment accumulation along 2 culverts, and isolation of some of the wetlands with same impact.

Wetland area in upper reaches of North Simms should be identified on each side of the highway and small weirs installed in strategic lowland areas to renovate wetlands to a wetter status. Reconstruct the wetland areas and bring them back to way they were before. Negotiate with land owners to increase wetland area if feasible.

Each culvert should be checked for inlet and outlet pool. Should have the ability to backwater into the culvert to create a splash pool.

b) Vegetate ditches wherever highway construction has denuded ditch banks.

3.3 Willow Creek Watershed

3.3.1 System Profile

Biophysical Setting

The Willow Creek Watershed is one of several creeks which drains the area between the Oyster River Watershed and the Campbell River/Quinsam River Watershed. It is bordered by Simms Creek to the north and Woods Creek to the south. The Willow Creek watershed is composed of 4 main tributaries: Willow Creek, Larwood Creek, Beaver Creek and Newman Creek. The creek has high fish production value for Coho (*Oncorhynchus kisutch*), Cutthroat trout (*Oncorhynchus clarki*) and Steelhead/Rainbow Trout (*Oncorhynchus mykiss*) producing system. As one of the last unenhanced creeks in the area, it is considered an indicator creek.

Soils

The Watershed lies within the Coastal Western Hemlock (CWHxm) Biogeoclimatic zone. Soils within this region are humo-ferric podzols, imperfectly drained and leached soils. With a mixture of dry brunisols, rapidly draining brown soil (Valentine et al, 1986).

Climate

Average winter temperatures range from 0.9 C to 2.7 C. Average summer temperatures are 16.7 C (C.R. Climate station). The prevailing wind is from the southeast, especially during the winter months, and westerly during the summer months.

Land Use

The major landowners within the watershed are: TimberWest Forest Ltd., residential owners, Campbell River Airport, and the Homalco Indian Band (see chart below). TimberWest Forest Ltd. owns the majority of the land and it is designated within the Forest Land Reserve and Agricultural Land Reserve. However, an application has been made to remove some areas from the reserves for development purposes.

Land Owner	% Ownership of Watershed
TimberWest Forest Limited	60
Residential Lot owners (single and multifamily housing)	8
Campbell River Airport	8
Homalco Indian Reserve No.9	3
B.C. Forest District	1
Other	20

Source: KPA 1996

The Campbell River Airport has encroached significantly on the upper watershed and there are plans to expand the runway. The Homalco Indian Band is located in the middle of the watershed. They built a bridge across the main stem of Newman Creek for development purposes. The subdivision has stormwater outfalls to Newman Creek, because of the modest size of the subdivision no problems were seen.

3.3.2 Limiting Factors

The three most significant factors limiting fish production in Willow Creek are (Roth 1998):

$ Limited off channel habitat.
$ Limited instream cover.
$ Loss of suitable spawning areas.

Other limiting factors include lack of LWD and sedimentation of spawning and rearing habitat (Roth 1998).

Table 5 is a summary of limiting factors and USHP habitat and riparian ratings by tributary and reach. Habitat parameters that were rated >poor= or >fair= have been included in the table. Higher rating values indicate reaches with a greater number of limiting factors.

3.3.3 Areas of Critical Habitat Concern

Based on the data matrices and habitat and riparian rating tables for Willow Creek Watershed, 17 reaches were identified with limiting factors affecting the overall system to salmonid carrying capacity (refer to Table 6 and Figure 3). Four reaches were identified in the Willow Creek mainstem, one reach was identified in Larwood Creek, four reaches were identified in Larwood Creek Tributary 1, one reach was identified in Beaver Creek, four reaches were identified in Beaver Creek Tributary 1, and three reaches were identified in Newman Creek.

Larwood Creek and its Tributary are below the carrying capacity of the system indicating that future enhancement projects may increase fish production (Roth 1998). Beaver Creek Tributary 1 is under immediate threat of extinction (Roth 1998). This tributary has been impacted by logging, ditching, and road drainage from Jubilee Parkway. The associated wetland is currently under Agricultural Land Reserve designation, but there is an application to change the designation to urban development.

3.3.4 Assessment of Areas of Critical Habitat Concern

Willow Creek watershed critical habitat limitations are primarily based on urban encroachment including construction of Jubilee Parkway, Dogwood Street, the Inland Island Highway, the airport, Homathko Crescent, and residential development in the Larwood Creek Tributary. The headwaters of Willow Creek have been impacted by the airport and its associated ditches. The airport has encroached into this area interrupting several wetland complexes and reducing base flows. The Inland Island Highway has also interrupted wetland complexes and impacted the creek through ditching. The lower watershed is impacted by urban encroachment, stormwater impacts, and altered sites. There are proposed developments by Georgia Park Realty and TimberWest adjacent to the tributary from Erickson Road.

Willow Creek Watershed areas of critical habitat concern were assessed in the field with the creek stewards. These areas are described below and are shown on Figure 3.

1) Larwood Creek - It was decided to include all Larwood tributaries into one critical habitat area to deal with the following issues:

    a) Larwood has been impacted by urban encroachment resulting in low base flows and flooding due to high peak flows.

    b) Stormwater impacts include water quality from first flush road runoff, sedimentation, and erosion. Larwood lacks detention and treatment of stormwater. Presently there are two ponds in the west branch. Locations for additional ponds and wetland complexes in Larwood and its west branch such as a pond above or below Erickson road would provide detention and treatment. The north branch has no room for ponds and therefore infiltration such as roof and driveway drainage into soils and swales on lots is recommended, if feasible based on site conditions. Swaling or widening of ditches to allow infiltration is also recommended for the entire tributary.

    c) Larwood is impacted by altered sites, including channelization and structural simplification of channel. A large portion of the drainage area is now in stormwater pipes, many of which bypass the upper reaches. In particular, the Erickson Road outfall upstream of the crossing. It drains the majority of the western watershed of Larwood. An assessment should be made to return this drainage to the upper reaches of Larwood in order to increase flows in the summer. This could include provision of splitters for base flows. This would benefit the spawning and rearing reach between Larwood Road and Erickson Road.

There is erosion in the lower channel and provision of a pond or large backwater channel would benefit this reach. Bioengineering on some of the cutbanks would reduce erosion.

Each culvert should be checked for viable inlet and outlet pools. Culverts should be back watered by an outlet pool.

The Willow Creek Watershed Society has constructed several rock weirs upstream of Erickson Road to create pool habitat. Several weirs have been blown out. Weirs which will hold in the system should be installed. The stream gradient is very low in this reach and at low to moderate flows the channel and rock weirs have become filled with fines. Gravel recruitment from strategic locations above where there are fines is recommended.

d) Lack of riparian vegetation due to urban encroachment should be managed by encouragement and active programs with landowners to contribute some native planting if possible. The Georgia Park Realty pond and its outlet should be planted with riparian vegetation.

Recommend infiltration at source such as roof and driveway drainage into soils and swales on lot for significant renovations and new construction, if feasible based on site conditions.

2) Tributary from Erickson Rd flowing through Nature Conservancy and within proposed development area by Georgia Park Realty and TimberWest into Willow

Ck. Limitation of this tributary is as follows:

a) Develop defined channel above Erickson Road and connect to wet area, provide riparian setback as per the City of Campbell River=s regulations. Below Erickson Road check channel definition and capacity of the system. Maximize use of the pond.

b) Increase wetted period of ephemeral tributary and provide winter rearing potential for coho below the conservation area.

c) Near term subdivision and commercial development on tributary may cause undesirable changes to tributary flow and water quality.

3) Beaver Ck Tributary - This area encompasses two tributaries of Beaver Ck and large wetland complexes at the Island Highway as well as culverts in the Island Highway for drainage into these wetlands and Beaver Ck. Limitations include:

a) Reduced base flows impact the system, in particular the western tributary where it crosses Jubilee. The system is largely charged via wetland complexes.

b) These wetland complexes have been traversed by the Island Highway. We counted 11 culverts along the new Island Highway draining the remaining recharge area west of the highway.

c) We should establish the full extent of the wet area and their contribution to flow regime and water quality to define protection areas between Beaver and the new Island Highway.

Small weirs could be installed in strategic lowland areas to renovate wetlands to a wetter status.

d) Jubilee and Homathko Crescent have impacted western tributary of Beaver Ck because of extensive ditching along Jubilee. These ditches should have check dams to slow down flow.

e) Review future development plans east of Beaver Ck and review stormwater management. Development may cause undesirable changes to tributary flow regime and water quality.

4) Willow Creek - Between the new Island Highway and Jubilee limitations identified include:

a) The alteration of base flows due to airport ditches has occurred. The southern tributary to Willow Ck has been disrupted by the ditch system significantly reducing flow. Tributaries to the west have been impacted similarly and will be discussed in critical habitat area 5.

b) Proposed new airport development may disrupt stormwater flows to Willow Creek and, if not properly maintained, loss of riparian setbacks from top of bank may impact habitat value.

c) Lack of instream structures including LWDs and boulder limits this reach. Refer to recommendation below.

d) The high percentage of fines in stream bed should be addressed by introducing instream structure including pool/riffle wherever possible and LOD. These should be installed where access is available and should be made a requirement of proposed adjacent airport developments.

5) Headwaters of Willow Creek adjacent to airport - This area was encroached by the existing airport and was further expanded in size because of the longer runway proposal at the airport. Critical habitat area limitations are as follows:

a) Significant impact to base flows due to airport ditching and reduction of base flow to Willow Creek. Large area of the watershed was interrupted and removed by the airport and presumably now flows into Newman Creek to the south. Part of the northern wetland of Willow has been drained by deep ditches of the airport and further reduces base flows into Willow.

Ditches at the airport should be modified to slow down the drainage and to increase infiltration especially along the perimeter of the airport away from the active airport surfaces. Investigate the possibility of turning out long ditch systems into adjacent wetland area at the headwaters of Willow to further increase storage adjacent to the airport. This will rejuvenate the northern wetland.

Small weirs could be installed in strategic lowland areas and at the outlet to creeks to renovate wetlands to a wetter status.

b) Structural changes instream have introduced fines into the system. Riparian planting of cleared ditches at the edge of the airport should be encouraged. Instream complexing introducing pool/riffle and LOD is encouraged in accessible areas.

c) Erosion of surface drainage due to peak flows is partly due to over steepened ditch banks. Ditches should be made into swales. Ditch maintenance should include re-sloping of ditch banks to maximum 2:1 wherever possible and planting of wetland and riparian species at least to top of bank. Bioengineering of over-steepened banks where 2:1 slopes are not possible using willow or red osier dogwood is recommended. Some of the larger systems may benefit as well from detention systems.

6) Small tributary flowing in Newman Creek at the south end of airport which is presently under development pressure. Critical limitations are:

a) Southeastern tributary to Newman Creek has significant ditching which has robbed water from the Willow Creek watershed. These ditch systems seem to be stable because of check dams and a small diversion at the south end to Newman Tributary. Ditch maintenance should include re-sloping of ditch banks to 2:1 wherever possible and planting of wetland and riparian species at least to top of bank. Bioengineering of over-steepened banks where 2:1 slopes are not possible using willow or red osier dogwood is recommended. Some of the larger systems may benefit as well from detention systems.

b) This tributary has been impacted by riparian removal, erosion, and instream sedimentation. Recommendations of these impacts are the same as 6.1 above.

4 CONCLUSIONS AND RECOMMENDATIONS

TERA Planning Ltd was retained by Urban Systems Ltd and the City of Campbell River to undertake this environmental assessment and set out the fish and wildlife determinants in three watersheds in Campbell River, mainly Nunns, Simms and Willow Creeks.The extensive, previous investigations, of the aquatic and terrestrial habitat has been assessed and its contribution to habitat value and function identified. Based on limitations to aquatic and riparian habitat value and function to provide sustainable supportive capacity to aquatic and terrestrial organisms, recommendations for candidate critical habitat areas were made. These candidate critical habitat areas and their specific limitations helped identifiy environmental management practices and best management practices to mitigate and enhance these limitations.

Major impacts of urban development include water quality, volume reduction, rate control and sedimentation. Significant increases in stream sedimentation can impact channel morphology and substrate composition with negative impacts to fish (Platts et al. 1989). In general, high levels of sedimentation result in a decrease in fish production. Fine sediment fills up the interstitial spaces between gravels thereby impeding redd construction (Slaney and Zaldokas 1997) and fry emergence (Hall and Lantz 1969), and decreasing interstitial flow causing depressed oxygen levels for eggs and alevins (Slaney and Zaldokas 1997).

Aquatic invertebrates, the primary food source for salmonids, are as sensitive if not more sensitive to elevated levels of suspended sediment as salmonids (Newcombe 1985, Newcombe and MacDonald 1991).

In general, the data reviewed for each of the three creek systems were extensive and of widely varying scope. While Willow Creek had the most detailed information, Simms Creek lacked identification of wetlands, detailed reach breakdowns, and delineation of riparian zones. Nunns Creek was somewhere in between Willow and Simms but because of more extensive human alterations to the system the data was workable.

Other data limitations included inconsistant wetland classification systems used, in particular classifications based on hydrophylic vegetation present. The National Classification for wetlands specifies the use of soil information in conjunction with vegetation information and the duration of wetted cycles. This allows the classification of wetlands not only as to its chronological evolution, but also its long term contribution to the watershed.

General recommendations include:

1) The biophysical information for each of the stream systems should be brought to the same level. In particular, Simms Creek should have a detailed reach by reach inventory, an assessment of its riparian vegetation, and clear delineation of its wetlands. For Nunns Creek, some of the remnant wetlands could be identified by soil auger tests and the historical extent of the Nunns Creek wetlands at its headwaters established.
2) An overall wetland management plan for each of the three systems would be appropriate, this should include an assessment of their contribution to the system, and a management plan including enhancement of the remnant wetland complexes.

3) A beaver management plan would identify areas where beavers can be encouraged and where they should not be encouraged. In particular, riparian

management in the light of riparian species palatable and non-palatable to beavers and where they should be planted would be useful. Other recommendations include beaver-proof ponds and wetlands where beavers are discouraged. Beavers quickly exhaust their food supply and move on, but should be encouraged to sustainable levels in those portions of the watersheds where they are of benefit to other terrestrial and aquatic organisms.

4.1 Nunns Creek Watershed

Of the three stream systems, Nunns Creek is the most encroached by urban development. It has lost most of its at headwater wetlands, which have been ditched to give way to rural development. Further rural and infrastructure developments are planned and these may provide opportunities to remedy some of the limitations within the systems. These are, in order of priority:

1) Willis Road expansion would allow the establishment of further detention and treatment within Tributary 3. This can be included within the source control, provision of swales to wider ditch system further downstream, and in-line detention ponds in strategic locations within Tributary 3. Ditches and some of the detention structures could be enhanced through marsh and riparian planting to make them into viable terrestrial and aquatic systems. The cost of such improvements could be borne by the Willis Road expansion.

2) Above Trask Road headwater diversion could be accomplished by enhancing the system as follows:

   $ headwater ditches swaling and ditch widening
   $ diversion along property lines in road right-of-ways to Trask Road
   $ installation of a wetland complex and detention pond upstream of Trask Road

- $ all systems should be planted with marsh and riparian vegetation

The cost of this system could be borne by the development application of the adjacent landowner to achieve a habitat balance under the Fisheries Act using Section 32.

3) The third most critical item for Nunns Creek is the erosion control of the stormwater outfalls at 2nd and 4th Avenues, starting with the provision of:

- $ an outlet pond with proper erosion control
- $ a rock liner within the ditches to prevent erosion and bank cutting
- $ wetland and riparian plantings at the stormwater outlets to provide nutrients and shading

This stormwater program could be managed by phasing this project and a charge against major development proposals in this part of the watershed that encroach on fish habitat or incur poor stormwater water quality changes.

4.2 Simms Creek Watershed

Simms Creek should be brought up to the same data standard as Willow and Nunns Creeks. This includes delineation of aquatic and terrestrial resources. As a system, it has significant critical limitations as follows.

1) The Galerno reach has serious erosion which needs to be addressed through erosion control mechanisms outlined.

2) The clay-lined reach below Galerno to the Old Island Highway needs some instream structural erosion control measures which could be installed gradually over time.

3) Once wetlands have been identified within the system, a wetland management plan should be developed. This should include wetlands that are west of the New Island Highway and, where possible, reinstatement to the Simms Creek system.

4.3 Willow Creek Watershed

Willow Creek is the largest creek system of the three investigated as well as the least disturbed by residential, transportation and airport development. The database for Willow Creek is the best of the three systems and allows some clear recommendations for critical habitat areas. Probably the most significant critical habitat area and its amelioration includes the headwaters of Willow Creek as follows:

1) The renovation of swales and ditches at the airport as well as a management and enhancement concept for remnant wetlands should allow more water storage and increase some of the summer flows and decrease some of the storm flows. In particular, in the light of the proposed expansion of the airport runway some of the costs of this program could be borne by the proponent. An environmental enhancement bank could be established for all of the other proposed ancillary facilities to the airport which then would gradually buy into the overall Willow Creek management program.
2) Larwood Creek has been extensively impacted by residential and commercial development. This requires the following action.

    $ the Larwood Creek system needs to incorporate flow rate control and infiltration, detention and treatment
    $ provision of small stormwater outlet ponds to the north branch including the establishment of pocket wetlands where feasible
    $ returning some of stormwater to Larwood Creek through splitter to recharge the mainstem of Larwood Creek (at

Larwood Street)

$ create a large backwater channel below Erickson Road to create some detention, treatment and rearing habitat

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Table 1
Nunns Creek Watershed
Urban Salmon Habitat Program Ratings and Limiting Fish Habitat Factors

Reach #	Habitat Rating	Riparian Rating	Limiting Factors	Potential Mitigation Techniques	Resulting Habitat Benefit
Tributary 1					
N Trib1. R1	24	40	High % fines and % wetted area. High incidence of sediment deposition.	Install check dams & streamside LWD. Identify opportunities to increase flows during the summer. Explore potential of utilizing Municipal storm water drainage plan. Explore alternative means of removing sediment from stream bed.	Encourage fines to settle out in low gradient areas. Extend summer flows and increase spawning and rearing habitat.
N Trib1. R2	22	84	High % fines and % wetted area.	Install check dams & streamside LWD. Identify opportunities to increase flows during the summer. Explore potential of utilizing Municipal storm water drainage plan.	Encourage fines to settle out in low gradient areas. Extend summer flows and increase spawning and rearing habitat.
N Trib1. R3	28	22			
N Trib1. R4	31	46	High % fines, % pool area, and % wetted area.	Install check dams & streamside LWD. Install weirs. Identify opportunities to increase flows during the summer. Explore potential of utilizing Municipal storm water drainage plan.	Encourage fines to settle out in low gradient areas. Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour. Extend summer flows and increase spawning and rearing habitat.
N Trib1. R5	25	60	High % fines and % wetted area.	Install check dams & streamside LWD. Identify opportunities to increase flows during the summer. Explore potential of utilizing Municipal storm water drainage plan.	Encourage fines to settle out in low gradient areas. Extend summer flows and increase spawning and rearing habitat.
N Trib1. R6	27	72			
N Trib1. R7	27	20			
N Trib1. R8	27	60			
N Trib1. R9	29	20			

Note: Information adapted from Urban Salmon Habitat Program Assessment conducted July 1, 1998 to August 28, 1998 (Roth 1998).

Table 1
Nunns Creek Watershed
Urban Salmon Habitat Program Ratings and Limiting Fish Habitat Factors

Reach #	Habitat Rating	Riparian Rating	Limiting Factors	Potential Mitigation Techniques	Resulting Habitat Benefit
Tributary 2					
N Trib2. R1	29	54	High % fines, % pool area, % wetted area. Sources of non point pollution and sediment. Erosion concerns due to high peak flows. Water quality degradation	Install check dams & stream side LWD. Install weirs. Identify opportunities to increase flows during summer. Explore potential of utilizing Municipal storm water drainage plan. Explore Opportunities to retrofit storm drains to enter settling pond prior to discharging into creek.	Encourage fines to settle out in low gradient areas. Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour. Extend summer flows and increase spawning and rearing habitat. Reduce impacts from sediment run off. Control flow rates. Improved water quality.
N Trib2. R2	29	28			
Tributary 2a					
N Trib2a. R1	17	14	% pool area and % wetted area. Sources of non point pollution and sediment. Erosion concerns due to high peak flows. Water quality degradation	Install weirs. Identify opportunities to increase flows during the summer. Explore potential of utilizing Municipal storm water drainage plan. Explore Opportunities to retrofit storm drains to enter settling pond prior to discharging into creek.	Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour. Extend summer flows and increase spawning and rearing habitat. Reduce impacts from sediment run off. Control flow rates. Improved water quality.
Tributary 3			Fish barrier/obstruction and limited summer flow.	Remove existing culvert and replace with a bride or open bottome culvert. Secure land in upper watershed to create detention ponds.	Access for adult salmonids to 1 km of productive habitat. Extend summer flows and increase spawning and rearing habitat.
N Trib3. R1	42	58	High % fines, % pool area, % wetted area.	Install check dams & stream side LWD. Install weirs. Identify opportunities to increase flows during summer. Explore potential of utilizing Municipal storm water drainage plan.	Encourage fines to settle out in low gradient areas. Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour. Extend summer flows and increase spawning and rearing habitat.
N Trib3. R2	31	32			
N Trib3. R3	19				

Note: Information adapted from Urban Salmon Habitat Program Assessment conducted July 1, 1998 to August 28, 1998 (Roth 1998).

Table 1
Nunns Creek Watershed
Urban Salmon Habitat Program Ratings and Limiting Fish Habitat Factors

Reach #	Habitat Rating	Riparian Rating	Limiting Factors	Potential Mitigation Techniques	Resulting Habitat Benefit
Tributary 4			High % fines and % wetted area. Sources of non point pollution and sediment. Erosion concerns due to high peak flows. Water quality degradation	Install check dams & stream side LWD. Identify opportunities to increase flows during summer. Explore potential of utilizing Municipal storm water drainage plan. Explore Opportunities to retrofit storm drains to enter settling pond prior to discharging into creek.	Encourage fines to settle out in low gradient areas. Extend summer flows and increase spawning and rearing habitat. Reduce impacts from sediment run off. Control flow rates. Improved water quality.
N Trib4. R1	29	30			
N Trib4. R2	31	10	% pool area.	Install weirs.	Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour.
N Trib4. R3	39	38			
N Trib4. R4	37	22			
Tributary 4a					
N Trib4a. R1	31	10	% wetted area. Sources of non point pollution and sediment. Erosion concerns due to high peak flows. Water quality degradation	Identify opportunities to increase flows during the summer. Explore potential of utilizing Municipal storm water drainage plan. Explore Opportunities to retrofit storm drains to enter settling pond prior to discharging into creek.	Extend summer flows and increase spawning and rearing habitat. Reduce impacts from sediment run off. Control flow rates. Improved water quality.
N Trib4a. R2	33	14			

Note: Information adapted from Urban Salmon Habitat Program Assessment conducted July 1, 1998 to August 28, 1998 (Roth 1998).

Table 2
Nunns Creek Watershed
Preliminary List of Areas with
Critical Habitat Concern

Reach #	USHP* Habitat Rating	USHP Riparian Rating	Limiting Factors
Tributary 1 (Mainstem)			
N Trib1. R1	24	40	High incidence of sediment deposition. Other limiting factors are LWD and boulder cover.
N Trib1. R3	28	22	LWD, boulder cover, altered stream sites, % wetted area.
N Trib1. R4	31	46	LWD, boulder cover, % wetted area.
N Trib1. R9	29	20	LWD, boulder cover, % fines, % wetted area.
Tributary 2			
N Trib2a. R1	17	14	Sources of non point pollution and sediment. Erosion concerns due to high peak flows. Other limiting factors are % pool area and instream cover.
Tributary 3			
N Trib3. R1	42	58	~~Culvert at ERT is a barrier to adult salmonids.~~ Five potential barriers throughout this reach. Limited summer flows. Percent pool area, LWD, boulder cover, % fines, % wetted area.
N Trib3. R2	31	32	Limited summer flows. LWD, boulder cover, % fines, % wetted area.
Tributary 4			
N Trib4. R3	39	38	LWD, boulder cover, 100% fines, altered stream sites, % wetted area.
*USHP=Urban Salmon Habitat Program			

As per discussions with TERA planning, May 18, 2005.

Table 3
Simms Creek Watershed
Urban Salmon Habitat Program Ratings and Limiting Fish Habitat Factors

Reach #	Habitat Rating	Riparian Rating	Limiting Factors	Potential Mitigation Techniques	Resulting Habitat Benefit
S R1	92	56	Erosion sites, obstructions, altered stream sites, % wetted area	riparian planting, identify opportunities to increase flows during the summer	Increase bank stability and reduce sedimentation
S R2	28	9	LWD, % crown cover, erosion sites, obstructions, altered stream sites, % wetted area	LWD placement, riparian planting, identify opportunities to increase flows during the summer	Increase bank stability and reduce sedimentation
S R3	140	84	% pool area, erosion sites, obstructions, altered stream sites, % wetted area	install weirs, riparian planting, identify opportunities to increase flows during the summer	●Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour ● Increase bank stability and reduce sedimentation
S R4	17	28	% pool area, erosion sites, obstructions, altered stream sites	install weirs, riparian planting	●Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour ● Increase bank stability and reduce sedimentation
S R5	48	122	% pool area, erosion sites, obstructions, altered stream sites, % wetted area	install weirs, riparian planting, identify opportunities to increase flows during the summer	Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour ● Increase bank stability and reduce sedimentation
S R6	22	36	% pool area, erosion sites, obstructions, altered stream sites, % wetted area	install weirs, riparian planting, identify opportunities to increase flows during the summer	●Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour ● Increase bank stability and reduce sedimentation
S R7	17	21	% pool area, erosion sites, % wetted area	install weirs, riparian planting, identify opportunities to increase flows during the summer	●Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour ● Increase bank stability and reduce sedimentation
S R8	28	15	% pool area, erosion sites, obstructions, altered stream sites, % wetted area	install weirs, riparian planting, identify opportunities to increase flows during the summer	●Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour ● Increase bank stability and reduce sedimentation
S R9	26	45	% pool area, erosion sites, obstructions, altered stream sites, % wetted area	install weirs, riparian planting, identify opportunities to increase flows during the summer	●Increase wetted area and rearing habitat for salmonids, through the development of upstream pools and downstream scour ● Increase bank stability and reduce sedimentation
From Rockland Road to Galerno Road			Sedimentation	Install check dams & stream side LWD	●Encourage fines to settle out in low gradient areas

Note: Information adapted from the Urban Salmon Habitat Program Assessment conducted between September and November of 1996 (Urchuck, K, et al. 1997).

Table 4
Simms Creek Watershed
Preliminary List of Areas With
Critical Habitat Concern

Reach #	USHP* Habitat Rating	USHP Riparian Rating	Limiting Factors
S R1 (Mainstem)	92	56	34 erosion sites, sedimentation, 17 obstructions, 33 altered stream sites, % wetted area, spawning limited by lack of gravel.
S R3 (South Simms)	140	84	79 erosion sites, moderate bank stability, 10 obstructions, 33 altered stream sites, % pool area, % wetted area, summer rearing.
S R5 (North Simms)	48	122	22 erosion sites, moderate bank stability, 6 obstructions, 10 altered stream sites, % pool area, summer rearing, land use farms/grass, high trophic level.
S R6 (North Simms Trib. 1)	22	36	5 erosion sites, 4 obstructions, 5 altered stream sites, stormwater system.
*USHP= Urban Salmon Habitat Program			

Note: Information adapted from the Urban Salmon Habitat Program Assessment conducted between September and November of 1996 (Urchuck, K, et al. 1997).

Table 5
Willow Creek Watershed
Urban Salmon Habitat Program Ratings and Limiting Fish Habitat Factors

Reach #	Habitat Rating	Riparian Rating	Limiting Factors
Willow Creek Mainstem			
W R1	35	28	LWD, instream cover (pool & boulder), crown cover, % fines, % wetted area, pH
W R2	27	38	LWD, instream cover (pool & boulder), crown cover, pH, riparian
W R3			LWD, instream cover (pool & boulder)
W R4	29	38	% pool area, LWD, instream cover (pool & boulder), crown cover
W R5	29	175	% pool area, LWD, instream cover (pool & boulder), crown cover
W R6	25	126	LWD, instream cover (pool & boulder), crown cover
W R7	31	51	% pool area, LWD, instream cover (pool & boulder), crown cover, % fines
W R8	31	226	LWD, instream cover (pool & boulder), crown cover, % fines, dissolved oxygen
W R9	27	38	LWD, instream cover (pool & boulder), crown cover, pH
W R10	25	6	LWD, instream cover (pool & boulder), crown cover
W R11	27	66	LWD, instream cover (pool & boulder), crown cover,% fines
W R12	25	46	Boulder cover, crown cover, % fines, % wetted area
W R13	31	40	LWD, boulder cover, crown cover, % fines, % wetted area
W R14	29	8	LWD, boulder cover, crown cover, % fines, % wetted area
W R15	31	156	% pool area, LWD, boulder cover, % fines, % wetted area
Willow Creek Tributary 1			
W Trib1. R1	23	40	LWD, % fines, % wetted area.
W Trib1. R2	21	24	LWD, percent wetted area, boulder cover.
Willow Creek Tributary 2			
W Trib2. R1	27	80	LWD, boulder cover, percent fines, percent wetted area
W Trib2. R2	25	98	

Note: Information adapted from the Urban Salmon Habitat Program Assessment conducted in the summer of 1997 (Roth 1998).

Table 5
Willow Creek Watershed
Urban Salmon Habitat Program Ratings and Limiting Fish Habitat Factors

Reach #	Habitat Rating	Riparian Rating	Limiting Factors
Willow Creek Tributary 3			
W Trib3.	25	78	LWD, instream cover, percent fines, pH
Larwood Creek			
L R1	20	36	% fines, boulder cover
L R2	26	74	% fines, boulder cover, riparian, crown cover, percent wetted area
L R3	31	38	% fines, riparian, obstructions, instream cover (pool & boulder), crown cover, percent wetted area
L R4	37	58	% fines, instream cover (pool & boulder), crown cover, percent wetted area, LWD, dissolved oxygen, pH, erosion
Larwood Creek Tributary 1a			
L Trib1a. R1	35	0	% pool area, instream cover, LWD, % wetted area, riparian, crown cover
L Trib1a. R2	35	20	% pool area, instream cover, LWD, % wetted area, % fines
L Trib1a. R3	29	22	LWD, % wetted area, crown cover, % fines, boulder cover
L Trib1a. R4	27	22	LWD, % wetted area, % fines, boulder cover
L Trib1a. R5	25	58	LWD, % wetted area, % fines, boulder cover
Beaver Creek			
B R1	35	58	Obstructions, LWD, boulder cover, crown cover, % fines, % wetted area
B R2	29	56	LWD, boulder cover, crown cover, % fines, % wetted area
Beaver Creek Tributary 1			
B Trib1. R1	35	6	% pool area, LWD, instream cover (pool & boulder), crown cover, % wetted area
B Trib1. R2	37	16	
B Trib1. R3	39	17	% pool area, LWD, instream cover (pool & boulder), crown cover, % wetted area, Dissolved Oxygen, pH
B Trib1. R4	41	14	

Note: Information adapted from the Urban Salmon Habitat Program Assessment conducted in the summer of 1997 (Roth 1998).

Table 5
Willow Creek Watershed
Urban Salmon Habitat Program Ratings and Limiting Fish Habitat Factors

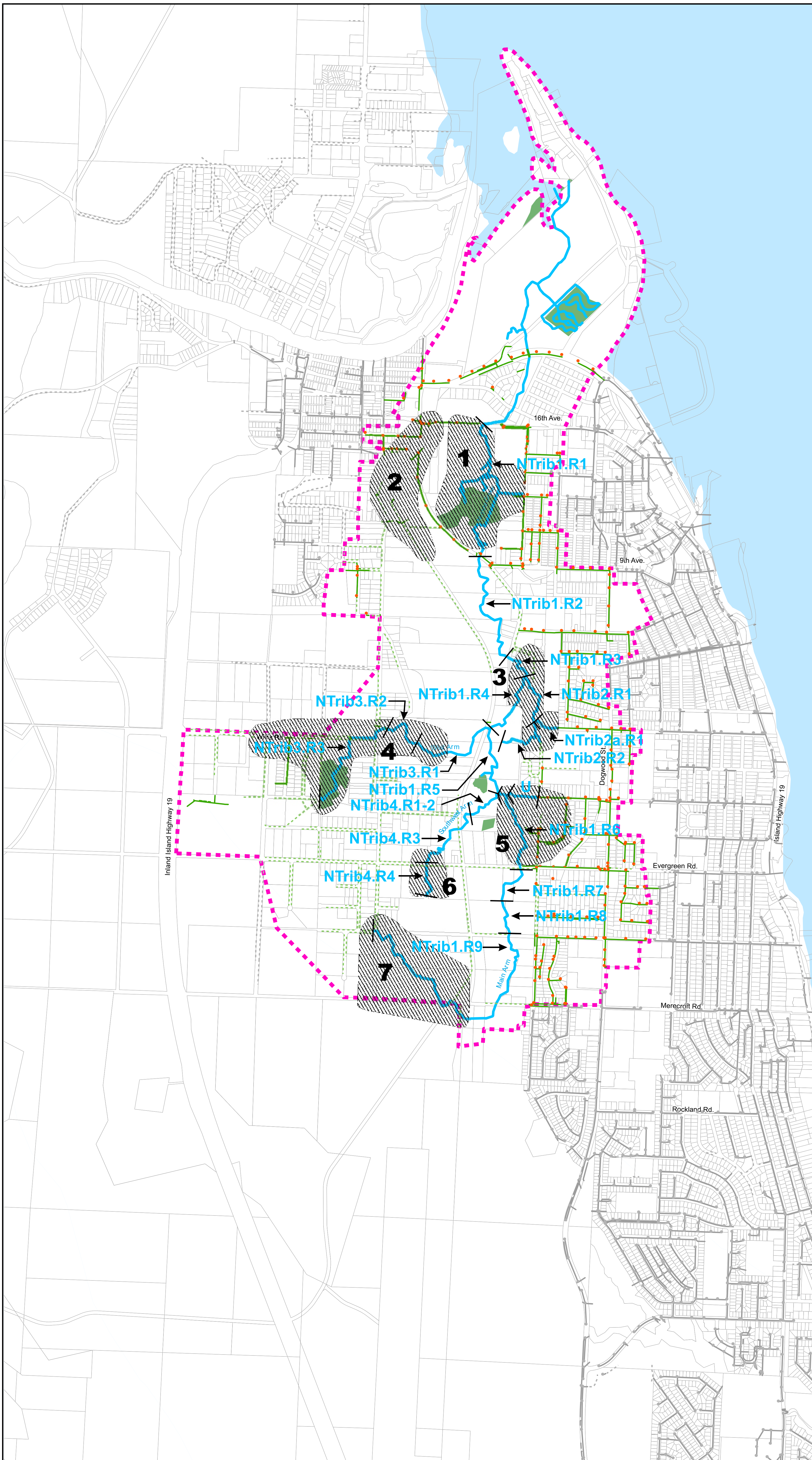
Reach #	Habitat Rating	Riparian Rating	Limiting Factors
Newman Creek			
N R1	35		% pool area, LWD, instream cover (pool & boulder), crown cover, % wetted area, pH
N R2	37		
N R3	35		
N R4	37		% pool area, LWD, instream cover (pool & boulder), % wetted area, pH
N R5	25	28	LWD, boulder cover, % fines, % wetted area
N R6	29	32	LWD, boulder cover, crown cover, % fines, pH
N R7	27	74	LWD, boulder cover, % fines, % wetted area, pH
N R8	31	174	LWD, instream cover (pool & boulder), % fines, % wetted area, pH
Newman Creek Tributary 1			
N Trib1. R1	35	20	% pool area, LWD, instream cover, crown cover, % wetted area
N Trib1. R2	37	10	% pool area, LWD, instream cover, crown cover, % wetted area, obstruction, erosion, pH
N Trib1. R3	33	0	% pool area, LWD, instream cover, crown cover, % wetted area
Newman Creek Tributary 1a			
N Trib1a. R1	23	6	% pool area, instream cover, crown cover, LWD, % wetted area
N Trib1a. R2	37	14	Boulder cover, LWD, % wetted area

Note: Information adapted from the Urban Salmon Habitat Program Assessment conducted in the summer of 1997 (Roth 1998).

Table 6
Willow Creek Watershed
Preliminary List of Areas With
Critical Habitat Concern

Reach #	USHP* Habitat Rating	USHP Riparian Rating	Limiting Factors
Willow Creek Mainstem			
W R1	35	28	LWD, boulder cover, % crown cover, 77% altered stream sites
W R4	29	38	LWD, instream cover, % crown cover
W R7	31	51	LWD, instream cover, % crown cover
W R15	31	156	LWD, boulder cover, % fines, % wetted area
Larwood Creek			
L R3	31	38	LWD, boulder cover, % fines, altered sites, % wetted area, possible obstruction
L Trib1. R1	35	35	% pool area, LWD, instream cover, % crown cover, % wetted area
L Trib1. R2	35	35	LWD, boulder cover, % crown cover, % fines, % wetted area
L Trib1. R3	29	29	LWD, boulder cover, % fines, altered stream sites, % wetted area
L Trib1. R4	27	27	LWD, boulder cover, % fines, altered stream sites, % wetted area
Beaver Creek			
B R2	29	56	LWD, boulder cover, % crown cover
B Trib1. R1	35	6	% pool area, LWD, instream cover, % crown cover, % wetted area
B Trib1. R2	37	16	% pool area, LWD, instream cover, % crown cover, % wetted area
B Trib1. R3	39	17	% pool area, LWD, instream cover, % crown cover, % wetted area
B Trib1. R4	41	14	% pool area, LWD, instream cover, % crown cover, % wetted area, dissolved oxygen
Newman Creek			
N R2	37		% pool area, LWD, instream cover, % crown cover, % wetted area
N R4	37		% pool area, LWD, instream cover, % crown cover, % wetted area
N R6	29	32	LWD, boulder cover, % crown cover, % fines
*USHP= Urban Salmon Habitat Program			

Note: Information adapted from the Urban Salmon Habitat Program Assessment conducted in the summer of 1997 (Roth 1998).



District of Campbell River

Integrated Stormwater Management Plan

Figure 1
Nunns Creek Watershed Reach Identification and Critical Areas

/ = boundary of reach break with reach identifier
U = un-named

critical area

Note:
- reach breaks are approximate
- for description of reaches or critical areas refer to report

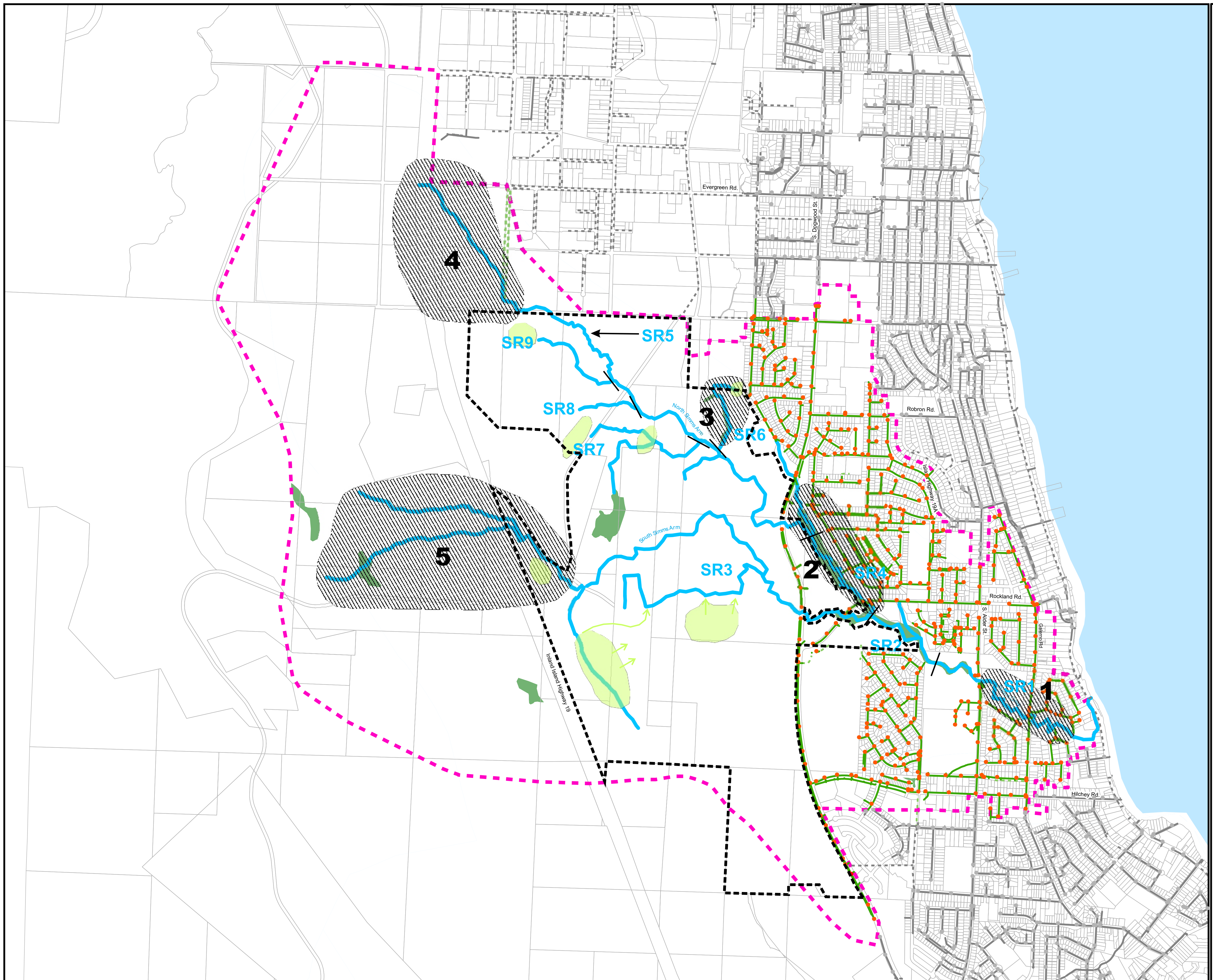
Storm Manhole Within Watershed
Storm Manhole Outside Watershed
Storm Main Within Watershed
Storm Main Outside Watershed
Nunns Creek
Ditches Within Watershed
Ditches Outside Watershed
Nunns Creek Watershed
Wetlands

0 250 500
Metres

Scale 1:20 000

Source: District of Campbell River

URBAN SYSTEMS
1479.0005.01 February 2005



District of Campbell River Integrated Stormwater Management Plan

Figure 2
Simms Creek Watershed Reach Identification and Critical Areas

/ = boundary of reach break with reach identifier

Beaver Lodge Forest Lands

critical area

anecdotal wetland to be confirmed

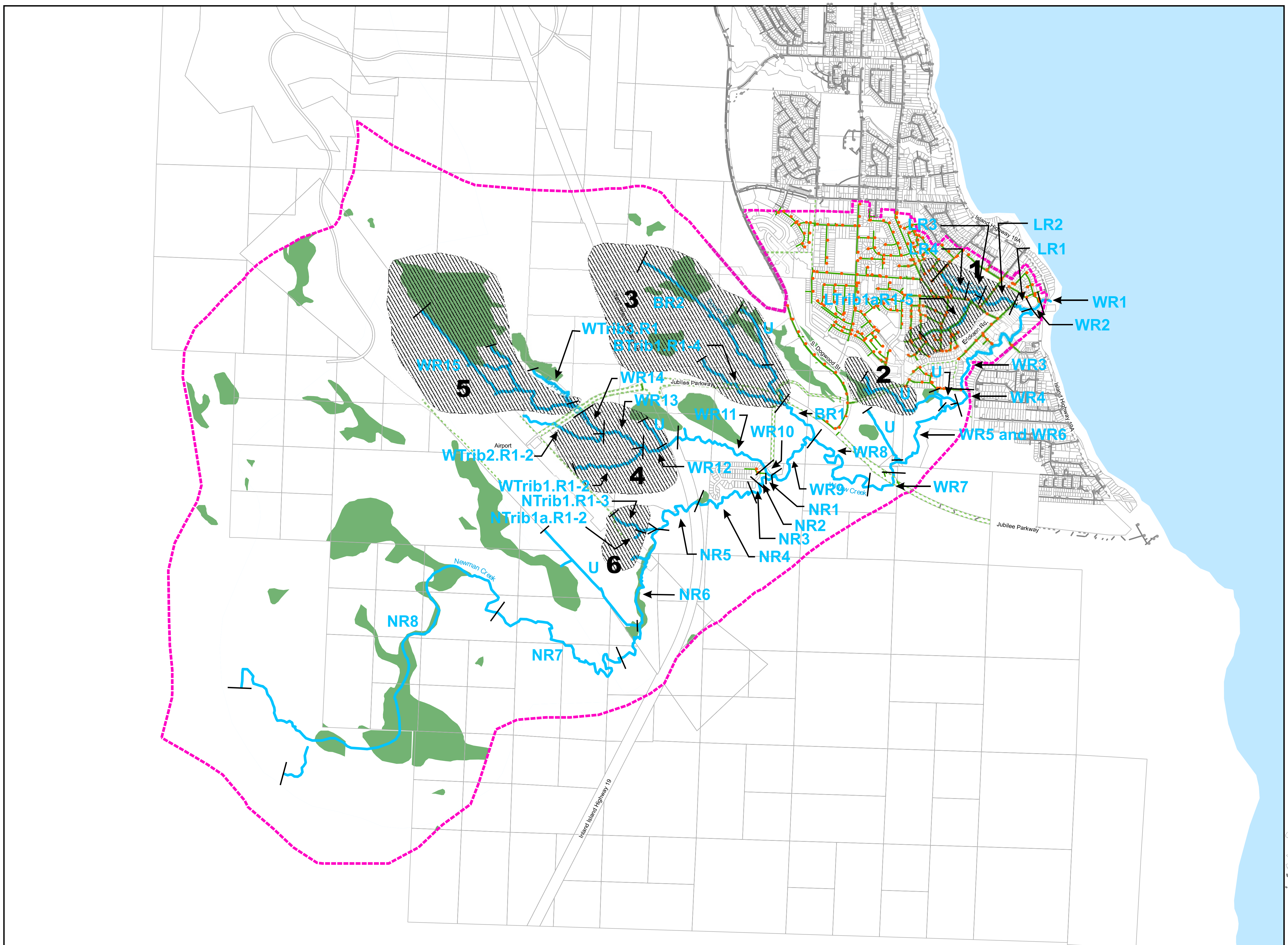
Note:
- reach breaks are approximate
- for description of reaches or critical areas refer to report

Storm Manhole Within Watershed
Storm Manhole Outside Watershed
Storm Main Within Watershed
Storm Main Outside Watershed
Nunns Creek
Ditches Within Watershed
Ditches Outside Watershed
Nunns Creek Watershed
Wetlands

0 205 410
Metres
Scale 1:30 000

Source: District of Campbell River

URBANSYSTEMS.



District of Campbell River

Integrated Stormwater Management Plan

Figure 3

Willow Creek Watershed Reach Identification and Critical Areas

/ = boundary of reach break with reach identifier

U = un-named

critical area

Note:
- reach breaks are approximate
- for description of reaches or critical areas refer to report

Storm Manhole Within Watershed

Storm Manhole Outside Watershed

Storm Main Within Watershed

Storm Main Outside Watershed

Nunns Creek

Ditches Within Watershed

Ditches Outside Watershed

Nunns Creek Watershed

Wetlands

0 205 410

Metres

Scale 1:30 000

Source: District of Campbell River

URBANSYSTEMS.

APPENDIX C

HYDROGEOLOGICAL REPORT

PITEAU ASSOCIATES
GEOTECHNICAL AND
HYDROGEOLOGICAL CONSULTANTS

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May 2, 2005

Urban Systems Ltd.
#2353 – 13353 Commerce Parkway
Richmond, B.C.
V6V 2L1

Attention: Jeff Rice, P. Eng.

Dear Sirs:

Re: Hydrogeotechnical Assessments for Development of Integrated Stormwater Management Plan for Nunns, Simms and Willow Creeks, Campbell River

Piteau Associates Engineering Ltd. (Piteau) was retained by Urban Systems Ltd. (Urban Systems) to conduct a hydrogeological assessment of the Nunns, Simms and Willow Creek areas in Campbell River. This assessment was designed to provide information to assist with the development of an Integrated Stormwater Management Plan (ISMP) for the three areas.

The study area is located in the District of Campbell River, and is west and south of the District's business core. It is located along the Straight of Georgia shoreline, south of Campbell River, east of Quinsam River, and extends in the south to about Shelter Point (see Fig 1). This irregular shaped Study Area is about 15 km long and up to about 7.5 km wide (see Fig. 1).

This assessment was conducted with the knowledge that, in many areas of British Columbia, it has been found that ground infiltration of stormwater runoff has a number of benefits, which includes:

1. Helping to reduce peak runoff flow;

2. Filtering out contaminants prior to discharge to streams; and

3. Helping to sustain low flows in local streams and ditches.

WORK CONDUCTED

The study involved an office review of information on geology, surface soils, surface water drainage, logs of water wells, operation of on-site sewage disposal systems and vegetation types. Allan Dakin, a senior hydrogeologist with Piteau, visited the site on December 7th, 2004. While on site, he visited representative reaches of the three creeks and examined areas where sediments were exposed in road cuts, building excavations and riverbanks.

Sources of information included: reports on surface drainage, a regional soils map, logs of drilled wells and interviews with individuals who are familiar with local area drainage patterns. The inferred groundwater conditions at the site were compared with hydrogeologically similar areas, such as Quadra Island (Piteau, December 1987), Point Grey, Vancouver (Piteau, December 2002) and Piteau (2003).

The existing data includes several reports on surface water drainage, which are listed in the references. The reports with the most relevant information relating to the local area groundwater resource are those that included information on: soils, geology, stream low flows and water temperature and chemistry. However, information on land cover, land use and types of vegetation was also useful for assessing past and present groundwater recharge and discharge areas. Also reviewed was the B.C. Ministry of Water, Land and Air Protection's database for water well records and locations in the area. This included well depths, yields depths to water and in some cases, lithologic profiles.

CLIMATE

The Campbell River Airport climate station is located at an elevation of about 105 metres above main sea level (m-asl), and is in the southern part of the Study Area. Monthly and daily precipitation data is available from 1953. Based on the normalized record for the period 1971 to 2000, the station receives about 1,451.5mm of precipitation annually. The highest monthly average occurs in November (230.7mm), and the lowest in July (40.4mm).

The average annual temperature at the airport station is 8.6°C. As groundwater temperatures are usually not more than about 1°C above or below the annual mean air temperature, it is expected that local area groundwater temperature will range between 7.5 and 9.5°C.

SURFACE DRAINAGE

Surface water runoff from the Willow and Simms creeks flows mostly eastward towards the ocean, via a network of small streams and ditches, while Nunns Creek flows northwards into the Campbell River Estuary (see Figs. 1 and 2). In some of the upland areas, the stream channels are not well developed, which suggests that prior to urban development and construction of drainage ditches in the area, much of the runoff was directed through a network of shallow channels and swampy areas. In other areas, particularly along Willow Creek, the stream channel is deeply incised.

GEOLOGY

The regional geology map shows that the area is underlain primarily by glaciomarine deposits. These deposits consist mostly of silty sand and pebbly sand near ground surface and silts and clay below. After the glacial ice left the area some 10,000 years ago, most of the area was submerged by the ocean. Subsequent to this the isostatic rebound caused a relative land surface rise of about 200m.

In areas around the major drainage channels, thin veneers of alluvial and colluvial deposits have accumulated. The marine deposits are rarely thicker than 12m, and underlying this is typically either sedimentary bedrock or a glacial outwash sand unit (Quadra Sand). The glaciomarine units typically have a relatively low permeability and the underlying Quadra Sand unit is moderately permeable.

There are only 11 records of deep holes drilled in the study area, and all of these are located in the Willow drainage basin (see locations on Fig. 2 and a list in Table II). Of these wells, eight are located in the airport area and three are located east of the airport. Reported well depths ranged up to 41m, and averaged 23m. The depths to water ranged from 1.2m to 13m below ground, and the average depth (including the dug wells) was about 3m below ground. Reported well yields ranged up to 12 L/s and the median value was 4.2 L/s.

Copies of representative drilled wells are included in Appendix A.

The lithology records from these holes plus field observations were used to prepare the hydrogeological section presented in Fig. 3. This information has been compared with profiles of geologically similar areas, such as Quadra Island, where there are a lot of lithologic records for deep drilled wells. From this it is believed that the thickness of the underlying Quadra Sand unit becomes thinner with increasing distance towards the southern part of the three creek drainage areas. The Halstead and Treichel (1966) groundwater mapping suggests that groundwater can be obtained from unconfined aquifers in the upper part of the till unit, and from confined aquifers beneath the till.

Based on available information it is judged that in many areas of the Nunns Creek drainage basin, there is a 0.5 to 3m thick layer of marine moderately permeable silt or sand, and/or weathered till, which overlies low permeability glacial till (typically a dense silty clay). In the Willow Creek basin the till either overlies, or interfingers with, one or more zones of well sorted fine to coarse grained dense sand (see illustration in Fig. 4). This sand unit is likely part of the regionally extensive Quadra Sand unit. As there are very few water well records in the Simms Creek area, the subsurface conditions are assumed to be a transition from that found in the Nunns Creek area and that in Willow Creek basin.

While the Quadra Sand unit consists mainly of sand, in some areas it has beds of clay, silt and gravel present, which typically represents less than 10 per cent of the unit thickness. According to Clague (1977), there is no systematic gradation in mean particle size either vertically through a section or areally along the length of the Georgia Depression where it is found. Most of the silt is present in the lower part of the unit, and gravel is most common in the upper part. For example, in the sea cliff exposures of Quadra Sand at the Point Grey Peninsula, where the University of

British Columbia campus is located, the silt beds extend from about mean sea level to elevation 18 m-asl. Below this unit (below sea level), there is a sand and gravel aquifer that sustains well yields in the 2 to 4 L/s range.

A similar situation is present in the Cape Mudge area on Quadra Island (Piteau, 1987), where the till unit is up to 35m thick and the underlying Quadra Sand unit extends to 40m below sea level.

SURFICIAL SOILS

The dominant soil types mapped in the all three drainage areas is the Dashwood gravelly loamy sand unit (Dgls on Fig. 2). This unit is typically located in the sloping upland areas of all three drainage areas and is a moderate to well drained unit (see Photo 1). The next most prevalent unit is the imperfectly drained Bowser loamy sand unit, which occupies much of the lower parts of the Simms and Willow drainage areas. As indicated on the table located opposite the Fig. 2 map pocket, the Dashwood soils have the potential for infiltration stormwater under long term (saturated) flow conditions at a rate of about 250mm per hour (mm/h). This contrasts with an estimated 8 mm/h for Bowser soils. These infiltration capacities are based on the soil granular size descriptions, the depth of the soil horizon and experience with conducting percolation tests in similar types of soils. As such these values should be used as a planning guide and not for detailed design of infiltration works.

In the upper reaches of the Willow and Simms Creek drainage basins, the dominant soil unit is the well drained Qualicum loamy sand and gravelly loamy sand unit (see Photo 2). This unit has an estimated long-term infiltration capacity of 10 mm/h.

There are number of small peat filled depressions scattered around in the Simms and Willow Creek catchments. These organic soils are poorly drained and mapped as the Arrowsmith soil unit on Fig.2. In the western part of Nunns Creek and the northwestern corner of Simms Creek, there is an extensive area of well drained silty clay loam soils, which are mapped as the Fairbridge Unit. These soils are typically located in groundwater discharge areas, which are often underlain by low permeability sediments, either at surface or several metres below ground.

There are a lot of dug wells in the upper reaches of the Nunns Creek drainage area. All of these are relatively shallow (less than 6m deep) dug wells with no yield or lithologic information (see locations on Fig. 2) and data in Table II. It is noted that many of these wells are located in the poorly drained Tolmie soil unit (infiltration of 1mm/hr). Judging by the density of dug wells in some areas, it appears that small subdivisions have been created with houses relying on water supplies from these wells until the municipal water supply system was constructed in the area. The presence of these shallow wells suggests that there is a perched aquifer unit in these areas, and that they have provided yields that were at one time sufficient for household supply. This water abstraction, along with the construction of drainage ditches during urban development, will have had a significant impact on base flows in creeks, particularly Nunns Creek and it's tributaries. While the wells are likely mostly abandoned, the impact of open ditches and/or permeable granular bedding placed around municipal pipes will be still significant. A similar impact from service trenches is likely to have occurred in the urban areas of both Simms and Willow Creeks.

CREEK BASE FLOWS

The creek summer flow information for both Simms and Willow Creeks was reviewed and is summarized on Table III. As most of the flow during the summer periods originates as groundwater, these low flow data provide an order of magnitude estimate of the groundwater recharge to the upper perched aquifer. When expressed as a flux, or flow per unit catchment area, the flows can be compared with other drainage basins.

As indicated on Table III the fluxes for both the Willow Creek and Simms Creek flow monitoring stations are mostly in the 1.4 to 2.6 L/s/Km^2 range, and these are much lower than the fluxes for the other regional rivers, which were typically greater than 8 L/s/Km^2.

Many of the regional Rivers have lakes and large wetlands in the catchments, which help to maintain moderately high fluxes. The highest recorded flux in the Study Area streams was 3.8 L/s/Km^2, which was recorded near the Simms Creek mouth. The gradual increase in low flow flux, with distance, measured from the creek source, suggests that there may be a strong groundwater discharge into the lower reaches of Simms Creek. Possibly there is a discharge from the underlying Quadra Sand unit into the creek channel. This observation is consistent with the profile shown on Fig. 4, which suggests that the groundwater flowing in the Quadra Units will discharge to the valley occupied by the lower reaches of either Simms or Nunns Creeks.

A similar profile is illustrated in Fig. 3, where it is postulated that groundwater will flow from a sand unit that intersects with the Willow Creek Valley. In this creek, the fluxes remained relatively constant with distance along the creek channel (1.6 to 2 L/s/Km^2), which suggests that the groundwater inflow is relatively constant along the length of the stream channel.

During extensive dry periods, a higher component of groundwater in the stream flow would be reflected in proportionally higher TDS values and lower DO. Also in the study area the stream water temperatures would approach the annual average air temperature of 8.6 ^{o}C.

Flow and physiochemical data was collected from a very extensive set of areas in Willow Creek and its tributaries (Roth 1998). The physiochemical parameters measured were: temperature, total dissolved solids (TDS), pH and dissolved oxygen (DO), and the results are listed on Table IV.

The data listed on Table IV was collected from Willow Creek and it is tributaries in September and October 1997 and would be expected to have a proportionally high groundwater component. However, the flow measured near the creek mouth was 3.86 m^3/s, which is much higher than the 0.047 m^3/s low flow measured in a similar reach in July 2001 (see Table III). This is borne out by few streams having water temperatures in the 7.5 to 9.5 ^{o}C range which would be close to groundwater temperatures. Also as noted in note 3 on Table IV the flow in Reach 8 of Newman Creek was recorded immediately following an intense rainfall event. Consequently, the data listed on Table IV cannot be used to provide an estimate on the stream base flows (hence groundwater discharge).

Nunns Creek water quality and flow data was collected in the summer of 1998 and the results are presented on Table V. The flow at the mouth was 0.05 m^3/s, and did not change significantly with distance from the mouth. The recorded flow at Reach 5 was 0.16 m^3/s, and this either indicates that the difference is within the flow measurement resolution, or some of the stream flow was infiltrating into the ground. This data clearly shows that the groundwater contribution to Nunns Creek flow is not very significant. This is likely a consequence of extensive urban development in the east side of the basin, and semi-rural development in the southern area.

GROUNDWATER FLOW SYSTEMS

Some of the precipitation falling on the upland areas in all basins seeps into the ground, and likely flows along the surface of the marine clay unit. The flow will either find a place where it can seep through the cap into the underlying Quadra Sand unit, or discharge into nearby stream channels and ditches.

As indicated previously, if the groundwater reaches the deep Quadra Sand unit, it likely migrates eastwards and/or northwards, and either discharges directly into the lower reaches of all three creek channels, or possibly sustains springs located along the eastern side of the Study Area. These deep flow systems do not always follow the surface topographic slopes, as is illustrated on Fig. 4.

Due to the relatively high water tables and piezometric head elevations and moderate sediment permeability, ground infiltration of storm water runoff will only be practical in parts of the Study Area, due to low permeability soils and/or high water tables. However, in some areas the construction of ditches and service trenches will lower the water table and hence create additional subsurface storage capacity in the adjacent drained sediments. Thus drained soils on developed lots could be utilized for temporary storage of stormwater runoff and then be available for slow release during the ensuing dry season. For example, soak-a-way pits for roof runoff and drive ways could possibly become viable in areas where the water table was relatively shallow prior to development.

It is judged that the construction of drainage ditches in the upland areas has lowered the shallow (perched) water tables in some of these areas (see Photo 3).

GROUND INFILTRATION OF STORMWATER

Design Concepts and Justification

In many parts of the Study Area, ground infiltration systems could be incorporated into landscaping and engineering plans, to direct water towards points where ground infiltration is feasible. The Infiltration rating numbers presented on Fig. 2 are intended to indicate the relative capacities of soils to absorb storm water runoff. This indicates Dashwood soils (Rank 1) have the greatest potential and Arrowsmith soils have the lowest potential (Rank 13).

Systems that collect stormwater runoff need to have a number of considerations, including: landscaping to channel water to the infiltration system, an adequate storage compartment to hold the required amount to be slowly infiltrated after the rainfall event, and a clarification system to eliminate suspended sediments and floating detritus. A regular (annual or 10-year) clean out of some structures should be anticipated.

Improving water quality is important to maintain the lifetime of the infiltration system that would be reduced due to clogging, which is the cause of most failures. Measures that can be taken to improve water quality include a flotation (for oily water) and settlement chamber that allows carried material to settle, filter cloth that can be periodically replaced, a detention pond for settlement, or a filter chamber with sand that can remove fine silts and clays from stormwater.

Shallow Infiltration Systems

Shallow infiltration systems could be designed to infiltrate water into many areas within the well drained units, such as the Dashwood and Qualicum soils. These soils cover extensive areas in the Simms and Willow Creek drainage basins and have infiltration rankings of 1 and 3 respectively. Dashwood soils are also present in about 25% of the Nunns Creek drainage basin.

Examples of shallow infiltration enhancement systems include: soak-a-way pits, seepage basins, shallow infiltration wells and seepage trenches.

The hydraulic conductivity of the subsurface soils in the Study Area is likely quite variable, due to the presence of localized permeable sand and/or gravel seams, or interbeds, in the middle of relatively low permeability loamy soils. For this reason performing infiltration tests in linear trenches in representative areas will be required, prior to development of more detailed plans for stormwater infiltration. For example, infiltration tests performed in soils similar to Dashwood indicated infiltration rates to a 0.6m wide trench in the range from about 0.1 to 0.4 L/s/m length of trench (Piteau Associates, 2004).

It is better to have a wide distribution of infiltration systems introducing the water into different areas and strata, rather than a few concentrated areas discharging into one strata. This will reduce the potential for water table mounding, and in some areas, the potential for slope instability.

As a guide, conducting one test per soil type per 5 hectares could be used for preliminary planning. This could be modified if the results show a relatively high degree of consistency. A typical cost for constructing a test trench, running an infiltration test, analyzing the results and preparing a report for ten pits typically costs between $400 and $600 per pit.

Vertical Infiltration Wells

Clean stormwater that cannot infiltrate into shallow soils in the upland areas could be discharged into the Quadra Sand Unit below the low permeability till-like unit. The concept for this method is illustrated on Figs. 4 and 5.

As indicated on the hydrogeologic profile provided on Figs. 3, the depths to the top of the deep Quadra Sand aquifer units range from about 4 to 7m below ground. While no tests have been conducted in the Study Area, the results of tests run in hydrogeologically similar areas (such as the Point Grey peninsular and at Cape Mudge) suggest that short term inflow rates of between 0.5 to 2 L/s per well may be feasible in the upland parts of the Study Area. The actual infiltration rate for an individual well will depend on a number of factors including: well depth, depth to static water level, formation permeability and continuity of the aquifer.

Two to three 30m deep test holes will be required to assess the feasibility of the deep hole infiltration method. A well typically costs about $9,000 and an infiltration tests cost in the range $1,800 to $3,500 depending of the availability and cost of a water source, such as a fire hydrant or tanker truck. Engineering and interpretation costs would typically cost an additional $4,000 to $5,000 per well. These well should be located in areas where development is planned, and where there is not much data on deep drilled wells, such as the western parts of Nunns and Simms Creeks. Selected wells can also be used for long term monitoring of groundwater levels and water quality. Water level monitoring is best performed using an electronic data logger that can be set to record water levels at intervals such as 15 minutes and run off a battery for several months. A data logger costs about $1,000 and typically runs for about seven years on a non renewable battery.

It is important to appreciate that all ground infiltration systems will not be effective for very long if suspended solids and bacteria are not adequately removed from surface runoff, prior to discharge into the ground. This can be accomplished with properly designed, constructed and maintained vegetated swales or other similar stormwater “best management practices.”

Detailed hydrogeological assessments should be conducted prior to construction and operation of a deep infiltration well. This type of investigation should consider both positive and negative impacts, such as stream base flow enhancement, slope instability and potential for groundwater contamination. As note in Appendix B, groundwater contamination resulting from ground infiltration of surface water runoff is very rare occurrence.

Hydrogeologic Assessment and Monitoring

If ground infiltration of surface water runoff is being seriously considered, a more detailed hydrogeologic assessment should be carried out. This type of study typically involves digging test pits and installing standpipe piezometer tubes, and possibly drilling some deep test wells. In-situ permeability tests could be run in the piezometers and inflow tests conducted on the wells. Water levels are typically monitored for several months and water samples are collected for geochemical analyses. Ideally, the manual water level monitoring can be supplemented by automatic monitoring using a datalogger.

The hydrogeological assessment should be supplemented by dry season surface water monitoring, in selected drainage channels that conduct groundwater from discharge areas. Ideally this type of monitoring will include: water levels, flows (often calculated from levels), temperature and electrical conductivity (EC). As baseflows typically do not change rapidly during the dry season, monthly monitoring is considered a reasonable minimum. Supplemental monitoring using a data logger is definitely an advantage. It is suggested that three representative stations be selected in each of the three drainage areas. One station should be located as close as possible to the creek mouth, one about half way along the stream channel and one in either the main channel or in a major tributary that drains from an area where significant development is likely to take place.

The cost for setting up and operating these stations could range greatly as it depends on the availability of easily accessible stable sections of stream channel. In order to automatically measure stream flow, the geometry needs to be well established so that a reliable correlation between levels measured using a data logger and stream flow can be established. Alternatively monthly measurements can be performed using a stream velocity meter and measuring the stream channel cross-sectional area. A lot of the cost is for technician time, including travel to the site. However, if there are a number of stations established in easy to access sites, the cost per station can typically be kept down to an acceptable monthly amount.

CONCLUSIONS

1. The sediments underlying the Study Area are mostly very variable and in many areas it is moderately permeable, and in those areas were the water table is not near surface, there is good potential for infiltration of stormwater runoff.

2. The deep (> 5m) aquifers in the area are relatively thin and of limited real extent. Consequently they rarely sustain perennial flow in any of the local surface drainage features.

3. Continued development in the area using conventional surface drainage networks will lead to a reduction of baseflow, particularly when the area of impervious surface exceeds 15% of the catchment area.

4. Infiltration of stormwater runoff has a number of benefits, including: 1) helps to reduce peak runoff flow, 2) filters out contaminants prior to discharge to streams, and 3) helps to sustain low flows in local streams and ditches.

5. A series of perforated storm pipes installed in shallow sand filled trenches could absorb significant amounts of water, and once in the ground this water will help sustain baseflow in nearby channels during the ensuing summer.

RECOMMENDATIONS

The District should consider establishing a hydrogeological monitoring network. As a minimum, this could include:

1. Establishing low-flow monitoring stations near the mouth of each of the creeks, and monitoring water levels, flow, temperature and electrical conductivity (EC) during the months of June to September.

2. Constructing shallow (test pit) monitoring wells in areas where the water table is within about 4m from ground surface, and where new development is likely to take place in the near future. This will provide baseline information that would be valuable when considering the construction of stormwater ground infiltration systems and for impact assessment.

I trust that this is sufficient for your present purposes

Yours very truly,

PITEAU ASSOCIATES ENGINEERING LTD.

R. Allan Dakin, P.Eng.

RAD/dlb
Att.

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TABLES

TABLE I

CLIMATE NORMAL FOR CAMPBELL RIVER AIRPORT STATION - 1971 TO 2000.

Temperature:	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	1.3	3.0	4.8	7.7	11.2	14.2	16.9	16.9	13.4	8.3	4.2	1.7	8.6
Standard Deviation	2.2	1.7	1.2	1.1	1.3	1.3	1.2	1.2	1.4	0.8	1.8	2.0	0.7
Daily Maximum (°C)	4.6	6.9	9.5	13.0	16.8	19.7	23.0	23.1	19.5	13.0	7.6	4.8	13.5
Daily Minimum (°C)	-2.0	-1.0	0.1	2.3	5.6	8.7	10.8	10.7	7.3	3.5	0.8	-1.4	3.8
Extreme Maximum (°C)	16.1	17.5	20.6	28.5	33.2	36.9	37.2	**37.8**	31.6	24.2	17.8	13.3	
Date (yyyy/dd)	1968/20	1991/26	1965/11	1998/30	1983/29	1982/18	1965/31	**1971/10**	1988/03	1992/01	1975/03	1976/17	
Extreme Minimum (°C)	**-23.9**	-17.8	-12.8	-5.6	-2.2	-0.6	2.2	1.7	-2.8	-9.7	-20.4	-18.5	
Date (yyyy/dd)	**1969/30**	1972/01	1976/03	1972/03	1966/27+	1977/02	1971/06	1966/29+	1972/27	1984/31	1985/26	1980/07	
Precipitation:													
Rainfall (mm)	165.3	139.6	124.8	82.5	67.1	61.2	40.4	48.6	58.9	151.8	218.0	185.9	1344.1
Snowfall (cm)	33.4	19.4	11.1	1.6	0.0	0.0	0.0	0.0	0.0	1.1	12.7	29.6	109.0
Precipitation (mm)	198.5	158.7	136.0	84.2	67.1	61.2	40.4	48.6	58.9	152.9	230.7	214.5	1451.5
Average Snow Depth (cm)	4	2	0	0	0	0	0	0	0	0	1	2	1
Median Snow Depth (cm)	4	1	0	0	0	0	0	0	0	0	0	0	0
Snow Depth at Month-end (cm)	4	0	0	0	0	0	0	0	0	0	1	6	1
Extreme Daily Rainfall (mm)	76.7	76.5	63.6	44.5	42.2	37.3	43.7	49.2	53.4	80.0	75.9	**87.8**	
Date (yyyy/dd)	1968/17	1983/22	1997/17	1969/03	1977/27	1972/10	1974/16	1984/05	1997/16	1999/27	1971/08	**1993/12**	
Extreme Daily Snowfall (cm)	**53.3**	26.0	42.0	11.4	0.0	0.0	0.0	0.0	0.0	29.0	43.2	46.0	
Days with Rainfall:													
>= 0.2 mm	16.4	15.1	17.4	15.3	13.8	13.0	8.7	9.0	9.6	16.9	20.3	17.4	172.8
>= 5 mm	8.8	7.7	7.4	5.4	4.6	4.4	2.7	3.1	3.8	8.0	11.4	10.1	77.3
>= 10 mm	5.7	4.9	3.8	2.7	1.8	1.6	1.3	1.5	1.9	5.2	7.5	6.4	44.4
>= 25 mm	1.8	1.4	1.1	0.30	0.23	0.17	0.10	0.17	0.37	1.8	2.5	2.2	12.1
Days With Snowfall:													
>= 0.2 cm	4.7	3.6	2.2	0.40	0.0	0.0	0.0	0.0	0.0	0.13	1.7	4.1	16.9
>= 5 cm	2.2	1.4	0.60	0.13	0.0	0.0	0.0	0.0	0.0	0.03	0.72	1.8	6.9
>= 10 cm	1.2	0.73	0.30	0.10	0.0	0.0	0.0	0.0	0.0	0.03	0.48	1.0	3.8
>= 25 cm	0.23	0.07	0.10	0.0	0.0	0.0	0.0	0.0	0.0	0.03	0.03	0.28	0.74
> 30 °C	0.0	0.0	0.0	0.0	0.10	0.72	2.4	2.0	0.10	0.0	0.0	0.0	5.3
> 35 °C	0.0	0.0	0.0	0.0	0.0	0.03	0.0	0.20	0.0	0.0	0.0	0.0	0.23

NOTES:

1) From Canadian Climate Normals, Environment Canada website.
2) Elevation of station is 105.5m-asl.
3) Location: Latitude 49° 57' N, Longitude 125° 16' W.

TABLE II
INFORMATION ON WELLS

BCGS Well No.	WTN	UTM		Diameter	Construction		Depth To			Well
		East	North		Method	Date	Well Bottom	Water	Bedrock	Yield
		m	m	mm			m	m	m	L/s
092F094412 5	505	337254	5535719	127	Drilled		21.3	1.8	-	1.8
092K004231 1	1270	-	5545232	-	Drilled	-	95.7	-	-	-
092K004214 14	4242	-	5543732	-	Dug	-	4.3	-	-	-
092K004214 12	4245	-	5543099	-	Dug	-	4.9	4.3	-	-
092K004232 3	4250	-	5543839	-	Dug	-	4.9	4.0	-	-
092K004214 22	4259	-	5542876	-	Dug	-	4.6	2.1	-	-
092K004214 13	4260	-	5543243	-	Dug	-	5.5	3.7	-	-
092K004214 8	4261	-	5542681	-	Dug	-	6.1	-	-	-
092K004214 15	4263	-	5543797	-	Dug	-	2.4	1.5	-	-
092K004212 16	4264	-	5541623	-	Dug	-	6.1	3.7	-	-
092K004212 17	4266	-	5541980	-	Dug	-	6.7	4.6	-	-
092K004214 11	4267	-	5543111	-	Dug	-	5.5	-	-	-
092K004214 24	4271	-	5543799	-	Dug	-	6.1	4.6	-	-
092K004212 9	4273	-	5542447	-	Dug	-	3.7	-	-	-
092K004214 1	4276	-	5542584	-	Dug	-	8.2	-	-	-
092K004212 10	4282	-	5542505	-	Dug	-	11.3	1.2	-	-
092K004212 7	4283	-	5541994	-	Dug	-	7.0	3.0	-	-
092K004212 21	4287	-	5541609	-	Dug	-	7.6	2.4	-	-
092K004212 5	4288	-	5541905	-	Dug	-	3.7	-	-	-
092K004212 15	4289	-	5541708	-	Dug	-	7.6	5.5	-	-
092K004214 2	4298	-	5542604	-	Dug	-	6.1	2.4	-	-
092K004212 22	4302	-	5541677	-	Dug	-	3.0	-	-	-
092K004212 3	4305	-	5541682	-	Dug	-	6.7	-	-	-
092K004232 1	4317	-	5544404	-	Dug	-	3.7	3.0	-	-
092K004212 13	4323	-	5541607	-	Dug	-	5.8	-	-	-
092K004212 18	4324	-	5542081	-	Dug	-	6.7	1.8	-	-
092K004214 7	4330	-	5542681	-	Dug	-	6.1	3.0	-	-
092K004232 2	4337	-	5543863	-	Dug	-	5.5	-	-	-
092K004214 21	4342	-	5543309	-	Dug	-	14.2	12.8	-	-
092K004214 6	4343	-	5542619	-	Dug	-	4.0	2.1	-	-
092K004214 23	4345	-	5543732	-	Dug	-	8.2	6.1	-	-
092K004214 5	4347	-	5542621	-	Dug	-	6.4	3.7	-	-
092K004214 16	4349	-	5543821	-	Dug	-	4.3	-	-	-
092K004214 9	4350	-	5542803	-	Dug	-	2.1	-	-	-
092K004212 24	4353	-	5541796	-	Dug	-	6.1	3.0	-	-
092K004212 1	4354	-	5541898	-	Dug	-	10.4	8.5	-	-
092K004212 20	4359	-	5542450	-	Dug	-	4.6	2.4	-	-
092K004212 2	4360	-	5541794	-	Dug	-	5.5	1.8	-	-
092K004212 8	4362	-	5542351	-	Dug	-	4.3	3.4	-	-
092K004231 4	4364	-	5544903	-	Dug	-	4.6	3.7	-	-
092K004214 10	4365	-	5543005	-	Dug	-	7.9	-	-	-
092K004212 12	4370	-	5541711	-	Dug	-	6.7	4.0	-	-
092K004231 2	4372	-	5544475	-	Dug	-	5.2	3.0	-	-
092K004212 11	4373	-	5542052	-	Dug	-	11.0	10.4	-	-
092K004231 3	4374	-	5545269	-	Dug	-	3.0	1.2	-	-
092K004214 3	4377	-	5542599	-	Dug	-	7.9	6.4	-	-
092K004214 4	4382	-	5542611	-	Dug	-	6.4	-	-	-
092K004212 6	4385	-	5541904	-	Dug	-	4.3	-	-	-
092K004214 17	4391	-	5542798	-	Dug	-	5.5	-	-	-
092K004212 19	4398	-	5542142	-	Dug	-	5.8	1.8	-	-

See notes on last page

TABLE II
INFORMATION ON WELLS

BCGS Well No.	WTN	UTM East	UTM North	Diameter	Construction Method	Construction Date	Depth To Well Bottom	Depth To Water	Depth To Bedrock	Well Yield
		m	m	mm			m	m	m	L/s
092K004212 14	4401	-	5541753	-	Dug	-	5.5	2.4	-	-
092K004214 19	4409	-	5543096	-	Dug	-	4.6	-	-	-
092K004212 4	4422	-	5541905	-	Dug	-	7.6	5.2	-	-
092K004212 26	4423	-	5541950	-	Dug	-	3.7	2.7	-	-
092K004214 20	4425	-	5543226	-	Dug	-	6.1	-	-	-
092K004212 23	4429	-	5541680	-	Ukn	-	-	-	-	-
092K004214 18	4431	-	5542878	-	Dug	-	4.9	3.7	-	-
092K004212 25	4437	-	5541955	-	Dug	-	4.3	-	-	-
092F094412 1	6963	337847	5536514	-	Drilled	-	25.9	1.2	25.9	-
092F094421 1	6971	340447	5536559	-	-	-	-	-	-	-
092F094421 2	6972	340564	5536638	-	-	-	-	-	-	-
092F094421 3	6973	339819	5536271	-	Drilled	-	28.0	3.0	28.0	-
092F094421 4	6974	340255	5536378	-	Drilled	-	19.5	-	19.5	-
092F094441 1	6987	340730	5538991	-	-	-	-	-	-	-
092F094442 1	6988	-	5538289	-	Dug	-	3.7	1.5	-	-
092F094442 2	6989	340525	5538946	-	-	-	-	-	-	-
092F094442 3	6990	-	5540862	-	-	-	-	-	-	-
092F094442 4	6991	340450	5539550	-	Dug	-	3.0	2.4	-	-
092F094442 5	6992	340529	5539291	-	-	-	-	-	-	-
092F094443 1	6993	340392	5539688	-	Dug	-	4.0	1.8	-	-
092F094443 2	6994	340200	5540397	-	-	-	-	-	-	-
092F094443 4	6995	340363	5539826	-	Dug	-	6.7	1.8	-	-
092F094443 5	6996	339943	5540607	-	-	-	-	-	-	-
092F094443 3	7101	340336	5539909	-	-	-	6.7	5.8	-	-
092K004212 27	14919	-	5542014	-	Drilled	01-Jan-57	35.1	5.5	5.2	3.0
092F094412 2	21060	337257	5535766	152	Drilled	24-Nov-67	20.4	3.0	-	6.1
092F094412 9	28575	-	5536057	-	Drilled	01-Aug-73	45.7	4.6	18.0	4.6
092F094412 8	39688	337182	5535741	102	Drilled	10-May-78	41.5	1.8	40.8	0.2
092F094412 7	39715	337223	5535700	152	Drilled	18-May-78	22.3	1.8	-	12
092F094412 6	42264	337284	5535693	127	Drilled	01-May-79	21.3	-	-	1.8
092F094412 3	44380	337198	5535714	-	Drilled	04-Feb-80	76.2	-	28.0	-
092F094412 4	44394	337226	5535747	-	Drilled	06-Feb-80	17.1	-	15.8	-
Minimum				102		01-Jan-57	2.1	1.2	5	0.2
Median				127		14-May-78	6.1	3.0	23	3.0
Average				132		05-May-74	11.2	3.6	23	4.2
Maximum				152		06-Feb-80	96	13	41	12

Notes:

1) See locations of wells on Fig. 2.
2) Well information from BC Ministry of Water Lands and Air Protection website
3) WTN = last five digits of Ministry well tag number.

See notes on last page

TABLE III

SUMMARY OF STREAM MEAN AND ANNUAL LOW FLOWS

Station ID	Name	Period	Category	Area Km2	MAD m^3/s	MSD m^3/s	MAD Flux $L/s/Km^2$	MSD Flux $L/s/Km^2$
08HDO05	Quinsam River near Campbell River	1956-1999	Regulated	280	8.60	3.15	30.7	11.3
08HD011	Oyster River below Woodhus Creek	1973-1999	Natural	298	14.20	9.10	47.7	30.5
08HDO12	Springer Creek near Sayward	1976-1980	Natural	-	0.55	0.25	-	-
08HDO14	Black Creek at Sturgess Road	1980-1989	Regulated	71.7	-	0.04	-	0.6
08HDO16	Hyacinthe Creek on Quadra Island	1990-1999	-	7.68	0.28	0.02	35.8	3.1
08HDO21	Quinsam River at Argonaut Bridge	1993-1999	-	-	2.01	1.32	-	-
08HD023	Little Oyster River at Yorke Road	1994-1999	-	-	-	0.08	-	-
08HBOOl	Qualicum River near Bowser	1913-1974	Regulated	148	7.30	2.96	49.3	20.0
08HBOl 1	Tsolum River near Courtney	1914-1999	Regulated	258	10.80	2.18	41.9	8.4
08HBO22	Nile Creek near Bowser	1959-1999	Regulated	15	1.03	0.27	68.7	17.8
08HB024	Tsable River near Fanny Bay	1960-1999	Natural	113	7.99	3.48	70.7	30.8
08HBO25	Browns River near Courtney	1960-1999	Natural	86	5.78	2.86	67.2	33.3
08HBO75	Dove Creek near the Mouth	1985-1999	Natural	41.1	1.93	0.34	47.0	8.3
R1	Nunns Creek near mouth	Aug-98	Natural	12.5		0.05		4.0
S1	Simms Creek at Mouth	Jul-01		12.5	0.300	0.047	24.0	3.8
S2	Simms Creek at Alder Street	Sep-01		10.8	0.259	0.023	24.0	2.1
S3	South branch of Simms, at Dogwood Street	Sep-01		4.7	0.113	0.001	24.0	0.2
S4	North branch of Simms, at Dogwood Street	Sep-01		2.2	0.053	0.003	24.1	1.4
W1	Willow Creek at Mouth	Sep-01		22.6	0.520	0.037	23.0	1.6
W2	Willow Creek at Home Street	Jul-01		21.0	0.493	0.042	23.5	2.0
W3	Willow Creek at Dogwood Street	Sep-01		19.3	0.444	0.037	23.0	1.9
W5	North branch of Willow Creek at Island Highway	Sep-01		4.3	0.099	0.011	23.0	2.6
W6	South branch of Willow Creek at Island Highway	Jul-01		10.8	0.248	0.022	23.0	2.0

Notes:

1) Data from Northwest Hydraulic Consultants, Apr. 2002, except for Nunns Creek data which was from Roth (1999).
2) See locations of Simms and Willow Creek stations on Fig. 1.
3) 08HB series of stations are Water Survey of Canada regional stations.
4) MAD = Mean Annual Discharge
   MSD = Mean Summer (June to September for WSC stations) and lowest recorded discharge in 2001 for the Simms and Willow sites.
5) Flux = flow per unit catchment area

TABLE IV

WILLOW CREEK PHYSIOCHEMICAL INFORMATION

Creek	Tributary	Reach	Map Label	pH unit	DO mg/L	TDS mg/L	Temp ^oC	Flow m^3/s
Willow	Main	1	M1	6.5	9.2	80	15.3	na
	Main	2	M2	6.5	9.2	74	15.7	3.86
	Main	3	M3	na	na	na	na	na
	Main	4	M4	7.0	9.8	67	14.5	0.64
	Main	5	M5	7.0	9.9	74	14.5	0.33
	Main	6	M6	8.0	10.1	74	13.8	0.45
	Main	7	M7	7.0	9.6	67	13.8	0.35
	Main	8	M8	7.0	1.7	67	14.0	0.4
	Main	9	M9	6.5	8.7	67	15.0	0.47
	Main	10	M10	7.1	9.7	46	13.7	0.2
	Main	11	M11	7.2	9.6	44	13.6	0.2
	Main	12	M12	7.2	10.2	39	11.2	2.6
	Main	13	M13	7.0	9.4	44	12.1	1.13
	Main	14	M14	7.0	9.3	33	12.6	0.12
	Main	15	M15	6.2	11.2	53	10.0	0.16
	Trib 1	1	TR	7.2	10	51	12.0	0.67
	Trib 2	1	TR1	7.0	8.9	126	7.0	0.04
	Trib 3	2	TR2	6.7	9.3	56	11.6	0.01
Larwood	Main	1	L1	7.0	8.4	107	16.9	0.31
	Main	2	L2	7.0	8.8	142	16.9	0.16
	Main	3	L3	7.0	8.3	162	15.0	0.08
	Main	4	L4	6.5	5.8	181	15.4	0.03
	Trib 1a	1	LT1	7.0	9.2	147	15.6	na
	Trib 1a	2	LT2	7.0	9.4	169	15.6	0.05
	Trib 1a	3	LT3	7.0	9.2	161	15.8	0.01
	Trib 1a	4	LT4	7.0	8.9	157	15.8	0.02
	Trib 1a	5	LT5	7.0	8.7	151	16.1	0.01
Beaver	Main	1	B1	6.5	8.4	48	12.7	na
	Main	2	B2	6.5	9.2	33	12.6	0.06
	Trib 1	1	BT1	6.6	7.8	52	11.4	na
	Trib 1	2	BT2	5.5	7.6	54	11.5	0.92
Newman	Main	1	N1	6.5	8.5	100	15.0	0.47
	Main	2	N2	6.5	9.2	105	14.5	0.63
	Main	3	N3	na	na	na	na	na
	Main	4	N4	6.5	9.6	34	12.5	na
	Main	5	N5	7.0	8.8	32	13.3	0.17
	Main	6	N6	na	na	na	na	na
	Main	7	N7	6.4	11.1	13	8.6	6.34 (3)
	Main	8	N8	6.2	9.9	11	8.2	8.42 (3)
	Trib 1	1	NT1	6.8	9.7	40	12.2	0.03
	Trib 1	2	NT2	6.3	8.2	37	11.9	0.02
	Trib 1	3	NT3	na	na	na	na	na
	Trib 1a	1		6.5	8.4	45	11.7	na
	Trib 1a	2		6.6	7.5	41	13.7	0.21

Notes:

1) See locations of the reaches on Fig. 2

2) Data was obtained from Roth 1998, and was recorded during September and October 1997.

3) Flow measured in Willow Creek Reaches 7 and 8 followed an intense rainfall event.

na = data is not available. Due primarily to lack of flowing water in the stream.

nd = no data available.

TABLE V

NUNNS CREEK PHYSIOCHEMICAL INFORMATION

Creek	Tributary	Reach	Map Label	pH unit	DO mg/L	TDS mg/L	Temp ^oC	Flow m^3/s
Nunns	Main	1	R1	6.7	6.5	116	17.0	0.05
	Main	2	R2	7.4	9.8	117	na	na
	Main	3	R3	7.5	9.8	128	na	0.03
	Main	4	R4	7.5	9.9	130	na	0.04
	Main	5	R5	7.5	9.9	na	na	0.16
	Main	6	R6	7.0	8.7	133	na	0.08
	Main	7	R7	6.9	8.7	114	na	na
	Main	8	R8	7.0	8.8	95	na	na
	Main	9	R9	6.5	8.3	na	na	na
	Trib. 2	1	TR1	7.3	10.3	128	na	0.01
	Trib. 2	2	TR2	6.7	9.2	na	na	na
	Trib. 3	1	T1	6.4	6.8	na	na	na
	Trib. 3	2	T2	6.9	8.9	na	na	na
	Trib. 3	3	T3	6.9	7.1	33	12.6	0.12
	Trib. 4	1		7.1	8.9	na	na	na
	Trib. 4	2		6.6	5.6	na	na	na
	Trib. 4	3		6.4	6.9	na	na	na
	Trib. 4	4		6.3	6.9	109	na	na
	Trib. 4a	1		6.7	6.4	na	na	na
	Trib. 4a	2		6.3	2	na	na	na

Notes:

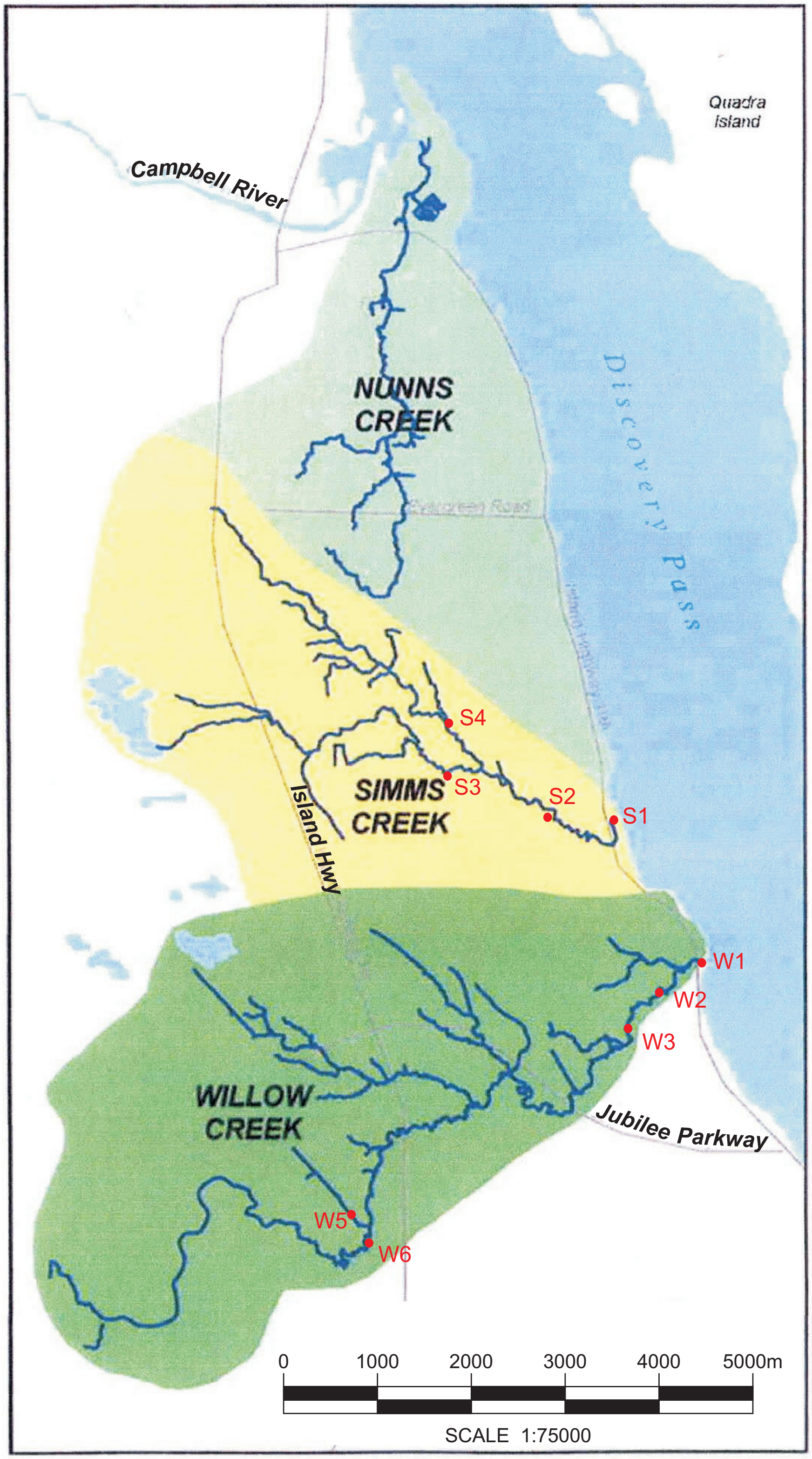
1) See locations of the reaches on Fig. 2

2) Data was obtained from Roth (1999), and was recorded during July and August 1998.

na = data is not available. Due primarily to lack of flowing water in the stream.

FIGURES

DWG. NUMBER: 2656-002.CDR



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		BY:	DATE:
ASSESSMENT OF GROUNDWATER ISSUES FOR SIMMS, WILLOW AND NUNNS CREEK ISMP CAMPBELL RIVER, B.C.	AREA LOCATION MAP	RAD/ss	MAY 05
		APPROVED:	FIG: 1

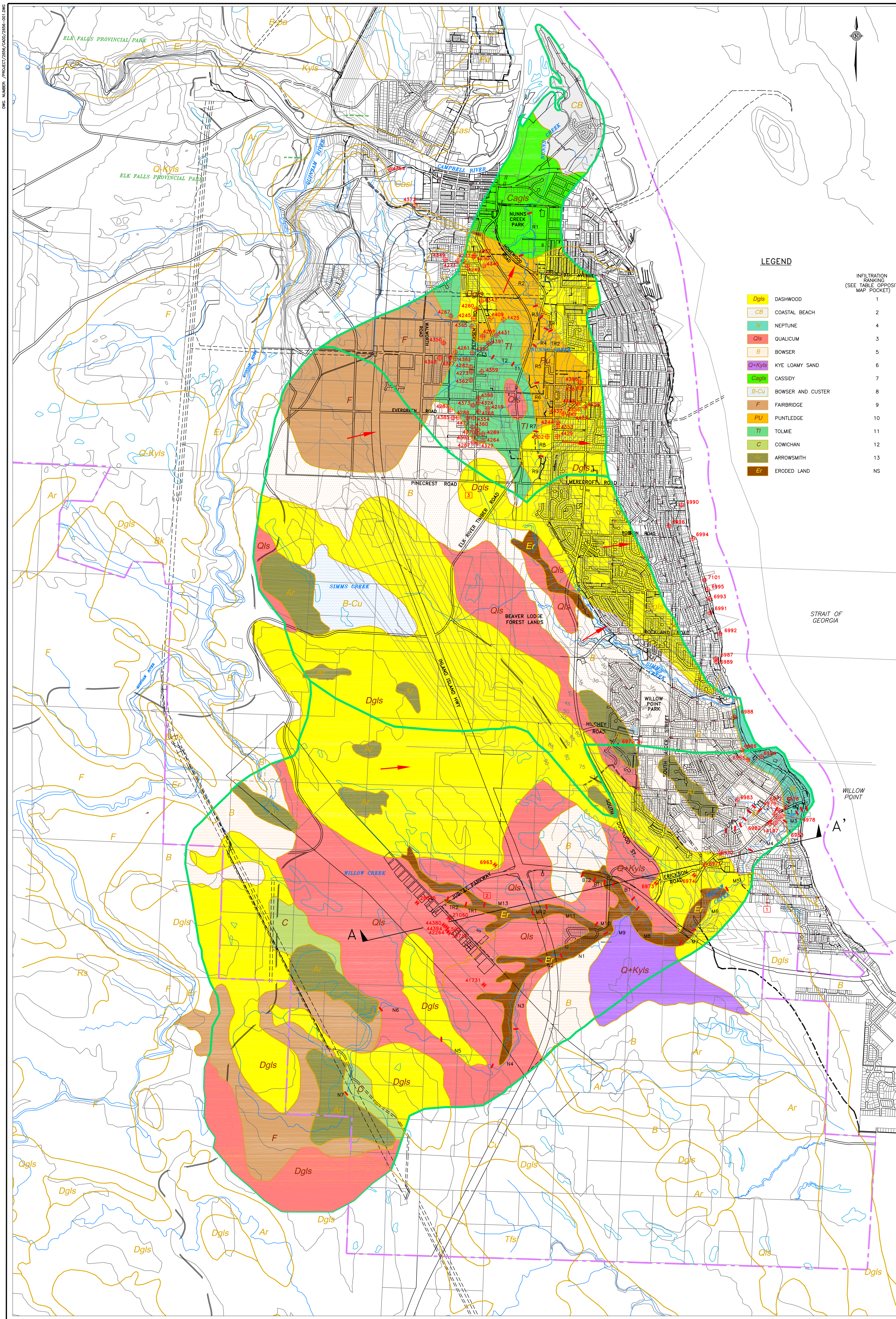
SOIL TYPES IN THREE CREEKS AREA

(table to accompany Fig. 2)

Soil Series	Symbol	Soil				Soil Depth		Infiltration	Infltration rate	
		Classification Group		Drainage	Texture[1]	Min (m)	Max (m)	Rating see note 5	Short term (mm/hr)	Long term (mm/hr)
Arrowsmith	Ar	Typic Mesisol Terric Mesisol	TY. M T.M	very poor	Mesic (organic)	1.00	> 3	13	1	0
Bowser	B	Brown Podzolic		imperfect	LS	0.61	0.91	5	40	8
Cadboro	Cd	Black		well	GLS	0.43	0.56	n	51	13
Cassidy	Ca	Alluvial		variable	SL	0.43	0.56	7	25	6
	Ca	Alluvial		variable	GLS				13	3
Chemanis	ChSal	Alluvial		well	GLS	0.43	0.56	n	51	13
	ChSil	Alluvial		variable	SiL				11	2
Coastal Beach	CB	Sand and Gravel		variable	S & G	0.25	> 2	2	500	250
Cowichan	C	Orthic Gleysol	O.G.	poor	SiL to SiCL	0.25	0.36	12	5	1
Custer	Cu	Podzol		imperfect	LS	0.23	0.33	8	40	4
Dashwood	Dgls	Brown Podzolic		well	GLS	0.64	0.77	1	500	250
Eroded land	Er			variable	variety	0.00	0.00	n	variable	
Fairbridge	F	Concretionary Brown		well	SiL to SiCL	0.43	0.56	9	10	3
Kye	Ky	Podzol		well	SL to LS	0.69	0.84	6	40	8
Neptune	N	Rendzina		well	GLS to SL	0.31	0.61	3	300	10
Puntledge	Pu	Concretionary Brown		moderate to well	fine LS	0.4	0.5	10	13	3
Qualicum	Qgls	Brown Podzolic	O.DYB.	well to rapid	SL to LS	0.91	1.12	4	40	10
	Qls	Brown Podzolic	O.HFP.							
Rough Montainous Land	Rm	Variety of rocks		variable	rocky	0.00	0.10		6	1
Rough Stony Land	Rs	Variety of rock materials		variable	rocky	0.00	0.10		6	1
Tolmie	Tl	Dark Grey Gleisolic		poor	L	0.5	0.6	11	4	1

Notes

1. Textures: C =clay; G = gravel, Si =silt; S =sand; LS = Loamy sand; SL = sandy loam; SiCL = silty clay loam, SiL = silt loam
2. Based on Day, Farstad and Liard, 1959.
3) See distribution of soils on Fig. 2 in map pocket opposite.
4) On Fig. 2, the soil type is often included in the symbol. For example: Cagls = Cassidy soil which is dominantly GLS or gravelly loamy sand.
5) The lowest infiltration rating number has the highest potential for sustained infiltration into the soil type located within the three drainage areas.



NOTES:

1. SEE AREA LOCATION ON FIG. 1
2. BASE MAP FROM URBAN SYSTEMS LTD.
3. WATER WELL DATA BASED ON BC MINISTRY OF WATER, LANDS AND AIR PROTECTION WEB SITE. SEE LIST OF INFORMATION ON WELLS IN APPENDIX A.
4. NUNNS CREEK SAMPLING REACHES ARE LABELLED IN THE MIDDLE OF EACH REACH WHICH IS LOCATED APPROXIMATELY.

LEGEND

- DUG WELL (WELL TAG NUMBER SHOWN)
- DRILLED WELL (WELL TAG NUMBER SHOWN)
- Ar — SOIL TYPE SEE LEGEND ON PAGE OPPOSITE THE FIGURE POCKET AND INFILTRATION RATING IN LEGEND AT MIDDLE RIGHT OF THIS FIGURE
- 10 — TOPOGRAPHIC CONTOUR m–asl (5m INTERVAL)
- A — A' HYDROGEOLOGICAL CROSS SECTION (ON FIG. 3)
- 3 — APPROXIMATE LOCATION OF OF PHOTO NO.3
- INTERPRETED DIRECTION OF DEEP (>6m) GROUNDWATER FLOW
- B7 — PHYSIOGRAPHIC STREAM MONITORING REACH IN WILLOW AND NUNNS CREEKS. (SEE TABLE IV & V RESPECTIVELY) SEE NOTE 4.

0 200 400 600 800 1000m

SCALE 1:20,000

URBAN SYSTEMS LTD.

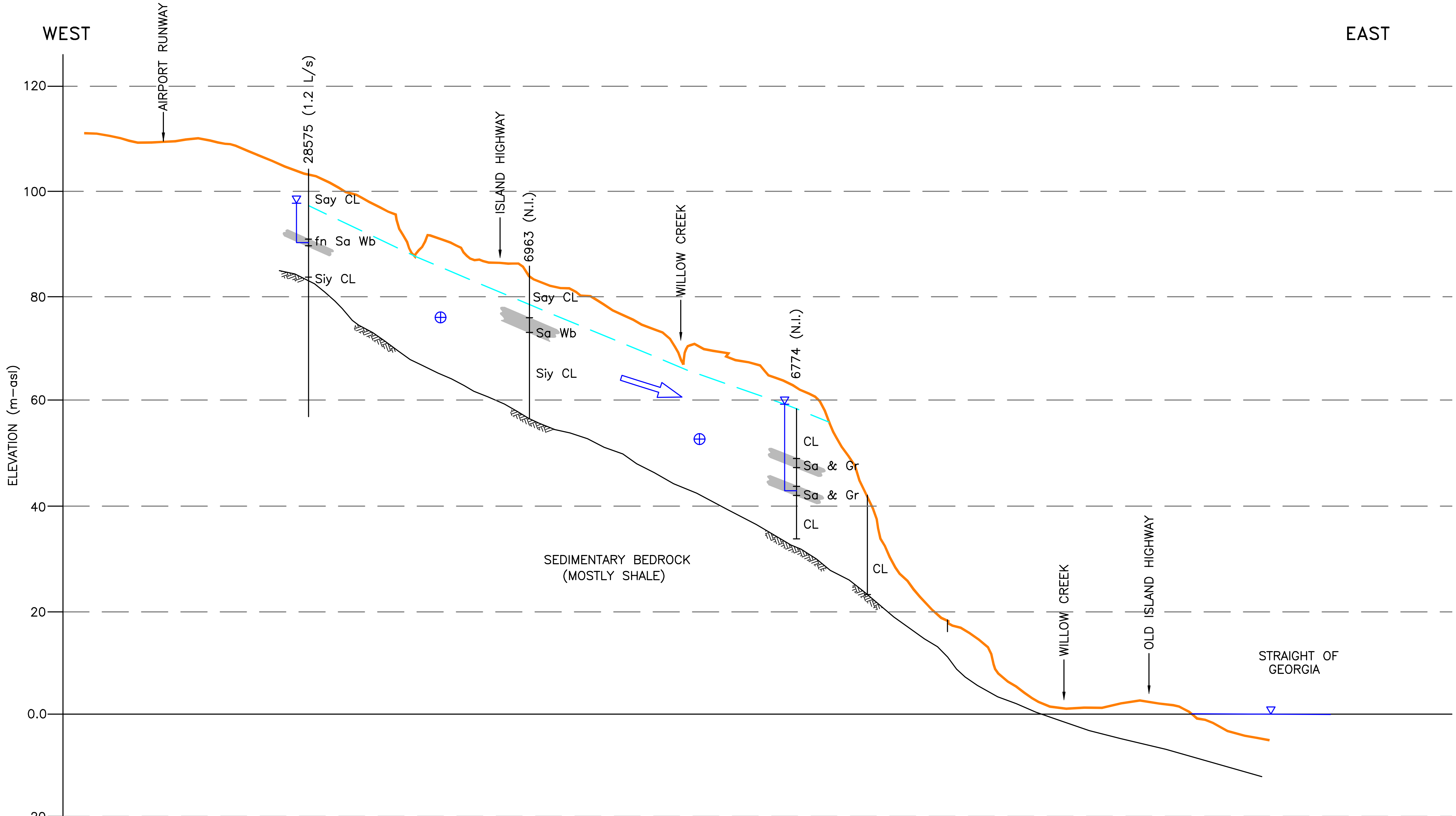
PITEAU ASSOCIATES
GEOTECHNICAL AND HYDROGEOLOGICAL CONSULTANTS
VANCOUVER LIMA

ASSESSMENT OF GROUNDWATER ISSUES FOR SIMMS, WILLOW AND NUNNS CREEK ISMP, CAMPBELL RIVER, B.C.

AREA MAP SHOWNING LOCATIONS OF WATER WELLS

BY:	DATE:
RAD/sl	MAY 05
APPROVED:	FIG: 2

DWG. NUMBER: /PROJECT/2656/CADD/2656-002.DWG



LEGEND

INFERRED GROUNDWATER FLOW RELATIVE TO THE PLANE OF THE SECTION:

- PARALLEL
- IN TO
- OUT OF
- PIEZOMETRIC HEAD IN PRICIPAL AQUIFER
- PIEZOMETER SCREEN, WITH INDICATED LENGTH OF SAND POCKET, AND PIEZOMETRIC LEVEL AND DATE

N.I. = NO INFORMATION ON WELL YIELD

NOTATION:

Siy = SILTY
Sa = SAND
Say = SANDY
Gr = GRAVEL
CL = CLAY
fn = FINE
Wb = WATER BEARING

0 200 400 600 800 1000m

HORIZONTAL SCALE 1:20,000
VERTICAL SCALE 1:800

NOTES:

1. SEE LOCATION OF HYDROGEOLOGICAL SECTION ON FIG. 2 AND APPENDIX A FOR MORE INFORMATION ON WELLS.

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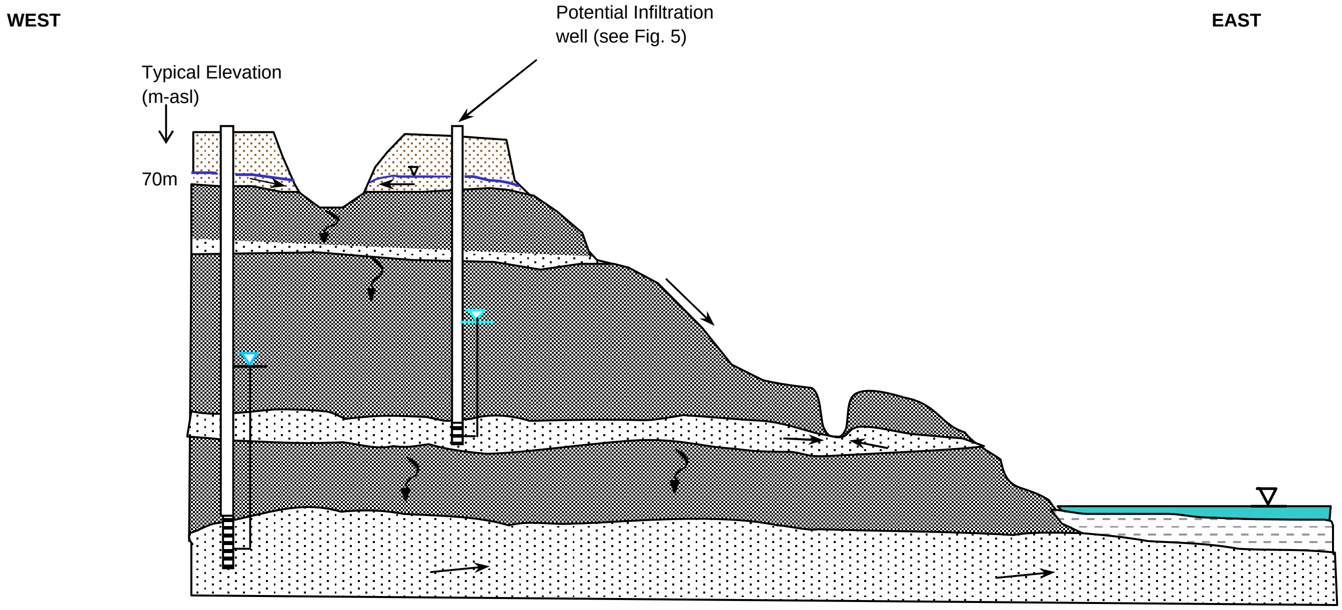
ASSESSMENT OF GROUNDWATER ISSUES FOR SIMMS, WILLOW AND NUNNS CREEK ISMP, CAMPBELL RIVER, B.C.

HYDROGEOLOGICAL SECTION A–A'

BY: RAD/sl
DATE: MAY 05
APPROVED:
FIG: 3

JOB NUMBER : 2656



LEGEND

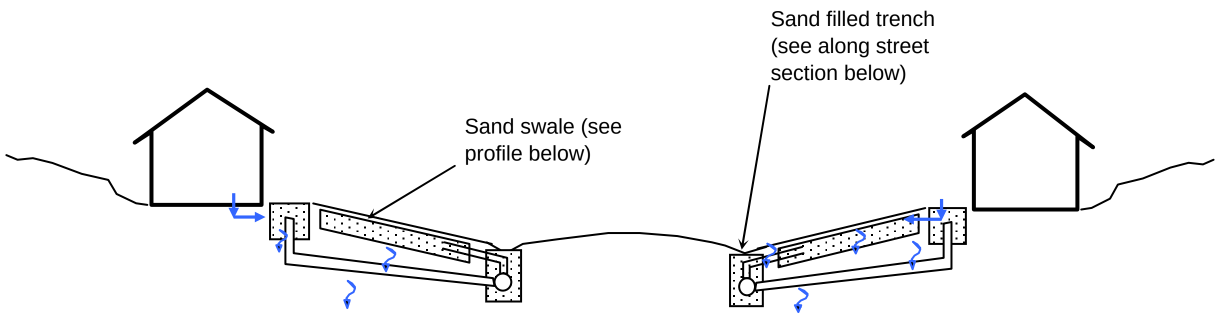
- Upper Units: alluvium, glacial outwash and weathered till
- Lower Silt-Clay Units
- Recent alluvial and marine sediments
- Potential deep sand aquifers
- Inferred groundwater flow parallel to the plane of the section
- Groundwater table or piezometric head
- Postulated unsaturated groundwater flow

NOT DRAWN TO SCALE

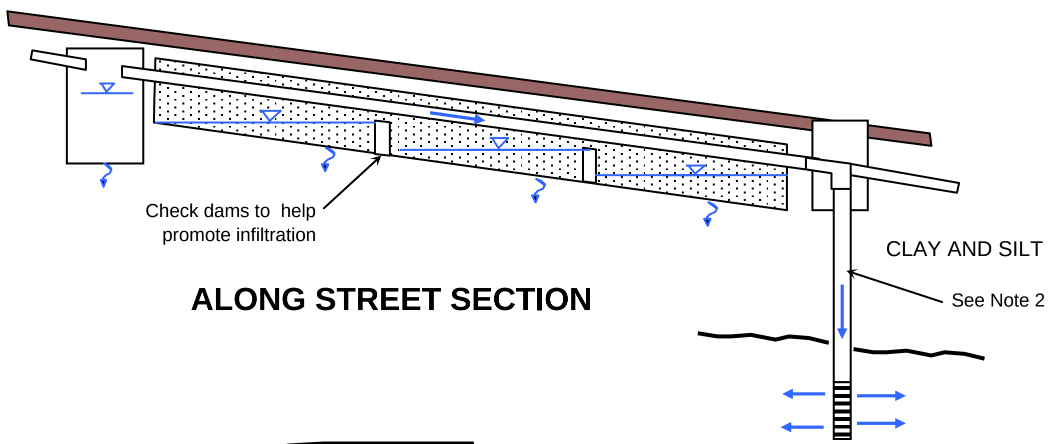
NOTES
1) This profile is based on information from outside the Nunns and Simms Creek areas and is presented for illustration purposes only.
2) There is no information on deep drilled holes in the Nunns and Simms Creek areas.

URBAN SYSTEMS LTD.	**PITEAU ASSOCIATES** HYDROGEOLOGICAL & GEOTECHNICAL CONSULTANTS VANCOUVER LIMA		
ASSESSMENT OF GROUNDWATER ISSUES FOR SIMMS, WILLOW AND NUNNS CREEK ISMP, CAMPBELL RIVER, B.C.	**SCHEMATIC PROFILE OF SEDIMENTS IN THE NUNNS AND SIMMS CREEK AREAS**	Drawn:	Date May. 2005
		Approved:	Fig. **4**

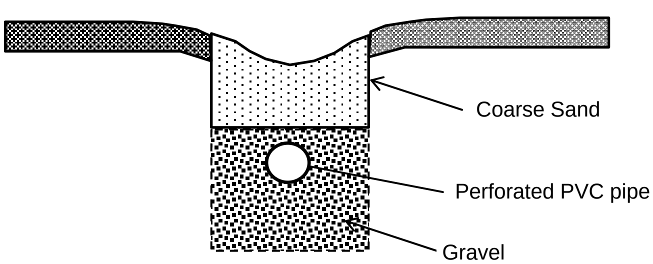
JOB NUMBER : 2656

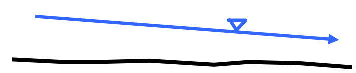


CROSS STREET SECTION



ALONG STREET SECTION





PROFILE THROUGH SAND SWALE

NOT DRAWN TO SCALE

NOTES
1) Not drawn to scale
2) See typical Willow Creek area deep sediment profile on Fig. 3.

URBAN SYSTEMS LTD.	**PITEAU ASSOCIATES** HYDROGEOLOGICAL & GEOTECHNICAL CONSULTANTS VANCOUVER LIMA

ASSESSMENT OF GROUNDWATER ISSUES FOR SIMMS, WILLOW AND NUNNS CREEK ISMP, CAMPBELL RIVER, B.C.	**SCHEMATIC SECTIONS OF SUBSURFACE STORM WATER INFILTRATION SYSTEMS**	Drawn:	Date May 2005
		Approved:	Fig. **5**

File:2449 2656_Figs Fig. 5 05/05/2005 10:04 AM

APPENDIX A

LOGS OF DEEP WELLS IN THE WILLOW CREEK AREA

BRITISH COLUMBIA

Well Tag Number 000000004349	Construction Date 19500101
Owner: HARRISON Address: Area: WELL LOCATION: SAYWARD Land District District Lot Plan Lot Township Section Range Indian Reserve Meridian Block Quarter Island BCGS Number (NAD 27) 092K004214 Well 16 Well Use Unknown Well Use Construction Method Dug Diameter 0.0 inches Well Depth 14.0 feet Elevation 0 Bedrock Depth UNK feet Screen from 0 to 0 feet Slot Size 1 0 Slot Size 2 0 Slot Size 3 0 Slot Size 4 0	Driller Unknown License Number PRODUCTION DATA AT TIME OF DRILLING: Well Yield 0 Artesian Flow 0 Static Level UNK feet Water Utility Lithology Info Flag Y Pump Test Info Flag File Info Flag Sieve Info Flag Screen Info Flag Water Chemistry Info Flag Field Chemistry Info Flag Site Info (SEAM) Other Info Flag

GENERAL REMARKS:

From 0 To 0 Ft. till

Date entered to WELL

BRITISH COLUMBIA

Report 1 - Detailed Well Record

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

Well Tag Number: 6963

Owner: WILLOW POINT WATER D

Address:

Area:

WELL LOCATION:
COMOX Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094412 Well: 1

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 0.0 inches
Well Depth: 85.0 feet
Elevation: 0
Bedrock Depth: 85 feet

Driller: PACIFIC WATER WELLS
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Artesian Flow:
Static Level: 4 feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:
ABANDONED

From 0 to 22 Ft. wet sandy clay
From 22 to 32 Ft. clean wet sand
From 32 to 85 Ft. clay and hardpan
From 0 to 85 Ft. shale

- Return to Main

Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 44380

Owner:

Address: AIRPORT

Area: CAMPBELL RIVER

WELL LOCATION:
COMOX Land District
District Lot: Plan: Lot:
Township: 1 Section: 18Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094412 Well: 3

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Unknown Constru
Diameter: 0.0 inches
Well Depth: 250.0 feet
Elevation: 0
Bedrock Depth: 92 feet

Construction Date: 1980-02-04 00:00:00.0

Driller: J.B. CASWELL DRILLING
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Artesian Flow:
Static Level: feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:
SOME IRON CONTENT (STAINED FIXTURES). GOOD TASTING, GOOD QUANTITY. DOMESTIC USE INDUSTRI/

From	0	to	8	Ft.	brown clay
From	8	to	17	Ft.	grey clay
From	17	to	36	Ft.	brown silty clay
From	36	to	44	Ft.	brown silty clay sand
From	44	to	69	Ft.	brown sand 10 % gray clay
From	69	to	92	Ft.	gray clay angular gravel 1 %
From	92	to	250	Ft.	sandstone

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6974

Owner: WILLOW POINT WATER D

Address:

Area:

WELL LOCATION:
COMOX Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094421 Well: 4

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 0.0 inches
Well Depth: 64.0 feet
Elevation: 0
Bedrock Depth: 64 feet

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

Driller: PACIFIC WATER WELLS
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 0 (Driller's Estimate)
Artesian Flow:
Static Level: feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:
ABANDONED

From 0 to 64 Ft. hardpan and thick clay
From 0 to 64 Ft. black shale

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 6973 Owner: WILLOW POINT WATER D Address: Area: WELL LOCATION: COMOX Land District District Lot: Plan: Lot: Township: Section: Range: Indian Reserve: Meridian: Block: Quarter: Island BCGS Number (NAD 27): 092F094421 Well: 3 Class of Well: Subclass of Well: Orientation of WEll: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 0.0 inches Well Depth: 92.0 feet Elevation: 0 Bedrock Depth: 92 feet	Construction Date: 1950-01-01 00:00:00.0 Driller: PACIFIC WATER WELLS Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Artesian Flow: Static Level: 10 feet Water Utility: Water Supply System Name: Water Supply System Well Name: Surface Seal Flag: Surface Seal Material: Surface Seal Method: Surface Seal Depth: Surface Seal Thickness: Lithology Info Flag: Pump Test Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Site Info Details: Other Info Flag: Other Info Details:

GENERAL REMARKS:
ABANDONED

From	0	to	44	Ft.	clay and hardpan
From	44	to	48	Ft.	fairly tight sand and gravel (w.b.)
From	48	to	61	Ft.	hardpan
From	61	to	66	Ft.	sand and fine gravel (some water)
From	66	to	92	Ft.	hardpan and clay
From	92	to	0	Ft.	black shale

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 21060

Owner: D O T

Address: AIRPORT

Area: CAMPBELL RIVER

WELL LOCATION:
COMOX Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094412 Well: 2

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Well Depth: 67.0 feet
Elevation: 0
Bedrock Depth: UNK feet

Construction Date: 1967-11-24 00:00:00.0

Driller: PACIFIC WATER WELLS
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 20 (Driller's Estimate) Gallons
Artesian Flow:
Static Level: 10 feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:

From 0 to 1 Ft. topsoil
From 1 to 4 Ft. tight sand
From 4 to 7 Ft. sandy grey clay
From 7 to 9 Ft. sandy blue clay
From 9 to 21 Ft. blue clay
From 21 to 30 Ft. fine silty sand
From 30 to 31 Ft. tight fine sand
From 31 to 40 Ft. compact silt
From 40 to 43 Ft. silty fine sand, layered silt hard
From 43 to 49 Ft. very fine w.b. sand
From 49 to 67 Ft. fine w.b. sand

- Return to Main

Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 28575

Owner: BC FOREST SERVICE

Address: CAMPBELL RIVER AIRPORT

Area:

WELL LOCATION:
SAYWARD Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094412 Well: 9

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Unknown Constru
Diameter: 0.0 inches
Well Depth: 150.0 feet
Elevation: 0
Bedrock Depth: 59 feet

Construction Date: 1973-08-01 00:00:00.0

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

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 15 (Driller's Estimate) Gallons
Artesian Flow:
Static Level: 15 feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag: Y
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:
ABANDONED WELL.

From	0	to	2	Ft.	brown topsoil and roots
From	2	to	8	Ft.	brown sandy clay
From	8	to	40	Ft.	brown sandy clay
From	40	to	45	Ft.	fine brown sand (w.b.)
From	45	to	58	Ft.	sandy blue clay (w.b.)
From	58	to	59	Ft.	stoney blue clay
From	59	to	64	Ft.	rock (shale)
From	64	to	90	Ft.	shale
From	90	to	95	Ft.	shale (2 GPM)
From	95	to	150	Ft.	hard and soft layers of shale
From	0	to	0	Ft.	null
From	0	to	0	Ft.	Pulled screen and drilled into shale to
From	0	to	0	Ft.	150 ft.Pulled casing back to 45 ft. Set
From	0	to	0	Ft.	screen. Too much clay mixed in sand.
From	0	to	0	Ft.	Pull out casing, fill hole

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Construction Date: 1978-05-10 00:00:00.0

Well Tag Number: 39688

Owner: SUPERIOR FLIGHT LTD

Address: AIRPORT

Area: CAMPBELL RIVER

WELL LOCATION:
COMOX Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094412 Well: 8

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 4.0 inches
Well Depth: 136.0 feet
Elevation: 0
Bedrock Depth: 134 feet

Driller: J.B. CASWELL DRILLING
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: .5 (Driller's Estimate) Gallons
Artesian Flow:
Static Level: 6 feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:

From 0 to 9 Ft. gravel and clay till
From 9 to 122 Ft. till - mainly gray clay with rubble rock
From 0 to 0 Ft. and boulders
From 122 to 134 Ft. sand - fine
From 134 to 136 Ft. shale

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Construction Date: 1978-05-18 00:00:00.0

Well Tag Number: 39715

Owner: SUPERIOR FLIGHT LTD

Address: AIRPORT

Area: CAMPBELL RIVER

WELL LOCATION:
COMOX Land District
District Lot: Plan: Lot:
Township: Section: Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094412 Well: 7

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 6.0 inches
Well Depth: 73.0 feet
Elevation: 0
Bedrock Depth: UNK feet

Driller: J.B. CASWELL DRILLING
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 40 (Driller's Estimate) Gallons
Artesian Flow:
Static Level: 6 feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:

From	0	to	1	Ft.	topsoil
From	1	to	9	Ft.	gravel clay till (brown clay)
From	9	to	27	Ft.	till - gray clay rubble rock
From	27	to	49	Ft.	sand - coarse dry
From	49	to	73	Ft.	sand coarse wet 40 GPM

- Return to Main

Information Disclaimer

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 42264

Owner: CAMPBELL RIVER MUN

Address: MUNICIPAL AIRPORT

Area: CAMPBELL RIVER

WELL LOCATION:
COMOX Land District
District Lot: Plan: Lot:
Township: 1 Section: 18Range:
Indian Reserve: Meridian: Block:
Quarter:
Island
BCGS Number (NAD 27): 092F094412 Well: 6

Class of Well:
Subclass of Well:
Orientation of WEll:
Status of Well: New
Well Use: Unknown Well Use
Observation Well Number:
Observation Well Status:
Construction Method: Drilled
Diameter: 5.0 inches
Well Depth: 70.0 feet
Elevation: 0
Bedrock Depth: UNK feet

Construction Date: 1979-05-01 00:00:00.0

Driller: J.B. CASWELL DRILLING
Well Identification Plate Number:
Plate Attached By:
Where Plate Attached:

PRODUCTION DATA AT TIME OF DRILLING:
Well Yield: 6 (Driller's Estimate) Gallons
Artesian Flow:
Static Level: feet

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

Surface Seal Flag:
Surface Seal Material:
Surface Seal Method:
Surface Seal Depth:
Surface Seal Thickness:

Lithology Info Flag:
Pump Test Info Flag:
File Info Flag:
Sieve Info Flag:
Screen Info Flag:
Water Chemistry Info Flag:
Field Chemistry Info Flag:
Site Info (SEAM):
Site Info Details:
Other Info Flag:
Other Info Details:

GENERAL REMARKS:
SUFFICIENT QUANTITY FOR WASHING PLANES.

From	0	to	14	Ft.	sandy brown clay
From	0	to	0	Ft.	60 - 80 % clay
From	14	to	41	Ft.	grey clay
From	41	to	61	Ft.	sand with 10 % brown clay
From	61	to	69	Ft.	sand - fine gravel 6 - 8 GPM
From	69	to	70	Ft.	grey clay
From	0	to	0	Ft.	null

- Return to Main

BRITISH COLUMBIA

Report 1 - Detailed Well Record

Well Tag Number: 44394 Owner: Address: AIRPORT Area: CAMPBELL RIVER WELL LOCATION: COMOX Land District District Lot: Plan: Lot: Township: 1 Section: 18Range: Indian Reserve: Meridian: Block: Quarter: Island BCGS Number (NAD 27): 092F094412 Well: 4 Class of Well: Subclass of Well: Orientation of WEll: Status of Well: New Well Use: Unknown Well Use Observation Well Number: Observation Well Status: Construction Method: Drilled Diameter: 0.0 inches Well Depth: 56.0 feet Elevation: 0 Bedrock Depth: 52 feet	Construction Date: 1980-02-06 00:00:00.0 Driller: J.B. CASWELL DRILLING Well Identification Plate Number: Plate Attached By: Where Plate Attached: PRODUCTION DATA AT TIME OF DRILLING: Well Yield: 0 (Driller's Estimate) Artesian Flow: Static Level: feet Water Utility: Water Supply System Name: Water Supply System Well Name: Surface Seal Flag: Surface Seal Material: Surface Seal Method: Surface Seal Depth: Surface Seal Thickness: Lithology Info Flag: Pump Test Info Flag: File Info Flag: Sieve Info Flag: Screen Info Flag: Water Chemistry Info Flag: Field Chemistry Info Flag: Site Info (SEAM): Site Info Details: Other Info Flag: Other Info Details:

GENERAL REMARKS:
SOME IRON CONTENT. DOMESTIC USE, GOOD QUANTITY.

From	0	to	12	Ft.	brown clay
From	12	to	45	Ft.	fine sand 1 % silty clay
From	45	to	52	Ft.	fine sand 80 % clay a. gravel
From	52	to	56	Ft.	bedrock (sandstone)

- Return to Main

Information Disclaimer

APPENDIX B

BACKGROUND INFORMATION ON SURFACE WATER INFILTRATION SYSTEMS IN CANADA

APPENDIX B

STORMWATER GROUND INFILTRATION SYSTEMS

B.1 General Comments

Infiltration systems include a wide range of devices that are designed to redirect surface water runoff into the ground. They can range from a simple splash pad with a pod of gravel handling roof runoff, to a complex system of buried sumps and perforated pipes handling runoff from a large area. Ideally, a watershed will have as many evenly distributed small systems as is possible, in order to try and emulate the pre-development conditions at the site. The systems must be carefully designed to discharge water at a rate that the ground can accept, and have appropriate pre-treatment, so that it can operate over at least several 10's of years and to protect groundwater quality.

Upland infiltration devices (such as infiltration trenches, porous pavements, percolation ponds, and grass roadside drainage swales) are located at urban source areas. Infiltration (percolation) ponds are usually located at stormwater outfalls, or at large paved areas. These ponds, along with perforated storm sewerage, can infiltrate flows and pollutants from all upland sources combined.

B.2 Experience in Ontario

The Ontario Ministry of the Environment (1999) encourages the use of infiltration systems in its Stormwater Management Planning and Design manual. However, they do raise a concern about contamination from salt applied to the municipal streets. Pages 3 to 17 of this document set out their recommendations, including:

- If the infiltration system is to be a stand-alone system, then design for reduced infiltration, relative to clean water infiltration (i.e., over-size the facilities) will be considered.
- Install enhanced pre-treatment (more than one pre-treatment device in series) in all infiltration facilities receiving runoff from roads.

- Pre-treatment can be provided by a combination of grass swales, filter strips or grit/oil separators. A pre-treatment volume of 15 mm/pervious hectare is recommended.

In Ontario, guidelines promote the use of infiltration drainage following a treatment train approach. If the ground is suitably permeable, roof drainage is disposed of to soak-a-ways. The next options to be considered are conveyance controls, such as swales, followed by end of pipe controls, such as infiltration trenches, basins and wetlands.

As part of the Great Lakes cleanup program, J.F. Sabourin and Associates (1999) conducted an assessment of roadside ditches and other storm management practices in Toronto, and concluded that grass swale infiltration systems with perforated pipes and infiltration trenches, were capable of retaining and infiltrating the runoff from a 25mm storm. The capital and maintenance cost of this type of system was estimated to be 28% less than a conventional curb and gutter system, and also had far less impact on the local water quality.

Some twenty infiltration basins were constructed in the 1970's in Guelph, Ontario. These are now believed to have sealed and become wetlands, indicating the need for some form of pre-treatment to remove fine material from the water entering the infiltration system. Recent experience with other types of infiltration systems has proved more successful.

In 1993, an experimental 2.1 km section of a perforated storm pipe infiltration system was installed in the City of Etobicoke. It was designed to minimize the runoff and at the same time recharge the local aquifer (A.M. Candras Associates, 1997). This system has demonstrated that stormwater into moderately low permeability sediments is feasible and beneficial.

B.3 Experience in British Columbia

Stormwater infiltration systems have been used in many areas of British Columbia, either as a designed system or as a consequence of water seeping from surface ditches and buried pipe networks. The Provincial Runoff Quality Control Guidelines (BC Environment, 1992) state that (Section 7.2.3) “Groundwater recharge, which has been lost due to increase in impervious area caused by development, is enhanced by BMPs which are designed to promote infiltration of collected runoff”.

The Township of Langley has developed a system of perforated pipes connected to manholes that has performed satisfactorily since about 1987. This urban area, located over the Brookswood Aquifer, consists of very permeable sand and gravel and is capable of accepting a relatively high rate of stormwater infiltration. Field testing and back analysis of a portion of a section of one of these perforated pipes was carried out by Piteau in 2000. These hydraulic analyses have shown that the perforated infiltration pipe system could accept an average flow rate of 0.2 L/s per metre length of pipe, from a 1: 5 year design storm event (Piteau, 2001). Higher short term (less than one hour) rates were also possible. There was no evidence of any significant reduction of the infiltration capacity, due to a silt build up at the pipe – soil interface. The District of Chilliwack has been relying on a network of over 200 soak-away well systems for stormwater infiltration into the Vedder Aquifer for at least 15 years. These systems are designed for a 28.3 L/s (1 cfs) discharge and consist of a 1.2m diameter concrete settling chamber, a 1.2m diameter concrete filter chamber and a 0.6m diameter steel infiltration well (see details on Fig. E1). According to one of the District's representatives (pers. com. W. Moseanko, Oct. 2000), they clean out the chambers at least twice a year and have only had a problem with one well, which was located in a high water table area.

A settlement pond system with vertical wells has been successfully used in the Vedder area of Chilliwack (Piteau, 1989). Subsequent monitoring of their down-gradient production wells has not shown any evidence of contamination from this infiltration system (Carmichael, et. al. 1995).

PHOTOS

Photo 1.
Excavated gravelly loamy sand unit (Dashwood soil) on Twillingate Road, south of Willow Creek.
(December 7th, 2004)

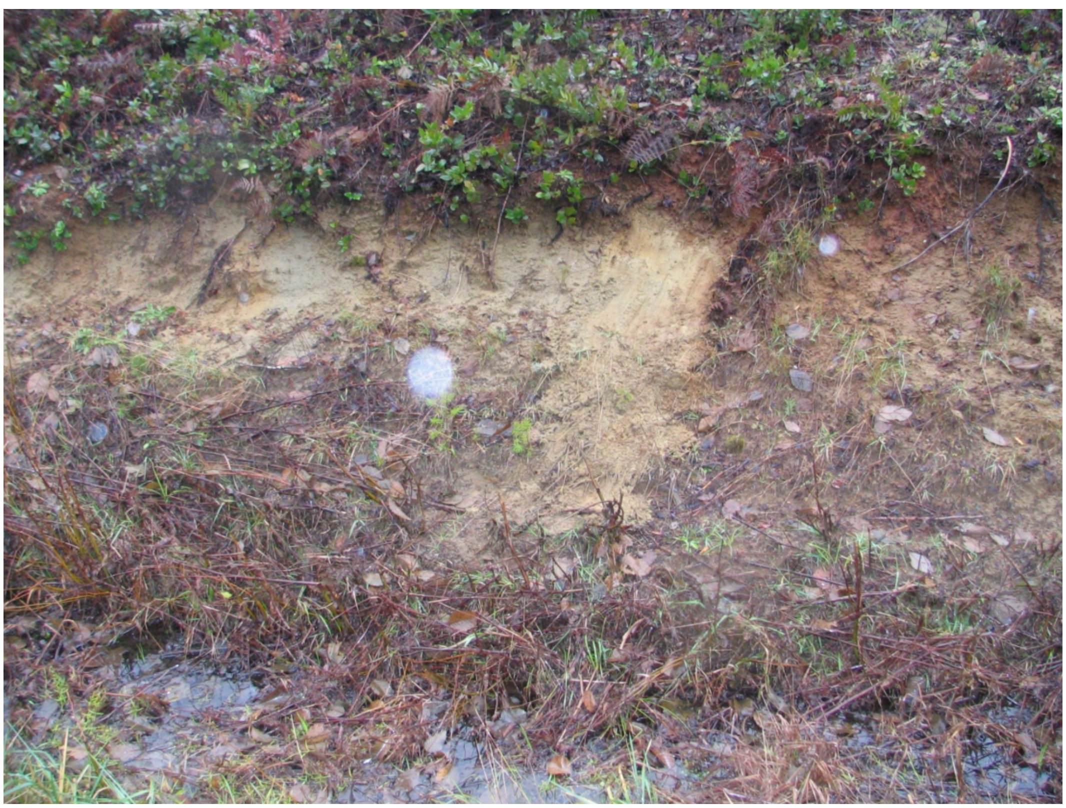


Photo 2.
Exposed Quadra sand unit on road cut near the Campbell River Airport.
(December 7th, 2004)

Photo 3.
Exposed Bowser loamy silt soils exposed in drainage ditch located near the Nunns - Simms Creek drainage boundary (see location on Fig.2)
(December 7th, 2004)

APPENDIX D

HYDROLOGIC / HYDRAULIC MODELING
INPUT AND RESULTS

(Electronic Version on CD-ROM only)

APPENDIX E

STAKEHOLDERS WORKING GROUP MATERIALS

(Electronic Version on CD-ROM only)

APPENDIX F

PUBLIC OPEN HOUSE

PRESENTATION MATERIALS AND FEEDBACK

(Electronic Version on CD-ROM only)

APPENDIX G

ADDITIONAL CORRESPONDENCE FROM RESIDENTS

Jeff Rice

From: Michael Roth [michael.roth@dcr.ca]

Sent: Monday, December 06, 2004 11:15 AM

To: Jeff Rice

Subject: Meeting with Von Poser - notes

Hi Jeff, I met with the Von Poser's this morning (501 Trask Road) - Simms/Nunns Watersheds

The concerns expressed are specific to off-site runoff that is being directed onto their property from the:

1. Beaver Lodge Lands (from the west), apparently MoF redirected runoff from a pond/wetland which may have caused problems. MoF did the work at least 8-10 years ago and it sounds like there is some history here;
2. New subdivision development to the east (900 Cortez Rd, Highland Eng is the lead consultant). Runoff that used to move east from the Von Poser's is now contained on site - due to additional fill material placed on 900 Cortez;
3. Existing ditch capacity along Trask Road. The ditch is undersized and causes flooding. Our Public Works dept. looked at this last month, at the request of the Von Poser's, and are considering maintenance works for the spring of 2005 to redirect runoff from the parking area on the west side of Trask rd into the ditch that feeds into Nunns Ck, and
4. The Von Poser's have a paddock on the south side of the property (rear), they loose top soil each year, stability issues and vegetative cover may be a concern that is not helped by its current use.

I am not sure if resolving any one issue will solve the problems, or if this is a 'headwater' property (actually two headwaters) that may always be subject to high water table issues. You may wish to discuss this property and related runoff that comes from the area of the Beaver Lodge Lands with MoF.

I advised the Von Poser's that the ISMP's are not intended to be site specific, that the solutions and recommendations will be based on overall objectives for each watershed. One for your consideration.

thanks,

Michael Roth, CTech
Environmental Coordinator
District of Campbell River
301 St. Ann's Road
Campbell River, BC V9W 4C7

Ph. (250) 286-5711
Fx. (250) 286-5762
Web: www.dcr.ca

APPENDIX H

CAMPBELL RIVER DRAINAGE COMPLAINT SUMMARY

(2000 – 2004)

(Electronic Version on CD-ROM only)

APPENDIX I

COST ESTIMATES

City of Campbell River
Nunns Creek Integrated Stormwater Management Plan (ISMP)

CAPITAL COSTS

Pipe Size (mm dia)	$/lin.m.[1]
300	$180
375	$230
450	$285
525	$340
600	$391
675	$440
750	$490
900	$590
1050	$690
1200	$800
1350	$900
1500	$1,000

Manholes (mm dia)	$/each	$/metre[2]
1050	$2,500	$20
1200	$3,500	$25
1350	$5,000	$35
1500	$6,000	$40
1800	$7,250	$50

Detention Ponds	250	$/cu.m. storage volume
Riparian Planting	25	$/sq.m.
Road Removal / Restoration	40	$/sq.m.

[1] Price includes installation and imported bedding / backfill.
[2] Assumes 155 metre spacing between manholes.

Other Unit Costs

Catch basins	$/each
Top inlet catch basin	1,700

Service Connections	$/lin.m.
100	100
150	115
200	130

Inspection Chambers	500	ea	
Rip Rap	35	$/cu.m.	
Oil Interceptor	25,000	$/each	
Disonnection of Roof Leaders	500	$/lot	
Swales	20	$/ lin.m.	
Swales with Perforated Pipe	120	$/lin.m.	
Ditch Excavation	70	$/lin.m.	
Wetland Vegetation	45	$/sq.m.	
Check Dams	250	$/ea	
Rock Liners	80	$/lin.m.	
Porous Pavement	60	$/sq.m.	
LWD's	150	$/each	
Gravel / cobble substrate	80	$/sq.m.	
Bioengineered slope stabilization :			
Live reinforced earth walls	150	$/lin.m	
Wattle fences	90	$/lin.m	
Live stakes (e.g. whips)	5	$/sq.m.	based on 1 m spacing

O & M COSTS

Detention Ponds	4	% of Capital Cost
Pipes / Manholes	1	% of Capital Cost
Water Quality Structures	4	% of Capital Cost
Environmental / Fisheries	5	% of Capital Cost

Present Worth of O&M Costs:

$$PW = \frac{1-(1+i)^{-n}}{i}$$

where i = 5.50%
n = 30 years

City of Campbell River
Nunns Creek Integrated Stormwater Management Plan (ISMP)
Class D Construction Cost Estimate

Municipal Storm Sewer Upgrades to Service Existing Development

Model ID	Proposed Pipe Size (mm dia.)	Pipe Cost ($/m)	Length (m)	Capital Cost ($) [1]	O&M Cost ($/yr)	Present Worth of O&M Cost ($)
1754	1050	690	87	$ 75,760.00	$ 800.00	$ 11,700.00
1755	1050	690	186	$ 161,880.00	$ 1,700.00	$ 24,800.00
1756	1050	690	150	$ 130,500.00	$ 1,400.00	$ 20,400.00
1567	900	590	87	$ 67,060.00	$ 700.00	$ 10,200.00
1566	1050	690	111	$ 96,580.00	$ 1,000.00	$ 14,600.00
1557	900	590	33	$ 25,440.00	$ 300.00	$ 4,400.00
210	600	391	21	$ 12,080.00	$ 200.00	$ 3,000.00
1553	600	391	65	$ 37,200.00	$ 400.00	$ 5,900.00
1947	600	391	12	$ 6,860.00	$ 100.00	$ 1,500.00
1549	600	391	47	$ 26,860.00	$ 300.00	$ 4,400.00
1548	600	391	46	$ 26,280.00	$ 300.00	$ 4,400.00
1547	600	391	102	$ 58,260.00	$ 600.00	$ 8,800.00
1546	600	391	109	$ 62,320.00	$ 700.00	$ 10,200.00
202	450	285	123	$ 57,240.00	$ 600.00	$ 8,800.00
1283	600	391	150	$ 85,700.00	$ 900.00	$ 13,100.00
1282	600	391	150	$ 85,700.00	$ 900.00	$ 13,100.00
217	450	285	56	$ 26,080.00	$ 300.00	$ 4,400.00
215	450	285	36	$ 16,780.00	$ 200.00	$ 3,000.00
192	600	391	10	$ 5,800.00	$ 100.00	$ 1,500.00
1561	450	285	69	$ 32,120.00	$ 400.00	$ 5,900.00
			Total	$ 1,096,500.00	$ 11,900.00	$ 174,100.00
			+35% Contingency	$ 383,800.00	$ 4,200.00	$ 61,000.00
			+15% Engineering	$ 164,500.00		
			Total (Capital)	$ 1,644,800.00	$ 16,100.00	$ 235,100.00
					Grand Total (Capital + O&M)	**$ 1,879,900.00**

[1] Capital cost assumes road removal and restoration for top of trench width (width based on 1.5 m cover on sewer and 1.5:1 excavated side slopes on trench).

City of Campbell River
Nunns Creek Integrated Stormwater Management Plan (ISMP)
Class D Construction Cost Estimate

Detention Ponds to Service Future Development

Development ID	Location	Storage Volume (m^3)	Perimeter (m)[1]	Capital Cost ($)[2]	O&M Cost ($/yr)	Present Worth of O&M Cost ($)
4/5	Old Petersen Road	4,100	170	$ 1,037,750.00	$ 41,600.00	$ 604,700.00
8	Willis Road / Inland Highway	440	60	$ 114,500.00	$ 4,600.00	$ 66,900.00
9	Evergreen Road / Inland Highway	1,500	100	$ 382,500.00	$ 15,300.00	$ 222,400.00
2nd Ave	2nd Ave / Nunns Creek	2,300	130	$ 584,750.00	$ 23,400.00	$ 340,100.00
4th Ave	4th Ave / Nunns Creek	2,400	130	$ 609,750.00	$ 24,400.00	$ 354,700.00
			Total	$ 2,729,250.00	$ 109,300.00	$ 1,588,800.00
			+35% Contingency	$ 955,300.00	$ 38,300.00	$ 556,100.00
			+15% Engineering	$ 409,400.00		
			Total (Capital)	$ 4,093,950.00	$ 147,600.00	$ 2,144,900.00
					Grand Total (Capital + O&M)	**$ 6,238,850.00**

[1] Perimeter calculation assumes a square pond at 2.5m depth.
[2] Capital cost assumes a 3 metre wide riparian planting buffer around perimeter of pond.

City of Campbell River
Nunns Creek Integrated Stormwater Management Plan (ISMP)
Class D Construction Cost Estimate

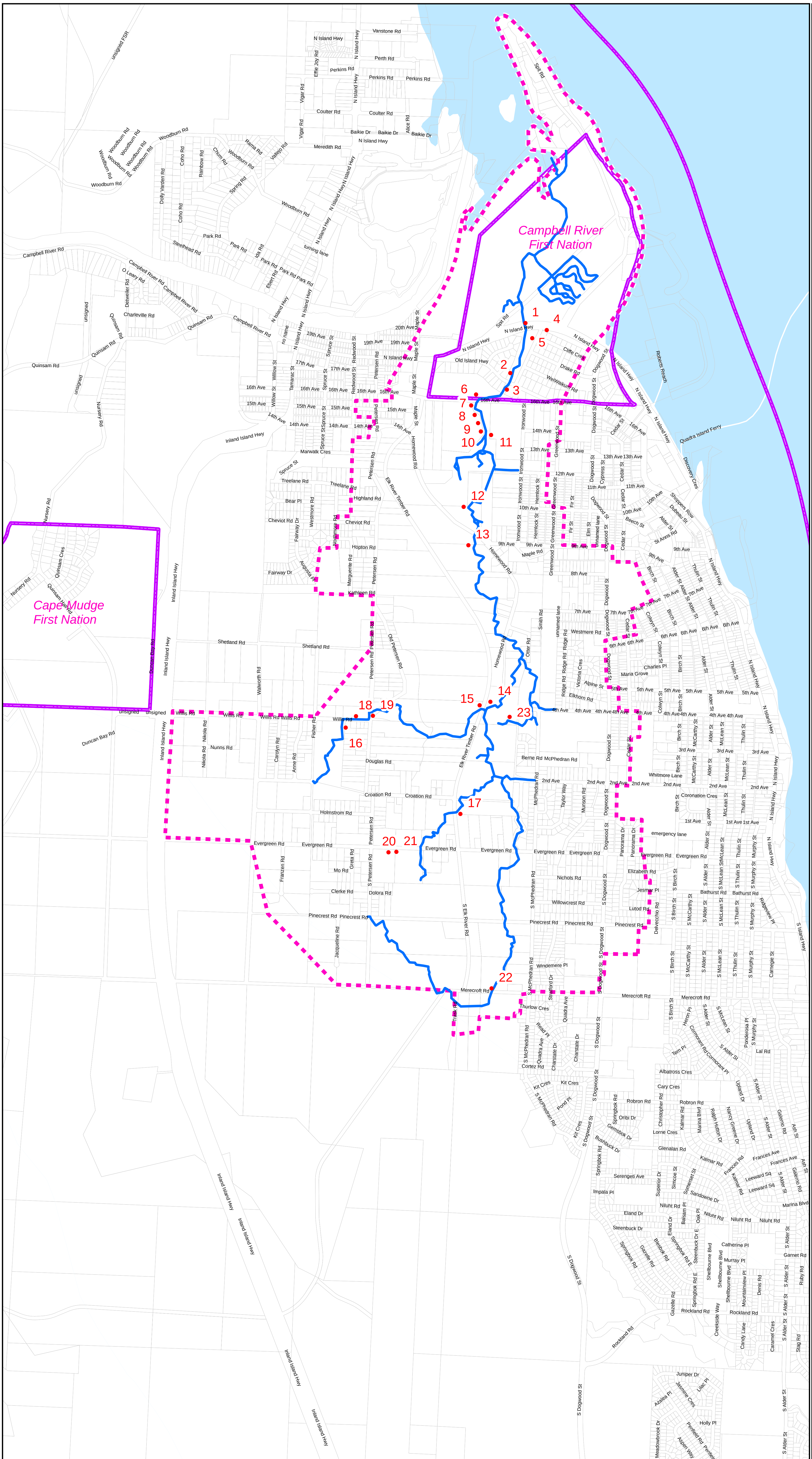
Trunk Storm Sewer to Service Future Development

Proposed Pipe Size (mm dia.)	Approximate Alignment	Length (m)	Capital Cost ($)[1]	O&M Cost ($/yr)	Present Worth of O&M Cost ($)
600	ERT Rd to Campbell River	2,200	$ 1,311,200.00	$ 13,200.00	$ 191,900.00
600	Willis Road to Nunns Creek West Arm	950	$ 566,200.00	$ 5,700.00	$ 82,900.00
600	Evergreen Rd to Nunns Creek SW Arm	1,400	$ 834,400.00	$ 8,400.00	$ 122,100.00
		Total	$ 2,711,800.00	$ 27,300.00	$ 396,900.00
		+35% Contingency	$ 949,200.00	$ 9,600.00	$ 139,000.00
		+15% Engineering	$ 406,800.00		
		Total (Capital)	$ 4,067,800.00	$ 36,900.00	$ 535,900.00
				Grand Total (Capital + O&M)	**$ 4,603,700.00**

[1] Capital cost includes 1200mm dia. manholes at 155 metre spacing. Capital cost also assumes road removal and restoration for top of trench width (width based on 1.5 m cover on sewer and 1.5:1 excavated side slopes on trench).

APPENDIX J

PHOTO INVENTORY



City of Campbell River

Integrated Stormwater Management Plan

Nunns Creek Watershed

Photography Locations

- Photograph Location
- Nunns Creek
- Nunns Creek Watershed
- District Boundary

0 195 390
Metres

Scale 1:20 000

Source: City of Campbell River

This map was prepared for the purposes of this planning study and are provided for general reference only. Site specific information must be obtained and provided to the City to confirm the actual site conditions at any location.

URBANSYSTEMS.
PLANNERS • ENGINEERS • LANDSCAPE ARCHITECTS

1479.0005.01 May 2005

Nunns Creek Photo Log

1. Highway 19 looking downstream on Nunns Creek

2. Old Highway looking downstream on Nunns Creek

3. Old Highway looking upstream on Nunns Creek

4. East on Cliffe Crescent

5. South on Quattell Avenue

6. 16th Ave. downstream edge of sidewalk.
   Note water surface proximity to elevation of sidewalk

7. Nunns Creek Park

8. Nunns Creek Park

9. Nunns Creek Park

10. Nunns Creek Park

11. Nunns Creek Park, development proximity

12. Nunns Creek Park, beaver activity and floodplain

13. Nunns Creek and Homewood Road upstream

14. Nunns Creek and ERT Road – confluence of 2 reaches

15. Nunns Creek and ERT Road 900 dia. culvert well above channel invert

16 Nunns Creek and Willis Road upstream

17. Nunns Creet and ERT Road between Croation Road and Evergreen Road

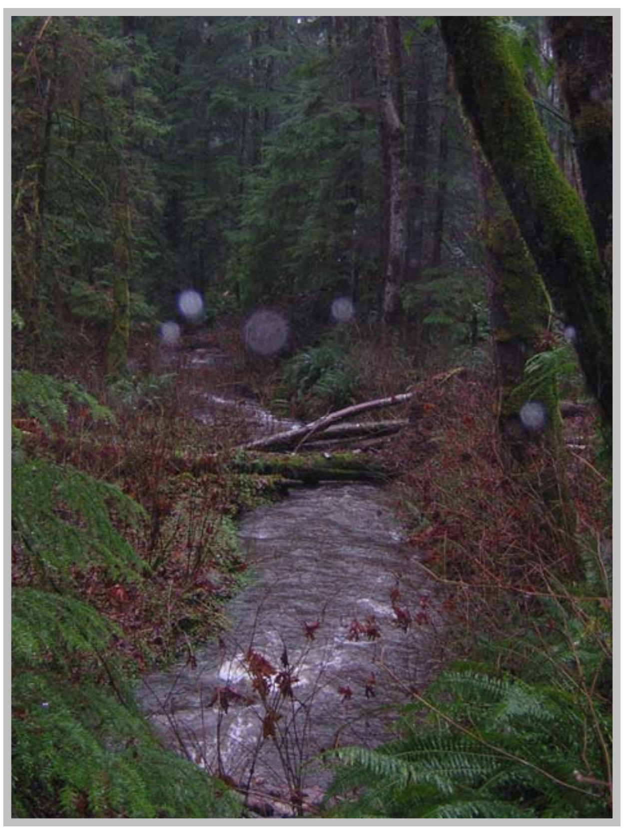

18. Nunns Creek utilized as road ditch


19. Nunns crossing through private property at Petersen and Old Petersen Road


20. Evergreen Rd east of Petersen Rd south side road ditch


21. Ditch undergoing severe erosion


22. Nunns Creek and Merecroft Road downstream


23. Nunns Creek west of Berne Road

APPENDIX K

SUMMARY OF EXISTING CITY OF CAMPBELL RIVER POLICIES

Summary of Existing City of Campbell River Documents
Which Address Stormwater Management

Reference	Title (Date)	Comments
Draft OCP Bylaw 2555	Draft Official Community Plan (December 2004)	• Defines broad principles, goals, objectives and implementation strategies for community growth and development • Four overall key principles / values: (1) protect / enhance the physical environment; (2) ensure effective land use; (3) promote residential diversity and strong neighbourhoods; and (4) enhance greenways network and parks development • Four specific goals related to environmentally sensitive areas: (1) protect sensitive areas; (2) minimize air, land and water pollution; (3) protect and conserve the quality and quantity of groundwater and surface water; and (4) minimize loss of life and damage to property in areas with flooding risk or slope instability • Strong environmental protection and sustainability components in many provisions • Commits to encouraging and supporting growth and development in the District that is in accordance with the Integrated Stormwater Management Plans (ISMP's) • Encourages the use of alternative design standards where appropriate to mitigate stormwater impacts • Encourages increased densities and cluster development instead of urban sprawl • Identifies current and future commercial, industrial and residential development areas • Stormwater management goals are to maintain pre-development flows to downstream systems and to capture, convey and treat water that flows through a site from upstream areas
Bylaw 597	Building Bylaw (1974)	• Requirements for plans and specifications for buildings • Permits for installing culverts
Bylaw 692	Soil Removal and Deposition Bylaw (1978)	• Basis for permits to move soil • Prohibits adverse affects from soils movement
Bylaw 1340	Subdivision Bylaw (1983)	• Requires engineering studies and mitigation for flooding, settlement or unusual soil or drainage conditions • References Engineering Design Standards (Appendix A) (see below) • Requires servicing developments with storm drainage systems, based on broad land use types, including storm drains in all but "rural" and "resource" zones • Cost sharing for "higher standard" of service for storm drains disallowed, except where a Development Cost Charge (DCC) has been established • Establishes basis for cost sharing
Bylaw 2341 (inclusive 2564, 2680, 2744 and 2789)	Development Cost Charges Bylaw (1995)	• Establishes purpose and basis for Development Cost Charges (DCCs), specifically including those for stormwater drainage in the Quinsam Area • DCCs in Quinsam Area typically based on number of units (residential) or gross building square footage (commercial, industrial and public assembly)
Bylaw 2700 (and amend-ments)	Zoning Bylaw	• Regulates use of land and structures within District • Siting adjacent to lakes and watercourses • Siting in floodplains • Landscaping requirements in certain zones • Parking requirements • For each zone, typical requirements relate to: permitted uses; lot size; lot coverage/density; minimum dimensions for yards; building heights; usable open space; conditions of use • Establishes streamside protection and enhancement areas

Reference	Title (Date)	Comments
Bylaw 2709	Frontage Improvement Bylaw (1998)	• Requires certain improvements to serve developments, including stormwater-related • Extent of improvements based on general zoning uses (rural/resource; industrial; all others) • Establishes unit costs to be charged for the improvements, including specifically for storm drains, storm drain connections, and trees
Bylaw 2791	Campbell River Estuary Management Commission Bylaw (1999)	• Establishes a commission to advise the District on matters related to implementation of the Campbell River Estuary Management Plan (CREMP) • CREMP sets a number of policies and actions for restoration, enhancement and protection of the estuary, including preparation of a stormwater management plan for areas surrounding the estuary • Commitment to land development and management that (1) meets objectives for protection of aquatic habitat per Provincial “Land Development Guidelines” and (2) minimizes water contamination from runoff per Provincial “Urban Water Runoff Guidelines”
CREMP	Campbell River Estuary Management Plan (1995)	• The Plan addresses long-term protection and enhancement of the Estuary including recommendations related to habitat restoration, dredging, industrial relocation and upland development. Among the proposed overall policies are several directly relating to stormwater: • Develop and manage land per Provincial Land Development Guidelines • Minimize water contamination from runoff per Provincial Urban Water Runoff Guidelines • Complete a stormwater management plan for the estuary and surrounding lands Other policies relate to shoreline erosion, upland development clustering to encourage open space and development of greenways
CREMP (rev)	Campbell River Estuary Management Plan Update (2002)	• Reviews actions undertaken since adoption of 1995 CREMP and provides direction on priorities over next 5 years • Recommends establishing performance standards for stormwater runoff quality and habitat protection • Recommends establishing stormwater management plans for watercourses flowing into the estuary
Bylaw 2864	Storm Water Management Parcel Tax Assessment Roll Bylaw (2000)	• Directs preparation of assessment roll for purposes of imposing a parcel tax to cover costs related to stormwater management • Parcel tax to be an amount for each parcel
Bylaw 2865	Storm Water Management Parcel Tax Bylaw (2000)	• Tax to be imposed on all parcels (except exempt properties) within District • Revenues identified for stormwater management purposes • $12/year for five years (2001-2005)
Bylaw 2871	Local Improvement Charges Bylaw (2000)	• Establishes annual charges per frontage foot for various local improvements • Improvements include: curb & gutter; roads; storm sewers; sidewalks and landscaping
Bylaw 2926	Storm Drain System Connections Bylaw (2001)	• Storm drain connections required under a variety of conditions • Establishes connection charges • Not required when adjacent to certain water courses (including Campbell River and Discovery Passage)

Reference	Title (Date)	Comments
Appendix A, Bylaws 1340 & 2709	Engineering Design Standards (November 2000)	Part I sets standards for roadway designs that affect impervious area and hydraulic connection of impervious area: • Tables I & IA – minimum pavement widths with curb types for various land uses • Table III – sidewalk requirements • Table V – sets pavement designs (materials, etc .) • Sec 13.1 thru 13.7 – requires tree planting along roadways and sets standards Part III directly concerns storm drainage: • Sec 1.1 – systems must meet District's "stormwater management plans" • Sec 1.4.1 – design minor systems for 5-year event, except 10-year for commercial / industrial • Sec 1.4.2 – design major systems for 100-year event; allows flow paths in roadways and walkways • Sec 3 – requires sediment control plans for developments during construction; sets limits on discharge of total suspended solids (TSS) in runoff; requires slope protection; establishes other requirements for sediment controls during construction • Sec 4 – requires conformance with District's approved stormwater management plan where applicable; shows preference for regional stormwater detention facilities and for wet ponds; sets requirements for design of detention facilities
Appendix B, Bylaws 1340 & 2709	Specifications (November 2000)	• References "Master Municipal Construction Documents: Specifications and Standard Detail Drawings" • Includes a variety of items related to construction of stormwater facilities, including erosion control
Appendix, Bylaws 1340 & 2709	Approved Product List (November 2000)	• Describes approved suppliers of certain storm drainage features • Includes: pipe, culverts, fittings, manholes, catch basins and headwalls
EAP	Environmental Action Plan (December 2003)	• Outlines District's environmental goals and objectives, projects to complete over next 5 years, departments responsible for undertaking projects, funding sources and partnership opportunities • Projects include future ISMP studies, environmental monitoring, guidelines and bylaws for runoff and erosion control, design guidelines for BMP's, acquiring dedicated property or restrictive covenants for sensitive areas
MPP	Master Parks Plan (2005)	• Not reviewed because draft report not completed
ADS	Alternative Design Standards (2005)	• Not reviewed because draft report not completed
MTP	Master Transportation Plan (May 2004)	• Outlines current conditions of District's road network and provides recommendations for future improvements • Recommends that all residential collector roads be upgraded to full urban standard (curb, gutter and sidewalk) • Recommends 2 sidewalks on residential collector roads and 1 sidewalk in commercial / industrial collector roads • Some new roads suggested for Willow and Simms Creek watersheds, upgrades to existing roads for Nunns Creek watershed
DCRAS	Campbell River Airport Water Supply Study (Sept. 2004)	• Discusses possible alignments of new water service to airport and development of lands in vicinity of alignments • Within uplands of Willow Creek watershed
CPM	Council Policy Manual (February 2004)	• Policies for administrative, finance, parks/recreation, property, public works and purchasing • Provides timing schedules for inspection of utilities, roads, etc and outlines recording and action procedures by public works department

Adapted and amended from the Integrated Stormwater Management Plan for Holly Hills and Perkins Road Drainages, prepared by Urban Systems, March 2004.

APPENDIX L

CITY OF CAMPBELL RIVER
INTEGRATED STORMWATER MANAGEMENT PLANS (ISMP)
TERMS OF REFERENCE

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Campbell River, B.C. V9W 4C7
Telephone: (250) 286-5739
Facsimile: (250) 286-5741
dave.morris@dcr.ca

DISTRICT OF CAMPBELL RIVER
REQUEST FOR PROPOSAL NO. 370
INTEGRATED STORMWATER MANAGEMENT PLANS

The District of Campbell River (DCR) is seeking to secure the services of a qualified engineering consultant for the completion of three Integrated Stormwater Management Plans (ISMP). The ISMP's are to be developed for the Nunns, Simms and Willow Creek Watersheds, which include areas of agricultural (forestry), rural, and urban development.

Attached are Instructions to Proponents and Terms of Reference that are to be used as the basis for your proposal.

1.0 Submission Requirements

1.1 The District will accept proposals using the two-envelope system, one envelope must contain the "Proposal Section" itself, and the second envelope must contain the "Budget Section". Both sections of the proposal submissions must be submitted in sealed, opaque envelopes clearly marked "Proposal Section" or "Budget Section" with the proponent's name and address and "Request for Proposal No 370 INTEGRATED STORMWATER MANAGEMENT PLANS", addressed to the Materials Manager, District of Campbell River, c/o Engineering Department, 301 St. Ann's Road, Campbell River, BC, V9W 4C7.

1.2 Proposals must be received at the above location no later than **4:30 p.m. local time, Monday, September 27th, 2004.** Proposals will NOT be opened in public.

1.3 Proposals received and not conforming to Items 1.1 and 1.2, above, will be returned (unopened) to Proponent(s) without consideration.

1.4 The District does not accept proposals received via our facsimile machine or e-mail.

1.5 All prices proposed are to be in Canadian funds.

1.6 Proposals, rather than tenders, have been requested in order to afford proponents a more flexible opportunity to employ their expertise and innovation, and thereby satisfy the District's needs in a more cost effective manner. Proposals should be based on these Instructions, the attached Terms of Reference, and the attached Draft Professional Services Agreement.

1.7 Your proposal should clearly show your complete company name, nearest location to the District of Campbell River, and name and telephone number of primary contact person(s).

1.8 All "Proposal Sections" of the proposal submissions should include six (6) copies preferably in an 8-inch x 11-inch format. Proposal submissions must be suitable for black and white photocopying. The "Budget Section" (one (1) copy only) of the proposal submission shall be in a **separate sealed envelope**.

1.9 Proponents are solely responsible for any costs or expenses related to the preparation and submission of proposals.

1.10 After the closing time and date, all proposals received by the District become the property of the District.

1.11 No Proponent may withdraw their proposal for a period of 60 days after the actual date of closing.

1.12 All material (documents, drawings and data) generated as a result of the contract will become the property of the District; the District will have the right to copy and publish the material for it's own purposes.

1.13 The awarding of a contract as a result of this Request for Proposal will not permit the successful Proponent to advertise the relationship with the District without the District's prior authorization.

1.14 All services provided must be in accordance with all laws and regulations pertaining to the services. The Consultant will be responsible for acquiring and paying for all required licences, permits, and approvals from authorities having jurisdiction including a valid District of Campbell River Business Licence. The laws of the province of B.C. shall govern this proposal and any subsequent contract resulting from this proposal. The successful proponent will be required to enter into a signed professional services agreement with the District, refer to the attached Draft Professional Services Agreement.

2.0 <u>Definitions</u>

2.1 The District of Campbell River is referred to as the "District".

2.2 The entity submitting a proposal is referred to as the "Proponent".

2.3 The Successful Proponent is referred to as the " Consultant".

3.0 <u>Confidentiality and Freedom of Information</u>

3.1 Your proposal should clearly identify any information that is considered to be of a confidential or proprietary information (the "Confidential Information"). However, the District is subject to the provisions of the *Freedom of Information and Protection of Privacy Act.* As a result, while Section 21 of the Act does offer some protection for third party business interests, the District cannot guarantee that any Confidential Information provided to the District will remain confidential if a request for access in respect of your proposal is made under the *Freedom of Information and Protection of Privacy Act.*

4.0 <u>Pricing</u>

4.1 The activities or tasks listed in the attached Terms of Reference are minimum requirements to be undertaken. Proposals must include a price breakdown including hourly/daily rates, direct expenses, subcontracts (if applicable), internal costs (e.g., computer usage charges), travel costs, and any other applicable costs. In the event the Consultant incurs additional expenses (subject to the approval of the District), such expenses will be reimbursed at cost without mark-up.

4.2 All invoices paid as a result of this Request for Proposal will be paid as per the District's standard payment terms "current month's invoices will be paid net 30 days".

4.3 Proposals must include a Payment Schedule based on the milestones achieved. Proponents should include a budget for each milestone to demonstrate that the payment for the milestone is commensurate with its anticipated cost.

4.4 The Consultant shall include a project progress report with each monthly invoice summarizing: the work done in the past month; progress compared to budget; issues requiring the attention of the District, Agencies or stakeholders; anticipated changes in the scope of work; signed Change of Scope form(s) for agreed upon changes(s); and any other communication deemed to be required or useful that was not otherwise communicated.

5.0 Cancellation

5.1 The District reserves the right to cancel this Request for Proposal at any time and for any reason, and will not be responsible for any loss, damage, cost or expense incurred or suffered by any Proponent as a result of that cancellation.

5.2 The District reserves the right to terminate the Contract, at its sole and absolute discretion, on giving 90 days' written notice to the Contractor of such termination and the Contractor will have no rights or claims against the District with respect to such termination. Cancellation would not, in any manner whatsoever, limit the District's right to bring action against the Contractor for damages for breach of contract.

6.0 Accuracy of Information

6.1 The District makes no representation or warranty, either express or implied, with respect to the accuracy or completeness of any information contained or referred to in this RFP.

7.0 Responsibility of Proponent

7.1 Each Proponent is responsible for informing themselves as to the contents and requirements of this RFP. Each Proponent is solely responsible to ensure that they have obtained and considered all information necessary to understand the requirements of the RPF and to prepare and submit their proposal. The District will not be responsible for any loss, damage or expense incurred by a Proponent as a result of any inaccuracy or incompleteness in this RPF, or as a result of any misunderstanding or misinterpretation of the terms of this RPF on the part of any Proponent.

8.0 References

8.1 Your proposal should identify other municipal organizations for which your company has provided similar services. Please provide references stating organization name, contact name, phone number and fax number to support this.

9.0 Enquiries

9.1 All technical questions should be directed to Michael Roth, Environmental Coordinator at (250) 286-5711. Questions regarding the submission of proposals should be directed to David G. Morris, C.P.P., C.P.M., Materials Manager at (250) 286-5739.

9.2 If a Proponent is in doubt as to the true meaning of any part of this Request for Proposal, or finds omissions, discrepancies or ambiguities, a request for interpretation or correction may be submitted to the Materials Manager. If deemed necessary by the District, an addendum will be issued to all Proponents registered as having received this Request for Proposal. This procedure also applies should the District, of its own accord, wish to expand or delete any part of this Request for Proposal. Only the written Request for Proposal and any addenda issued by the Materials Manager should be relied upon by Proponents when preparing and submitting their proposals.

10.0 Indemnification

10.1 The successful proponent (Consultant) and any Sub-consultants shall at all times indemnify and save harmless the District and or any of its officers, employees or agents from and against all claims and demands, loss, costs, damages, actions, suits, fees, or other proceedings by whomsoever made, brought or prosecuted, in any manner based upon, occasioned by or attributable to the execution of this agreement, or any action taken or things done or maintained by virtue of this agreement or the exercise in any manner of rights arising under this agreement except claims for damage resulting from the negligence of any officer, servant or agent of the District while acting within the scope of their duties of employment.

11.0 Insurance

11.1 Where available, the Contractor must submit to the District, upon acceptance of its proposal, a Certificate of Insurance containing the following:

- Provision naming the District as an additional named insured to the Comprehensive General Liability Policy;
- Cross Liability Clause;
- Comprehensive General Liability Policy in an amount not less than $3,000,000;
- A provision requiring the Insurer to give the District 15 days' notice of cancellation or lapsing or any material change in the insurance policy; and
- Certificate confirming liability insurance in an amount not less than $2,000,000 with the Insurance Corporation of British Columbia on any licensed motor vehicles of any kind to be used to carry out the Work.

12.0 Declarations

12.1 In submitting a proposal the Proponent declares that:

- I (we) do not (or any related company) have any family, ownership, and operating relationships with the District, or any elected official, staff or other officials holding public office in the District and agree that the District reserves the right to reject any proposal that may be perceived to be in a conflict of interest.

- I (we) am (are) not or have not:

(a) an individual who has; or
(b) an individual who was a shareholder or officer of a company that has; or
(c) a company that has; or
(d) a company with a shareholder or officer who has; or
(e) a company that is, or was a shareholder of a company that is, or was a shareholder of a company that has; or
(f) a company that has a shareholder or officer who is also a shareholder or officer of another company that has;
(g) had a bid bond retained, or

had all or part of a performance bond retained, or breached a contract with the District, or failed to complete its obligations under any prior contract with the District (or any other publicly funded jurisdiction or organization in British Columbia), or has been charged or convicted of an offence in respect of the District (or any other publicly funded jurisdiction or organization in British Columbia) contract.

13.0 Sub Contracting

13.1 Under no circumstances may the services or any part thereof be sub-contracted, transferred or assigned to another firm, person or company without the prior written authorization of the District.

14.0 Evaluation Process

14.1 An evaluation committee made up of District staff will be reviewing proposal submissions. Please also refer to the Evaluation Criteria outlined in the following section.

14.2 Notwithstanding any custom or trade practise to the contrary, the District reserves the full right to, in its sole discretion and according to its own judgment of its best interest to:

a) reject any and all proposals,
b) waive any technical or formal defect in a proposal and accept that proposal, and
c) award the contract to other than the lowest cost Proponent.

14.3 The District reserves the right to conduct pre-selection meetings with Proponents. Proponents may be requested, as part of the evaluation process, to provide a presentation, which may include a run through of their proposal submission.

14.4 A maximum of two short-listed proponents may be requested to personally present their proposal to the District, at no cost to the District.

14.5 The District further reserves the right to conduct post-selection meetings in order to correct, change or adapt the selected proposal to the wishes of the selection committee.

14.6 The successful Proponent may be required to enter into a written contract, in a form approved by the District.

14.7 The lowest or any proposal will not necessarily be accepted.

14.8 Award of any contract resulting from this RFP may be subject to District of Campbell River Council approval and budgetary considerations.

15.0 <u>Evaluation Criteria</u>

15.1 Evaluation of proposal submissions will be conducted in the following two separate steps. The District of Campbell River will evaluate proposal submissions for best value based on the following criteria:

"PROPOSAL SECTION"	**WEIGHING**
FIRM ➢ General/Related Experience (including DCR) ➢ Experience with Similar Type Projects	**15**
PERSONNEL ➢ Project Manager/Director & Project Team ➢ General Related Experience (including DCR) ➢ Experience with Similar Type Projects ➢ Qualifications of Team Members ➢ Local knowledge	**20**
APPROACH/METHOD ➢ General Approach ➢ Understanding of Needs ➢ Clarity of Approach/Organization of Activities ➢ Allocation of Level of Effort ➢ Team Organization ➢ Role/Responsibilities Defined ➢ Project Controls and Reporting ➢ Quality of Presentation	**30**
"BUDGET SECTION"	
➢ Proponent's Upset fee schedule	35
TOTAL	**100**

Following the completion of the evaluation in Step 1, the top two scoring proposals will proceed to Step 2 of the evaluation. Overall evaluation of the top two scoring proposals will be based on the information provided in Step 1 and the budget information provided in Step 2.

INTRODUCTION

The District of Campbell River (the District), a community of approximately 30,000 people, is located 150 kilometers north of Nanaimo on the east coast of Vancouver Island. Development in the community has primarily taken place in a two to three kilometer wide strip of land, which rises up from Discovery Passage at the northern tip of the Georgia Basin and stretches along the coastline for over 14 kilometers.

The District is requesting proposals for the completion of three Integrated Stormwater Management Plans (ISMP). The ISMP's are to be developed for the Nunns, Simms and Willow Creek Watersheds, which include areas of agricultural (forestry), rural, and urban development. The ISMP's are to be undertaken using the methodology outlined below. While opportunities exist to reduce duplication during phases common to each of the studies, the final ISMP's must be prepared as independently bound reports.

BACKGROUND

From the 1960's through the mid 1990's, the District completed various studies to address stormwater management issues. These studies were often associated with site-specific development, projects or problem areas. In some cases, these studies did not address the larger strategic stormwater issues associated with an entire watershed. In 2000, the District of Campbell River initiated a 5-year program to complete a series of integrated stormwater management plans (ISMP). To date ISMP studies have been successfully completed for the Holly Hills and Perkins Road drainages.

In order for the District to complete the comprehensive District-wide stormwater management strategy it will be undertaking a series of integrated stormwater management plans (ISMP) for the areas as per this Request For Proposals for the Nunns (also known as Camp Creek), Willow (also known as Swansky Creek) and Simms Creek Watersheds.

Additional ISMP studies to be completed as part of the District's 5-year program include: the Foreshore; Casey/Painter Barclay; Quinsam, and Kingfisher Creek drainages. These studies do not form part of this RFP and will be tendered through a separate process in the near future.

The District did initiate a series of overall watershed master drainage plans in 1995 and 1996. Master drainage plans were completed for the Willow Creek (1996), Simms Creek (1995) and the west and lower sections of the Nunns Creek catchments in 1995 and 2002 respectively. Specific recommendations were made in these studies to address the impact of future land development, with the goal to preserve the pre-development flow characteristics of the stream as urbanization proceeds. The plans were consistent with the Federal Department of Fisheries Land Development Guidelines and relevant Provincial guidelines which ultimately led to revisions to the District's Design Standards and Specifications between 1997 and 2000. The District will through 2004 & 2005 undertake another review of its current design standards. The goal of this two-phase study will be to identify and develop alternative storm-water design standards for area specific neighbourhoods and catchment areas.

Recently, engineering, planning and environmental specialists have come to agree that an integrated approach to stormwater management is required to protect watersheds. This approach is science based, addressing the impacts of urbanization on fish habitat, flooding and property damage. The ISMP will bring together land use planners, stormwater engineers and ecological specialists in an interdisciplinary approach to develop proactive solutions to the changes that urbanization brings to the District's stormwater system and natural habitat.

A number of issues are driving the need to complete a comprehensive District-wide stormwater management strategy. Including: the reconstruction of Island Highway 19A from the Jubilee Parkway to Hidden Harbour, and upgrading of the sanitary sewer collection system. Other factors that have been considered include the District's concern over existing undersized stormwater infrastructure. Up to the mid 1990's rainfall estimates were based on data from the Comox Valley. These estimates have proven to be considerably lower than actual Campbell River rainfall events. With historic urban development concentrated along the Campbell River foreshore and new urban development now moving in a westerly direction away from the foreshore, downstream pipe capacity for new upland developments may as a result of the early estimates have capacity limitations.

In addition, it will also be necessary to coordinate any proposed stormwater drainage improvements with other long-range management plans. The list includes: the District's Long Range Road Reconstruction Plan (LIP); Utility Renewal Plans; Capital Works Plan; Long Range Plan for Road Overlays; and Estuary Management Plan. Coordination with these other plans is critical to cost effective implementation of each plan. In addition, the District is currently reviewing its Official Community Plan (Winds of Change, 1997) and recommendations for changes to land use may need to be addressed through this initiative. Other planning exercises underway that may be considered include; Phase One of a Master Parks Plan and Phase One of a review of Alternative Design Standards.

STUDY AREAS

Physical Setting

The Nunns, Simms and Willow Creek Watersheds make up a number of local creeks that drain the low lying moraine plateau that lies between the Oyster River Watershed and the Campbell River / Quinsam River Watershed. All three watersheds have high fisheries values as a Coho (*Oncorhynchus kisutch*), Pink (*Oncorhynchus gorbuscha*) limited but historical runs of Steelhead (*Oncorhynchus mykiss*) and Chinook Salmon (*Oncorhynchus tshawytsch)* and various Trout species.
Located within the Coastal Western Hemlock Biogeoclimactic zone, the predominant tree species include Western hemlock, Douglas fir, Red cedar, Sitka spruce, Grand fir, Big Leaf maple and Red alder. Invasive plant communities have recently been identified that if left unchecked may lead to changes in vegetation ground cover and loss of species diversity.

Climate

Temperatures range from 0.9 C to 2.7 C. Average summer temperatures are 16.7 C. (C.R. Climate station). The prevailing wind is from the southeast, especially during the winter months, and westerly during the summer months.

Soils

The watersheds lie within the Coastal Western Hemlock (CWHxm) Biogeoclimatic zone. Valentine et al. notes that the soils are within this region are typically humo-ferric podzols, imperfectly drained and leached soils. With a mixture of dry brunisols, rapidly draining brown soil.

Watershed Profiles

Nunns Creek Watershed

Nunns Creek Watershed (Map 1) was one of the first sites in Campbell River to be settled by Europeans in the late 1880's and is divided into a number of distinct areas.

The lower watershed, from the estuary to 16th Street, makes up part of the inter-tidal zone, influenced by the same tides that move into the Campbell River estuary. The creek is confined to a well-established channel that flows through a marshland area. Historic impacts to this area have included changes in the moisture regime through road construction and flow control gates that created back flooding during extreme high tides. Although the gates have been removed, the effects of sediment deposition and increased in-stream vegetation has resulted in seasonal flooding of adjacent upland areas.

The lower watershed is also home to the Campbell River Indian Band and has seen recent growth in residential development, construction of a major shopping complex and decommissioning of the existing road allowance (Tyee Spit Road).

The next section of the creek from 16th Street to Homewood Street is a continuation of the low gradient system that moves up from the estuary. This area includes a municipal park and additional provincial forest land leased to the District from the Nature Trust of BC. The parks space provides active recreational opportunities that include baseball fields, a skateboard park, a riparian leave strip next to the creek and numerous foot trails. The Ironwood Mall and a mixture of light industrial and commercial businesses bound the south-eastern boundary of the park.

Once over Homewood Road the topography climbs gradually providing variable gradients that are indicative of Coho / Cutthroat systems on the east coast of Vancouver Island. The surrounding land is rural residential with large private lots, many of which span both banks of the creek. Currently limited development in this area has helped to maintain the creeks integrity with good riparian cover of mixed trees in the upper canopy and shrubs in the under story.

From Second Avenue the creek levels off and becomes unconfined. This flat bench land is the headwaters of the creek and shares it southerly boarder with the Simms Creek and Haig-Brown Kingfisher Creek Watersheds. Development in this area is a mix or rural residential and single-family homes. The Official Community Plan identifies this portion of the watershed as an area that will, over the short-term, experience continued urban growth.

Simms Creek

Simms Creek (Map 2) is 6 km south of the town center and drains an area of approximately 1,252 hectares. Simms creek has two main tributaries each with a number of smaller secondary tributaries.

The lower watershed has been completely developed and is a mixture of high, medium and low-density housing. This lower reaches of the watershed have lost most of the original riparian cover and consequently experiences flash floods and increased sediment loading during early spring and late fall.

The middle portion of the watershed by contrast still has a substantial riparian zone throughout much of its length, due in part to the preservation of 415 hectares of forestland. This area, the Beaver Lodge Forest Lands, is protected by its own provincial legislation and is under the administration of the Ministry of Forests and co-managed with the Beaver Lodge Lands Trust Committee and Greenways Land Trust.

The upper watershed is located outside of the District's existing Residential Containment Boundary and is bisected by the Inland Island Highway. Comprised of forestland and undeveloped large lots it is zoned as Comprehensive Development Area One (CD-1).

Willow Creek Watershed

Willow Creek Watershed (Map 3) drains an area of approximately 2261 hectares; the watershed runs from an elevation of 140 m in a southeast direction draining into the Discovery Passage. Located on the northern tip of the Georgia Basin, it is bordered on the north by Simms Creek and on the south by Woods Creek. The Willow Creek watershed is comprised of 4 main tributaries: Willow Creek, Larwood Creek, Beaver Creek and Newman Creek.

Most of the land falls within the District of Campbell River's municipal border with a small section of the Newman creek headwaters remaining in the Regional District of Comox-Strathcona.

The lower watershed is highly developed with a mixture of single and multi-family residential homes. Existing zoning calls for residential infill in some of the lands adjacent to Highway 19A. The lower watershed also includes 80 acres of provincially protected lands managed by the Nature Trust of BC. Once the site of the Willow Point Waterworks this area now provides recreational greenway opportunities and salmon spotting to area residents.

The middle to upper watershed is currently undergoing major transition from forestland to residential, industrial and commercial subdivision with comprehensive development planning underway for portions of the lands adjacent to the municipal airport, the Dogwood Street Extension and Jubilee Parkway. TimberWest Forest Ltd., which has within the last eight years harvested most of the second growth merchantable timber, holds the majority of the undeveloped land as inventory.

The Homalco Indian Band is located mid-way up the watershed and is currently preparing a comprehensive development plan. Recent construction of a bridge crossing the main stem of Newman Creek will facilitate continued development of their lands for residential and recreational community needs.

Campbell River's Municipal Airport, located in the upper watershed is currently contemplating infrastructure upgrades. As part of the development of an overall strategic plan, works currently being reviewed include water and sewer upgrades and a runway extension.

Another recent change to the watershed has been the development of the Campbell River bypass. This is a four-lane highway that was built through 1996/1997 as part of the Vancouver Island Inland Highway Project. Works undertaken included the culverting of the Willow Creek tributary and bridge crossing of Newman Creek.

Community Profile

A number of community groups involved in stewardship of this area have been established since the mid nineties. These include the Willow Creek Watershed Society, the Nunns Creek Stewards and the Simms Creek Stewards. Other organizations that have participated in governance of the subject watersheds include: Fisheries & Oceans Canada; Ministry of Water Land and Air Protection; the Campbell River Indian Band (Nunns Creek), The Nature Conservancy of Canada; the Discovery Coast Greenways Land Trust and the Campbell River Stewardship Advisory Council.

It is expected that the successful consultant team will be able to utilize the biological and antidotal information these stakeholders have developed through there own resources. Each stewardship group is active in its respective watershed and has varying capabilities, opportunities for enhancement and restoration activities that compliment the ISMP for each watershed should be seen as a key objective in building community capacity and education for the protection of the natural environment.

GOALS & OBJECTIVES

The goals of the integrated stormwater management plans (ISMP) are:

I. To establish an achievable and supportable vision for each watershed that will result in development of stormwater management solutions and policies that maintain, restore and enhance the natural watershed characteristics while meeting engineering, environmental and land use needs;
II. To protect the community from flooding, erosion and destruction of private and public property;
III. To promote community development while recognizing neighbourhood values and unique characteristics of the area, and
IV. To integrate engineering, planning and environmental solutions to the benefit of each watershed.

The objectives of the three ISMP's are:

I. To document the existing condition of the watershed including the stormwater infrastructure, biophysical inventory, and existing and future land use patterns;
II. To identify the required stormwater management infrastructure and land use policies necessary to ensure the protection of residents and property with protection of the aquatic habitat;
III. To ensure that stakeholder interests and senior environmental agency support for the study recommendations is balanced with the social and economic interests of the community;

IV. To develop a decision matrices that will allow the District to analyze and evaluate options that meet the multiple needs of the community;
V. To recommend an integrated approach to achieving cost effective solutions which will assist the District and its partners in establishing watershed based stormwater policies, a stormwater infrastructure program, and
VI. Provide the District with an evaluation and recommendation(s) that will lead to the development of sustainable financial tools that support the District's land use plan and capital works program, including but not limited to the establishment of a stormwater utility and development cost charges.

METHODOLOGY

The proposal should clearly outline the methodology the consultant will use in achieving the objectives of this Proposal Call. In meeting the above objectives, the consultant should, as a minimum, carry out the following tasks:

1. Within 1 week of acceptance of your proposal facilitate and chair a project initiation meeting with appropriate District attendees to confirm the scope of work and to gather input. As a minimum, District staff to be invited includes representatives from the Engineering, Planning, Finance, Parks and Public Works departments.

2. The Consultant will meet with and gather information from key stakeholders including but not limited to: the Senior Environmental Agencies; landowners (including Forestry Industry Sector); First Nations; MoT; Non-Government Organizations (at a minimum the Nunns, Simms & Willow Creek Watershed Societies and the Discovery Coast Greenways Land Trust), area residents and businesses. The consultant shall pursue the formation of a stakeholder-working group that includes representation from the various parties, including the District. The working group will act as a resource pool for input and feedback on various land use and environmental issues. The stakeholder-working group should meet on a regular basis, as required, to provide input on the development and review of the studies recommendations.

3. Host a minimum of at least two-community open houses. The purpose of the open houses will be to gather community comment to judge the recommendations of the studies and to determine if further revisions are required.

4. Arrange and chair a 50% project completion review meeting with District staff as well as any other relevant stakeholders/working group to confirm project status and identify potential conflicts.

5. Arrange and chair a 90% project review meeting with District staff as well as any other relevant stakeholders/working group to review the draft final report.

6. The Consultant will be responsible for promotion, facilitation and preparation of minutes from all open houses, working group, stakeholder and District meetings.

Existing Stormwater and Watercourse System

1. Review existing engineering studies and related reports for each study area.

2. Review and identify existing rainfall and runoff data. In consultation with District engineering staff recommend additional information or data gaps to be filled.

3. Verify watershed catchments and drainage areas.

4. Gather and review existing biological and flow studies and watershed reports prepared by the District, senior environmental agencies and watershed stewardship groups.

5. Review the District's Engineering Standards and Specifications; identify gaps or deficiencies and make recommendations where appropriate changes might facilitate better use of current Best Management Practices for ISMP's.

6. Map soil conditions and review existing groundwater data.

7. Inventory and evaluate the capacity of the existing stormwater system including ditches, creeks, pipes and overland flow paths. Special attention should be paid to piped systems constructed prior to the mid 1990's. Where required, cross sectional data should be obtained at critical points, specific anthropogenic features and representative segments of identified drainages and catchment areas.

8. Identify known habitat issues in the watershed through discussion with District staff and stakeholders/working group.

9. Where critical habitat concerns are identified during the review of existing studies and stakeholder input, undertake a preliminary site assessment of any significant elements of the noted biophysical features, habitat use, fish and wildlife presence.

10. Delineate and prepare plans showing the watershed and sub-basin boundaries and key site-specific areas of concern.

11. Develop a database of existing and new data for integration with the District's GIS database. Data should include but not be limited to: Geometric; Land Use; Soils; Rainfall; Runoff; Watershed catchments; Contour; Legal address; Utility; Existing mapping, and Survey information as necessary (Arc View GIS and AutoCAD compatible for future use).

Land Use

1. Review the existing and proposed OCP, neighbourhood studies and other land use documentation to identify the existing and proposed land use pattern in the area. Where appropriate include a review of current draft OCP chapter updates as prepared by the District.

2. Identify any special land use designations in the catchments and identify how this information may affect the ISMP (First Nations, forestry, land, wildlife and agricultural reserves, etc.).

3. Map the existing and future land use designations and zoning on each parcel in the catchments.

4. Document and identify gaps in the land use and development policies and regulations for the area.

Hydrologic and Hydraulic Analysis

The District intends to develop the long-term capabilities to accurately model hydrologic and hydraulic data and recognizes that existing data may be limited. It also understands that continuous modeling requires ongoing data collection. The District intends to work towards modeling capabilities using XP-SWMM. It is expected that any input and output files developed under this assignment will remain the property of the District.

While the District does not currently have the in-house software to model hydrologic and hydraulic data using XP-SWMM it will be considering a short-term agreement to contract these services out as needed, and will explore this option under a separate arrangement.

To assist in modeling of various flow rates the District will attempt to provide the following information: An inventory of all available storm drain infrastructure including pipes; sizes; lengths; date of installation; composite materials; grades; invert sizes, and contour mapping associated with inlet rims.

Therefore all modeling should be completed using XP-SWMM as proposed:

1. Develop concept model of the groundwater system of each watershed, including determining areas of potential infiltration and groundwater recharge.

2. Identify base flows for streams and ditches that may have direct influence on the streams.

3. Develop an integrated model of the hydrologic and hydraulic conditions for the watershed using the available rainfall and runoff data.

   Perform a sensitivity analysis and calibrate and verify the model. Modeling should include but not be limited to: total area, impervious area, impervious and pervious roughness coefficients, impervious and pervious depression storage, and infiltration parameters. In addition, for those models simulating pipes, ditches, swales or natural channel(s), perform sensitivity analysis on key hydraulic parameters that may affect routing and the calculation of flow velocity and depth, including roughness coefficients, expansion and contraction coefficients, loss coefficients, detention volumes and boundary water surface conditions. Parameters must be varied individually by plus or minus 20% as part of the analysis.

4. Evaluate the existing and future land use conditions for various return periods including the 2-, 5- 10- 25- and 100- year storms.

5. Compare and contrast the results of modeling existing and future land use conditions with and without various low impact development designs.

Alternatives, Evaluation and Recommendations

1. Identify alternatives that should be considered to move from event based modeling to continuous based modeling including but not limited to: possible locations of flow meters, additional rain gauges and surveying needs. Any recommendations must also include a discussion on the implications of such alternatives and estimated costs for of such activities.

2. Identify and evaluate innovative stormwater management solutions that consider sustainability, long-term operation and maintenance, capital and operating costs, community amenities, and the health of the watercourses.

3. Review options for stormwater management alternatives at the watershed level and recommend modeling tools that can be used to direct site-specific developments in maintaining post development flows to mimic predevelopment flows.

4. Establish the drainage and biological benefits of various solutions and the level of protection supported by each solution. Determine the future condition of the watercourses using existing and proposed future land use plans.

5. Prioritize critical habitat protection, restoration and or enhancement opportunities that require either immediate mitigation or that might pose a risk to adjacent upland residential, commercial or industrial property in the long-term.

6. Recommend best management practices (BMP's) in a comprehensive strategy that outlines the integrated goals and objectives and which level of protection is possible for the watershed. BMP's such as ground infiltration, detention, stormwater treatment and surface flows, etc. will be considered. Determine which BMP's are best constructed by the private sector or by public sector.

7. Report on new and innovative solutions that may be appropriate as a pilot project or policy and the implications of such a solution.

8. Identify the specific type, size and location of the required drainage and watercourse works including any modifications to existing facilities or the recommendations of existing studies. Indicate whether implementation should be by the public or private sectors.

9. Present the options, evaluation and recommendations to the working group for comments and direction.

10. Develop short and long-term evaluation methods the District may employ to measure the success of the recommended solutions.

11. Provide a cost estimate of the recommended solutions.

12. Identify preliminarily changes necessary to the District's Engineering Standards and Specifications, Official Community Plan as well as other documents to implement the recommended solutions.

13. Recommend alternative legislative tools such as relevant sections of the Local Government Act or Community Charter that can be utilized to ensure land use decisions be managed to meet water resource needs.

14. Develop and recommend a long-term monitoring program that can be used to evaluate the effectiveness of the stormwater management program. The program should include a discussion of target limits and mechanisms for making future adjustments to the program, as needed.

15. Identify funding mechanisms that could be used to implement recommendations (DCC's, Stormwater Utilities, GMF, GEF, etc.). Where DCC's and utility charges may be applied identify the eligible items.

Communications Strategy

1. The Consultant will report to the District's Project Manager (Engineering Services, Environmental Coordinator). Using Microsoft Project and summary memos the Consultant will provide a project status report and list of accomplishments, at a minimum, every 3 weeks. The Consultant will be responsible for the compilation and distribution of minutes to the Project Manager for all meetings and open houses.

2. Prepare and distribute media releases promoting the District's ISMP process. Ensure that regular updates are distributed to the local newspapers. Any media articles must be approved by the Project Manager prior to their release.

3. The Consultant will provide the working group with copies of any draft version of the ISMP report and maps for use by District staff and stakeholders. In addition, the Consultant will provide a separate and comprehensive ISMP study for the Nunns, Simms and Willow Creek Watersheds. The Consultant will provide the District 15 bound copies plus a digital CD-Rom version of each final ISMP report. The digital files are to be compatible with (MS-Word and pdf) and the District's ArcView GIS and AutoCAD systems. In addition, for each report an executive summary to a maximum of 3 pages is required.

DELIVERABLES

1. Document existing watershed conditions and predict future needs including infrastructure requirements, land use considerations and alternative legislative policies necessary to meet the recommendations.

2. Ensure that all stakeholders and interest groups have been afforded an opportunity for input into the development of the Plans.

3. Develop a cost effective baseline model that can be adapted to meet the future needs of the District.

4. Prepare separately bound integrated stormwater management plan for the Nunns, Simms and Willow Creek Watersheds that establish an achievable vision for each watershed, which includes protection of private and public properties and integrates engineering, planning and environmental values for each distinctive neighbourhood.

5. Present a summary report of each study to Mayor and Council providing an overview of the studies and their recommendations.

TIMING

Works under this project shall be completed as follows:

Week of October 11, 2004:	Project Start up and initial meeting.
December 2004:	50 % completion review.
February 2005:	Review final draft and project completion.

QUALIFICATIONS

The proposal will include the names of all team members proposed to carry out the work assignment. Included should be their specific roles in the assignment and a detailed summary of qualifications and experience on similar projects.

The corporate qualifications and experience in similar work should be included.

BUDGET

To aid you in preparing your budget it should be noted that a maximum of $ 100,000 (taxes included) will be provided to complete all three studies. The proposal should have a detailed budget and must include the following:

- Hourly rates of each team member;
- Number of hours anticipated for each team member;
- Anticipated disbursement costs;
- Total upset price, and
- Amount of assistance expected from District staff. (Information searches, etc.)

INFORMATION

The following reports are available for viewing in the Municipal Engineering Department along with reference and construction drawings. Documents in italics can also be viewed at the District website www.dcr.ca

Winds of Change, Campbell River's Official Community Plan, 1997
Zoning Bylaw No. 2700
District of Campbell River Design Standards and Specifications (Bylaw 1340)
Floodplain Mapping Program Campbell & Quinsam Rivers – Klohn Leonoff, 1989
Campbell River Estuary Management Plan, 1996
Simms Creek Hydrology Study & Drainage Plan – October 1991
Stormwater Management Plan - Simms Creek - Aug 1995
Simms Creek Watershed Landscape Design Management Study–Fall 96
Simms Creek Report – 1997
Simms Creek Assessment & Rehabilitation Project – Report #1 – Jan 97
Nunn's Creek Master Drainage Plan – August 1995
Nunns Creek Area Review – November 2000
Fish Habitat Restoration Prescriptions and Cost Summary for Nunns Creek – March 2002
Nunns Creek Lower Watershed Management Study – June 2002

Stormwater Management Plan - Willow Creek - Mar 1996
1997 Urban Salmon Habitat Program-Assessment Willow Creek-May 1998
Willow Creek Management Strategies for Land & Water Use – April 2003
Watershed Maps for each system
Various stream reports and data for low flow riffle crest studies for Willow and Simms Creeks.

THIS PROFESSIONAL SERVICES AGREEMENT made
as of the ____ day of _______, 2004

BETWEEN:

District of Campbell River
301 St. Ann's Road
Campbell River, B.C. V9W 4C7

(the "District")

AND:

(the "Consultant")

A. The District requires the professional services of the Consultant and desires to engage the Consultant to perform the services set out in this Agreement.

B. The Consultant has agreed to perform the services in accordance with the terms and conditions of this Agreement.

In consideration of the terms, covenants and conditions of this Agreement, the District and the Consultant agree as follows:

1. <u>CONSULTANT'S SERVICES TO THE DISTRICT</u>

1.1 The Consultant must provide and is responsible for the services outlined in a work plan submitted to the District by the Consultant in response to the Request for Proposal No: (the "Proposal") attached hereto as Schedule "A" and forming an integral part of this Agreement, and confirmed on District Purchase Order No. .

1.2 The Consultant may engage professional sub-consultants for the performance of specific tasks forming part of the Services, as approved in writing by the District. The sub-consultants may not be replaced without the prior written consent of the District.

1.3 The Consultant must administer, coordinate, and manage all services of sub-consultants, and is responsible for all work performed by the sub-consultants in relation to the Services and will pay all fees and disbursements of all sub-consultants.

1.4 The Consultant must perform the Services:

a) with that degree of care, skill and diligence normally applied in the performance of services of a similar nature;

b) in accordance with current professional practices; and

c) in conformance with the latest design standards and codes applicable at the time of design.

1.5 The Consultant must furnish all personnel required to perform the Services, and all personnel must be competent and qualified to perform the Services.

1.6 Where specific personnel have been proposed by the Consultant for the performance of the Services, and have been accepted by the District, the personnel may not be replaced without the prior written consent of the District.

1.7 The Consultant must commence the Services in a timely manner and carry out the Services in accordance with the completion dates set out in the work plan, or as mutually amended in writing by the Consultant and the District from time to time.

2. <u>BASIS OF PAYMENT TO THE CONSULTANT</u>

2.1 In consideration of the Services performed by the Consultant to the satisfaction of the District, the District will pay the Consultant the fees and reimbursable expenses prescribed in Schedule "B" attached hereto and forming an integral part of this Agreement.

2.2 Payment to the Consultant will be based on hours worked by the employees of the Consultant multiplied by their hourly rates as indicated in the proposal and shall not exceed $ without prior written authorization from the District.

2.3 The limit on the fees to be paid by the District to the Consultant does not diminish the duties and obligations of the Consultant to provide the Services.

2.4 Disbursements for which the District will reimburse the Consultant shall be at cost plus 5% and will be limited to the following:

a) transportation and reasonable living out expenses of the Consultant's employees to comply with the work plan or to meetings requested by the District at locations other than the Consultant's offices;

b) long distance telephone calls, facsimiles, telegrams and telex reasonably incurred by the Consultant in delivering the Services;

c) reproduction of drawings and specifications as required by the work plan;

d) advertising, delivery of reports, specifications or correspondence by courier, where this method of delivery has been requested by the District.

e) additional Comprehensive General Liability Insurance in compliance with clause 5.1 of this Agreement.

f) additional professional liability insurance in compliance with clause 5.4 of this Agreement.

2.5 Reimbursement of expenses by the District will be at the rates prescribed in the Consultant's proposal or where not prescribed, will be at actual cost with an additional 5% to cover administrative expenses.

2.6 All other expenses not listed above are considered to be included in the Consultant's fees.

2.7 The Consultant shall submit invoices to the District representative or delegate on a monthly basis.

2.8 On each invoice the Consultant shall list the names, hours worked and pay rates of all employees of the Consultant or sub-consultants that have worked on the Services for the phase of the work plan.

2.9 Attached to each invoice shall be copies of invoices for all disbursements claimed; confirmation of payments made to sub-consultants, and a brief report detailing work completed to date, work completed during the period covered by the invoice and work outstanding to complete the Services.

2.10 If the District does not approve of or wishes to further review, audit or otherwise seek clarification concerning the Consultant's invoices, the District is not liable for interest charges in respect of the invoice for the period from the date the invoice is submitted until the date that the invoice is paid.

2.11 If the District approves the amount of an invoice, the District will cause the invoice to be paid on or before the 15th day of the month following receipt and approval of the invoice.

2.12 The Consultant must keep proper accounts and records of all costs and expenditures forming the basis of any billing to the District, including but not limited to hours worked, details of all disbursements and percentage amounts of work completed.

2.13 The District is entitled to verify the accuracy and validity of all billing and payments made by auditing and taking extracts from the books and records of the Consultant.

3. CHANGES TO SCOPE OF SERVICES

3.1 The District may at any time vary the scope of work to be provided by the Consultant.

3.2 If the Consultant considers that any request or instruction from the District constitutes a change in the scope of the Services, the Consultant must advise the District within ten days in writing.

3.3 Without written advice within the time period specified, the District is not obligated to make any payments for additional fees to the Consultant.

4. INDEMNIFICATION

4.1 The Consultant shall at all times indemnify and save harmless the District and or any of its officers, employees or agents from and against all claims and demands, loss, costs, damages, actions, suits, fees, or other proceedings by whomsoever made, brought or prosecuted, in any manner based upon, occasioned by or attributable to errors, omissions or negligent acts of the Consultant that occur related to the execution of this Agreement, or the exercise in any manner of rights arising under this Agreement, except claims for damage resulting from the negligence of any officer, servant or agent of the District while acting within the scope of their duties of employment.

4.2 The Consultant is responsible for Workers' Compensation Board assessments relating to the Services under this Agreement and the work of its sub-consultants.

4.3 The Consultant indemnifies the District from and against all claims related to personal injury including death, property damage, losses, costs and expenses arising out of or related to the provision of the Services including Workers' Compensation Board claims and assessments.

4.4 This release and covenant of indemnification shall survive the termination of this Agreement.

5. <u>INSURANCE</u>

5.1 At all times during this Agreement, the Consultant must maintain public liability and property damage insurance with an insurer satisfactory to the District in accordance with the following terms:

a) Comprehensive General Liability Insurance in the amount of not less than $3,000,000.00 inclusive per occurrence for bodily injury or property damage. The District must be added as an ADDITIONAL NAMED INSURED and the policy must contain an endorsement to provide the District with thirty (30) days prior written notice of cancellation or material changes to the policy.

b) Automobile, public liability and property damage in the amount of not less than $2,000,000.00 per occurrence per owned, non-owned or hired vehicle.

5.2 The Consultant must provide to the District, prior to the commencement of the Services, a certificate of insurance or other evidence which satisfies the District that the required insurance has been acquired and is in force.

5.3 The Consultant is responsible for any deductible amounts under the policies. Other than the additional insurance identified in clause 2.4, the cost of all insurance required by this contract shall be included in the Consultant's fees.

5.4 The Consultant will obtain professional liability (errors & omissions) insurance in an amount not less than $3,000,000 per claim and no limit in the aggregate for all claims.

6. <u>DISTRICT APPROVALS</u>

No reviews, approvals or inspections carried out or information supplied by the District or its employees derogate from the duties and obligations of the Consultant, with respect to the services, and all responsibility for the services is the Consultant's.

7. TERMINATION

7.1 At any time, in its sole judgement, the District may terminate the services of the Consultant in whole or part by giving 10 days written notice to the Consultant signed by the (Department Head) or delegate.

7.2 If termination is not for cause, the Consultant shall be paid at the rate prescribed for all Services properly performed to the date of the delivery of the notice according to the terms of this Agreement, plus necessary and reasonable wind up costs incurred, if any, in closing out the Services or the part terminated.

8. CONFIDENTIALITY

8.1 The Consultant acknowledges that in performing the Services required under this Agreement, it will acquire information about certain matters which is confidential to the District, and the information is the exclusive property of the District.

8.2 The Consultant undertakes to treat as confidential all information received by reason of its position as Consultant, and agrees not to disclose it to any third party either during performance of the Services or after the Services have been rendered under this Agreement.

9. OWNERSHIP OF DOCUMENTS

9.1 All drawings, plans, models, designs, specifications, reports and other documents produced from the Services shall become the sole property of the District, and the District shall have the right to utilize all of them for its benefit in any way it sees fit without limitation.

9.2 If required by the District, the Consultant will assign any copyright of the product of the Consultant's Services and will obtain similar assignments from the sub-consultants.

10. TIME

Time is of the essence in carrying out the Services.

11. RESOLUTION OF DISPUTES

11.1 This Agreement shall be governed by the laws of the Province of British Columbia.

11.2 All matters in dispute between the parties in relation to this agreement shall be referred to the arbitration of a single arbitrator, if the parties so agree, or to three arbitrators failing such an agreement, in which case each party shall appoint one arbitrator, and the first two named shall choose the third arbitrator. Any arbitration shall be conducted in accordance with the Commercial Arbitration Act (British Columbia). The award and determination shall be binding upon the parties hereto and their successors and assigns.

11.3 The cost of arbitration will be borne equally by the parties.

IN WITNESS WHEREOF THE parties hereto have executed this Agreement the ________day of __________, 2004.

The Corporate Seal of the District of Campbell River
was affixed in the presence of:

)
)
____________________________________)
MAYOR
)
)
____________________________________)
CLERK)

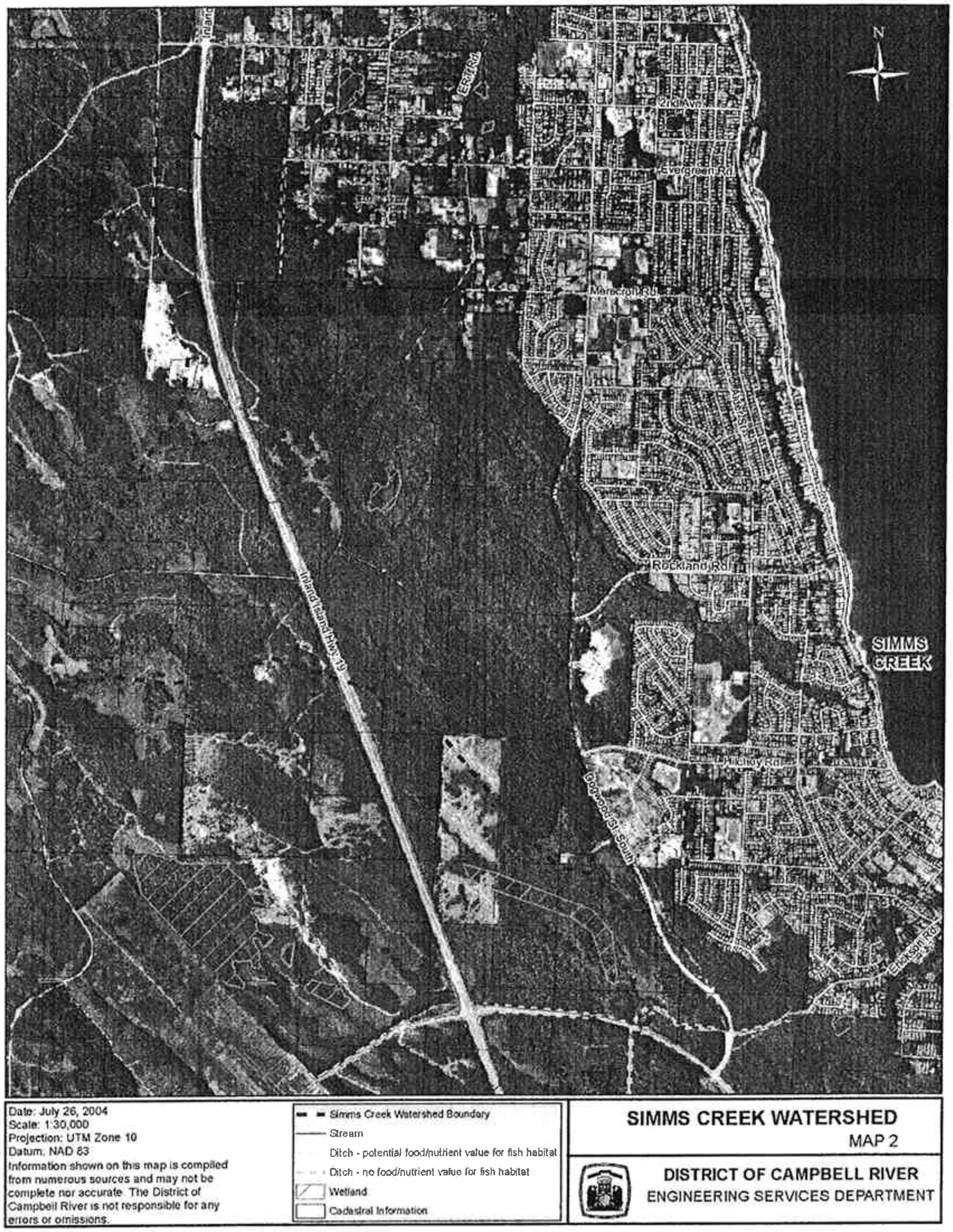
____________________________________	____________________________________
AUTHORIZED SIGNATORY	WITNESS
____________________________________	____________________________________
AUTHORIZED SIGNATORY	WITNESS

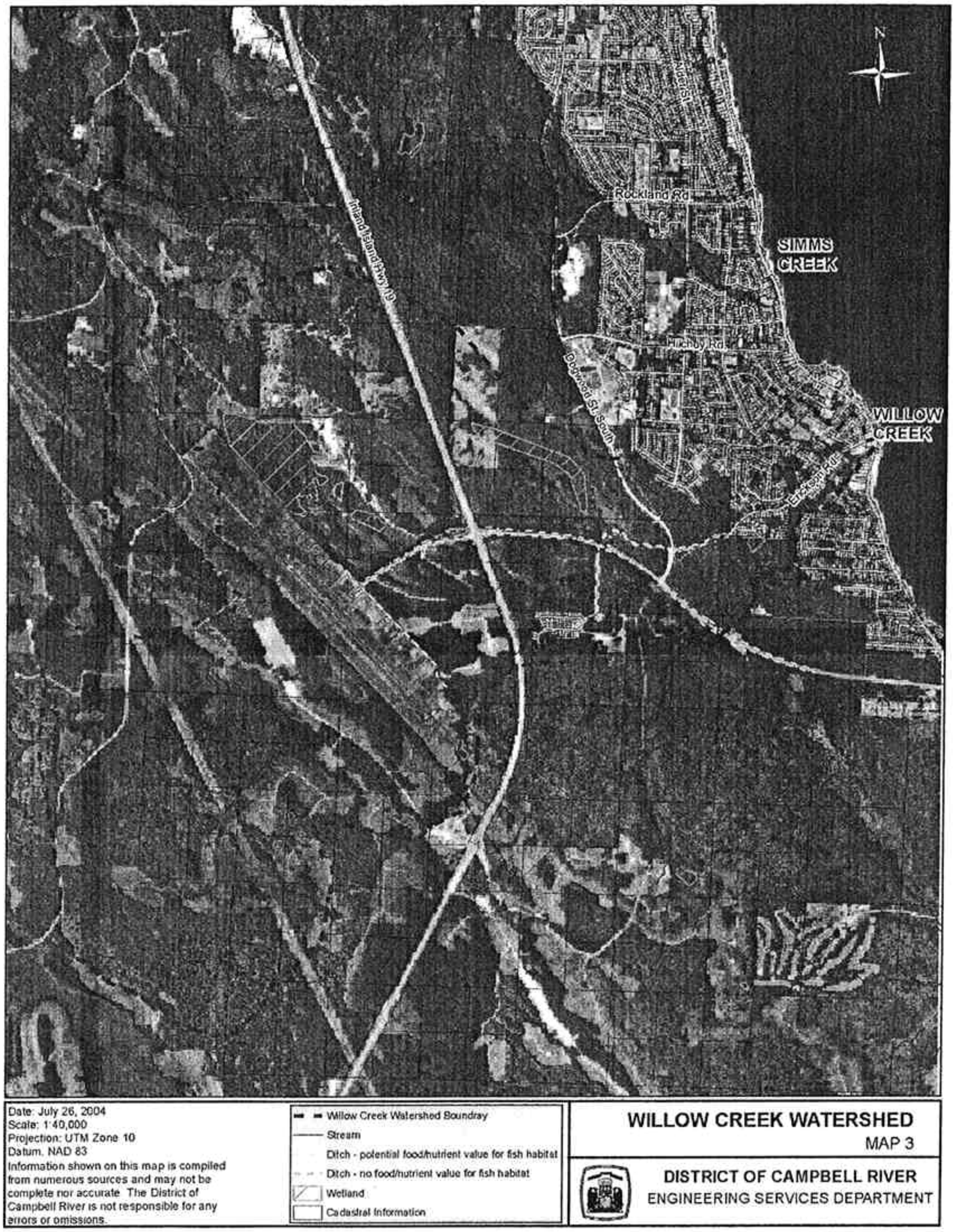
BETWEEN:

The District of Campbell River

AND:


N
NUNNS CREEK
Campbell River
10th Ave
Inland Island Highway 19
Petersen Rd
Dogwood St
2nd Ave
Evergreen Rd
Merecroft Rd
Date: July 26, 2004
Scale: 1:25,000
Projection: UTM Zone 10
Datum: NAD 83
Information shown on this map is compiled from numerous sources and may not be complete nor accurate. The District of Campbell River is not responsible for any errors or omissions.
Nunns Creek Watershed Boundary
Stream
Ditch - potential food/nutrient value for fish habitat
Ditch - no food/nutrient value for fish habitat
Wetland
Cadastral Information
NUNNS CREEK WATERSHED
MAP 1
DISTRICT OF CAMPBELL RIVER
ENGINEERING SERVICES DEPARTMENT


N
2nd Ave
Evergreen Rd
Rockland Rd
SIMMS
CREEK
Date: July 26, 2004
Scale: 1:30,000
Projection: UTM Zone 10
Datum: NAD 83
Information shown on this map is compiled from numerous sources and may not be complete nor accurate. The District of Campbell River is not responsible for any errors or omissions.
Simms Creek Watershed Boundary
Stream
Ditch - potential food/nutrient value for fish habitat
Ditch - no food/nutrient value for fish habitat
Wetland
Cadastral Information
SIMMS CREEK WATERSHED
MAP 2
DISTRICT OF CAMPBELL RIVER
ENGINEERING SERVICES DEPARTMENT


N
Rockland Rd
SIMMS CREEK
Hilchey Rd
WILLOW CREEK
Date: July 26, 2004
Scale: 1:40,000
Projection: UTM Zone 10
Datum. NAD 83
Information shown on this map is compiled from numerous sources and may not be complete nor accurate. The District of Campbell River is not responsible for any errors or omissions.
Willow Creek Watershed Boundray
Stream
Ditch - potential food/nutrient value for fish habitat
Ditch - no food/nutrient value for fish habitat
Wetland
Cadastral Information
WILLOW CREEK WATERSHED
MAP 3
DISTRICT OF CAMPBELL RIVER
ENGINEERING SERVICES DEPARTMENT