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Douglas Creek Study (Project No. 15/11)

Draft- Report
November 2011
KWL Project No. 437.083

Prepared for:

The Corporation of the District of Saanich

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Contents

Figures

Tables

Appendices

Section 1

Introduction

1. Introduction

1.1 Background

The Douglas Creek watershed is a 5.5 km^2 urbanized watershed in the eastern part of the District of Saanich (see Figure 1-1). Historically, the watershed had about 7 km of stream channel draining the watershed which extends south from Mount Douglas Park to about McKenzie Avenue near Gordon Head Road. Now only about 800 m of the original stream channel remains within the lower reaches of the channel in the Mount Douglas Park and about 80 km of stormwater sewers draining the remaining watershed. The combination of increased impervious area and increased using sewers for drainage in the watershed has significantly increased the speed with which rainfall is transferred to the stream. This has increased peak flows in the open channel downstream which has led to channel erosion and damage to stream habitat.

The urbanization in the watershed has also led to reduced water quality and changed baseflows in the natural stream channel. Sources of the water pollution include both non-point source such as grit and oil from street runoff, as well as point sources such as furnace oil leaks, and illegal dumping of deleterious materials into stormwater sewers such as paint, used oil and other household chemicals. An inverted weir structure has been installed near the main outlet of the stormwater sewer system to try to address water quality issues. However, as the structure was only designed for smaller discharges it becomes overwhelmed during large winter storms resulting in carrying over the pollutants and poor water quality in the channel downstream.

Since 1995, the Friends of Mount Douglas Park Society (FMDPS) and the District of Saanich, in co-operation with Department of Fisheries and Oceans (DFO) and Ministry of Environment (MoE) have work hard to improve the lower reaches of Douglas Creek to help improve habitat quality. The FMDPS have installed large woody debris (LWD), riffles, spawning gravel, riparian planting and carcase fertilization all in an effort to improve habitat for Chum and Coho salmon. Fry have been released into the creek and a small number of adults have returned. However, these returns have been low and sporadic. This is believed to be partially the result of poor incubation conditions unstable spawning habitat due to high winter flows and low survival rates for juveniles as a result of poor water and rearing habitat quality.

The focus of this study is to review both the condition of the lower reaches of Douglas Creek as well as the watershed as a whole to develop both short term and longer term solutions to water quantity and water quality issues. By developing options to address the water quality and water quantity issues at a watershed scale rather than at a local reach scale, it is hoped that stream habitat can be improved to help support a healthy aquatic ecosystem and fish population.

1.2 Previous Studies and Reports

Several past studies have been completed for both the Douglas Creek watershed as well as the lower natural reaches of the creek in Mount Douglas Park; A list of the primary reports reviewed and referenced in this study are listed below.

Douglas Creek Stormwater Retrofit Project prepared by Murdoch Landscape Planning and Design Ltd. in 2005.

This study prepared by Murdoch Landscape Planning and Design Ltd. outlines the current condition of the watershed and provided recommendations on source control approaches such as rain gardens, and bio-swales to treat stormwater runoff to improve. The report compares both effective impervious area and drainage density for both historical conditions and current land-use for the watershed as a whole as well as for each of the sub-basins. The report also estimates potential pollution loading in the watershed. Finally, examples of source controls to reduce effective runoff and improve water quality are discussed including design approaches. This report provides the primary basis for summarizing current watershed conditions which have helped guide recommendations in this study.

The Management of Hazardous Waste Hydrocarbons on the Douglas Creek Watershed, M. Cooke et. al., University of Victoria, 2005.

This study outlines the impacts to aquatic habitat and human health from pollutants in the Douglas Creek watershed as well as the results of water quality sampling completed in the Douglas Creek watershed. In particular, focus on impacts motor oils on human health and aquatic ecosystems as well as a summary of the legislation which prohibits discharge of deleterious substances into water bodies. Water samples taken throughout the watershed over a two week period indicate that concentrations of Polycyclic Aromatic Hydrocarbons (PAH) were higher than those recommended in the BC Water Quality Guidelines for the protection of Aquatic Life. Longer term sampling would be required to estimate the day to day concentrations exceed the Water Quality guidelines. In addition, the Capital Regional District (CRD) stormwater sampling program has indicated that sediment samples taken from the mouth of Douglas Creek exceed the Canadian Council of Ministers of Environment (CCME) Sediment Guidelines for copper concentrations with other heavy metal concentrations near the recommended maximums. Although the spilling of hazardous waste onto watershed and subsequently into a water body is prohibited by legislation, enforcement of the legislation is lacking because of complex pathways that pollutants can enter water bodies, difficulty in re-tracing and locating sources and limited resources available for enforcement. The primary recommendation for this study is increased public awareness of impacts of hazardous materials on water courses through public education.

Douglas Creek Salmon Habitat Assessment, S. Hocquard, University of Victoria, 2005

This study provides a summary of the results of a stream habitat assessment for Douglas Creek carried out using the methods described in the Urban Salmon Habitat Program Assessment Procedures for Vancouver Island (Michalski et. al., 1998). The procedure includes surveying the stream to measure physical habitat types and identify stream reaches, evaluating in-stream habitat including pools, cover, and substrate composition, measuring water quality using pH and dissolved oxygen (DO) meters, describing riparian habitat quality using standard classification and terminology then comparing the results with established standards. The three upper reaches of Douglas Creek were assessed from downstream of the Ash Road culvert to the weir. The results of the assessment indicate that pH (6.5), temperature (10.9 ^{o}C) and DO (10.7 mg/l) were good during the site visit completed in October 2005. Habitat areas rated as good include pool area (avg. 56%) and cover in pools (avg. 24%). Poor habitat parameters included erosion sites (avg. 24% of reach length, crown cover (avg. 24%), off-channel habitat (0) and in-stream habitat from vegetation (avg 2% per reach).

Detention Options for Douglas Creek, Bocksei et. al., 2003.

This is a comprehensive study looking at detention options within the sub-basins with a focus on reducing the 10-year event peak flow. The study provides background information on watershed condition and involved estimating hydrological estimates for peak-flows in the watershed. The report reviews various types of Stomwater BMPs and water quality control practices. Site specific detention, infiltration options are outlined. Seven stormwater management areas are identified within the watershed for detention using wetlands or dry-ponds/swales. The options indicate reduction in flows during the first half-hour and hour of 10-year event. However, they do not provide any information on reduction in peak flows or storage requirements to reduce peak flows to pre-development conditions.

In addition to these reports, the FOMDS have collected biological, water quality and water quantity data intermittently along the lower reaches of the Mount Douglas Creek. Although the data does provide a good overview of the stream conditions, significant gaps in the data limit the usefulness for analytical study.

Monitoring Restoration Success in Douglas Creek, Brown et. al., 2003.

This report assesses stream health of Douglas Creek using biological and biophysical variables including benthic macro-invertebrate populations and fecal coli form levels. The report compares Douglas Creek conditions with reference site in Colquitz Creek. The report identifies evidence of bed scouring, unstable banks and low summer flows. Insect populations indicate that Douglas Creek pollution levels are higher than those at the Colquitz Creek reference site. However, biota indicators may show that water quality is better downstream of Ash Road crossing in compared with the reaches upstream of Ash Road. Fecal coli form numbers are highest near the upstream end of the creek in comparison with downstream reaches. It is likely that the improvement of water quality downstream is the result of mixing, dilution, and filtering of water as it passes downstream.

1.3 Project Team and Stakeholders

Kerr Wood Leidal (KWL) and Murdoch deGreeff Landscape Architects (MDI) were retained by The Corporation of the District of Saanich (District) to complete the Douglas Creek Study. The study was lead by staff from the Planning, Engineering and the Parks departments. A summary of the project team is included in Table 1-1.

Table 1-1: Project Team

Corporation / Company	Team Member	Role
The Corporation of the District of Saanich	Dwayne Halldorson, Engineering	Project Manager
	Michael Roth, Planning	
	Corry Manton, Parks	
	Rae Roer, Parks	
Kerr Wood Leidal Associates Ltd.	Craig Sutherland	Project Engineer
	David Lee	Hydrologic/Hydraulic Modeller
Murdoch deGreeff Inc.	Scott Murdoch	Landscape Architect / Stream Biologist
	Paul deGreeff	Landscape Architect / Planner

On September 8, 2011, the project team met with members of the FOMDS and representative from the Department of Fisheries and Oceans (DFO) to review past work completed in the watershed and discuss potential options to resolve water quantity and water quality issues. The meeting was followed by a short field visit to Douglas Creek to review previously completed stream restoration work and discuss future plans.

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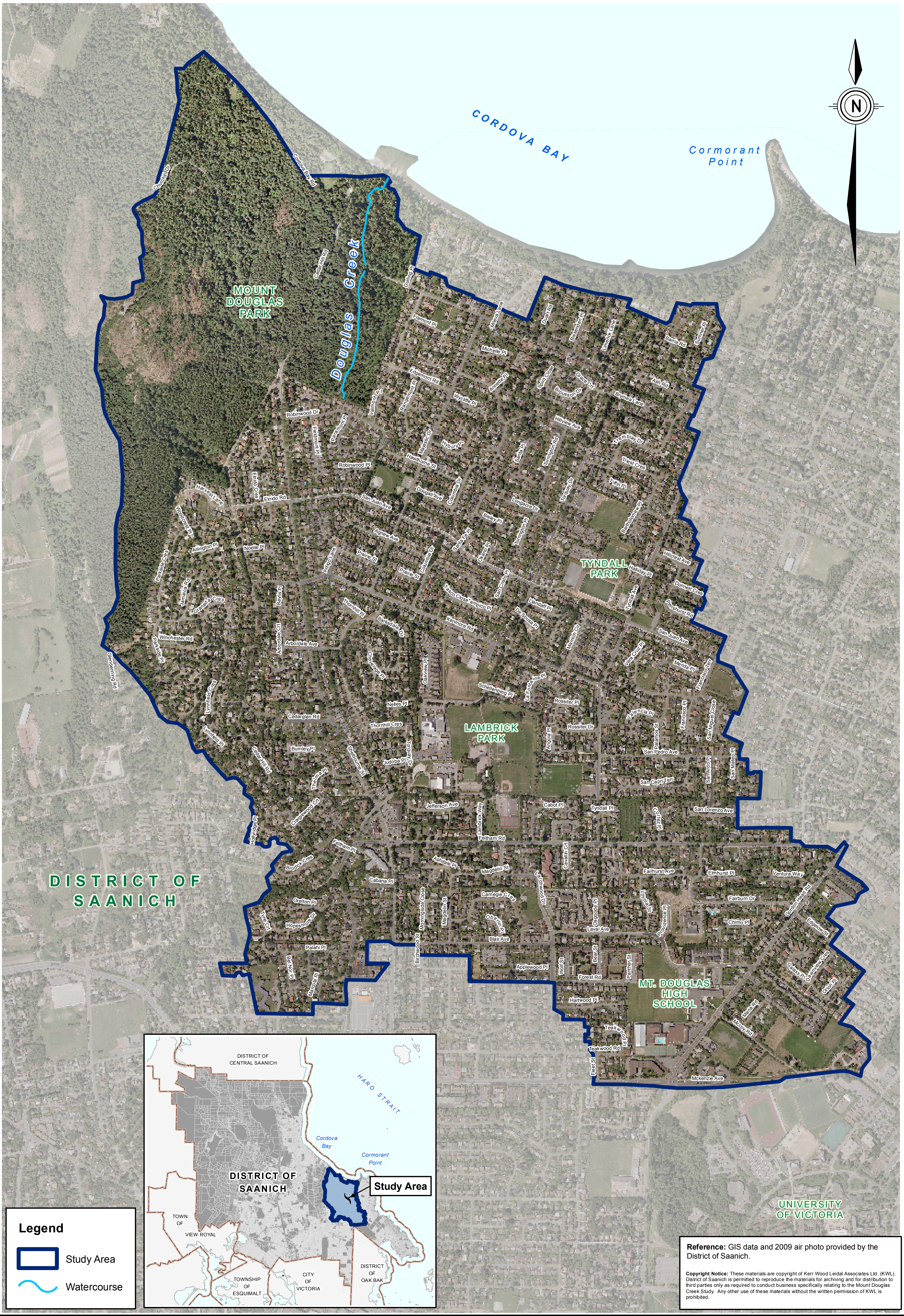

Reference: GIS data and 2009 air photo provided by the District of Saanich.

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Mount Douglas Creek Study

Project No.	Date
437-083	November, 2011

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Study Area
2009 Air Photo

Figure 1-1

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Section 2

Study Area

2. Study Area

2.1 Douglas Creek Watershed

The Douglas Creek watershed is a 5.5 km^2 urbanized watershed in the eastern part of the District of Saanich. The watershed drains an are roughly bounded by Blair Ave, Larchwood Drive, and McKenzie Ave to the south, Gordon Head Road, San Juan Ave, Hill Crest Ave, and Tyndal Ave to the east, Mount Douglas and the ridge to the west, and Ash Road to the north of Cedar Hill Cross Road. The watershed is divided into eight subcatchments based on stormwater drainage network. Most of the subcatchments (Tyndall, Lambrick, Blair, Parkside, and Shelbourne) drain to the stormwater main along Shelbourne Street while the remaining catchments (Ash, Mount Douglas, and Ravine) drain directly to the natural channel flowing through Mount Douglas Park. A detailed map showing the watershed and sub-basin boundaries are shown in Figure 2-1.

Historically the watershed was forested with Douglas Fir and Gary Oak meadows (Lea, 2002). In the late 1800s, the land was cleared for agriculture. Photos from the 1920s show that the predominant land cover in the watershed was still agricultural; However, starting in the 1950s the watershed was developed for housing and is now almost entirely suburban residential development with some commercial development along the Shelbourne Street corridor. Photos of the watershed taken from Mount Tolmie to Mount Douglas are shown in Figure 2-2.

Existing development in the watershed consists primarily of single-family residential lots (51.4%) with some multi-family development (8.1%) and commercial development (0.5%). The majority of the multi-family and commercial development is concentrated along the southern boundary of the watershed and along the Shelbourne Street corridor. The remainder of the area are natural parks (15%) as well as urban parks and other public lands such as schools (4.9%). Road surfaces make up a large percentage of the watershed area (20%). Figure 2-3 shows the existing landuses in the watershed.

Surface soils in the watershed have been heavily disturbed by development with very little of the surficial forest soils remaining in the watershed upstream of Mount Douglas Park. These disturbed and compacted surficial soils are underlain by native parent soils including Vashon Tills, Capilano Sediments, and Colquitz Gneiss formations (Muller, 1983). A soils map showing approximate areas of surficial sand/silt, clay and bedrock is shown in Figure 2-4.

Development of the watershed has led to increase in impermeable area. Recent aerial photography interpretation completed by Caslys Consulting Ltd based on 2009 aerial photography was used to calculate total impermeable surfaces in the watershed. The total percentage of impermeable area has been estimated to be about 37.6%, including Mount Douglas Park. For the watershed area upstream of the park, the total impervious area has been estimated to be about 41%.

Interestingly, the total impervious areas calculated using the aerial photography interpretation is higher than estimated in previous studies (see Table 2-1). Previous estimates where based on typical impervious area values for various land-use types. Using the percentage of landuse types in the watershed, the total impervious area was calculated. In comparison, the impervious areas calculated for this study are based on impervious areas measured from aerial photography. This difference is partially as a result of the difference between total impervious area and effective impervious area[1] as well as the result of increases in impervious cover on properties. This increase is due to larger homes being built on properties resulting in increased imperviousness but not increased housing density. These increases in lot coverage may not be accounted for in estimates of percentage impervious areas for various land-uses used in previous studies.

Within the developed area, a total of about 60% of the impervious area are public roads with the remaining area being roofs, driveways, parking lots and patios. A breakdown of the impervious areas in each of the sub-basins is shown in Table 2-1. A map showing the impervious and pervious areas within the watershed is shown in Figure 2-5.

Table 2-1: Impervious Area Estimates for Douglas Creek Watershed

Source	Percent Impervious Area
Kerr Wood Leidal, 2011	37%[a]
Murdoch Landscape Planning and Design, 2005	32%[b]
Bocskei et. al., 2003	31%[b]
Notes: a – based on total impermeable area measured from aerial photography interpretation completed by Caslys Consulting Ltd using 2009 aerial photography. b - based on area-weighted average of typical % impermeable surfaces for each landuse type in the watershed calculated using landuse/zoning data from District of Saanich.	

2.2 Douglas Creek Channel

The Lost Streams of Victoria maps complied by Suthrest (2003) indicate that historically the watershed was drained by a small network of creek channels totalling about 7 km in length (see Figure 2-6). During development of the watershed, the majority of these creek channels were in-filled and drainage was converted to a network of stormwater sewers. The total length of stormwater sewers in the catchment is approximately 80 km. In general the stormwater sewers the sub-catchments in the east of the watershed to the main trunk sewer which runs along Shelbourne Street. The only exception is the Ash Road sub catchment that drains to a 750 dia. stormwater sewer that discharges to the Douglas Creek

Only about 800 m of the historical creek network that runs through Douglas Creek is still in the natural channel. Upstream of the Ash Road culvert, the channel has a relatively flat slope and consists of several riffle pool sequences. The reaches upstream of the Ash Road crossing could provide good physical habitat for Coho provided downstream access issues, peak flow and water quality issues could be addressed. Downstream of the culvert the stream slope steepens and is showing signs of down cutting and bank erosion. In some places, almost the entire granular bed load has been eroded to expose the underlying consolidated silt/sand glacial till. It is within this lower section of the channel that FMDPS have focussed the majority of their stream restoration efforts. These efforts will be discussed in more detail in Section 3 below.

[1] Effective Impervious Area are impervious surfaces directly connected to the stormwater system such as roads, sidewalks, driveways and roofs with connected drain leaders.

2.3 Douglas Creek Water Quality

The land-use change in the watershed has led to increased impervious surfaces increasing the amount of rainfall running off the land surface and an increase in drainage conveyance (pipes, ditches and open channels) increasing the speed with which both water and pollutants are carried to the stream. The CRD have carried out annual storm water quality monitoring for selected stormwater outfalls across the region to review impacts to marine receiving water quality. The last sampling at the outlet of Douglas Creek was carried out in 2007. As part of the CRD Stormwater Sampling program, the following standards are used to assess water quality conditions for stormwater outfalls in the CRD:

1. comparison of fecal coliform testing with public health bathing standard of 200 fecal coliform per 100 ml; and
2. comparison of chemical contaminants to the Marine Sediment Quality Guidelines (Washington State Department of Ecology).

Recorded fecal coliform concentrations from 2003 to 2007 indicate levels typically indicate higher concentrations in winter and lower concentrations in summer. Most values are higher than the 200 per 100 ml standard at the mouth with the highest concentration recorded on Jan 30, 2007 at a concentration of 1,100 per 100 ml. This results indicate a moderate public health concern similar to Bowker Creek

The MSQG was selected for sediment sampling as it is well validated and has been reviewed by a scientific panel (Reid Crwother. 1998) as well as relative ease of use compared with other systems. The results of the analysis are shown in Table 2-2

Table 2-2: CRD Stormwater Quality Monitoring Results for Douglas Creek – Outlet #0559

Parameter	Recorded Value				CRD Marine Sediment Quality Guidelines Value[1] (µg/g)	BC Freshwater Sediment Quality Guideline Value[2] (µg/g)
	1993-11/16	1997/07/03	2000/07/10	2006/06/21		
Arsenic	1	1	5	3	57	5.9
Cadmium	0.1	0.1	0.1	0.2	5.1	0.6
Chromium	17	24	35	19	260	37
Copper	22	21	33	24	390	36
Lead	8	8	13	14	450	35
Mercury	0.08	0.02	0.02	0.02	0.41	0.174
Silver	0.0	0.1	0.1	0.1	6.1	0.5
Zinc	54	75	110	124	410	123
LPAH	0.2	0.1	0.1	0.1	5.2	0.1
HPAH	1	0	0	0	12	1

Notes:
1 – Standard values for based on Marine Sediment Quality Guidelines (Washington State Department of Ecology)
2 – Adapted from the Canadian Council for Ministers of Environment (CCME) Canadian Sediment Quality Guidelines

Based on these values the contaminant rating at the mouth of Douglas Creek was rated as low for marine receiving water. However, it is interesting to note that sediment sampling taken from upstream within the watercourse in 1997 resulted in a moderate contamination rating. This is indicating that pollution loads may be decreasing as water travels along the water course. This is a similar finding to the other water quality sampling done in the watershed.

Other studies suggest that water quality is impacting Douglas Creek biota (Browne, J, et. al. 2003). Examples include:

- Aquatic insect population data suggests pollutions levels are higher in Douglas Creek than in the Colquitz Ck. reference site.
- Biota statistics suggest water quality is better downstream of Ash Rd. (may be due to dilution of pollutants or filtering and cleaning of the water as it moves downstream).
- Fecal coli form numbers are highest at the head of the creek and decrease as the stream nears the ocean.

Landuse conditions in 2004 were related to potential pollution loads to the stream (Murdoch 2005). Sub-basins that potentially have the greatest water quality impact to the stream are the Shelbourne and Blair sub-basins followed by the Ash and Tyndal sub-basins (see Figure 2-7). Pollutants that were assessed were sediment, zinc, BOD, and nitrogen loading. The existing weir structure will hold back some contamination during low flows but is easily overwhelmed with only a moderated increase in stream flow. Maintenance on the form of sediment removal would also be required to avoid re-suspention of sediment and contaminants during moderate to high flow events.

With or without conclusive water quality data, the overall risk to the aquatic ecosystem is high given the high level of drainage connectivity in the watershed. Oil spills for example have occurred in the watershed and resulted in contamination of the stream. In terms of developing a sustainable fish population in the watershed, this level of connectivity must be reduced especially for species that permanently (e.g. Aquatic insects, Cutthroat trout, etc.) or have long term residence periods in the stream (e.g. Coho salmon, Sea run Cutthroat trout).

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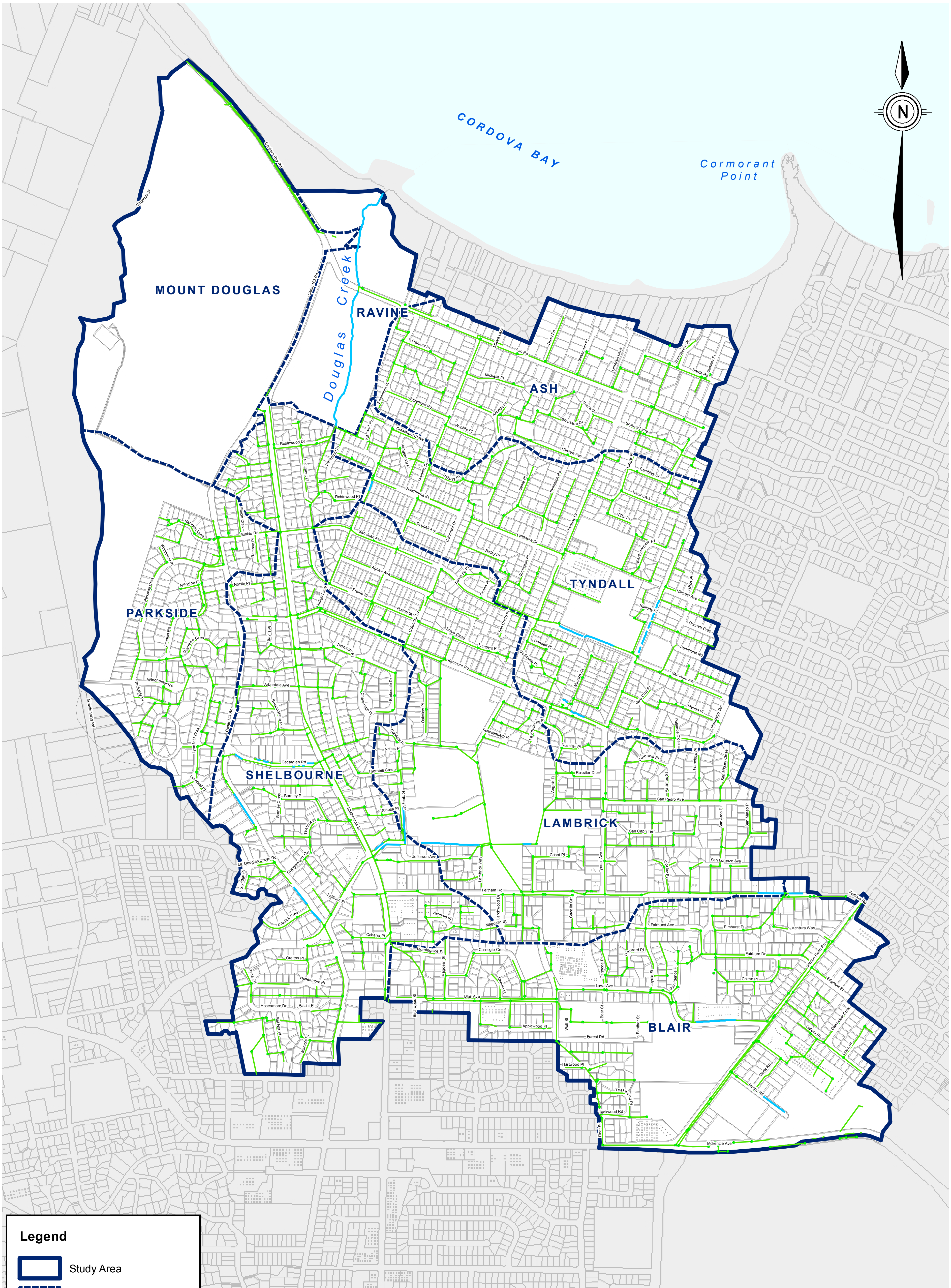

Reference: GIS data provided by the District of Saanich.

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Project No. 437-083
Date November, 2011

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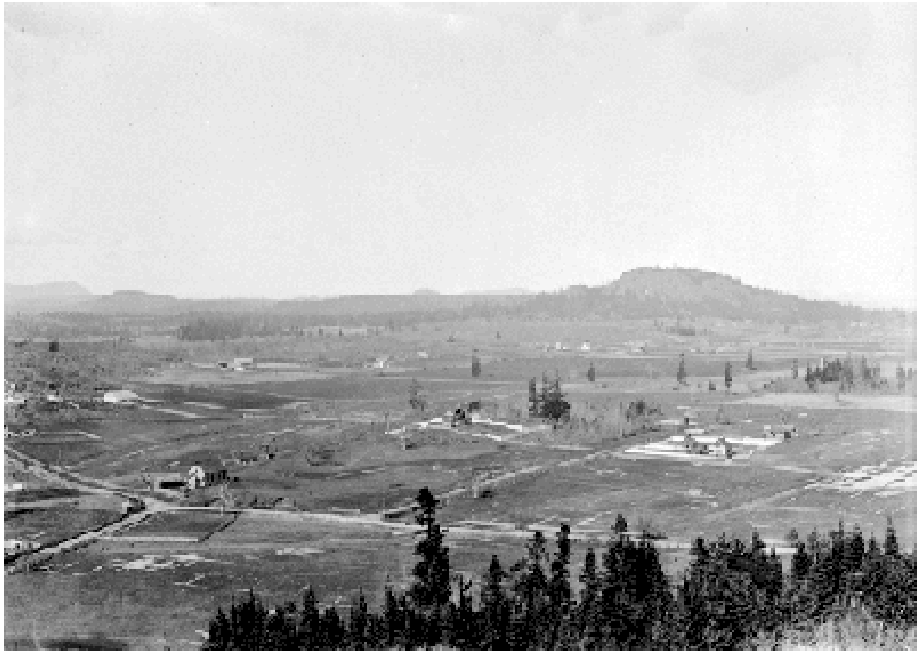
Douglas Creek Watershed and Sub-basins

Figure 2-1



Douglas Creek Watershed looking from Mount Tolmie to Mount Douglas 1880s

Douglas Creek Watershed looking from Mount Tolmie to Mount Douglas 2003

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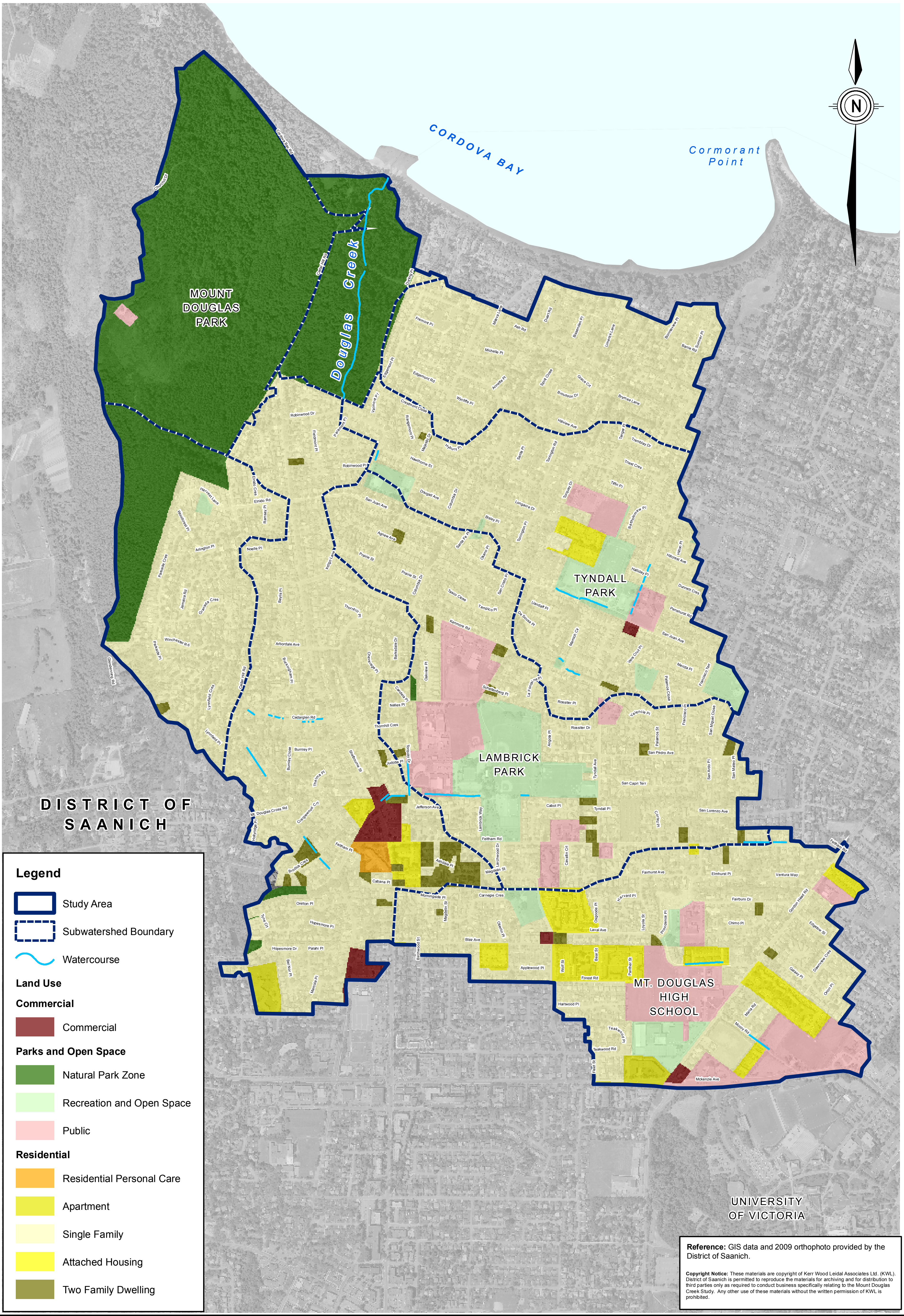
Project No.	Date
0478.083	Nov 2011

Source: Murdoch deGreeff, 2005

Historical Photos of Douglas Creek Watershed

Figure 2-2



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District of Saanich
Mount Douglas Creek Study

Project No.	Date
437-083	November, 2011

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Existing Land Use

Figure 2-3

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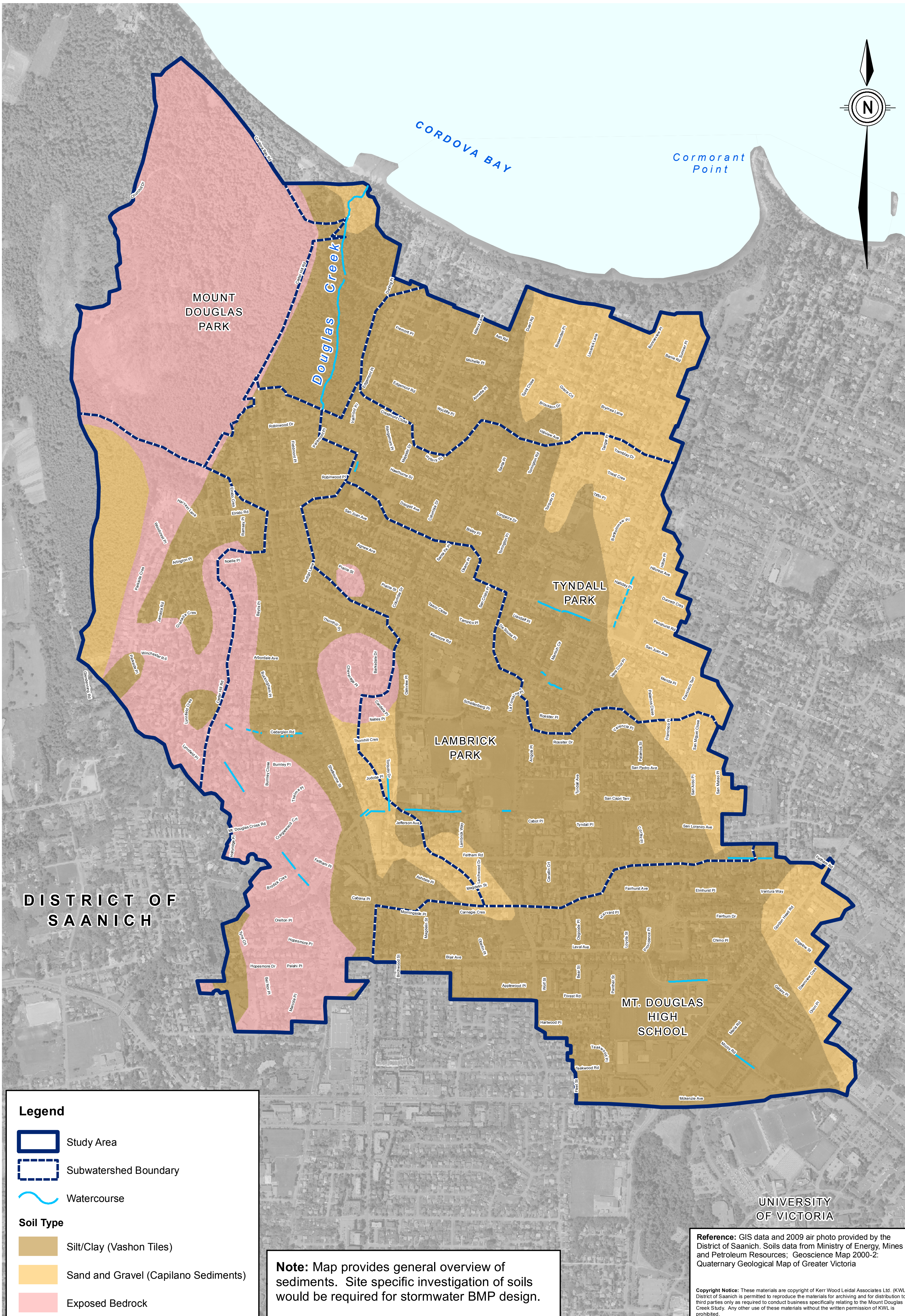

Note: Map provides general overview of sediments. Site specific investigation of soils would be required for stormwater BMP design.

Reference: GIS data and 2009 air photo provided by the District of Saanich. Soils data from Ministry of Energy, Mines and Petroleum Resources; Geoscience Map 2000-2: Quaternary Geological Map of Greater Victoria

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District of Saanich
Mount Douglas Creek Study

Project No.	Date
437-083	November, 2011

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Soils Map

Figure 2-4

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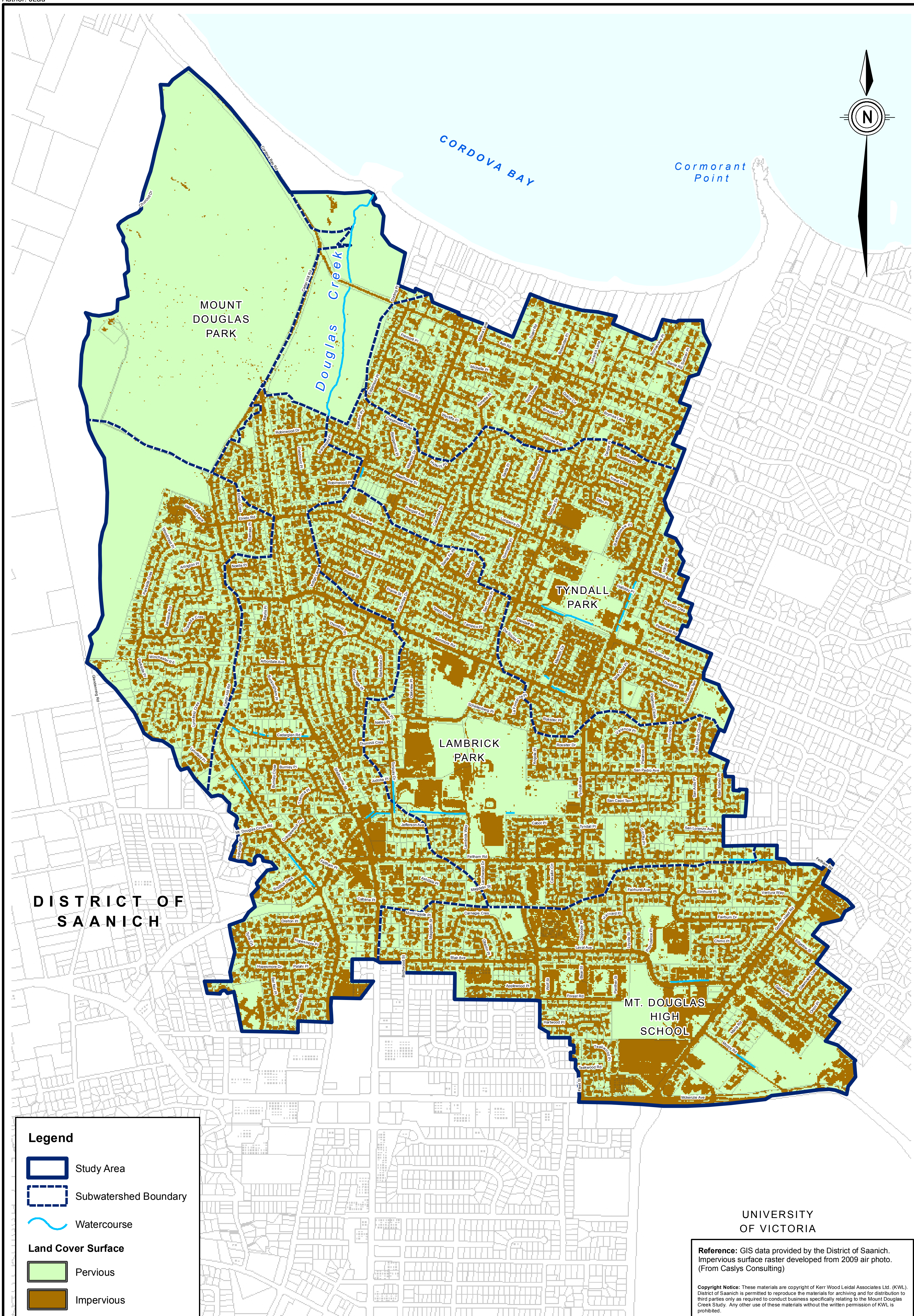

Reference: GIS data provided by the District of Saanich. Impervious surface raster developed from 2009 air photo. (From Caslys Consulting)

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District of Saanich
Mount Douglas Creek Study

Project No.	Date
437-083	November, 2011

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Pervious and Impervious Areas

Figure 2-5

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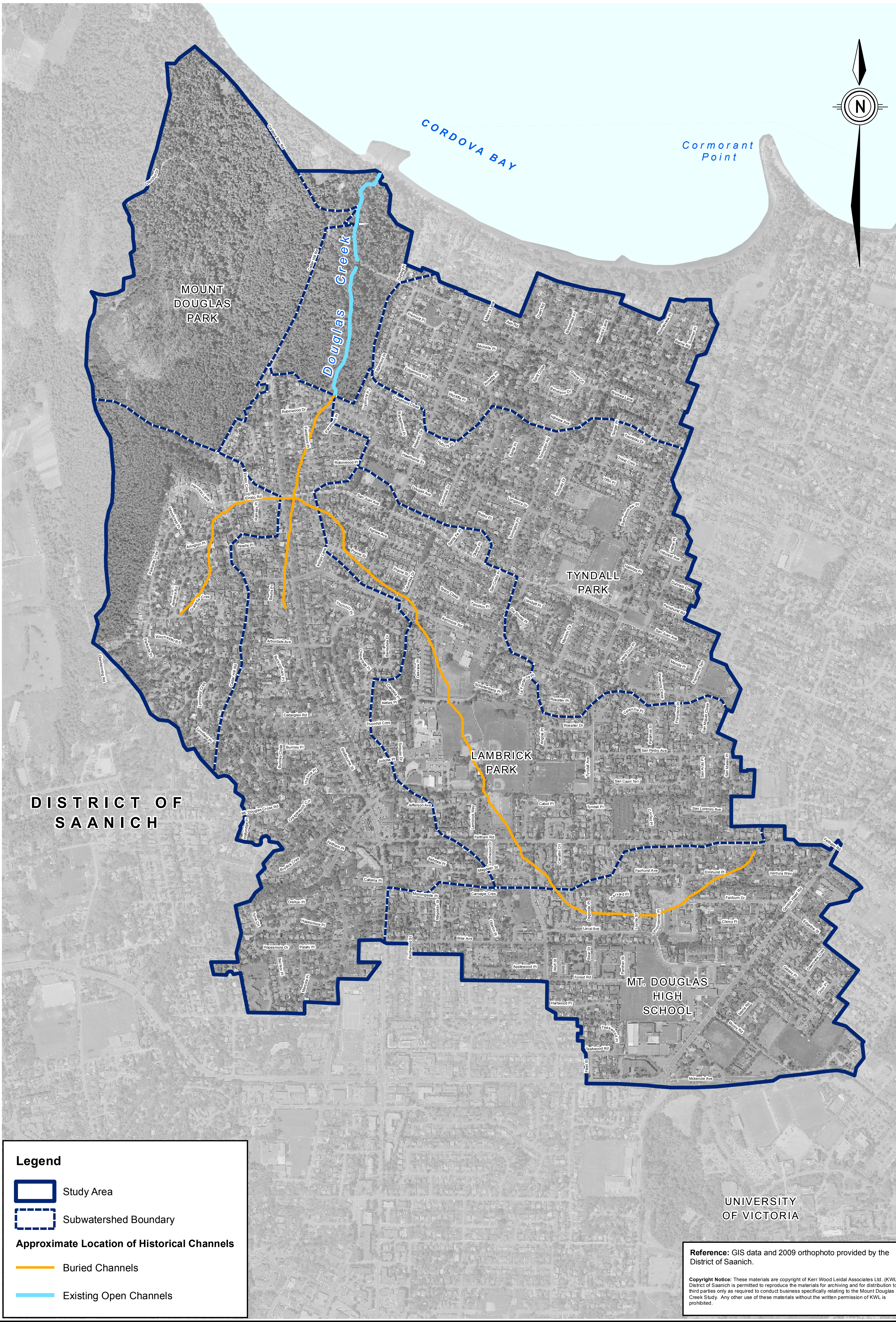

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District of Saanich
Mount Douglas Creek Study

Project No.	Date
437-083	November, 2011

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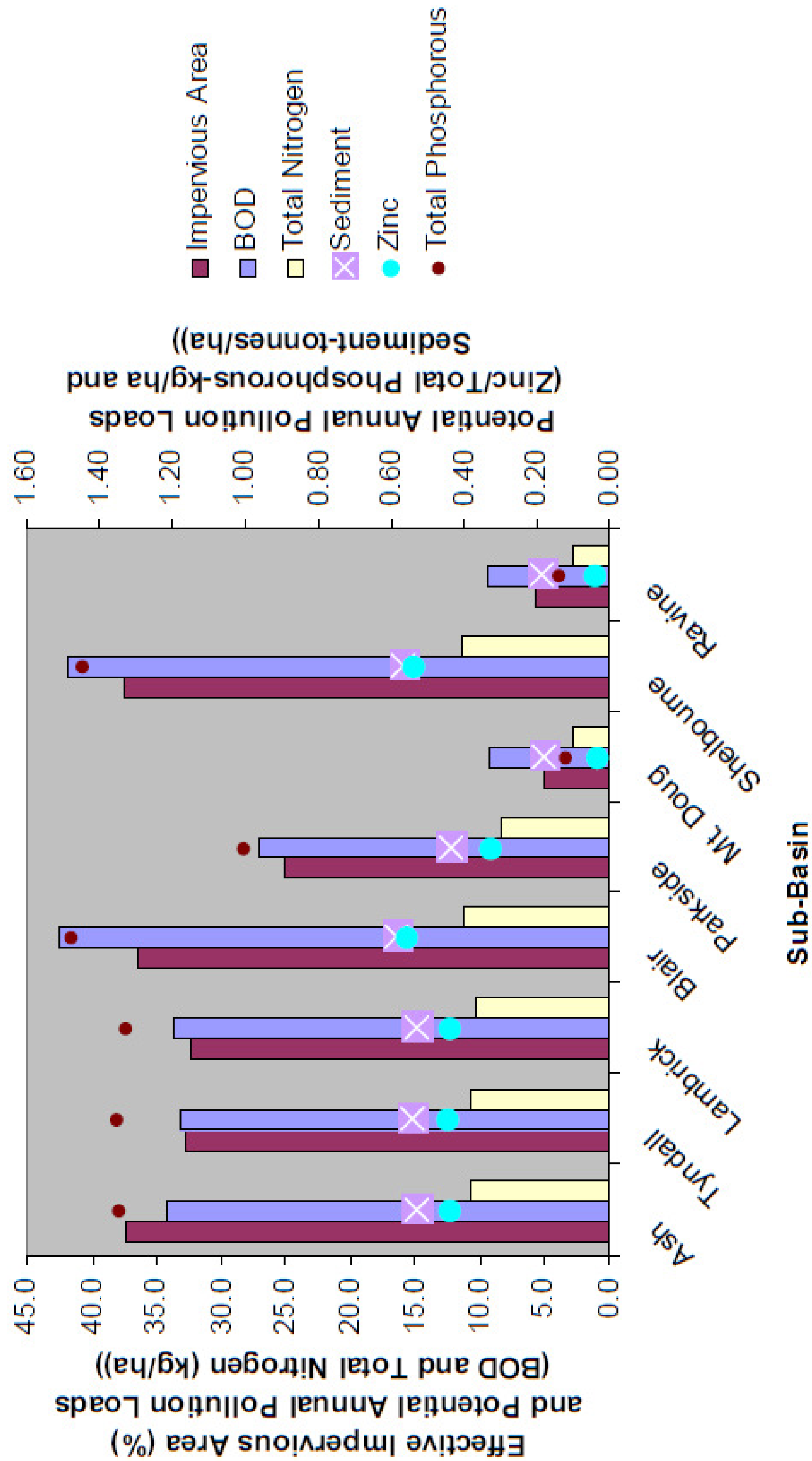
Douglas Creek Historical Channels

Figure 2-6



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Project No.	Date
0478.083	Nov 2011

Source: Murdoch deGreeff, 2005

Potential Polution Loading for Sub-basins

Figure 2-7

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Section 3

Mount Douglas Creek Aquatic Habitat

3. Mount Douglas Creek Aquatic Habitat

3.1 Overview

Aquatic habitat in the open channel portion of Douglas Creek was reviewed to determine existing aquatic habitat conditions, and to assess opportunities and constraints as it relates to salmon habitat and fish production. The section of open channel was divided into two reaches based on channel morphology. The lower reach extends from the marine environment to Ash Road and the upper reach extends from Ash Road to the end of the channel where it meets the stormwater sewer.

The lower reach is steeper with grades of 3 to 5 and is characterized by a confined channel situated at the bottom of a ravine. Salmonid habitat in the lower section is poor condition as a result of high flows and channel degradation (evident by bank erosion and exposed till on the channel bottom). Tables 3.1 and 3.2 below summarize aquatic habitat conditions for the upper and lower reaches. In general, the lower section of stream is relatively steep. Although it could support small pockets of spawning habitat and rearing habitat during low flow conditions, it best described as a transition section of stream. In other words, fish would typically migrate through this section of stream on their way to better habitat conditions upstream. The offspring of fish that spawn in this reach face the difficult challenge of not being carried into the marine environment during moderate and high flow conditions. There is no refuge habitat in this reach.

The upper reach is less steep with grades of 2 to 4%. The stream banks are moderately sloped, although the channel is incised due to bed degradation. This type of channel would typically support riffle-pool channel morphology. The habitat complexity in the upper reach is poor, due to lack of pools and riffles, in stream and over-stream cover, and potential poor water conditions. Although it has potential for fish production, the odds of a catastrophic event (such as a pollutant spill, warm water/low DO during summer low flow conditions, etc.) are very high. Species with life stages that must remain in the stream for a year or greater are, therefore, more at risk than species that leave their natal streams immediately after emerging from the reed (e.g., Pink and Chum salmon).

3.2 Opportunities and Constraints

The opportunities and constraints were assessed based on the assumption that water quality and volume control BMP's were implemented such that water quality and flow volumes were ideal for fish production in the 800 metre section to stream. Under these ideal conditions, we would expect to develop more stable channel morphology with increased habitat complexity (see Figures 3.1).

The stream has the potential to support a small population of Cutthroat trout and Coho salmon. The habitat potential is higher in the upper reach, due to reduced gradients and higher habitat complexity potential. There are several constraints that would need to be addressed in order for the stream to support a viable population of salmon. The potential population of fish will be small, given the small size of the stream. Assuming a channel width of 5 m during spawning flows with roughly 5 to 10% of the area is suitable for spawning there could about 200 to 400 m^2 of spawning habitat. This could support 20 to 40 spawning pairs of Coho salmon based on spawning habitat requirements of 11.7 m^2 per spawning pair (Bjornn and Reiser 1991) By comparison, the Colquitz River, a significantly larger stream, supports a population of anywhere from 50 to 300 adult Coho salmon. These numbers are based on fish fence counts on the Colquitz River. It should be noted that the Colquitz River is not producing to its full potential, as it is also an urban stream.

Lower Reach Constraints

The lower reach is constrained by the physical landform of the ravine setting. There is no opportunity to develop off-channel habitat within the lower reach. This significantly reduces the potential for this reach to support Coho salmon. The lack of gravel and cobble sediment loads to the channel will be a long term constraint, because the stream has been disconnected from the upper watershed by the stormwater sewer system. Gravel supplements will be required on an annual basis to replenish lost material to the marine environment. Additions of LWD will be required to enhance in-stream and over-stream cover. Although it is not a constraint in the long-term, natural vegetation will require time to colonize eroded banks.

Upper Reach Constraints

The upper reach is constrained by the lack of refuge habitat, in the form of off-channel habitat. The structural form of the channel is poor (poorly defined riffles and pools), as is in stream habitat complexity. Lack of gravel and cobble sediment loads to the channel will be a long- term constraint, because the stream has been disconnected from the upper watershed. Gravel supplements will be required on an annual basis to replenish losses to the downstream reach.

Lower Reach Potential and Opportunities

The lower reach has the potential to support a small population of Cutthroat Trout and juvenile Coho Salmon. With moderated flows, there were will be more opportunities to increase LWD complexity within the channel - without the risk that it will be dislodged by high flows.

Upper Reach Potential and Opportunities

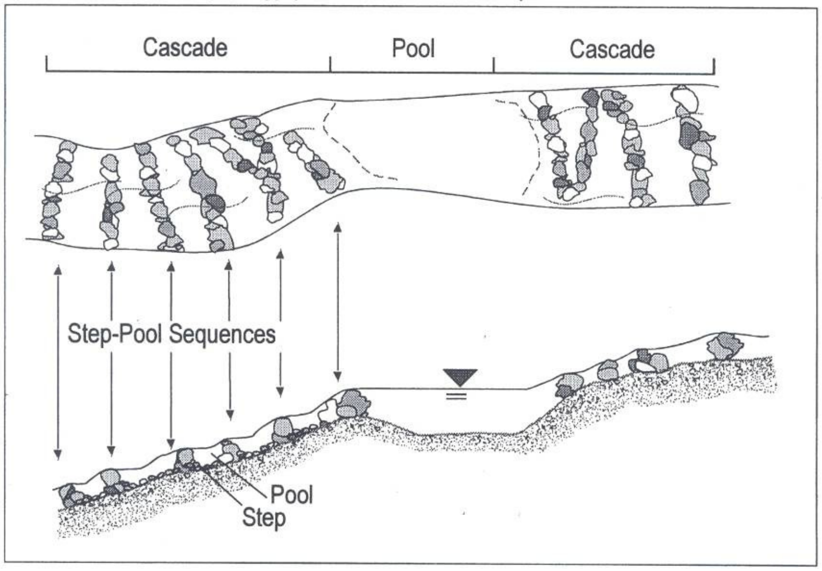
There is more potential for fish production in the upper reach. This section of stream could support good pool-riffle habitat, provided the peak flows are moderated. The addition of LWD and in stream boulders would provide in stream habitat complexity (see Figure 3-1). There may be opportunities to develop off-channel habitat, provided there is access from the degraded channel. A long-term strategy will be to raise the bed of the channel, by supplementing long- term sediment throughout the reach.

Table 3.1 Existing rearing habitat conditions in Douglas Creek.

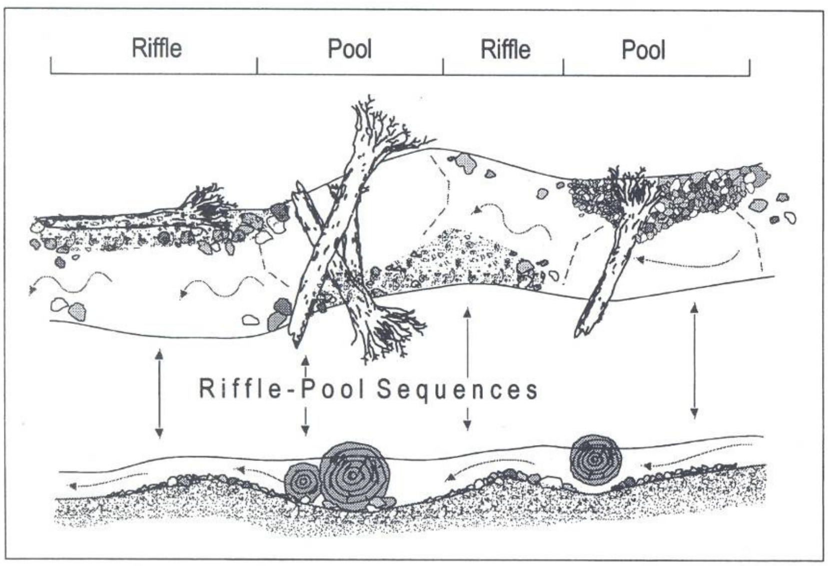
Reach	Oxygen	Temperature	Suspended Sediments	Nutrients	Stream Flow Velocity and Depth/Migration	Cover
Lower	Typically okay	Moderate	Moderate	Moderate to poor	Poor Channel has degraded, and is now at the hardpan till layer due to high flows that scour the channel. Low flow condition likely not a limiting factor in terms of water volume. Expect extremely high velocities in excess of 2 m/s during bank full flows. No off-channel (refuge) habitat in this section of stream due to ravine setting.	Poor Pool dept: shallow, typically <0.5 m deep during low flow conditions. Instream cover in the form of Large Woody Debris (LWD) lacking Over-stream cover especially during low flow conditions. Banks are perch quite high above the channel and therefore offer little cover during low flow conditions. New weirs will act as control points within the channel and if stable will reduce the amount of bed degradation. However, these should be monitored as they may act as barriers to various life stages of salmonids during various flow conditions (e.g. During low flow may be an upstream migration barrier to juveniles).
Upper	Probably experiences periods of low DO immediately downstream of weir during summer low flow conditions. DO probably okay 100m downstream of weir due to oxygenation due to turbulence.	Moderate to poor Risk of high temperature influxes associated with smaller summer rain events.	Mod to Poor	Moderate to poor	Poor Similar to lower reach Velocities are probably lower due to reduced gradient, and the throttling affect of the culvert under Ash Road. No off-channel (refuge) habitat (incised channel results in no flood plain).	Poor Similar to lower reach Small aggregate material abundant due to past enhancement efforts but there is not LWD or high quality pool habitat. Riffle habitat minimal throughout this reach.

TABLE 3-2: Existing spawning and egg rearing habitat conditions for in Douglas Creek.

Reach	Oxygen	Temperature	Suspended Sediments	Nutrients	Stream Flow Velocity and Depth/ Migration	Cover
Lower	Typically okay	Moderate to Good	Moderate to poor The amount of suspended sediment will be high given the land use of the upper watershed. This can negatively affect egg survival due to smothering of redds and reduce oxygen availability for eggs.	Mod to poor	Poor High flow conditions will make fish passage difficult. There are few refuge areas within the stream for adults to rest out of the current. Pools are shallow and offer little cover for adults. The Culvert at Ash Road is also a significant migration inhibitor at moderate to high flows due to the expected high velocities and the overall length of the pipe. Expect extremely high velocities in excess of 2 m/s during bank full flows. Velocities even higher through the culvert at Ash Rd.	Poor Pool depth- shallow, typically <0.75 m deep during moderate flow conditions and offer little cover for adults. Instream cover in the form of Large Woody Debris (LWD) lacking Over-stream cover especially during low flow conditions. Banks are perch quite high above the channel and therefore offer little cover during low flow conditions.
Upper	Typically okay. During higher fall and winter flow conditions DO levels are probably okay throughout the stream channel. May be issues with sediment smothering however.	Moderate to Good	Moderate to Poor Similar to above	Mod to poor	Poor Lower gradient channel more suitable for spawning but lacks structure (riffle/pool) for good spawning conditions. Very little refuge area with the channel and no access to floodplain during high flow events.	Poor Similar to lower reach Small aggregate material abundant due to past enhancement efforts but there is no LWD or high quality pool habitat. Riffle habitat minimal throughout this reach.



Cascade-Pool channel morphology potential for lower reach



Riffle-Pool channel morphology potential for upper reach

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Project No.	**Date**
0478.083	Nov 2011

Slaney. P.A. and D. Zaldokas, 1997

Stream Habitat Examples

Figure 3-1

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Section 4

Hydrology and Hydraulics

4. Hydrology and Hydraulics

4.1 Hydrologic/Hydraulic Modelling

The stormwater sewer system in Douglas Creek watershed has been modelled using the InfoSWMM stormwater modelling package by Innovyze®. This model integrates the EPA-SWMM stormwater model into the ESRI ArcGIS environment. This allows models to be easily updated using underlying Geographical Information System (GIS) data without the need to import data from other sources.

The District's stormwater sewer GIS database for the Douglas Creek watershed was reviewed and missing data was identified. Where pipe invert elevation data was missing in the database, elevations where assumed using linear interpolation between known invert elevations or by assuming that pipe inverts where 1.5 m below ground surface where data was not available. A map showing the locations where data is missing is shown in Figure 4-1. The model should be updated after the missing invert elevations have been surveyed.

The hydrologic runoff component of the model has not been calibrated because of the lack of reliable stream flow measurements in the watershed. However, calibrated model parameters used for the Bowker Creek watershed immediately to the south of the study area have been used in this model. A summary of the parameters used in the model is included in Table 4-1

Table 4-1: Summary of InfoSWMM model parameters

Parameter	Value
Impervious area Manning's n	0.05
Pervious area Manning's n	0.40
Impervious Area Depression Storage	2 mm
Pervious Area Depression Storage	4 mm
Infiltration Model	Green-Ampt
Capillary suction	178 mm
Conductivity	3.5 mm/hr
Initial Deficit	0.05
Routing Model	Dynamic wave
Flow routing	100% to outlet

Only the existing land-use and drainage condition has been modelled. A review of the OCP and zoning mapping indicates that limited development is planned for the area and that future total impervious area is not expected to change significantly.

4.2 Hydrologic/Hydraulic Results

The 2-year, 10-year, 25-year and 100-year design storms have been simulated using the model. The rainfall hyetographs have been developed using the SCS Type 1A storm using the District's Intensity-Duration-Frequency data shown in Standard Municipal Drawing DES 10 last updated in October 2003. A copy of the hyetographs is shown in Figure 4-2.

The peak design flows for each of the sub-catchments is shown in Table 4-2.

Table 4-2: Sub-basin Results

Sub-basin Name	Max. Discharge (m^3/s)		Notes
	10-yr	25-yr	
Ash	1.02	1.2	
Tyndall	1.97	2.54	
Lambrick	2.99	3.26	
Blair	1.25	1.25	Pipe backwatered
Parkside	0.934	1.26	
Shelbourne	6.61	7.68	Includes Lambrick, Blair, Parkside and Shelbourne Sub-basins

As shown in Table 4-2, the peak discharges at the Ash Road culvert estimated with the InfoSWMM model are higher than those estimated in the Historical Discharge Estimates for Douglas Creek report (Rham, 2002). These estimates were based on flood frequency analysis of six years of synthesized stream flow data. Recorded stream flow data on Douglas Creek for the period from April 16, 2000 to December 31, 2001 was compared with stream flow data for the Sandhill Creek watershed, which has longer period of record. A linear regression of the data from the two stations was used to extend the Douglas Creek dataset over the entire period of record for the Sandhill Creek station.

The estimated peak flows using the recorded data are likely lower than the modelled results as Sandhill Creek is located in a semi-rural area with large percentage of the watershed in agricultural landuse with some commercial and residential development. In addition, Sandhill Creek remains an open stream throughout its entire length with some ponds along the main stem. This would result in Sandhill Creek having a less flashy response to streamflow in comparison to Douglas Creek, which would likely result in reduced peak flow estimates using the regression approach.

The model has been used to review the network capacity and identify any pipes that are undersized. The model results have been compared with design criteria from the District's standard specifications (Subdivision Bylaw 7452 – Schedule H), which specify that no surcharging of pipes shall occur during peak flows for the:

1. 10-year return period storm event for pipes less than 900 mm diameter; and
2. 25-year return period storm event for pipes greater than 900 mm diameter.

Figure 4-3 shows the pipes within the network that do not meet the municipal design criteria.

A full set of the model output is included in Appendix A.

The results indicate that in general the storm sewer network meets the municipal standard. However, the model results indicate that existing storm sewer system may be over-capacity in some locations. The most notable locations are along the Shelbourne corridor from , this also appears to cause some i. The other location is the main storm sewer flowing from the Lambrick sub-basin through Lambrick Park.

Although the modelling of the system has identified some deficiencies, testing of alternative storm sewer upgrade solutions was outside the scope of this study.

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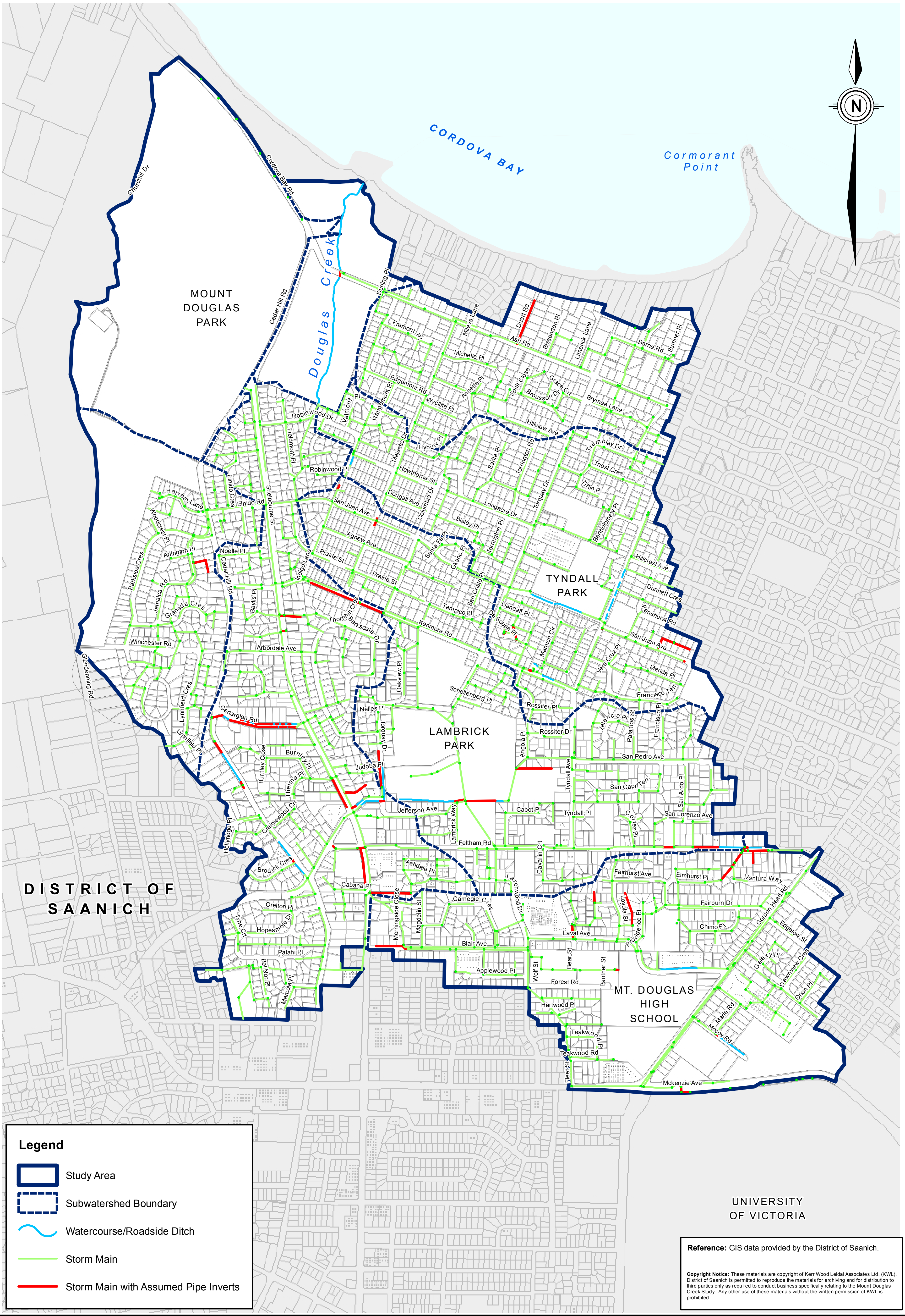

Reference: GIS data provided by the District of Saanich.

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Project No.	Date
437-083	November, 2011

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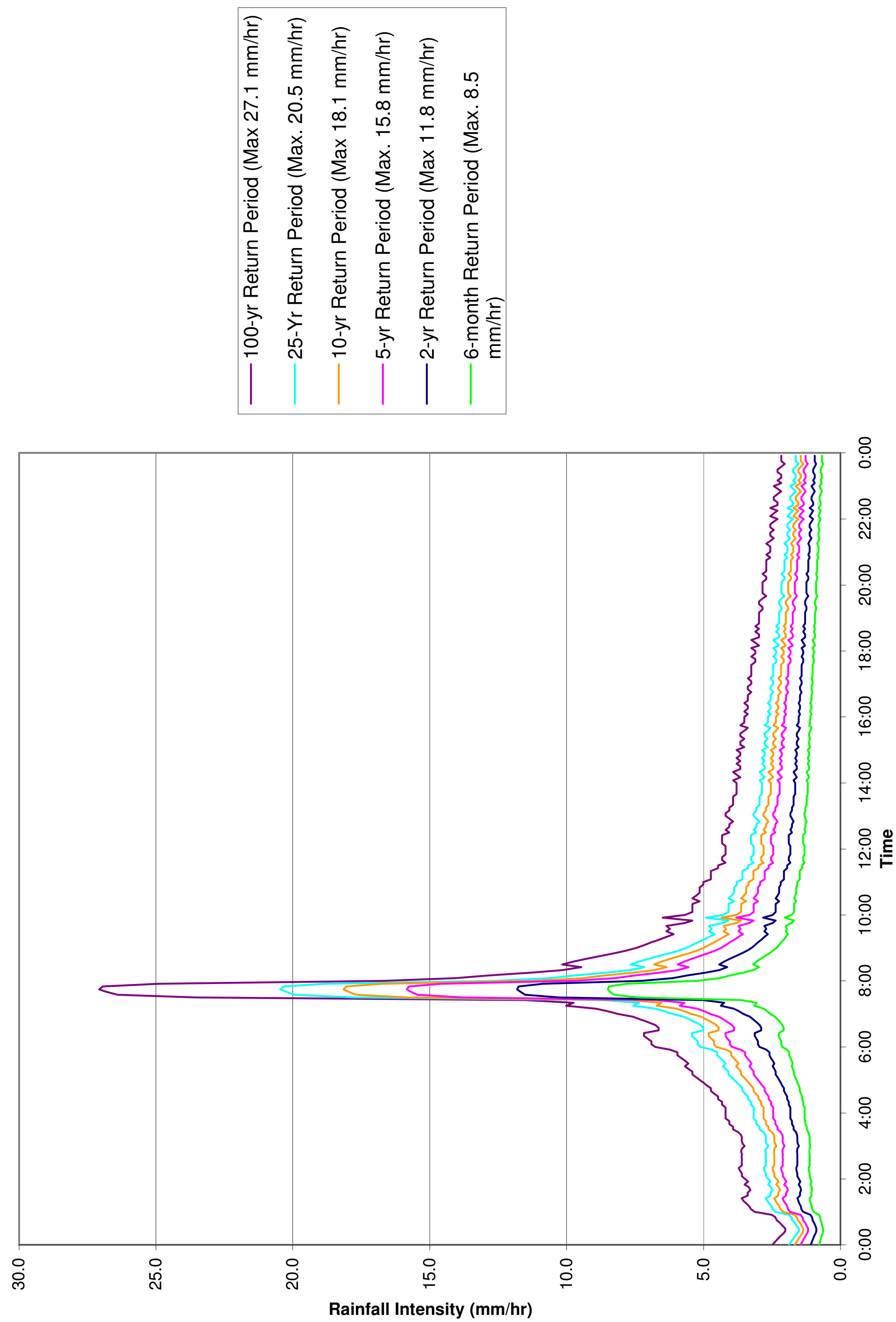
Location of Missing Invert Elevation Data for Stormwater GIS

Figure 4-1



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Project No.	Date
0478.083	Nov 2011

SCS Rainstorms.xls

Design Rainfall Hyetographs

Figure 4-2

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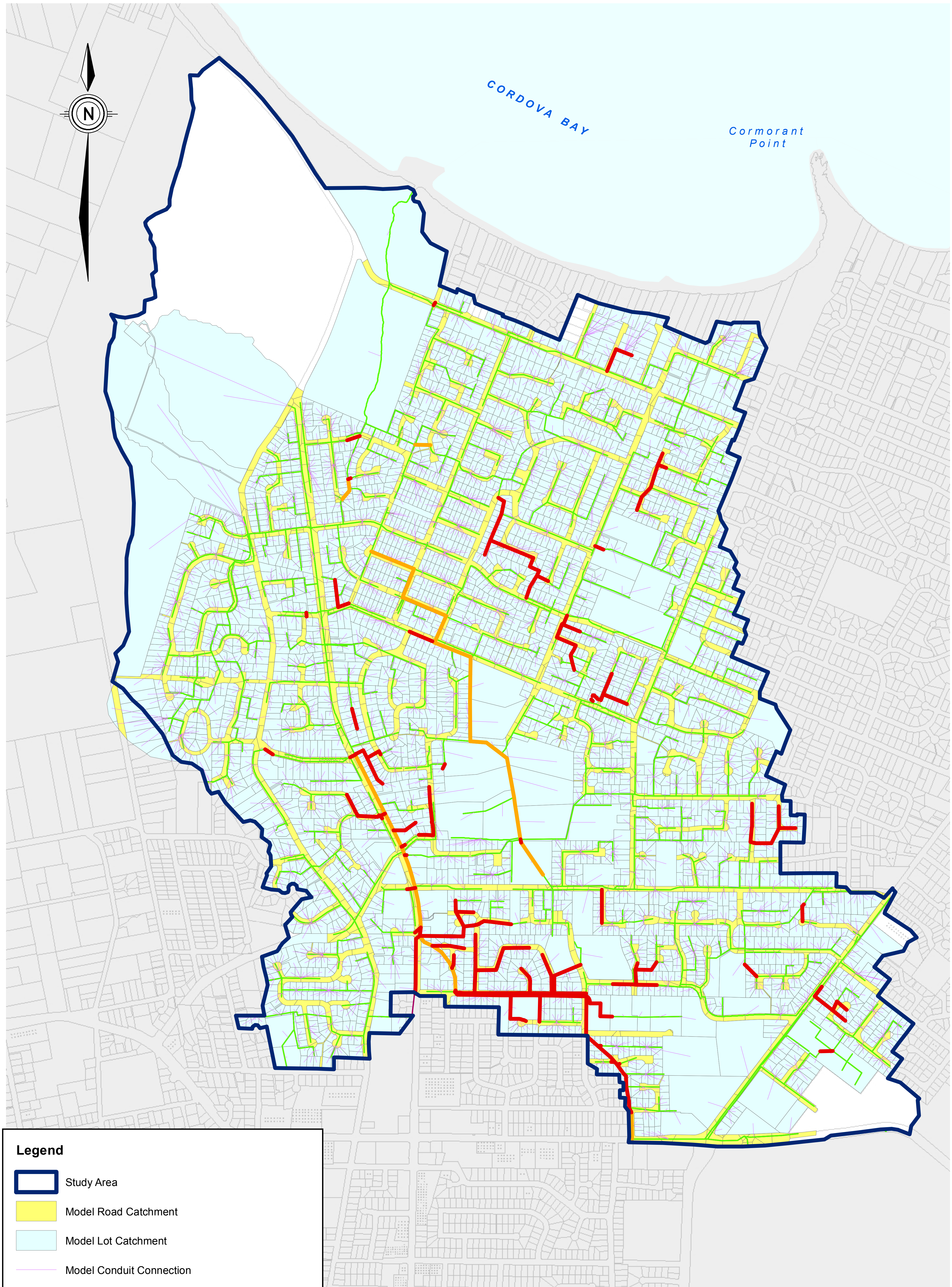

Reference: GIS data provided by the District of Saanich.

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Modelled Stormwater Drain Network Results

Figure 4-3

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Section 5

Stream Protection and Water Quality Improvement Options

5. Stream Protection and Water Quality Improvement Options

5.1 Stream Protection and Water Quality Improvement Practices

A multitude of options exist to reduce peak flows for protection of physical stream habitat and improve water quality to protect health of fish present in Douglas Creek. These can be broadly categorized into one of the five categories:

Regulatory/Policy

This comprises of federal and provincial regulations and guidelines as well as District by-laws and standards of practice (zoning, development, stormwater quality by-laws, etc.). These are usually implemented on a District-wide scale. However, specific by-laws at a watershed scale can be implemented. Regulations and policies provide direction and certainty for new development or redevelopment in the watershed. They can be used to implement best management practices within private lands. However, they are usually only implemented as the opportunity arises as part of new development or re-development in the watershed. As such, they can often require a long period of time to result in any significant change at a watershed scale.

Public Awareness / Education

This includes public awareness education programs at city or regional level as well as local or neighbourhood initiatives and stewardship programs such as Friends of Mount Douglas Park Society. Public awareness and education allows for public engagement and a sense of ownership which can lead to improved practices at an individual or family level. They should form a part of any future plans in the watershed but can not achieve the stream protection and water quality improvement objectives alone.

Source Controls

These are usually stormwater best management practices or low impact development techniques that are initiated as part of new development or re-development in the watershed. They can either be initiated by private development or as part of retrofitting of public facilities. They focus on treating stormwater at the source. Similar to regulatory or policy options, implementation of on-site source controls on private lands often requires significant periods of time before significant improvements are made at a watershed scale.

Regional Stormwater Facilities

These are larger scale stormwater management projects which manage stormwater at sub-watershed or watershed scale. They often involve large public capital projects which can have large up-front costs and often require large undeveloped areas in the watershed for construction. However, because they treat stormwater from a large area this can often result in achieving outcomes faster than through on-site source controls.

Operation and Maintenance

On-going operation and maintenance of facilities is key to the success of the project. Both on-site source controls as well as public stormwater management projects require maintenance to operate effectively. Having secured on-going funding for maintenance is important in implementing the plan.

Examples of the various approaches for each of the five categories are outlined in Table 5-1.

Table 5-1: List of Example Stormwater BMPs

Category	Type of BMP	Best Management Practices	Scale of Implementation
Regulatory / Policy	Non-structural	Riparian Zone/Preservation	District Wide / Watershed
		Zoning/Landuse - Impervious Area Reduction/Restrictions	
		Stormwater Quality By-laws / Sediment and Erosion Control By-laws	
		Site Design Standards	
Public Awareness Education	Non-Structural	Public Education	District Wide / Watershed
		Local Stewardship Groups	Watershed / Neighbourhood
Source Controls	Structural (Low Impact Development)	Vegetated Swales / Grass Channels	Individual Lot or Small neighbourhood
		Rain Gardens	
		In-filtration trenches / pits	
		Roof Downspout Systems / Rain Barrels	
		Porous Pavements	
		Green Roofs	
	Structural (Traditional)	Oil/Grit Separators	Individual Lot or Small neighbourhood
		Catch-basin Filters	
Regional Stormwater Facilities	Structural	Engineered Wetlands	Sub-watershed or watershed
		Wet Detention Ponds / Vaults	
		Dry Detention Ponds / Vaults	
		Diversions	
		Mechanical Treatment (Vortex) Systems	
		Mount Douglas Park Inverted Weir / Baffle	
Operation and Maintenance	Operation and Maintenance	Design/Construction/Inspection/Enforcement	District Wide / Watershed
		Spill Identification and Response	
		Street Cleaning / Catchbasin Cleaning	
		Maintenance of Stormwater and Sanitary Sewer Systems	
		Detection and removal of cross connections	
		Water Quality / Quantity Monitoring	
		Complaint Reporting and Response	

5.2 Stream Protection and Water Quality Improvement Criteria

In order to compare the options, a common set of criteria have been selected by which to compare the tested options. These include detention criteria for stream protection/erosion control as well as stormwater treatment criteria for improving water quality.

Stream Protection/Erosion Control Criteria

The most common stream protection/erosion control criteria used in stormwater management is to reduce the more frequently occurring larger events to pre-development levels, such as the 2-year return period event and the 5-year return period event. However, determining pre-development amounts is often not consistent as estimation is often based on professional judgement. The District has adopted standard peak unit flow rates to be used in development.

The District Engineering Specifications (Schedule H to Bylaw 7452, Subdivision Bylaw) requires detention be provided in new development such that peak flow of the 2-year return period event is reduced to 5 L/s/ha or 10 L/s/ha for Type I and Type II watershed respectively. Type I watersheds are those that require higher standards for environmental protection and include Colquitz River/Elk and Beaver Lakes, Tod Creek and Prospect Lake, Hobbs Creek/Mystic Vale and Gorge Waterway. Type II watersheds are typically those that drain directly to the ocean. Currently, Douglas Creek is designated a Type II watershed. It should be noted that Bylaw 7452 is currently under review and the Type I and Type II watershed designations may be either changed or removed completely.

Stream Water Quality Improvement Criteria

In addition to physical habitat requirements, salmonids also require a constant supply of clean, cool water. The basic water quality requirements for typical salmonid life stages are outlined in Table 5-2.

Table 5-2: Stream water quality criteria for salmonid life stages.

Life Stage	Parameter	Ideal Range
Spawning Adults	Water Temperature	Coho 4.4-9.4 degrees C. Cutthroat Trout 6.1-17.2 degrees C.
	Dissolved Oxygen	>8 mg/L
	Suspended Sediments	Migration stopped at loads of 4000 mg/L (Bell 1986)
Egg Incubation	Water Temperature	Coho 4.4-13.3 degrees C.
	Dissolved Oxygen	Coho >8 mg/L
	Suspended Sediments	Depositon of fine sediment on the redd can adversely affect egg survival rates by decreasing DO levels and impeding emergence of fry.
Rearing	Water Temperature	12 to 15 degrees C.
	Dissolved Oxygen	8 mg/L or greater Growth rate declines as levels fall below 5 mg/L
	Suspended Sediments	Normally not a problem Negative impact at levels >14-15 mg/L

Water quality guidelines for aquatic habitat have been established by the BC Ministry of Environment (http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html). These reports establish criteria based on ambient water quality for various contaminants. However, since there is little available data for Douglas Creek it is not possible to comment on specific contaminant level criteria for Douglas Creek.

Receiving Water Quality Improvement Criteria

As previously discussed, the CRD use the public health criteria for fecal coliform and the MSQG sediment quality guidelines to monitor contamination of receiving water. The CCME marine sediment contamination guidelines also could be used for assessing receiving water quality.

5.3 Comparison of Stream Protection and Water Quality Improvement Options

A review of the potential stormwater BMP approaches with a particular focus on the Douglas Creek Watershed was undertaken. This review involved development of a multiple accounts evaluation (MAE) or a decision matrix approach to identify the positive and negative attributes of each potential BMP approach. This involves selecting criteria by which to measure and compare the various options and then assigning values to each of these criteria such that the options can be compared. Unlike cost-benefit analysis, the MAE approach allows for a variety of criteria to be compared rather than solely a cost-benefit ratio. It also eliminates the need to assign a single quantitative value to the benefits of the project which can often be difficult to determine. The BMP options selected for review were based on discussions during the meeting with District staff and stakeholders as well as discussion between members of the design team members. The criteria were measured qualitatively based on professional judgement and expertise of the project team. In order to account for any bias or preconceptions in the project team that may effect the assessment, the results were independently reviewed by the project technical reviewer and adjustments were made accordingly.

The criteria selected to compare the options include:

Peak flow reduction: Does the option reduce peak flows in the lower reaches of the watershed to protect stream habitat from erosion (10 L/s/ha or 5 L/s/ha), based on DoS Specifications.

Baseflow quantity: Does option maintain current baseflow conditions in the watershed?

Baseline water quality improvement: Does option improve water quality to meet established targets?

Spills: Does option allow identification, capture and clean-up of potential spills in the watershed.

Implementation time: In what time frame can the option be fully implemented such that significant improvements are made at a watershed scale?

Ease of Implementation: What external constraints exist to implementation, if any (public perception/concerns, community support, technical challenges, implemented by the district or implemented by others, etc)?

Relative Costs: Comparison of capital costs to funders. Costs considered only include public costs and do not include costs associated with private development. Time scales for costs considered with projects having higher up-front costs considered to have higher costs in comparison with smaller projects that could be implemented over-time but may have the same total costs than the larger single project.

The options compared include:

1. Implementing source controls on public lands including public roads and public facilities (schools, recreation facilities, etc.)
2. Implementing source controls on private lands as part of development or re-development

3. Distributed Stormwater Management Facilities includes construction of Ponds/Vaults/Wetands throughout the watershed.
4. Single pond/wetland near the head of Douglas Creek channel to detain larger events and provide water quality management.
5. Mount Douglas Park Diversion includes construction of stormwater sewer to by-pass large flow events around lower reaches of Douglas Creek and discharge directly to the ocean.
6. Engineered Water Quality Treatment Facility (i.e. Vortecnix Unit) includes installation of one or two engineered stormwater treatment facilities at the head of Douglas Creek channel and within the Ash Road watershed prior to discharge to the creek.
7. Upgrades to Inverted Weir/Baffle/Skimmer include upgrading existing inverted weir to reduce occurrence of discharge of collected contaminants during large runoff events.
8. Baseflow augmentation through storage and slow release of stormwater or construction of ground water channel to collect ground water runoff from Mount Douglas slopes.

The results of the assessment are included in Table 5-3.

Option 1 – Single Engineered Stormwater Management Facility

The first option investigated to improve water quality and reduce peak flows involves use of two engineered water quality treatment facilities and construction of a large diameter diversion sewer to divert high flows around the lower reaches of Douglas Creek through Mount Douglas Park (shown in Figure 5-1).

This option would involve installation of two engineered stormwater treatment facilities to provide mechanical treatment of stormwater to meet water quality objectives. The larger facility would be installed near Robinwood Drive near the outlet of the 1,775 mm diameter stormwater sewer main at the head of the Douglas Creek channel. This system would be designed to treat runoff from the majority of the watershed. A smaller unit would be installed in the Ash Road watershed to treat runoff from this area. The system proposed is multi-stage treatment system with a vortex style separator which traps suspended solids, and a baffle-weir system which traps floatables. These systems are also capable of capturing major spills, provided they are cleaned and maintained regularly. The City of Victoria has installed similar systems at Rock Bay and James Bay to help improve water quality in the Inner Harbour.

This option would also involve diverting high stormwater flows around the lower section of the creek through a new 1,200 mm diameter stormwater sewer. The proposed alignment for the sewer would be to run from the existing inverted weir near the head of the , along the existing trail which runs near the eastern boundary of Mount Douglas Park to Ash Road, east along Ash Road to Durling Place. The diversion would then follow Durling Place and the existing stormwater sewer alignment which flows down to Cordova Bay from the end of Durling Place. Besides eliminating the need to construct a pipe alignment through Mount Douglas Park to the north of Ash Road, this alignment would allow flow from the Ash Road sub-basin to be diverted away from Mount Douglas Creek.

The primary advantage of this option is that it could be implemented relatively quickly and would allow for nearly instant improvements to water quality and reduced peak flows in the channel. It can also be designed such that water quality and stream flow could be achieved under most storm conditions.

Table 5-3: Multiple Accounts Evaulations

Option #:	Option Description:	Peak Flow:	Base Flow:	Baseline WQ:	Spills:	Implementation time:	Ease of Implementation:	Capital Cost to funders (relative):
1	Source Control (Public)	partial	partial (minor)	partial (minor)	partial (minor)	long	requires long term investment & buy-in	deferred (long implementation timeline
2	Source Control (Private)	partial	partial (minor)	partial (minor)	partial (minor)	long	requires by-law changes, incentives programs, etc (question of watershed-scale implementation vs. municipality-wide)	low (private implementation)
3	Source Control (Site-specific)	partial (minor)	partial (minor)	partial	partial	moderate	requires long term investment & buy-in	low/defferred (as above)
4	Weir Baffle/Skimmer	no	no	yes	yes	short	relatively easy, but skimmer may require innovative design solution	moderate
5	Piped By-pass	yes	no	no	no	short	looks like pathways could be used for infrastructure ROW - feasible	high
6	Off-channel Habitat	no	no	no	no	short	limited opportunity due to incised ravine landscape	moderate
7	Large Wetland - Bottom End	partial?	no	partial	partial	short	some suitable sites, but requires politically sensitive tree/shrub removal in park	moderate
8	Distributed Ponds/Wetlands (Public)	partial	partial (minor)	partial	partial (minor)	moderate	limited 'leftover' park/municipally owned sites for implementation - only limited application	moderate
9	Vortecnex Unit (Near ex. Weir)	no	no	yes	partial?	short	relatively easy to install	high
10	Baseflow Augmentation	no	yes	no	no	moderate	requires water supply and/or storage - needs further evaluation	low
11	Option 3 + 4 +8+ 10	partial	yes	yes	yes	varies	varies	moderate

The engineered stormwater treatment facilities would be designed to capture up to 80% of total suspended solids during the 6-momth event and up to 60% during the 2-year event. This meets both the City of Victoria stormwater criteria as well as the Washington State stormwater quality criteria. However, these systems only separate sediments from the stormwater and capture floating contaminants such as oils that are not in suspension. The systems do not provide any treatment for contaminants in solution or those not attached to sediments.

It has been assumed that flow in excess of the capacity of the 1,200 mm dia. pipe would be returned to Douglas Creek. It is estimated that the capacity of the 1,200 mm dia. diversion pipe would be sufficient to carry flows in excess of the 2-year event up to the 25-year event. Additional flow in excess of the 25-year event flow would be returned to the creek.

The capital costs for this project are estimated to be about $4.6 Million, including engineering and a 25% contingency. Detailed breakdown of the conceptual costs are included in Appendix B.

Option 2 – Upgraded Weir and Single Wetland/Detention Area

This option would involve upgrades to the existing weir to improve its efficiency at trapping floatable debris and pollutants and to construct a detention/wetland area upstream of the weir to provide water quality treatment and reduction in peak runoff flows (see Figure 5-2).

The existing inverted weir near the head of the Douglas Creek channel in Mount Douglas Park provides limited water quality management for the reaches of the stream downstream of the stormwater sewer. It operates by trapping floatable debris and pollutants in a small pond area upstream of the weir. Flow passes though the weir in a series of 200 mm diameter pipes sloping from the bottom of the weir on the upstream side to near the crest on the downstream side. This allows water to be siphoned from the bottom of the pool without allowing the floatable debris to pass. It works reasonably well under baseflow conditions; however, during high flow conditions the capacity of the small pipes through the weir is exceeded and water passes over the weir carrying any collected pollutants with it. As it is difficult to access the pond to remove any collected debris prior to storm events occurring, most of the debris is carried downstream during larger rainfall events. Under baseflow conditions the storage behind the weir is limited because water levels only need to rise about 300 mm before flowing over the weir.

Raising the weir to increase freeboard and storage behind the weir is possible. Preliminary review of hydraulics indicates that raising the weir more than about 500 mm could impact the capacity of the 1,775 mm diameter stormwater sewer upstream. A baffle could be installed upstream the weir to help capture floating contaminants but still allow water to flow over the weir. A more detailed review of the hydraulics for the upgrades to the weir should be completed as part of design after relative elevations of the weir and pipes can be confirmed.

As previously discussed, it is difficult to access the pond upstream to provide regular maintenance to remove contaminants collected during low flow period. One option to assist with maintenance may be to install a small diameter by-pass pipe around the weir structure with an in-line oil water separator. At the upstream end of the pipe, an overflow weir could be installed near the water surface level which would allow the top surface of the layer to be skimmed from the pond. This would be similar to the simmers used in swimming pool design. A vertical sluice gate could be installed over the opening to prevent water from flowing through the oil-water separator during high flow. Maintenance would involve opening the sluice gate during low-flow period, letting flow pass through the oil-water separator for a period of time to allow the surface water to be skimmed and then removing collected material from the oil water separator.

Retrofitting the weir and excavating a small pond upstream could provide about 1,000 m^3 of storage for detention without a significant impact to the park. However, a detention volume of only 1,000 m^3 for the entire watershed is not nearly enough to reduce peak flows by any significant margin. An analysis of detention pond sizing requires that approximately 5,000 m3 of detention storage would be required to meet the 10 L/s./ha peak 2-year return period criteria. To meet the more stringent Type I watershed criteria (5 L/s/ha) more than 20,000 m3 of detention storage would be required. Providing this amount of storage in Mount Douglas Park would have likely have significant impacts to the current habitat in the park, and may be impractical because of the topography in the park.

The cost to upgrade the weir and construct small pond (~1,000 m^3) is estimated to be approximately $400,000 including engineering and 25% contingency. A detailed breakdown of the costs is included in Appendix B.

Option 3 – Distributed Stormwater Management Facilities and Source Controls

This option involves implementation of stormwater management facilities and source controls distributed throughout the watershed. The Development of Detention Options for the Douglas Creek Watershed report (Bosckei et. al., 2003) identified seven potential locations for stormwater management facilities in the watershed. These include a 3,000 m^3 wet detention pond at Lambrick Park, a 700 m^3 dry detention pond at Tyndall Park and a 1,250 m^3 detention pond in Mount Douglas Park near Ash Road and Durling Place which proved to be the most practical options for storage.

The location of these facilities is shown in Figure 5-3.

The options were selected based on a review of the stormwater sewer network, available open undeveloped areas or areas of limited use in parks where facilities could be constructed, and the feasibility of connecting stormwater sewers to these areas. The options previously identified have been reviewed and the options with the largest detention potential have been selected to be re-evaluated as part of this study. The results are shown in Table 5-4.

Table 5-4: Detention Results

Detention Pond/Wetland	Volume (m^3)	Pre-detention Peak 2-yr Return Period Flow (m^3/s)	Post-detention Peak 2-yr Return Period Flow (m^3/s)	Difference (m^3/s)	Flow Target using 10/s/ha (m^3/s)
Tyndall	700	0.189	0.0644	-0.125	
Blair	1,000	0.38	0.203	-0.177	
Lambrick	3,000	0.41	0.058	-0.352	
Total Upstream of Ash Road		5.0	4.35	-0.654	4.17
Ash	1,250	0.65	0.38	-0.27	
Total Downstream of Ash Road		5.6	4.68	-0.924	5.06

The results indicate that installing the proposed detention ponds could reduce 2-year return period peak flows in Douglas Creek by about 13.0% upstream of Ash Road and about 16.5% downstream of Ash Road. These detention ponds could provide sufficient detention to allow the peak 2-year return period discharge within the stream to be close to the 10 L/s/ha reduced peak flow criteria set out in the DoS Engineering Specifications. However, additional storage would be required to meet the 5 L/s/ha requirements for Type I watersheds.

In addition to stormwater management facilities distributed throughout the watershed, this option would also involve implementation of stormwater source controls throughout the watershed. These would provide retention of smaller storm events (up to the 6-month event) and natural flirtation to improve water quality. On private lands, the source controls would be implemented as opportunities arise as part of private development or redevelopment. However, a large portion of the impermeable surfaces in the watershed are managed by the District including roads, public buildings and other improvements in parks (such as parking lots and tennis courts). Table 5-5 summarizes the percentage of private and publically controlled impermeable surfaces in the watershed.

Table 5-5: Percentage of Impermeable Areas

Sub-basin	Watershed Area (ha)	Impervious Area (ha)	Fraction of Impervious Area	
			Buildings	Roads
Ash	49.3	42.3%	42.4%	57.6%
Tyndall	79.3	46.2%	39.3%	60.7%
Lambrick	96.5	48.6%	36.2%	63.8%
Blair	93	45.1%	38.8%	61.2%
Parkside	47.5	29.1%	43.3%	56.7%
Mount Douglas	68.1	1.3%	3.6%	96.4%
Shelbourne	101.6	46.6%	41.4%	58.6%
Ravine	22	4.7%	5.6%	94.4%
Total	**557.3**	**37.6%**	**39.2%**	**60.8%**

This would involve a long term source control implementation strategy throughout the watershed. A typical treatment surface area ratio of 5% rain garden to impervious area would be required to treat stormwater from the publically controlled surfaces in the watershed. Municipal roads for example (having a total impervious area of 111 ha.) would require 55,500 m^2 of rain garden to manage pollution loads and runoff from a 6 month rain event. It is estimated that at an average rate of approximately $350,000 a year, all of the publically controlled impermeable road surfaces with curb and gutter could have source controls installed within approximately 25 years. The total estimated cost about $8.3 Million not including inflation.

Treatment of all the public surfaces may not be feasible because of constraints such as traffic requirements on roads, limited areas within public lands for source control areas, lack of community support for projects and geographical site constraints such as slope or underlying bedrock. However, construction of source controls on at least half of the publically controlled impervious surface would reduce the directly connected impermeable surfaces in the watershed to about 26% from 37%. It would also provide opportunities for public awareness of stormwater management issues and provide a model for private development to follow.

Providing both source controls and distributed stormwater management facilities would improve both stormwater quality and would help to reduce peak flows during larger storm events. However, implementation of this option alone would not likely meet the same level of water quality improvement and flow reduction as Option 1.

Preferred Option

Because of the complex nature of the stormwater management issues in the Douglas Creek watershed, no clear preferred option is apparent. Land-use in the watershed has changed over the past 100-years to create the water quality and peak flow impacts to stream habitat. Therefore, a single quick solution to the issues is not likely possible.

Option 1 provides a feasible solution which can meet some of the stormwater quality and quantity criteria for protection of stream habitat and fish health. The systems are designed to remove sediment load and floatable pollutants. Removing sediment can reduce other pollutant loads such as heavy metals, fecal coliform and other pollutants which can be attached to sediment particles. However, they will not likely provide improvements to fecal coliform, BOD or temperature criteria. Option 2 would provide only minor improvement to water quality and no significant reduction in peak flows. Finally, implementing Option 3 could eventually meet the stormwater quality control targets but peak flow reduction targets would not be fully met. This option also has the risk of not being fully implemented because of constraints with construction of source controls in some areas and not being able to secure long-term funding for the source control implementation strategy.

In the end, a combination of the options selected by the stakeholders will be the most likely course of action. This will require an on-going adaptive management style of planning approach.

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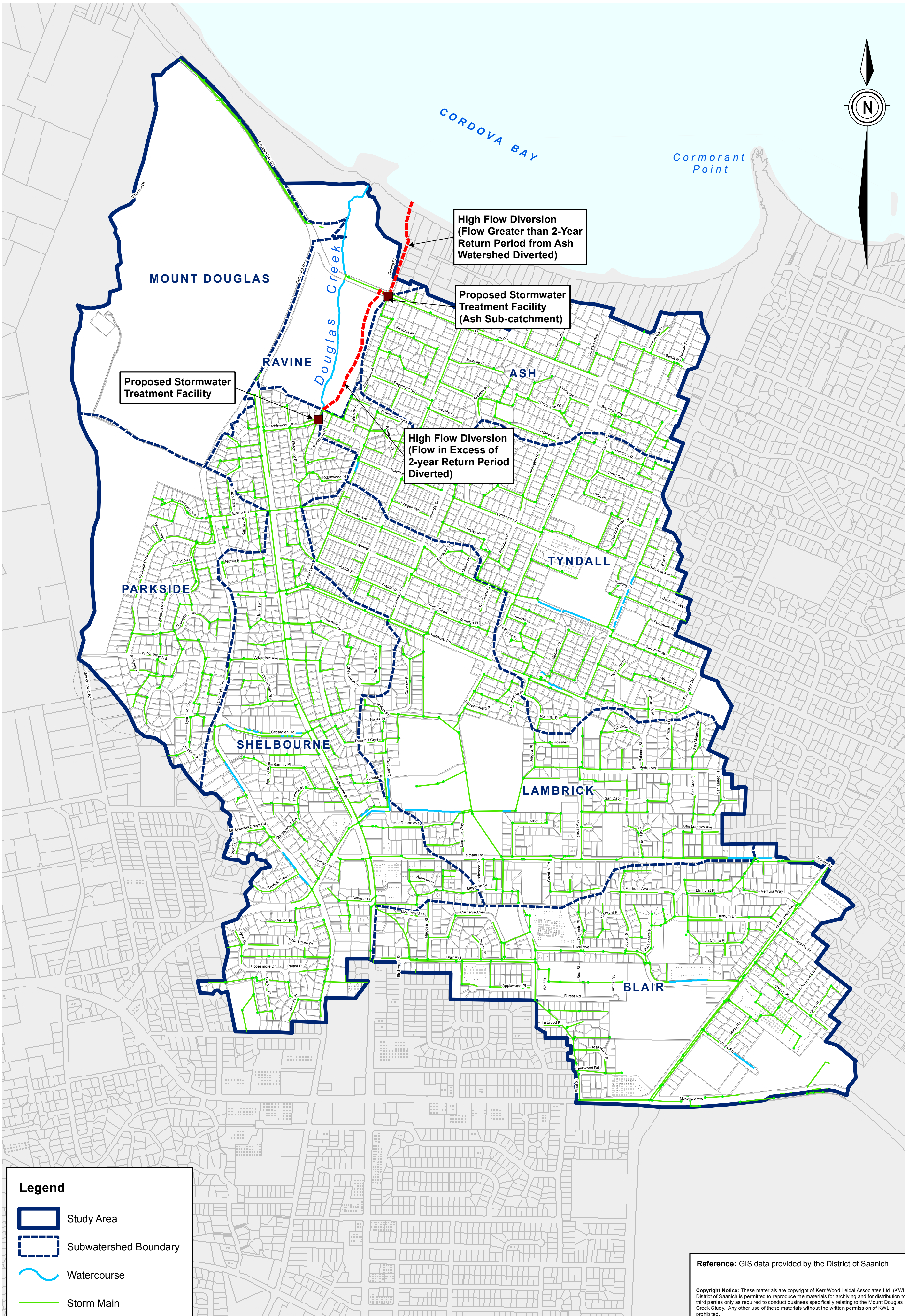

Reference: GIS data provided by the District of Saanich.

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Mount Douglas Creek Study

Project No. 437-083

Date November, 2011

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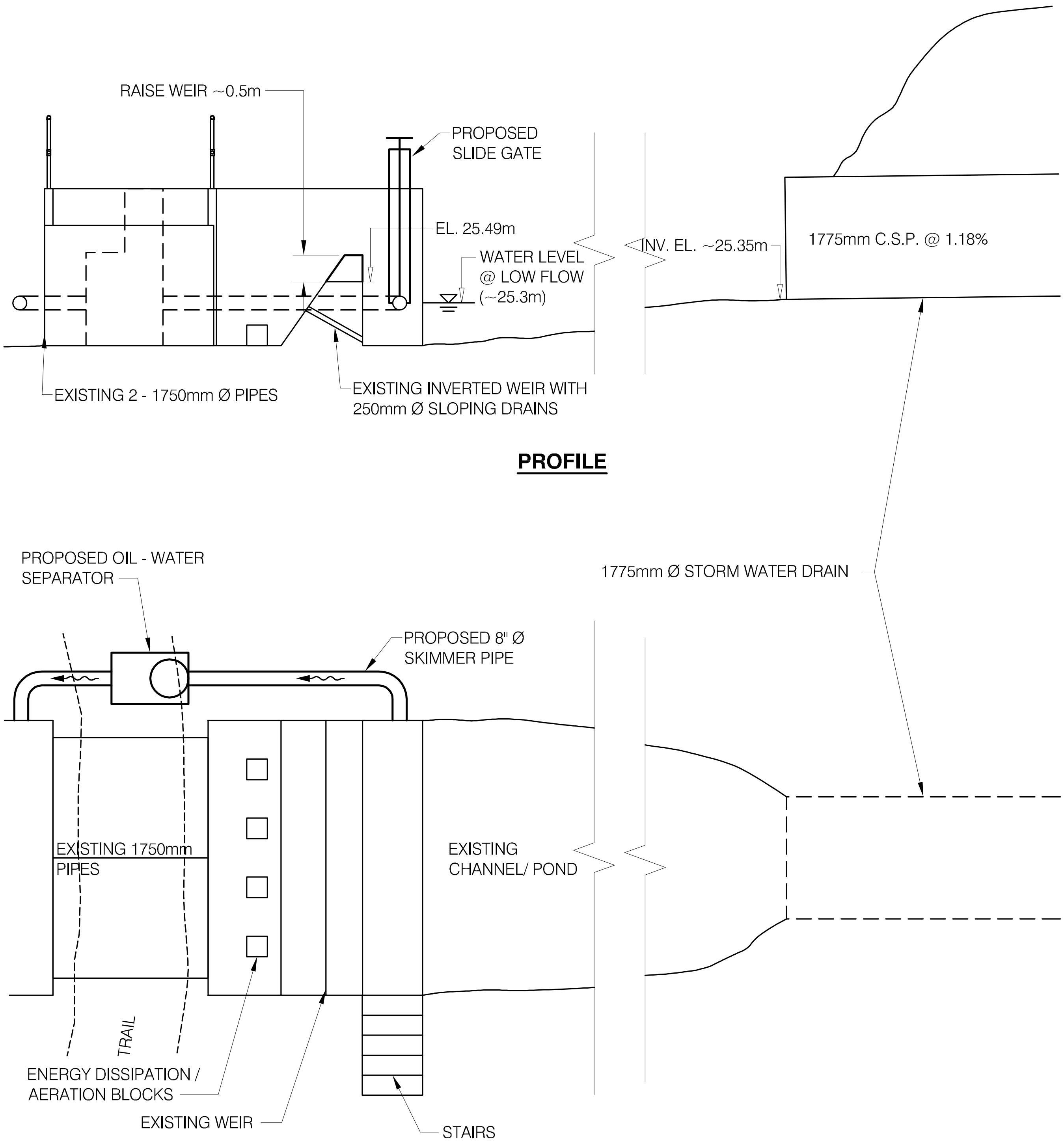
Option 1 -Single Engineered Stormwater Facility (Treat and Divert)

Figure 5-1



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OPTION 2
UPGRADE EXISTING WEIR

FIGURE 5-2

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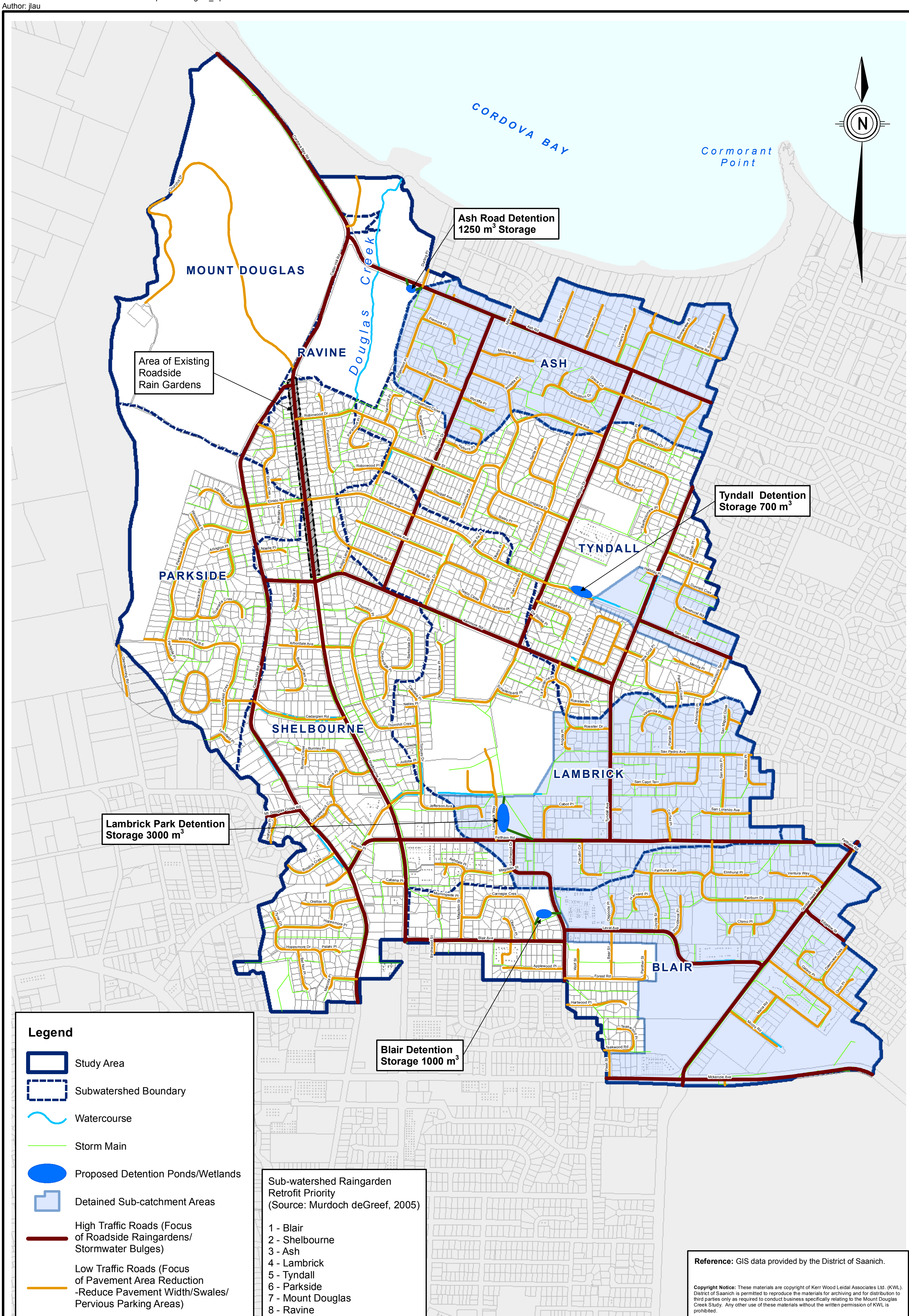

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Mount Douglas Creek Study

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437-083	November, 2011

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Option 3 -Distributed Stormwater Management Facilities (Detention/Wetlands and Rain Gardens)

Figure 5-3

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Section 6

Implementation Plant

6. Implementation Plan

6.1 Adaptive Management

As there is no clear single solution to improve water quality and stormwater management, an adaptive management approach is proposed. Adaptive management usually involves on-going implementation of smaller and less costly projects over-time while monitoring results to determine effectiveness. This allows for flexibility in implementing the plan and reduces the reliance on a single large and costly project which is not flexible to future advances in technology or changes in planning focus. The preferred strategy for implementation is to:

1. Construct upgrades to existing weir which help to improve maintenance of the water quality and improve capacity to retain contaminants during small rainfall events;
2. Continue to implement stormwater management source controls on public properties and roads focusing on high poluation load areas first such as high to moderate traffic roads, parking lots, etc.;
3. Reduce public impermeable areas in watershed by implementing pavement narrowing along residential roads;
4. Adopting the draft stormwater management by-law to improve stormwater management on private lands during redevelopment;

As the plan is implemented, monitoring of stream conditions should continue. This information will provide critical feedback to the implementation of the source controls. Through monitoring of stream conditions, changes can be made to the implementation plan over time. For instance, it may become apparent that sufficient improvments in water quality may be achieved by focusing first on those areas with high pollution that on-going implementation in lower pollution potential areas may not be needed. Further discussion of the monitoring plan is outlined in Section **Error! Reference source not found.**.

6.2 Non-structural Water Quality Protection Measures

In addition to any structural measures to protected water quality and reduction in peak flow, a continued focus on non-structural measures for water quality protection will be necessary for successful implementation of the plan. Some of these measures include:

Maintenance

- Street Sweeping
- Catch Basin Cleaning
- Maintenance of stormwater treatment facility
- Maintenance of rain gardens
- Maintenance of detention ponds
- Spill response plans

By-laws and Enforcement

- Continue enforcing Bylaw 7501 – Regulation and Protection of Natural Water Courses, Discharges and Drains.
- Adopt new Stormwater Management Bylaw for new developments not falling under the Subdivision and Development Bylaw.
- Consider adoption of the CRD Stormwater Quality Model Bylaw and associated BMPs for water quality protection including
- Enforce the by-laws as necessary

Public Education/Awareness

- Conduct a stormwater awareness survey to determine what key factors are contributing to stormwater quality issues.
- Provide public information based on issues identified in the survey.
- Engage local schools in the watershed stream-keeper activities
- Ensure recycling facilities for hazardous materials (oil, paint, anti-freeze, etc.) are easily accessible and affordable.

6.3 Monitoring Success

The success of the implementation of the plan should be monitored. This will allow for the plan to be adapted if expected outcomes are not achieved. A clear set of measureable targets should be selected and monitoring be continued to measure success against these targets. Monitoring should account for fluctuations in streamflow conditions (i.e. continuous monitoring compared to spot monitoring) and should allow for measurement of a range of indices including physical, chemical and biological. Where possible the monitoring program should use data that is already collected for other purposes and take advantage of partnerships with other stakeholders in the watershed. An example monitoring program is outlined in Table 6-1.

Table 6-1: Example Monitoring Program

Parameter	Monitoring Type	Data collection Interval	Responsibility
Physical			
Streamflow	Re-establish water level/streamflow gauge	Continuous	Province / Municipality
Temperature	Temperature Recorder at Streamflow Gauge	Continuous	Province / Municipality
Conductivity	Conductivity Senor/Spot Measurements	Continuous or Spot Measurements	Municipality / FMDPS
DO	DO Sensor /Spot Measurements	Continuous or Spot Measurements	Municipality / FMDPS

Parameter	Monitoring Type	Data collection Interval	Responsibility
Turbidity	Turbidity Senor / Spot Measurements	Continuous or Spot Measurements	Municipality / FMDPS
Chemical			
Water Sampling	CRD Stormwater Outfall Monitoring Program	Seasonally	CRD
Sediment Sampling	CRD Stormwater Outfall Monitoring Program	Every 4 to 5 years	CRD
Biological			
Benthic Sampling	Compared with Colquitz Reference Site	3 or 4 years	Municipality
Fry Release Counts/Fish Kills/Returning Adult Counts	FMDPS Reporting	Annually	FMDPS

Monitoring within the Douglas Creek watercourse should be the primary focus of the monitoring plan. However, it may be prudent to conduct physical water quality sampling from each of the subasins which can then help define which areas have higher pollution loads. Spot measurements of conductivity, DO and turbidity during dry weather and wet weather conditions could provide some indication of relative pollution loads in the watersheds. It may also be helpful in locating any serious point source pollution locations.

6.4 Financing Options

Implementation of the stormwater plan for Douglas Creek will require a reliable source of funding for general administration, operation, maintenance and capital improvements.

General Revenue

Stormwater quality management and peak flow reduction operation and maintenance costs could be funded from general revenues collected from property taxes and other sources. The primary disadvantage to this approach is that stormwater management initiatives would have to compete for funding with other municipal programs.

Stormwater Management Utility

A stormwater management utility is a dedicated funding source for stormwater management operations. Through this method, property owners are charged a user fee proportional to the demand that their property places on the stormwater system. Individual charges can be calculated using an appropriate billing unit (such as directly connected impervious area), or according to type of customer (commercial, residential, etc.). SMU fees are proven to be fair method of paying for stormwater quality management services.

Development Cost Charges

The primary purpose of Development Cost Charges (DCCs) is to generate funds for capital improvements that provide the capacity in existing utilities to serve new development. DCCs are collected from new developments to recover the costs of increased demands on stormwater and other utilities to meet growth. They are frequently used to repay debt service on capital improvements and thus can be considered option for specified projects.

Stormwater Impact Fees

Stormwater Impacts Fees are designed to reflect the impacts of new development on stormwater quality and quantity and the costs of providing additional stormwater management measures. The fees levied are set by uniformly applied schedule often In this way, new developments consistently provide funding for regional stormwater facilities rather than

Senior Government Funding and Other Grant Programs

Both Provincial and Federal Governments provide funding for capital costs for municipal infrastructure. Some of the potential funding sources are included in Table 6-1.

Table 6-2: Available Funding Sources

Name	Agency	Cost Share	Amount
Infrastructure			
Building Canada Fund	Infrastructure Canada	Varies	Varies
Gas Tax	Infrastructure Canada	Varies	Varies
Green Municipal Fund	Union of BC Municipalities	Up to 50%	Up to $350,000
Infrastructure Planning Grant Program	BC Ministry of Community Development	Up to 50%	Up to $10,000
Stewardship/Habitat Enhancement			
EcoAction Community Funding	Environment Canada	Up to 50%	Up to $100,000
Evergreen Foundation	Evergreen Foundation	Up to 100%	Up to $2000
Habitat Conservation Trust Fund	Habitat Conservation Trust Foundation	Varies	Varies

Note:
The grants listed in the table above provide a summary of some of the grants available at the time of writing. It is recommended that research into available grants be completed as part of capital planning prior to construction.

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Section 7

Recommendations and Submission

7. Recommendations and Submission

7.1 Recommendations

Based on the outcome of this study, we recommend that:

1. Missing stormwater system data identified in the analysis be collected and input to the InfoSWMM model be updated to reflect actual as-built conditions in these locations;
2. The existing Douglas Creek weir be upgraded to increase containment capacity and improve maintenance as well as excavating a small pond/wetland area to provide some additional water quality benefit for the stream;
3. A stormwater source control program for public lands within the watershed be developed and implemented starting with treating runoff from potential heavy pollution loads (such as high volume roads, and parking lots) then moving to lower potential pollution loads.
4. Further detailed investigation of the district detention/wetland facilities at Ash Road, Tyndall Park, Lambrick Park, and Blair Park identified in the study;
5. The proposed revisions to the stormwater bylaw be adopted to require stormwater source control as part of any re-development not only during subdivisions.
6. Develop and implement a maintenance program to improve stormwater quality including street sweeping, catch basin cleaning, wetland/pond maintenance including the Douglas Creek weir, and spill response.
7. Develop and implement a monitoring program both within Douglas Creek channel and at key locations in the watershed to monitor success of implementation.

7.2 Report Submission

Prepared by:

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Reviewed by:

Bruce Kenning, P.Eng.
Technical Review

Statement of Limitations

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Revision History

Revision #	Date	Status	Revision	Author
0	Nov 2011	Submitted	Draft Report for Review	CS

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Appendix A

InfoSWMM Hydrologic/Hydraulic Model Output

Saanich 437-083

Design standards:

1. no surcharging under peak 10-year return period storm for pipes less than 900 mm dia.
2. no surcharging under peak 25-year return period storm for pipes greater than 900 mm dia.

Definitions from InfoSWMM:

Free Surface - Capacity < 1
Backwater - Ratio < 1
Exceeds Capacity - Ratio and Capacity > 1
Capacity is the current link depth / link maximum depth.
Ratio is the current flow / full flow (as calculated by Manning's equation)

If at any time during the simulation, the link is defined as "Backwater" or "Exceeds Capacity" then these classifications will be reported as the Maximum Flow Class. It can be assumed that, hydraulically speaking, the flow class can be ranked as:

Free Surface -> Best
Backwater -> Medium
Exceeds Capacity -> Worst

Also note that Max Flow Class does not necessarily happen at the "Maximum Flow Day-Time"

Surcharging/Backwatered Conduits - Equal or Less than 900 mm dia. - 10-year Return Period Event

ID	Maximum Flow (m3/s)	Maximum Flow Class	Max.Flow Day-Time (day-time)	Maximum Velocity (m/s)	Max.Flow/ Full Flow	Max.Depth/ Full Depth	Reserve Capacity (m3/s)	Total Flow Volume (ML)	Both End Surcharge Time (hrs)	Both End Surcharge Time (min)	Upstream Surcharge Time (hrs)	Downstream Surcharge Time (hrs)	Above Full-Flow Time (hrs)	Capacity Limited Time (hrs)	Instability Index	Diameter (m)
DGM001548	0.002	Exceeds Capacity	0 - 08:00 hrs	0.133	8.045	1	-0.002	0.026	23.126	1387.56	23.126	23.127	6.328	5.87	1	0.15
DGM014957	0.066	Exceeds Capacity	0 - 08:03 hrs	3.757	5.089	1	-0.053	1.587	16.043	962.58	16.043	16.043	15.004	15.004	0	0.15
DGM003649	0.009	Backwater	0 - 07:58 hrs	0.531	0.551	1	0.008	0.131	1.551	93.06	1.551	1.551	0.01	0.01	0	0.15
DGM003646	0.011	Backwater	0 - 07:58 hrs	0.686	0.45	1	0.014	0.161	1.494	89.64	1.494	1.495	0.01	0.01	2	0.15
DGM001598	0.005	Backwater	0 - 07:48 hrs	0.318	0.436	1	0.007	0.062	0.692	41.52	0.692	0.692	0.01	0.01	1	0.15
DGM001651	0.004	Backwater	0 - 08:18 hrs	0.293	0.201	1	0.016	0.025	0.605	36.3	0.605	0.605	0.01	0.01	1	0.15
DGM001597	0.016	Backwater	0 - 07:46 hrs	1.002	0.793	1	0.004	0.253	0.603	36.18	0.603	0.604	0.01	0.01	0	0.15
DGM003834	0.011	Backwater	0 - 07:52 hrs	0.671	0.654	1	0.006	0.163	0.441	26.46	0.441	0.441	0.01	0.01	0	0.15
DGM002480	0.012	Backwater	0 - 07:58 hrs	0.688	0.851	1	0.002	0.163	0.343	20.58	0.343	0.343	0.01	0.01	0	0.15
DGM003835	0.031	Exceeds Capacity	0 - 07:52 hrs	1.764	1.383	1	-0.009	0.454	0.29	17.4	0.29	0.29	0.66	0.29	0	0.15
DGM003836	0.038	Exceeds Capacity	0 - 08:00 hrs	2.135	1.083	1	-0.003	0.563	0.29	17.4	0.29	0.29	0.348	0.264	0	0.15
DGM003833	0.014	Backwater	0 - 07:58 hrs	0.812	0.751	1	0.005	0.19	0.279	16.74	0.279	0.279	0.01	0.01	0	0.15
DGM003744	0.014	Backwater	0 - 07:56 hrs	1.053	0.292	1	0.033	0.191	0.166	9.96	0.166	0.166	0.01	0.01	0	0.15
DGM003832	0.026	Exceeds Capacity	0 - 08:00 hrs	1.485	1.157	1	-0.004	0.349	0.154	9.24	0.154	0.154	0.248	0.138	0	0.15
DGM002496	0.013	Exceeds Capacity	0 - 08:26 hrs	0.398	2.257	1	-0.007	0.163	2.781	166.86	2.781	2.782	1.143	0.751	3	0.2
DGM006345	0.009	Exceeds Capacity	0 - 07:58 hrs	0.272	1.137	1	-0.001	0.114	2.357	141.42	2.357	2.358	0.205	0.348	2	0.2
DGM009083	0.038	Exceeds Capacity	0 - 07:46 hrs	1.197	1.069	1	-0.002	0.589	1.278	76.68	1.278	1.278	0.013	0.015	0	0.2
DGM001599	0.029	Backwater	0 - 07:48 hrs	0.986	0.901	1	0.003	0.465	1.14	68.4	1.14	1.14	0.01	0.01	1	0.2
DGM003629	0.013	Backwater	0 - 07:58 hrs	0.526	0.451	1	0.016	0.183	0.89	53.4	0.89	0.89	0.01	0.01	2	0.2
DGM002125	0.054	Exceeds Capacity	0 - 08:00 hrs	1.732	2.04	1	-0.028	0.725	0.719	43.14	0.719	0.719	0.943	0.718	2	0.2
DGM002516	0.022	Exceeds Capacity	0 - 08:00 hrs	0.707	1.855	1	-0.01	0.281	0.673	40.38	0.673	0.673	0.808	0.438	0	0.2
DGM003634	0.021	Backwater	0 - 08:00 hrs	0.712	0.56	1	0.016	0.281	0.513	30.78	0.513	0.513	0.01	0.01	1	0.2
DGM015500	0.005	Backwater	0 - 08:11 hrs	0.258	0.068	1	0.075	0.006	0.511	30.66	0.511	0.512	0.01	0.185	2	0.2
DGM003636	0.02	Backwater	0 - 07:58 hrs	0.69	0.595	1	0.014	0.286	0.508	30.48	0.508	0.508	0.01	0.01	1	0.2
DGM002126	0.007	Backwater	0 - 08:14 hrs	0.319	0.239	1	0.023	0.097	0.433	25.98	0.433	0.433	0.01	0.01	1	0.2
DGM011616	0.025	Backwater	0 - 08:00 hrs	0.81	0.987	1	0	0.366	0.341	20.46	0.341	0.341	0.01	0.076	0	0.2
DGM003639	0.02	Backwater	0 - 07:58 hrs	0.703	0.738	1	0.007	0.275	0.331	19.86	0.331	0.331	0.01	0.01	0	0.2
DGM004032	0.026	Backwater	0 - 07:58 hrs	0.836	0.664	1	0.013	0.344	0.331	19.86	0.331	0.331	0.01	0.01	0	0.2
DGM012848	0.047	Backwater	0 - 08:17 hrs	1.706	0.481	1	0.051	0.548	0.277	16.62	0.277	0.277	0.01	0.01	0	0.2
DGM012760	0.015	Backwater	0 - 08:17 hrs	0.707	0.195	1	0.064	0.173	0.248	14.88	0.248	0.248	0.01	0.01	0	0.2
DGM003784	0.021	Backwater	0 - 08:00 hrs	0.655	0.633	1	0.012	0.275	0.24	14.4	0.24	0.24	0.01	0.01	1	0.2
DGM003633	0.016	Backwater	0 - 08:00 hrs	0.815	0.677	1	0.008	0.222	0.229	13.74	0.229	0.229	0.01	0.01	0	0.2
DGM004408	0.03	Backwater	0 - 08:18 hrs	1.211	0.246	1	0.092	0.291	0.218	13.08	0.218	0.218	0.01	0.01	1	0.2
DGM002450	0.026	Backwater	0 - 07:56 hrs	0.956	0.66	1	0.013	0.347	0.21	12.6	0.21	0.21	0.01	0.01	0	0.2
DGM011617	0.023	Backwater	0 - 07:58 hrs	0.775	0.799	1	0.006	0.342	0.183	10.98	0.183	0.183	0.01	0.01	1	0.2
DGM001580	0.038	Backwater	0 - 08:10 hrs	1.767	0.199	1	0.154	0.189	0.17	10.2	0.17	0.172	0.01	0.01	0	0.2
DGM002449	0.013	Backwater	0 - 08:07 hrs	0.714	0.407	1	0.019	0.157	0.155	9.3	0.155	0.155	0.01	0.01	0	0.2
DGM002455	0.037	Backwater	0 - 08:04 hrs	1.379	0.616	1	0.023	0.486	0.119	7.14	0.119	0.119	0.01	0.01	0	0.2
DGM011613	0.018	Backwater	0 - 07:58 hrs	0.671	0.811	1	0.004	0.241	0.089	5.34	0.089	0.089	0.01	0.01	0	0.2
DGM003669	0.013	Backwater	0 - 08:06 hrs	0.507	0.378	1	0.021	0.1	0.08	4.8	0.08	0.08	0.01	0.01	0	0.2
DGM003672	0.01	Backwater	0 - 08:03 hrs	0.405	0.276	1	0.026	0.085	0.037	2.22	0.037	0.037	0.01	0.01	0	0.2
DGM002454	0.032	Backwater	0 - 08:00 hrs	1.297	0.952	1	0.002	0.411	0.036	2.16	0.036	0.036	0.01	0.01	0	0.2
DGM003820	0.034	Backwater	0 - 07:58 hrs	1.371	0.872	1	0.005	0.456	0.035	2.1	0.035	0.035	0.01	0.01	0	0.2
DGM015497	0.071	Exceeds Capacity	0 - 07:58 hrs	1.444	2.459	1	-0.042	1.076	1.84	110.4	1.84	1.841	1.495	1.477	2	0.25
DGM002457	0.069	Backwater	0 - 08:00 hrs	1.407	0.515	1	0.065	0.936	1.449	86.94	1.449	1.45	0.01	0.01	2	0.25
DGM001530	0.105	Backwater	0 - 07:50 hrs	2.752	0.422	1	0.143	0.488	1.22	73.2	1.22	1.22	0.01	0.01	3	0.25
DGM003641	0.049	Exceeds Capacity	0 - 08:00 hrs	1.068	1.102	1	-0.005	0.682	1.127	67.62	1.127	1.127	0.206	0.177	1	0.25
DGM002456	0.064	Backwater	0 - 08:00 hrs	1.629	0.924	1	0.005	0.859	0.944	56.64	0.944	0.944	0.01	0.038	2	0.25
DGM004498	0.038	Backwater	0 - 08:00 hrs	1.081	0.632	1	0.022	0.507	0.893	53.58	0.893	0.893	0.01	0.01	1	0.25
DGM003638	0.019	Backwater	0 - 07:58 hrs	0.568	0.482	1	0.02	0.261	0.885	53.1	0.885	0.886	0.01	0.01	2	0.25
DGM003640	0.038	Backwater	0 - 07:58 hrs	0.835	0.96	1	0.002	0.528	0.689	41.34	0.689	0.689	0.01	0.112	1	0.25

ID	Maximum Flow (m3/s)	Maximum Flow Class	Max.Flow Day-Time (day-time)	Maximum Velocity (m/s)	Max.Flow/ Full Flow	Max.Depth/ Full Depth	Reserve Capacity (m3/s)	Total Flow Volume (ML)	Both End Surcharge Time (hrs)	Both End Surcharge Time (min)	Upstream Surcharge Time (hrs)	Downstream Surcharge Time (hrs)	Above Full-Flow Time (hrs)	Capacity Limited Time (hrs)	Instability Index	Diameter (m)
DGM002127	0.069	Exceeds Capacity	0 - 08:02 hrs	1.408	1.523	1	-0.024	0.978	0.604	36.24	0.604	0.604	0.705	0.603	1	0.25
DGM015498	0.067	Backwater	0 - 07:52 hrs	1.357	0.864	1	0.01	1.014	0.544	32.64	0.544	0.544	0.01	0.01	3	0.25
DGM004433	0.021	Backwater	0 - 07:54 hrs	0.489	0.293	1	0.05	0.153	0.381	22.86	0.381	0.381	0.01	0.01	1	0.25
DGM006337	0.067	Backwater	0 - 07:54 hrs	1.695	0.338	1	0.132	1.006	0.362	21.72	0.362	0.362	0.01	0.01	1	0.25
DGM015499	0.068	Backwater	0 - 08:02 hrs	1.837	0.623	1	0.041	0.999	0.358	21.48	0.358	0.358	0.01	0.01	1	0.25
VC_KWL5	0.066	Exceeds Capacity	0 - 07:58 hrs	1.467	1.245	1	-0.013	0.994	0.357	21.42	0.357	0.358	0.514	0.241	1	0.25
DGM006331	0.063	Exceeds Capacity	0 - 08:02 hrs	1.274	1.128	1	-0.007	0.943	0.324	19.44	0.324	0.324	0.428	0.308	0	0.25
DGM006332	0.061	Exceeds Capacity	0 - 08:02 hrs	1.278	1.092	1	-0.005	0.91	0.281	16.86	0.281	0.281	0.326	0.243	0	0.25
DGM002130	0.029	Backwater	0 - 08:00 hrs	0.632	0.811	1	0.007	0.397	0.237	14.22	0.237	0.237	0.01	0.049	0	0.25
DGM001589	0.021	Backwater	0 - 08:00 hrs	0.658	0.338	1	0.04	0.271	0.219	13.14	0.219	0.22	0.01	0.01	1	0.25
DGM003770	0.075	Backwater	0 - 08:00 hrs	1.537	0.984	1	0.001	1.029	0.169	10.14	0.169	0.17	0.01	0.044	1	0.25
DGM003821	0.042	Backwater	0 - 08:08 hrs	1.09	0.754	1	0.014	0.491	0.139	8.34	0.139	0.139	0.01	0.01	0	0.25
DGM002010	0.048	Backwater	0 - 08:08 hrs	1.22	0.479	1	0.052	0.644	0.098	5.88	0.098	0.098	0.01	0.01	0	0.25
DGM001595	0.05	Backwater	0 - 08:00 hrs	0.778	0.765	1	0.015	0.663	1.214	72.84	1.214	1.214	0.01	0.01	2	0.3
DGM001594	0.044	Backwater	0 - 07:58 hrs	0.855	0.72	1	0.017	0.571	1.113	66.78	1.113	1.113	0.01	0.219	2	0.3
DGM004499	0.058	Backwater	0 - 08:00 hrs	0.837	0.649	1	0.031	0.77	0.997	59.82	0.997	0.997	0.01	0.01	0	0.3
DGM003618	0.043	Backwater	0 - 07:58 hrs	0.69	0.426	1	0.057	0.611	0.655	39.3	0.655	0.655	0.01	0.01	2	0.3
DGM011058	0.049	Backwater	0 - 07:58 hrs	0.867	0.648	1	0.027	0.673	0.588	35.28	0.588	0.588	0.01	0.01	2	0.3
DGM004418	0.103	Backwater	0 - 08:00 hrs	1.459	0.626	1	0.062	1.435	0.428	25.68	0.428	0.428	0.01	0.01	2	0.3
DGM003674	0.056	Backwater	0 - 08:14 hrs	0.909	0.659	1	0.029	0.723	0.381	22.86	0.381	0.381	0.01	0.01	0	0.3
DGM002128	0.118	Exceeds Capacity	0 - 08:00 hrs	1.664	1.362	1	-0.031	1.671	0.284	17.04	0.284	0.284	0.588	0.284	1	0.3
DGM001577	0.057	Backwater	0 - 07:54 hrs	0.968	0.666	1	0.029	0.808	0.271	16.26	0.271	0.271	0.01	0.01	0	0.3
DGM003673	0.041	Backwater	0 - 08:12 hrs	0.844	0.552	1	0.034	0.445	0.235	14.1	0.235	0.235	0.01	0.01	1	0.3
DGM001605	0.066	Exceeds Capacity	0 - 08:00 hrs	0.933	1.006	1	0	0.919	0.235	14.1	0.235	0.236	0.033	0.075	0	0.3
DGM003815	0.036	Backwater	0 - 08:08 hrs	0.71	0.438	1	0.046	0.321	0.169	10.14	0.169	0.169	0.01	0.01	0	0.3
DGM011060	0.056	Backwater	0 - 07:56 hrs	1.014	0.61	1	0.036	0.783	0.054	3.24	0.054	0.054	0.01	0.01	1	0.3
DGM001578	0.218	Exceeds Capacity	0 - 07:46 hrs	2.695	1.017	1	-0.004	3.017	0.435	26.1	0.435	0.435	0.129	0.096	1	0.35
DGM011057	0.109	Exceeds Capacity	0 - 07:56 hrs	1.433	1.366	1	-0.029	1.551	1.425	85.5	1.425	1.426	0.514	0.418	2	0.375
DGM001601	0.089	Backwater	0 - 08:00 hrs	0.833	0.495	1	0.09	1.308	1.412	84.72	1.412	1.413	0.01	0.01	1	0.375
DGM001600	0.078	Backwater	0 - 08:00 hrs	1.096	0.796	1	0.02	1.165	1.353	81.18	1.353	1.353	0.01	0.218	2	0.375
DGM003642	0.073	Backwater	0 - 07:52 hrs	0.748	0.438	1	0.094	1.09	1.266	75.96	1.266	1.266	0.01	0.01	2	0.375
DGM011061	0.106	Backwater	0 - 07:58 hrs	1.14	0.79	1	0.028	1.515	1.167	70.02	1.167	1.167	0.01	0.085	2	0.375
DGM002146	0.132	Backwater	0 - 08:00 hrs	1.196	0.789	1	0.035	1.784	0.175	10.5	0.175	0.175	0.01	0.01	0	0.375
DGM003782	0.064	Backwater	0 - 07:58 hrs	0.986	0.193	1	0.268	0.886	0.153	9.18	0.153	0.154	0.01	0.01	3	0.375
DGM003668	0.114	Backwater	0 - 08:00 hrs	1.382	0.467	1	0.13	1.615	0.129	7.74	0.129	0.13	0.01	0.01	1	0.375
DGM004509	0.048	Backwater	0 - 08:07 hrs	0.682	0.112	1	0.382	0.333	0.092	5.52	0.092	0.092	0.01	0.01	0	0.375
DGM003822	0.078	Backwater	0 - 08:11 hrs	0.733	0.462	1	0.09	0.855	0.188	11.28	0.188	0.188	0.01	0.01	0	0.4
DGM003696	0.216	Exceeds Capacity	0 - 08:00 hrs	1.717	1.171	1	-0.032	3.04	0.148	8.88	0.148	0.149	0.354	0.148	0	0.4
DGM001522	0.129	Backwater	0 - 07:50 hrs	0.963	0.233	1	0.424	0.871	0.997	59.82	0.997	0.998	0.01	0.01	3	0.45
DGM003627	0.225	Backwater	0 - 08:29 hrs	1.862	0.382	1	0.364	1.655	0.453	27.18	0.453	0.453	0.01	0.01	1	0.45
DGM001520	0.092	Backwater	0 - 07:54 hrs	1.975	0.166	1	0.465	0.709	0.308	18.48	0.308	0.308	0.01	0.01	3	0.45
DGM009081	0.135	Backwater	0 - 07:48 hrs	1.554	0.675	1	0.065	1.611	0.208	12.48	0.208	0.209	0.01	0.01	0	0.45
DGM003626	0.11	Backwater	0 - 07:52 hrs	0.988	0.857	1	0.018	1.564	0.04	2.4	0.04	0.04	0.01	0.01	0	0.45
WC_KWL22	0.242	Backwater	0 - 07:52 hrs	0.433	0.144	1	1.44	1.591	1.173	70.38	1.173	1.174	0.01	0.01	3	0.5
WC_KWL9	0.071	Backwater	0 - 08:08 hrs	0.298	0.035	1	1.981	1.11	0.346	20.76	0.346	0.346	0.01	0.01	5	0.5
DGM001552	0.194	Backwater	0 - 07:50 hrs	0.995	0.24	1	0.616	0.394	0.917	55.02	0.917	0.918	0.01	0.01	3	0.525
DGM003726	0.163	Backwater	0 - 08:26 hrs	0.759	0.225	1	0.561	1.663	0.672	40.32	0.672	0.672	0.01	0.01	2	0.525
DGM003725	0.163	Backwater	0 - 08:26 hrs	1.679	0.414	1	0.231	1.66	0.622	37.32	0.622	0.622	0.01	0.01	2	0.525
DGM003724	0.122	Backwater	0 - 07:56 hrs	1.312	0.397	1	0.185	1.66	0.499	29.94	0.499	0.5	0.01	0.01	1	0.525
DGM003723	0.122	Backwater	0 - 07:56 hrs	1.236	0.426	1	0.165	1.66	0.325	19.5	0.325	0.325	0.01	0.01	1	0.525
DGM003823	0.659	Exceeds Capacity	0 - 08:02 hrs	3.046	1.165	1	-0.093	9.443	0.277	16.62	0.277	0.277	0.402	0.215	1	0.525
DGM003811	0.607	Backwater	0 - 08:02 hrs	2.956	0.938	1	0.04	8.535	0.088	5.28	0.088	0.088	0.01	0.01	0	0.525
DGM001513	1.554	Exceeds Capacity	0 - 07:50 hrs	5.496	3.602	1	-1.123	38.035	2.071	124.26	2.071	2.072	7.069	2.071	2	0.6

ID	Maximum Flow (m3/s)	Maximum Flow Class	Max.Flow Day-Time (day-time)	Maximum Velocity (m/s)	Max.Flow/ Full Flow	Max.Depth/ Full Depth	Reserve Capacity (m3/s)	Total Flow Volume (ML)	Both End Surcharge Time (hrs)	Both End Surcharge Time (min)	Upstream Surcharge Time (hrs)	Downstream Surcharge Time (hrs)	Above Full-Flow Time (hrs)	Capacity Limited Time (hrs)	Instability Index	Diameter (m)
DGM002448	2.081	Exceeds Capacity	0 - 07:58 hrs	7.358	3.316	1	-1.453	51.272	1.778	106.68	1.778	1.779	6.245	1.778	2	0.6
DGM001581	0.303	Backwater	0 - 07:50 hrs	1.489	0.236	1	0.98	3.609	1.417	85.02	1.417	1.417	0.01	0.01	2	0.6
DGM001512	0.424	Backwater	0 - 08:00 hrs	1.666	0.214	1	1.554	5.838	1.17	70.2	1.17	1.17	0.01	0.01	3	0.6
DGM001516	0.1	Backwater	0 - 07:48 hrs	0.522	0.11	1	0.806	0.854	0.537	32.22	0.537	0.537	0.01	0.01	2	0.6
DGM001511	0.416	Exceeds Capacity	0 - 08:00 hrs	2.032	1.037	1	-0.015	5.74	0.47	28.2	0.47	0.47	0.119	0.12	2	0.6
DGM006325	0.395	Backwater	0 - 08:00 hrs	1.514	0.96	1	0.016	5.454	0.273	16.38	0.273	0.274	0.01	0.031	1	0.6
DGM003826	0.665	Exceeds Capacity	0 - 08:03 hrs	2.352	1.038	1	-0.025	9.585	0.236	14.16	0.236	0.236	0.153	0.118	0	0.6
DGM004033	0.467	Backwater	0 - 08:04 hrs	1.057	0.847	1	0.084	7.582	0.685	41.1	0.685	0.685	0.01	0.192	2	0.75
DGM004030	0.443	Backwater	0 - 08:04 hrs	1.002	0.619	1	0.272	7.195	0.507	30.42	0.507	0.507	0.01	0.021	1	0.75
DGM004434	0.989	Exceeds Capacity	0 - 08:02 hrs	2.238	1.008	1	-0.008	15.039	0.375	22.5	0.375	0.375	0.073	0.07	1	0.75
DGM002014	0.963	Backwater	0 - 08:03 hrs	2.528	0.926	1	0.077	14.642	0.35	21	0.35	0.35	0.01	0.053	1	0.75
DGM002011	0.96	Exceeds Capacity	0 - 08:03 hrs	2.172	1.265	1	-0.201	14.558	0.34	20.4	0.34	0.34	0.555	0.259	0	0.75
DGM001630	0.788	Exceeds Capacity	0 - 08:03 hrs	1.783	1.267	1	-0.166	11.166	0.332	19.92	0.332	0.332	0.476	0.332	0	0.75
DGM004029	0.43	Backwater	0 - 08:04 hrs	1.381	0.687	1	0.196	6.993	0.32	19.2	0.32	0.32	0.01	0.01	0	0.75
DGM002006	0.916	Backwater	0 - 08:03 hrs	2.079	0.928	1	0.071	13.911	0.286	17.16	0.286	0.286	0.01	0.031	0	0.75
DGM012837	0.964	Backwater	0 - 08:03 hrs	2.851	0.754	1	0.315	14.617	0.283	16.98	0.283	0.283	0.01	0.018	1	0.75
DGM002013	0.961	Exceeds Capacity	0 - 08:03 hrs	2.31	2.133	1	-0.511	14.578	0.283	16.98	0.283	0.283	1.402	0.262	1	0.75
DGM004028	0.426	Backwater	0 - 08:07 hrs	1.443	0.691	1	0.19	6.889	0.236	14.16	0.236	0.236	0.01	0.01	0	0.75
DGM002005	0.912	Backwater	0 - 08:03 hrs	2.545	0.877	1	0.128	13.852	0.187	11.22	0.187	0.187	0.01	0.024	0	0.75
DGM004024A	0.409	Backwater	0 - 08:07 hrs	1.41	0.661	1	0.21	6.623	0.174	10.44	0.174	0.174	0.01	0.01	0	0.75
DGM004024B	0.399	Backwater	0 - 08:10 hrs	1.321	0.854	1	0.068	6.444	0.155	9.3	0.155	0.155	0.01	0.01	0	0.75
DGM012651	0.78	Backwater	0 - 07:43 hrs	1.462	0.302	1	1.804	16.142	1.479	88.74	1.479	1.479	0.01	0.01	3	0.9
DGM003643A	0.926	Backwater	0 - 08:02 hrs	1.52	0.444	1	1.158	13.868	1.45	87	1.45	1.45	0.01	0.01	3	0.9
DGM003643B	0.925	Backwater	0 - 08:02 hrs	1.992	0.846	1	0.169	13.82	1.401	84.06	1.401	1.401	0.01	0.117	3	0.9
DGM003632	1.158	Exceeds Capacity	0 - 08:04 hrs	2.149	1.097	1	-0.102	18.63	1.297	77.82	1.297	1.297	0.449	0.421	2	0.9
DGM003631	1.147	Exceeds Capacity	0 - 08:04 hrs	1.811	1.092	1	-0.097	18.479	1.266	75.96	1.266	1.267	0.438	0.396	4	0.9
DGM003614	1.079	Exceeds Capacity	0 - 08:06 hrs	1.696	1.923	1	-0.518	17.175	1.02	61.2	1.02	1.02	1.228	1.004	2	0.9
DGM003619	1.119	Exceeds Capacity	0 - 08:04 hrs	1.818	1.021	1	-0.023	17.842	1.02	61.2	1.02	1.02	0.152	0.196	3	0.9
DGM003637	0.859	Backwater	0 - 08:02 hrs	1.641	0.818	1	0.192	12.642	0.825	49.5	0.825	0.828	0.01	0.01	1	0.9
DGM003635	0.828	Backwater	0 - 08:03 hrs	1.776	0.725	1	0.314	12.129	0.548	32.88	0.548	0.551	0.01	0.01	2	0.9
DGM004436	1.601	Exceeds Capacity	0 - 08:03 hrs	2.517	1.297	1	-0.367	23.648	0.535	32.1	0.535	0.536	0.599	0.453	1	0.9
DGM012532	1.598	Exceeds Capacity	0 - 08:02 hrs	2.512	1.21	1	-0.277	23.611	0.495	29.7	0.495	0.496	0.423	0.38	1	0.9
DGM004435	1.011	Exceeds Capacity	0 - 08:02 hrs	1.589	1.123	1	-0.111	15.357	0.463	27.78	0.463	0.463	0.372	0.332	1	0.9
DGM003628	1.47	Backwater	0 - 07:48 hrs	2.812	0.698	1	0.637	11.614	0.438	26.28	0.438	0.439	0.01	0.012	2	0.9
DGM003751	0.971	Backwater	0 - 08:07 hrs	1.701	0.526	1	0.876	15.35	0.381	22.86	0.381	0.381	0.01	0.01	1	0.9
DGM003750	0.954	Exceeds Capacity	0 - 08:06 hrs	1.955	1.438	1	-0.291	15.02	0.381	22.86	0.381	0.381	0.715	0.362	1	0.9
DGM003747	0.91	Backwater	0 - 08:07 hrs	1.72	0.792	1	0.239	14.413	0.3	18	0.3	0.301	0.01	0.01	0	0.9
DGM003745	0.917	Backwater	0 - 08:07 hrs	1.916	0.923	1	0.077	14.166	0.293	17.58	0.293	0.293	0.01	0.06	0	0.9
DGM003743	0.9	Backwater	0 - 08:07 hrs	1.798	0.948	1	0.049	13.972	0.274	16.44	0.274	0.274	0.01	0.047	0	0.9
DGM003740	0.886	Backwater	0 - 07:56 hrs	1.732	0.854	1	0.151	13.701	0.262	15.72	0.262	0.262	0.01	0.053	0	0.9
DGM003739	0.893	Backwater	0 - 07:56 hrs	1.783	0.846	1	0.162	13.696	0.214	12.84	0.214	0.214	0.01	0.014	0	0.9
DGM003737	0.889	Backwater	0 - 07:56 hrs	1.726	1.01	1	-0.009	13.443	0.202	12.12	0.202	0.202	0.02	0.045	0	0.9
DGM003736	0.89	Backwater	0 - 07:58 hrs	1.669	0.956	1	0.041	13.397	0.192	11.52	0.192	0.192	0.01	0.022	0	0.9
DGM003731	0.829	Backwater	0 - 07:58 hrs	1.561	0.9	1	0.092	12.512	0.173	10.38	0.173	0.173	0.01	0.016	0	0.9
DGM003621	0.703	Backwater	0 - 08:00 hrs	1.958	0.653	1	0.373	10.119	0.093	5.58	0.093	0.093	0.01	0.01	0	0.9

Surcharging/Backwatered Conduits - Greater than 900 mm dia. - 25-year Return Period Event

ID	Maximum Flow (m3/s)	Maximum Flow Class	Max.Flow Day-Time (day-time)	Maximum Velocity (m/s)	Max.Flow/Full Flow	Max.Depth/Full Depth	Reserve Capacity (m3/s)	Total Flow Volume (ML)	Both End Surcharge Time (hrs)	Both End Surcharge Time (min)	Upstream Surcharge Time (hrs)	Downstream Surcharge Time (hrs)	Above Full Flow Time (hrs)	Capacity Limited Time (hrs)	Instability Index	Diameter (m)
DGM001517	1.95	Backwater	0 - 07:46 hrs	2.269	0.822	1	0.421	44.192	0.679	40.74	0.679	0.68	0.01	0.01	2	1.35
DGM001523	4.115	Backwater	0 - 07:46 hrs	3.472	0.767	1	1.248	45.129	1.086	65.16	1.086	1.086	0.01	0.177	4	1.35
DGM001526	1.771	Backwater	0 - 09:27 hrs	1.838	0.654	1	0.935	46.143	1.253	75.18	1.253	1.254	0.01	0.024	2	1.35
DGM001531	1.819	Backwater	0 - 09:29 hrs	1.68	0.499	1	1.828	46.893	1.539	92.34	1.539	1.54	0.01	0.245	4	1.35
DGM001546	1.868	Backwater	0 - 07:58 hrs	1.935	0.671	1	0.917	51.735	1.617	97.02	1.617	1.618	0.01	0.048	3	1.35
DGM001549	1.891	Backwater	0 - 08:00 hrs	1.852	0.672	1	0.923	52.053	1.74	104.4	1.74	1.74	0.01	0.037	3	1.35
DGM001582	2.169	Backwater	0 - 08:00 hrs	1.938	0.705	1	0.906	56.253	1.848	110.88	1.848	1.849	0.01	0.231	4	1.35
DGM001588	2.211	Backwater	0 - 07:58 hrs	1.545	0.748	1	0.745	56.77	1.92	115.2	1.92	1.92	0.01	0.01	2	1.35
DGM001641	1.496	Exceeds Capacity	0 - 08:02 hrs	1.731	8.124	1	-1.312	20.153	0.149	8.94	0.149	0.149	9.613	0.147	0	1.05
DGM001644	1.544	Exceeds Capacity	0 - 08:03 hrs	1.812	1.164	1	-0.218	20.719	0.143	8.58	0.143	0.143	0.38	0.123	0	1.05
DGM002022	2.26	Exceeds Capacity	0 - 08:02 hrs	2.621	1.257	1	-0.462	32.811	0.281	16.86	0.281	0.281	0.676	0.277	0	1.05
DGM002023	2.198	Exceeds Capacity	0 - 08:03 hrs	2.736	1.009	1	-0.019	33.031	0.281	16.86	0.281	0.281	0.051	0.076	0	1.05
DGM002024	2.457	Exceeds Capacity	0 - 08:03 hrs	2.837	1.135	1	-0.293	36.579	0.089	5.34	0.089	0.09	0.575	0.089	0	1.05
DGM002582	1.549	Exceeds Capacity	0 - 08:02 hrs	1.947	1.772	1	-0.675	20.719	0.116	6.96	0.116	0.117	0.859	0.114	0	1.05
DGM002583	1.74	Backwater	0 - 08:02 hrs	2.345	1.077	1	-0.125	22.82	0.116	6.96	0.116	0.117	0.092	0.01	0	1.05
DGM002584	1.788	Backwater	0 - 08:00 hrs	2.376	0.818	1	0.399	23.024	0.196	11.76	0.196	0.196	0.01	0.01	0	1.05
DGM002585	1.887	Exceeds Capacity	0 - 08:00 hrs	2.57	1.142	1	-0.234	24.649	0.242	14.52	0.242	0.242	0.261	0.16	0	1.05
DGM002586	1.806	Backwater	0 - 08:00 hrs	2.662	0.729	1	0.671	24.658	0.248	14.88	0.248	0.248	0.01	0.01	1	1.05
DGM002587	1.945	Backwater	0 - 07:58 hrs	2.414	0.985	1	0.03	27.005	0.35	21	0.35	0.35	0.01	0.01	0	1.05
DGM002588	1.969	Backwater	0 - 07:58 hrs	2.031	1.011	1	-0.022	28.038	0.363	21.78	0.363	0.363	0.019	0.093	0	1.2
DGM002589	1.973	Backwater	0 - 07:56 hrs	2.138	0.94	1	0.126	28.996	0.386	23.16	0.386	0.386	0.01	0.085	1	1.2
DGM002590	2.051	Backwater	0 - 08:02 hrs	2.078	0.825	1	0.435	30.829	0.41	24.6	0.41	0.41	0.01	0.021	1	1.2
DGM002593	2.067	Exceeds Capacity	0 - 08:06 hrs	2.199	1.595	1	-0.771	31.09	0.41	24.6	0.41	0.41	0.898	0.399	1	1.2
DGM002595	2.071	Backwater	0 - 08:06 hrs	2.643	0.877	1	0.291	31.126	0.496	29.76	0.496	0.496	0.01	0.118	1	1.05
DGM002596	2.131	Exceeds Capacity	0 - 08:02 hrs	2.46	1.188	1	-0.337	32.065	0.364	21.84	0.364	0.364	0.66	0.363	0	1.05
DGM003645	1.218	Backwater	0 - 07:43 hrs	1.622	0.528	1	1.087	33.639	1.836	110.16	1.836	1.836	0.01	0.01	4	1.2
DGM003647	1.242	Backwater	0 - 07:43 hrs	1.336	0.623	1	0.752	34.019	1.997	119.82	1.997	1.997	0.01	0.01	4	1.2
DGM003650	1.253	Backwater	0 - 07:43 hrs	1.108	0.602	1	0.83	34.204	2.192	131.52	2.192	2.192	0.01	0.034	5	1.2
DGM004014	2.192	Exceeds Capacity	0 - 08:02 hrs	2.544	1.204	1	-0.371	32.455	0.305	18.3	0.305	0.305	0.657	0.291	0	1.05
DGM004016	2.53	Exceeds Capacity	0 - 08:00 hrs	3.146	1.472	1	-0.812	32.553	0.299	17.94	0.299	0.3	0.701	0.168	1	1.05
DGM004402	7.576	Backwater	0 - 08:02 hrs	4.48	0.698	1	3.276	130.921	0.04	2.4	0.04	0.042	0.01	0.01	0	1.775
DGM004406	7.513	Backwater	0 - 08:04 hrs	3.217	0.727	1	2.823	131.256	0.304	18.24	0.304	0.306	0.01	0.01	0	1.775
DGM006336	1.894	Exceeds Capacity	0 - 09:29 hrs	1.866	1.096	1	-0.167	50.752	1.605	96.3	1.605	1.606	0.346	0.579	4	1.35
DGM012646	1.549	Exceeds Capacity	0 - 08:03 hrs	1.886	1.743	1	-0.66	20.719	0.129	7.74	0.129	0.13	0.84	0.126	0	1.05
DGM012647	0.961	Backwater	0 - 08:03 hrs	1.263	0.733	1	0.35	13.009	0.067	4.02	0.067	0.068	0.01	0.01	0	1.05
DGM012744	8.379	Backwater	0 - 07:56 hrs	4.186	0.825	1	1.783	130.772	0.244	14.64	0.244	0.246	0.01	0.029	0	1.775
DGM012780	2.08	Exceeds Capacity	0 - 08:06 hrs	2.402	1.152	1	-0.274	31.327	0.474	28.44	0.474	0.474	0.63	0.463	1	1.05
DGM012845	2.365	Backwater	0 - 08:26 hrs	3.252	0.578	1	1.723	32.628	0.3	18	0.3	0.3	0.01	0.062	1	1.05

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Appendix B

Conceptual (Level-D) Cost Estimates

Option 1 - Single Engineered Solution - Treat and Divert

ITEM	QTY	UNIT	RATE	TOTAL	Notes
Project Startup					
Mobilization				$142,000	Assum 5 % of construction
Insurance/Bonding				$57,000	Assume 2% of construction
Subtotal				**$199,000**	
Diversion Pipe					
1,200 mm diameter concerete pipe	800	lin m	$515	$412,000	
Manholes	8	ea	$7,000	$56,000	Assume one manhole every 100 m
Trenching and backfill	800	lin m	$390	$312,000	
Ashphalt Cutting and Road Restoration	220	lin m	$195	$42,900	
Trail surfacing	580	lin m	$25	$14,500	
Connection of Existing Services	7	ea	$500	$3,500	Assume one connection every 30 m along road
Subtotal				**$840,900**	
Stormwater Treatment					
Treatment Plant Design/Supply	1	ea	$1,000,000	$1,000,000	
Construction / Installation	1	ea	$1,000,000	$1,000,000	
Subtotal				**$2,000,000**	
Total Construction				$3,039,900	
Engineering				$365,000	Assume 12%
Operartion and Maintenance				$500,000	Assume $10,000 per year for 50 year service life
Contningency (25%)				$759,975	
Total Estimated Life-cycle Cost (Level-D)				**$4,664,875**	

Notes:
Cost includes supply and installation of 1,200 mm diamater pipe with approximately 220 m under road and remainder under existing park trail
Conceptual (Level-D) cost estimate is based on limited knowledge of site conditions using typical unit rates and past experience with similar projects.
The cost estimate is suitable for strategic planning and/or option comparisons. Further detailed site investigation and design required for detailed construction cost estimate.

Option 3 - Distributed Water Management - Source Control and Detention

ITEM	QTY	UNIT	RATE	TOTAL	Notes
Project Startup					
Mobilization				$594,000	Assum 5 % of construction
Insurance/Bonding				$238,000	Assume 2% of construction
Subtotal				**$832,000**	
Detention Pond/Wetland					
Detention Pond/Wetland	4,950	m^3	$100	$495,000	
Planting	4,950	m^2	$35	$173,250	
Connections to Stormwater System	3	ea	$50,000	$150,000	
Subtotal				**$818,250**	
Rain Gardens					
Rain Gardens (Roads)	55,500	m^2	$150	$8,325,000	
Rain Gardern (Public Buildings)	30,500	m^2	$90	$2,745,000	
Subtotal				**$11,070,000**	
Total Construction				$12,720,250	
Engineering				$636,000	Assume 5%
Operartion and Maintenance				$2,500,000	Assume $50,000 per year for 50 year service life
Contningency (25%)				$3,180,063	
Total Estimated Life-cycle Cost (Level-D)				**$19,036,313**	

Notes:
Cost includes supply and installation of 1,200 mm diamater pipe with approximately 220 m under road and remainder under existing park trail
Conceptual (Level-D) cost estimate is based on limited knowledge of site conditions using typical unit rates and past experience with similar projects.
The cost estimate is suitable for strategic planning and/or option comparisons. Further detailed site investigation and design required for detailed construction cost estimate.