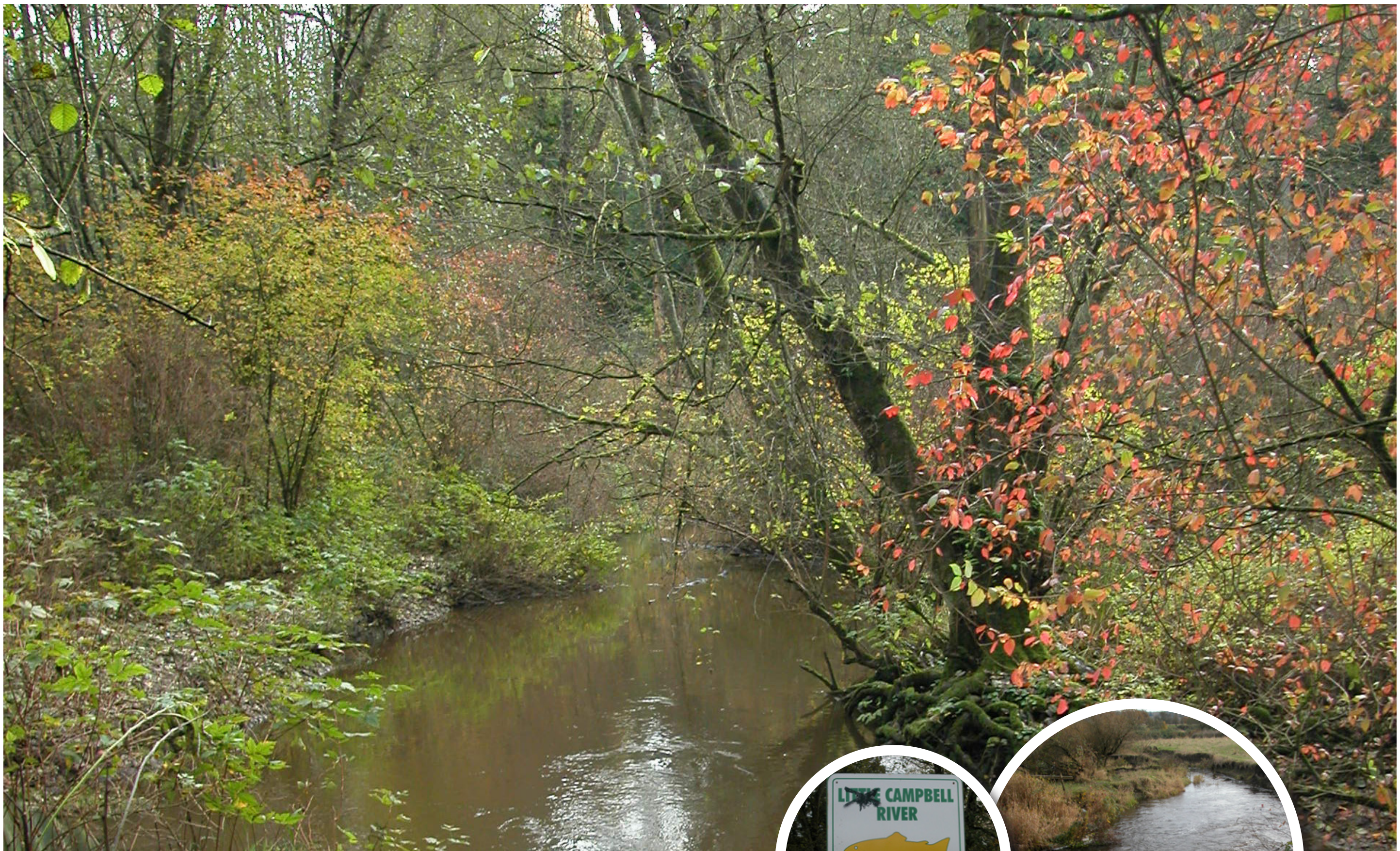

Revised Report

Douglas NCP Storm Drainage Servicing Concept

February, 2007

Prepared for

Cressey Development
& Equitas

For Review By The
City of Surrey

Prepared by

CH2MHILL

W112005001VBC

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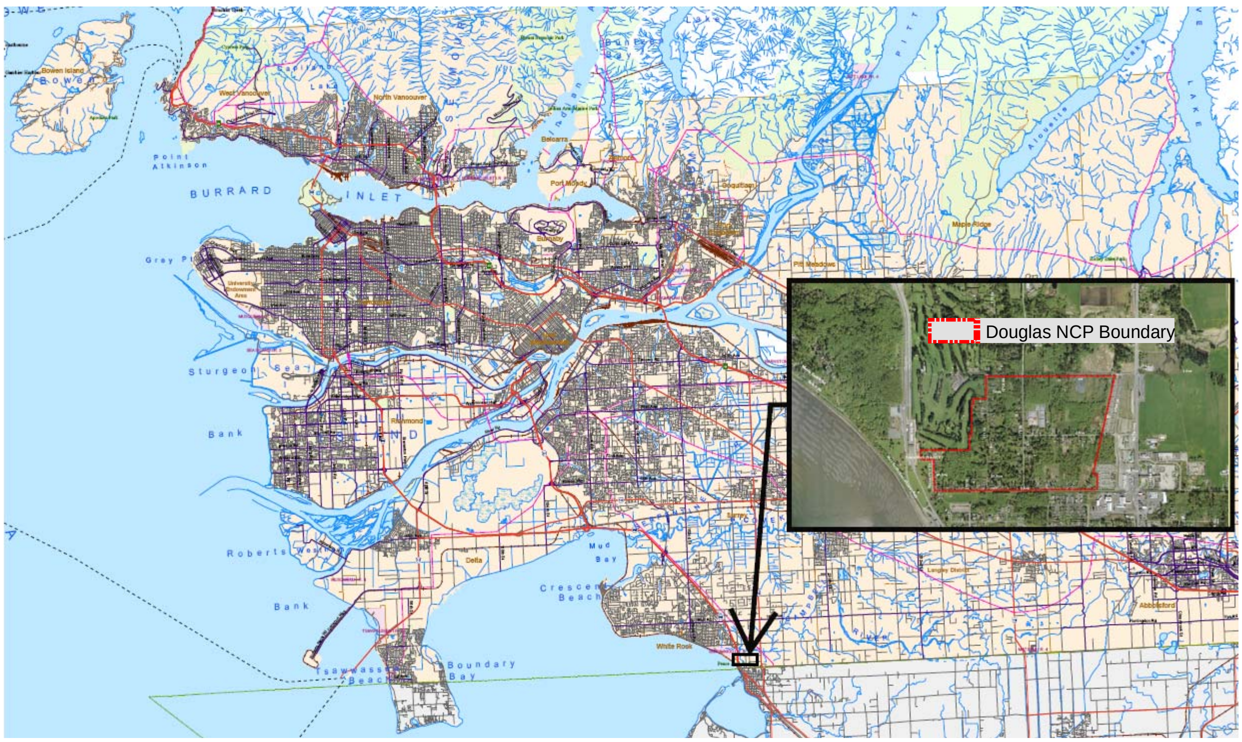
1 Introduction

The following report provides a review and update to the drainage servicing plan for the Douglas Neighbourhood Concept Plan (Douglas NCP). Douglas NCP is located in South Surrey, immediately east of the Peace Arch border crossing. (See Figure 1-1 – Vicinity Map)

This report was prepared by Gabor Vasarhelyi, Mauricio Herrera, and Eric Emery of CH2M HILL. The financial analysis in Section 6.4 was prepared by Aplin & Martin.

FIGURE 1-1
Vicinity Map



(Source background map: B.C. Ministry of Transportation)

The proposed neighbourhood covers an area of approximately 80 ha (198 acres) of land east of Highway 99, south of 4th Avenue and west of 176th Street in the City of Surrey (Figure 1-2). The Douglas NCP is within the Campbell River (also known as the Little Campbell River) watershed.

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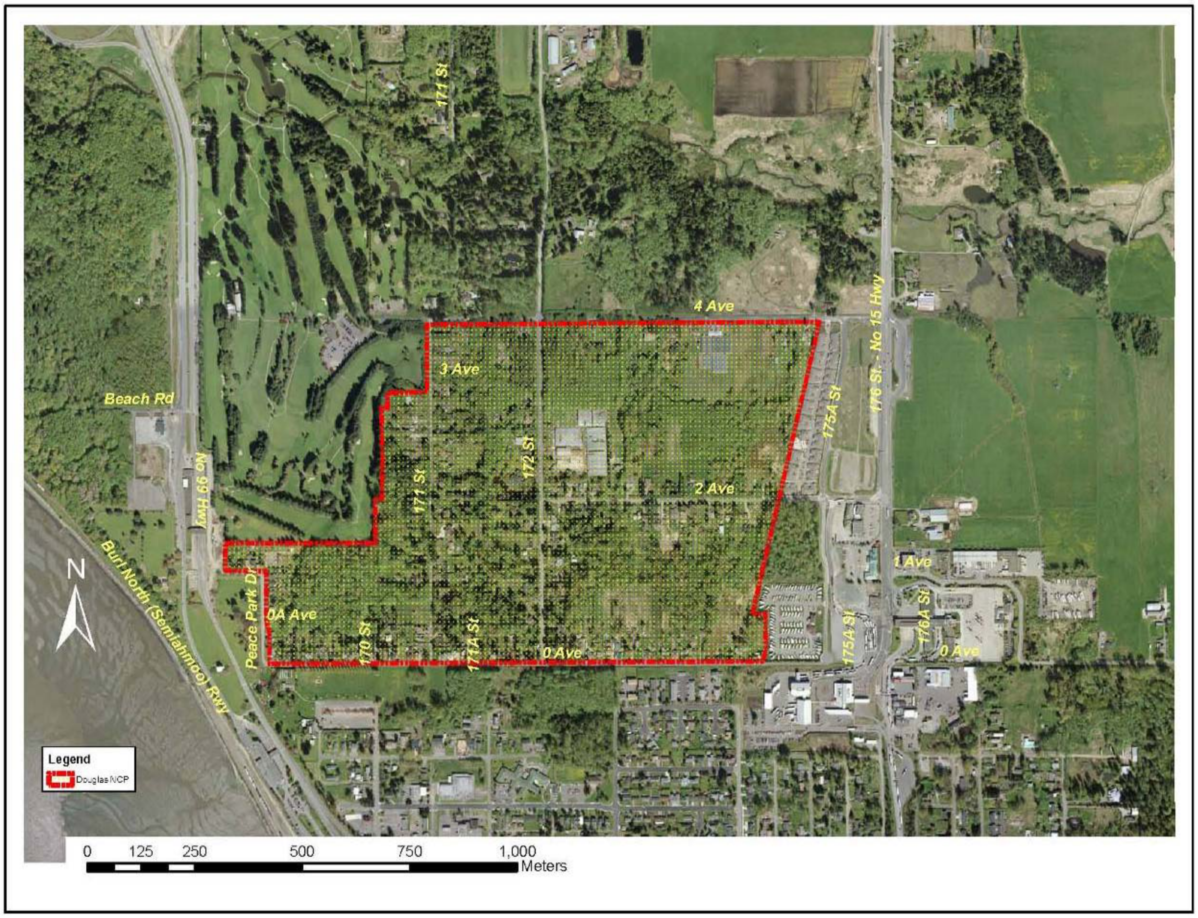
FIGURE 1-2
Location Map



In 1999, the City of Surrey completed and approved a land use and servicing plan for the Douglas Neighbourhood Concept Plan (Douglas NCP). The servicing plan was completed as part of the Douglas NCP by McElhanney Consulting. The servicing plan was based on the approved land use at the time, as well as the engineering standards applicable in 1999.

Cressey Development is in the process of developing an area of approximately 24 ha (60 acre) in the east of the Douglas NCP. Equitas and other developers are planning the development of other areas in the easterly part of the NCP in conjunction with Cressey's plan. The proposed land use plan includes development densities that are higher than those approved in 1999. The plans also propose basements for the buildings. The proposed changes require a review and update of the NCP and servicing plan to address technical, environmental, and hydraulic concerns. These changes not only concern the proposed Cressey development, but also involve implications on the entire NCP.

The objective of the 2006 NCP Amendment presented in this document is to develop a revised stormwater servicing plan for the Douglas NCP that will support the updated development plans proposed by Cressey and address implications on the NCP area. In particular, the following issues are addressed in this report:

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- Potential increased flooding and erosion along the lower reach of Campbell River, and its tributaries which drain the western portion of the Douglas NCP, in particular the reach of the Campbell River and tributaries through lands owned by the Peace Portal Golf Course (PPGC)
- Servicing depths for basements and how servicing can deal with the relatively flat topography, as well as concerns about the impact on groundwater
- Off-site right of way needs for storm drainage servicing for the Douglas NCP
- Review and approval of the Servicing Plan by the City of Surrey

The scope of the present work includes the following:

- Establishing baseline (or current land use) hydraulic conditions for the lower reach of the Campbell River Watershed
- Developing a hydrologic/hydraulic model to assess the impact of the proposed Douglas NCP land use and servicing on the lower reaches of the Campbell River as well as the related tributaries between the Douglas NCP and the River
- Comparing system performance during existing and proposed future development conditions
- Developing a storm drainage servicing concept for the Douglas NCP that can meet the acceptance of the land owners, the City, and the environmental agencies

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2 Background

2.1 Campbell River

Campbell River originates in the Township of Langley, east of 240th Street. The water course is approximately 27 km long between 240th Street and Highway 99 in the City of Surrey, at the downstream end of the study area. The River discharges into Boundary Bay in the Pacific Ocean, approximately 2.7 km downstream of Highway 99. The slope of the river bed is gentle, approximately 0.26 % along its 27 km length.

The area of the Campbell River Watershed upstream of Highway 99 is approximately 7,101 ha or 71 km^2, as shown in Figure 2-1. Approximately 3,385 ha are located in the City of Surrey, 3,166 ha in the Township of Langley and 550 ha in Whatcom County in the State of Washington. The primary focus of the present study is the impact of post development stormwater discharges in the lower portion of the Campbell River watershed. This focus area includes 295 ha between 176th Street and Highway 99 and south of 8th Avenue that encompasses the area of the Douglas NCP.

The topography of the Campbell River watershed may be characterized as gentle rolling hills above a flat, variable width floodplain. Ground elevations vary between sea level at the outfall to the Ocean and 130 m at the easterly boundary of the watershed.

The existing land use in the watershed is predominantly rural and agricultural. There are areas with existing and planned residential, commercial, and light industrial centres located in Campbell Heights, the Township of Langley, and the Fergus Creek sub-watershed in Surrey. A cursory review of stormwater management practices in the watershed shows that the area is serviced primarily with open channels. Most impervious areas are discharged to pervious areas, and Low Impact Development (LID) practices have been applied in recent development projects. The current total impervious area represents 8.7 percent of the watershed.

One of the tributaries to the lower reach of Campbell River is Fergus Creek. McElhanney is in the process of developing an Integrated Stormwater Management Plan (ISMP) for Fergus Creek and has provided hydrologic parameters for the Fergus Creek watershed.

The 2.7 km reach of Campbell River downstream of Highway 99 was included in the analysis for the evaluation of tidal impact on the hydraulic performance of Campbell River and its tributaries. The area of Douglas NCP and the PPGC south of Campbell River was modelled to a level of detail that was sufficient for the conceptual design of the storm drainage system for the NCP, to evaluate the impact of the Douglas NCP drainage system, as well as evaluate options to deal with impacts.

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Legend

- Points Of Interest
- Campbell River
- Upstream of Highway 99
- Douglas NCP
- Campbell River Tributaries

0 500 1,000 2,000 3,000 4,000 Meters

Client: Cressey Developments
Project: Douglas NCP Surrey, B.C.
Date: October, 2006
Title: **Campbell River Watershed**
Figure: **2.1**

2.2 Douglas NCP

Douglas NCP is located at the south-westerly corner of the Campbell River watershed. The 80.1 ha NCP represents 1.1% of the 7,101 ha Campbell River watershed upstream of Highway 99. The NCP drainage system has two outfalls into Campbell River. The westerly outfall reaches Campbell River 270 m upstream of Highway 99 via an existing storm drain through the PPGC. The easterly outfall reaches Campbell River 2,200 m further upstream via an existing storm drain system in 176th Street.

Existing land use in the Douglas NCP area is primarily agricultural with some low density residential development along the major streets, such as 0 Avenue, 4th Avenue, and 172nd Street. There are commercial and residential developments east of the NCP, along 176th Street, and a golf course west of the NCP.

The approved 1999 NCP is based on a land use that included 954 dwelling units on 48.8 ha land, allocated 0.7 ha area for commercial use, 5.35 ha for a joint school/park site, 1.4 ha for detention ponds, and 5.3 ha for parks and open space, for a total of 61.55 ha developable land and 18.55 ha area for public roads within the 80.1 ha total area of the NCP.

The 2006 NCP Amendment uses the same land allocation, except the 1.4 ha area for detention ponds is added to residential land use, and higher population densities are used in the residential areas. The proposed land use for the 2006 NCP Amendment includes 1,674 primary and 300 secondary dwelling units on 50.2 ha land, and allocates 0.7 ha area for commercial use, 5.35 ha for a joint school/park site, and, 5.3 ha for parks and open space, for the same total of 61.55 ha developable land and 18.55 ha public roads.

Douglas NCP increases the total impervious area of the watershed by 0.55%, to a total of 9.25%. This increase will remain, similar to the rest of the watershed, disconnected (or "ineffective impervious area" in hydrologic terms) if LID practices are applied to stormwater management.

The proposed land use for the 2006 Amendment of the Douglas NCP is illustrated in Figure 2-2.

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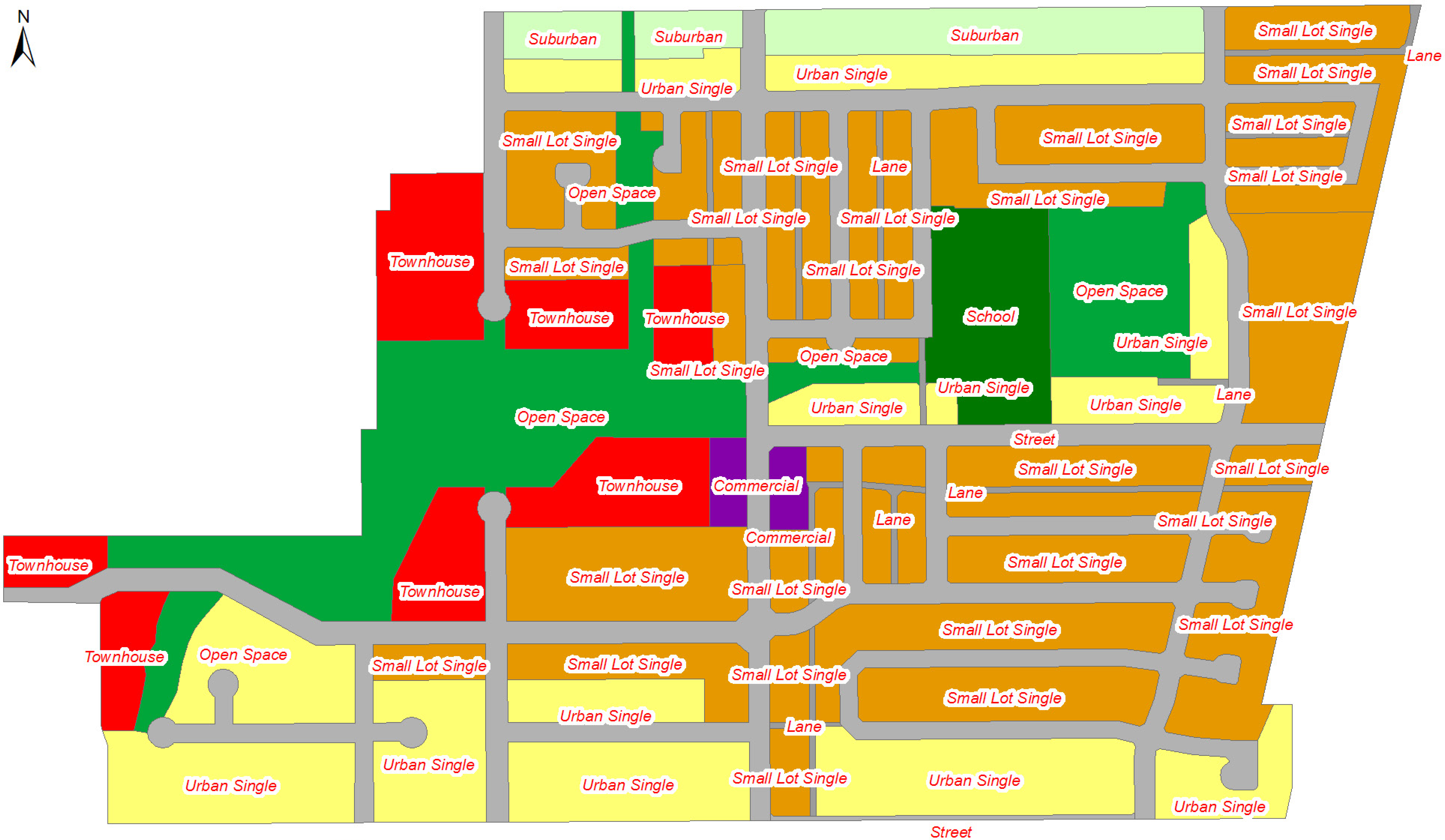

Legend

Proposed Land Use

- Commercial
- Lane
- Open Space
- School
- Small Lot Single
- Street
- Suburban
- Townhouse
- Urban Single

0 50 100 200 300 400 Meters

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Client: Cressey Developments

Project: Douglas NCP Surrey, B.C.

Date: October, 2006

Title: **Proposed NCP Land Use**

Figure: **2.2**

3 Approach

A systems analysis approach was adopted to analyze the impact of the Douglas NCP on the lower section of the Campbell River, with the following methodology:

- Establish baseline hydrologic conditions in the reach of Campbell River located between 176th Street and Highway 99. "Baseline condition" is defined as development conditions on the Campbell River watershed prior to any proposed development within the boundaries of Douglas NCP.
- Develop a drainage concept for the NCP that fits the needs of the proposed development to accommodate basements and satisfies the City of Surrey drainage design criteria.
- Evaluate the potential impact of the development on Campbell River without the implementation of any LID or other stormwater management practices and identify needs for mitigating measures.
- Develop applicable LID or other stormwater management practices and evaluate the impact of the development on Campbell River when the various mitigation measures are implemented.

To support the evaluations, an XP-SWMM model was built and calibrated, making best use of the available information. After the model was calibrated, it was used to assess the baseline and various future conditions, including the proposed development in the Douglas NCP. To be consistent with the focus of the study, the watershed upstream of 176th Street was discretized in 35 sub-areas – a level of detail that was appropriate to define runoff conditions and facilitate a simplified model calibration based on data from the 12th Avenue flow gauge. A similar level of detail was applied to the northerly tributary of the Campbell River reach, between 176th Street and Highway 99, which includes the Fergus Creek Basin.

The performance of the drainage system is evaluated at the following locations:

Flows:

- Campbell River upstream of Highway 99
- Overflow into the golf course from the east
- Pipe flow into the golf course from the east
- Campbell River downstream of 176th Street and the NCP East connection

Water surface elevations at:

- Campbell River at the Fergus Creek confluence
- Ponding in the southerly depression of the golf course
- Campbell River downstream of 176th Street

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In addition, flow duration curves for the following sites were developed using the long-term simulation results, using 12 months of rainfall data for the year of 2002:

- Campbell River upstream of Highway 99
- Campbell River downstream of 176th Street and the NCP East connection

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4 Data Analysis

An extensive data collection exercise was completed to validate the baseline condition model of the Little Campbell River. This section describes the sources of the data.

The primary sources of data included the City of Surrey, the Township of Langley, the City of White Rock, the Greater Vancouver Regional District, and other sources. The data set included topography, color ortho photos, digital maps, soils, land use, rainfall and flow data, information on existing drainage systems, previous concept plans, and currently proposed development plans for Douglas NCP.

4.1 Topography

Topographic survey data was obtained in the forms of 1-m contours, digital topographic maps, and high resolution color ortho photos for the part of the watershed that is located north of the international border in British Columbia. Digital topographic maps and black & white low resolution ortho photos were obtained for part of the watershed located south of the border in Whatcom County. This compiled information was used for delineating flow pattern and catchment boundaries for most of the watershed.

More detailed topographic survey data was available for the parts of the Douglas NCP currently planned for development.

A detailed topographic survey was performed for the reach of Campbell River east of 176th Street to west of Highway 99 to provide more detailed information for the hydraulic analysis of this river reach. The survey provided cross-section and profile information for the river bed, and detailed information of the geometry of the crossing bridges and culverts. Information from this survey was used to develop the hydraulic model for this reach of Campbell River.

4.2 Storm Drainage System

The GIS database of the closed conduit storm drainage system, owned and maintained by the City of Surrey and the Township of Langley and the City of White Rock, was obtained from the municipalities.

PPGC (Hub Engineering) provided some available as-built information for the golf course storm drain.

The easterly part of Douglas NCP drains to existing storm drains in 2nd and 4th Avenue. These City maintained storm drains discharge into a Ministry of Transportation (MoT) maintained storm drain system in 176th Street. Since no system data was available for the storm drains in this area, a detailed survey was conducted to locate manholes, storm drain inlets and outfalls, and provide information on invert and ground elevations, pipe shapes, sizes and materials.

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Information from these data sources was used to develop the detailed hydraulic model for the area and the immediate vicinity of Douglas NCP.

4.3 Land Use

Zoning data, in combination with lot legal data and ortho photos provided by the municipalities, were used to define existing land use on the Campbell River watershed (including the Douglas NCP area).

For proposed future land use within the Douglas NCP, the land use plan proposed by Cressey for the easterly part of the NCP, and the land use plan approved in 1999 for the westerly part, was used in the analysis.

4.4 Soils

Watershed scale soils information was obtained from the Soils of the Langley-Vancouver Map Area, RAB Bulletin 18, for British Columbia and from the U.S. Natural Resources Conservation Service (NRCS) database for Whatcom County. While neither set of data has provided direct information on the infiltration parameters of the various soils, the description of the soils provided sufficient information for initial estimates for the hydraulic conductivity of the soils, which was one of the primary parameters used in model calibration.

Figure 4-1 illustrates the soil distribution of the Campbell River watershed according to the NRCS (formerly SCS, Soil Conservation Service of the US Department of Agriculture) Hydrologic Soils Group classification of A through D.

Type A soils are *"Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravely sands. These soils have a high rate of water transmission "*.

Type D soils are *"Soils having a very slow infiltration rate when thoroughly wet. These consist chiefly of clay soils with a high swelling potential that have fine texture. These soils have a low rate of water transmission".*

Type B and C soils have hydraulic conductivity characteristics between the above two extremes.

It is observed that the upper area of the watershed is composed mainly of soils Type B with moderate infiltration rates. The upper area contains a significant portion of soils Type A with high infiltration rates. The presence of these permeable soils in the upper watershed indicates that groundwater contributes significant base flows and plays an important role in the flow characteristics of Campbell River. This finding was taken into account, both during model development and calibration, to properly account for this significant process.

Soil Type C, with slow infiltration rates, is present on the south-center and northwest slopes of the watershed, while soil Type D, with very low infiltrates rates, is dominant in the south-westerly part of the watershed that includes that area of Douglas NCP.

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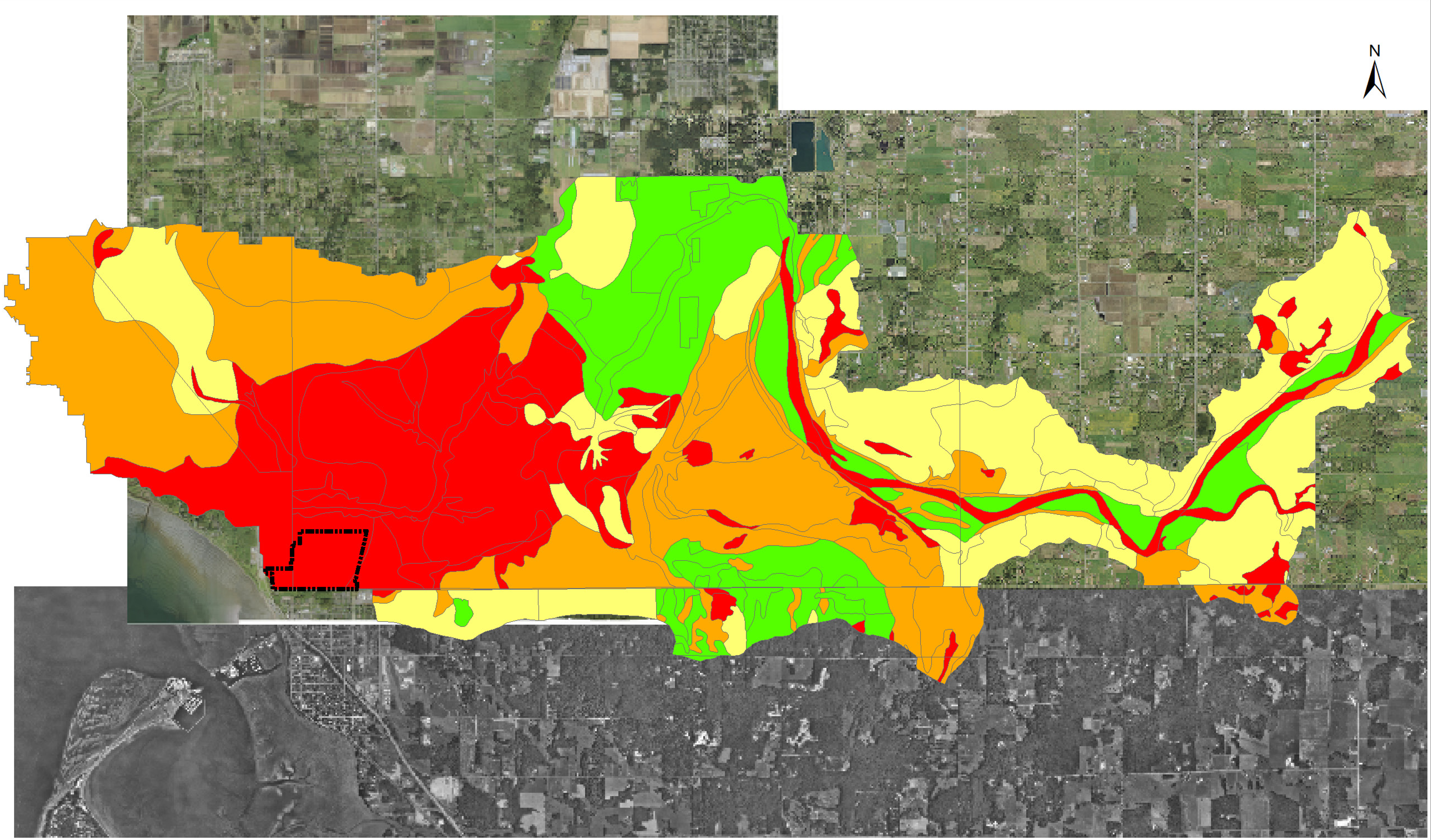

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Project: Douglas NCP Surrey, B.C.

Date: October, 2006

Title: **Campbell Watershed Soil Distribution**

Figure: **4.1**

Site specific soils information was obtained from the soils reports prepared for Cressey (Levelton, January 2005 and Thurber, June 2005) and for Equitas (Trow, June 2006). These investigations confirmed the presence of silt, clayey silt, and sandy silt soils in the upper 1.0 to 1.5 m soil layer. The infiltration capacity of these upper soil layers impacts the speed of absorption and the volume of rainfall that may be stored in the voids of the soils; therefore, infiltration capacity has significant impact on the surface runoff potential. The soil types found in the Douglas NCP area has low infiltration capacity; therefore, the surface runoff potential of the area is high.

The soil reports identified the presence of groundwater and indicated the seasonal variation of the groundwater level. The observed groundwater level in the test pits and bore holes was lower during summer dry periods (between 1 and 2 m below surface) and higher (less than 1 m below to near surface) during winter wet periods. While the permeability rate of the soils is low, and the change in groundwater levels is slow, some infiltration capacity is present and available when groundwater levels are kept low in the project area. This site condition may be considered in planning for the implementation of Low Impact Development (LID) practices for stormwater management.

4.5 Precipitation Data

Four rainfall gauges are located within, or in the vicinity of the Campbell River watershed, with various lengths of available observation records:

- WK47 White Rock Pump Station (GVRD, 1994 - 2006)
- Semiahmoo Fish & Game Club (City of Surrey, 2000 - 2006)
- SU48 Cloverdale Pump Station at 164th Street (GVRD, 1994 - 2006)
- TL36 Langley Central at 237th Street and 52nd Avenue (GVRD, 1993 - 2006)

The rainfall records for these stations are relatively short (12 to 13 years for the GVRD stations and five years for the City of Surrey station), but continuous and consistent with some data gaps in each of the data sets.

GVRD publishes IDF curves for their stations, based on observations of the past decade, which may be used for generating synthetic design storms for this study. Of the four stations, the White Rock and the Semiahmoo Fish & Game Club stations are located within, while the Cloverdale and Langley Central stations are located approximately 7 km north of the Campbell River watershed. No IDF curves are available for the Semiahmoo Fish & Game Club station; therefore, the IDF curves for the White Rock station were used for generating synthetic storms for the Campbell River system evaluations.

An evaluation of the rainfall records from the four stations indicates that there is no consistent variation in the timing of the storm events at the four stations that would justify the use of data from multiple rain gauges for the hydrologic analysis. The Semiahmoo Fish & Game Club station is located within and close to the centroid of the watershed and has available records for the period when reliable flow data is available for Campbell River; therefore, the records of this station have been selected for model calibration and continuous simulations.

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The City of Surrey, in their 2004 Design Criteria Manual, published Intensity-Duration-Frequency (IDF) curves based on 33 years of records prior to 1996 at the White Rock Sewer Treatment Plant for use in the design of storm drainage facilities in the South Surrey area. These IDF curves were used for generating short duration design storms for the conceptual design of the Douglas NCP storm drainage system.

4.6 Flow Data

There is a flow monitoring station at the 12th Avenue Bridge on Campbell River with available flow records for the years of 2000 to 2006. This station is maintained by the City of Surrey. Data from this station includes flow and water levels and was used for the calibration of the hydrologic/hydraulic model upstream of 12th Avenue.

A new flow monitoring station was installed in February 2006 on Campbell River at the Highway 99 culvert. The intent of this station was to provide water level and flow data for fine tuning the calibration of the watershed model for flows and calibrating the model for water surface elevations at the lower reach of Campbell River. The monitoring station includes two water level gauges, one upstream and one downstream of the Highway 99 culvert, and two bidirectional velocity sensors in two of the three barrels of the culvert. The reach of the Campbell River is under tidal influence. The water level sensors operate well, but the velocity sensors do not seem to provide useful information. During the relatively short observation period since the station was installed, no significant storm and subsequent flow events occurred in the area to provide useful information for refined model calibration for this phase of the project.

4.7 Tidal Influence

Campbell River discharges into Boundary Bay of the Pacific Ocean 2.7 km downstream of Highway 99. The lower reaches of the river are flat and wide, shaped by the tidal movement of water. Tide influence on the flow conditions at the lower reaches of Campbell River need to be included in the evaluation of the hydraulic performance of Campbell River and its tributaries.

Tide information was obtained from the Marine Environmental Data Service of the Fisheries and Oceans Canada. Of the available stations, data from Point Atkinson was selected for this study, as the closest permanent station to the Campbell River outfall with continuous records that are necessary for model calibration for water surface elevations. The Point Atkinson tidal data will have to be adjusted for the Campbell River outfall location when it is used for model calibration.

Site observations indicated that critical flooding events in the PPGC occurred when high flows in Campbell River coincided with high tide elevations in Boundary Bay. To simulate such conditions, large tide elevations were used for the evaluation of critical storm events and mean tide elevations for continuous simulations as boundary conditions in the models. The following geodetic tide elevations were used in the models with 25 hour tidal cycle:

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Tide Elevations at Point Atkinson	Mean Tide	Large Tide
Higher High Water (HHW)	1.30 m	1.96 m
Lower Low Water (LLW)	-1.94 m	-3.11 m

4.8 Hydrologic Parameters

Soils data was analyzed to estimate soil conductivity for runoff computations. Soils information was extracted from the "Soils of Langley-Vancouver Map Area" report by BC Ministry of Environment, 1981. Soil descriptions were interpreted to estimate the hydrologic parameters of the various soil types. The Green-Ampt infiltration parameters that are recommended for use in SWMM models, where more detailed soils data is not available, were used in the models for this study (Appendix A)

Land use data was analyzed to identify land use type and the associated impervious surfaces on the watershed, using the data in Table 5-3 of the City of Surrey Design Criteria Manual as a guide for percent impervious values for the various land use types:

Land Use Type	Percent Impervious Ratio
Commercial	90
Industrial	90
Residential	
RA, RA-G	50
RH, RH-G	55
RF, RF-SS, RM-D	65
RF-G, RM-M, RM-10, RM-15, RM-19, RM-30, RM-45, RM-70, RM-135, RMC-135	65
RMC150, RF-9, RF-12, RF-SD	80
Parks, Playgrounds, Cemeteries; Agricultural Land	20
Institution; School; Church	80

GIS analysis was applied to define applicable impervious values for each catchment area. For areas within the Douglas NCP, lots and streets were separated for a better definition of percent impervious values and the better definition of potential development impact due to various stormwater management practices in private lands and public road right-of-ways. Please see Figure 2-2 for proposed land use within the Douglas NCP.

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Some hydrologic parameters for Fergus Creek used in the ISMP study have been provided by McElhanney. The hydrologic method used in the Fergus Creek ISMP is different from the method used in this study and the provided hydrologic parameters are not applicable to the Campbell River/Douglas NCP model. The hydrologic parameters for the Fergus Creek basin were defined using the same method used for the rest of the watershed.

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5 Drainage System Analysis

The drainage system analysis has three distinct steps:

1. Establishing "Baseline" hydrology corresponding to the existing development condition in the Campbell River watershed.
2. Evaluating potential development impacts without mitigation measures.
3. Developing measures to mitigate development impacts and confirming that any changes to baseline hydrology are acceptable.

The focus of this analysis is a quantitative evaluation where changes to peak flow rates, water surface elevations, critical flow velocities, and runoff volumes are measured.

5.1 Baseline Hydrology

The Baseline Hydrologic analysis consists of the following steps:

- Developing an evaluation tool (hydrologic and hydraulic model)
- Calibrating the model
- Evaluating system performance during short duration storm events as well as during a longer period using continuous simulation
- Establishing "Baseline" hydrologic parameters at significant points of the system

5.1.1 Developing the Evaluation Tool

The drainage system analysis requires the combination of a hydrologic and hydraulic model to determine flows and channel routing effects to predict water surface elevations and flows in response to rainfall events. The XP-SWMM model was selected and set-up for the Campbell River watershed. The model was initially used to define the flow characteristics for the existing, or baseline, condition. The model was then used to determine the effect of various storm drainage servicing options for the future land use conditions for the Douglas NCP.

The model upstream of 176th Street was developed to a level of detail that was sufficient for a reasonable estimation of flow rates in Campbell River. System geometry was established from 1-m contour topography and field observation of crossing culverts and bridges. The model downstream of Highway 99 was also limited in details, but sufficient for simulating tidal influence on the reach of Campbell River between 176th Street and Highway 99. The northerly tributary of this reach (which includes the Fergus Creek basin) was developed to a level of detail that is similar to the model upstream of 176th Street.

The model for the reach of Campbell River between 176th Street and Highway 99, and its southerly tributary that includes Douglas NCP, was developed based on data obtained by

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topographic surveys to a level of detail that is sufficient for the evaluation of the hydraulic performance of all storm drainage structures within this focus area of the study.

5.1.2 Model Calibration

Model calibration is important because it provides a validation of the results of the hydrologic and hydraulic modelling. Calibration is a process in which model parameters are adjusted until a reasonable agreement is found between the observed watershed response and the computed model output for the same time and location. For watershed models, it is typical to use flow as the response function for calibration.

Adjusted parameters from the calibration of flows at the monitoring site were translated to the lower section of the watershed. The original intent was to improve the calibration for the lower section by applying flow data from two newly-installed monitoring gauges located upstream and downstream of the culvert crossing under the Highway 99. However, no significant rainfall events occurred since this gauge was installed in mid-February 2006. Although the calibration presented in this study provides a reasonable validation of the watershed response, it is expected that further improvements can be achieved as data from the Highway 99 culvert station become available. The calibration results are shown in Figure 5-1.

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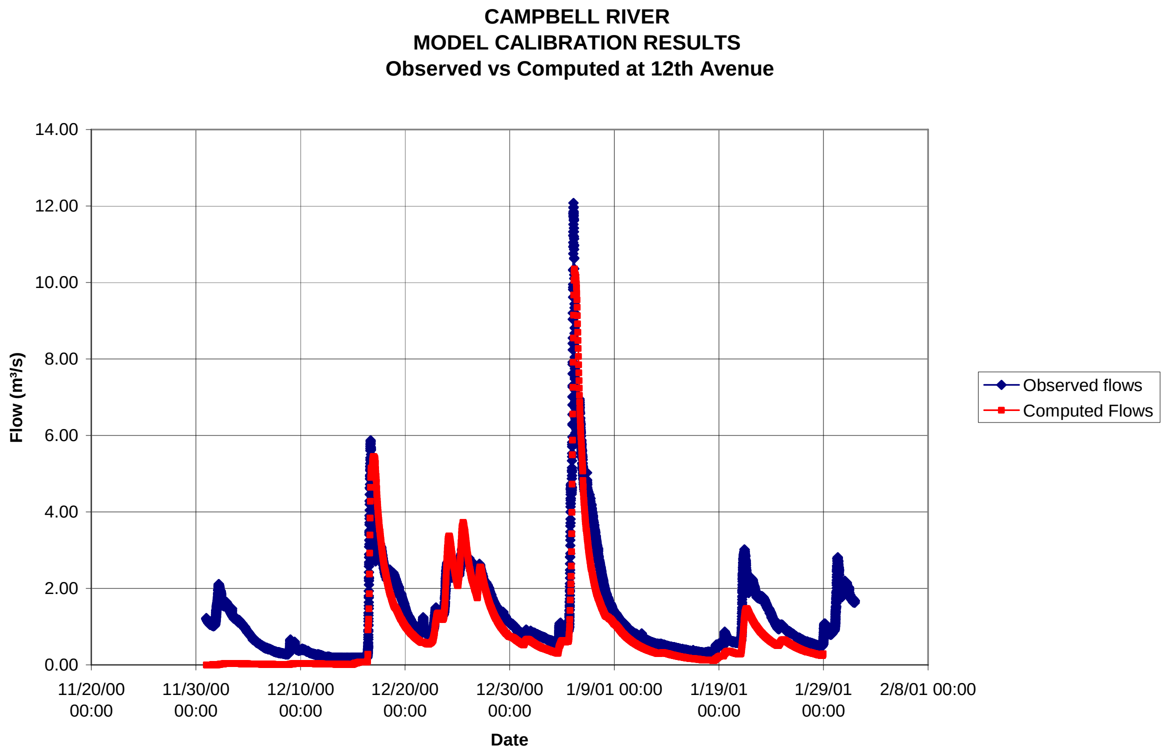
FIGURE 5-1
Calibration Results



5.1.3 Design Storm Events

For the evaluation of system performance during design storm events, 24-hour duration, 2-, 5-, 10-, 25-, 50-, and 100-year return frequency design storm events were developed. The basis of these design storms is the SCS Type 1a distribution and the IDF curves for the GVRD White Rock station for rainfall depth.

Return Frequency	2-year	5-year	10-year	25-year	50-year	100-year
24-hour Maximum Rainfall Depth	47.0 mm	77.6 mm	97.7 mm	123.1 mm	142.0 mm	160.7 mm

These 24-hour duration storm events were used to establish baseline hydrologic conditions for Campbell River during single storm events.

In addition, a significant storm event occurred October 16-18, 2003 in the area. The total rainfall for the 42-hour duration storm was 209 mm, with a 24-hour maximum of 143 mm at the Semiahmoo Fish & Game Club. This storm was used for evaluating system performance during extreme, long duration events such as the October 2003 storm.

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To simulate a potentially critical scenario, these events were time shifted to match the peak of the flow, with the peak of a large tide in the reach of Campbell River within PPGC.

The criteria for the design of the storm drainage system within Campbell River is the City of Surrey's 100-year return frequency design storm event for the South Surrey area of a duration that generates the highest peak flow rates in the Douglas NCP storm drainage system. To facilitate this criterion, the following 100-year return frequency design storms were developed:

Storm Duration	30-min	1-hour	2-hour	6-hour	12-hour	24-hour
100-year Return Frequency Rainfall Depth	25.7 mm	37.2 mm	45.3 mm	56.7 mm	69.4 mm	95.2 mm

5.1.4 Rainfall for Long-Term Simulation

To understand the extent of the impact of urbanization, other more frequent events, with recurrence periods of less than two years, must be evaluated. Because these events have been found to play a major role in channel-forming processes, it is particularly important to evaluate the impact of the Douglas NCP on the low flow range of the hydrologic regime. In addition, small rainfall events account for most of the pollutant wash-off from urban surfaces, reinforcing the need to analyze these smaller events. The rainfall records of the year 2002 were used for the long term analysis. The records of the year 2002 were selected because the rainfall was average/low for the year without extreme storm events, and the available data set was nearly complete with very few missing information. In addition, the Campbell River model includes fine details of the Douglas NCP storm drainage system that requires the use of short time steps for the simulation. This model set-up made a longer (for example, several years), continuous simulation impractical for this study.

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5.2 Baseline Hydrologic Parameters

To evaluate system performance and the potential impact of development servicing options within the Douglas NCP, the following locations have been selected in the model for summarizing and comparing flow and water surface elevations:

- Campbell River upstream of Highway 99 – Flow. (Conduit NCR9000 in the model) This is a location downstream of all discharges from the Douglas NCP into Campbell River, and representative to the river reach through PPGC.
- Campbell River at the Fergus Creek Confluence – Water Surface Elevation. (Node CR14000) This location is in the centre of the frequently flooded area within the PPGC.
- Campbell River downstream of 176th Street – Flow (Conduit NCR23000) and water surface elevation (Node CR23000). This reach is downstream of the easterly connections from the Douglas NCP into Campbell River.
- Southerly depression in PPGC. This is a low point without surface escape route for flows within the golf course. Water surface elevation is within and flows into the depression measured at the following locations:
  - Water surface elevation in southerly depression (Node PP05Det)
  - Pipe flow into the PPGC from the east (Conduit LPP07000)
  - Surface flow into the southerly depression (Conduit LPPGC-over)

Flows and water surface elevations are measured during 2-, 5-, 10-, 25-, 50-, and 100-year return frequency 24-hour duration synthetic design storms, as well as the observed October 2003 storm, coinciding with a large tide in Boundary Bay.

Floodplain boundaries for the reach of Campbell River between 176th Street and Highway 99 were delineated based on the computed water surface elevations in the river.

Flow duration, mean flows, and runoff volumes are measured at the above two locations in Campbell River (NCR9000 and NCR23000). Mean flows and runoff volumes from the Douglas NCP area are measured as the sum of the flows of all outlets from the NCP. These values were defined by continuous simulation using the records of the year 2002.

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5.2.1 Campbell River Upstream of Highway 99

Peak flows in Campbell River upstream of Highway 99 (Conduit NCR9000) for 24-hour duration synthetic design storms coinciding with a large tide in Boundary Bay, vary from 4.1 m^3/s for a 2-year storm to 78.8 m^3/s corresponding to a 100-year storm, as shown on Figure 5-2. The observed October 2003 storm under the same tidal conditions would have generated 83.4 m^3/s flows at the same location, as shown on Figure 5-3.

FIGURE 5-2
Campbell River Flows Upstream of Highway 99

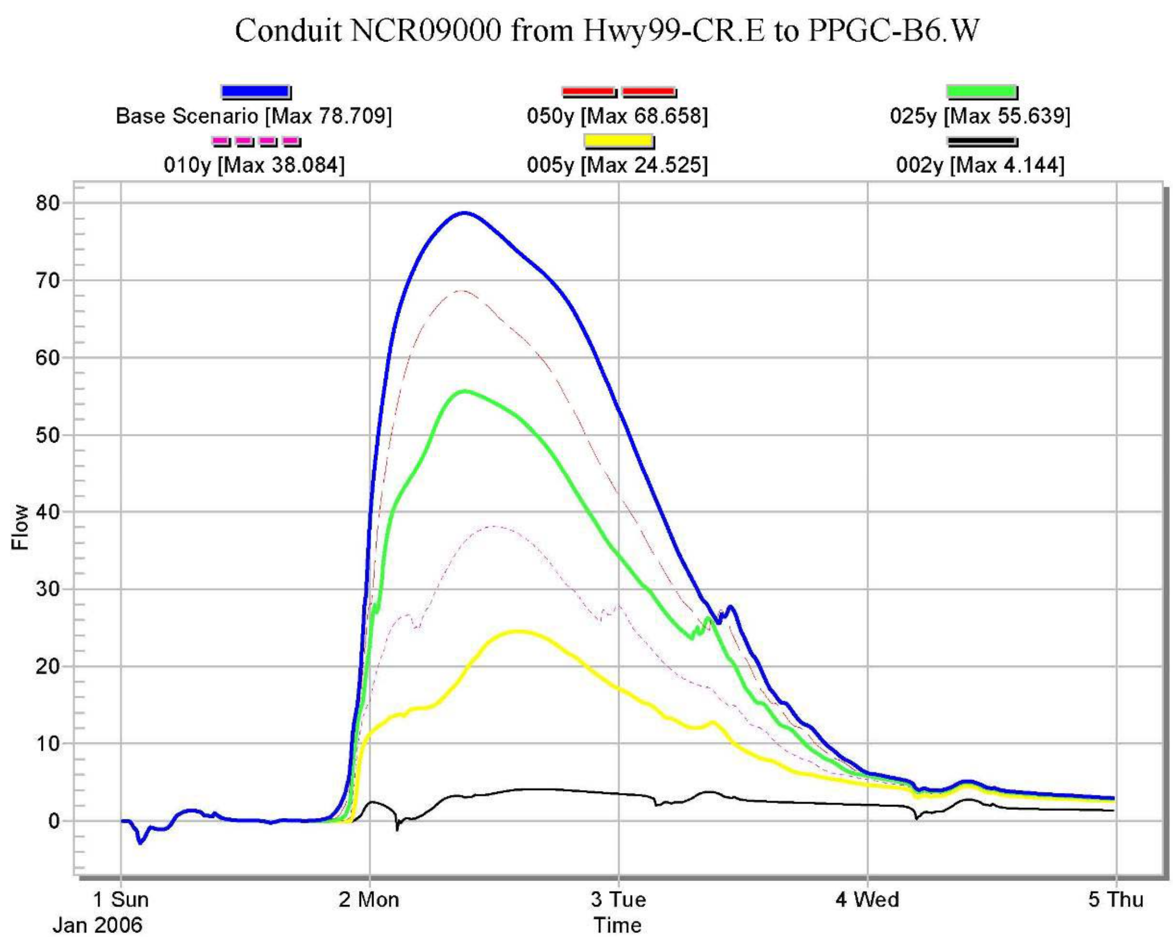

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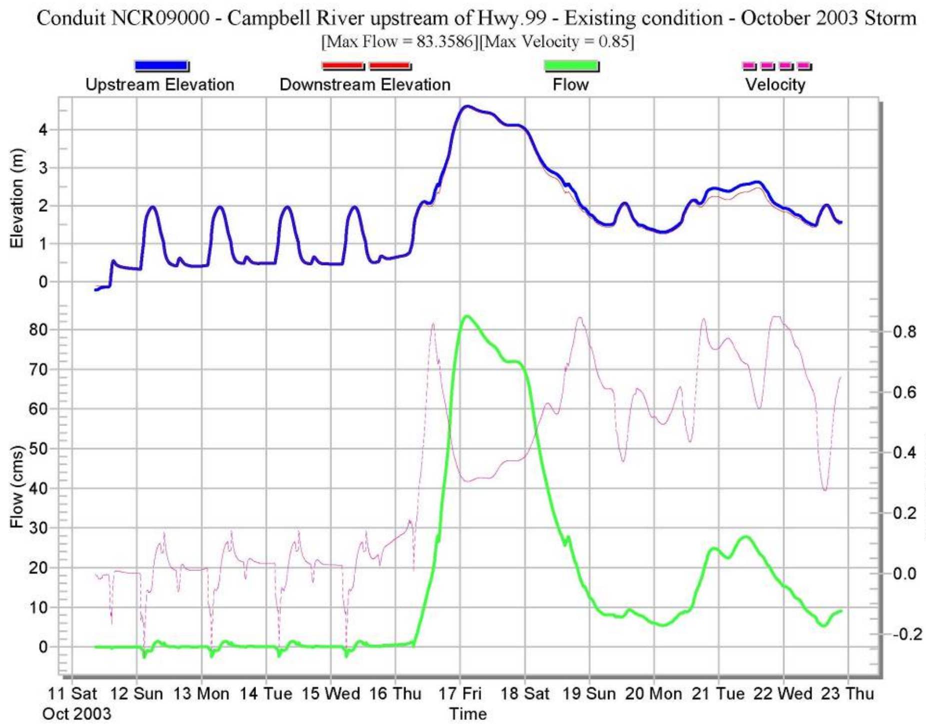
FIGURE 5-3
Campbell River Flows Upstream of Highway 99 – October 2003 Storm



The water surface elevations in this area (Fergus Creek confluence, Node 14000) vary from 2.0 m during a 2-year storm to 4.53 m during a 100-year storm (Figure 5-4). The 2-year flow is an approximate bank full flow condition, while the 100-year flow creates water depths up to 2.5 m in the golf course. The observed October 2003 storm would have created approximately 14 cm higher water surface elevations (4.67 m, Figure 5-5) than the 100-year storm.

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FIGURE 5-4
Campbell River Water Surface Elevations at Fergus Creek Confluence

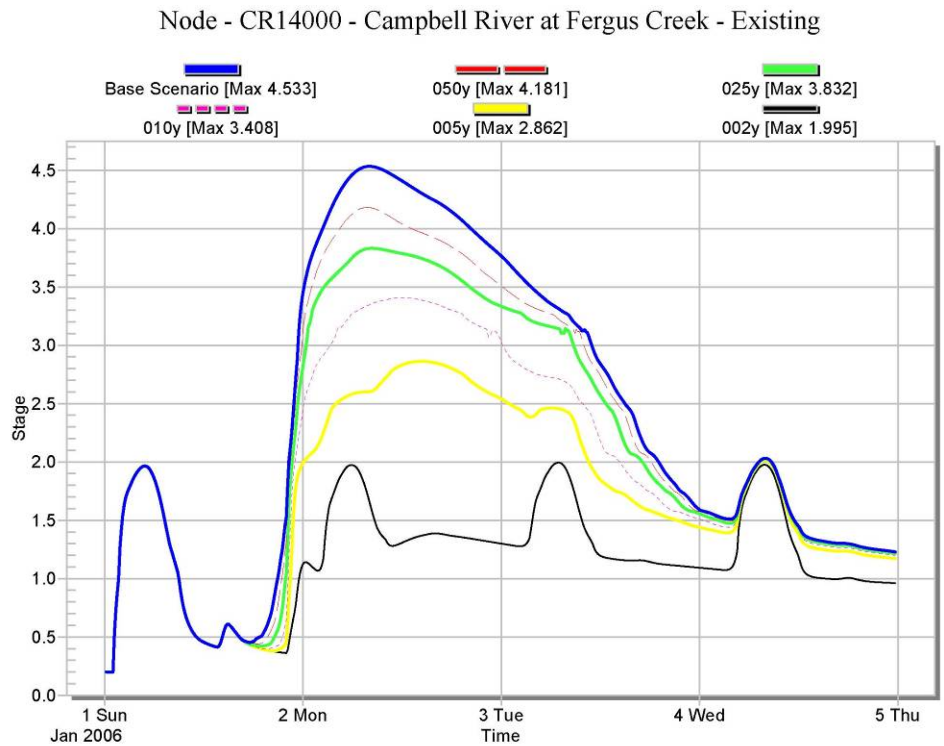
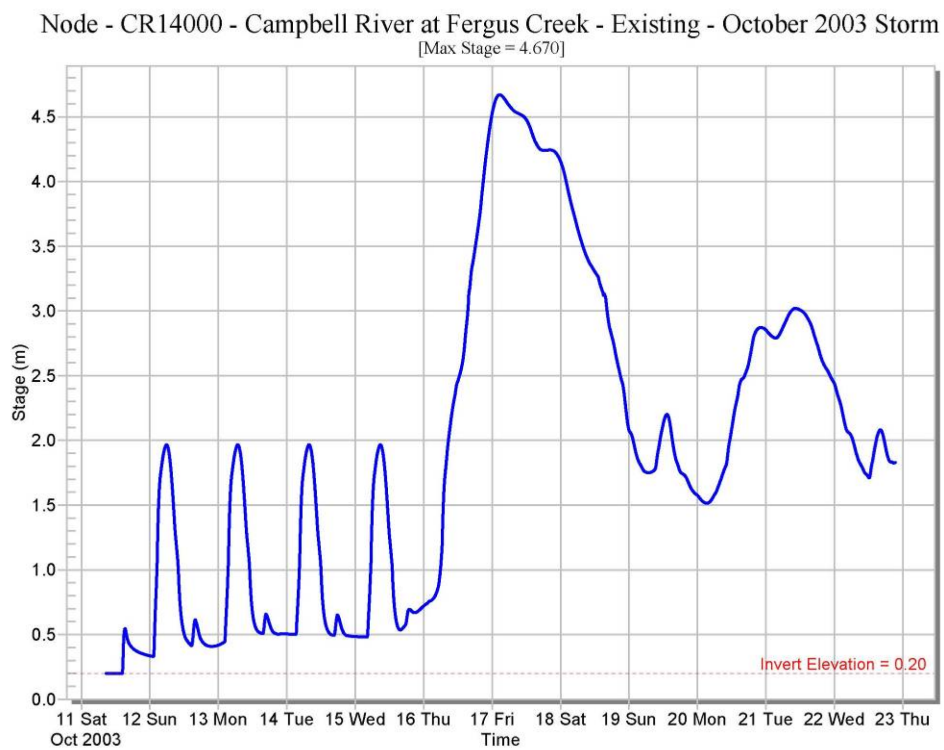


FIGURE 5-5
Campbell River Water Surface Elevations at Fergus Creek Confluence – October 2003 Storm



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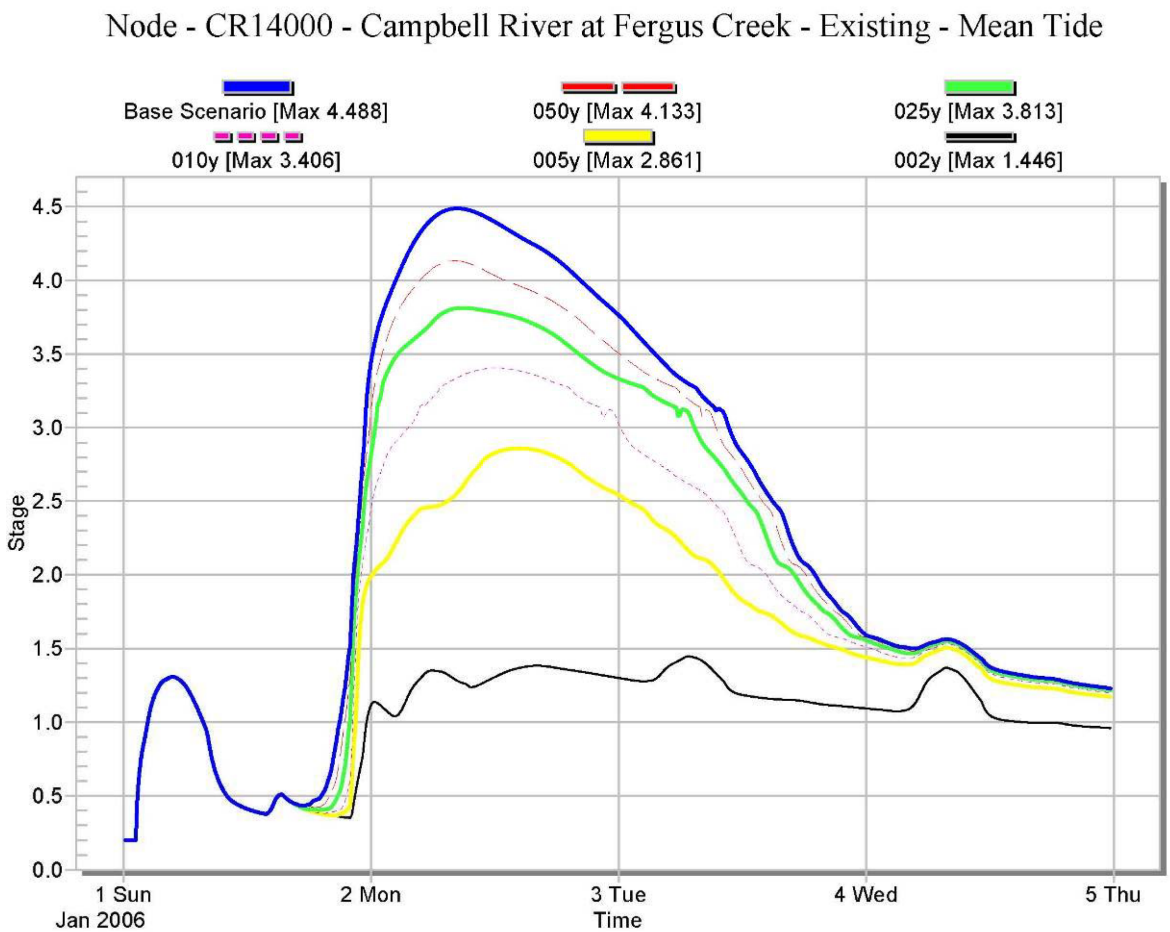
These water surface elevations indicate that bank full flow conditions could occur in this lower reach of Campbell River during large tides, even without significant flows in the river. Similar water surface elevations during a mean tide with minimal river flow are approximately 0.7 m lower. The influence of tide on water surface elevations in the lower reaches of Campbell River is greater with low river flows and gradually decreases as the rate of flow in the river increases. The difference between maximum water surface elevations during a large and a mean tide is 55 cm for a 2-year storm, and only 4 cm for a 100-year storm. Please see and compare Figures 5-4 and 5-6.

FIGURE 5-6
Campbell River Water Surface Elevations at Fergus Creek Confluence – Mean Tide



The profile of the Campbell River reach between 172nd Street and Highway 99 (Figure 5-7) and the cross-sections of the same reach (Figure 5-8) indicate that during a 100-year storm:

- The water surface elevations are relatively uniform throughout the reach and are primarily controlled by the hydraulic capacity of the natural river bed, and to a lesser degree, by the capacity of the Highway 99 culvert at the downstream end of the reach.
- The small bridges within the PPGC are flowing full and overtopped, but they do not create a significant constriction in Campbell River.

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- The depth of inundation is up to 2.5 m over the bank of Campbell River.

FIGURE 5-7
Campbell River Profile between 172nd Street and Highway 99 – 100-Year Storm

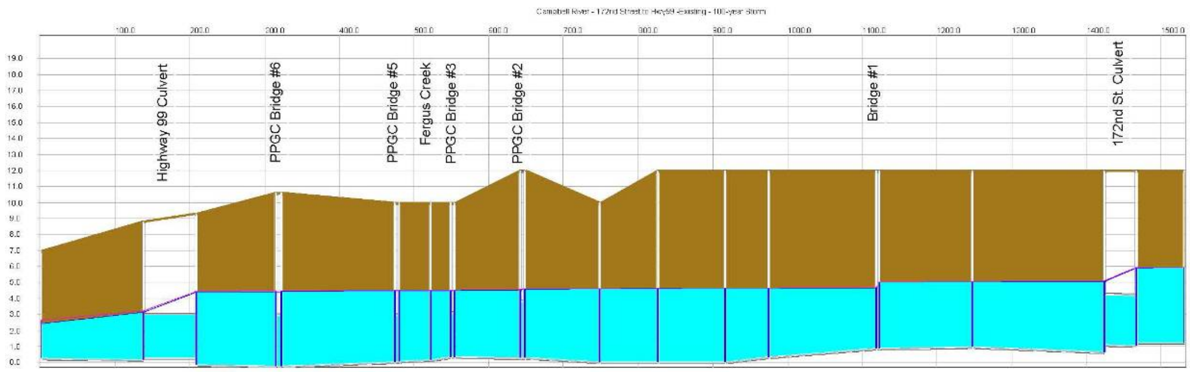

FIGURE 5-8
Campbell River Cross-Sections between 172nd Street and Highway 99 – 100-Year Storm

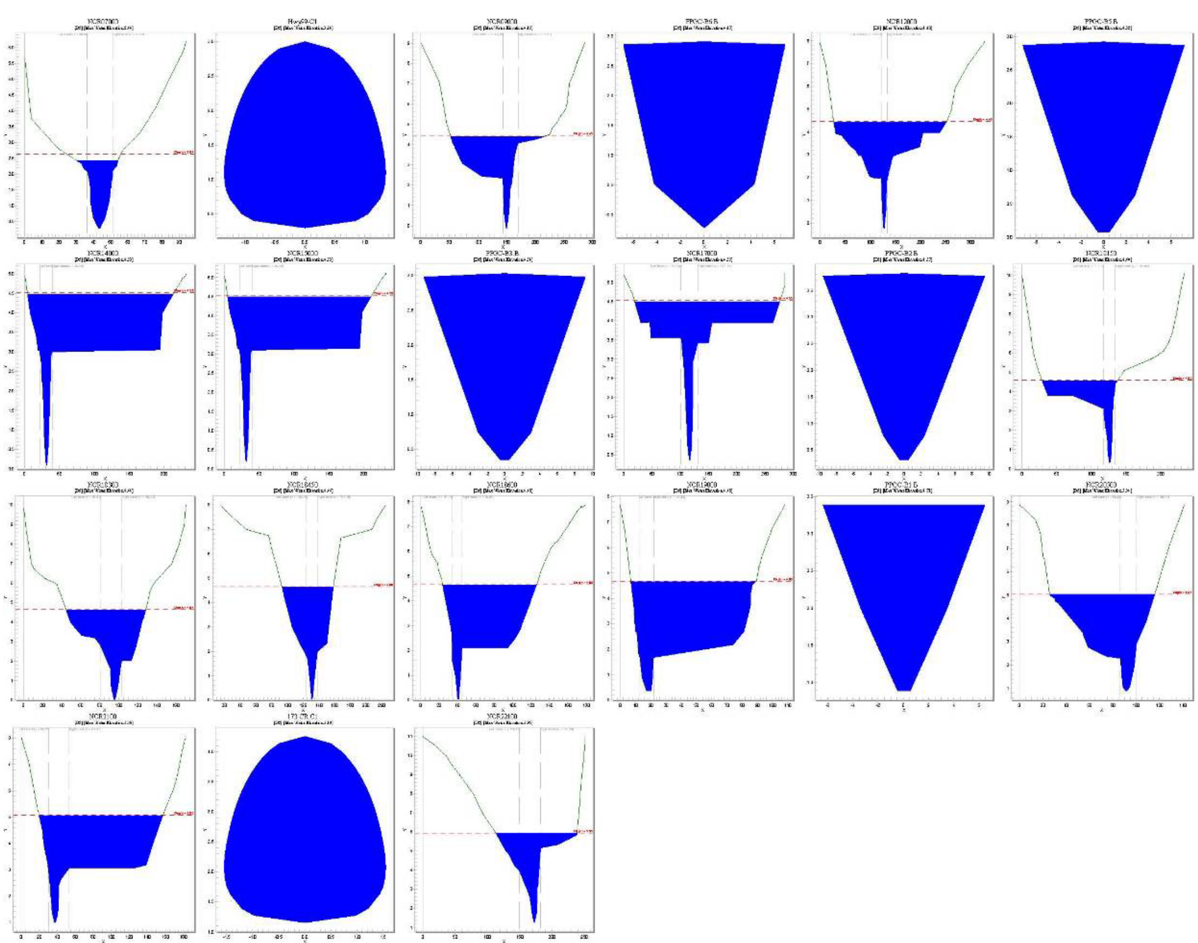

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Figure 5-9 shows the limits of the floodplain during a 2-year, 5-year, and 100-year storm, as well as during the observed October 2003 storm.

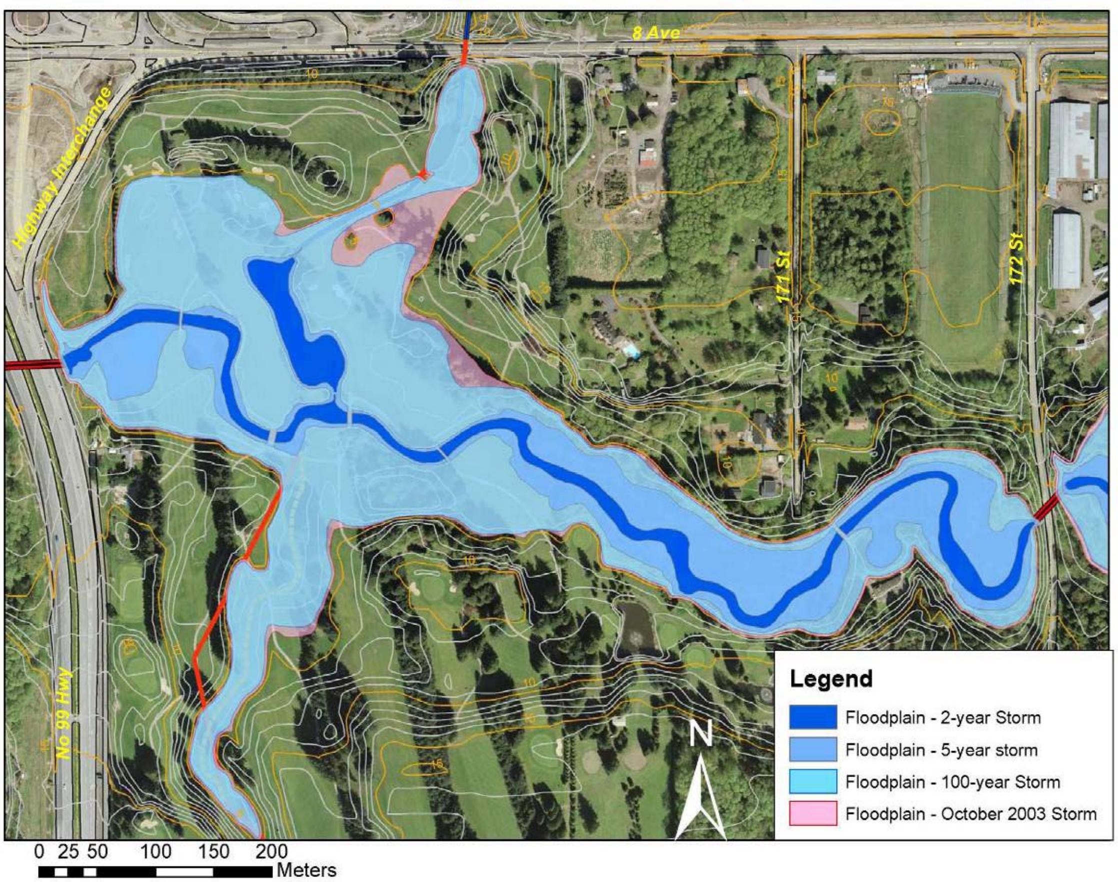
During a 2-year storm, bank full flow conditions occur in Campbell River. Flow in the floodplain is minimal.

During a 5-year storm, the flooding is more extensive, particularly immediately upstream of Highway 99 and in the easterly half of the reach, from 172nd Street to approximately 150 east of the Fergus Creek confluence where a 50 to 60 m wide area is flooded. Erosion problems are observed at the location where the overland flow returns to the river bed.

During a 100-year storm, most of the golf course area along Campbell River is flooded, including the valley south of the Fergus Creek Confluence.

The observed October 2003 storm would have created slightly more extensive flooding than the 100-year storm. The increased inundation is more noticeable in the flat areas along Fergus Creek on the north side of the river.

FIGURE 5-9
Campbell River Floodplain between 172nd Street and Highway 99



Generalized flow conditions in Campbell River have been defined by continuous simulation using the rainfall records of the year 2002. Representative flow values for this one year observation period upstream of Highway 99 are:

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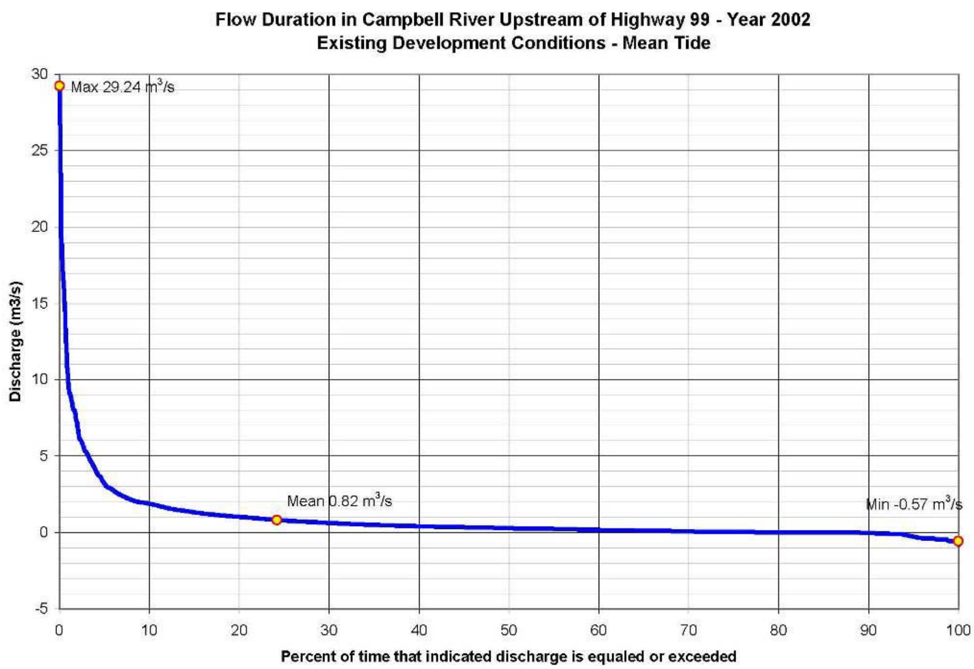
Maximum flow rate:	29.24 m^3/s
Minimum flow rate	-0.57 m^3/s
Mean flow rate:	0.820 m^3/s
Runoff volume:	25,780,000 m^3

The negative minimum flow rate is due to tidal influence in the river reach. The duration of flow rates in Campbell River is shown in Figure 5-10.

FIGURE 5-10
Flow Duration in Campbell River Upstream of Highway 99 – Year 2002



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5.2.2 Campbell River Downstream of 176th Street

Flows in Campbell River downstream of 176th Street (Conduit NCR23000) during 24-hour duration synthetic design storms range from 3.6 m^3/s, during a 2-year storm, to 66.0 m^3/s during a 100-year storm, as shown on Figure 5-11. The observed October 2003 storm under the same tidal conditions would have generated 72.3 m^3/s flows at the same location as shown on Figure 5-12. The boundary condition for this data set is the large tide in Boundary Bay; however, the tidal influence on this reach of Campbell River is minimal.

FIGURE 5-11
Campbell River Flows Downstream of 176th Street

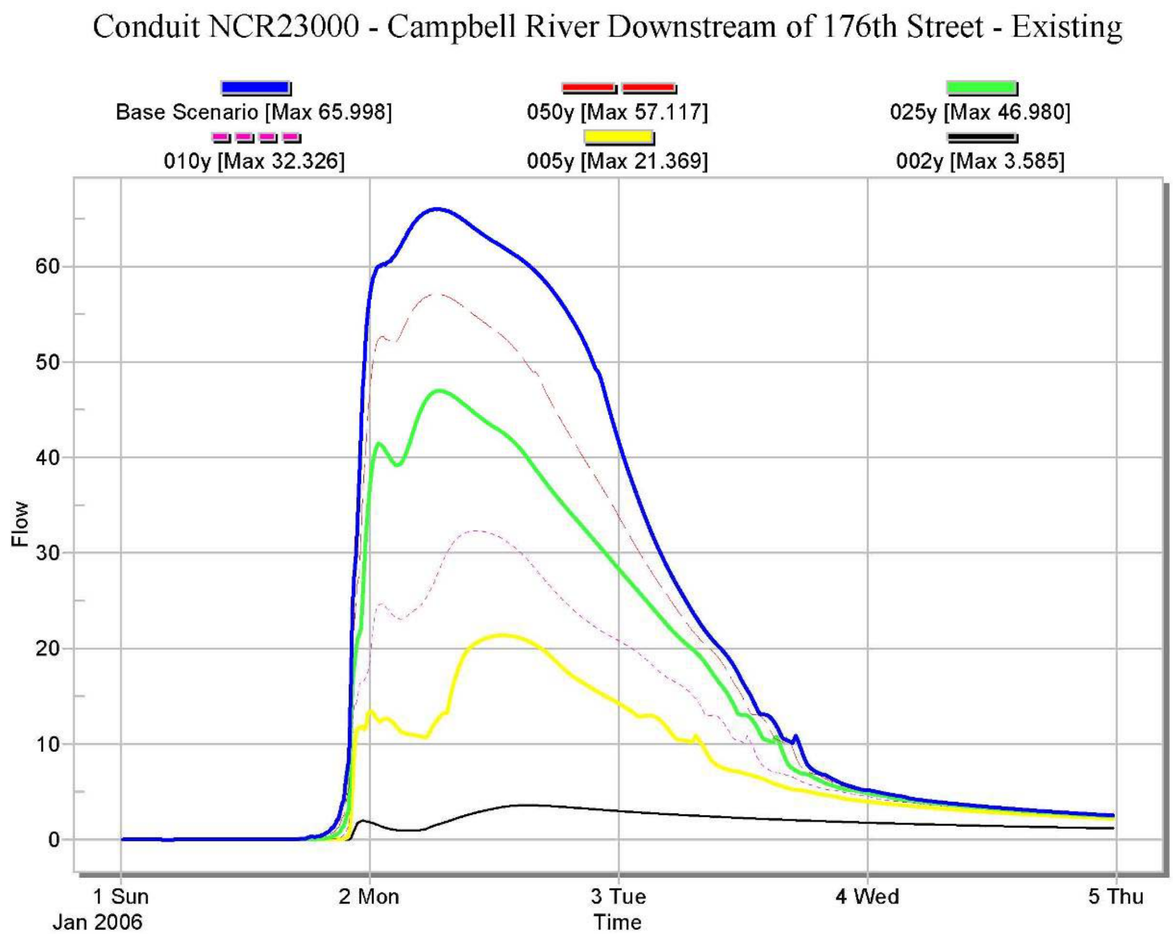

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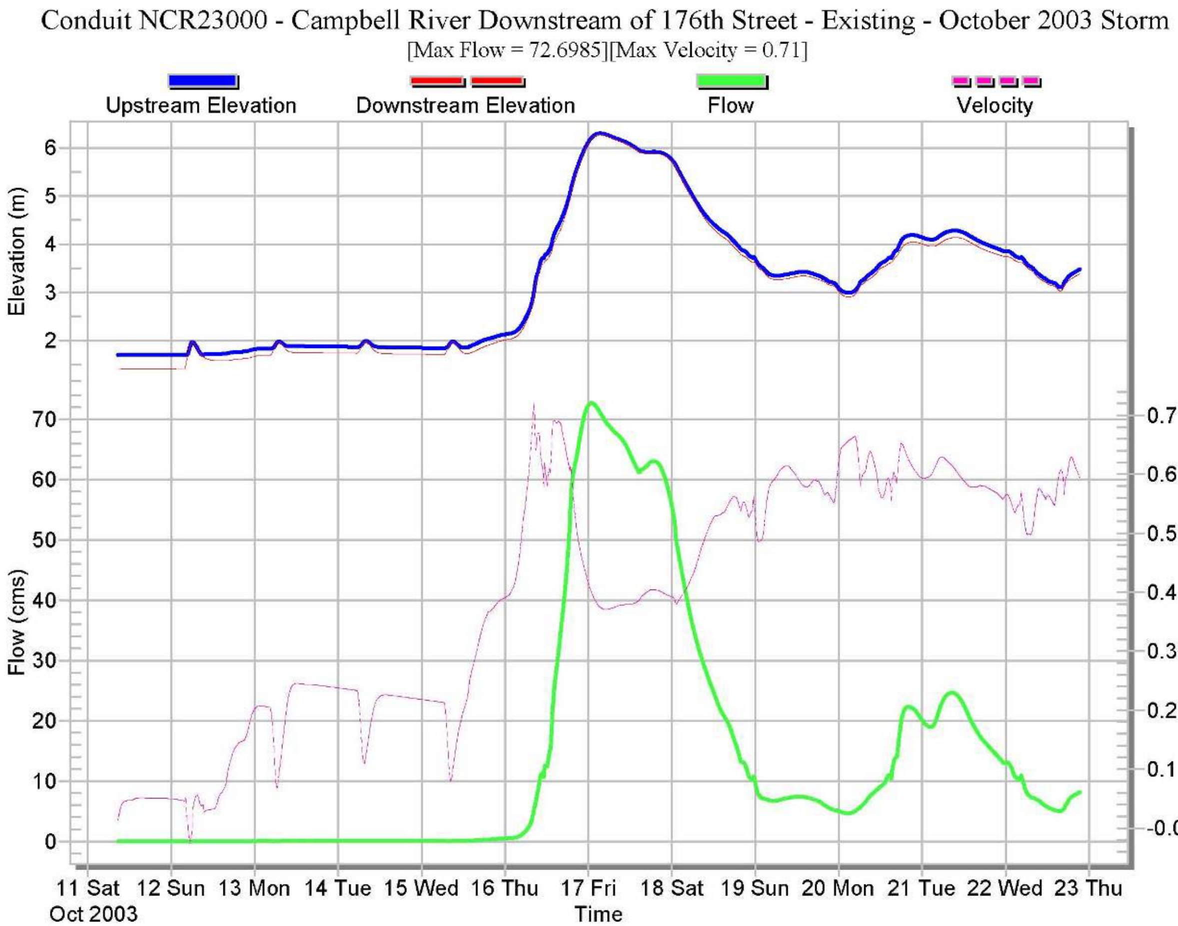
FIGURE 5-12
Campbell River Flows Downstream of 176th Street – October 2003 Storm



The water surface elevations in this area (Node 23000) vary from a 2.8 m during a 2-year storm to 6.04 m during a 100-year storm (Figure 5-13). The observed October 2003 storm could have created approximately 26 cm higher water surface elevations (6.60 m, Figure 5-14) than the 100-year storm.

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FIGURE 5-13
Campbell River Water Surface Elevations Downstream of 176th Street

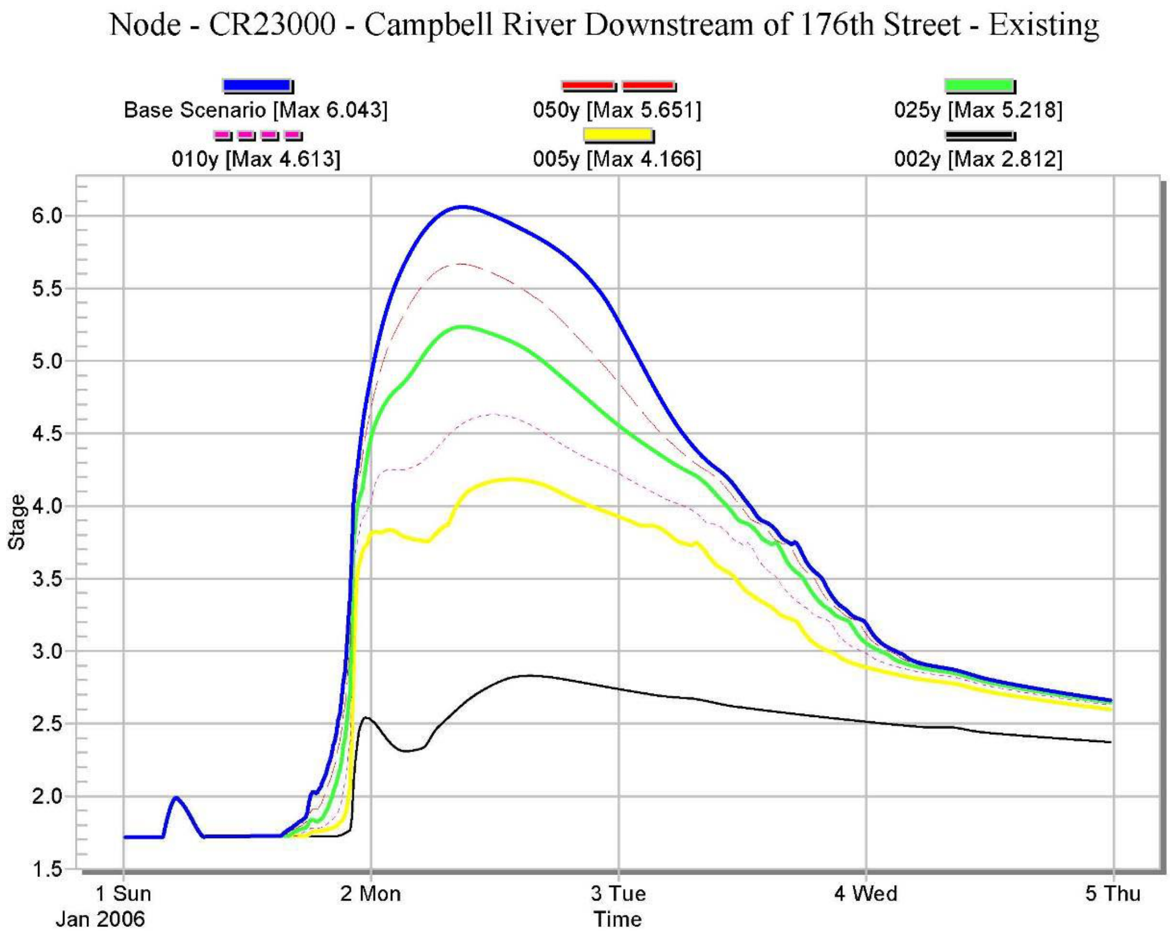

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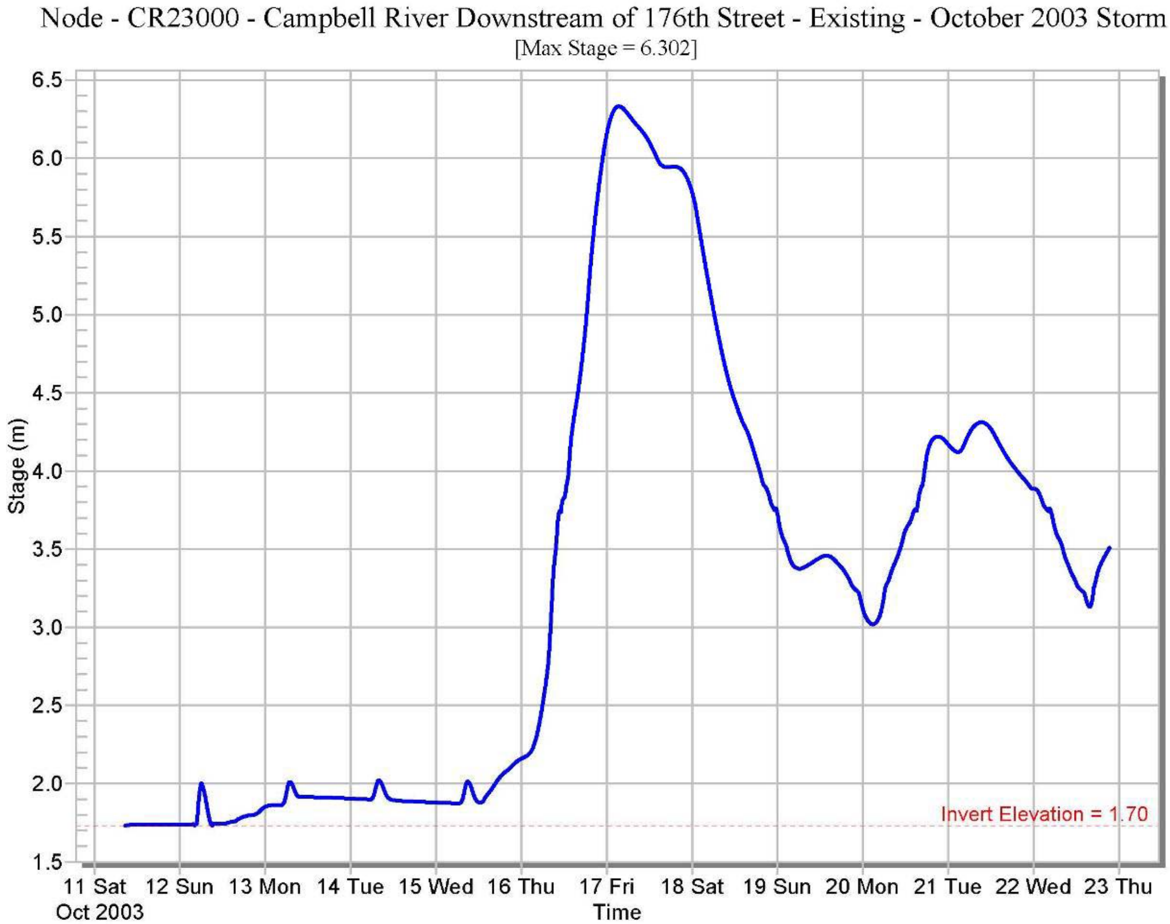
FIGURE 5-14
Campbell River Water Surface Elevations Downstream of 176th Street – October 2003 Storm



The profile of the Campbell River reach between 176th Street (Highway 15) and 172nd Street is shown on Figure 5-15 and the cross-sections of the same reach on Figure 5-16 during a 100-year storm. There are no bridges or culverts on Campbell River between these two major road crossings. The river valley is flooded during various frequency storm events, as shown on Figure 5-17.

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FIGURE 5-15
Campbell River Profile between 176th Street and 172nd Street – 100-Year Storm

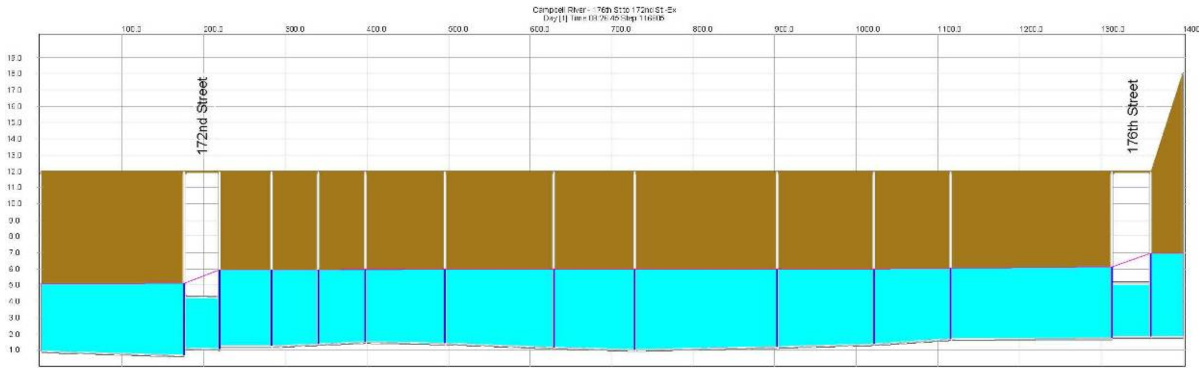

FIGURE 5-16
Campbell River Cross-Sections between 176th Street and 172nd Street – 100-Year Storm

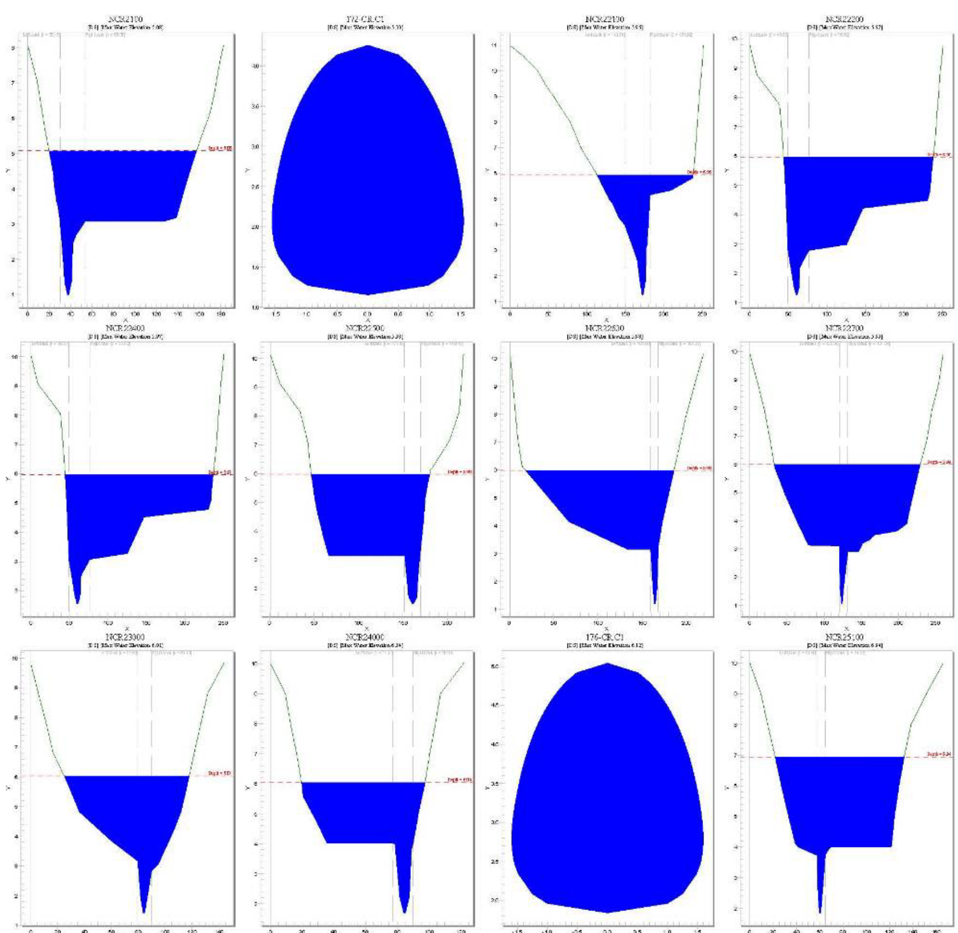

Figure 5-17 shows the limits of the floodplain during a 2-year, 5-year, and 100-year storm, as well as during the observed October 2003 storm.

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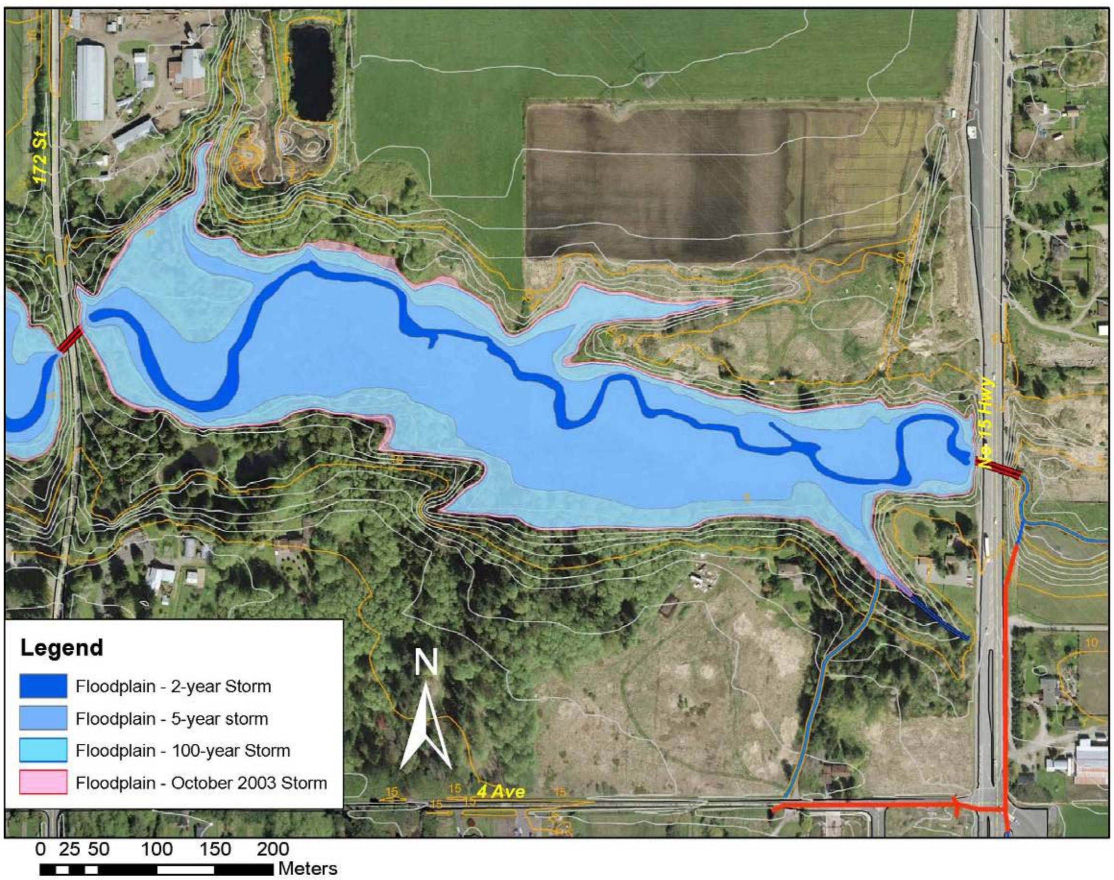
During a 2-year storm, bank full flow conditions occur in Campbell River. Flow in the floodplain is minimal.

During a 5-year storm, the flooding is extensive throughout the reach approaching the steeper slopes of the river valley.

During a 100-year storm, flooding fills the approximately 150 m wide river valley.

The observed October 2003 storm would have created slightly higher water surface elevations, but the extent of flooding is not significantly greater than the flooding during a 100-year storm.

FIGURE 5-17
Campbell River Floodplain between 176th Street (Highway 15) and 172nd Street



Generalized flow conditions in Campbell River have been defined by continuous simulation using the rainfall records of the year 2002. Representative flow values for this one year observation period downstream of 176th Street are:

Maximum flow rate:	26.93 m^3/s
Minimum flow rate	0.001 m^3/s

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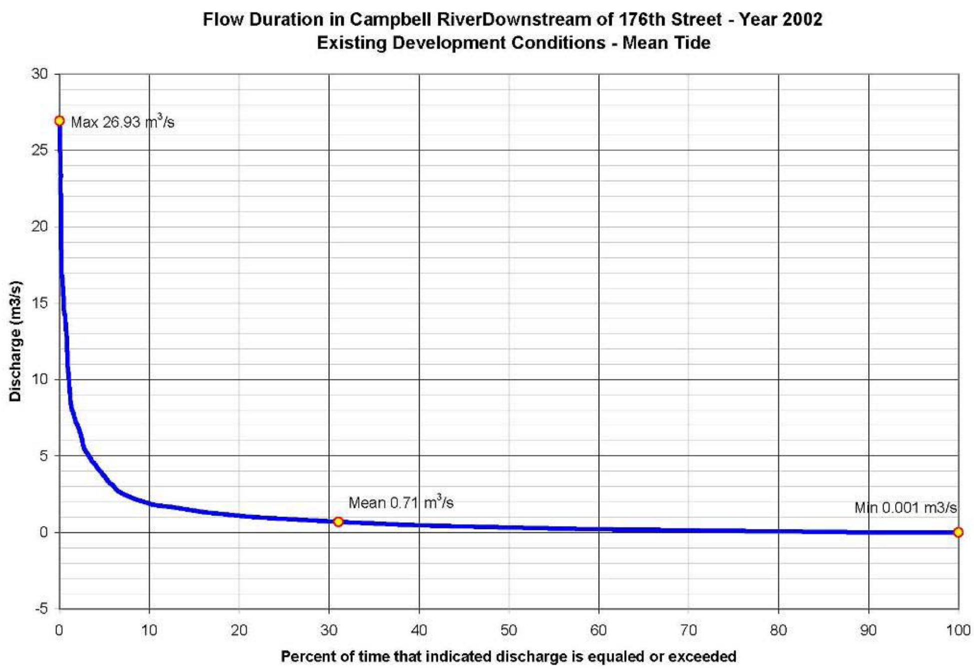
Mean flow rate:	0.708 m^3/s
Runoff volume:	22,280,000 m^3

The duration of flow rates in Campbell River downstream of 176th Street are shown in Figure 5-18.

FIGURE 5-18
Flow Duration in Campbell River Downstream of 176th Street – Year 2002



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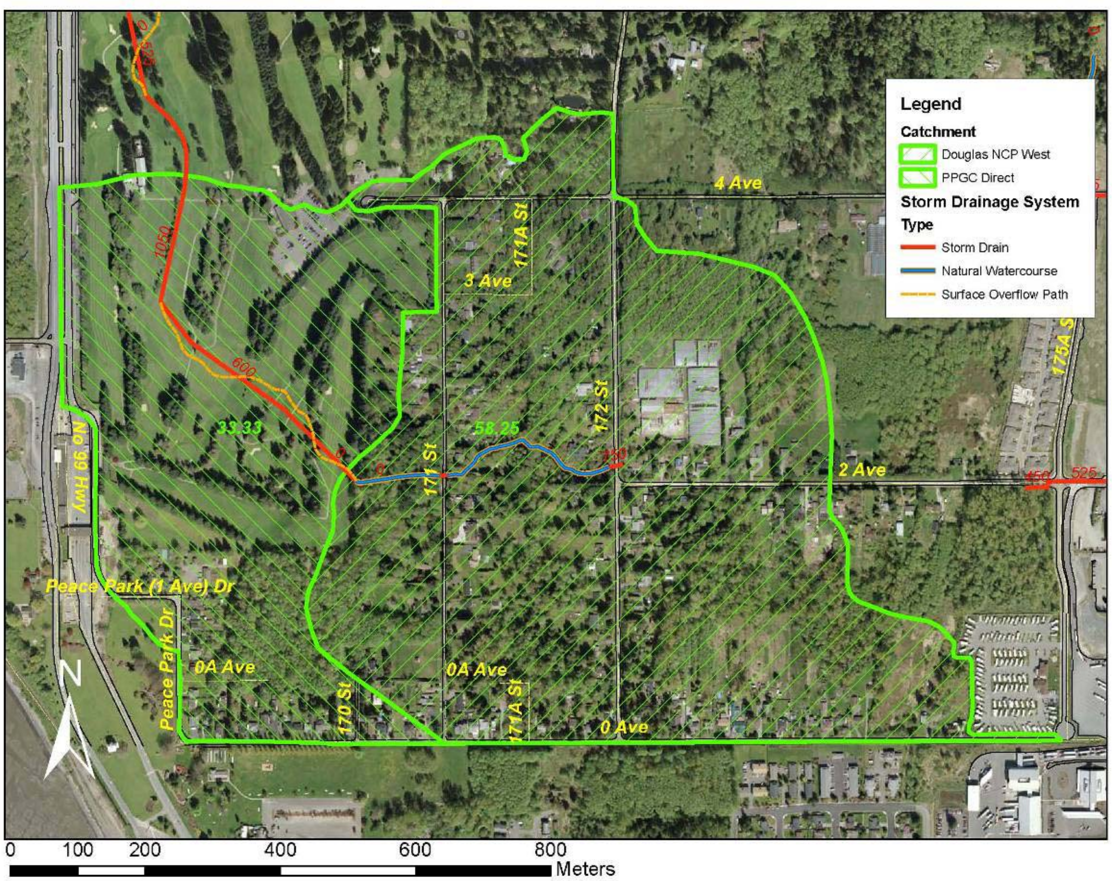
5.2.3 PPGC Southerly Depression

The southerly depression is a former valley of a natural watercourse that once flowed north to the Campbell River. The valley was cut off by an area of fill over a utility corridor crossing, thereby creating a bowl or depression. The area is drained by an existing storm drain through the PPGC. The storm drain has three sections. The lower section downstream of the utility corridor is a 525 mm diameter pipe, the middle section under the utility corridor is a 1,050 mm pipe, and the upper section is a 600 mm pipe. The inlet of the storm drain is at the easterly boundary of PPGC. The ground elevation at the bottom of the depression is approximately 4.5 m and the overflow elevation at the utility corridor is approximately 9.0 m.

The area draining to the depression has two distinct catchments (please see Figure 5-19). One catchment is a direct surface runoff from a 33.33 ha area form the PPGC and the south-westerly part of Douglas NCP. The other catchment is a 58.25 ha area in the westerly part of Douglas NCP draining to the inlet of the existing PPGC storm drain.

FIGURE 5-19
Existing Catchments to PPGC South Depression



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Stormwater runoff from the easterly catchment is handled by the PPGC storm drain until the capacity of the pipe is reached, and then stormwater flows on the surface into the depression. Figure 5-20 shows the direct surface from the 33.33 ha catchment area and Figure 5-21 shows the storm drain pipe and surface overflow from the easterly 58.25 ha catchment into the depression. The figure indicates that surface overflow from the east occurs during all storm events except the 2-year storm. These overflows are not influenced by the tide.

FIGURE 5-20
Direct Surface Runoff into PPGC South Depression - Existing

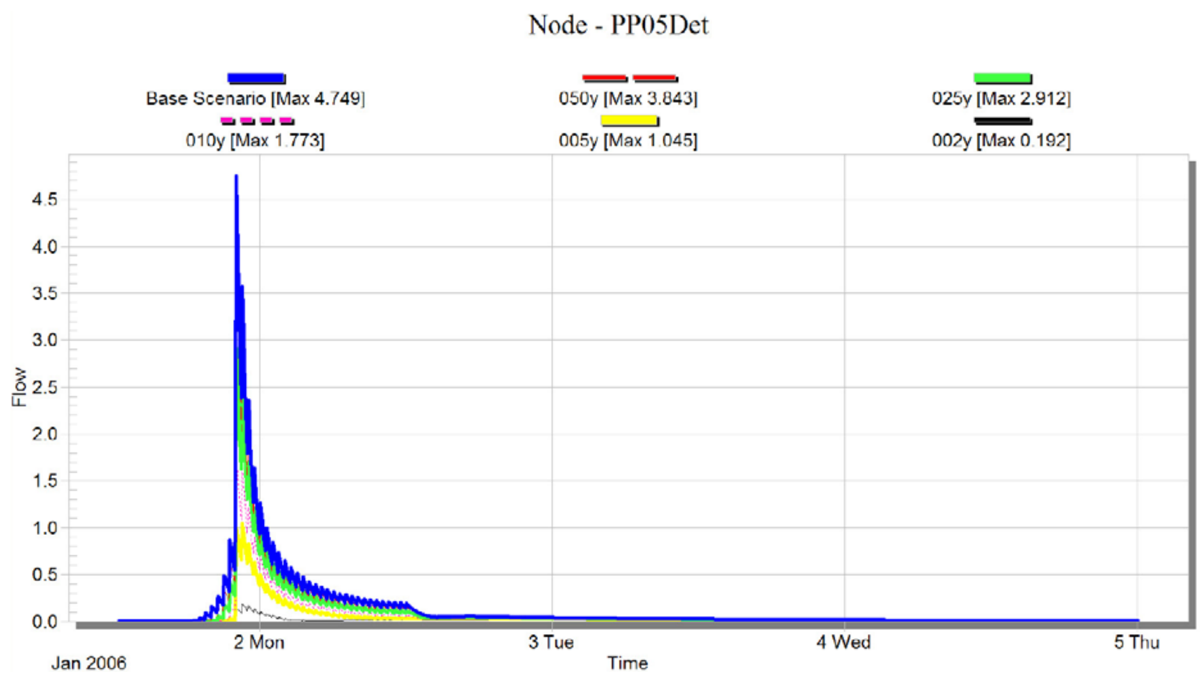

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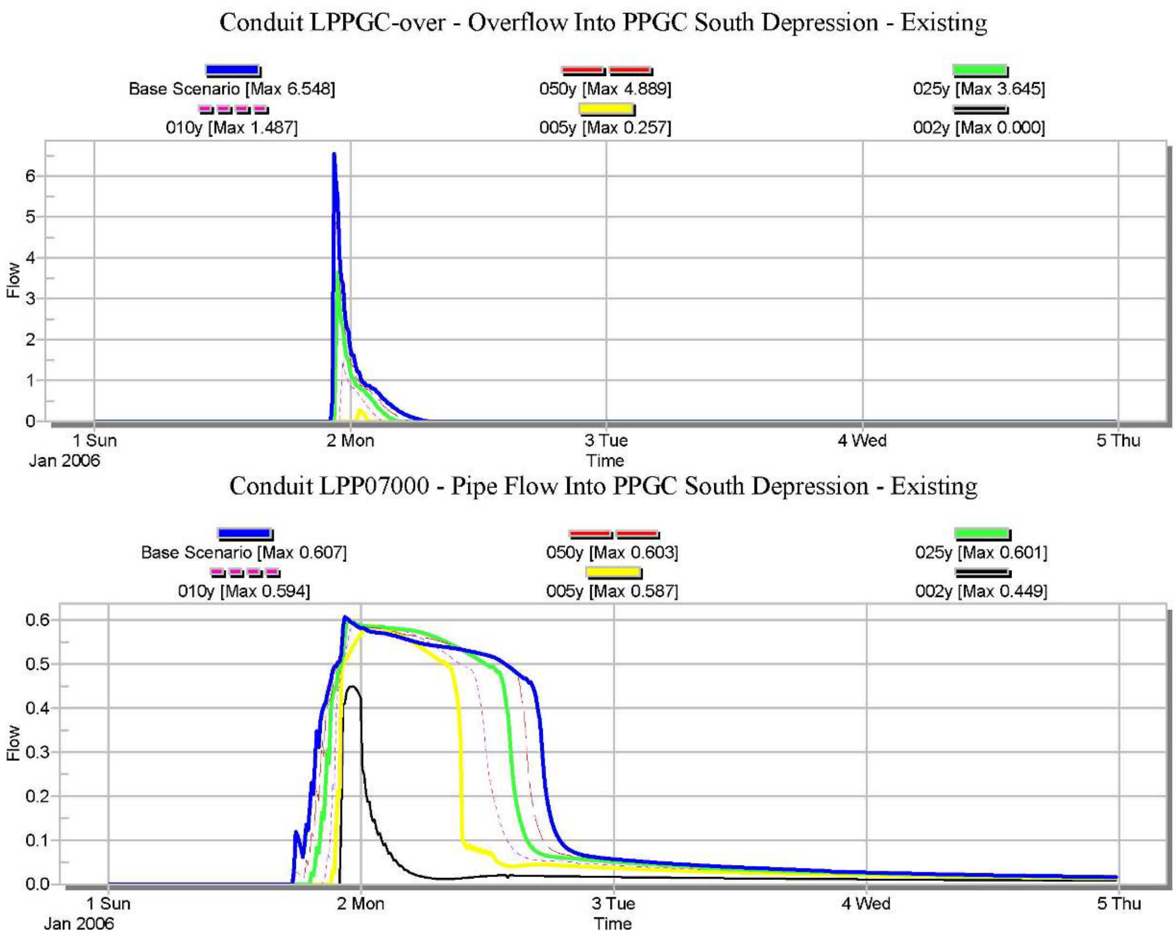
FIGURE 5-21
Pipe and Surface Overflow from the East into PPGC South Depression - Existing



The outlet of the depression is a lawn basin (grated manhole cover) into the PPGC storm drain. Due to the limited capacity of the lawn basin, ponding would occur in this area even if the existing storm drain would have more capacity than it currently has. Figure 5-22 shows the computed water surface elevations during various storm events. The maximum water surface elevation during a 100-year return frequency storm event is 7.7 m, approximately 3.2 m water depth in the depression. Figure 5-23 shows the profile of the PPGC storm drain through the golf course during a 100-year return frequency storm event.

The simulated flooding extent has not been confirmed by observations by PPGC personnel. The likely reason for this is that the available information for the geometry of the existing storm drain through the PPGC does not properly describe the actual field conditions. There were some indications that other storm drains may exist in the area that reduce the flows to the easterly inlet to the system; however, no information on those potentially existing storm drains was available for this study.

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FIGURE 5-22
Water Surface Elevations in the PPGC South Depression - Existing

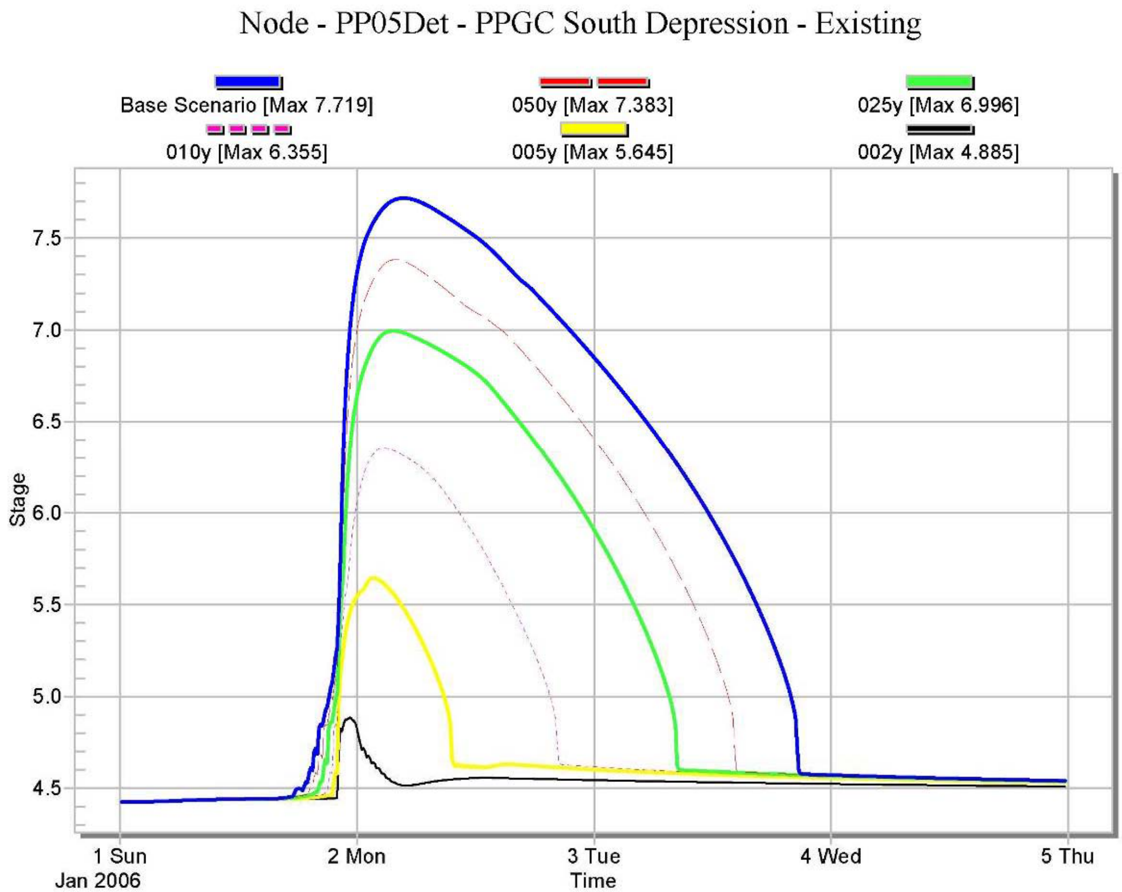

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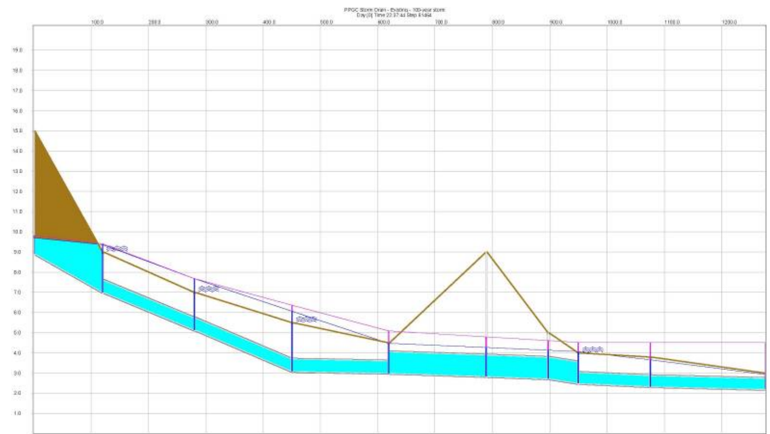
FIGURE 5-23
PPGC Storm Drain Profile - Existing – 100-Year Storm



The extent of flooding in the area is shown on Figure 5-24. This figure indicates that the observed October 2003 storm would have created less flooding than the 100-year storm in this area.

FIGURE 5-24
Floodplain in PPGC South Depression – Existing

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6 Douglas NCP Storm Drainage System

The purpose of the storm drainage system for Douglas NCP is to provide storm drainage service for the proposed development that satisfies the City of Surrey drainage design criteria for hydraulic capacity, and provides stormwater management to ensure that the proposed development will not contribute negatively on downstream properties, flooding, erosion, and the natural habitat. The proposed development includes basements in the residential buildings; therefore, the design of the storm drainage system needs to satisfy the following criteria:

- The storm drain pipes need to be able to carry the runoff from the City of Surrey's standard 100-year return frequency design storm without surcharge.
- The critical storm for the design of the storm drain pipes in the South Surrey area is the 2-hour duration 100-year return frequency storm, which is a 45.3 mm total rainfall within a 2-hour period.
- The hydraulic grade line in the pipe must be 300 mm below the floor elevation of the basements, which equates to a minimum of 2.4 m below the ground elevation at any point of the development.

Development interest and conceptual development plans exist for the easterly half of the Douglas NCP. A site configuration plan for the westerly part of the NCP is available from the Douglas NCP approved in 1999. For the purposes of this study it was assumed that the design criteria defined for the easterly part of the NCP will apply to the entire Douglas NCP. Stormwater management options considered for the Douglas NCP include the detention basin concept used in the 1999 NCP and three levels of distributed stormwater management alternatives within the NCP area. The storm drainage servicing concept includes the 2-outfalls and the 3-outfalls scenario. To take into account the two developments, the four stormwater management options, and the two storm drainage servicing options, the following scenarios have been evaluated in this study:

Development Scenarios:

- **NCP**: The entire area of Douglas NCP is developed as planned in the 2006 NCP Amendment.
- **INTERIM**: The part of Douglas NCP located east of 172nd Street and an area west of 172nd Street and south of 4th Avenue is developed, but the south-westerly part of the NCP will remain in its current state of development.

Stormwater Management Scenarios:

- **DETENTION**: A traditional storm drainage system is used where impervious areas are connected to storm drains and peak flow control is provided in two community detention ponds.

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- **LID0**: Impervious areas are directly connected to storm drains discharging stormwater into Campbell River or to a westerly water course leading to an existing storm drain through the PPGC.
- **LID1**: A groundwater interflow path is provided using the trenches of public utilities in street right-of-ways and utility house connections backfilled with granular material. Street flows discharged to vegetated swales in parkways for filtering and infiltration prior to discharging to storm drains. Roof drains are disconnected and roof runoff is filtered through grassy landscaped areas prior to discharging into vegetated swales in parkways. Interflow path is intercepted at each manhole and discharged to watercourses at appropriate locations.
- **LID2**: Similar to LID1, but absorbent soils are used in landscape areas for enhanced infiltration and stormwater quality management.

Storm Drainage Servicing Scenarios:

- **2-Outfalls**: The 2-outfalls scenario is similar to the configuration of the existing system, where stormwater runoff from the entire NCP area is discharged into Campbell River through two outfalls at 176th Street and upstream of Highway 99. In this scenario, a part of the westerly tributary of the NCP is diverted to the easterly outfall to reduce flows to the storm drain through the PPGC. Alternatives of this scenario vary in the potential improvements applied to the existing PPGC storm drain.
- **3-Outfalls**: In addition to the two outfalls into Campbell River, a third outfall from the 0 Avenue/Peace Park Drive to Semiahmoo Bay is introduced to drain the south-westerly portion of Douglas NCP. The objective of this scenario is to minimize stormwater runoff from the NCP to the existing PPGC storm drain to avoid the need for improvements to the storm drain and the associated construction that would interfere with the operation of the PPGC.

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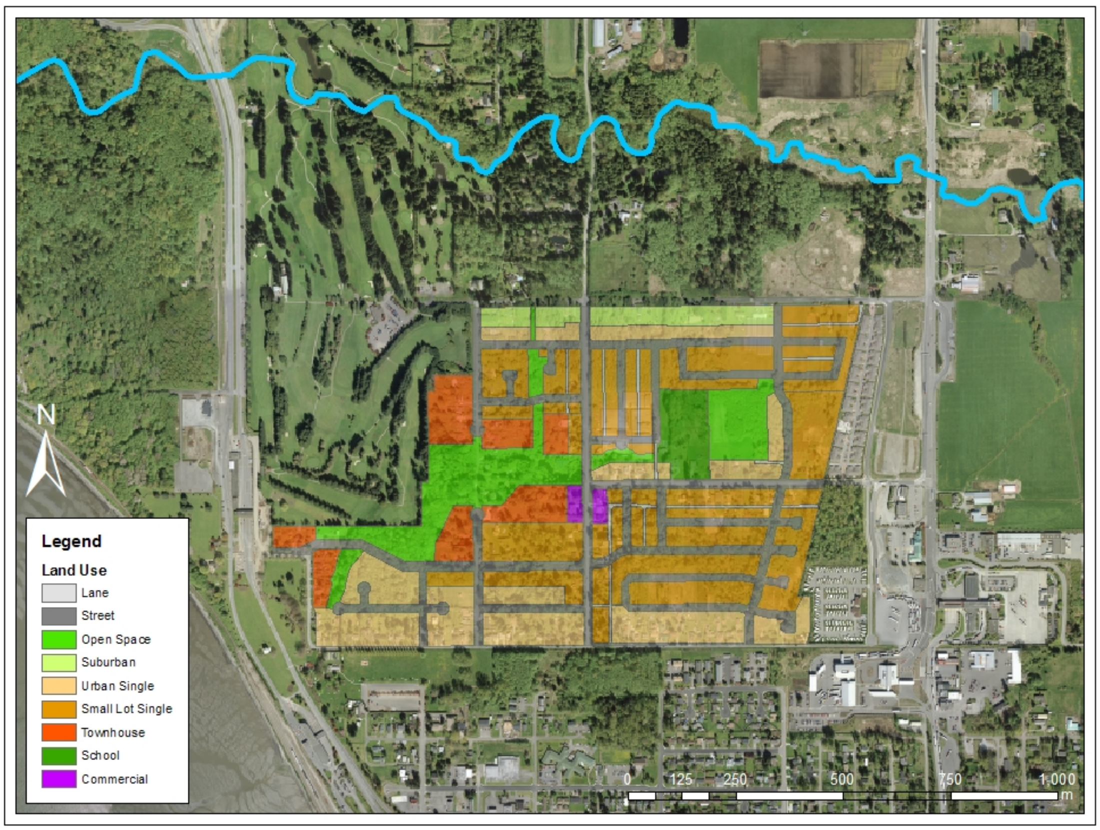
6.2 Storm Drainage Servicing Concepts

6.2.1 2-Outfalls Storm Drainage Servicing Concept – NCP Development Scenario

This concept is based on the "NCP" development scenario, when the entire planning area of Douglas NCP is developed.

The servicing concept includes a network of underground storm drains providing drainage outlet to the streets and each lot within the Douglas NCP. A development plan for this scenario is shown on Figure 6-1. The objective of the drainage configuration is to allow for the development of one part (east) of the NCP independent from the other (west) part.

FIGURE 6-1
Development Plan – NCP Development Scenario



The storm drainage system for the 59.0 ha easterly basin (45.7 ha Douglas NCP on-site and 13.3 ha off-site) directs stormwater to the intersection of 4th Avenue and 176th Street at the north-east corner of the basin and then it discharges into Campbell River via an off-site storm drain along the west side of 176th Street. This drainage concept eliminates any discharges from Douglas NCP into the existing storm drains in 2nd Avenue, 4th Avenue,

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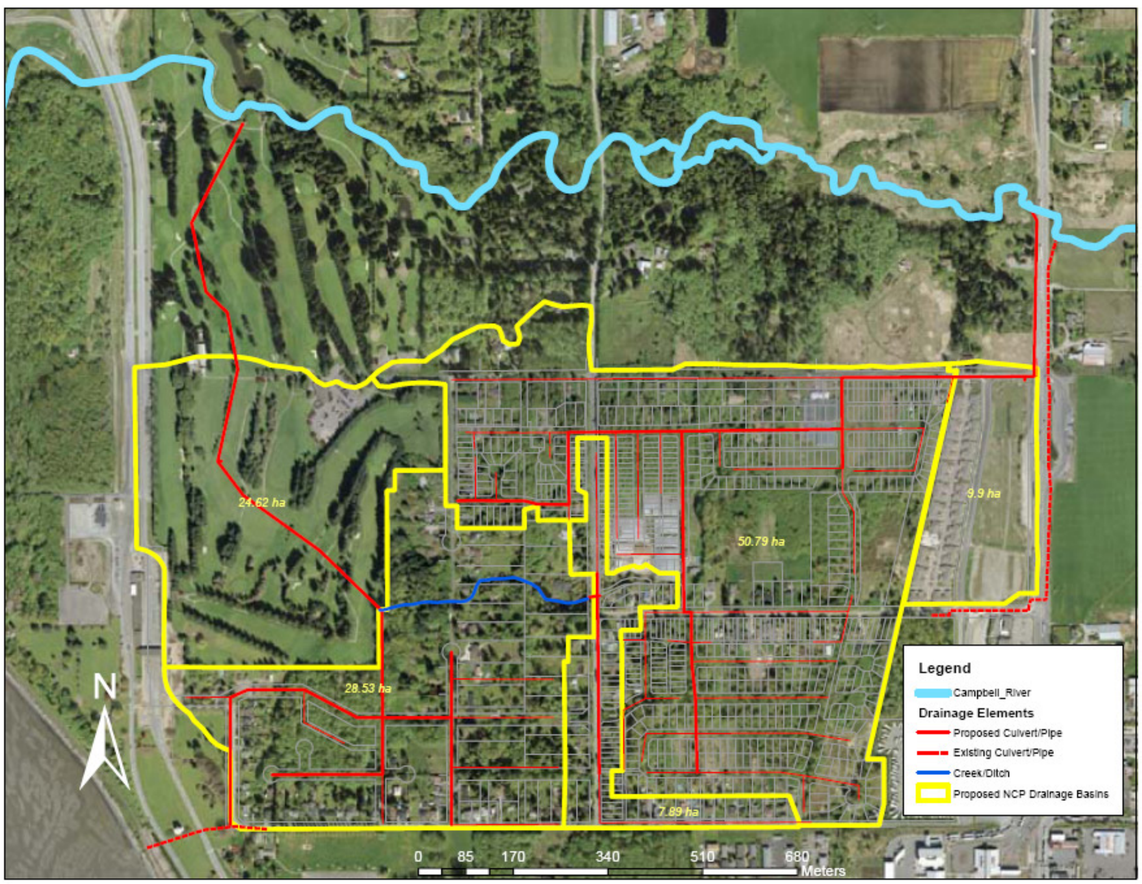
and 176th Street. The size of the storm drain pipes varies up to 1,650 mm in diameter at the downstream end of the system.

This servicing concept reduces the existing 58.25 ha surface drainage area to the inlet of the existing PPGC storm drain to 36.4 ha, or to 63% of the existing catchment. While surface runoff to the westerly watercourse upstream of the PPGC storm drain is reduced by the servicing concept, base flows are replenished by groundwater discharge from the 19 ha easterly area, as discussed with the stormwater management scenarios in Section 6.

In the 2-Outfalls Scenario, the storm drainage system for the 36.4 ha westerly basin (34.4 ha Douglas NCP on-site and 2.0 ha off-site) directs stormwater to the inlet of the existing PPGC storm drain at the boundary between Douglas NCP and the PPGC. The size of the storm drain pipes varies up to 1,500 mm diameter at the downstream end of the system.

Figure 6-2 shows the 2-Outfalls storm drainage servicing concept for the "NCP" development scenario.

FIGURE 6-2
2-Outfalls Storm Drainage Servicing Concept – NCP Development Scenario



In addition to the off-site storm drain along 176th Street, the servicing concept includes off-site improvements and the upgrade of the existing storm drain through the PPGC. In the 2-Outfalls storm drainage servicing concept, the following improvement options have been considered for the PPGC storm drain:

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Alternative 1: Partial pipe replacement through the PPGC and detention at the inlet

- Retain the 1,050 mm center portion of the PPGC storm drain
- Replace both the lower 525 mm section and the upper 600 mm section with 1,050 mm diameter pipes
- Provide 2,200 m^3 active detention storage at the inlet of the PPGC storm drain on Douglas NCP land; potential environmental concerns may have to be addressed to place a detention basin in this area.

Alternative 2: Full replacement of pipes through the PPGC

- Replace the entire PPGC storm drain from Douglas NCP to Campbell River with 1,650 mm diameter pipes; no detention storage is required.

Alternative 3: Partial pipe replacement through the PPGC, deep pipe and improved inlet

- Retain the 1,050 mm center portion of the PPGC storm drain
- Replace both the lower 525 mm section and the upper 600 mm section with 1,050 mm diameter pipes
- Place the upper section of the replacement pipe as deep as reasonable
- Provide a deep manhole with enlarged (~1,650 mm) and improved (trumpet) inlet to the storm drain pipe
- The pipes in the south-westerly part of Douglas NCP need to be oversized, but no detention storage is required at the inlet of the PPGC storm drain

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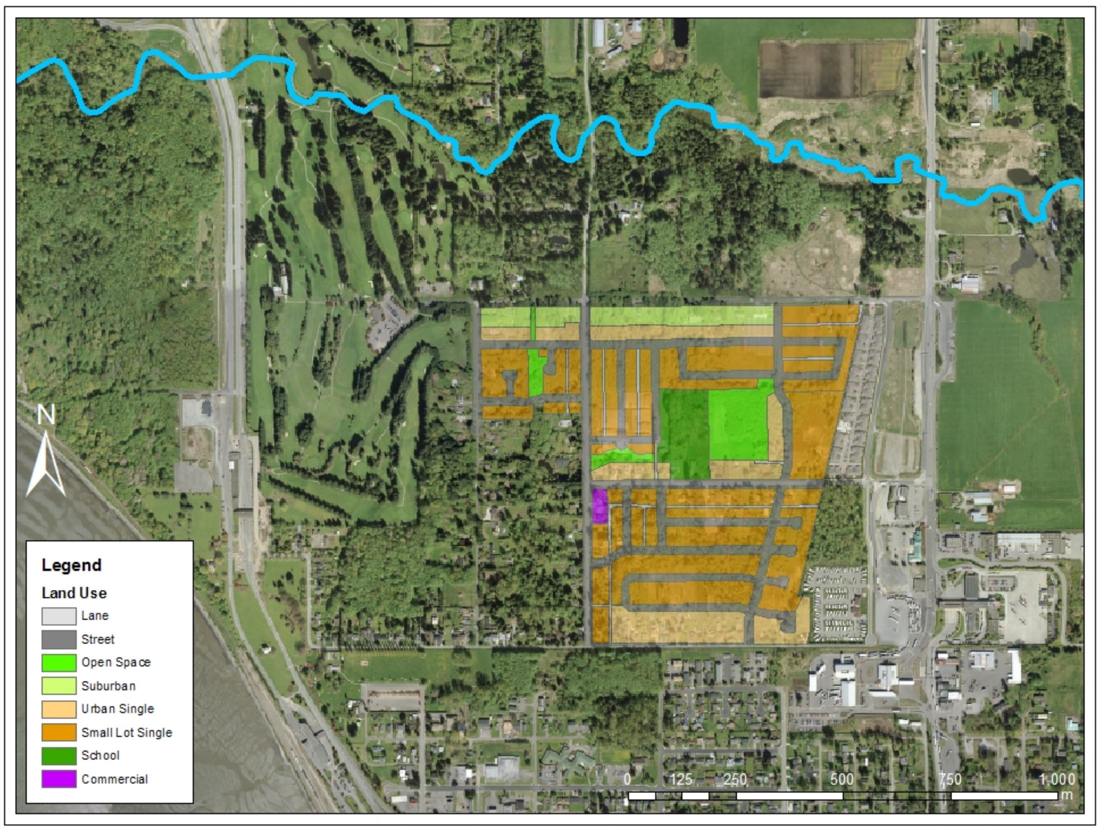
6.2.2 2-Outfalls Storm Drainage Servicing Concept – INTERIM Development Scenario

This concept is based on the “INTERIM” development scenario, when only the eastern part of the planning area of the Douglas NCP is developed.

The servicing concept includes a network of underground storm drains providing drainage outlet to the streets and each lot within the part of Douglas NCP that is planned for development. A development plan for this scenario is shown on Figure 6-3. The objective of the drainage configuration is to allow for the development of the eastern part of the NCP independent from development plans for the western part.

FIGURE 6-3
Development Plan – Interim Development Scenario



The storm drainage system for the 59.0 ha easterly basin is identical to the system for the NCP development scenario described in Section 6.1.1.

The westerly basin largely remains in its current state of development. The only drainage facilities proposed for this scenario are storm drain pipes along 172nd Street, and upgrading the culvert under 172nd Street just north of 2nd Avenue. The size of the storm drains is up to

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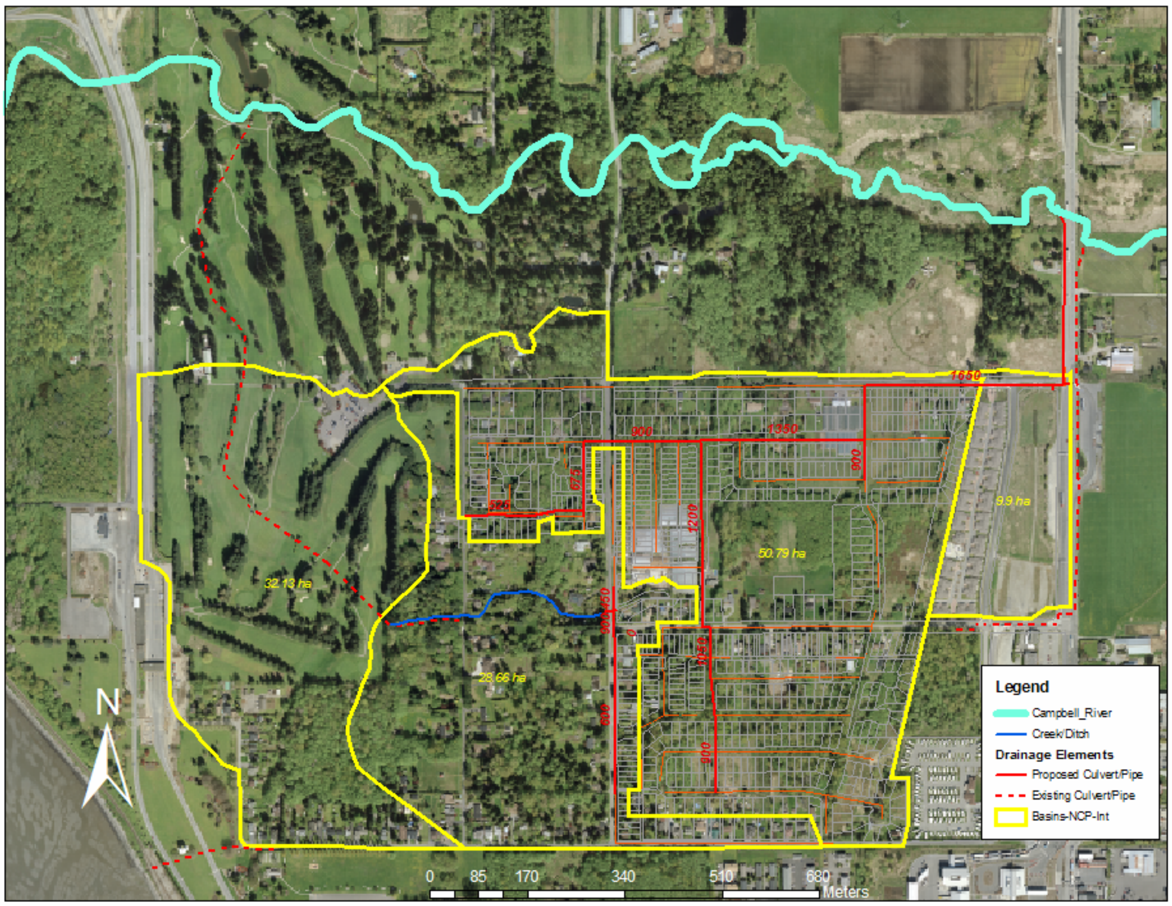
900 mm, and the size of the culvert is 1,200 mm in diameter. Figure 6-4 shows the 2-Outfalls storm drainage servicing concept for the "INTERIM" development scenario.

FIGURE 6-4
2-Outfalls Storm Drainage Servicing Concept – Interim Development Scenario



This servicing concept reduces the existing 58.25 ha surface drainage area to the inlet of the existing PPGC storm drain to 28.7 ha, or to 49% of the existing catchment. Stormwater runoff to the existing PPGC storm drain is also reduced; therefore, no improvements to the PPGC storm are proposed in this scenario. The off-site improvements are limited to the construction of the storm drain along 176th Street for this development scenario.

While surface runoff to the westerly watercourse upstream of the PPGC storm drain is reduced by the servicing concept, base flows are replenished by groundwater discharge from the 19 ha easterly area, as discussed with the stormwater management scenarios in Section 6.

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6.2.3 3-Outfalls Storm Drainage Servicing Concept – NCP Development Scenario

This concept is based on the "NCP" development scenario, when the entire planning area of Douglas NCP is developed, as shown on Figure 6-1.

The objective of the **3-Outfalls** scenario is to minimize the area draining to the inlet of the existing PPGC storm drain and to eliminate the need for drainage system improvements within the golf course. The objective is achieved by creating a third outfall – in addition to the two outfalls to Campbell River – from the 0 Avenue/Peace Park drive intersection to Semiahmoo Bay, along the alignment of a small, existing storm drain servicing the area. This new outfall will provide service to the 24.8 ha south-westerly portion of Douglas NCP and 11.1 ha off-site tributary of the existing storm drain.

A potential issue with this scenario is that it diverts 24.8 ha area of the tributary of the small watercourse between 172nd Street and the inlet of the existing PPGC storm drain and the Campbell River watershed, reducing not only stormwater runoff, but base flows to the small watercourse. This issue may be addressed by re-directing the groundwater collected with the interflow path and part of the low flows from the easterly drainage basin and discharging it at the upstream end of the small tributary. A hydro-break can be used to control the discharge rate. To complement this alternative, a low flow diversion to the drainage system in the south-westerly part of Douglas NCP can also be added. The low flow diversion system would consist of a small pipe directing low flows to the north into the small watercourse, while larger flows would be directed to the south and west along 0 Avenue to the outfall to Semiahmoo Bay.

Figure 6-5 shows the 3-Outfalls storm drainage servicing concept for the "NCP" development scenario.

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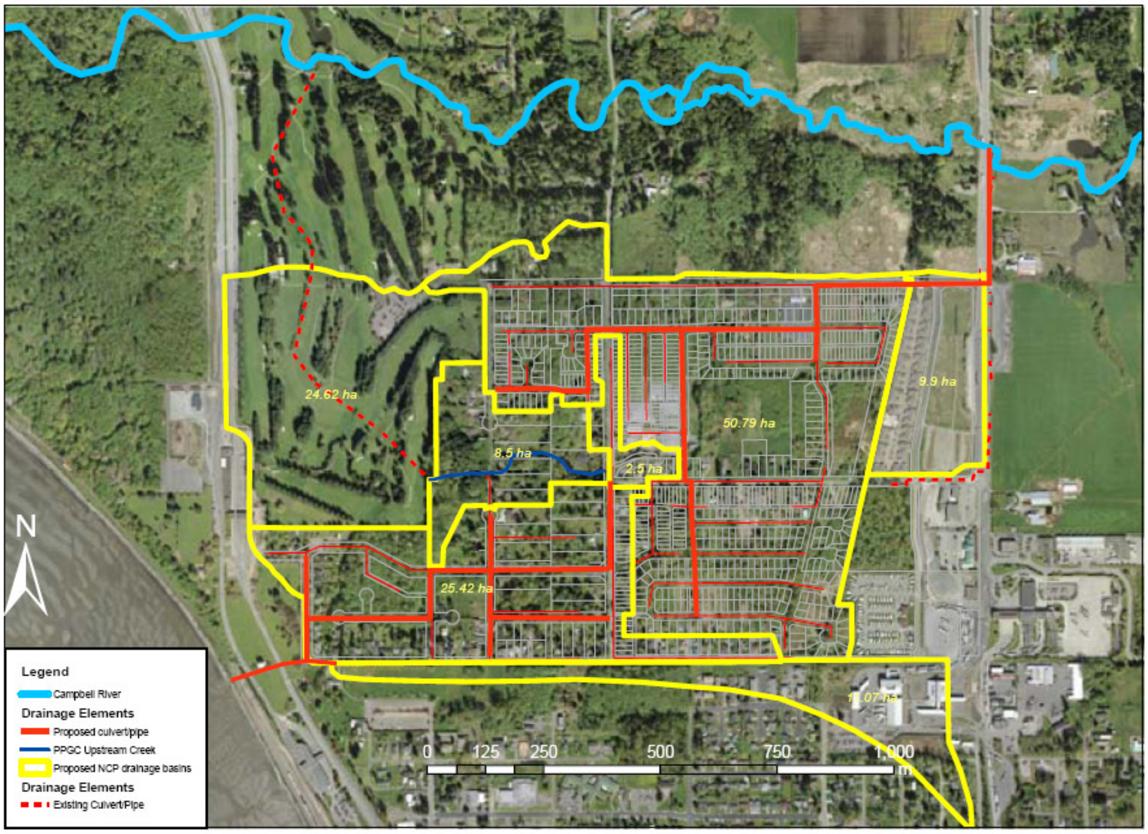
FIGURE 6-5
3-Outfalls Storm Drainage Servicing Concept – NCP Development Scenario



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6.3 Stormwater Management Concepts

6.3.1 DETENTION Concept

Two detention basins are planned; one at each of the two outlets of the two drainage basins of Douglas NCP. The purpose of the detention basins is to limit post development peak flow rates for the design storm of the system to the rate of pre-development flows at the same locations. The design criteria for the detention ponds in the approved 1999 Douglas NCP was to control peak flow rates for the 5-year return frequency storm. Due to the inclusion of basements for the buildings, the design storm for the storm drains in the 2006 NCP Amendment is the 100-year return frequency storm, of 2-hour duration for the pipes, and 24-hour duration for the detention ponds.

To satisfy the current design criteria, the required size of the ponds is 7,000 m^3 for the East and 2,200 m^3 for the West Detention Pond. The size of the West Pond is based on the assumption that the PPGC storm drain is upgraded to 1,050 mm diameter pipe (Alternative 1 for off-site improvements, please see Section 6.1.1). The maximum water surface elevations in the ponds must be at a level that it would not limit the hydraulic performance of the upstream storm drainage system. The approximate maximum water surface elevation is 7.0 m for the East and 8.5 m for the West Pond.

The size of the storm drain pipes is up to 1,650 mm in diameter for the east basin and up to 1,500 mm for the east basin.

Figure 6-6 shows the “DETENTION” concept for the “NCP” development scenario. In the “INTERIM” development scenario, only the East Pond would be built.

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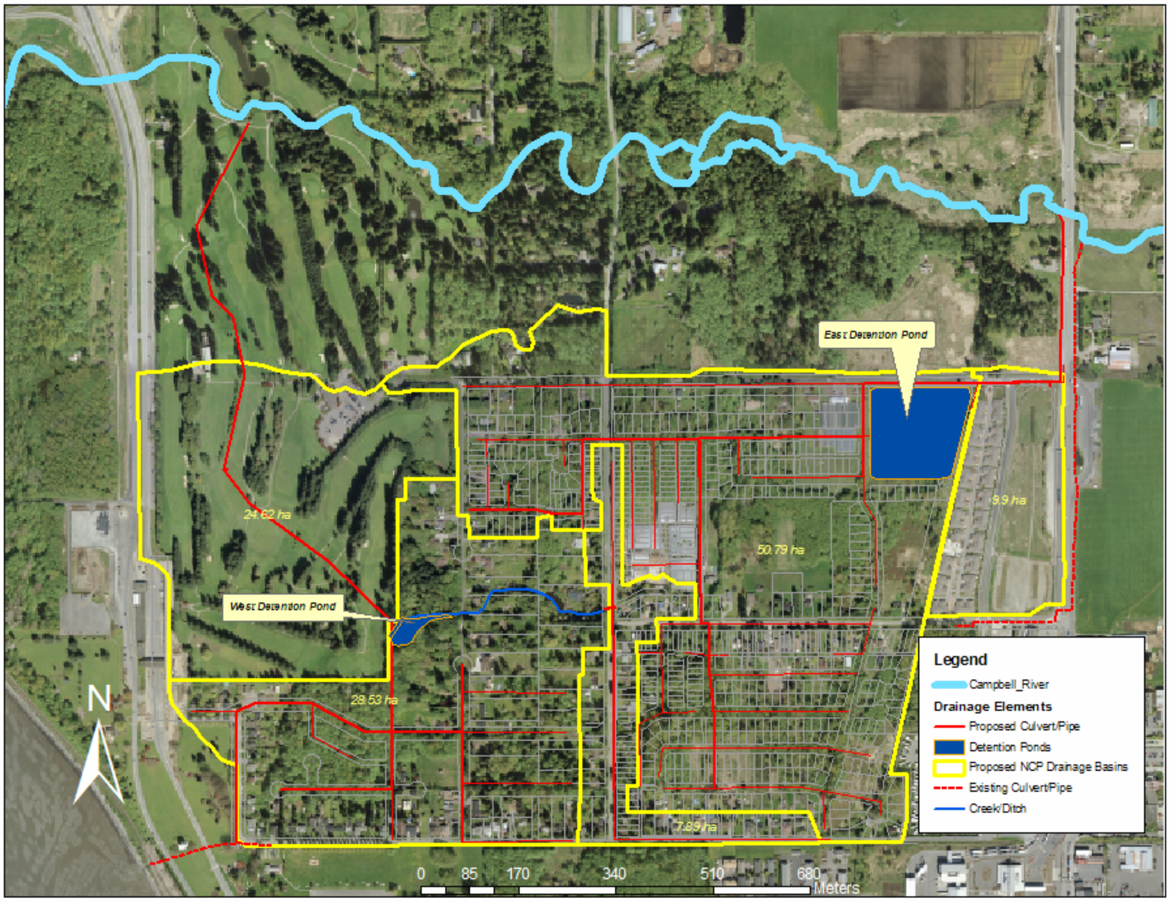
FIGURE 6-6
Storm Drainage Servicing Concept – NCP Development Scenario with Detention Concept for Stormwater Management



6.3.2 LID0 Concept

Roof drains, streets, all other impervious surface areas, and the perimeter drains around the basements are directly connected to storm drains. Stormwater is discharged into Campbell River at 176th Street from the east drainage basin and to the westerly water course at 2nd Avenue leading to the existing PPGC storm drain from the west drainage basin of the Douglas NCP.

The size of the storm drain pipes is up to 1,650 mm in diameter for the east basin, up to the East Detention Pond discharge point. The pipes below the East Pond are 1350 mm. The size of the pipes in the east basin is up to 1,500 mm. No management practices for stormwater quality treatment or groundwater control are provided in this scenario.

Off-site improvements to the PPGC storm drain (Alternative 1, 2, or 3) are included in the NCP scenario. No off-site improvements are included for the INTERIM development scenario.

Figure 6-7 shows the "LID0" concept for the "NCP" development scenario. The LID0 concept for the "INTERIM" development scenario is shown on Figure 6-8.

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FIGURE 6-7
Storm Drainage Servicing Concept – NCP Development Scenario with LID0 Concept for Stormwater Management

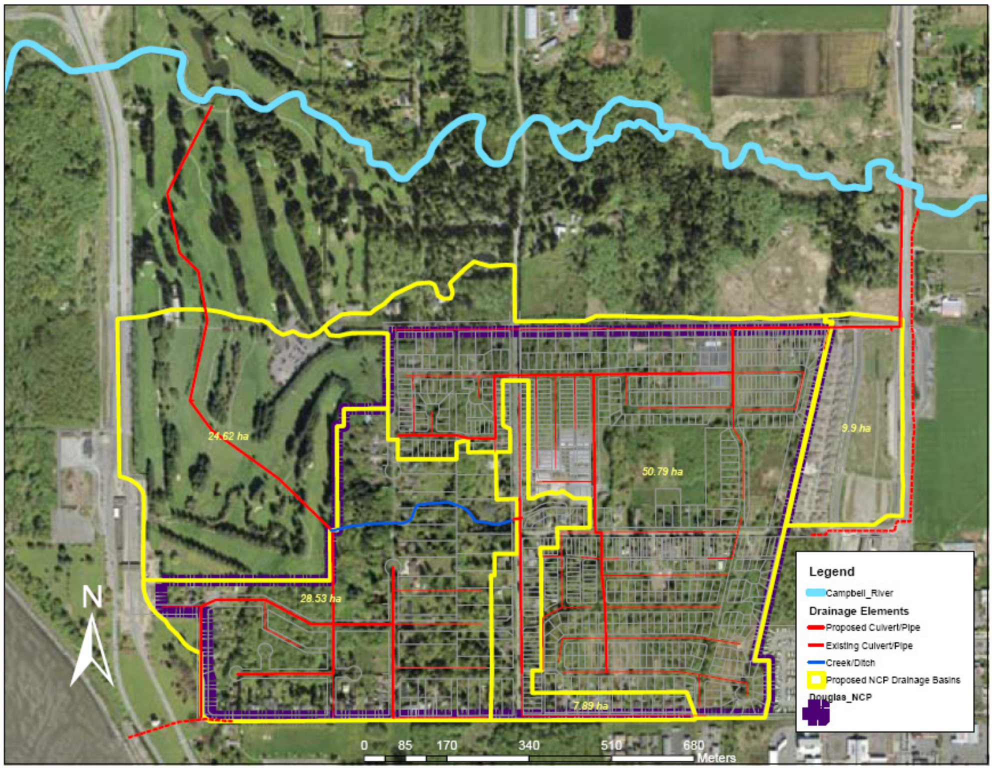
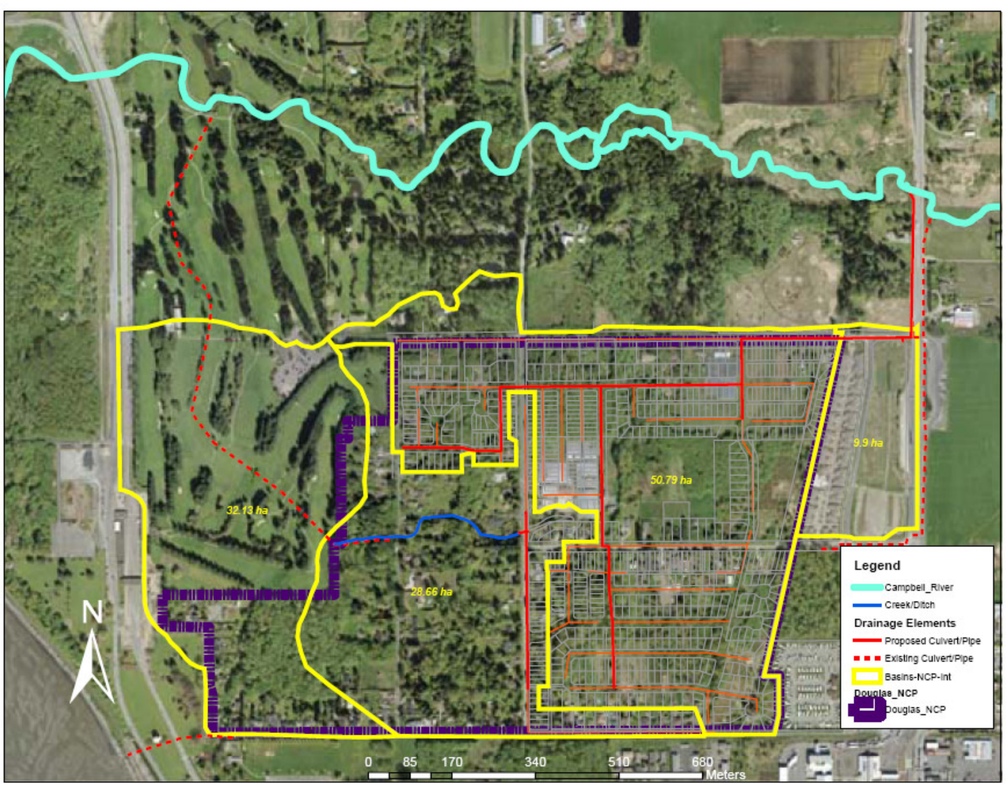


FIGURE 6-8
Storm Drainage Servicing Concept – Interim Development Scenario with LID0 Concept for Stormwater Management



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6.3.3 LID1 Concept

The following are the key elements of this concept:

- Parkways in streets are constructed as vegetated swales or depressions with a gravel filled infiltration chamber underneath and a raised overflow connected to storm drains (green streets)
- Street flows are directed into the vegetated swales through curb cuts
- Roof drains are discharged to landscape areas at the high end of each lot and filtered through the grass and landscape vegetation
- Surface drainage of landscape areas directed to the vegetated swales in the parkways
- Trenches of utility house connections are filled with gravel or similar granular material and connected to the trenches of public utilities (sanitary sewer, storm drain), also filled with granular material to create an interflow path for groundwater
- Trenches of public utilities are intercepted at each manhole by a perforated pipe connected to the manhole to prevent the accumulation of too much groundwater flow in the trenches. To ensure the stability of roadways, the migration of fine particles via groundwater flow in the trenches need to be prevented.
- The groundwater collected by the interflow path from the south-easterly part of Douglas NCP is discharged into the westerly watercourse through a low flow outlet from a manhole at 2nd Avenue. Groundwater collected from the rest of the Douglas NCP area is discharged into Campbell River through the regular storm drains.

LID1 stormwater management scenario provides some initial filtering of street runoff and provides opportunities for infiltration of runoff from both the streets and the development areas.

The network and the size of the storm drain pipes in this scenario is the same as in the LID0 scenario. The servicing concept with the interflow path for the NCP and INTERIM development scenarios are show on Figure 6-9 and 6-10.

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FIGURE 6-9
Storm Drainage Servicing Concept – NCP Development Scenario with LID1 Concept for Stormwater Management

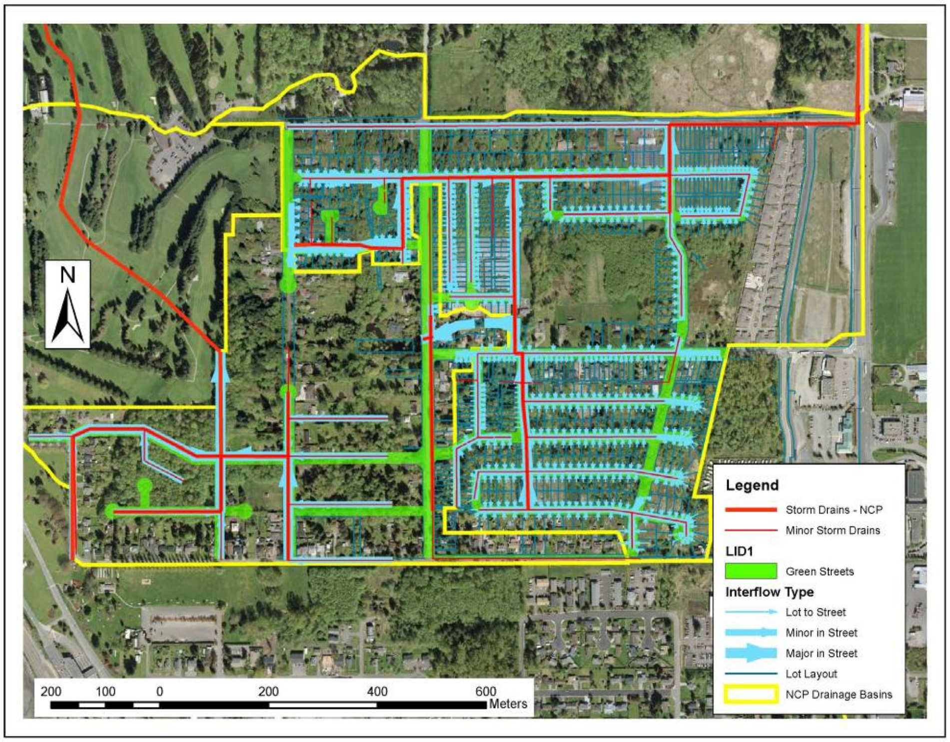
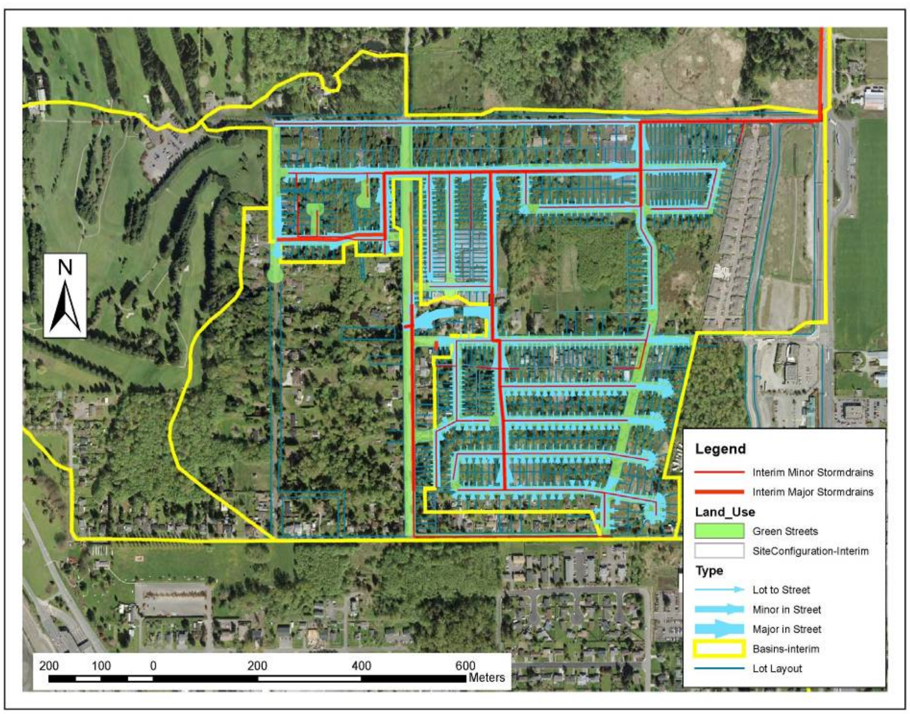


FIGURE 6-10
Storm Drainage Servicing Concept – Interim Development Scenario with LID1 Concept for Stormwater Management



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6.3.4 LID2 Concept

The LID2 concept is similar to LID1, but it adds absorbent soils to landscaping for enhanced stormwater retention and infiltration. The amount of rainfall captured is a function of the volume of the voids in the absorbent soils and other infiltration facilities. As an example, if 300 mm absorbent soil layer is provided on landscape areas, in addition to the street treatment described in the LID1 scenario, approximately the first 20 mm of rainfall is captured, filtered and infiltrated, providing enhanced stormwater quality treatment and groundwater recharge.

The storm drain pipe sizes in this scenario are the same as in the LID0 and LID1 scenarios.

FIGURE 6-11
Storm Drainage Servicing Concept – NCP Development Scenario with LID2 Concept for Stormwater Management

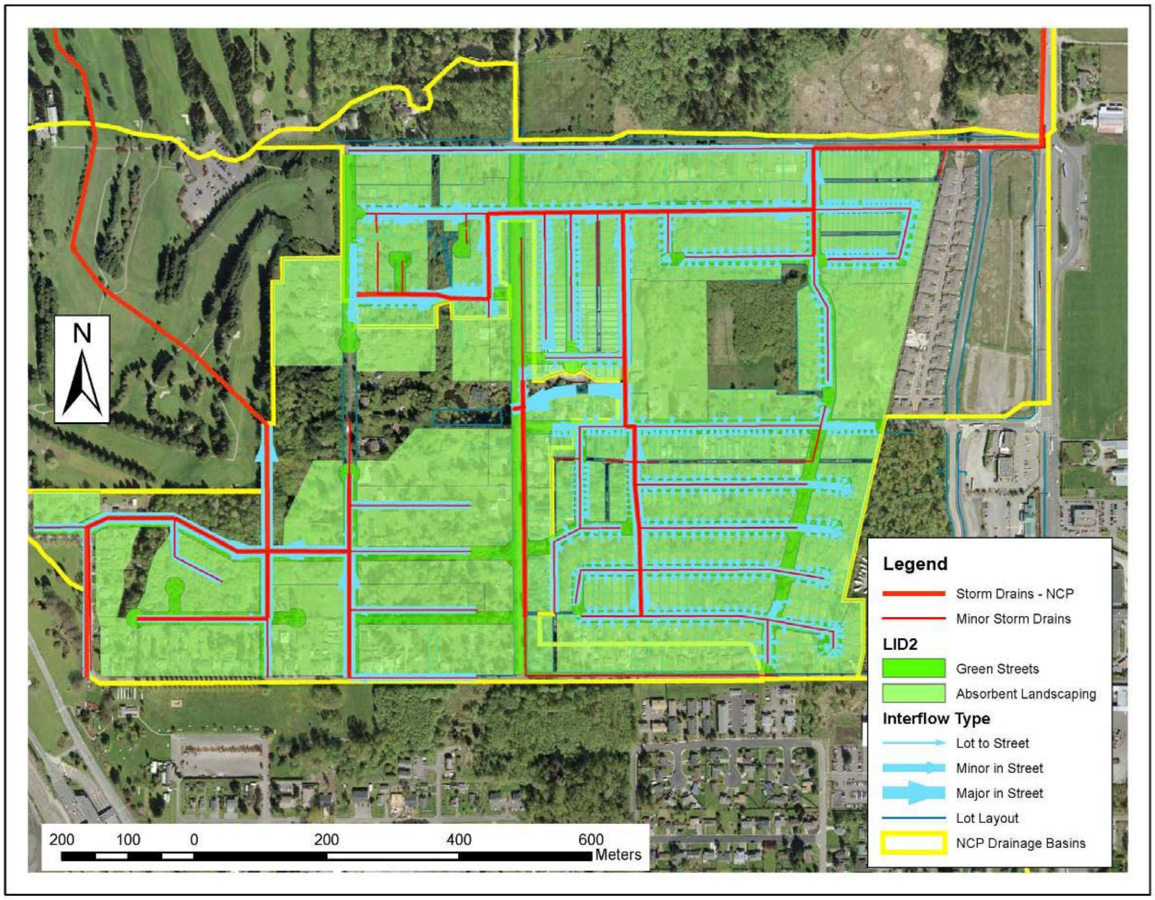

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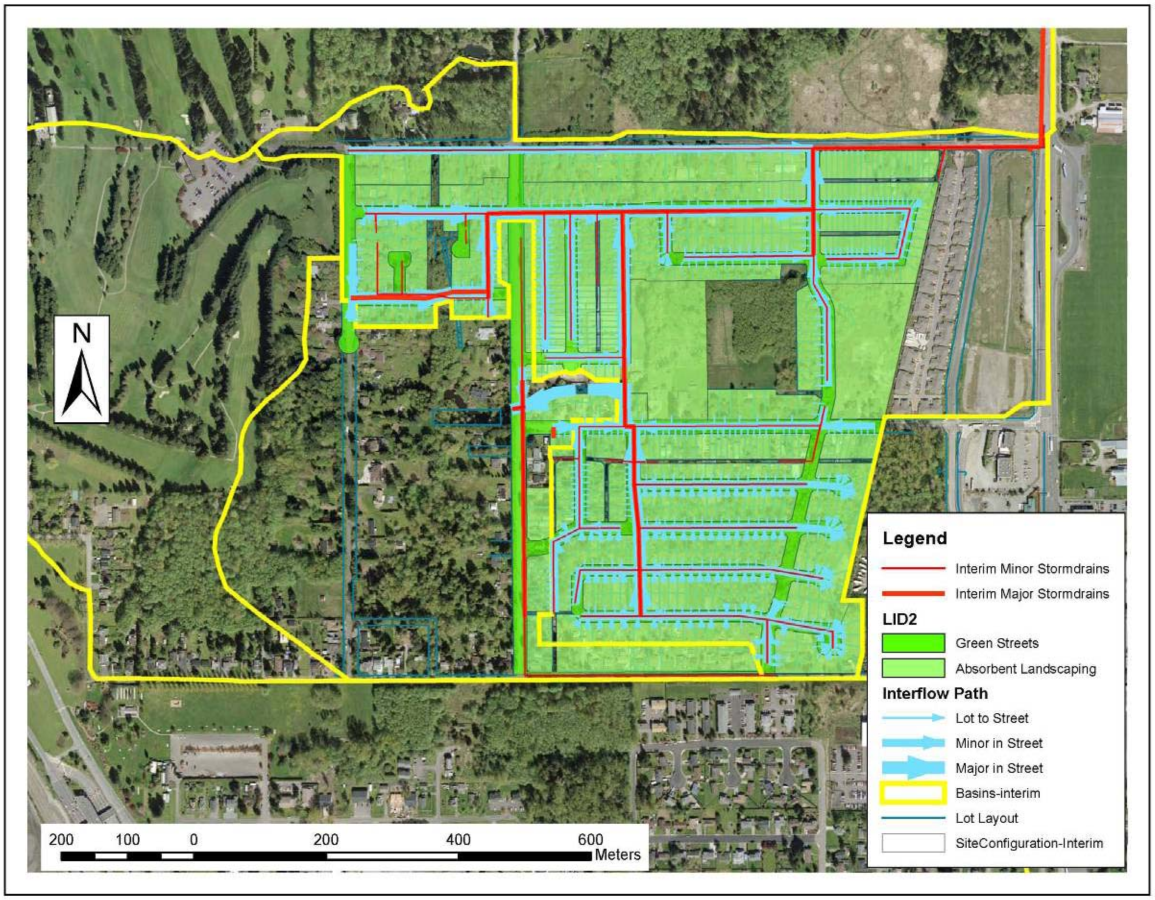
FIGURE 6-12
Storm Drainage Servicing Concept – INTERIM Development Scenario with LID2 Concept for Stormwater Management



6.3.5 Impact Analysis

The impact of the development and stormwater management scenarios have been evaluated at the locations described in the Baseline Scenario, Section 5. The results of the analyses are summarized in the following tables:

Campbell River West Reach between 172nd Street and Highway 99:

Table 6-1 Peak flow rates in Campbell River upstream of Highway 99 (Conduit NCR9000 in the model)

Table 6-2 Water surface elevations in Campbell River at the Fergus Creek Confluence (Node CR14000).

Campbell River East Reach between 176th Street and 172nd Street:

Table 6-3 Peak flow rates in Campbell River downstream of 176th Street (Conduit NCR23000)

Table 6-4 Water surface elevations in Campbell River downstream of 176th Street (Node CR23000)

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The Southerly Depression in PPGC:

Table 6-5 Water surface elevation in PPGC southerly depression (Node PP05Det)

Table 6-6 Pipe flow into the PPGC southerly depression from the east (Conduit LPP07000)

Table 6-7 Surface flow into the PPGC southerly depression (Conduit LPPGC-over)

In addition, flow duration curves for the following sites were developed using the long-term simulation results:

- Campbell River upstream of Highway 99
- Campbell River downstream of 176th Street and the NCP East connection

The changes in flow rates and water surface elevations were evaluated based on the following criteria:

Positive impact: The reduction in flow rates or water surface elevations is more than 1% of the value established in the Baseline Hydrologic Parameters

No impact: The change in flow rates or water surface elevations is less than +/- 1% of the value established in the Baseline Hydrologic Parameters

Negative impact: The increase in flow rates or water surface elevations is more than 1% of the value established in the Baseline Hydrologic Parameters

6.3.6 Stormwater Management Scenario Impacts

DETENTION Concept

Even though the post-development flows for the design storm are controlled to the rate of the pre-development rate of flows at the discharge points from Douglas NCP, the flows and water surface elevations in both the east and west reach of Campbell River did not change or slightly increased for the range of storms evaluated in this study.

The overflow rates into, and the water surface elevations in the southerly depression of PPGC, are significantly reduced due to a combination of detention and off-site improvements to the PPGC storm drain.

This experience is a proof of the theory that, while detention ponds may contribute to resolving local drainage problems, they have limited or no benefits to the flow regime of receiving waters if they are located downstream of the hydrologic centroid of the watershed. Douglas NCP is located at the downstream end of the Campbell River watershed; therefore, the DETENTION scenario is not recommended for further consideration.

LID0 Concept

There were no changes to flow rates and water surface elevation in both the east and west reach of Campbell River for most of the storm events evaluated. There is a slight increase in flow rates and water surface elevations for the 100-year storm and a slight decrease for the observed October 2003 storm.

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There are significant decreases in water surface elevations in the southerly depression of PPGC, but this change is due to the off-site improvements and is largely independent from the selected stormwater management scenario for Douglas NCP.

LID1 and LID2 Concepts

Similar to the LID0 concepts, the results indicate that the selected stormwater management scenario has no impact on the flood flows and water surface elevations in Campbell River.

Any change to the flooding conditions in the southerly depression is the result of off-site improvements to the PPGC storm drain, not the selected stormwater management scenario in Douglas NCP.

In addition to the evaluation of the impact of the development on peak flow rates and water surface elevations, the impact on mean flows and runoff volumes were also evaluated using the results of long term simulations. As shown in the two charts below (Figure 6-13 and 6-14), the development has no measurable impact on the flow regime of Campbell River. (Post-development mean flow rates are virtually identical to pre-development mean flow rates).

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FIGURE 6-13
Flow Duration in Campbell River Upstream of Highway 99 – Year 2002 – Douglas NCP with LID2 Stormwater Management Scenario

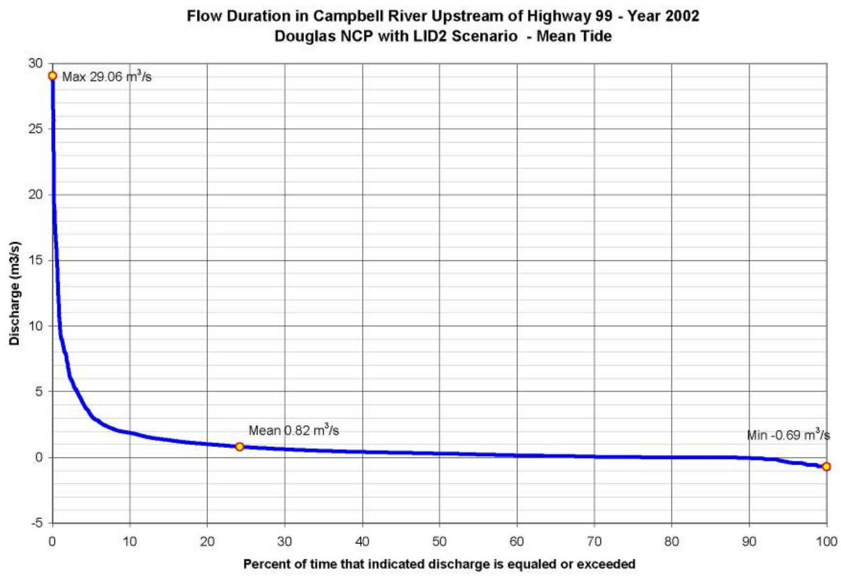
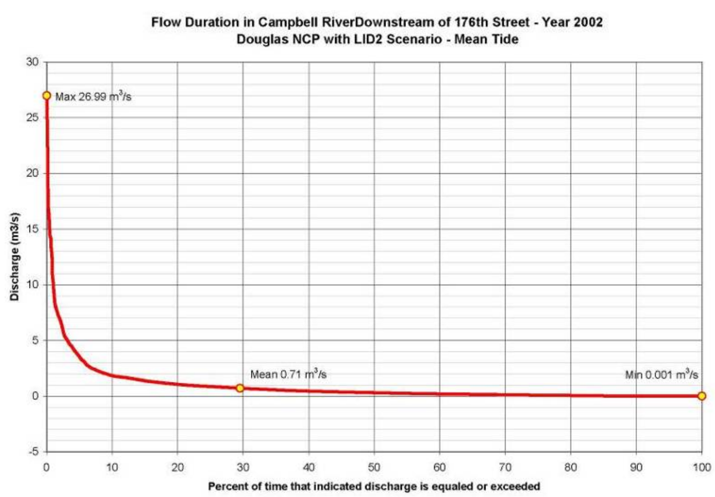


FIGURE 6-14
Flow Duration in Campbell River Downstream of 176th Street – Year 2002 – Douglas NCP with LID2 Stormwater Management Scenario



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6.3.7 Development Scenario Impacts

The difference between the two development scenarios is whether or not the westerly part of Douglas NCP is developed. Since the drainage basins of the two areas are separated, the two development scenarios have identical impacts to the east reach of Campbell River. The difference between the two scenarios is the impact to flooding conditions in the southerly depression of PPGC.

INTERIM Development Concept

In the INTERIM development scenario, a part of the Douglas NCP West catchment is diverted to the north-east, reducing the area draining to the PPGC by 30.92 ha, from 58.25 ha to 27.33 ha. The direct surface flow into the south depression remains the same 33.33 ha (Figure 6-15). This change in tributary area reduces the frequency and magnitude of flows into the depression from the east (Figure 6-16). The depth of ponding is also reduced in this area from the existing 7.7 m maximum water surface elevation during a 100-year return frequency storm to 7.1 m in the INTERIM development scenario (Figure 6-17). The duration of flooding is also reduced from roughly 2 days to about 1.5 days during a 100-year return frequency storm.

FIGURE 6-15
Interim Catchments to PPGC South Depression

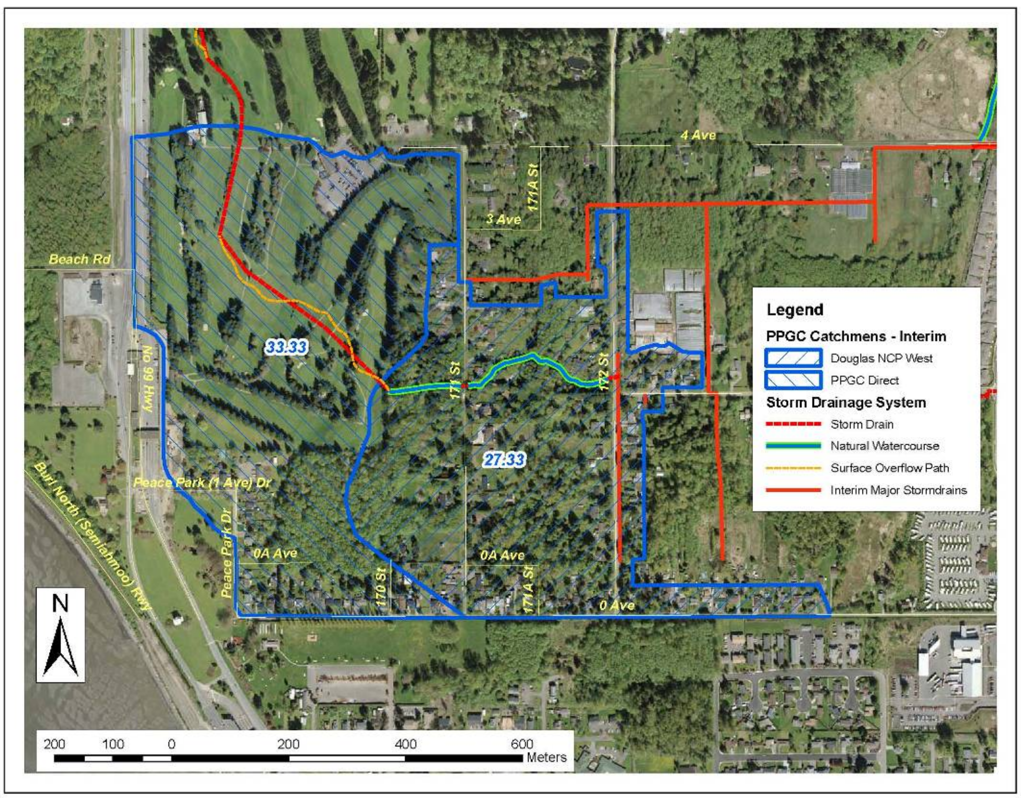

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FIGURE 6-16
Pipe and Surface Overflow from the East into PPGC South Depression - Interim

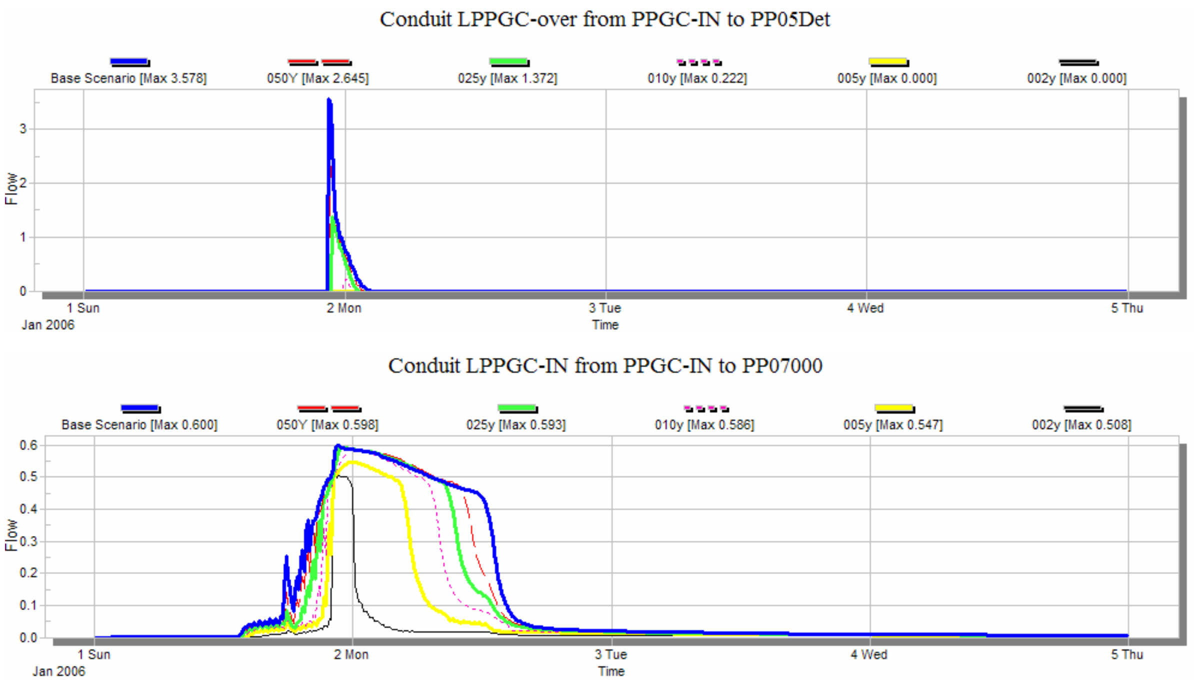
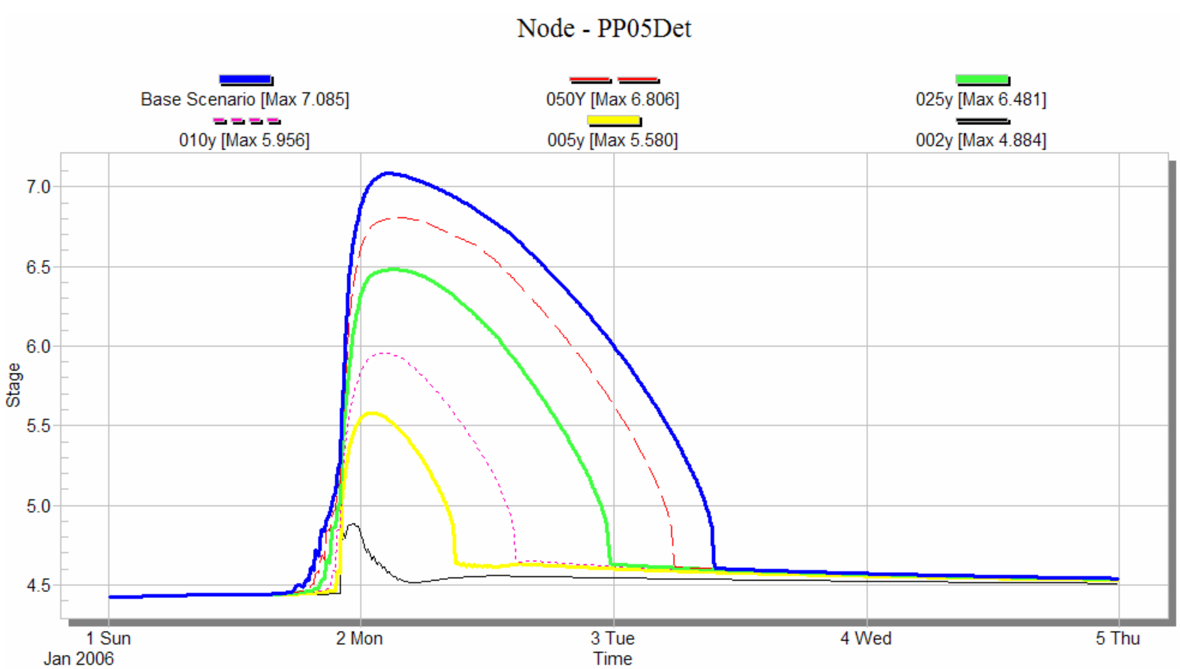


FIGURE 6-17
Water Surface Elevations in the PPGC South Depression - Interim



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NCP Development Concept

The development in the south-westerly part of Douglas NCP does not change the total tributary to the PPGC south depression, but it reduces the area of direct surface flow from 33.33 ha to 24.61 ha, and increases the area draining into the PPGC storm drain from the 27.33 ha INTERIM catchment to 36.41 ha (Figure 6-18). Off-site improvements to the PPGC storm drain will eliminate surface flows from the east and the maximum ponding elevation in the southerly depression will be reduced from the interim 7.0 m to 6.1 m (Figure 6-19). The duration of flooding is also reduced from roughly 1.5 days in the INTERIM, to one day. Ponding depth and the duration of flooding in this area may be further reduced by improving the capacity of storm drain inlets within the golf course.

FIGURE 6-18
NCP Catchments to PPGC South Depression

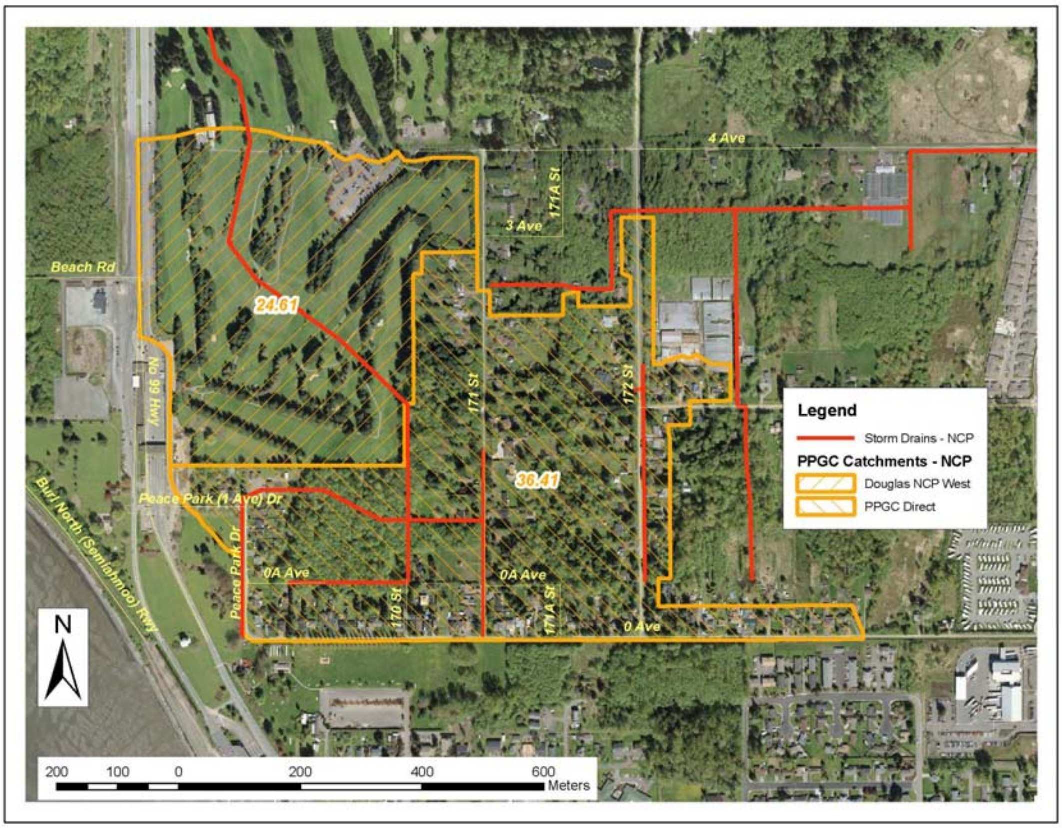

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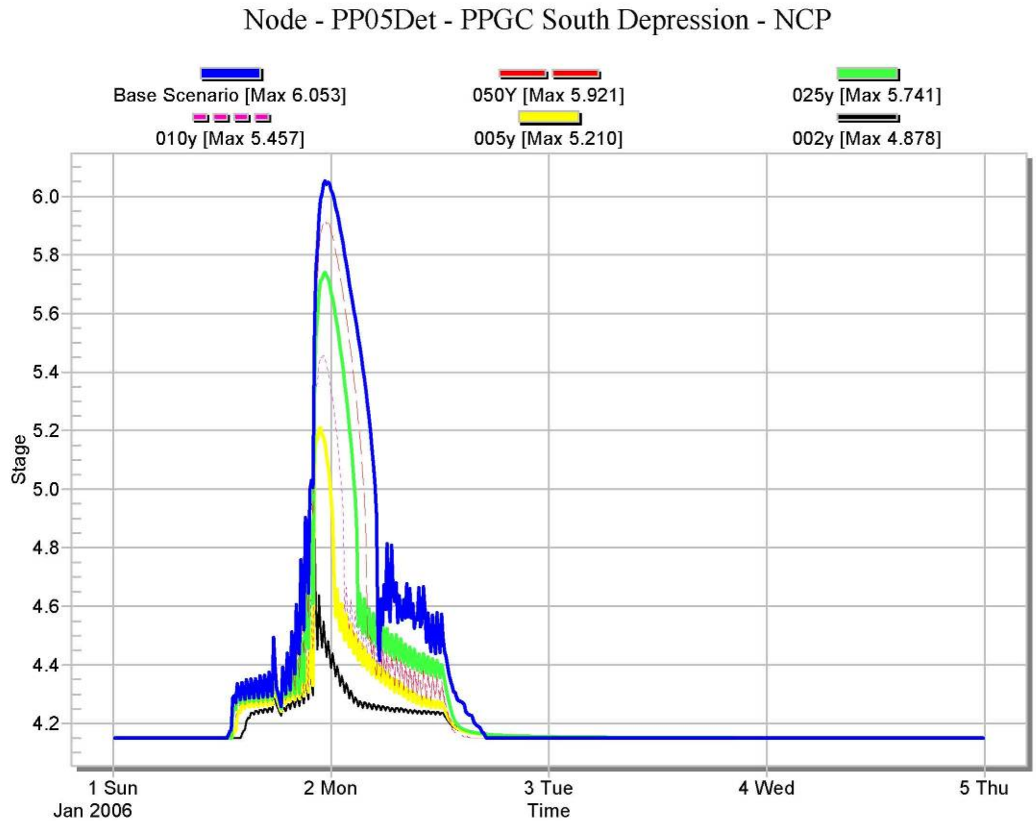
FIGURE 6-19
Water Surface Elevations in the PPGC South Depression – NCP



Outfall to the ocean from 0 Avenue

As mentioned earlier, this alternative diverts 24.8 ha of the westerly NCP area to the ocean. On one hand, this scenario will significantly reduce the storm flows currently draining through the PPGC, thus minimizing flooding concerns associated with future development of this area. On the other hand, this action will likely impact the hydrologic regime of the small tributary upstream of the PPGC. Due to the reduction in contributing area, it is expected that low and high flows in the stream will be reduced. The main concern, from the point of view of fish nutrient delivery, is the reduction in mean flows and the total volume of water discharged to the stream.

By means of continuous modelling, the impacts of this alternative on the tributary were analyzed. The analysis was performed for the year 2002. It was found that the total yearly volume of water discharged to the creek can be potentially reduced from 176,000 m^3 to 80,000 m^3, corresponding to existing and future conditions respectively. Also, mean yearly flows can be potentially reduced from 5.5 L/s to 2.5 L/s. This analysis provides an order of magnitude evaluation of flows that should be refined by a multi-year simulation. A detailed inspection of the creek to evaluate habitat values, and flow monitoring to better characterize the existing hydrologic regime of the water course, may be necessary to define mitigation objectives.

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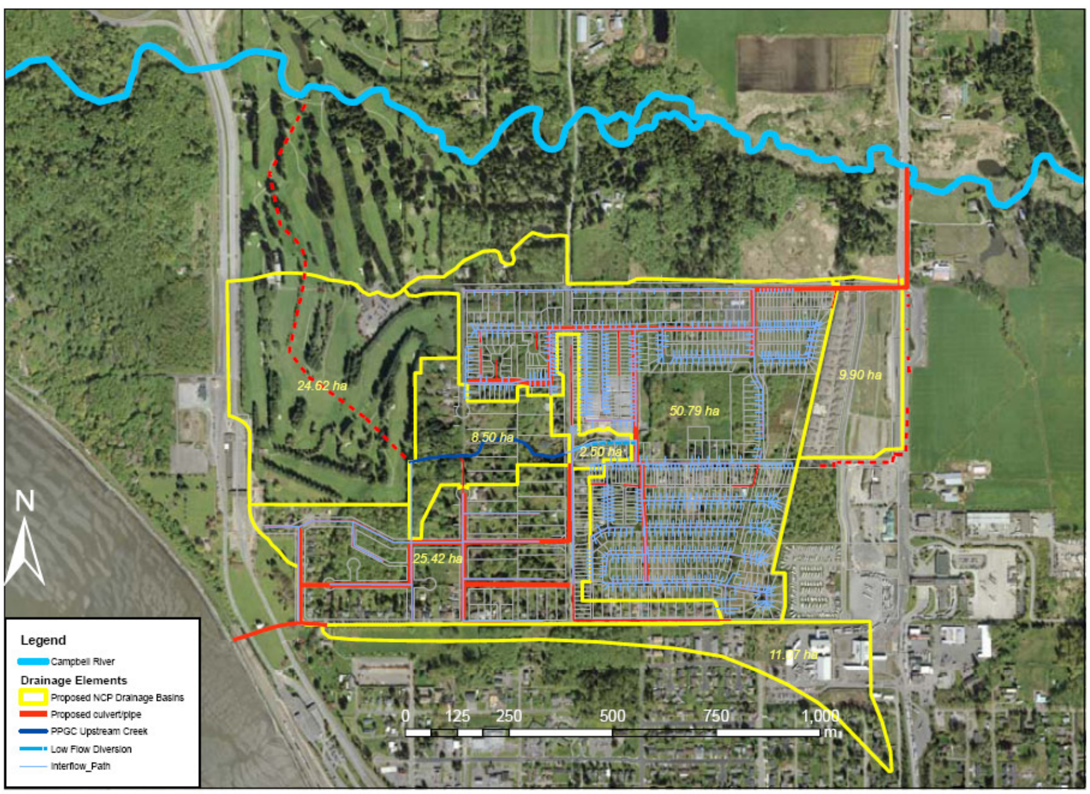
To address the issue of flow reductions, the addition of a low-flow outlet from the easterly NCP catchment is proposed as shown in Figure 6-20. A flow control device (hydro-break) will be necessary to ensure that the flows in the watercourse will not exceed the capacity of the existing PPGC storm drain. The detailed design of the storm drainage system should take into consideration the low-flow diversion needs.

The use of the LID1 option, with its corresponding interflow path, will direct the base flows (collected groundwater and low flows from storm events) from the 18.1 ha of the south eastern NCP to the creek. This option has the potential to add some 40,000 m^3 water per year to the stream (in terms of 2002 rainfall volumes). To complement this action, additional low-flow diversions form the areas west of 172nd Avenue may be considered if required by the resource agencies.

An analysis of the impacts of the 0 Avenue diversion, in Campbell River upstream of Highway 99 shows a reduction in flows and water levels as shown in Tables 6-1 to 6-7.

FIGURE 6-20
Storm Drainage Servicing Concept - NCP Development Scenario with Outfall from 0 Avenue, Low Flow Diversion and LID1 with Interflow Path for the South Easterly NCP



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6.3.8 Other Improvement Options

Highway 99 Culvert Improvements

Hydraulic analysis showed that the triple-barrel arch culvert under Highway 99 creates backwater in the PPGC. Field observations indicated that the configuration of the culvert inlet is hydraulically inefficient and vegetation growth (Figure 6-21) could create significant obstruction, which could result in even higher water surface elevations in PPGC than the maximum water surface elevation shown in this study.

A hydraulically efficient headwall at the inlet (east end of the culvert) could eliminate the potential for obstructions by vegetation ingrowths and would reduce backwater by reducing hydraulic losses at the entrance, particularly at the peak of major storm events (Figure 6-22). However, improvements to the Highway 99 culverts would impact the maximum water surface elevations during the peak of flooding events, when water surface elevations exceed 3.5 m. At this time, the depth of flooding is 1.5 m or higher above the banks of Campbell River and the golf course is likely not available for use. The Highway 99 culvert improvements, therefore, could reduce the maximum water surface elevations and the area impacted by the flood, but it would not have a significant impact on the usability of the PPGC.

FIGURE 6-21
Photo of the Highway 99 Culvert Inlet

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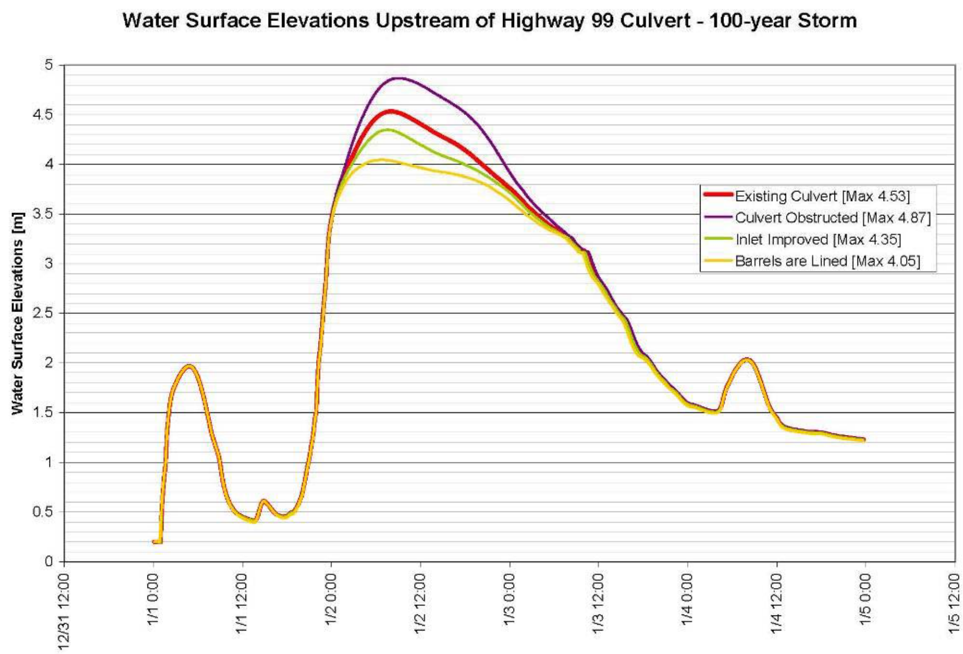
FIGURE 6-22
Potential Water Surface Elevations Upstream of Highway 99



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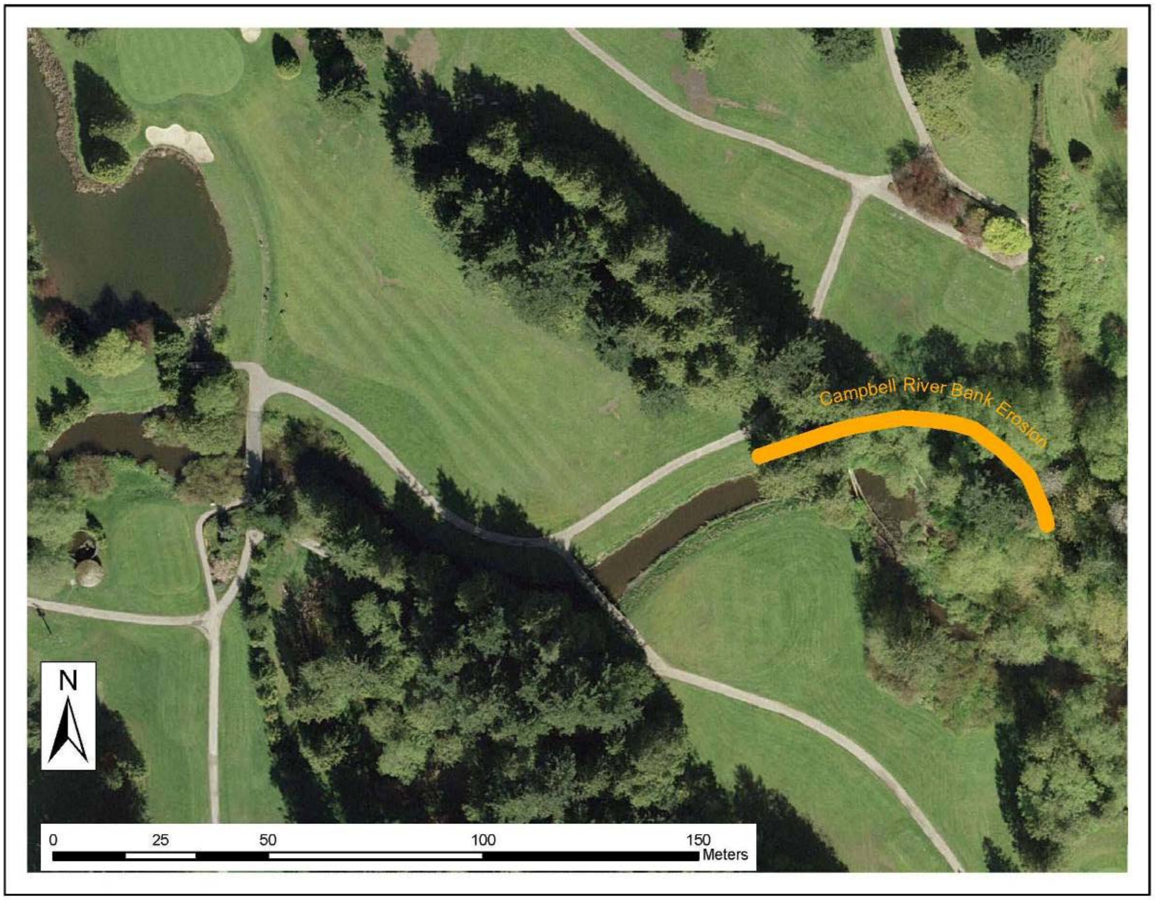
Campbell River Bank Stabilization

Bank erosion has been observed in the right (north) bank of a sharp bend in Campbell River, approximately 150 m east of the Fergus Creek confluence in the PPGC (Figure 6-23). This erosion appears to be a natural channel forming process; however it interferes with golf course operations. Carefully designed bank stabilization may eliminate this problem for PPGC without impacting the natural habitat values of Campbell River.

FIGURE 6-23
Bank Erosion in Campbell River



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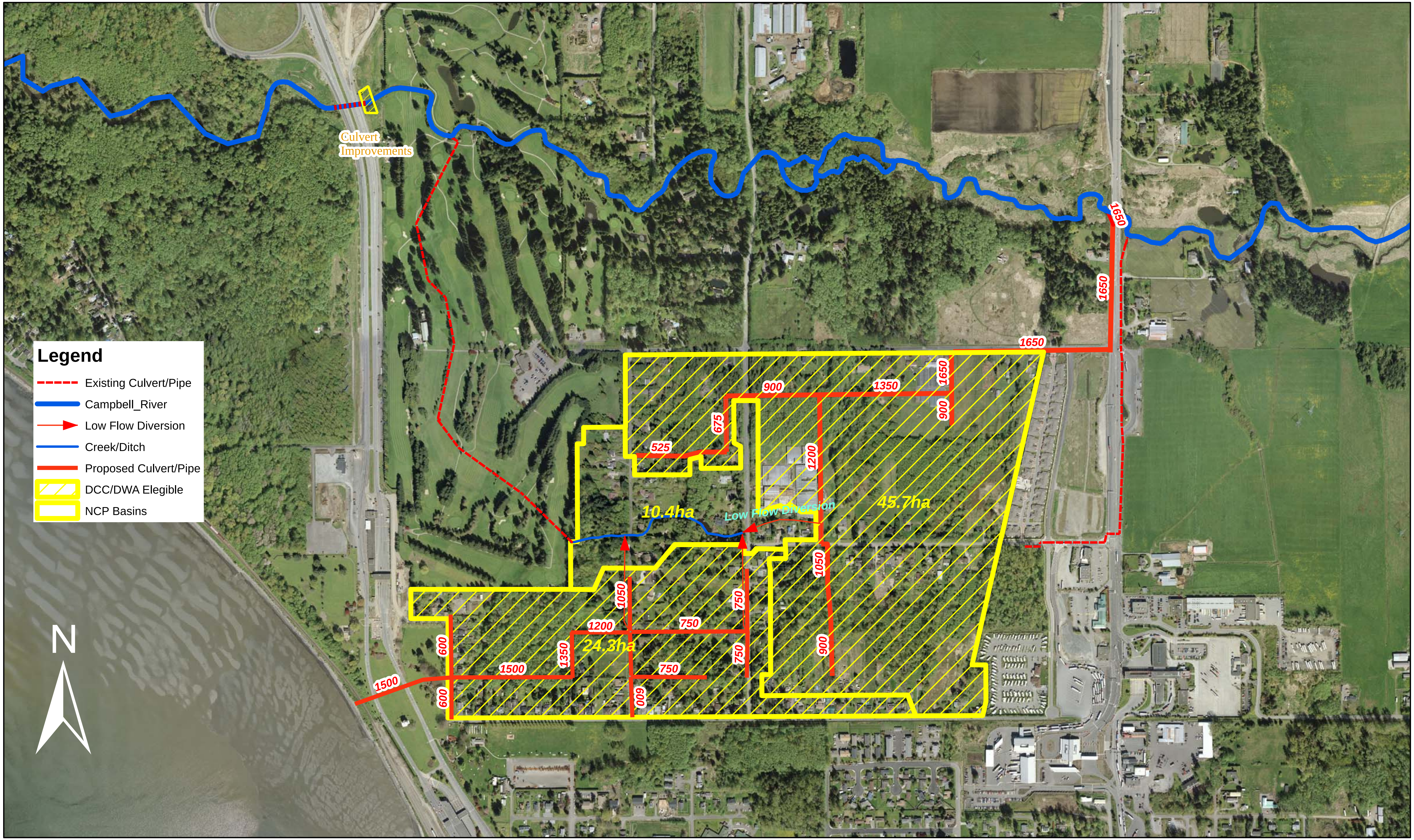

Client: Cressey Developments

Project: Douglas NCP Surrey, B.C.

Date: November, 2006

Title: **DCC Elegible Basins**

Figure: **6-24**

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6.3.9 Impact Matrix

To evaluate the impact of the development in the context of Campbell River and its tributaries, an "Impact Matrix" was developed to assist in the selection of stormwater management options for the Douglas NCP. The matrix was developed for the two development scenarios; the full development of the Douglas NCP area (NCP) and the partial development on the easterly part of Douglas NCP only (INTERIM).

Impacts of the various stormwater management scenarios were evaluated according to the following scale:

YES	**Significant positive impact**
YES	Positive impact
0	No impact
NO	Negative impact
NO	**Significant negative impact**

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Impact Matrix

NCP Development Scenario

Stormwater Management Scenarios and Other Improvement Options	Impact Location							
	Campbell River		PPGC	Water Quality		Groundwater		Westerly Watercourse
	East Reach	West Reach	South Depression	East Basin	West Basin	East Basin	West Basin	
DETENTION	NO	NO	NO	NO	NO	NO	NO	NO
LID0	0	0	NO	NO	NO	NO	NO	NO
LID1	0	0	NO	YES	YES	YES	YES	YES
LID2	0	0	NO	YES	YES	YES	YES	YES
0 Avenue Diversion	0	YES (High Flows) NO (Mean Flow)	YES	0	0	0	0	NO
LID1 with 0 Avenue-diversion and low-flow diversion(s)	0	YES	YES	YES	YES	YES	YES	YES
PPGC Storm Drain Improvements	0	0	YES	0	0	0	0	
Highway 99 Culvert Inlet	0	YES	0	0	0	0	0	
Campbell River Stabilization	0	YES	0	0	0	0	0	

Impact Matrix

INTERIM Development Scenario

Stormwater Management Scenarios and Other Improvement Options	Impact Location						
	Campbell River		PPGC	Water Quality		Groundwater	
	East Reach	West Reach	South Depression	East Basin	West Basin	East Basin	West Basin
DETENTION	NO	N/A	YES	NO	N/A	NO	N/A
LID0	0	0	YES	NO	0	NO	NO
LID1	0	0	YES	YES	0	YES	YES
LID2	0	0	YES	YES	0	YES	YES
PPGC Storm Drain Improvements	0	0	N/A	0	0	0	0
Highway 99 Culvert Inlet	0	YES	0	0	0	0	0
Campbell River Stabilization	0	YES	0	0	0	0	0

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TABLE 6–1
Campbell River Upstream of Highway 99

Location: **Campbell River Upstream of Highway 99**
Conduit Name: NCR09000

System Conditions	Peak Flow Rate during Various Frequency Storm Events							Change in Peak Flow from Baseline Condition							Percent Change in Peak Flow from Baseline Condition						
	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03
	m^3/s							m^3/s							%						
Baseline																					
Existing - Mean Tide	78.30	68.20	55.30	38.00	24.50	4.10		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing - Large Tide (Baseline Condition)	**78.70**	**68.70**	**55.60**	**38.10**	**24.50**	**4.14**	**83.35**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
DOUGLAS NCP																					
Detention	81.40	69.00	55.90	38.00	24.80	4.30	85.70	2.7	0.3	0.3	-0.1	0.3	0.2	2.4	3.4%	0.4%	0.5%	-0.3%	1.2%	4.8%	2.9%
No LID - Large Tide	80.40	68.30	54.80	37.70	24.70	4.10	80.85	1.7	-0.4	-0.8	-0.4	0.2	0.0	-2.5	2.2%	-0.6%	-1.4%	-1.0%	0.8%	0.0%	-3.0%
LID1 - Large Tide	78.70	68.40	55.40	37.80	24.60	4.10	80.90	0.0	-0.3	-0.2	-0.3	0.1	0.0	-2.4	0.0%	-0.4%	-0.4%	-0.8%	0.4%	0.0%	-2.9%
LID2 - Large Tide	78.60	68.40	55.40	37.70	24.60	4.10	80.88	-0.1	-0.3	-0.2	-0.4	0.1	0.0	-2.5	-0.1%	-0.4%	-0.4%	-1.0%	0.4%	0.0%	-3.0%
Interim																					
No LID - Large Tide	79.00	68.70	55.80	37.90	24.60	4.10	81.40	0.3	0.0	0.2	-0.2	0.1	0.0	-1.9	0.4%	0.0%	0.4%	-0.5%	0.4%	0.0%	-2.3%
LID1 - Large Tide	79.00	68.80	55.90	37.90	24.60	4.16	81.40	0.3	0.1	0.3	-0.2	0.1	0.0	-1.9	0.4%	0.1%	0.5%	-0.5%	0.4%	0.0%	-2.3%
LID2 - Large Tide	78.98	68.80	55.90	37.90	24.60	4.16	81.33	0.3	0.1	0.3	-0.2	0.1	0.0	-2.0	0.4%	0.1%	0.5%	-0.5%	0.4%	0.0%	-2.4%
0 Avenue Outfall LID0	78.53	68.27	53.48	36.78	23.97	4.00		-0.17	-0.43	-2.12	-1.32	-0.53	-0.14		-0.2%	-0.6%	-3.8%	-3.5%	-2.2%	-3.4%	

TABLE 6–2

Campbell River at Fergus Creek Confluence

Location: **Campbell River at Fergus Creek Confluence**

Node Name: **CR14000** Flow Line Elevation: 0.20 m

System Conditions	**Maximum Water Surface Elevation during Various Frequency**							**Change from baseline condition**							**Percent Change in Flow Depth from Baseline Condition**						
	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03
	m							m							%						
Baseline																					
Existing - Mean Tide	4.49	4.13	3.81	3.41	2.86	1.45		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing - Large Tide (Baseline Condition)	**4.53**	**4.18**	**3.83**	**3.41**	**2.86**	**2.00**	**4.67**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
DOUGLAS NCP																					
Detention	4.65	4.21	3.84	3.41	2.87	2.00	4.76	0.12	0.03	0.01	0.00	0.01	0.00	0.09	2.6%	0.7%	0.3%	0.0%	0.3%	0.0%	1.9%
No LID - Large Tide	4.61	4.18	3.82	3.40	2.86	1.99	4.57	0.08	0.00	-0.01	-0.01	0.00	-0.01	-0.10	1.8%	0.0%	-0.3%	-0.3%	0.0%	-0.5%	-2.1%
LID1 - Large Tide	4.53	4.18	3.83	3.40	2.86	1.99	4.57	0.00	0.00	0.00	-0.01	0.00	-0.01	-0.10	0.0%	0.0%	0.0%	-0.3%	0.0%	-0.5%	-2.1%
LID2 - Large Tide	4.53	4.17	3.83	3.40	2.86	1.99	4.57	0.00	-0.01	0.00	-0.01	0.00	-0.01	-0.10	0.0%	-0.2%	0.0%	-0.3%	0.0%	-0.5%	-2.1%
Interim																					
No LID - Large Tide	4.54	4.18	3.84	3.40	2.86	1.99	4.59	0.01	0.00	0.01	-0.01	0.00	-0.01	-0.08	0.2%	0.0%	0.3%	-0.3%	0.0%	-0.5%	-1.7%
LID1 - Large Tide	4.55	4.19	3.84	3.40	2.87	1.99	4.59	0.02	0.01	0.01	-0.01	0.01	-0.01	-0.08	0.4%	0.2%	0.3%	-0.3%	0.3%	-0.5%	-1.7%
LID2 - Large Tide	4.54	4.19	3.84	3.41	2.87	1.99	4.59	0.01	0.01	0.01	-0.01	0.01	-0.01	-0.08	0.2%	0.2%	0.3%	-0.3%	0.3%	-0.5%	-1.7%
0 Avenue Outfall LID0	4.52	4.16	3.78	3.38	2.84	1.97		-0.01	-0.02	-0.05	-0.03	-0.02	-0.03		-0.2%	-0.5%	-1.3%	-0.9%	-0.7%	-1.5%	

TABLE 6–3
Campbell River Downstream of 176th Street

Location: **Campbell River Downstream of 176th Street**
Conduit Name: NCR23000

System Conditions	Peak Flow Rate during Various Frequency Storm Events							Change in Peak Flow from Baseline Condition							Percent Change in Peak Flow from Baseline Condition						
	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03
	m^3/s							m^3/s							%						
Baseline																					
Existing - Mean Tide	66.0	57.1	47.0	32.3	21.4	3.6		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing - Large Tide (Baseline Condition)	**66.0**	**57.1**	**47.0**	**32.3**	**21.4**	**3.6**	**72.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
DOUGLAS NCP																					
Detention	68.8	57.7	47.6	32.8	21.7	3.7	75.60	2.8	0.6	0.6	0.5	0.3	0.1	2.9	4.2%	1.1%	1.3%	1.5%	1.4%	2.8%	4.0%
No LID - Large Tide	68.2	57.4	46.8	32.5	21.4	3.6	70.44	2.2	0.3	-0.2	0.2	0.0	0.0	-2.3	3.3%	0.5%	-0.4%	0.6%	0.0%	0.0%	-3.2%
LID1 - Large Tide	66.4	57.4	47.3	32.5	21.5	3.6	70.62	0.4	0.3	0.3	0.2	0.1	0.0	-2.1	0.6%	0.5%	0.6%	0.6%	0.5%	0.0%	-2.9%
LID2 - Large Tide	66.4	57.5	47.3	32.5	21.5	3.6	70.68	0.4	0.4	0.3	0.2	0.1	0.0	-2.0	0.6%	0.7%	0.6%	0.6%	0.5%	0.0%	-2.8%
Interim																					
No LID - Large Tide	66.4	57.4	47.2	32.5	21.5	3.6	70.5	0.4	0.3	0.2	0.2	0.1	0.0	-2.2	0.6%	0.5%	0.4%	0.6%	0.5%	0.0%	-3.0%
LID1 - Large Tide	66.4	57.4	47.3	32.5	21.5	3.6	70.6	0.4	0.3	0.3	0.2	0.1	0.0	-2.1	0.6%	0.5%	0.6%	0.6%	0.5%	0.0%	-2.9%
LID2 - Large Tide	66.4	57.5	47.3	32.5	21.5	3.6	70.7	0.4	0.4	0.3	0.2	0.1	0.0	-2.0	0.6%	0.7%	0.6%	0.6%	0.5%	0.0%	-2.8%
0 Avenue Outfall LID0	66.60	57.98	45.91	31.99	21.18	3.51		0.60	0.88	-1.09	-0.31	-0.22	-0.09		0.9%	1.5%	-2.3%	-1.0%	-1.0%	-2.5%	

TABLE 6–4
Campbell River Downstream of 176th Street

Location: **Campbell River Downstream of 176th Street**

Node Name: **CR23000** Flow Line Elevation: 1.70 m

System Conditions	**Maximum Water Surface Elevation during Various Frequency**							**Change from baseline condition**							**Percent Change in Flow Depth from Baseline Condition**						
	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03
	m							m							%						
Baseline																					
Existing - Mean Tide	6.04	5.65	5.22	4.61	4.17	2.81		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing - Large Tide (Baseline Condition)	**6.04**	**5.65**	**5.22**	**4.61**	**4.17**	**2.81**	**6.30**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
DOUGLAS NCP																					
Detention	6.16	5.68	5.24	4.63	4.18	2.84	6.41	0.12	0.03	0.02	0.02	0.01	0.03	0.11	2.0%	0.5%	0.4%	0.4%	0.2%	1.1%	1.7%
No LID - Large Tide	6.13	5.65	5.20	4.61	4.16	2.81		0.09	0.00	-0.02	0.00	-0.01	0.00	-6.30	1.5%	0.0%	-0.4%	0.0%	-0.2%	0.0%	-100.0%
LID1 - Large Tide	6.06	5.66	5.22	4.62	4.17	2.81	6.21	0.02	0.01	0.00	0.01	0.00	0.00	-0.09	0.3%	0.2%	0.0%	0.2%	0.0%	0.0%	-1.4%
LID2 - Large Tide	6.06	5.66	5.22	4.62	4.17	2.81	6.21	0.02	0.01	0.00	0.01	0.00	0.00	-0.09	0.3%	0.2%	0.0%	0.2%	0.0%	0.0%	-1.4%
Interim																					
No LID - Large Tide	6.06	5.66	5.23	4.62	4.17	2.81	6.22	0.02	0.01	0.01	0.01	0.00	0.00	-0.08	0.3%	0.2%	0.2%	0.2%	0.0%	0.0%	-1.3%
LID1 - Large Tide	6.06	5.66	5.23	4.62	4.17	2.82	6.22	0.02	0.01	0.01	0.01	0.00	0.01	-0.08	0.3%	0.2%	0.2%	0.2%	0.0%	0.4%	-1.3%
LID2 - Large Tide	6.06	5.66	5.23	4.62	4.17	2.82	6.22	0.02	0.01	0.01	0.01	0.00	0.01	-0.08	0.3%	0.2%	0.2%	0.2%	0.0%	0.4%	-1.3%
0 Avenue Outfall LID0	6.05	5.66	5.17	4.60	4.15	2.80		0.01	0.01	-0.05	-0.01	-0.02	-0.01		0.2%	0.2%	-1.0%	-0.2%	-0.5%	-0.4%	

TABLE 6–5

Pipe Flow into the Peace Portal Golf Course Storm Drain

Location: **Pipe Flow Into the Peace Portal Golf Course Storm Drain**

Conduit Name: LPPGC-IN

System Conditions	**Peak Flow Rate during Various Frequency Storm Events**							**Change in Peak Flow from Baseline Condition**							**Percent Change in Peak Flow from Baseline Condition**							
	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03
	m^3/s							m^3/s							%						
Baseline																					
Existing - Mean Tide	0.61	0.60	0.60	0.59	0.59	0.45		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing - Large Tide (Baseline Condition)	**0.61**	**0.60**	**0.60**	**0.59**	**0.59**	**0.45**	**0.59**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
DOUGLAS NCP																					
Detention	1.28	1.23	1.20	1.18	1.15	0.85	0.85	0.67	0.63	0.60	0.59	0.56	0.40	0.26	109.8%	105.0%	100.0%	100.0%	94.9%	88.9%	44.1%
No LID - Large Tide	6.60	4.63	4.70	4.00	3.30	1.80	1.15	5.99	4.03	4.10	3.41	2.71	1.35	0.56	982.0%	671.7%	683.3%	578.0%	459.3%	300.0%	94.9%
LID1 - Large Tide	4.74	4.45	4.98	3.66	2.67	1.41	0.80	4.13	3.85	4.38	3.07	2.08	0.96	0.21	677.0%	641.7%	730.0%	520.3%	352.5%	213.3%	35.6%
LID2 - Large Tide	6.52	6.17	6.12	4.98	3.55	1.26	0.71	5.91	5.57	5.52	4.39	2.96	0.81	0.12	968.9%	928.3%	920.0%	744.1%	501.7%	180.0%	20.3%
Interim																					
No LID - Large Tide	0.60	0.60	0.59	0.59	0.54	0.51	0.53	-0.01	0.00	-0.01	0.00	-0.05	0.06	-0.06	-1.6%	0.0%	-1.7%	0.0%	-8.5%	13.3%	-10.2%
LID1 - Large Tide	0.60	0.60	0.59	0.59	0.55	0.49	0.52	-0.01	0.00	-0.01	0.00	-0.04	0.04	-0.07	-1.6%	0.0%	-1.7%	0.0%	-6.8%	8.9%	-11.9%
LID2 - Large Tide	0.60	0.60	0.59	0.58	0.54	0.46	0.52	-0.01	0.00	-0.01	-0.01	-0.05	0.01	-0.07	-1.6%	0.0%	-1.7%	-1.7%	-8.5%	2.2%	-11.9%
0 Avenue Outfall LID0	0.59	0.59	0.56	0.53	0.51	0.42		-0.02	-0.01	-0.04	-0.06	-0.08	-0.03		-3.3%	-1.7%	-6.7%	-10.2%	-13.6%	-6.7%	

TABLE 6–6
Southerly Depression in Peace Portal Golf Course

Location: **Southerly Depression in Peace Portal Golf Course**
Node Name: **PP05Det** Flow Line Elevation: 4.80 m

System Conditions	Maximum Water Surface Elevation during Various Frequency							Change from baseline condition							Percent Change in Flow Depth from Baseline Condition						
	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03
	m							m							%						
Baseline																					
Existing - Mean Tide	7.72	7.38	7.00	6.36	5.65	4.89		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing - Large Tide (Baseline Condition)	**7.72**	**7.38**	**7.00**	**6.36**	**5.65**	**4.89**	**6.94**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
DOUGLAS NCP																					
Detention	6.15	5.99	5.81	5.52	5.22	4.88	5.25	-1.57	-1.39	-1.19	-0.84	-0.43	-0.01	-1.69	-20.3%	-18.8%	-17.0%	-13.2%	-7.6%	-0.2%	-24.4%
No LID - Large Tide	6.05	5.90	5.74	5.45	5.20	4.87	5.19	-1.67	-1.48	-1.26	-0.91	-0.45	-0.02	-1.75	-21.6%	-20.1%	-18.0%	-14.3%	-8.0%	-0.4%	-25.2%
LID1 - Large Tide	6.13	5.96	5.78	5.53	5.27	4.66	5.14	-1.59	-1.42	-1.22	-0.83	-0.38	-0.23	-1.80	-20.6%	-19.2%	-17.4%	-13.1%	-6.7%	-4.7%	-25.9%
LID2 - Large Tide	5.35	5.15	5.04	4.15	4.15	4.15	4.69	-2.37	-2.23	-1.96	-2.21	-1.50	-0.74	-2.25	-30.7%	-30.2%	-28.0%	-34.7%	-26.5%	-15.1%	-32.4%
Interim																					
No LID - Large Tide	7.08	6.81	6.48	5.96	5.58	4.88	6.33	-0.64	-0.57	-0.52	-0.40	-0.07	-0.01	-0.61	-8.3%	-7.7%	-7.4%	-6.3%	-1.2%	-0.2%	-8.8%
LID1 - Large Tide	7.08	6.81	6.48	5.95	5.58	4.88	6.33	-0.64	-0.57	-0.52	-0.41	-0.07	-0.01	-0.61	-8.3%	-7.7%	-7.4%	-6.4%	-1.2%	-0.2%	-8.8%
LID2 - Large Tide	7.07	6.79	6.45	5.93	5.58	4.88	6.33	-0.65	-0.59	-0.55	-0.43	-0.07	-0.01	-0.61	-8.4%	-8.0%	-7.9%	-6.8%	-1.2%	-0.2%	-8.8%
0 Avenue Outfall LID0	6.72	6.46	6.21	5.83	5.54	4.86		-1.00	-0.92	-0.79	-0.53	-0.11	-0.03		-13.0%	-12.5%	-11.3%	-8.3%	-1.9%	-0.6%	

TABLE 6-7
Overflow into the Peace Portal Golf Course Southerly Depression

Location: **Overflow Into the Peace Portal Golf Course Southerly Depression**

Conduit Name: PP05Det

System Conditions	Peak Flow Rate during Various Frequency Storm Events							Change in Peak Flow from Baseline Condition							Percent Change in Peak Flow from Baseline Condition						
	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03	100-year	50-year	25-year	10-year	5-year	2-year	October-03
	m^3/s							m^3/s							%						
Baseline																					
Existing - Mean Tide	6.55	4.89	3.65	1.49	0.26	0.00		0.0	0.0	0.0	0.0	0.0	0.0	-1.0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing - Large Tide (Baseline Condition)	**6.55**	**4.89**	**3.65**	**1.49**	**0.26**	**0.00**	**1.04**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
DOUGLAS NCP																					
Detention	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-6.55	-4.89	-3.65	-1.49	-0.26	0.00	-1.04	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	0.0%	-100.0%
No LID - Large Tide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-6.55	-4.89	-3.65	-1.49	-0.26	0.00	-1.04	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	0.0%	-100.0%
LID1 - Large Tide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-6.55	-4.89	-3.65	-1.49	-0.26	0.00	-1.04	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	0.0%	-100.0%
LID2 - Large Tide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-6.55	-4.89	-3.65	-1.49	-0.26	0.00	-1.04	-100.0%	-100.0%	-100.0%	-100.0%	-100.0%	0.0%	-100.0%
Interim																					
No LID - Large Tide	3.58	2.65	1.37	0.22	0.00	0.00	0.00	-2.97	-2.24	-2.28	-1.27	-0.26	0.00	-1.04	-45.3%	-45.8%	-62.5%	-85.2%	-100.0%	0.0%	-100.0%
LID1 - Large Tide	3.47	2.33	1.15	0.18	0.00	0.00	0.00	-3.08	-2.56	-2.50	-1.31	-0.26	0.00	-1.04	-47.0%	-52.4%	-68.5%	-87.9%	-100.0%	0.0%	-100.0%
LID2 - Large Tide	3.30	2.16	1.04	0.00	0.00	0.00	0.00	-3.25	-2.73	-2.61	-1.49	-0.26	0.00	-1.04	-49.6%	-55.8%	-71.5%	-100.0%	-100.0%	0.0%	-100.0%
0 Avenue Outfall LID0	1.04	0.46	0.00	0.00	0.00	0.00		-5.51	-4.43	-3.65	-1.49	-0.26	0.00		-84.1%	-90.6%	-100.0%	-100.0%	-100.0%		

6.4 Financial Analysis

6.4.1 Infrastructure Financing and Funding

The City of Surrey's 10 Year Capital Plan includes engineering works which are required for both the existing and future needs of the community. Typically the existing needs are funded from general revenue or utility monies or grants and infrastructure required for growth is principally (90 percent) funded by Developers through Development Cost Charges (DCCs). The City will only fund works which are included in the 10 year plan.

The City of Surrey has taken the following approach to infrastructure funding in NCP's:

- The City of Surrey has endorsed the use of DCC Frontender Agreements as a method of reimbursing developers for frontending the cost of major engineering infrastructure that is in the 10-Year Capital Servicing Plan.
- The long term DCC revenues and expenditures for major storm improvements within an NCP area must balance or show a positive cash flow at build-out. A Development Works Agreement can be considered to cover the cost of major infrastructure items that are not covered by DCCs.
- The City will not fund interim works.

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DCC Elements

TABLE 6-8
DCC Eligible Infrastructure

Item Location	Cost ($)	Current, Removal or Addition	ID # Current 10 Yr Plan	Amount in Current Program	Additions to Program	Notes
Detention Pond #1 1 Ave/170A St.	$1,200,000	Removal	6661	$1,200,000	-	
Detention Pond #2 176 St./4 Ave	$2,000,000	Removal	6664	$2,000,000	-	
Trunk Sewer 4 Ave: 175 St. to Campbell River	$364,800 (600 ∅)	Removal	6660	$364,800	-	600m @ $608/m
Trunk Sewer 173 St: 2A Ave to 3A Ave	$360,800 (1200∅)	Addition	-	-	$360,800	220m @ $1640/m
Trunk Sewer 3A Ave: 173 St to 174 St	$551,000 (1350 ∅)	Addition	-	-	$551,000	290m @ $1900/m
Trunk Sewer 174 St: 3A Ave to 4 Ave	$228,000 (1650 ∅)	Addition	-	-	$228,000	95m @ $2400/m
Trunk Sewer 4 Ave: 174 St to 176 St.	$840,000 (1650 ∅)	Addition	-	-	$840,000	350m @ $2400/m
Trunk Sewer 176 St: 4 Ave to Campbell River	$720,000 (1650 ∅)	Addition	-	-	$720,000	300m @ $2400/m
Trunk Sewer Peace Park Drive: 0A Ave to Outfall	$1,956,000 (1500 ∅)	Addition	-	-	$1,956,000	257m @ $7,610m
Culvert Upgrade Campbell @ Hwy 99	$150,000	Addition	-	-	$150,000	

This NCP would see a removal of $3,564,800 and addition of $4,805,800 in DCC works. These new works can be divided into two catchments: the northeast catchment and the southwest catchment. The purpose of this division is that the first developments in each catchment will trigger the construction of the necessary storm infrastructure. Therefore, any development in the northeast catchment, all lands east of 172 Street or north of the

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environmental protection area at approximately 2 Avenue, would trigger the construction of $2,699,800 in upgrades. Any development in the southwest catchment, all lands west of 172 Street and south of the environmental protection area, would trigger the construction of $1,956,000 in upgrades.

The upgrading of the existing culverts under Highway 99 is a project identified through the hydrologic modelling yet reflects an existing condition and not one resulting from development within the Douglas NCP area. Further, as the Douglas area accounts for only a tiny portion of the Campbell River watershed, it is proposed that the removal of vegetation and construction of headwalls be undertaken by the City and funded through City-wide DCC's.

It is noted that only those DCC elements in the current 10 year plan (DCC elements) will receive DCC reimbursements as per the current City policy. The proposed works in the NCP will be eligible if they are added to the 10 year plan (DCC elements).

6.4.2 Storm DCC Revenues and Expenditures

The Douglas area is anticipated to have a build-out of 1400 units which represents a population of 4200 people. Based on the catchments outlined above, approximately 950 units will be located within the 41.0-hectare northeast catchment, whereas 450 units will be within the 20.6-hectare southwest catchment. Regardless of any potential surplus or shortfall within these catchments, the $4,655,800 in storm DCC works must be funded by these proposed units with the remaining $150,000 undertaken by the City.

Complicating the financial analysis is the City's recent DCC increase, and the applicability of the one year "grace" period wherein in-stream applications would be eligible to develop under the existing DCC rates. All single-family applications that receive subdivision, and all multi-family applications that receive building permit by June 26, 2007 will pay the previous 2005 rates. It is possible, and conservative, to assume that up to half of all applications within both catchments would only contribute the previous rates.

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TABLE 6-9
Projected DCC Revenues

	Townhouse		Small Lot S.F.		Urban S.F.		Suburban		Commercial/School		Total	Total
	$1.01/$1.32/ft.²		$1545/$2,007		$2618/$3,401		$5,236/5,952		$1326/1000ft.²		Units	Revenue
	Units	Revenue(1)	Units	Revenue	Units	Revenue	Units	Revenue	Units	Revenue(2)		
NE'05	0	$0	187	$288,915	222	$581,196	8	$41,888			417	$911,999
NE'06	204	$336,600	85	$170,595	186	$632,586	15	$89,280			490	$1,229,061
SW'06	140	$231,000	62	$124,434	67	$227,867	0	$0		$87,649	269	$670,950
									Total at Buildout		1176	$2,812,010

(1) Based on 1,250 Ft.²/Unit

(2) Based on 37,600 Ft.² Commercial, 75,000 Ft.² School at $1326/1000ft² plus 30 units at $0.30/ Ft.²

TABLE 6-10
DCC Balance Sheet

	# of Units	DCC Revenues	DCC Expenditures	Difference
Northeast Catchment	907	$2,141,060	$2,699,800	-$558,740
Southwest Catchment	269	$670,950	$1,956,000	-$1,285,050
Total	**1176**	**$2,812,010**	**-$4,655,800**	**-$1,843,790**

Provided that the items listed above are included in the City's 10-year plan, the storm DCC revenues and expenditures result in a net deficit of $1,843,790. Throughout the Douglas NCP area, with 57.34-hectares of developable land, this represents a shortfall of $32,155/hectare.

As above, the first developer in each catchment will be required to construct the necessary drainage infrastructure. As neither catchment will generate enough DCC's to cover these costs, the proponents will have the option of pursuing a Development Works Agreement, (DWA), in order to establish a levy to recover these shortfalls. The levy would be calculated using actual costs of construction, however, in order to establish a DWA, a petition must be signed by a majority of the landowners representing a majority of the land value in the benefiting area. Further, the DWA must be approved by council prior to the developer entering into a servicing agreement to construct these works.

It is important to note that DWA's are traditionally only effective for a period of ten years, so if the area does not build-out within this time frame, the proponent would not recover their costs.

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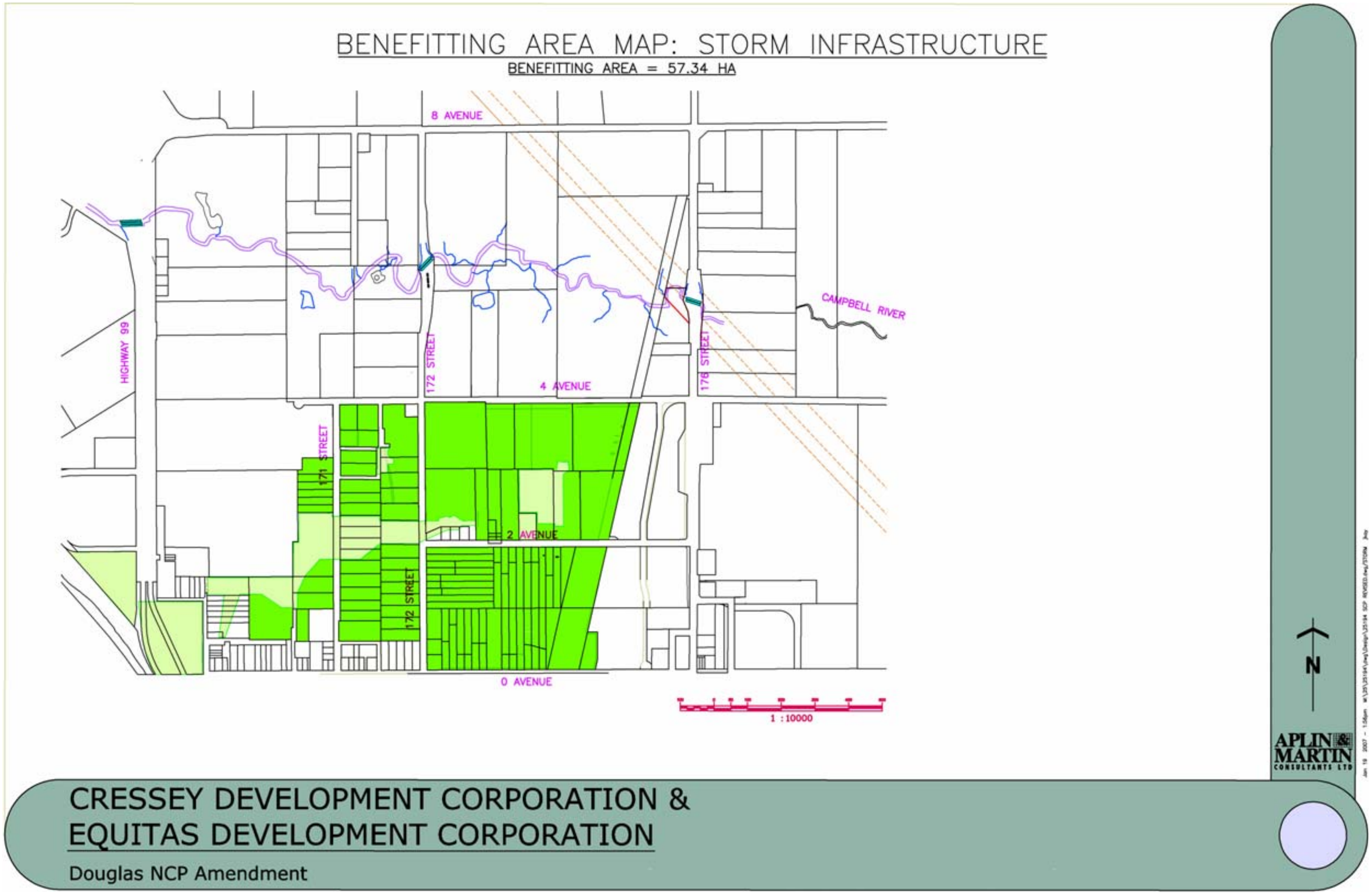
FIGURE 6-25
Benefitting Area Map (Aplin Martin)



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7 Conclusions

As a result of the evaluations of existing conditions in the Campbell River and its tributaries, and the potential impacts of various developments, stormwater management, and servicing scenarios, the conclusions of this study are:

- The evaluation of the existing conditions in Campbell River and its tributaries show that the floodplain of Campbell River is approximately 80 m to 200 m wide along the reach of the river between 176th Street and Highway 99. A significant part of the PPGC is located within this floodplain.
- The area of the Douglas NCP represents approximately 1.1% of the Campbell River watershed and it is located at the downstream end of the watershed.
- The peak of stormwater discharges from the Douglas NCP occur several hours before the peak of flows in Campbell River, and the rate of flows are well within the normal flow regime of the river.
- The proposed servicing concepts provide an effective storm drainage system that satisfies the needs of the Douglas NCP development (including basements in the buildings) and comply with the City of Surrey Drainage Design Criteria.
- The Douglas NCP has no impact on the flow regime of Campbell River, independent from which of the evaluated stormwater management scenarios (LID0, LID1, or LID2), except the DETENTION scenario, is selected for the development.
- The DETENTION stormwater management scenario would increase flows and water surface elevations in Campbell River.
- LID practices are not needed for stormwater surface runoff control, but they are needed for stormwater quality treatment and groundwater management.
- The LID0 scenario (direct connection to storm drains) has no beneficial impact on either stormwater quality or groundwater and does not provide adequate stormwater management for Douglas NCP.
- The LID1 scenario (green streets and interflow path) has a beneficial impact on both stormwater quality and groundwater management, and provides adequate stormwater management for Douglas NCP.
- The LID2 scenario (green streets, interflow path, and absorbent landscaping) has enhanced beneficial impacts on both stormwater quality and groundwater management, and would provide premium stormwater management for Douglas NCP.
- The drainage problem in the south depression of PPGC is a pre-existing condition. The INTERIM development scenario for Douglas NCP would provide some improvement in this area.

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- The full development of Douglas NCP will require off-site improvements to eliminate potential negative stormwater related impacts of the development and create beneficial impacts to the PPGC. Potential off-site improvements include:
  - 2-Outfalls scenario with improvements to the PPGC storm drain to accommodate post-development flows through the PPGC
  - 3-Outfalls scenario with a new outfall at 0 Avenue to limit post-development flows to the PPGC storm drain to the capacity of the existing pipe
- The 3-Outfalls servicing concept reduces peak flows in the small westerly watercourse and the lower section of Campbell River
- The 3-Outfalls servicing concept reduces mean flows in the small westerly watercourse and the lower section of Campbell River. This impact may be partially mitigated by low-flow diversions from the NCP
- The detention concept may be used in the off-site improvement concept for the PPGC storm drain, but it has no beneficial impact on the flow regime of Campbell River and may face potential environmental concerns due to construction in riparian habitat area.

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8 Recommendations

8.1 Recommend Drainage Servicing Concept

Based on the technical evidence presented in this document, the recommendations of this study are:

- *Consider the implementation of the 3-Outfalls storm drainage servicing concept with the LID1 stormwater management scenario and low-flow diversions into the small westerly watercourse for the full development of Douglas NCP, as illustrated in Figure 8.1*.
  - Construct the 176th Street outfall prior to the development of the areas of the Douglas NCP that are located east of 172nd Street
  - Disconnect the Douglas NCP drainage system from the 176th Street (Highway 15) drainage system
  - The drainage system for the areas located between 171st and 172nd Streets and within approximately 250m south of 4th Avenue is considered to be part of the easterly storm drainage system of Douglas NCP
  - Construct the 0 Avenue outfall prior to development of the Douglas NCP west of 172nd Street and south of 2nd Avenue
  - Provide low-flow diversion(s) to the westerly watercourse that is originated north of 2nd Avenue and east of 172nd Street and discharges into the PPGC storm drain. The location and the rate of flow diversion(s) need to be defined by discussions with the resource agencies, but the resultant flow rates in the watercourse should not exceed the capacity of the existing PPGC storm drain.
  - Clarify how the existing drainage system through the PPGC is installed and how it operates.
  - Consider the implementation of the LID1 stormwater management scenario for stormwater quality and groundwater management that includes:
    - "Green streets" for water quality treatment of street runoff in depressed street landscape areas
    - Infiltration chambers (gravel filled trenches) below street landscape areas (where feasible)
    - Roof drains discharging into landscape areas
    - Site drainage of individual lots discharging into street landscape areas rather than directly into storm drains

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  - An "interflow path" using permeable backfill in trenches of public utilities (storm drain and sanitary sewer) and house connections

- Low flow diversion(s) into the westerly watercourse to replenish base flows reduced by the diversion of contributing surface water catchment areas to other outfalls
- Consider improvements to the inlets of the Highway 99 culverts for improved hydraulic performance through the structures and reduced maximum water surface elevations in the PPGC during significant flooding events
- Consider assisting PPGC with an environmentally sensitive design to resolve the erosion problem in Campbell River approximately 150 m east of the Fergus Creek confluence

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Legend

- Existing Culvert/Pipe
- Campbell_River
- HydroBreak
- Proposed Culvert/Pipe
- Creek/Ditch

0 50 100 200 300 400 Meters

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Client:	Cressey Developments
Project:	Douglas NCP Surrey, B.C.
Date:	October, 2006
Title:	**Proposed Servicing Alternative**
Figure:	**8.1**

9 Glossary of Terms and Acronyms

1999 Douglas NCP	The approved Douglas Neighbourhood Concept Plan, July 1999
2006 NCP Amendment	The currently proposed amendment to the approved 1999 NCP
PPGC	Peace Portal Golf Course
LID practices	**L**ow **I**mpact **D**evelopment practices
ISMP	Integrated Stormwater Management Plan

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10 References

Douglas Neighbourhood Concept Plan, July 1999

Douglas Area Neighbourhood Concept Plan Stormwater Drainage, McElhanney Consulting Services, March 1999

Soils of the Langley-Vancouver Map Area, Report No. 15, RAB Bulletin 18, British Columbia Soil Survey, BC Ministry of Environment, 1981

Design Criteria Manual, City of Surrey, Engineering Department, May 2004

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11 Appendices

Appendix A

Green-Ampt infiltration parameters recommended for use in SWMM models:

USDA Soil Texture Classification	Average Capillary Suction	Saturated Hydraulic Conductivity	Initial Moisture Deficit
	mm	mm/hr	
Sand	49.5	235.6	0.346
Loamy Sand	61.3	59.8	0.312
Sandy Loam	110.1	21.8	0.246
Loam	88.9	13.2	0.193
Silt Loam	166.8	6.8	0.171
Sandy Clay Loam	218.5	3.0	0.143
Clay Loam	208.8	2.0	0.146
Silty Clay Loam	273.0	2.0	0.105
Sandy Clay	239.0	1.2	0.091
Silty Clay	292.2	1.0	0.092
Clay	316.3	0.6	0.079

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