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CLOVERDALE McLELLAN INTEGRATED STORMWATER MANAGEMENT PLAN

PROJECT 4809-711

Prepared by

Delcan

February 2011
EB3712

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February 23, 2011 OUR REF: EB3712

Mr. David Hislop, P. Eng.
Uplands Drainage Engineer
Engineering Department
City of Surrey
14245-56 Avenue
Surrey, B.C.
V3X 3A2

Re: Final Report – Project 4809-711
Cloverdale McLellan Integrated Stormwater Management Plan (ISMP)

Dear Mr. Hislop,

Delcan is pleased to provide the City of Surrey with **four (4) copies** of the final report for the ***Cloverdale McLellan Integrated Stormwater Management Plan.*** We have also provided you with a digital (.pdf) copy of the report as well as all related modeling, background reports and data files associated with the project.

We would like to acknowledge the contributions of a few people in this ISMP in particular yourself and Carrie Baron for your ongoing efforts and guidance throughout the whole project. As well please extent our appreciation to Ray Kerr, Mary Beth Rondeau, Dan Chow and Anna Mathewson for their participation in establishing a watershed vision.

We look forward to your review and are available at your convenience to discuss and clarify any aspect of the ISMP that needs clarification. Please feel free to contact me at (604) 438-5300 if you have any questions.

Sincerely,

Tom Reeve, P.Eng.
Project Manager

Encl.

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Executive Summary

The City of Surrey is a recognized leader in the field of integrated stormwater management planning as they continue to work towards the goal of completing ISMPs for all watersheds within the City by 2014. Delcan was retained by the City of Surrey to complete an Integrated Stormwater Management Plan (ISMP) for the Cloverdale McLellan watershed.

The study area watershed is the portion of Cloverdale that flows south to the Nicomekl River. It is bordered by the City of Langley and the Township of Langley to the east. The study area is approximately 13.1 km^2 and the majority has been developed to urban land use. The area covers some of the upland areas of the Nicomekl River watershed, which has an approximate area of 175 km^2 and discharges into Boundary Bay and the study area is only a small portion of the total watershed area (7.5%). The lowland agricultural area was not included in the study area as it is presently being studied by others and has been the subject of a number of past reports.

Water resource management is a longstanding City priority and the City continues to evolve and adapt a watershed-based approach that incorporates lessons learned in getting green infrastructure right. The ISMP approach focuses on the four fundamental principles:

- Account for the full spectrum of rainfall events;
- Use performance targets;
- Allow for adaptive management as our knowledge and understanding of the watershed increases; and
- Integrate the ISMP with the City's planning documents.

These principles have guided the analyses, discussion and implementation of the Cloverdale McLellan ISMP. The purpose is to protect properties from localized flooding, protect and enhance aquatic habitat, and accommodate future land development and population growth.

The first part of the ISMP is a review of the existing conditions of the study area. This included an environmental assessment, a review of applicable planning documents, and event based and continuous stormwater modeling. The existing condition assessment identified a number of watershed issues related to drainage, flooding and habitat. These issues are discussed specifically in the body of this report but some common elements occurred in multiple issues:

- **Flooding and agricultural lowlands**: One of the challenges of this area is that the lower portion of this study area is less than 3 meters in elevation making this land subject to flooding. That flooding can be caused by drainage from the urban uplands, backwater flooding from the lowland drainage system, flooding from the Nicomekl River and a combination of these events. Managing this land can present many challenges. This ISMP focuses on managing the upland drainage which can help contribute to making overall improvements to the lowland areas.
- **Stormwater practices in older neighbourhoods**: As with many older neighbourhoods there are issues with drainage infrastructure that were not designed to today's standards. Stormwater is conveyed off site without measures for peak flow control, stormwater volume reduction or stormwater quality measures. This can cause or increase downstream flooding and infrastructure issues. It can cause

increased erosion in watercourses which leads to degradation of habitat. In the new development area of East Clayton, new thinking on stormwater management is being applied but elsewhere in the study area the primary opportunity for change will be redevelopment.

- **Undersized infrastructure at outlet points**: The upland drainage is generally conveyed through pipe to the lowlands where it outlets to the open channel system. In a number of place in the watershed the final few links and reaches of the system are undersized. These links can cause a backwater that will increase the chance of surface flooding upstream. There are a number of cases where the undersized link is a culvert under the railway which can further complicate the solution with grade restrictions and property issues.

After the issues within the watershed were identified the project team consulted with stakeholders to determine a common vision for the watershed. The stakeholders that chose to participate in the ISMP were all internal to the City of Surrey. They provided insight in to the current direction of stormwater planning in the City of Surrey and provided support for making changes to current practice. The vision for the watershed was a stated support for improving the way that stormwater is managed through ‘greener’ land use and infrastructure practices. The stakeholder recognized that there were practical limitations on making widespread changes but support an approach that emphasized incremental changes towards sustainable stormwater management.

With this direction a number of implementation recommendations were made. These can be defined into two categories: planning and policy changes and specific infrastructure and habitat projects. A few of the key recommendations have been highlighted in the following areas:

- **Redevelopment**: A recommendation that redevelopment of single lots include stormwater low impact development measures. This would apply to commercial/industrial as well as residential redevelopment. One of the trends being observed across the lower mainland is that lots that when lots are being redeveloped they are usually developed to have greater overall impervious area. This could have an incremental impact on the watersheds and over time can cause drainage, flooding and environmental issues. That is why one of the key recommendations of this ISMP is to change the way redevelopment of land is done to, at a minimum mitigate the impact, but ideally to make an improvement. Because most of the watershed is already developed one of the most important ways to improve the watershed health is to take advantage of redevelopment opportunities to make small incremental changes within the watershed.
- **Watercourse Setbacks**: A recommendation that the City preserves and enhances watercourse setbacks through the watershed. There are few remaining watercourses within the study area but those that remain are important and need protection and enhancement. The goal is to have watercourses with 30 meters setback and an additional 6 meter setback for maintenance access. There are a few places in the study area where this setback exists but many more where it has been reduced by past development. Similar to the recommendations related to redevelopment the ISMP proposes to take advantage of development and redevelopment opportunities to make reasonable incremental improvements to the riparian area setbacks which over time can improve the overall health of the watershed.

- **Infrastructure improvements**: A number of infrastructure improvements have been recommended as part of this study. The majority of them are to improve pinch points and undersized infrastructure in the lower portion of the study area. The majority of the infrastructure required are in the lowland areas

One of the challenges of this ISMP was to solicit active interest from stakeholders. One of the ways this showed in the level of involvement in review and development of the ISMP implementation recommendations. This means, that although the project team has insured the recommendations are technically sound, there will be additional effort required to obtain buy-in and implementation of the ISMP. The exercise will help further define how this ISMP gets implemented. The ISMP has proposed specific infrastructure projects as well as changes as to how the development and redevelopment is undertaken.

Abbreviations

ALR – Agricultural Land Reserve

B-IBI – Benthic Index of Biotic Integrity

BMP – Best Management Practice

CPR – Canadian Pacific Railway

DCC – Development Cost Charges

DFO – Department of Fisheries and Oceans

GIS – Geographic Information System

ISMP – Integrated Stormwater Management Plan

LAP – Local Area Plan

LID – Low Impact Development

MoE - Ministry of Environment

NCP – Neighbourhood Concept Plan

OCP – Official Community Plan

RAR – Riparian Areas Regulation

ROW – Right-of-Way

1. Introduction

Delcan has been retained to complete an Integrated Stormwater Management Plan for the Cloverdale McLellan ISMP. The study area is located in the east of Surrey bordering the City of Langley and the Township of Langley to the east. The study area is approximately 13.1 km^2 and the majority has been developed to urban land use. The area covers some of the upland areas of the Nicomekl River watershed, which has an approximate area of 175 km^2 and discharges into Boundary Bay. The features of the study area are discussed in more detail in section 1.3 of this report.

Overview

Stormwater is water that flows across the land and is routed into drainage systems and ultimately into natural areas such as oceans, creeks, lakes and wetlands. Unlike sewage, stormwater is not typically treated before it enters our waterways. In some cases it is filtered by oil grit separators or wetlands, usually located at the end of a pipe system, but in most cases it flows directly from streets and gutters into creeks, rivers and lakes.

As our landscape changes from undeveloped, natural areas to cities with houses, businesses, roads and parking lots, the "permeable" or "porous" areas are reduced and replaced with hard surfaces that don't absorb stormwater. To avoid flooding, erosion and habitat degradation, measures and tools to manage the runoff must be implemented in the form of a stormwater management program.

Urban areas have large tracts of constructed impervious surfaces such as roads, driveways, roofs, and parking lots. When stormwater runoff flows over these hard surfaces, it can accumulate pollutants. Stormwater pollutants originate from many different sources ranging from fuel and oil on roads, to litter, and sediment from construction sites. Improving stormwater quality in the long-term requires effective management of these pollutants at their source, as well as treatment of stormwater before it enters our waterways.

In urban areas, the increase in impervious areas has reduced the amount of rain that is retained by vegetation or infiltrated into the ground. Consequently, higher volumes of stormwater runoff enter the drainage system and receiving waterways than would occur under natural conditions. Urbanization has also changed the timing of stormwater discharges into receiving streams. Traditionally, stormwater drainage systems have been constructed to remove stormwater from urban areas as quickly as possible to minimize the risk of flooding and prevent negative impacts to traffic and use of public facilities such as parks and playing fields. The increased volume entering waterways can cause accelerated scouring (in-stream erosion) of waterways. With effective stormwater management, the runoff water is released over a longer period of time and with lower peak discharges, which maintains healthier water environments and better mimic the natural hydrologic regime.

1.1. Goals and Objectives

British Columbia's municipalities have a mandate to manage drainage and stormwater systems. Conventional stormwater systems are designed to protect properties from flooding after rainfall events by collecting and safely conveying water downstream. However, as the science of stormwater management evolves, it is becoming increasing clear that traditional stormwater practices are contributing to waterway degradation and the decline of fish populations. To counter these impacts, Metro Vancouver's municipalities have committed to developing Integrated Stormwater Management Plans (ISMPs) for each of their watersheds by 2014. Surrey has continued to be a leader in stormwater management.

Before the 1970s, comprehensive urban drainage planning was not fully considered in urban development in Surrey. By the early 1970s, however, drainage had become an issue in the suburban areas and the agricultural lowlands that often were the outlet for stormwater runoff. Water resource management is a longstanding City priority and the City has recently used tools such as Master Drainage Plans (MDPs) Liquid Waste Management Plans, and now ISMPs. Now in its fifth decade of continuous implementation experience, the City continues to evolve and adapt a watershed-based approach that incorporates lessons learned in getting green infrastructure right.

The term, 'Integrated Stormwater Management Planning' has gained widespread acceptance by local governments and environmental agencies to describe a comprehensive approach to stormwater planning. ISMPs provide clear direction for applying land use planning principles to stormwater management. The purpose is to protect properties from localized flooding, protect and enhance aquatic habitat, and accommodate future land development and population growth.

Delcan has been retained by the City of Surrey to deliver an Integrated Stormwater Management Plan for the Cloverdale McLellan watershed. Cloverdale McLellan is one of the watershed areas in Surrey for which an ISMP is being developed. **Figure 1.1** shows the Cloverdale McLellan watershed in the context of all of Surrey's ISMPs.

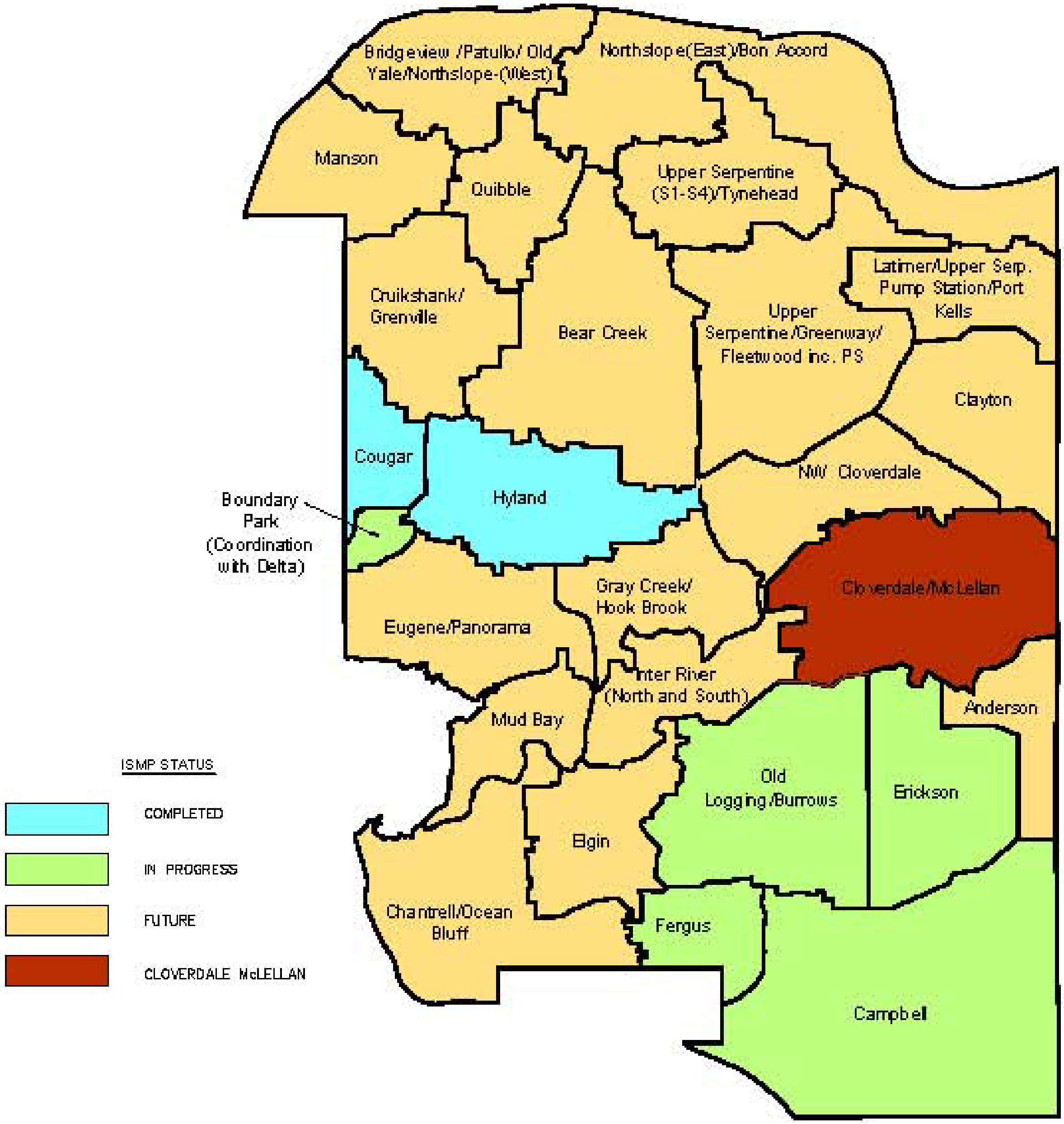

Figure 1.1 Existing and Future ISMP Study Areas

1.1.1. Principles of Integrated Stormwater Management

Stormwater Planning: A Guidebook for British Columbia (May 2002) and the Metro Vancouver *Template for Integrated Stormwater Management Planning* (December 2005) provides a framework for effective stormwater management throughout the province. It established the framework for rainfall capture and a design approach based on performance targets. In 2007 the Inter-Governmental Partnership and the Green Infrastructure Partnership collaborated to produce *Beyond the Guidebook: Context for Rainwater Management and Green*

Infrastructure in British Columbia. Now that practitioners are comfortable with the concepts of 'rainfall capture' and 'source control' in practice, local governments and developers are turning their attention to achievable outcomes and results that have net environmental benefits for the watersheds. Together, these two publications bring some of the key ideas behind rainwater management into the local BC context.

The following four fundamental principles from these publications have guided the analyses, discussion and implementation of the Cloverdale McLellan ISMP:

- Account for the full spectrum of rainfall events;
- Use performance targets;
- Allow for adaptive management as our knowledge and understanding of the watershed increases; and
- Integrate the ISMP with the City's planning documents.

Full Spectrum of Rainfall

The understanding in integrated stormwater planning is that, within the rainfall spectrum, light rainfall events account for the majority of the annual rainfall. **Figure 1.2** shows the breakdown of rainfall events into three categories for the rainfall gauge closest to the study area.

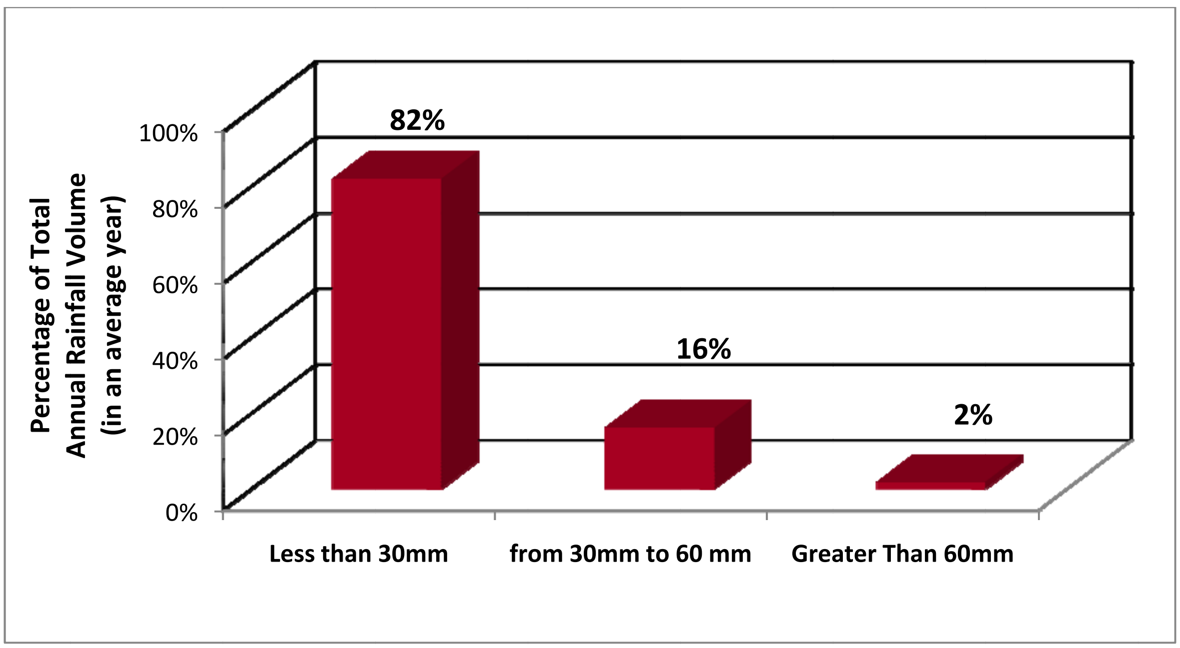

Figure 1.2: Rainfall Distribution for the Surrey Municipal Hall Rainfall Gauge

This understanding of the rainfall spectrum is fundamental in framing discussions about integrated stormwater management solutions. It creates a language of stormwater/rainwater management that is used to deal with each type of event within the spectrum. **Table 1.1** shows the different management objectives for each type of rainfall event.

Table 1.1: Rainfall Management Objectives

Rainfall Type	Range	Design Objective	Description
Light	< 30 mm	Rainfall Capture	Keep rain on site by means of 'rainfall capture' measures such as rain gardens and infiltration features
Heavy	30 – 60 mm	Runoff Control	Delay overflow runoff by means of detention storage ponds which provide 'runoff control'
Extreme	> 60 mm	Flood Mitigation	Reduce flooding by providing sufficient hydraulic capacity to 'contain and convey'

Performance Targets

Performance targets are required to move from integrated stormwater planning to implementation. They provide the necessary direction with the flexibility for designers to adapt solutions in the future. Performance targets can be applied at either the site level or the watershed level and they provide local government staff and developers with practical guidance for development.

For a performance target to be implemented and effective, it must be quantifiable. It must summarize the complexity of the rainfall-runoff requirements into a single number that is simple to understand. Performance targets based on runoff volume fulfill these criteria. For example, a performance target for a residential lot in a new development may be to increase rainfall capture so that a 25 mm rainfall event will result in no site runoff.

Adaptive Management

Adaptive management is an iterative decision making process that is used in uncertain circumstances. In the context of integrated stormwater management, the aim of adaptive management is to reduce uncertainty and risk over time by monitoring the outcomes of decisions and adapting accordingly. Adaptive management acknowledges that we don't have all the answers for every watershed. Instead, we can apply best management practices (BMPs) based on available science and then monitor the impacts. A monitoring plan is developed to track key indicators within the watershed. As we observe the effectiveness of each BMP, the overall approach can be adapted to modify or reject various practices. That is why an ISMP is not a rigid document but rather has flexibility built in and is revisited as our knowledge of the watershed grows.

Integration with Planning Documents

An ISMP is a planning document based on a scientific study of an area consisting of one or more watersheds. In order for the Cloverdale-McLellan ISMP to be linked to other planning documents, the plan should identify inconsistencies with the other planning documents and provide recommendations for changes to those documents. ISMPs are most appropriately linked to a municipality's key planning documents: the Official Community Plan (OCP) and Neighbourhood Concept Plans (NCPs). The OCP describes the fundamental philosophy and principles behind the policies for future growth in the community. The NCPs reflect this philosophy in greater detail for individual neighbourhoods. Correspondingly, the ISMP describes the policies and principles behind the protection of natural creeks, wetlands, and other features dependent on rainfall and the natural hydrologic cycle, as well as aquatic and terrestrial ecosystems of value to the community. This ISMP must also consider flood protection and preservation of agricultural land downstream of the urban area.

The analyses and details presented in the ISMP must be consistent with the objectives outlined in other planning and policy documents. The concept is there are linkages in both directions between engineering and planning documents that highlight the "living" nature of these documents and the ongoing need to update them. Significantly for Cloverdale McLellan, the Sustainability Charter is shown as the overarching document governing all planning in the city and the NCPs already provide some direction for the watershed.

1.2. Project Scope and Process

The Cloverdale McLellan ISMP applies the principles of integrated stormwater management planning discussed above to provide the City with guidance in two areas:

1. **Direct Future Growth**: Provide policy and planning directions for future development and land-use changes to reduce or offset the negative impacts of these changes; and
2. **Solve Existing Problems**: Provide solutions to the current problems in the watershed that have resulted from past development and construction. As well as provide direction to the challenge of managing existing and proposed development within the floodplain.

The study was delivered in four phases with each phase addressing a central question:

- Phase 1 – Existing Conditions: "*What do we have?*"
- Phase 2 – Visioning: "*What do we want?*
- Phase 3 – Implementation: "*How do we put it into action?*"
- Phase 4 – Targets and Monitoring: "*How do we stay on target?*"

This ISMP report is structured to present the results in an easily accessible way for City of Surrey staff, land developers and engineers.

- Section 2 of the report documents the existing conditions of the watershed and outlines the results of the analyses to understand the issues within the watershed. It divides the discussion into three broad categories: planning, engineering and environment.
- Section 3 outlines the watershed vision that was developed with City of Surrey staff. The vision provides a high level direction for the watershed.
- Section 4 provides a discussion of the issues, options and constraints associated with implementing the vision in the watershed.
- Section 5 outlines the implementation plan.

- Section 6 prescribes the measures for monitoring the implementation plan to see if it is being implemented effectively and producing the desired results.

1.3. Study Area

The study area is located in the east of Surrey bordering the City of Langley and the Township of Langley to the east. The study area is approximately 13.1 km^2 and the majority has been developed to urban land use. The area covers some of the upland areas of the Nicomekl River watershed, which has an approximate area of 175 km^2 and discharges into Boundary Bay. **Figure 1.4** shows the study area location within the larger context of the Nicomekl watershed. From this figure we can see that the study area is only a small portion of the total watershed area (7.5%).

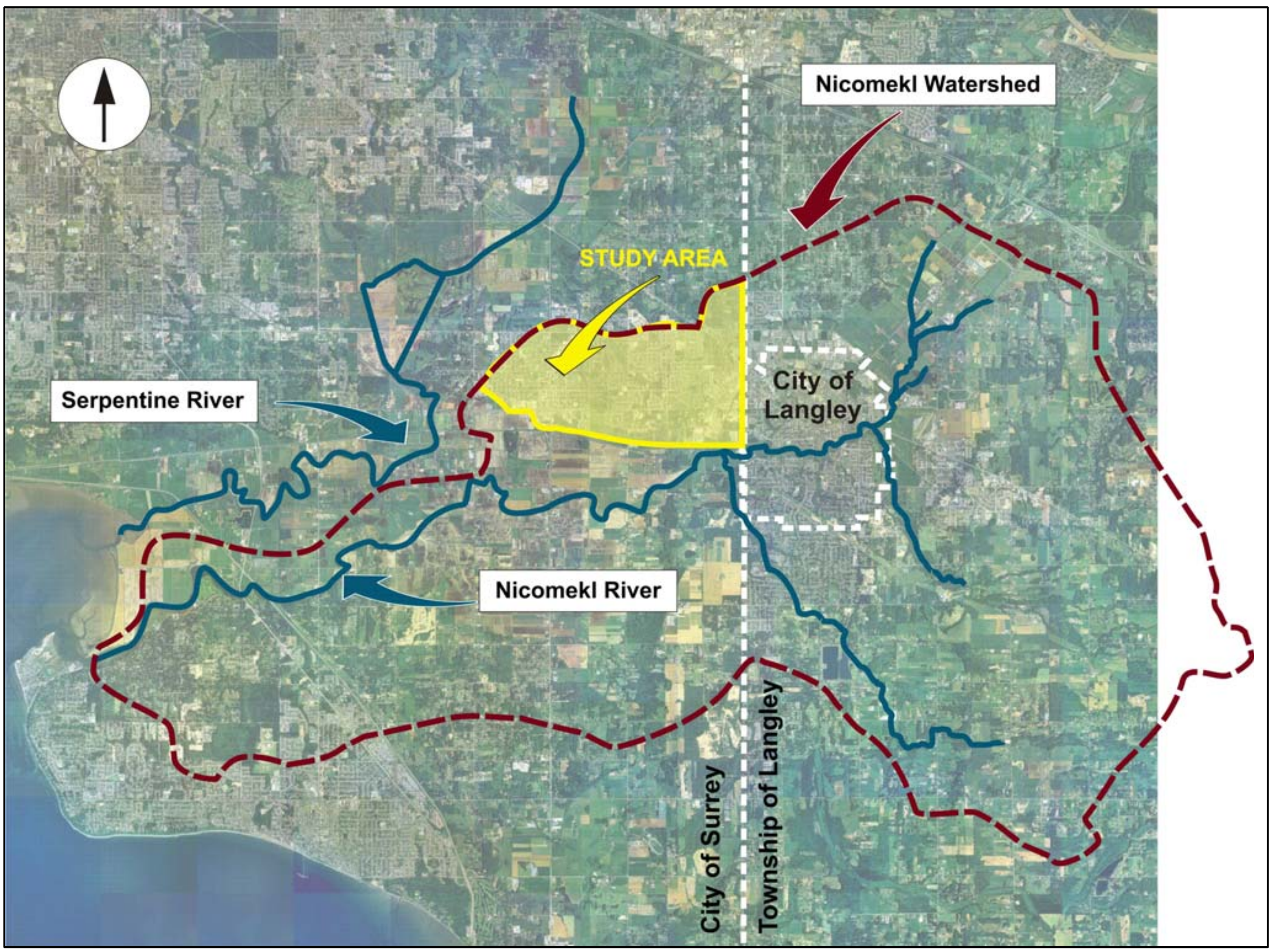

Figure 1.4: Study Area Location

The lowland agricultural area was not included in the study area as it is being studied by others. However there are links to the studies of the higher urban area and the lowland because the management of one area will impact the others. There are several outlets from the upper urban area that drains into the agricultural lowlands. For the purposes of this study, Delcan has divided the area into seven major catchments. **Figure 1.5** shows the upland drainage catchments and major drainage systems. From this figure we can see that the study area consists of an urbanized uplands area effectively draining to the lowland agricultural land in the agricultural land reserve (ALR).

Links to Other Studies

There are a number of past and current studies for the area, which are important to consider. Some of the key aspects related to this ISMP are outlined below.

Associated Engineering. **Cloverdale Canal Hydraulic Analysis**. January 1996.

This report examined the Cloverdale Canal from the intersection of 175th Street and 58th Ave to Highway 10. The purpose of the report, commissioned by the City of Surrey, was to determine the minimum building elevation for new construction in the area of the Canal. Modeling was done for the 10 year and 100 year events for 1 hour and 5 hour storms. The 1 hour storm was found to be the worst case scenario. The study recommended that flood construction levels of 2.64 m and 2.88 m be used for south and north of 57th Avenue respectively. This included 0.3 m of freeboard. Recommendations were made for upgrading the siphon under Highway 10 and channel improvements, which would reduce the flood level to 1.7 m and 2.1 m for the 10 and 100 year events respectively. These siphon upgrades were carried out in 1997 and 1998, and involved the installation of twin 1800 mm diameter steel pipes.

The analyses preformed by Associated Engineering also included a review of the channel downstream of Highway 10 to determine the appropriate starting water elevation for Cloverdale Canal. This concluded that 0.3 m and 1.0 m were appropriate for summer and winter storms respectively.

Associated Engineering. **Southwest Cloverdale Drainage Pump Station and Canal Works**. December 1996.

This report was completed shortly after the Cloverdale Canal Hydraulic Analysis. It reviewed alternative routes for the lower portion of Cloverdale Canal from Highway 10 to the Nicomekl River. It also provided recommendations on pump station upgrades. The final route included channel upgrades along the south of Highway 10 and 168th Street to 50th Avenue. This study provides insight for this ISMP in the form of understanding of the downstream conditions.

KWL. **South Cloverdale Master Drainage Plan/Functional Plan – Draft Report**, May 2002

The MDP covered nearly the same study area as this ISMP but also covered the agricultural lowland up to the Nicomekl River. KWL created an XPSWMM model, which was provided for this study and updated to support the ISMP. The MDP contained a number of recommendations regarding infrastructure

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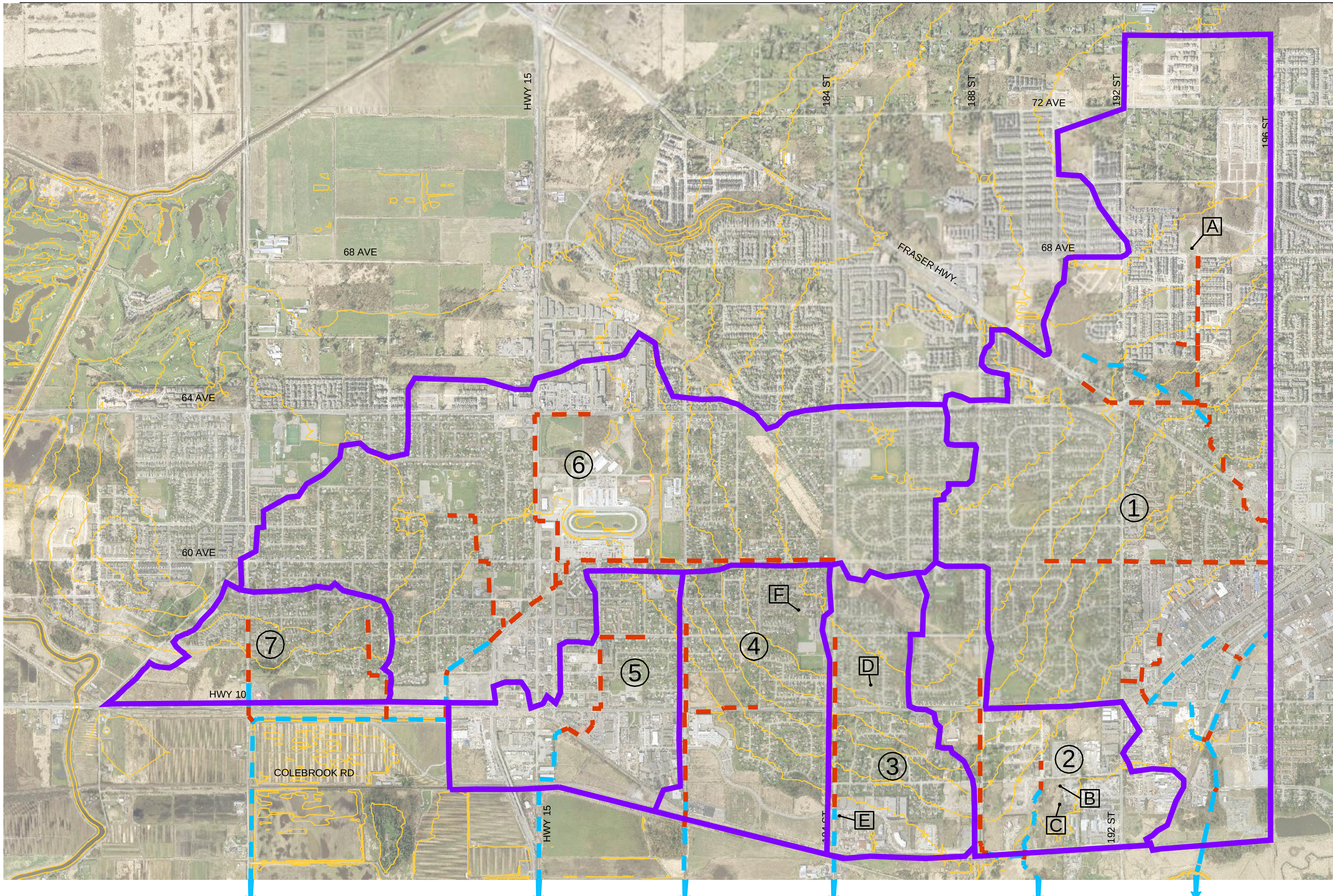
Figure 1.5: Study Area and Major Catchments
Cloverdale McLellan ISMP



N.T.S.

LEGEND

- MAJOR CATCHMENT BOUNDARY
- MAJOR SEWER
- OPEN CHANNEL
- 5m CONTOURS
- ① CATCHMENT ID
- Ⓐ PHOTO ID

CATCHMENT AREAS

1.–McLELLAN CREEK
2.–CUMMINS BROOK
3.–184th STREET
4.–180th STREET
5.–HIGHWAY 15
6.–WEST CLOVERDALE
7.–168th STREET

EB-3712

improvements, stormwater source control, and environmental protection/enhancement. These recommendations have been considered in preparing the ISMP.

Stantec. **Upland Cloverdale Drainage Review**, November 2008

The purpose of this report was to investigate the flooding that occurred during March 2007. The work involved updating an existing PCSWMM model and calibrating it for the March event. The work also included a field inspection of the Highway 10 siphon and found that it had no structural deficiencies and approximately 300 mm of sediment. The calibration undertaken as part of this study allowed the model to be adjusted to be within 10% of the total runoff volume and closely matched with reported flooding during the event. This work is important because it is the most detailed modeling exercise focusing on the Cloverdale Canal to date. The report recommends upgrades along the infrastructure leading to the Cloverdale Canal and the maintenance of the structures within the Canal itself.

KWL. **Lowland Study**, Ongoing

KWL has been retained by the City of Surrey to study the lowland agricultural area. The study has not been complete at this time. However Delcan and KWL have been in contact exchanging technical information from the modeling work. The downstream outputs from Delcan's model are inputs into the lowland model. The preliminary output from the KWL lowland model was provided to Delcan and used as a factor in determining downstream boundary conditions for Delcan's modeling. The final results of this study could determine higher flooding elevations for part of Cloverdale including the existing and potentially proposed development in or near downtown Cloverdale.

2. Existing Conditions

This section of the report documents the existing conditions of the study area including the following:

- Overview of the sub-catchments in the study area;
- Review of the existing planning documents governing development;
- Investigation and modelling of the existing infrastructure; and
- Review of the environmental conditions.

2.1. Sub-Catchment Overview

ISMPs are generally prepared and implemented on a watershed or sub-watershed basis. As shown in **Figure 1.5**, the Cloverdale-McLellan ISMP is actually a collection of seven sub-catchments that makes up a small portion of the Nicomekl watershed. The following is a brief overview of the characteristics of the seven sub-catchments.

2.1.1. McLellan Creek

The most prominent open channel system in the study area is McLellan Creek (see **Figure 1.5**). McLellan Creek has a drainage area of 550 hectares. The lower reaches of McLellan Creek also have a portion of contributing drainage area from the City of Langley, but that portion is outside the study area. There are open channel portions in both the upper and lower reaches that are divided by an 1100 m section of enclosed creek under the commercial/industrial area at 196th Street.

The upper portion of the McLellan Creek watershed is within the East Clayton NCP area, which is a mixed use neighbourhood consisting primarily of single family and multi-unit residential. The area is currently undergoing development. Some of the parcels containing upper McLellan Creek have not yet been developed, so the upper creek is still a natural open channel. Within the upper portion of McLellan Creek there are four major stormwater ponds in the East Clayton NCP, three of which have already been built.

Figure 2.1: Photo A -East Clayton NCP Pond

The largest of the four proposed East Clayton ponds is Pond A located north of 68th Street at the alignment of 194th (see **Figure 2.1** for photo and **Figure 1.5** for location). This pond has a drainage area of 78 hectares and services some of the development that was outlined in the East Clayton NCP Extension North of 72nd Avenue. It has been constructed as a wet pond within a park and is an example of a stormwater pond implemented as a park amenity. The discharge from the pond is carried via storm sewer down 194th Street where it joins the enclosed portion of McLellan Creek south of 64th Avenue.

A stormwater pond designated 'Pond B' in the East Clayton NCP plan, is located at 194th Street and 65th Avenue, which has a drainage area of 52 hectares. This pond has a water quality forebay at the inlet designed to remove sediment. The outlet for the pond discharges into the storm sewer along 194th Street.

Pond C was constructed west of 196th Street and north of 68th Avenue. It was included in the East Clayton NCP and its location was revised slightly in the East Clayton North Extension NCP. It has a drainage area of 39 hectares.

The eastern border of Surrey is 196th Street. Both the Township of Langley and the City of Langley border the McLellan sub-catchment. The Township of Langley is north of Fraser Highway and the City of Langley is south of Fraser Highway. There are some storm connections across the Surrey/Langley border where stormwater flow from Surrey is directed to Langley. There is a letter agreement between the City of Langley and City of Surrey regarding drainage connections across the municipal border. This agreement specifies the maximum peak flow rate to be conveyed from Surrey to the City of Langley at each transfer point.

The lower portion of the McLellan Creek catchment is a mix of commercial and light industrial developments. McLellan Creek runs along the Canadian Pacific Railway (CPR) before entering a small forested area and discharging into the Nicomekl River. Within the lower portion of the catchment, the land use has a high percentage (90% or greater) of impervious area with no municipal stormwater management facilities noted.

2.1.2. Cummins Brook

Cummins Brook is a tributary of the Nicomekl River to the west of McLellan Creek. **Figure 1.5** shows the catchment location. The upstream portion of this watercourse is a narrow channel that outfalls from a storm drain and flows south along a property line to 54th Avenue. The channel is bordered by suburban development to the west and industrial land to the east. The brook takes on a more natural form starting at the storm drain outfall on the south side of 54th Avenue at 189A Street (See **Figures 2.2** and **2.3**), but has been impacted by surrounding residential and industrial development. The brook flows south into industrial zoned land including areas of fill and parking.

Figure 2.2: Photo B-Storm outlet a 54th Ave

Figure 2.3: Photo C -Setback from Cummins Brook

2.1.3. 184th Street

The 184th Street sub-catchment is 90 hectares and drains the area roughly described as east of 184th Street, west of 186th Street, and south of 60th Avenue and is shown on **Figure 1.5**. The upper portion of the catchment is single family residential land use. The middle portion of the catchment is one acre residential. The lower portion of the catchment is light industrial. There is a small dry pond in a park called '78K – Greenbelt' off 184B Street near 56A Street (see **Figure 2.4**). There is also a small stormwater pond that treats runoff from the industrial development just south of 53rd Avenue (see **Figure 2.5**). The majority of the drainage in this catchment is directed to 184th Street where it eventually outlets near the industrial development north of the Canadian Pacific Railway.

Figure 2.4: Photo D - Dry pond in 78K - Greenbelt

Figure 2.5: Photo E - Water quality pond at 53rd Avenue.

2.1.4. 180th Street

The 180th Street sub-catchment is 120 hectares and contains the land south of 60th Avenue, east of 180th Street and west of 184th Street (**Figure 1.5**). The majority of the catchment is single family residential and there is a small portion of light industrial land in the lower part of the catchment. There are a few parcels of undeveloped land both in the residential area and industrial area totaling approximately 30 hectares and representing 25% of the catchment. The majority of the sub-catchment drainage is conveyed to the trunk sewer along 180th Street where it discharges into the open channel/ditch system at the Canadian Pacific Railway.

There is a small dry pond at the end of the cul-de-sac on 58B Avenue (**Figure 2.6**). It was constructed in 1980 and provides 500 m^3 of storage. However, the headwall could not be located as shown in the as-built drawings and the pond may have been altered since construction.

Figure 2.6: Photo F - Dry pond at 58B cul-de-sac

2.1.5. Highway 15

The Highway 15 sub-catchment is 80 hectares and includes the area west of 180th Street, south of 60th Avenue and a portion of the Cloverdale Town Centre (**Figure 1.5**). The land use is a mix of single family residential, multi-unit residential, commercial and light industrial. The primary north-south drainage trunk is along 177B Street through Cloverdale Square Village to the open channel system south of the abandoned rail line (owned by BC Hydro). The outlet for this sub-catchment is a culvert under the rail line just east of the Cloverdale Bypass on the alignment of 176th Street. No stormwater ponds were noted for this catchment.

2.1.6. West Cloverdale

The West Cloverdale sub-catchment is the second largest in the study area at 420 hectares (**Figure 1.5**). The northern and western portions of the development are primarily single family residential land use. There are some commercial properties in the northern part of the sub-catchment and part of the Town Centre is within this sub-catchment. There are a number of green spaces in the form of parks, utility right-of-ways (ROWs) and undeveloped parcels totaling approximately 50 hectares.

A unique feature of this sub-catchment is Fraser Downs Racetrack and Casino. This facility, located to the east of Highway 15 and north of 60th Avenue, has been developed into several commercial buildings, a large parking area, stables and a racetrack. The majority of the site is comprised of impervious area and no major stormwater ponds were noted on site. There are, however, stormwater ponds located north of 62nd Avenue.

The trunk sewer network for this sub-catchment runs west along 60th Avenue to Highway 15, then southwest along the alignment of the Cloverdale Bypass and discharges into an open channel system at 58th Avenue and 175th Street (sometimes referred to as the Cloverdale Canal). This open channel system runs south and through a siphon under Highway 10.

2.1.7. 168th Street

This 70 hectare catchment is primarily single family residential land use (**Figure 1.5**). The lower portion of the catchment is within the Agricultural Land Reserve. The two main discharge points for the storm sewers are into the roadside ditches along 168th Street and 172nd Street. This drainage is conveyed across Highway 10 at 168th Street.

2.2. Planning and Land Use

An important part of the ISMP process is to understand how existing planning documents govern land development, protection of water resources and planned infrastructure upgrades. This ISMP has a two-way link with the City's relevant planning documents, meaning that the existing planning documents provide input into the ISMP and the ISMP provides recommendations for revisions to the existing planning documents and for the preparation of new planning documents. The highlights of those documents are provided below.

2.2.1. Surrey Documents

The City has several documents that guide land development in the area. Following is a summary of the key documents and the content that directed the development of this ISMP.

Sustainability Charter

The City of Surrey has developed a Sustainability Charter, which is an overarching policy document to guide the City's approach to socio-cultural, environmental, and economic sustainability. It is a living document that will establish high-level principles to direct all future initiatives. Future planning and engineering documents will be required to consider the Sustainability Charter, which contains goals regarding transportation, employment, lands, community services, environmental protection and land development. Most relevant to the Cloverdale McLellan ISMP are those goals that could impact creeks and drainage systems. Some of the rainwater/stormwater-specific goals that influence the ISMP are listed below:

- Protect the integrity of the City's ALR and industrial land base for food production, employment and agro-business services that support the local economy. Work with these sectors to find ways to enhance the productivity of ALR lands in Surrey;
- Respect natural areas and minimize the impacts of economic activities on the environment;
- Promote environmentally friendly businesses and "green" building practices;
- Terrestrial Habitat and Life: Create a balance between the needs of Surrey's human population and the protection of terrestrial ecosystems;
- Water Quality/Aquatic Habitat and Life: Protect Surrey's groundwater and aquatic ecosystems for current and future generations; and
- The Built Environment: Establish a built environment that is balanced with the City's role as a good steward of the environment:
    a) Minimize the impacts of development on the natural environment;
    b) Promote the use of native species and reduce the impact of invasive species;
    c) Promote permeable surfaces where possible in new developments;
    d) Incorporate opportunities for natural areas and urban wildlife; and
    e) Protect unique and valuable land forms and habitats.

The Sustainability Charter reinforces some of the principles of integrated stormwater management. This helps add weight to the ISMP's recommendations as City Council has already indicated that sustainable stormwater and riparian management is important.

Official Community Plan (OCP)

The OCP is a statement of objectives and policies to guide City planning decisions. To guide land use and development in Surrey in order to achieve orderly growth for complete sustainable communities with sensitivity to environment. OCP is a statement of objectives and policies to guide city planning decisions and provides guidance for physical structure of city, land use management, industry, commerce and residential growth, transportation systems, community development, provision of city services and amenities, agricultural land use, environmental protection and enhanced social well being. Taking a comprehensive and long-term perspective, the plan provides guidance for the:

- Physical structure of the City of Surrey;
- Land use management;
- Industrial, commercial and residential growth;
- Transportation systems;
- Community development;
- Provision of City services and amenities;
- Agricultural land use;
- Environmental protection; and
- Enhanced social well-being.

The OCP was adopted by City Council under By-Law No. 12900 and is reviewed on an annual basis with major reviews taking place every 10 years. It establishes general land use designations, policies to guide development and a map illustrating land use designations for each parcel of land in the City. For each designation, the plan also documents allowable zoning categories and maximum allowable density to guide the preparation and implementation of secondary plans such as Local Area Plans and NCPs.

The OCP contains several policies that relate to the ISMP. Of particular relevance are those policies that impact stormwater management and riparian protection. These policy statements express the City's desire to manage stormwater and fish habitat in an environmentally sustainable way. The Cloverdale McLellan ISMP incorporates these principles in order to stay aligned with the City's priorities.

Secondary Plans

Some of the most relevant planning documents related to ISMPs are the City's secondary plans because they contain area-specific recommendations for land-use, development, and infrastructure. The OCP sets out the broad objectives and policies to guide growth and development within the City, and the secondary plans reflect these policy directions in more detail for the City's neighbourhoods. These secondary plans are known as

Neighbourhood Concept Plans (NCPs) or Local Area Plans (LAPs). Secondary plans provide more detailed land use and density directions, as well as the requirements for servicing, amenities and financing based on the principle of 'developer pays.' Public involvement plays a varying degree of importance in the preparation of these plans, but is particularly important for NCPs. **Figure 2.7** shows the approved secondary plans in the Cloverdale McLellan area.

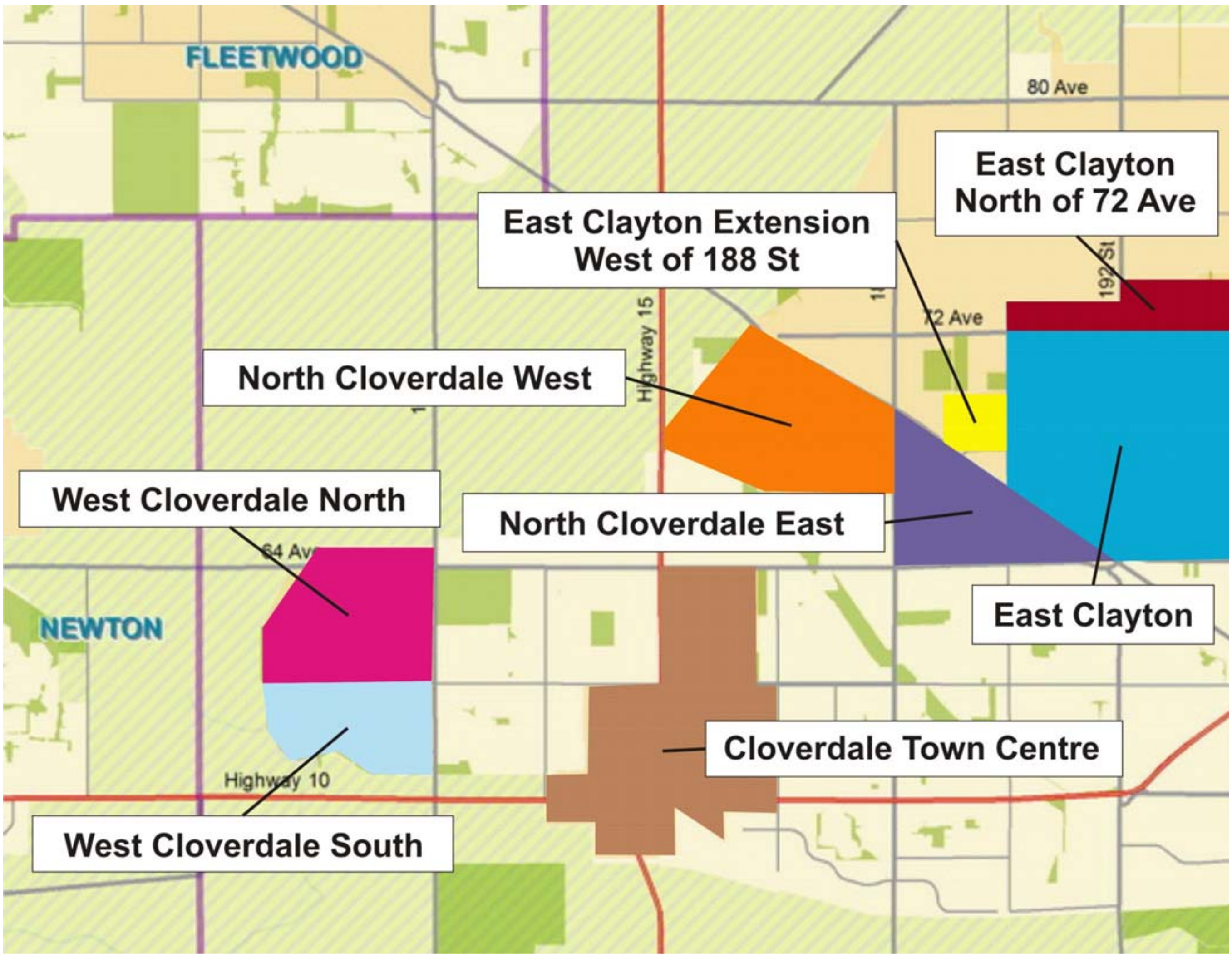


Figure 2.7: Existing Secondary Plans in the Cloverdale McLellan Study area

The development dates for the City of Surrey's existing NCPs range from 1994 to 2005. During that time period, the philosophy of stormwater management in Surrey has evolved further.

There are eight secondary plans have been reviewed as part of this ISMP. The East Clayton NCP is discussed in detail as it is the most recent and contains the largest area of land that is not yet developed.

East Clayton NCP, March 2003

The East Clayton NCP prescribes the form of desired development for the area north of the Fraser Highway and 64th Avenue, east of 188th Street, south of 72nd Avenue, and west of 196th Street. This NCP is partially within the Cloverdale ISMP study area with 190 hectares draining to McLellan Creek and 85 hectares draining to North Cloverdale Creek, a tributary of the Serpentine River. This NCP is highly relevant to the ISMP because it directs development in the largest undeveloped area of the Cloverdale McLellan study area and takes a sustainable approach to stormwater management similar to that of the ISMP.

The East Clayton NCP is regarded as a progressive plan that envisions a compact community with higher than average densities, a mix of housing types, an interconnected street network, and a natural drainage system. The development area includes over 225 hectares of land that will eventually provide homes for over 13,000 people.

There are many sustainability elements included in the East Clayton NCP. One of the principles guiding development in the area is to 'preserve the natural environment and promote natural drainage systems (in which stormwater is held on the surface and permitted to seep naturally into the ground).' To this end, several performance targets are recommended including the use of infiltration BMPs on site and within public road ROWs. Relevant stormwater requirements within the NCP are:

- Stormwater retention ponds for flood control and infiltration;
- Urban forestry requirements for lots;
- Riparian parks; and
- Roadway drainage infiltration systems.

The Cloverdale McLellan ISMP examines these recommendations and evaluates whether changes or revisions are required to bring the East Clayton NCP into line with this ISMP.

Bylaws

There are numerous bylaws that the ISMP project team considered for the implementation of the watershed vision. The most relevant are:

- Zoning Bylaw;
- Subdivision and Development Bylaw;
- Development Cost Charges Bylaw; and
- Surrey Stormwater Drainage Regulation and Charges Bylaw.

These bylaws contain many of the tools and funding mechanisms that will provide the means to implement the recommendations in the ISMP.

Surrey Design Criteria Manual, 2004

The Surrey Design Criteria Manual provides design guidance for private and public developments and infrastructure within the City of Surrey. It contains guidelines for planning and designing stormwater drainage facilities and systems in the City. It can guide the design in hydrology and hydraulics as well as provide design criteria for specific stormwater management features such as wet ponds. The stormwater design criteria provide developers with guidance for dealing with medium and larger storms but do not provide detailed requirements for the small frequent storms that this ISMP covers. Therefore the ISMP recommendations build on the guidance provided in the Surrey Design Criteria Manual to enhance stormwater and drainage designs at the site level for the full spectrum of storms. In the future, the Design Criteria Manual may be updated to make some of the recommendations included in this and other ISMPs universal requirements across the City of Surrey.

2.2.2. External Agency Documents

Other agencies such as the Ministry of Environment (MoE) and Department of Fisheries and Oceans (DFO) have some regulatory power regarding development, stormwater management and environmental protection within the City of Surrey. The most relevant documents from DFO for land development and stream protection that have an impact on the ISMP are the DFO Land Development Guidelines, the MoE Riparian Areas Regulation and the BC Water Act. A few important aspects of some of these documents are discussed below.

Other important external agency documents include the Wildlife Act, the federal Fisheries Act, the provincial Fisheries Protection Act, the Provincial Environmental Management Act, and Species At Risk Act (SARA). There are also a number of guideline documents and resources that could provide some direction to the ISMP including MoE Stormwater Planning: A guidebook for BC, Metro Vancouver’s Liquid Waste Management Plan (LWMP) or more recently the new Integrated Liquid Waste Resource Management Plans.

DFO Land Development Guidelines

The 1992 Land Development Guidelines were created to ensure that the quantity and quality of fish habitat is preserved and maintained at the productive level that existed prior to land development activities.

The Fisheries Act provides the legislative basis for DFO's policy for the management of fish habitat and the principle of no net loss of productive capacity (i.e. the maximum natural capacity). Each land development project is subject to the following guideline objectives:

- Provision and protection of leave strips adjacent to watercourses;
- Control of soil erosion and sediment in runoff water;
- Control of rates of water runoff to minimize impacts on watercourses;
- Control of instream work, construction and diversions on watercourses;
- Maintenance of fish passage in watercourses for all salmonid life stages; and
- Prevention of the discharge of deleterious substances to watercourses.

These guidelines are intended to assist land developers in identifying problems prior to development and present feasible solutions to prevent negative effects on fish and fish habitat. Their use will also avoid potentially costly mitigation, restoration and compensation requirements. An overall awareness of environmental concerns regarding land development, fish and fish habitat is essential in achieving sustainable development. One of the motivators behind ISMP development is to protect and enhance watercourse health by sustainable land development; therefore, this ISMP will make use of many of the same objectives outlined in the DFO Land Development Guidelines.

Riparian Areas Regulation (RAR)

The Riparian Areas Regulation (RAR) requires local governments to protect riparian areas during residential, commercial, and industrial development by ensuring that proposed activities are subject to a science-based assessment. The RAR directs local government to either include riparian area provisions in its zoning bylaws in accordance with the direction in the RAR, or to use the tools available under the Local Government Act that, in the opinion of the local government, provides protection comparable to or exceeding that established by RAR.

RAR uses setback delineations to protect fish habitat; however, these setbacks may not provide adequate protection for other valuable riparian features such as slope stability, erosion, floodplains, drainage maintenance access, park amenities, wildlife and tree protection.

Water Act

Under the Water Act, the province owns, and has the right to use and to receive the flow of, all water flowing in a natural watercourse (ie. rivers, streams, lakes, swamps, etc.) anywhere in the province. The Water Act focuses on allocating water licenses and controlling the use of fresh water. However, the Act has been expanded to include some explicit environmental protection measures for waters flowing in a stream, lake, or other body of surface water. In addition to regulating water use, the Water Act places restrictions on any actions that alter the water body in some significant way, even if the water is not actually used. Examples might include culverts, bridges, shoring up of stream banks, removing vegetation inside the stream or stream channel, etc. Moreover, the Fish Protection Act makes use of the Water Act powers to protect fish.

The Water Act was written to allocate water on a “first-come-first-serve” basis, and not specifically to protect the environment. Until recently, the government did not consider the rights of fish to water, although current government policy is a significant improvement. While the Act can be a useful tool, it still does not provide a comprehensive system of watershed protection or planning. However, it is important to note that any recommendations that cause changes to streams or watercourses will require Water Act notification or approval to be implemented.

2.3. Engineering and Infrastructure

The engineering analysis of the Cloverdale McLellan watershed provides an overview of the physical conditions in the watershed as they relate to drainage and stormwater management. The goal of the exercise was to provide an overview of the existing stormwater infrastructure, drainage issues, and opportunities for improvement in the study area.

The first step was to review the existing information available for the study area. This included background engineering reports, GIS resources and as-built drawings. The team also made use of the existing knowledge of the area by meeting with City of Surrey Operations and Engineering staff to understand the issues existing in the study area. Additionally, an open house was held to allow the public the opportunity to voice their concerns and provide input. Where applicable, the identified problem areas were visited.

The second step was to perform an infrastructure analysis for the catchment. The analysis included the creation of a stormwater event model and continuous stormwater model. The event model was created to examine the identified problem areas and determine if other infrastructure poses potential problems. A continuous model was created to better understand what impacts the changes in land-use might have had on the flow regime within the watercourse.

This section of the report summarizes the findings of the engineering analysis.

2.3.1. Stormwater Issues

Delcan investigated stormwater issues that were identified in previous engineering reports, raised by City of Surrey Operations and Engineering staff or highlighted by Delcan's stormwater model. The issues reported by operations staff have been discussed in more detail in **Appendix A.** In general, the issues identified can be categorized into three categories: capacity issues (C), local drainage issues (L) and water quality issues (Q). **Figure 2.8** shows the location of these identified issues and the issues are summarized in **Table 2.1**. The issues are introduced here but more information can be found in subsequent sections of this report where the causes and, where applicable, solutions are discussed.

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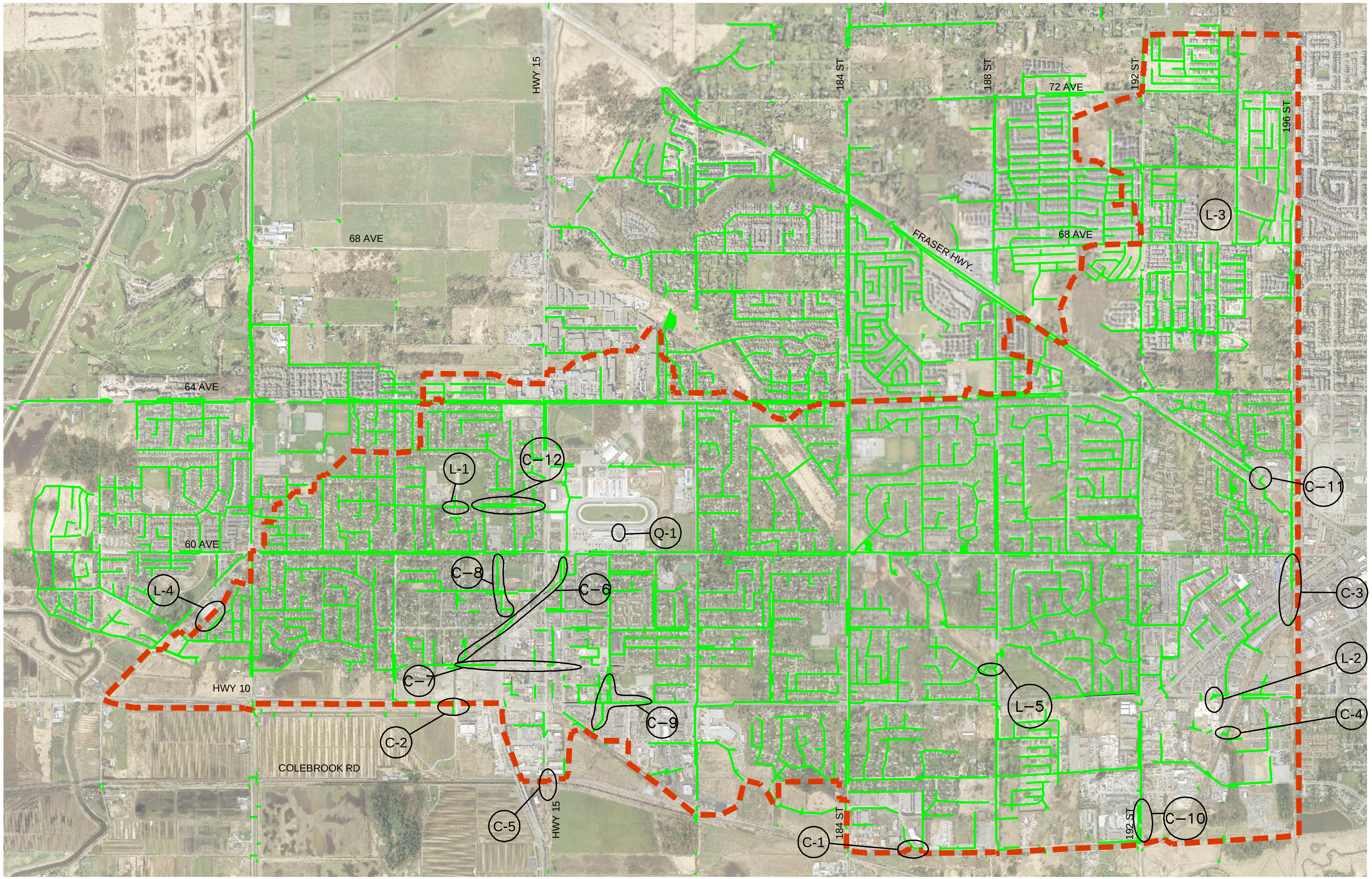
Figure 2.8 - Current Stormwater Issues
Cloverdale McLellan ISMP



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LEGEND

Study Area
Drainage main
C-X Capacity Issues
L-X Local Drainage Issues
Q-X Water Quality Issues

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Table 2.1: Historical Stormwater Issues

Issue	Description
C-1	City of Surrey operations staff have reported sewer surcharging which appears to be caused by poor conveyance capacity of the rail ditch, which is the outlet of this system.
C-2	During the highway 10 widening project, which involved the relocation of a portion of railway, some of the drainage channels south of Highway 10 were collected in a new storm sewer and conveyed to the north side of Highway 10. This redirection of drainage puts additional flows into the drainage system on the north, which must be conveyed south across Highway 10 via a siphon.
C-3	Reported that McLellan Creek channel has capacity issues as it first outlets in the lower portion of the creek.
C-4	Reported flooding and blockage of the fish-friendly box culvert located along McLellan Creek.
C-5	The construction of a new set of rail track just north of the existing set of tracks was completed. These tracks were constructed at a lower elevation. The changes also reduced the number of culverts crossing the tracks. Conveyance capacity across the railway tracks has been reduced and flooding problems have been reported.
C-6	The Cloverdale Canal and Racetrack trunk sewers are a major flow conveyance route for the West Cloverdale sub-catchment, which is 420 hectares in size. This system has been the subject of a number of studies (KWL 2002, Stantec 2008, Associated Engineering 1998). The system is subject to flooding and there are several documented ‘pinch points’ in the conveyance system.
C-7	The 57th Avenue storm sewer provides drainage for some of the Cloverdale Town Centre. This sewer was not in the GIS information provided but was added from as-builts and site visits. A portion of the sewer is 525 mm in diameter and undersized to convey the 5 year event.
C-8	The 175th trunk sewer system from 60th Avenue to 58A Avenue carries flows from a 120 hectare area the north of 58th Avenue and west of 175th Street was constructed in 1980 and ranges in size from 900 to 1050 mm diameter. The system connects downstream to the Cloverdale Bypass trunk main. The XPSWMM model found that this system is under capacity for the 5 year event.
C-9	The infrastructure flowing through Cloverdale Village Square south of Highway 10 at 177b Avenue is not sufficient to convey the design flows. Flooding of the parking area has been reported in the past. The XPSWMM model prepared for this ISMP identified that both infrastructure sizing and backwater conditions caused by downstream conveyance played a role.
C-10	The 192nd Street storm sewer provides drainage for the some residential and industrial areas between 52nd Avenue and 56th Avenue, west of 192nd. There is also some undeveloped land within the service area. A portion of the sewer appears to be undersized to convey the 5 year event because of a constriction at the rail crossing.

Issue	Description
C-11	Storm sewer charging issues were reported but the model did not show any problems at this location. However, the current infrastructure may not be reflected in the model as there was missing information on as-builts, and GIS information that could not be confirmed in the field.
C-12	The 61A Avenue sewer has been highlighted as having capacity issues. The XPSWMM model did not show any capacity issues; however, there might be blockage or backwater causing the problems.
L-1	There have been reports of poor surface drainage at this location and ponding on the park and on the shoulder of the roadway.
L-2	West of the railway, south of 56th Avenue, the private landowner has developed their property and filled in the existing ditch/creek without permission of DFO or the City of Surrey.
L-3	Traffic calming measures have been poorly coordinated with stormwater drainage and local grades and it has resulted in surface ponding and ice problems on the roadway.
L-4	During the open house, one local property owner noted a drainage problem occurring at their lot located behind Surrey Centre Elementary School located on Old McLellan Road.
L-5	The detention pond in the hydro ROW east of 188th Street just north of 56B Avenue needs further study. It was reported by City of Surrey operations staff that they have never known water to be in this pond. Delcan’s event model showed that water was present in the 5 year event but only 0.8 meters in depth, which does not represent a very high utilization.
Q-1	Water quality concerns in the Cloverdale Canal. It is suspected by City staff that this could be related to the runoff generated by the Fraser Downs facility.

Some commonalities between the conveyance issues became apparent when reviewing the above mentioned problems and running the XPSWMM model.

Capacity issues where upland areas drain to lowland: The interface between upland and lowland areas can create capacity problems in various ways. At the transition point between upland and lowland areas, the water flowing off the steeper gradient slows and deposits sediment, causing infrastructure or channels to be filled with sediment. The gradient is usually much flatter downstream causing infrastructure to have much less capacity.

In some locations, multiple catchments drain to the same downstream infrastructure system and must eventually be drained by pump station to the Nicomekl River. The lowland system capacity is dependent on the pump station to lower the water levels during major events. These lowland flooding issues are currently being studied by others but there are links between the lowland and upland.

As well, the lowland of this area is in the floodplain from the Nicomekl River. Development and infrastructure within the floodplain must consider both the drainage issues of the uplands and the potential for a major flood from the Nicomekl River. With potential sea level rise there may also be an increase in the floodplain level for properties in Cloverdale.

Capacity issues caused by pinch points: There are also various locations in which a conveyance system's capacity is limited by one low capacity link or crossing. These pinch points cause backwaters in the system and can lead to surface flooding. Some of these pinch points have been caused by improper sizing of crossing culverts installed under railways or roadway creek crossings.

Local drainage issues caused by insufficient inlet capacity: Although the underground infrastructure often has sufficient capacity to convey design flows, stormwater is not always conveyed efficiently into the infrastructure. This can result in surface flooding. The inefficient conveyance may be due to poor surface grading, insufficient inlets or debris blockages at inlets. Those systems were often not sized for the same standards required today.

These issues are generally linked to past development within the watershed. Infrastructure upgrades can resolve some of these issues in the short term, but over the long term, it is necessary to change the form of development to mitigate and prevent the occurrence of additional issues. In older areas of the city, the properties are sometimes built lower than the city storm systems, especially if storm sewers were installed to replace ditches after the adjacent land was already developed. In some cases, private pumps are required to deal with local drainage issues.

2.3.2. Soil conditions

Examination of surficial soils is critical to understanding the hydrology of an area and can play an important role in determining the applicability of infiltration-based stormwater BMPs. Based on the Surficial Geology Map (Geological Survey of Canada 1976) the soils in this watershed are predominantly:

- Capilano Sediments (approximately 69%);
- Vashon Drift (approximately 19%);
- Vashon Drift and Capilano Sediments (approximately 10%); and
- Salish Sediments (approximately 2%).

The soil conditions for the study area are summarized in **Table 2.2** and **Figure 2.16** shows the soil mapping for the study area.

Table 2.2: Study Area Soil Conditions

Soil	Properties	Permeability
Capilano Sediments	Heterogeneous glacial deposits generally consisting of clay, silt, sand, gravel, stones (ranging from pebbles to boulders), woody debris, peat and seashells. Most common Capilano Sediments in study area are group Cd (marine and glaciomarine stony, including till-like deposits, stoneless silt loam to clay loam with minor sand and silt normally less than 3 m thick but up to 30 m thick, containing marine shells) and Cb (raised beach medium to coarse sand 1 to 5 m thick containing fissile marine shell casts).	Low
Vashon Drift	Till, glaciolacustrine, and ice-contact deposits.	Low
Vashon Drift and Capilano Sediments	Lodgement and minor flow till, lenses and interbeds of sub-stratified glaciofluvial sand to gravel and lenses and interbeds of glaciolacustrine laminated stony silt.	Low
Salish Sediments	Lowland peat up to 14 m thick, which are bog, swamp and shallow lake deposits.	Low – poorly drained

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Figure 2.9 - Soil Mapping
Cloverdale McLellan ISMP

LEGEND

Study Area

Ca-e: Capilano Sediments
Ca, raised marine beach, spit, bar. And lag veneer, poorly sorted sand to gravel (except in bar deposits) normally less than 1 m thick but up to 8m thick, mantling older sediments and containing fossil marine shell casts up to 175 m above sea level;

Cb, raised beach medium to coarse sand 1 to 5m thick containing fissile marine shell casts;

Cc: raised deltaic and channel fill medium sand to cobble gravel up to 15 m thick deposited by proglacial streams and commonly underlain by silty clay loam;

Cd: marine and glaciomarine stony (including till-like deposits) to stoneless silt loam to clay loam with minor sand and silt normally less than 3m thick but to 30 m thick, containing marine shells. These deposits thicken from west to east.

Ce: mainly marine silt loam to clay loam with minor sand, silt, and stony galcio-marine material (see Cd, up to 60+m thick. In many of the upland areas sediments mapped as Cc and Cd are mantled by a thin veneer (less than 1m) of Ca.

VC: Vashon Drift and Capilano Sediments

Glacial drift including: lodgement and minor flow till, lenses and interbeds of sub-stratified glaciofluvial sand to gravel, and lenses and interbeds of glacio-lacustrine laminated stony silt; up to 25 m thick but in most places less than 8 m thick (correlates with Va, b); overlain by glaciomarine and marine deposits similar to Cd normally less than 3 m but in places up to10m thick. Marine derived lag gravel normally less than 1 m thick containing marine shell casts has been found mantling till and glaciomarine deposits up to 175 m above sea level; above 175 m till is mantled by boulder gravel that may be in part ablation till, in part colluviums, and in part marine shore in origin.

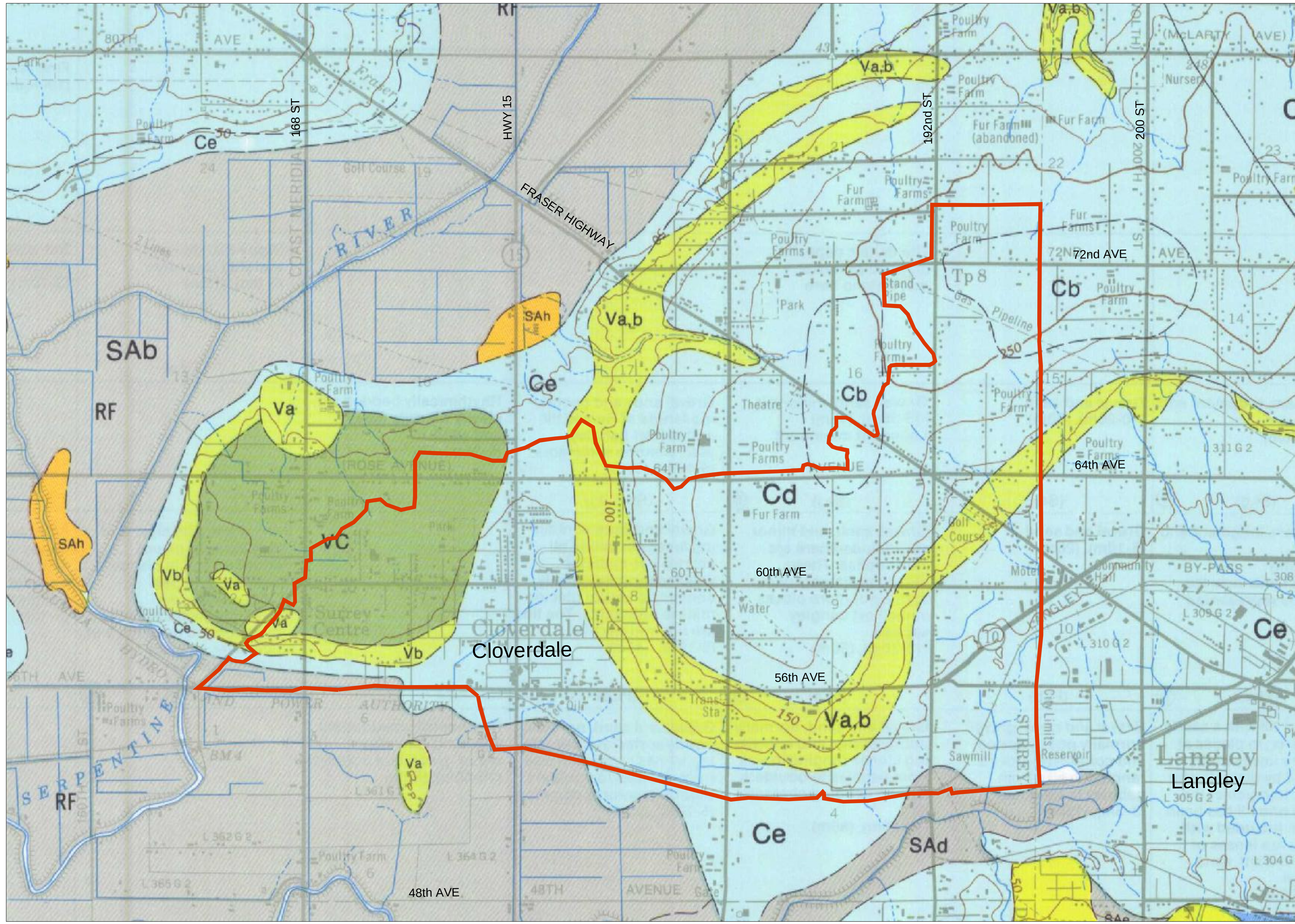
Va,b: Vashon Drift

Till, glaciofluvial, glaciolacustrine, and ice-contact deposits.

Va, lodgement till (with sandy loam matrix) and minor flow till containing lenses and interbeds of glaciolacustrine laminated stony silt;

Vb, glaciofluvial sandy gravel and gravelly sand and ice-contact deposits.

SAb-M: Bog, swamp, and shallow lake deposits.
lowland peat up to 14 m thick, in part overlying Fb,c (Fb – overbank sandy to silt load up to 2 m thick; Fc –overbank silty to silt clay load normally up to 2 m thick);



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Low soil permeability is often cited as a critical factor when implementing stormwater BMPs. However, poorly drained soils do not completely remove the feasibility of source controls. It is still possible to capture rainfall at the source and have a meaningful reduction in runoff. When designing typical BMPs, they generally contain common elements:

- A 'reservoir' in which to capture and detain water (i.e. small surface feature, granular fill trench, topsoil layer);
- Infiltration interface with native soil; and
- An overflow pipe or surface route for larger storms.

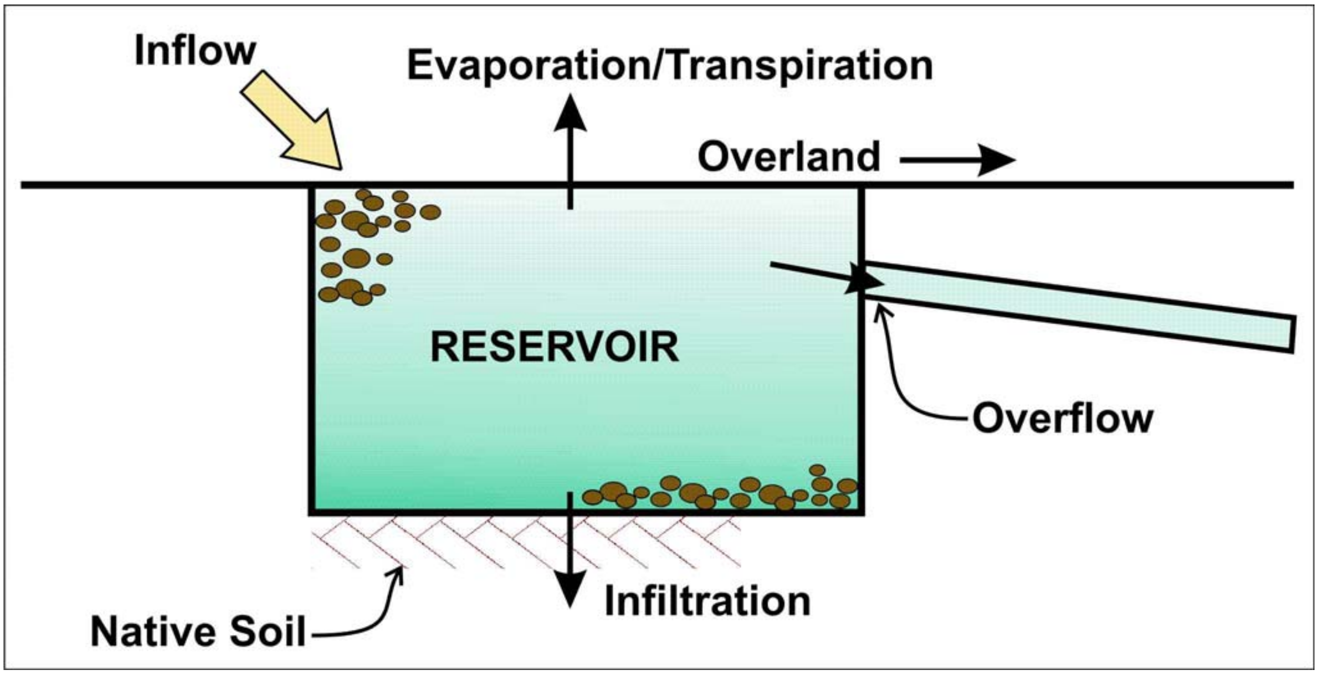

Figure 2.10: typical features of an infiltration BMP

Once the water is captured in the reservoir, it generally has a few routes to leave the system: infiltration, evaporation/transpiration, overflow and overland. The first thing to realize is that infiltration is not the only mechanism by which stormwater BMPs provide benefits. There is also benefit from increased evaporation and transpiration as well as the detention of the water prior to discharge through the overflow.

The second factor to consider is that while the presence of low-permeability soils is a factor in design, it does not eliminate the potential for water to be infiltrated. **Table 2.3** shows the infiltration rate ranges for each classification of soil.

Table 2.3: Typical Infiltration Rates

Hydrologic Soil Group	Hydrologic Soil Group	Infiltration Rate (mm/hr)
A	Sand or sandy loam	>150
B	Silt loam or loam	35 - 150
C	Sandy clay loam	3.5 - 35
D	Clay or silt	<3.5

While the infiltration rate between an A soil group and a D soil group appears dramatic, it is also important to notice that the lower permeability soil groups are not zero. In Cloverdale, the soil types range from B to D with the majority of the area being classified as C. Even if a low average infiltration rate of 5 mm/hr was selected, the soil would still be capable of infiltrating a 25 mm storm in about 5 hours. Lower permeability soils will affect the BMP design by impacting reservoir sizing and overflow design but it is still possible to design effective BMPs.

2.3.3. Event-Based Stormwater Model

Stormwater modeling is an important part of ISMP development. It is a tool used to highlight and confirm problem areas as well as a platform with which to test possible solutions. The level of modeling produced must be appropriate with the goal of screening for potential problems and confirming the issues behind known problem areas. For more detailed description of the modeling methodology and results, see **Appendix B**.

The majority of the drainage servicing for the catchment is handled by a dual drainage system. Underground infrastructure handles the minor storm events, typically less than 5 years, and the major storm events are conveyed overland typically using the road ROWs as conveyance channels. An XPSWMM model was created for the entire study area to model the minor system. This model was designed to include all sewers of sizes 400 mm or larger and screen them for potential capacity problems. This included all trunk sewers (sewers servicing more than 20 hectares) and some additional sewers. **Figure 2.11** shows the storm sewer network for the study area. Overall, there are 136 km of storm sewers in the study area and 59 km were included in the trunk sewer analysis. Modeling the major overland flow routes was not included for the entire study area but rather areas where known flooding issues were examined.

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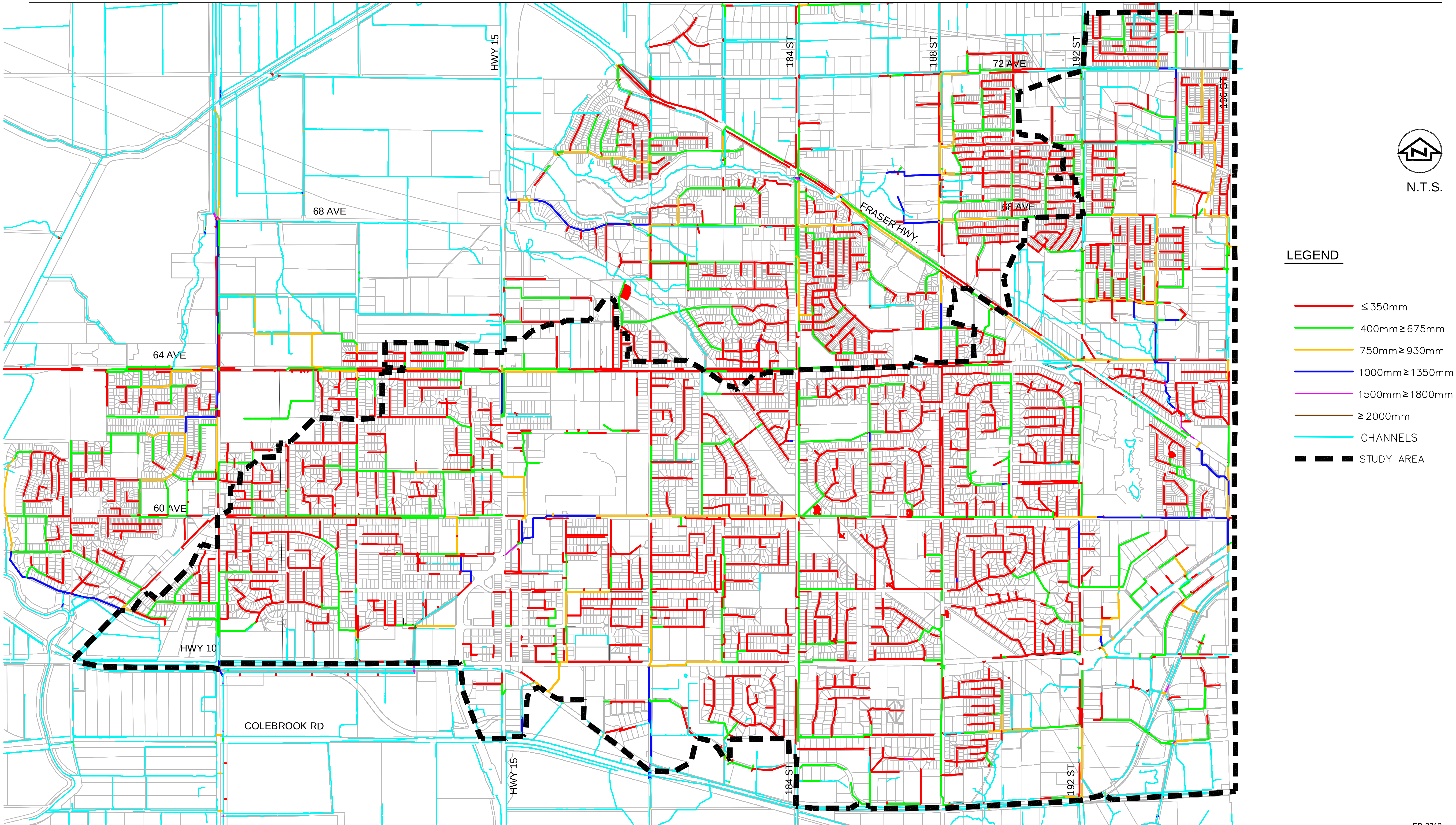
Figure 2.11 - Storm Sewer Network
Cloverdale McLellan ISMP



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XPSWMM Methodology

As discussed previously, the XPSWMM modeling files that were previously created to update the South Cloverdale Master Drainage Plan/Function Plan (KWL, 2002) were provided as a starting point for the event modeling in this study. The model results of the 2008 Stantec Study on the Cloverdale Canal was reviewed in connection with the Cloverdale Canal as they represent the most recent and in-depth work on that specific reach within the study area.

Delcan reviewed and updated all the input parameters provided and additional rainfall scenarios were created. The updates included new infrastructure such as new or upgraded trunk sewers and culverts. The update to the hydrology reflected land use changes as a result of recent development. We reviewed the model for inconsistencies with the GIS data received such as catchment delineation, storm drain connectivity and pipe sizing. Rather than rely on previous catchment data, Delcan determined catchment and sub-catchment boundaries based on contour data and a sewershed review. The sub-catchments are shown in **Figure 2.12**

Once the XPSWMM model was reviewed and updated, different storm events were run in the model. The standard flood scenarios were run, which cover return periods from 5 year to 200 year ranging in duration from 2 hours to 24 hours. The flood level was determined using the XPSWMM model and applied to the contour data. These scenarios were run for the entire model and were used to highlight adequate and inadequate drainage infrastructure.

XPSWMM Results Summary

For a detailed description of the modeling methodology and results see **Appendix B**. As summary of the key results are provided below.

The difference between the existing and future scenarios is primarily in the extent of development. Three scenarios have been modeled in XPSWMM:

- Existing storm network for the current development;
- Existing storm network for the future development; and
- Upgraded storm network for the future development.

The current development is based on existing land use GIS data and the 2009 aerial photo. The future development is based on the future land use also available in GIS data. Moreover, the future development scenario is based on the Surrey OCP and the Clayton NCP. Fourteen storm events were run in the model. The two-hour storms for the 5 and 100 year events have been extracted to GIS to show the results graphically.

The parameter Max d/D (depth/diameter) is an indicator of whether a pipe is under capacity. For the existing and future conditions, this parameter was mapped for the two-hour, 5 and 100 year events. The colour scheme indicates those pipes that are overcapacity or approaching capacity. These figures can be viewed in **Appendix B**. The model verified a number of conveyance problems that had been raised by City of Surrey staff.

Figure 2.12 - Storm Sub-Catchments

Cloverdale McLellan ISMP

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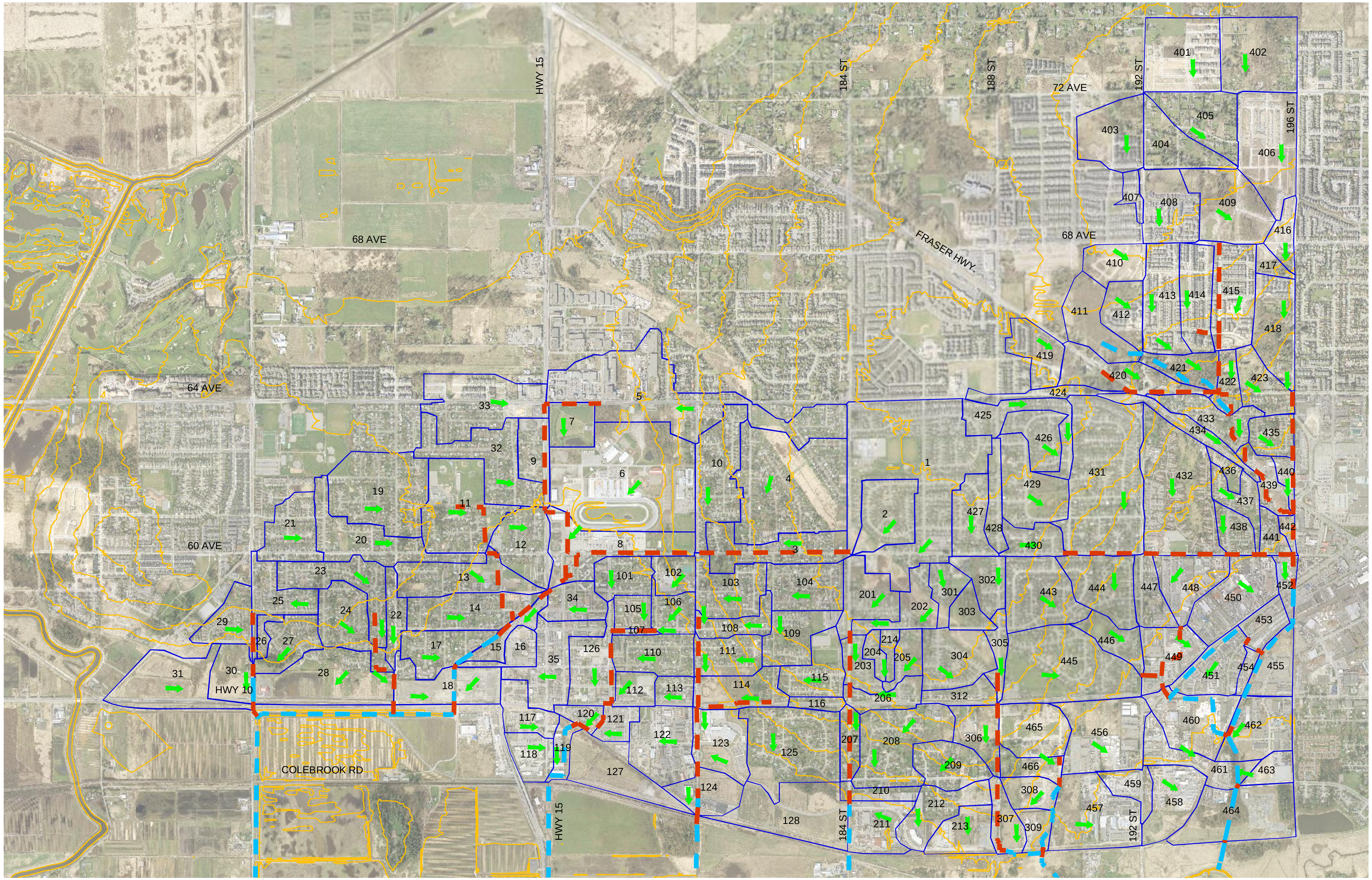

N.T.S.

LEGEND

XPSWWM SUB-CATCHMENTS
TRUNK SEWER
OPEN CHANNEL
5m CONTOURS
GENERAL STORM FLOW DIRECTION
105 CATCHMENT ID

EB-3712

After highlighting all the potential pipes that are under capacity, Delcan took a more detailed look at each of those highlighted pipes to determine the cause. This involved more detailed review of the as-built drawings and in some cases, site visits. In some cases it was determined that the pipes were not under capacity because site conditions such as manhole inverts and pipe connectivity were slightly different then the model. Where possible, these differences were corrected in the model. These specific links and their potential solutions are investigated further in Sections 4 and 5 of this report.

In general, the links showed that most of the storm sewer system was adequately sized for the 5 year storm event. For the 100 year event, even the underground infrastructure would not be enough to convey the flows and the overland flow routes would need to be used. The overland flow routing was not performed with the model but past reports and flooding history has identified some issues in the older areas of Cloverdale near Cloverdale Town Centre.

The majority of the problems identified were in the portion of the study area where the sub-catchments transition from the steeper upland areas to the flatter lowlands. An example of this is the Cloverdale Canal. The results have shown capacity problems was the main trunk line in the west Cloverdale sub-catchment, which outlets into Cloverdale Canal. This system that runs west along 60th Avenue and then southwest to 175th Street / 58th Avenue and is one of the longest trunk sewer systems in the study area. This area has been highlighted in a number of other engineering reports including the Upland Cloverdale Drainage Review (Stantec, 2008), South Cloverdale Master Drainage Plan (KWL, 2002), and Cloverdale Canal Hydraulic Analysis (Associated Engineering, 1996).

Immediately downstream of the trunk sewer system is an open channel system within the lowland area of which Cloverdale Canal is one reach. This system has been highlighted by the model and previous studies as a potential flooding area. This channel receives drainage from over 400 hectares of development. The channel is at a low gradient (modeled at less than 1%) and has a downstream siphon crossing under Highway 10. Some earth berms have been constructed along the edge of the existing townhouse development to protect these areas from flooding.

The modeling also showed that a few of the storm systems that discharge into lower McLellan Creek are under capacity for the 5 year event. Similar to the issues with the Cloverdale Canal, this area has low gradient sewers discharging into a channel that causes a backwater affect. These specific links and their potential solutions are investigated further in Sections 4 and 5 of this report.

2.3.4. Continuous Stormwater Model

Stormwater management systems for new urban development have been traditionally designed and analyzed with the aid of computer models employing design storm events, rather than continuous modeling using long-term historical rainfall data. It has generally been accepted that the latter method provides a more rigorous and realistic understanding of a system on a regular basis instead of just during infrequent events. Through the ISMP process, the creation of a continuous modeling adds value by:

- Increasing the understanding of the overall water balance of the system;
- Quantifying the impact of changes in land use and stormwater practices;
- Providing annual flow exceedance curves to see the direct impact on erosion potential within receiving streams; and
- Demonstrating the benefits of stormwater LIDs that target small, frequent rainfall events.

Continuous modeling differs from event modeling by focusing attention on quantifying more aspects of the hydrologic cycle. **Figure 2.13** shows some of the common processes in hydrological studies. Event based models tend to focus on surface runoff and treat all other processes as losses. By including more detailed modeling of infiltration, interflows, evaporation, evapotranspiration and groundwater, a better understanding of the overall catchment can be obtained.

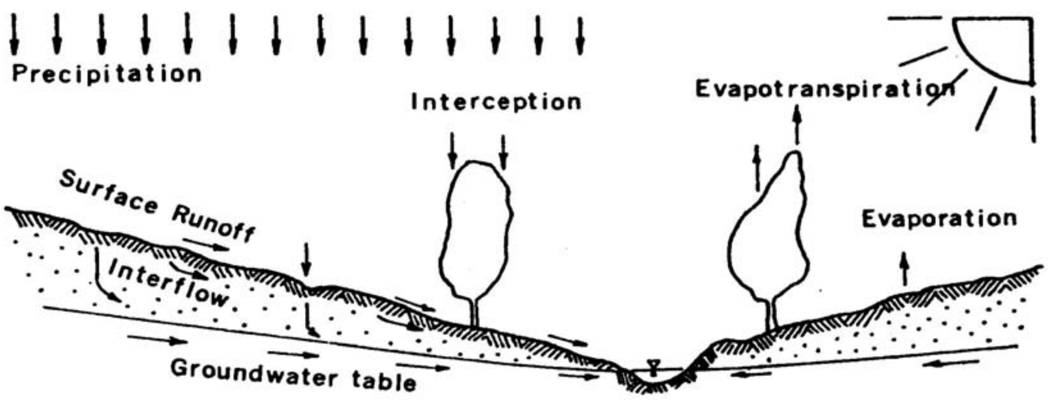

Figure 2.13: Typical hydrologic processes

QUALHYMO accounts for various hydrologic processes that produce runoff from urban areas. These include:

- Time-varying rainfall;
- Evaporation of standing surface water;
- Snow accumulation and melting;
- Rainfall interception from depression storage;
- Infiltration of rainfall into unsaturated soil layers;
- Percolation of infiltrated water into groundwater layers; and
- Interflow between groundwater and the surface water.

A continuous stormwater model was developed for the McLellan Creek Watershed. The methodology and results of the model are presented in full detail in **Appendix C**. The key points are summarized in this section. The McLellan Creek watershed was selected because there still remains a significant portion of open channel within the system.

QUALHYMO Methodology

QUALHYMO model parameters are usually determined through a calibration or verification process. However, since there are no short/long term discharge records for the McLellan Creek, they should be determined based on local experience outside of the specific catchment. McElhanney (2007) performed a study on some stream parameters in Surrey as part of the Fergus Creek ISMP. This study included the Salmon River at 72nd Avenue with a watershed of 49 km^2 and West Creek near Fort Langley with a watershed area of 11.4 km^2.

Continuous modeling with QUALHYMO requires the following recorded data:

- Hourly rainfall-precipitation data;
- Hourly air temperature data;
- Monthly evapotranspiration data; and
- Hourly flow data, if available, which is used for calibration of model parameters.

According to communications with Environment Canada, the climate stations at Surrey Municipal Hall, Surrey Kwantlen Park and other stations within the Surrey municipal area report only daily data. There is no hourly temperature data available for these stations. However, hourly data is available for the following nearby stations:

- Vancouver International Airport;
- Pitt Meadows CS;
- Abbotsford Airport; and
- White Rock CS.

The Pitt Meadows CS, being the closest, has been selected, and the data have been downloaded for year 2000-2009.

There are no climate stations in Surrey or the nearby area that measure monthly evapotranspiration. However, the evapotranspiration data can be calculated using other climate factors such as temperature, wind speed, etc. Agriculture and Agri-food Canada provides the data used in estimates by Penman and Thornthwaite methods for each eco-district.

Three land use scenarios were run:

- Predevelopment – a forested condition with minimal impervious areas;
- Existing conditions – based on air photo and current zoning; and
- Future land use – based on full build out of NCP lands.

The predevelopment scenario was included to provide an indication of what the conditions would have been for McLellan Creek prior to human land use changes. It is important to note the urban development was preceded by agricultural and forestry activities. As well the construction of dikes, drainage and pumping of wetlands and other human activities have had a long history in the area. In short, it is has been many generations since the environment of this area was 'unaltered' However it is still important to understand what that unaltered state might have been.

QUALHYMO Results

The McLellan Creek catchment is currently 63% impervious area. The future development scenario is approximately 66% impervious area. QUALHYMO presents the results of the model in terms of hourly stream flow for the duration of the run time. In this case, the ten years data is summarized into monthly average flow rates which are shown in **Figure 2.14.** The change between existing and future development scenarios is relatively minor because the 3% change in impervious area between these scenarios does not represent a major change in runoff volume.

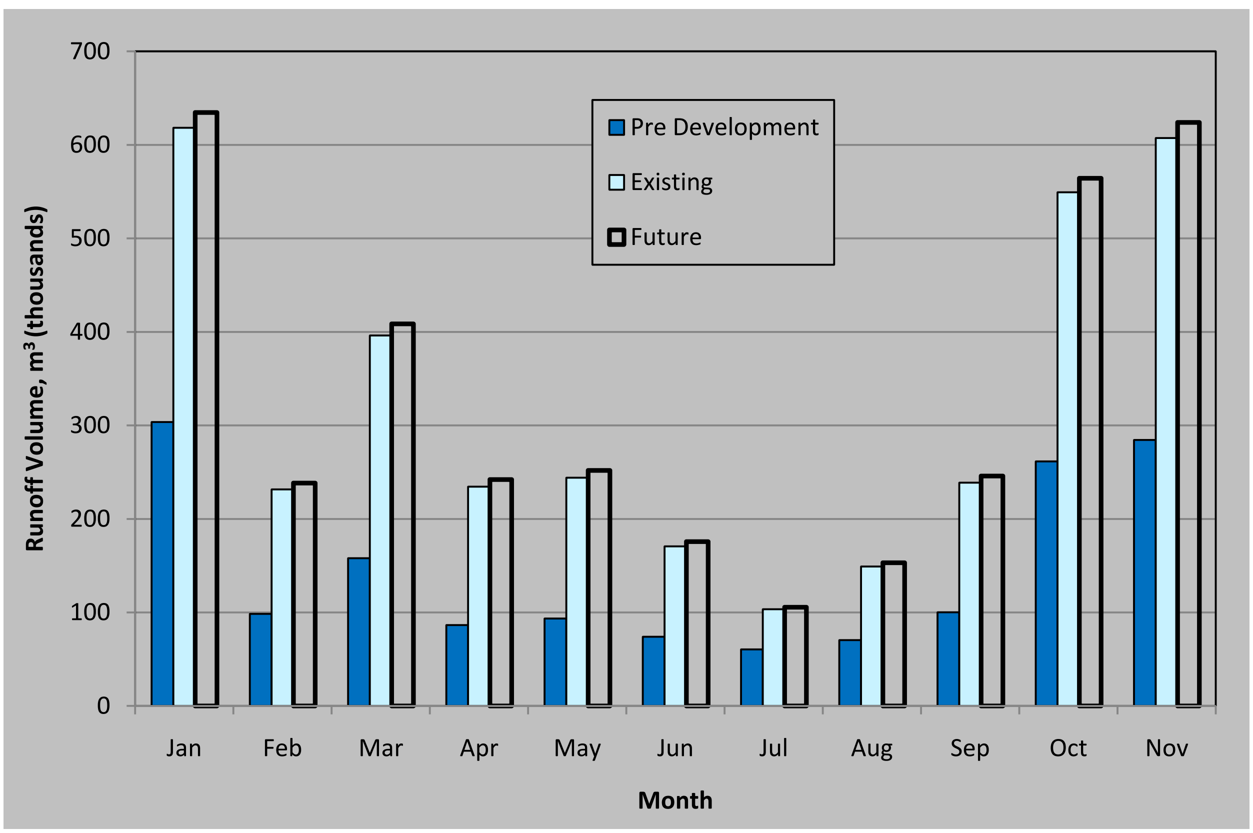

Figure 2.14: Average Monthly Flow in McLellan Creek at the outlet

A flow exceedance a graph represents the percent of time that a specified discharge is equalled or exceeded. It is important in understanding the changes in flow caused by development on an annual basis. The summary of stream flow exceedance for the McLellan sub-watershed is shown in **Figure 2.15.**

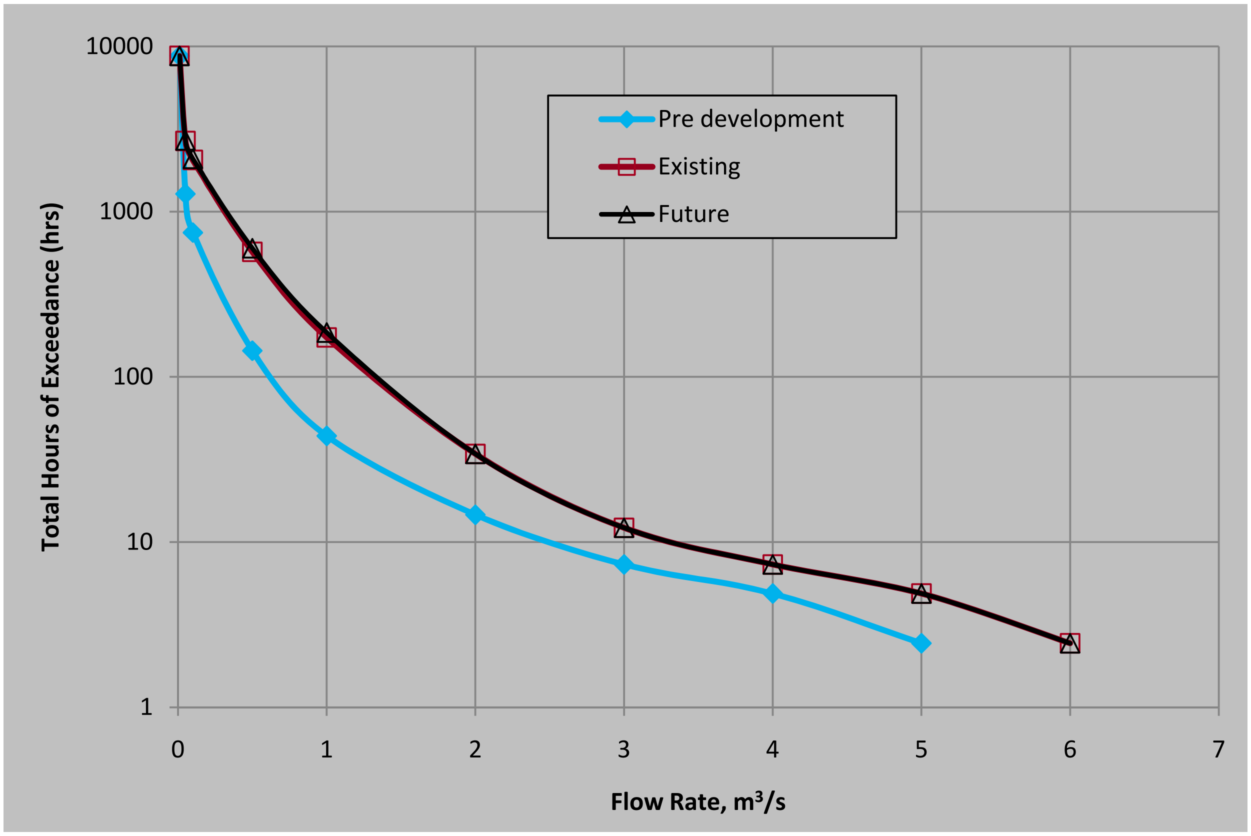

Figure 2.15 – Flow Exceedance Curve for McLellan Creek

The continuous model provides a relative comparison between development scenarios. As can be seen in the results, with the increase in impervious area, the amount of surface runoff is also increased as less water is evaporated or infiltrated.

The number of times that any given peak flow rate is exceeded is higher in the developed scenario for every case except low flows. For example, in the pre-development scenario, 1 m^3/s is exceeded in 44 hours of the year while in the existing scenario that same flow rate is exceeded 173 hours of the year.

This result is significant for the ISMP because it shows that the changes to the flow regime that have already occurred represent a much more significant change than the changes that could occur in the future. This means that the if the vision for the watershed is to improve the aquatic environment to more natural conditions, the plan must include changes that not only maintain, but also make improvements on the existing conditions.

2.3.5. Water Balance Model

The Water Balance Model is a decision support tool developed to help achieve desired urban stream health and environmental protection outcomes. The value of the tool lies in its ability to graph and report the differences between pre-development, post-development and mitigation scenarios for a study area, through running detailed hydrology simulations and comparisons. The simulation is performed with historically accurate climate data that spans a multi-decade period, recorded in hourly time steps.

The Water Balance Model tool is available in the public domain and accessible online (at www.waterbalance.ca). It used a QUALHYMO engine and 10 years of historical data to simulate site or area development. Within the tool is the ability to design site level stormwater BMPs which helps practitioners understand how to implement 'green solutions'.

In this ISMP the water balance model plays an important role in determining the performance criteria for the site level recommendations. Typical sites and developments were assumed and the water balance model was used to design simple, implementable BMPs for that site. As well, by showing scenarios for development with and without BMPs the water balance model can provide an indication of the type of benefit that can be realized which is an important aspect of justifying the requirement of BMPs.

The results of the site level water balance model results are discussed in Section 4 and Appendix C of this report.

2.4. Environment

Phoenix Environmental Services Ltd. (Phoenix) provided the environmental assessment for the Cloverdale McLellan ISMP. The full report from their investigation is available in **Appendix D**. Some of the key points of the existing environmental conditions are summarized below.

2.4.1. Methodology

The environmental objective of Phase 1 is to provide an inventory and assessment of existing aquatic (watercourses, wetlands) and terrestrial habitats (wildlife and corridors) within the study area using available information and limited "ground-truthing" site reconnaissance. The methodology for the Phase 1 environmental assessment entailed the following:

- Classified all watercourses and assessed their current health conditions including associated terrestrial habitats such as ravines, riparian areas, and wetlands;
- Identified significant terrestrial habitats including trees and forests, old fields, and wildlife corridors; and
- Identified sensitive environmental areas and areas of concern such as deteriorated watercourses (e.g. scour and erosion), potential sources of negative impacts to water quality, and degraded wildlife habitats.

The primary aquatic and terrestrial habitats are:

- Upper and Lower McLellan Creek;
- Cummins Brook;
- The riparian forests of both watercourses;
- Remnant forest stands (generally those greater than one hectare);and
- The BC Hydro utility ROW.

2.4.2. Watercourses

McLellan Creek

McLellan Creek is the primary fish habitat within the watershed and still has portions of natural aquatic habitat. Site visits and research on the Fisheries Database and the South Cloverdale Master Drainage Plan Draft Report (May 2002) confirmed that the lower reaches of the creek support juvenile trout and salmon populations year-round. Chum and Coho Salmon were observed in 1995 following restoration work; Chum and Coho Salmon, Cutthroat Trout, Rainbow Trout, and Steelhead were found during sampling in 1997; Coho were observed in 1999); and Coho were observed during the field visit by Phoenix in December 2009.

The headwaters of McLellan Creek are within a forested riparian area. The culverts appear to be appropriately sized and were not perched, as observed during field visits following a winter storm event. The portion of upper McLellan Creek located between 192nd and 194th (north of 64th Avenue) has a forested riparian zone and a well defined channel that does not show significant signs of erosion. The side channels that join the main stem at this location are currently classified as Class B. Very little flow was observed following a winter storm event.

Cummins Brook

Cummins Brook is the only other watercourse in the study area that flows partially within a natural channel (not channelized, ditched, or piped). However, recent modifications to Cummins Brook were observed in January 2010. The channel has been diverted as it passes through the industrial property on 52nd Avenue. It was confirmed with DFO that the relocation of the watercourse was not authorized. The riparian area of Cummins Brook is primarily reed canary grass, with sparse tree cover within the study area. The lower reach beyond the Study Area, south of the CPR tracks, enters a mixed deciduous/coniferous forest. The future development of the land surrounding Cummins Brook will play a large part in determining whether this watercourse continues to provide valuable food and nutrients to downstream fish habitats or degrades as a result of flow changes and water quality impacts from new developments and industrial activities.

Unnamed Nicomekl Tributaries

Farm ditches along the southern boundary (near Highway 10) are primarily classified as either Class A or Class A(O), but are low quality aquatic habitats due to high summer water temperatures and limited habitat diversity. The May 2002 South Cloverdale Master Drainage Plan Draft Report indicated temperatures ranging from 17 to 22 degrees Celsius; high conductivity levels and dissolved solids, dissolved oxygen levels between 3.5 and 8.1 mg/L; and low pH values, indicating high microbial activity. No salmonid species were found during the 2002 fish inventory of the South Cloverdale ditches.

One of the most significant of these watercourses is a Class A segment (indicating possible year-round fish presence) starting from the Cloverdale Bypass at 58th Avenue and flowing southwest to 57th Avenue in an engineered channel (possibly an old farm ditch). This creek is not high quality due to a lack of riparian vegetation (dominated by blackberry thickets), but has high potential for restoration between 56th and 57th Avenues, as it is not currently developed. The water quality is unknown, but may include untreated stormwater from the hectares of upstream development.

Benthic Index of Biotic Integrity (B-IBI)

The Benthic – Index of Biotic Integrity (B-IBI) is a recognized standard method for determining the health of the aquatic ecosystem of a stream using analysis of the benthic macroinvertebrate population composition. Two monitoring stations have been established by the City of Surrey: Station 1 is located in the upper reach of the Creek, north of 64th Avenue between 192nd and 194th Streets, and Station 2 is located in the lower reach, south of the Langley Bypass. Data summaries were provided by the City of Surrey.

Both sampling stations on McLellan Creek received scores indicating poor health (< 14 on a 35 point scale). No samples reached the threshold for "good health" at 21 points. Sampling of the Lower McLellan Creek in 2007 showed a slight improvement in the overall metric scoring (B-IBI), but the average number of individuals in the sample significantly decreased (2001: 502 individuals, 2007: 30 individuals). Biodiversity and total sampling size have generally decreased since sampling began in 2001.

Samples for Upper McLellan Creek generally had greater biodiversity and a higher proportion of pollution-sensitive species, indicating better water quality and aquatic ecosystem health than the downstream segments. This is to be expected, as the upper reaches are primarily downstream of residential areas, while the lower reaches are downstream of heavily urbanized industrial land.

Watercourse Classifications

Part of the upper reach of McLellan Creek is considered Class A (fish bearing) but does not have an adequate watershed to support a resident fish population and is cut off from Lower McLellan Creek by more than a kilometre of storm sewer. The length of culvert enclosures downstream, the associated gradients within long runs of culverts, and velocity barriers during higher runoff events eliminate the potential for restoring fish access into the upper reaches of McLellan Creek without removing culverts (i.e. "day-lighting") on a massive scale. Consequently, the mainstem of the Mclellan Creek headwaters are proposed to be re-classified as Class B (see **Figure 1** in **Appendix E**).

There is a small side ravine to the northeast of mainstem McLellan Creek north of 64th Ave. This watercourse is currently classified as Class B, but is currently exhibiting features of a Class C watercourse. During January 2010, the side ravine was essentially dry with no fluvial process evident in the leaf litter accumulation in the side ravine / tributary channel; even after several weeks of significant rainfall events (i.e. winter conditions). If more baseflows were delivered to this side ravine tributary, then it would have the ecological form and function of a Class B watercourse restored. Therefore, Phoenix recommends retaining the Class B classification for this tributary. As well, DFO has requested restoration works in this area.

Within the study area, the current Class B classification for Cummins Brook is supported by Phoenix, provided the headwaters detention pond is converted and retained as a permanent bio-pond. South of the study area, the current Class A classification of Cummins Brook is also supported by Phoenix's field observations. As no obvious fish migration barrier south of the rail tracks was observed, Phoenix proposes that the Class A classification extend at least as far north as the rail tracks or 52nd Ave. Upstream, lack of flow, depth, poor substrates and lack of bank vegetation along the recently constructed diversion channel cannot support upstream fish migration.

Overall, the primary concerns for the aquatic habitats within the study area are the peak flow volume and velocity, lack of base flow, water quality, and loss of biodiversity. Excessive peak flows threaten to undermine channel restoration activities. At the same time, base flows have been diverted into the storm sewer system, resulting in some remaining watercourses drying out.

2.4.3. Terrestrial Habitats

The majority of the study area is developed and the dominant cover type is impervious surfaces (buildings, sidewalks, parking, and roads). Based on the Ecosystem Management Study underway by HB Lanark, the Cloverdale area (not necessarily equivalent to the boundary for this study area) includes approximately 10% forest, 1.4% interior forest, 1.8% freshwater wetlands, and 8.6% old field habitat. No wetlands or interior forest (>100 m from edge) were identified during orthophoto analysis or field reconnaissance.

Trees and Wooded Areas

Within the study area, there are very few and small stands of deciduous forest remaining on undeveloped lots and along McLelllan Creek. However, a few areas of riparian forest and upland forest remain and those that are one hectare or greater were identified by orthophoto (see **Figure 2** in **Appendix E**). Many of these areas are within City parks or along the residential/agricultural edge. Due to the limited amount of habitat left in the study area, these forest stands are essential for providing refuge for birds and small mammals. Creating connections from these stands to the Nicomekl River or to the BC Hydro ROW would improve movement corridors for wildlife.

The largest forest within the study area is along the headwaters of McLellan Creek. An area of forest is also present along the lower reach of McLellan Creek. Key habitat connections outside the study area are to the diverse and primarily coniferous riparian forest along Cummins Brook south of the CPR tracks outside of the study area and to the deciduous forest at Hi-Knoll Park. The B.C. Hydro ROW also provides a connection across the watershed divide to the north, joining with St. Gelais Brook, a tributary of the Serpentine River.

Wildlife Inventory and Habitat

As a result of the minimal contiguous forested land, there is little significant wildlife habitat within the study area. The remaining forested areas do not contain adequate interior forest habitat to support wildlife other than small mammals and birds. The existing background information indicates that there are no known threatened or endangered species or interior forest habitats within the study area.

Based on previous studies, existing data, and field verification, the key wildlife habitats in the study area include the remaining riparian forest at the headwaters of McLellan Creek, the lower reach of McLellan Creek and the associated riparian area, and the BC Hydro right of way that transects the site from northwest to southeast. The riparian forests south of the study area along Cummins Brook and McLellan Creek are also potentially important to maintain connectivity with the Nicomekl River and its floodplain.

There are many impediments to wildlife movement between the fragmented, relatively small habitat patches within and beyond the study area including roads, fences, buildings, culverts and impervious areas. Although many habitats in the study area are not significant independently, the remaining patches and corridors of habitat (i.e. forests) warrant protection and enhancement for their potential benefit to City- and region-wide biodiversity resilience.

3. Watershed Vision

The vision defines the ISMP's general direction and is intended to reflect the City's long term objectives for the study area. This vision was developed by reviewing the existing conditions in the study area and holding a visioning workshop with City of Surrey staff.

3.1. Visioning Workshop

A visioning workshop was held for the consultant team to receive input from the City of Surrey in documenting the vision. During the workshop, the participants discussed the future direction for drainage and stormwater management in the study area. The workshop was held on April 21, 2010 with the following attendees:

Name	Title	Organization/Department
David Hislop	Uplands Drainage Engineer	City of Surrey/Engineering
Carrie Baron	Drainage & Environment Manager	City of Surrey/Engineering
Ray Kerr	Operations Manager	City of Surrey/Engineering
Mary Beth Rondeau	City Architect	City of Surrey/Planning & Development
Dan Chow	Senior Planner	City of Surrey/Planning & Development
Anna Mathewson	Manager, Sustainability	City of Surrey/Office of the City Manager
Thomas Reeve	Project Manager	Delcan
Adrian Corlett	Division Manager	Delcan
Ken Lambertsen	Principal	Phoenix Environmental

The discussions during the meeting focused on determining a vision that would be consistent with the desired changes in implementing land development. Guiding documents such as the Sustainability Charter have directed staff to implement sustainable practices where possible. Workshop participants expressed a desire to see an ISMP that placed an emphasis on being on the leading edge of sustainability.

3.2. Cloverdale-McLellan ISMP Vision

The visioning workshop determined that the ISMP vision should be to 'go green' with stormwater planning and stormwater infrastructure. To 'go green' means retroactively mitigating the negative impacts of past development in the area. The Cloverdale watershed has been impacted by land use changes that have increased the impervious area in the watershed. This in turn affects the water quality and habitat downstream. **Figure 3.1** illustrates the links between increasing urbanization and water quality and aquatic habitat. The more urbanized an area becomes without implementing stormwater BMPs, the greater the impact on the receiving water. The vision for the watershed is to use the best available practices to capture stormwater at its source and try to move the scale back towards the left. This means stormwater BMPs should be implemented to reduce rainfall runoff, encourage infiltration, and improve the water quality of stormwater runoff.

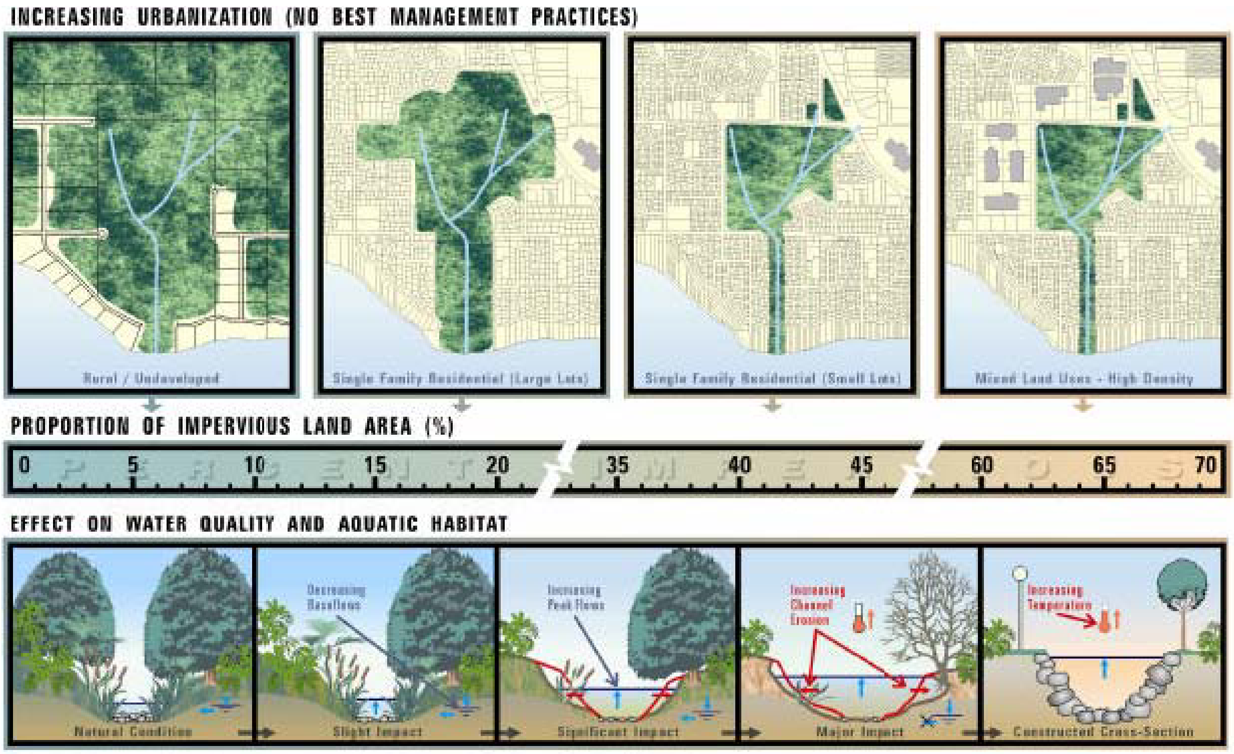

Figure 3.1: Links between Watershed Changes and Stream Health (BC Stormwater Planning Guide)

Vision Statement: Cloverdale McLellan watershed is a mix of urban and natural spaces. The Vision for the watershed is:

- to protect the existing natural resources and ensure no more loss of habitat
- to enhance and improve the water quality discharged to the natural environment
- to increase the riparian area available for the remaining streams
- to encourage low impact development stormwater management for all land use changes.

The categories listed below discuss the strategies coming out of the vision and provide direction for the implementation plan. Achieving the vision was also discussed at the workshop.

3.2.1. Stormwater Management for Land Development

The 1466 hectare watershed contains approximately 300 hectares of land that is undeveloped or low density. Of that undeveloped land, 115 hectares are subject to existing NCPs (primarily East Clayton). The remaining 200 hectares of undeveloped land, which has the potential for redevelopment, is land within the urban area that currently is either underdeveloped or has a one-acre residential designation with lot coverage. As well, it is anticipated that some lots with existing homes will be redeveloped into larger buildings with increased impervious areas.

Strategy for Land Development

- Require enhanced stormwater management source controls for private developments. Specific performance targets for developers and suggested BMPs should be included.

Direction for Implementation Plan:

- For single lot residential developments: recommend BMPs that could be reasonably applied at the lot level. Consider that single lot developments/redevelopments will likely not have a design engineer for stormwater. Include recommendations for an implementation and enforcement method.
- For, commercial, industrial, and institutional developments: recommend performance criteria to provide an enhanced stormwater design. Also provide realistic examples of stormwater BMPs that meet the performance criteria. Include recommendations for an implementation and enforcement method.

3.2.2. Vision for Stormwater Management for Right-of-Ways (ROWs)

Road development and renewal is an ongoing activity within the study area and represents an opportunity to improve stormwater management by implementing greener roadways.

Strategy for ROWs:

- Require that new roadways and roadway renewal projects implement stormwater source control measures to decrease runoff from roadways. This will require the implementation of rain gardens, pervious storm pipes and pervious pavement on all roadways where property, traffic and soil conditions allow.

Direction for Implementation Plan:

- Develop the template for ‘green street’ for each road classification and setting (grade, surrounding land use, etc).

3.2.3. Vision for Stream Corridors

Although development has enclosed many of the natural streams and drainage paths within the study area, some open channel portions still exist.

Strategy for Stream Corridors:

- Preserve all open channels and increase setback requirements to a minimum of 30 meters. Where 30 meters is not achievable, a hierarchy of setback requirements will be applied. Additionally, increase the length of open channel by day-lighting portions of the watercourses that have been enclosed.

Direction for Implementation Plan:

- Implement when feasible – develop a creek-by-creek plan for each watercourse within the study area. This will include a setback hierarchy plan.

3.2.4. Vision for Stormwater Infrastructure

The municipal infrastructure needs to provide adequate drainage and protection from flooding.

Strategy for Stormwater Infrastructure:

- Where deficiencies have been noted, stormwater infrastructure will be upgraded to correct deficiencies and provide an acceptable level of service.

Direction for Implementation Plan:

- Where undersized culverts and storm sewers have been identified, the ISMP identifies the required upgrades.
- Where feasible and impactful, the ISMP proposes high flow diversions to protect creeks from large storm events. Where feasible and impactful, the ISMP also proposes stormwater detention facilities to reduce peak flows downstream.

4. Discussion & Recommendations

The goal of the Cloverdale McLellan ISMP is to apply the principles of integrated stormwater management planning and provide guidance in two areas:

1. **Direct Future Growth**: Provide policy and planning directions for future development and land-use changes to reduce or offset the negative impacts of these changes; and
2. **Solve Existing Problems**: Provide solutions to the current problems in the watershed that have resulted from past development and construction.

With the vision for the future of the study area outlined above we are ready to outline how it can be implemented. A number of areas have been targeted and can be divided into two large categories and a number of sub categories:

- **Policy and programs** that direct how development should occur in the futures
  - **Green Field Development**
  - **Redevelopment**
  - **Watercourse Setbacks**
- **Specific projects** that prescribe physical changes to the watershed such as infrastructure upgrades
  - **Infrastructure Upgrades**
  - **Habitat Restoration**
  - **Demonstration Projects**

In this section of the ISMP the potential implementation items are described and discussed. Where appropriate, the recommendations have been tested using computer modeling to show they are reasonably implementable and effective. Some of the challenges are discussed and potential mechanisms for implementation are outlined.

4.1. Policy and Programs

Although the study area is largely developed, some green spaces, undeveloped land and potential for infill still exist. These lands represent the potential to impact the water balance, either positively or negatively. The vision has prescribed a 'shift' towards a healthier watershed. It is important to understand that wide scale changes are not possible given the current state of development. However, over the long term making small changes as development and redevelopment occurs will have an impact on the overall health of the watershed.

Anyone wanting to develop or change the use of land in Surrey must get approval from the City. Land use policies and development requirements are set out in the Official Community Plan, Neighbourhood Concept Plans, the Zoning By-law and many other City documents. In general a development application will go through the review process that includes

1. Subdivision process;
2. Rezoning process; and
3. Development Permit.

At each stage in the process City of Surrey staff will work with the developers to assure compliance to all the guidance documents and bylaws. In many cases the process also involve staff making a report to council for approval of the development.

Once it is finalized and approved, this ISMP will be added to the list of requirements and serve to guide developers and City staff in the implementation of stormwater management. When new development or redevelopment occurs, it will be important to use integrated stormwater management principles to improve the water balance in an attempt to shift the rainfall-runoff response of the catchment to mimic a more natural condition.

One of the barriers to success that has been identified is the lack of specific direction for developers/City staff. This ISMP therefore specifies, in greater detail, the requirements for stormwater management and, where applicable, the options available. The onus for implementing stormwater management usually falls on the developer with City Staff providing review. The easier to implement and more specific those requirements are, the more efficiently they will function.

4.1.1. Green Field Development

There are still some green field development areas within the study area.

East Clayton NCP Area

The upper portion of the McLellan catchment is currently undergoing development as guided by the East Clayton NCP. This NCP has been developed to include both source controls and end-of-pipe BMPs, and is a high profile example of sustainability within Surrey. One of the seven sustainability principles that guided the planning process was: “Preserve the natural environment and promote natural drainage systems (in which stormwater is held on the surface and permitted to seep naturally into the ground).” (East Clayton NCP, 2003)

The NCP contains a number of performance objectives for following this sustainability principle. For source controls at the lot level and within the road ROW, including:

- A maximum impervious surface area;
- Urban forestry requirements;
- Soil preservation; and
- Infiltration devices including the performance criteria.

Although there have been ongoing challenges with the implementation of BMPs, City staff have indicated that flow monitoring outside the Cloverdale-McLellan study area has shown positive results in the form of increased water quality. Delcan has reviewed the performance criteria contained within the East Clayton NCP and find that they incorporate the best available science and a reasonable approach to land development.

Recommendations:

- That the stormwater criteria outlined in the NCP continue to be enforced and adapted to the East Clayton area.
- That the implementation of the NCP be monitored in accordance with the monitoring plan outlined in this ISMP.

Outside East Clayton NCP Area

Scattered throughout the study area there is some undeveloped land. When developed, current integrated stormwater management policies must be applied to these properties.

Recommendation:

It is recommended that the following performance criteria targets should be met for new developments:

- Runoff control and flood mitigation as outlined in the City of Surrey Design Criteria;
- Only 10% of annual runoff volume will be allowed to flow off-site in the form of runoff; and
- Capture the first 25 mm of rainfall per day.

In some cases, off-site stormwater facilities might already be sized to control runoff. If this is the case, a detailed review of the design and operational effectiveness of those features must be done to confirm that they meet the above criteria.

4.1.2. Single Lot Redevelopment

Within the catchment, parcels of land still remain that may change from rural residential to a more intensive urban land use or the existing residential areas may become denser. Additionally, some commercial and industrial land is expected to be redeveloped in the future. These lands present a challenge and an opportunity for stormwater facilities design. In general, stormwater source control measures must be applied within the lots to be developed.

Commercial or Industrial

When new development or redevelopment occurs, it will be important to use integrated stormwater management principles to improve the water balance in an attempt to shift the rainfall-runoff response of the catchment to mimic a more natural condition. Delcan has developed recommended performance criteria to be applied to all commercial or industrial single lot redevelopment. To demonstrate that these performance criteria are achievable, we have designed some stormwater BMPs for a typical sample lot. **Figure 4.1** shows a typical lot as it is today. **Figure 4.2** shows possible BMPs applied to the site on redevelopment.

Figure 4.1: Existing Lot Conditions

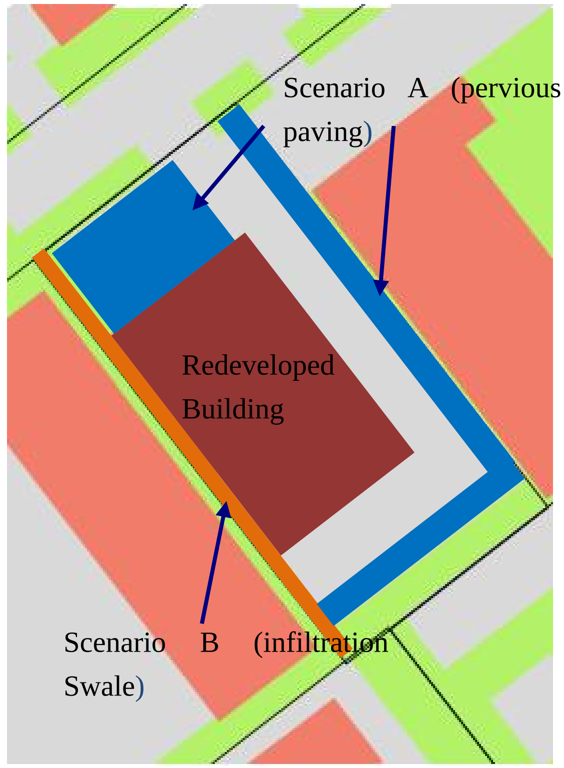

Figure 4.2: Proposed BMP Scenarios

The lot was assumed to be 95% total impervious surfaces (building or paving). Two source control scenarios were run:

1. Scenario A: Pervious Pavement – 35% of the lot was converted to pervious pavement.
2. Scenario B: Infiltration Swale – 5% of the land was used to provide an infiltration swale.

These BMPs were modeled using the Water Balance Model available at www.waterbalance.ca and the results of the annual water balance are shown in **Figure 4.3**. A full printout of the results is available in **Appendix C.** The results show that in Scenario A only 67% of the total rainfall that fell on the site was becomes runoff. This was an improvement in runoff of 12% over the existing condition (79% vs. 67%). For Scenario B the only 37% of the rainfall became surface runoff and the rest was infiltrated on site. This suggests that a target for 30% of the total available water to be infiltrated is achievable.

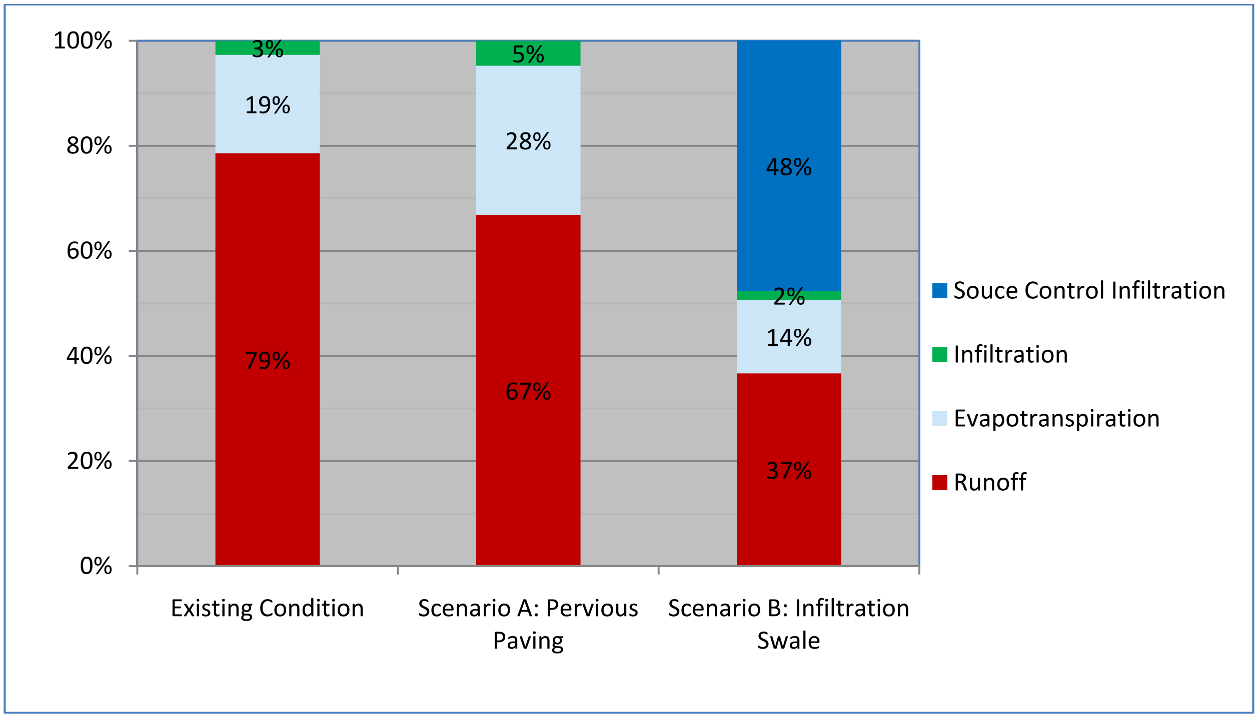

Figure 4.3: Annual site water balance results

Recommendations:

- Meet the servicing objectives outlined in the Surrey Design Criteria, Section 5.2, which deal with peak flow control; and
- Provide on-lot source controls that control runoff to a maximum of 70% of the annual runoff where 30% of the water is infiltrated or evaporated.

Residential – Single-Family Lot Redevelopment

The majority of the single-family residential development area in the catchment was constructed at a time when lower density was the norm. The zoning bylaw now allows construction on single family lots to cover up to 60% of the total lot area. With the trend to redevelop older homes into a larger footprint comes the potential to increase the impervious area of the lot. To illustrate the impact of this increase in impervious area, a typical lot is shown below in **Figure 4.4**. This lot, typical of a 1950s/1960s subdivision, would have an area breakdown as shown in **Table 4.1**.

Figure 4.4: Typical Residential Lot

Table 4.1: Current Lot Area Distribution

Type	Area (m^2)	%
Roof	161	22
Paved	95	13
Lawn	492	65
Total	**748**	**100**

If the lot is developed to its full potential as allowed by zoning and bylaws the lot coverage could look like **Figure 4.5** below. **Table 4.2** shows the assumed lot characteristics for the maximum development scenario.

Figure 4.5: Typical residential lot to maximum development

Table 4.2: Proposed Lot Area Distribution

Type	Area (m^2)	%
Roof	448	60
Paved	150	20
Lawn	150	20
Total	748	100

The lot changes depicted in **Figure 4.5** changes the runoff and impacts the water balance. The lot was modeled using a continuous model using 10 years of historical rainfall data. The results are illustrated in **Figure 4.6**. The figure shows how rainwater leaves the site. There are generally three available routes: losses (evaporation, transpiration), infiltration, and runoff. In general, the more rainwater that is turned into losses / infiltration, the closer the site mimics natural conditions.

The total runoff is more than doubled as a result of the lot redevelopment if no stormwater measures are implemented. If the redevelopment of existing residential lots becomes widespread in the coming years, it will impact the stormwater conveyance infrastructure and downstream receiving waters. To counter the negative impacts on the water balance, we recommend that source control measures be implemented at the lot level at the time of re-development.

To illustrate the potential source control options available, the water balance model was used to simulate the potential source control options. The redevelopment scenario shown in **Figure 4.6** was used as basis to test the performance of some source control BMPs. The roof water runoff was directed to an infiltration swale, the paved area was converted to pervious paving and the lawn was converted to 300 mm of absorbent topsoil (including the area of the infiltration swale). The results of the changes are shown in the **Figure 4.6**.

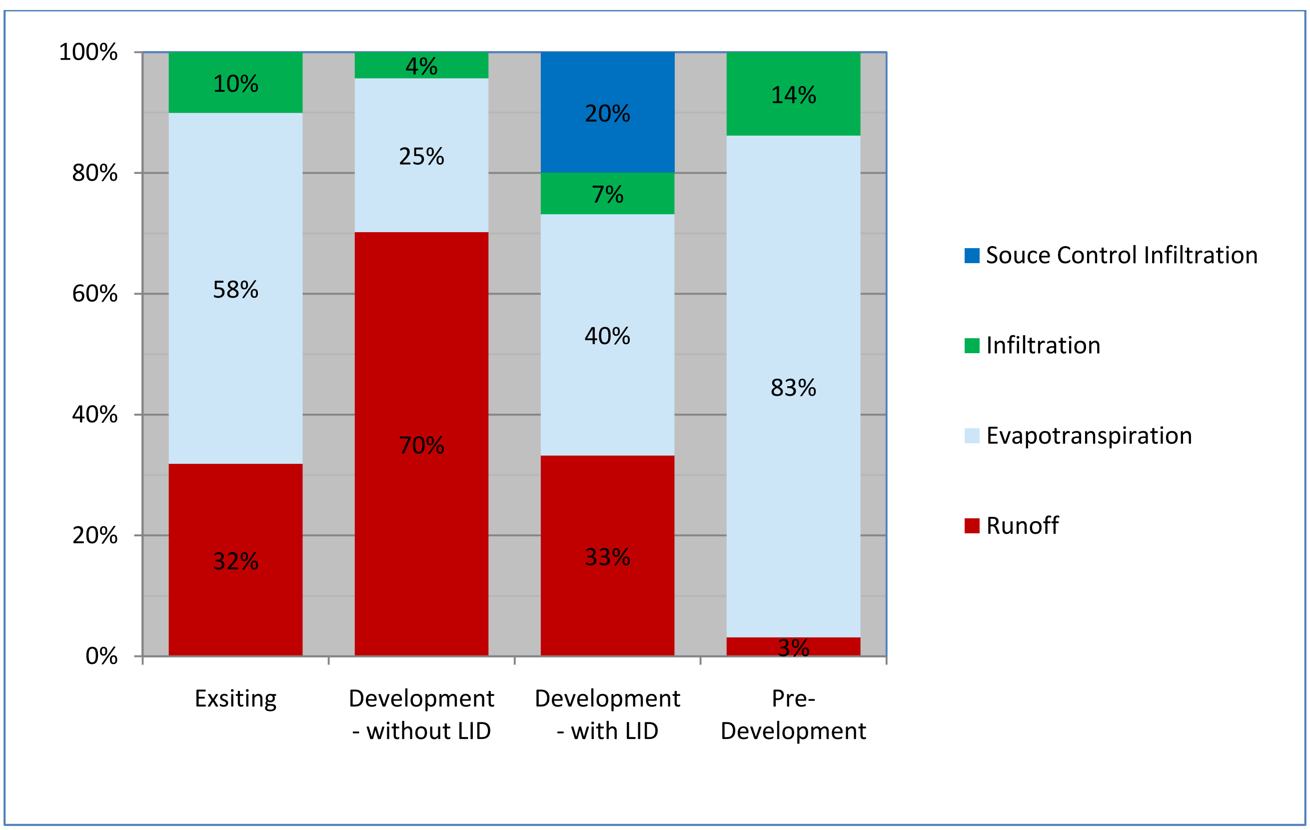

Figure 4.6: Water balance of residential lot

Figure 4.6 shows that development without low impact development BMPs will increase runoff from 32% to 70%; a 38% increase, and 6% loss of infiltration. By comparison, implementing source controls on the site can control runoff from the new development and limits runoff to virtually the same level as existing while improving infiltration by 17% (10% existing compared to 27% in LID/BMP scenario). Infiltration can benefit the health of watercourses by increasing baseflows which are important to maintaining good habitat in the dry summer months. The source control BMPs do not go as far as restoring the waterbalance to a pre-development/green field scenario but they do prevent further degradation from occurring.

If the above source controls are applied to all redeveloped lots, it can mitigate the effects of the increased impervious area. Without the implementation of source controls, there will be an increase in the severity and frequency of downstream flooding, increased pressure on infrastructure and increased environmental damage in the receiving watercourses.

Recommendations

We recommend adopting the following on-lot mitigation measures:

- Require the placement of 300 mm of absorbent topsoil with all new redevelopments;
- Require that new paved areas be pervious or be directed to infiltration feature such as infiltration trench or soak-away pit;
- Require roof runoff to be directed to an infiltration swale, infiltration trench or soak-away pit.

In order to implement the recommended measures, developers, builders and home owners must be informed of the requirements.

4.1.3. Watercourse Setbacks

Riparian areas are the borders to streams, creeks, and wetlands that link water and land. The blend of streambed, water, trees, shrubs and grasses directly influences and provides fish habitat. The purpose of implementing watercourse setbacks is to protect the features, functions and conditions that are vital in the natural maintenance of stream health and productivity. These vital features, functions and conditions are numerous and varied and include items as:

- Sources of large organic debris, such as fallen trees and tree roots;
- Areas for stream channel migration;
- Vegetative cover to help moderate water temperature;
- Provision of food, nutrients and organic matter to the stream;
- Natural areas, in which infiltration can occur, which support stream base flows;
- Stream bank stabilization; and,
- Buffers for streams to prevent silt and surface runoff pollution.

Riparian setbacks also provide benefits to community by reducing the risk of flooding and erosion and providing increased open space potentially available for recreation. Determining the specific 'requirements' for a watercourse setback can be challenging because the benefits it provides can be difficult to measure and quantify. Using Qualified Environmental Professionals to assess riparian setbacks using RAR on a site by site basis can provide further refinement. However, it can be costly to the land owner with no guarantee of a favourable result. The focus of RAR assessment is on the role of the riparian area in:

- Providing wood for instream channel habitat;
- Providing roots for bank stabilization; and
- Providing shade and maintaining temperatures.

The assessment does not focus on other needs of the riparian area such as a water recharge area or use for wildlife corridors or recreation needs. Therefore, this ISMP also provides direction to the City and developers in how riparian setbacks should be approached.

The watercourses within the study area can generally be classified into three categories:

- **Enclosed**: Much of what used to be natural watercourse or water bodies within the study area has been enclosed as part of past urban development.
- **Encroached**: Some remaining open channels have been left in place but development encroaches very close to the edge of the watercourse.
- **Natural**: There are still some sections of watercourses within the study area that have large riparian areas.

The purpose of this section of the ISMP is to outline how development and redevelopment should proceed with all three examples for the identified channels within the watershed.

Guiding Principles

This ISMP recommends the following guiding principles for watercourse setbacks:

- Although many watercourses have been altered, the ISMP's vision states that, at minimum, no additional destruction or encroachment should take place.
- The long term goal should be, to take advantage of redevelopment opportunities to reclaim watercourses and their riparian areas.
- The City of Surrey continues to employ a practice in which a minimum setback of 30 meters must be implemented or the developer can undertake a site-specific study to justify a reduced setback based on local conditions.

Watercourse Specific Recommendations

Upper McLellan Creek

A portion of the riparian area of upper McLellan Creek remains undeveloped. Although the fish habitat has been impacted by downstream works that restrict access for fish, the riparian area is still in good condition.

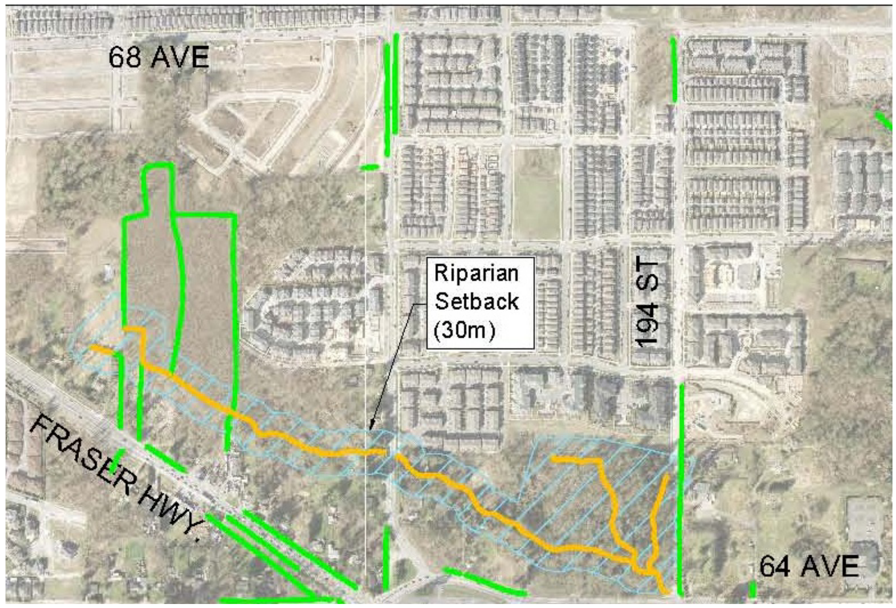

Figure 4.7: Upper McLellan Creek

Recommendations:

Setback recommendations are as follows:

- For all undeveloped portions of the watercourse, 30 meters from the top of the bank on both sides of the creek.
- This 30 meter setback should be publically owned and, where possible, fences should be used to control encroachment.
- An additional setback easement of six meters from the publically owned land to allow for City maintenance access and minimize the potential for tree hazards to damage private property. **Figure 4.7** shows the upper McLellan Creek reaches and their setback.

As a secondary recommendation of this ISMP, we recommend that where developments arise, any site-specific study undertaken to reduce this setback should take into account that upper McLellan Creek could be reconnected to lower McLellan Creek through eventual day-lighting of the enclosed portion of the channel.

Middle McLellan Creek

Middle McLellan is the area between 64th and the Langley Bypass and is shown below in **Figure 4.8**.

This section of the creek is over 1100 meters and has been enclosed. This has caused a loss of habitat in the enclosed portion as well as the loss of connectivity to the upstream portion of the creek. Day-lighting this creek would provide a large habitat benefit to the McLellan Creek system. **Figure 4.8**, shows the possible creek alignment. However, given the current status of the intensive development in the potential alignment of the creek and the cost associated with day-lighting, day-lighting is not recommended without first achieving political and community support. As the City of Surrey moves further towards policies that prioritize the restoration of watercourse health, it is possible that creek day-lighting will become a more realistic option in the future.

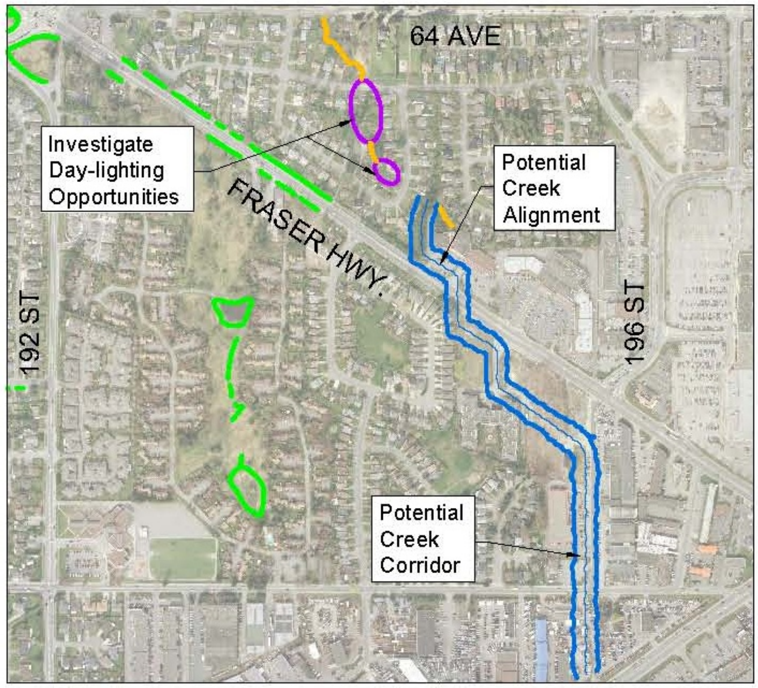

Figure 4.8: **Middle McLellan Creek (enclosed portion)**

Recommendations:

The City should, where applicable, make planning and development decisions that will facilitate future day-lighting. These steps would include:

- Prohibiting the construction of new buildings on or within 15 meters of the potential creek centerline;
- Acquiring property or easements along the corridor when the opportunity arises. This would be larger than the property/easement required for the maintenance of the storm drain; and
- Include day-lighting of McLellan Creek in discussions when preparing future planning documents.
- No further enclosures of the watercourse should take place.

Lower McLellan Creek

The lower McLellan Creek, shown in **Figure 4.9,** is a red coded fish habitat and despite some alterations and encroachment, possesses good habitat value. The portion of the watercourse north of alignment of 55A Avenue runs parallel to the railway. Various setbacks have been applied to this section of the creek in the past. The goal should be to increase the setback to 30 meters either side of the creek for a 60 meter corridor. However, in many sections, the total riparian corridor is only 15 meters so a dramatic change to 60 meters is not feasible without major land acquisition. As result a staged approach should be implemented to adjust to the conditions of site individual sight.

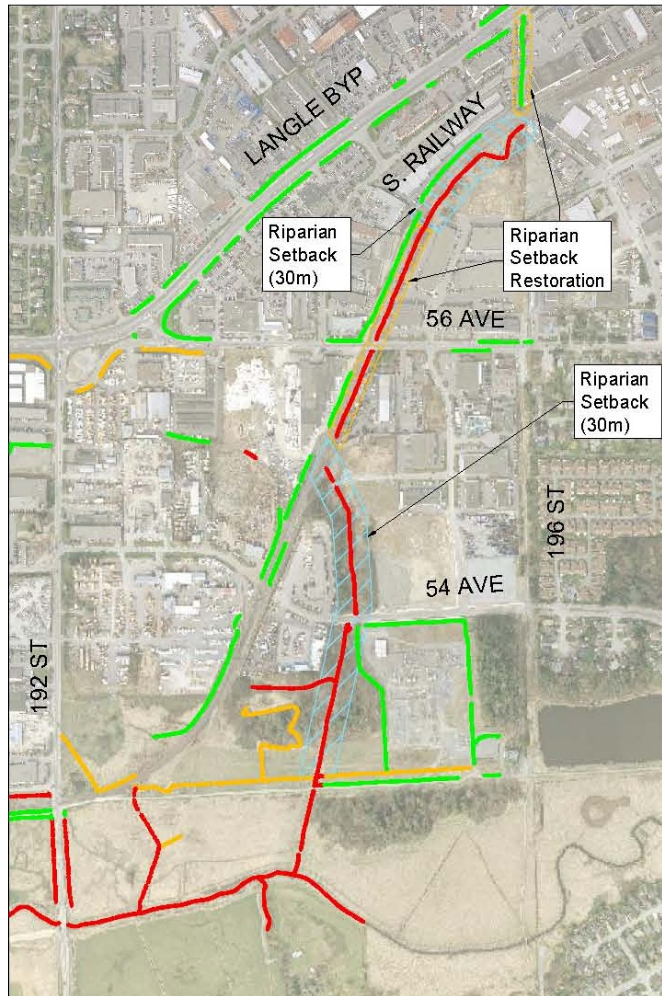

Figure 4.9: Lower McLellan Creek

Recommendations:

- No encroachments on existing setbacks within 30 meters of the creek.
- Implement the following improvements:
  - o Implement a policy of setback restoration by targeting an additional five meters off existing setbacks at the time of redevelopment to a desired 30 meters; and
  - o Existing and additional riparian setbacks should be publically owned. Efforts should be made to have the land dedicated at the time of development or redevelopment.

For the portion of McLellan Creek south of 55A Avenue, there is a sufficient setback from the existing developments. This high value habitat should continue to be protected by implementing a 30 meter setback from the top of the bank on both sides of the creek. This setback should be publically owned and, where possible, fences should be used to control encroachment. An additional setback easement of six meters from the publically owned land should be required to allow for City maintenance access and limit the potential for tree hazards to damage private property.

Cummins Brook

Cummins Brook, a tributary of the Nicomekl River to the west of McLellan Creek, is the only other watercourse in the study area that flows partially within a natural channel. There have been alterations and encroachments on some reaches of the watercourse. However, Cummins Brook has the potential to provide fish habitat if restorations take place (discussed in a later section of this report).

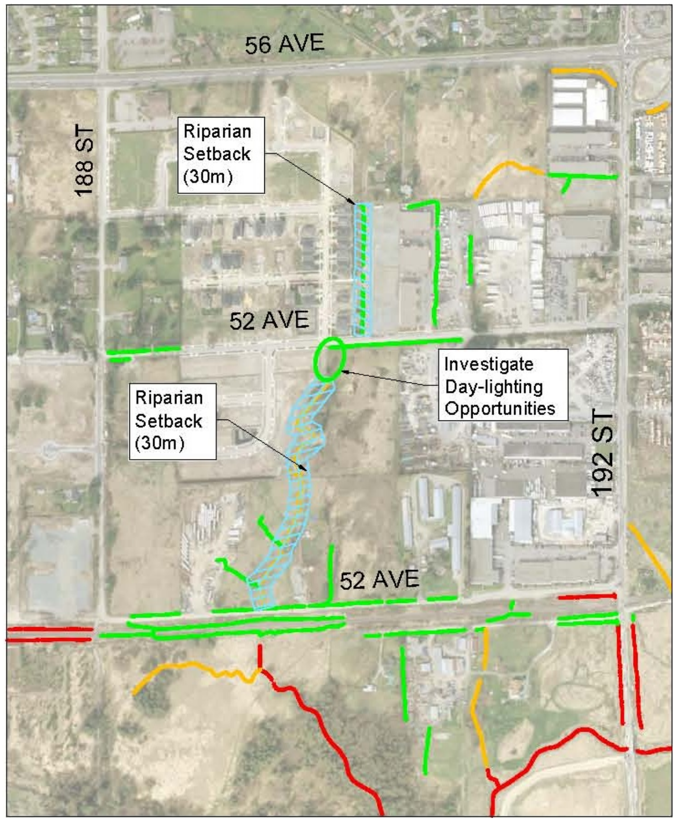

Figure 4.10: Cummins Brook

Recommendations:

- Do not allow encroachments on existing setback;
- Make the following improvements if feasible:
    - Require a 30 meter setback for new development with an additional six meter easement to allow for City maintenance access and limit the potential for tree hazards to damage private property;
    - Target an additional five meters above existing setbacks at the time of redevelopment to a desired target of 30 meters; and
    - Existing and additional riparian setbacks should be publically owned. Efforts should be made to have the land dedicated at the time of development or redevelopment.

Cloverdale Canal

Cloverdale Canal is the outlet and conveyance channel for a 420 hectare sub-catchment. Prior to development, this would have been the lowland portion of a creek system that would have extended through the location of the existing commercial and residential development. The portion south west of 58th and the Cloverdale Bypass is the last remaining open channel in the system and has been altered and channelized. The section from 58th Avenue to 57th Avenue is channelized between two multi-unit residential developments constructed within the last 20 years. The space allowed for the channel is approximately 13 meters. However there are still stretches of single family homes that could potentially be redeveloped in the future. At that time a 30 meter setback should be targeted with a six meter easement. Given the current site conditions this may not be possible at every property.

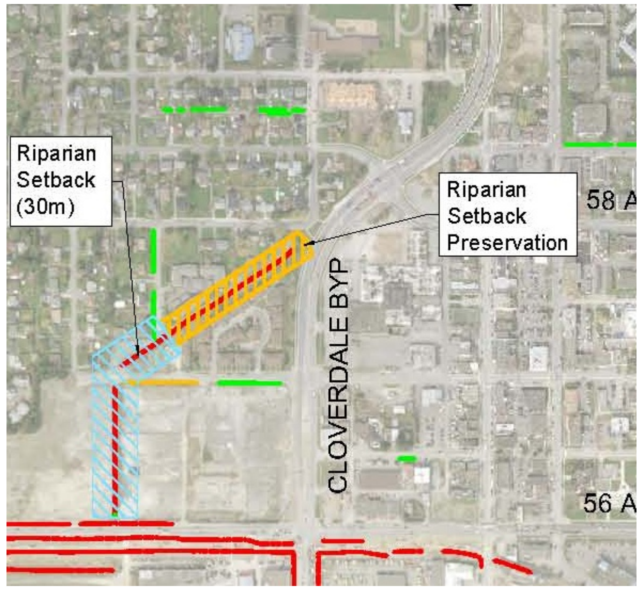

Figure 4.11: Cloverdale Canal

Recommendations:

- Do not allow encroachments on existing setback;
- Make the following improvements if feasible:
  - Target a 30 meter setback for new development with an additional six meter easement to allow for City maintenance access and limit the potential for tree hazards to damage private property;
  - Allow no more encroachment within 30 meters and do not increase any existing encroachments;
  - Require an additional five meters off existing setbacks at the time of redevelopment to a desired 30 meter setback; and
  - Existing and additional riparian setbacks should be publically owned. Efforts should be made to have the land dedicated at time of development.

Figure 4.12: Cloverdale Canal at 174th

4.2. Specific Projects

4.2.1. Infrastructure Upgrades

As discussed in previous sections, discussions with City of Surrey staff and the event based model have identified some drainage infrastructure that is under capacity. Over a dozen locations have been identified as potentially requiring upgrades and they are shown on **Figure 4.13**. Delcan has used the existing model to generate recommended upgrades. These recommendations are discussed in more detail below. In general, they are categorized into two groups: lowland drainage improvements and local drainage improvements.

Lowland Drainage Improvements

It is typical for flooding problems to occur at the transition from upland areas to lowland areas as the capacity of the infrastructure and channels are influenced by low grades, sedimentation and backwater effects. The flooding in these areas will be improved if increased stormwater source control measures are implemented in the uplands, which will reduce the peak flow and runoff volume. **Figure 4.13** shows the location of the proposed improvements and the recommendations for next steps are discussed below.

There are three ways to deal with infrastructure that is under capacity:

- Upgrade the capacity of the link by installing larger pipes;
- Reduce peak flows by detaining water upstream of the undersize infrastructure; and
- Bypass the infrastructure by re-routing some of the flows.

Cloverdale Canal and Racetrack Storm Sewer

The Cloverdale Canal and Racetrack trunk sewers are a major flow conveyance route for the West Cloverdale sub-catchment (**Figure 4.13, Item 1**) which is 420 hectares in size. This system has been the subject of a number of studies (KWL 2002, Stantec 2008, Associated Engineering 1998). The Stantec model is deemed to be the most accurate model for the system as their work included video inspection and obtained good calibration for the known event of March 2007. Delcan's model did not include the same focus on this one reach but it showed similar results in terms of capacity deficiencies. The system is subject to flooding and there are several undersized pipes in the system in the conveyance system. Most notable are the crossing of 57th Avenue, and the first enclosed reach between the 175th Street and 176A Street.

For the open channel portion south of 57th Avenue, Delcan's XPSWMM model found that the elevation in the system did not exceed the channel banks. This assumes:

- A siphon crossing of Highway 10 that is not blocked with debris or filled with sediment; and
- An operating condition for the downstream boundary of the model of a water level of 0.7 meters (this value was selected from past and current studies by Stantec and KWL).
- No flooding effects from the Nicomekl River.

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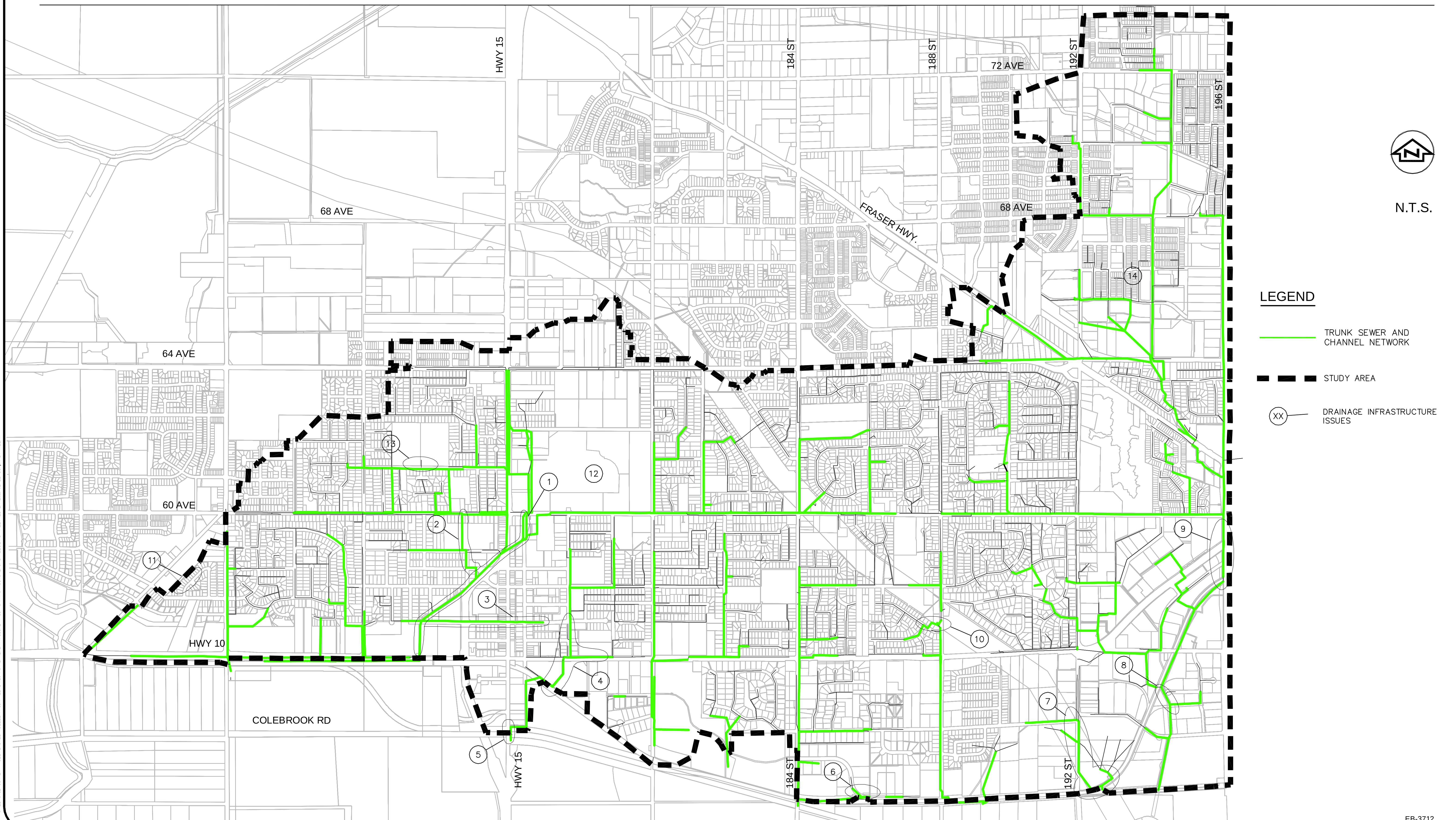
Figure 4.13 - Infrastructure Upgrades
Cloverdale McLellan ISMP



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The lowland area has been studied in more detail as part of other studies and some upgrades are already completed (e.g. berm construction to protect existing condo development, 57th Avenue Crossing upgrade).

For the open channel portion of the Cloverdale Canal between 58th Avenue and 57th Avenue, there have been some flood control berms constructed to protect the existing development. These were installed in response to flooding of the properties. These will need to be maintained as long as the development is in place and at risk of flooding. Ongoing maintenance of the canal to remove sediment and keep heavy vegetation from blocking the canal will also be required.

Recommendation:

To mitigate the potential for flooding in this system the three potential contributors to flooding must be addressed: the upland drainage system, lowland drainage system and the Nicomekl River. These systems are all linked and can act independently or together to cause flooding in the lowland areas next to the Cloverdale Canal. This ISMP focuses on the flooding from the upstream drainage system. Flooding caused by the lowland drainage system and the Nicomekl River are currently being studied by KWL.

For flooding caused by the surcharging of the storm sewer local system, it is recommended that Cloverdale Canal and the associated storm system continue to be maintained and upgraded. Lands adjacent to the canal should not be developed until the potential for flooding has been mitigated. The 2008 Stantec Report and Delcan's model confirmed the need for some upgrades to this system. This includes upsizing some of the lower reaches of the enclosed system (from where the system leaves 176A Street to the outlet). Delcan's model recommended that conveyance improvements here would provide a slight reduction in flooding for the 5 year event. Delcan's model also shows that the upgrade of this main to the next largest size of box culvert could slightly improve the performance such that there would be minimal surcharging. However, it is important to note that, although the model shows this system as undersized, the problem could be exaggerated by sediment or partial blockages of the system. Videoing and cleaning should be undertaken to confirm the condition of the underground infrastructure as there may be other problems that have not been identified by the modeling.

The Cloverdale Canal needs ongoing maintenance in order to prevent flooding of the upstream system or flooding of the properties adjacent to the canal. Delcan's model shows that, if the canal north of Highway 10 is maintained free of sediment and debris, it will not flood in a 100 year event. The Stantec model also showed that maintenance of the canal would benefit the system. However, because of the uncertainty, we recommend that a freeboard of 0.6 m be used above the elevations; not 0.3 m as outlined in the Stantec report.

The next step for assessment of this canal would be to perform a site survey of the reach and update the models for the final version of the uplands (Delcan) and lowlands (KWL) model results. If it is not included in the final KWL model, a dike breach analysis should also be performed on the Nicomekl River dikes to determine the worst case scenario. We also recommend that the analysis be undertaken to determine the risk for potential sea level rise to impact flooding on the property. It is anticipated that the flood elevations for the properties near the Cloverdale Canal will not be governed by the upland drainage system flooding but likely from a combination of the lowland drainage system and a dike breach.

175th Street Storm Sewer

The 175th trunk sewer system from 60th Avenue to 58A Avenue carries flows from a 120 hectare area north of 58th Avenue and west of 175th Street. It was constructed in 1980 and ranges in size from 900 mm to 1050 mm diameter (**Figure 4.13, Item 2**). The system connects downstream to the Cloverdale Bypass trunk main. The XPSWMM model found that this system is under capacity for the 5 year event. Replacing this trunk sewer with a 1500 mm diameter sewer would increase the capacity, making it sufficient to carry the 5 year flow event.

The 175th Street trunk system outlets into an already over capacity system along the Cloverdale Bypass. It is possible that, if the 175th Street trunk sewer was upgraded, it could be directed into Cloverdale Canal to reduce the requirements on the underground infrastructure.

Recommendation:

It is recommended that the 175th Street Storm Sewer be updated to a 1500 mm sewer. At the time of upgrade, some alternate routes may be considered to connect to the Cloverdale Bypass Sewer / Cloverdale Canal farther downstream.

57th Avenue Storm Sewer

The 57th Avenue storm sewer provides drainage for some of the Cloverdale Town Centre (**Figure 4.13, Item 3**). This sewer was not in the GIS information provided but was added from as-builts and site visits. A portion of the sewer is 525 mm in diameter and undersized to convey the 5 year event. There are also potential impacts from downstream backwater as the outlet for the system is the Cloverdale Canal. Analysis shows that a 750 mm diameter sewer will have capacity to carry the 5 year event if the maintenance of the Cloverdale Canal conveyance continues to be implemented as discussed above.

Recommendation:

It is recommended that the 57th Street storm sewer be upgraded to 750 mm diameter east of 175th Street.

Cloverdale Village Square

The infrastructure flowing through Cloverdale Village Square south of Highway 10 at 177b Avenue is not sufficient to convey the design flows (**Figure 4.13, Item 4**). Flooding of the parking area has been reported in the past. The XPSWMM model prepared for this ISMP identified that both infrastructure sizing and backwater conditions caused by downstream conveyance played a role. Making infrastructure improvements in the model did not remove the potential for surface flooding although there was some improvement seen as a result of installing larger pipes. Further investigation based on more specific site conditions is required. It may not be feasible to solve the problem completely with infrastructure improvements.

Recommendation:

It is recommended that these reaches be studied in more detail to determine the solution.

176th Street Rail Crossing

The rail crossing at 176th Street is the outlet for an 80 hectare catchment (**Figure 4.13, Item 5**). The existing crossing culvert configuration is a source of flooding since it was altered as part of the railway construction. Currently, only a single 1200 mm pipe is available to convey the flows. Modeling shows that a 1525 mm pipe would have sufficient capacity for the 5 year event. However, because of the backwater, the potential for sediment to block the pipes and the losses at inlets and outlets, the sizing and proposed configuration should be evaluated in more detail at the site level. Height restrictions may require that a twin culvert system be installed and, since it is under a railway, trenchless technology may be required for installation.

Recommendation:

It is recommended that the 176th Street Rail Crossing Street Storm Sewer be upgraded to 1525 mm diameter.

185A Street Storm Sewer

The area at 185A Street and 52nd Avenue has had reported surface flooding near where the system outlets to the rail ditch (**Figure 4.13, Item 6**). The analysis shows that the infrastructure is correctly sized and the outlet conditions appear to be the problem.

Recommendation:

It is recommended that the north rail ditch be cleaned of vegetation and debris to provide a free flowing outlet.

192nd Street Rail Culvert

The 192nd Street storm sewer provides drainage for the residential and industrial areas between 52nd Avenue and 56th Avenue, west of 192nd Street. (**Figure 4.13, Item 7**). There is also some undeveloped land within the service area. This system discharges to an open channel and is then conveyed across the railway via a 600 culvert. This culvert is to be undersized to convey the 5 year event. Because of the scheduled changes coming with the 192nd Street rail overpass, there is an opportunity to investigate and resize the infrastructure as part of the project.

Recommendation:

It is recommended the 192nd Street rail culvert be upgraded to 750 mm diameter.

55th Avenue Culvert

The 55th Avenue Culvert has been identified as a cause of flooding problems (**Figure 4.13, Item 8**). The analysis shows that the culvert is undersized to convey the 100 year event. Because the culvert is flat, sedimentation within the culvert is making the problem worse. Once further site investigation is completed, it can be confirmed that the culvert inverts and slope are contributing to the history of flooding and sediment buildup.

Recommendation:

It is recommended to replace this culvert with a box culvert of the same size but with the invert embedded to allow natural sediment movement through the bottom of the culvert.

196th Street Storm Sewer and Culverts

The 196th Street storm sewer and open channel is the beginning of the downstream reach of McLellan Creek. (**Figure 4.13, Item 9**). A portion of the sewer appears to be undersized to convey the 5 year event. With the scheduled changes to the 196th Street rail overpass, there is an opportunity to investigate and resize the infrastructure as part of the project.

Recommendation:

- It is recommended that the City of Surrey require that the 196th Street overpass project include a storm sewer investigation and upgrade for the trunk sewer system from 60th Avenue to downstream of the railway culverts.
- It is recommended that the 196nd Culvert be upgraded to 1800 mm diameter.

Local Drainage Improvements

Although most of the major infrastructure issues related to flooding are within the lowland area, there are some other identified problems that can be solved with infrastructure improvements.

188th Street Pond

The detention pond in the BC Hydro ROW east of 188th Street just north of 56B Avenue (**Figure 4.13, Item 10**) needs further study. It was reported by City of Surrey operations staff that they have never known water to be in this pond. Delcan's event model showed that water was present in the 5 year event but only 0.8 m in depth, which does not represent a very high utilization. With further investigation it should be possible to reconfigure this pond to provide a more regular benefit to the system.

Recommendation:

It is recommended that the pond be upgraded to provide water quality and water quantity control to the highest level possible given the property and infrastructure constraints of the site.

Fraser Downs Racetrack

It has been reported that the operation of the racetrack may be contributing to a water quality problem in the Cloverdale Canal (**Figure 4.13, Item 12**). Agricultural runoff from the stables might be washing into the storm sewer system. Delcan did not investigate the issue on site or meet with racetrack operators to verify the findings or discuss barriers to implementing stormwater quality protection measures. Any solution will need to involve the operators of the property and the first step to improving the situation is to establish contact for the purposes of better defining the problem.

Recommendation:

It is recommended that the race track operation be developed to include best management practices for water quality. The first step will be to meet and determine the extent of the problem.

Cloverdale Ball Park

There has been surface flooding reported at the Cloverdale Ball Park near 61A Avenue **(Figure 4.31, Item 13)**. Delcan has modeled the 750 mm storm sewer running along 61A and found that the sewer has sufficient capacity at this location. The cause appears to be poorly placed inlets and improper grading to those inlets.

Recommendation:

It is recommended that an additional catch basin be installed at the location of the flooding to facilitate drainage.

4.2.2. Habitat Restoration Projects

Several potential habitat restoration projects have been identified. A map showing their location can be viewed in **Appendix E**.

Cloverdale Canal

The Cloverdale Canal is a red-coded watercourse. This creek is not of high quality due to a lack of riparian vegetation (dominated by blackberry thickets), but has high potential for restoration between 56th and 57th Avenues, as it is not currently developed. The water quality is not documented as part of this study, but may include untreated stormwater from the hectares of upstream development. Additionally, it has been reported during operation of the race track that water from stable maintenance and cleaning is directed into the stormwater conveyance system.

Recommendations:

- The riparian areas of the Cloverdale Canal should be assessed for potential restoration, which would include removal of invasive species and planting the banks with native species that can provide shade to the watercourse.
- Plantings need to consider maintenance requirements for the channel.

Upper McLellan

Upper McLellan Creek still has undeveloped reaches and healthy riparian areas. However, there is proposed development in the location of the creek. As recommended in this ISMP and the East Clayton NCP, source control BMPs should help restore base flows in the creek. As well, leaving an adequate setback as outlined in the setback recommendation will maintain the health of the riparian area.

Recommendations:

- It is recommended that the base flows to the unnamed tributaries of McLellan Creek (north of 64th Avenue) be restored. Implementing source control measures in the East Clayton development should help restore base flows in the shallow soil layer. This should be carried out through development and redevelopment within the catchment.
- It is also recommended that the City of Surrey look to replace the lost forested wetland near Upper McLellan Creek by creating new streams and riparian areas. There primary area available where this might be possible is the remaining undeveloped area north of Fraser Highway and West of 192nd Street.

Lower McLellan

Lower McLellan Creek is the primary fish habitat that still has portions of natural habitat within the watershed. Site visits and research confirmed that the lower reaches of the creek support juvenile trout and salmon populations year round. The setback recommendations provide direction on protection of this feature and a small restoration project will help to enhance the feature.

Recommendations:

- There are portions in the lower McLellan Creek where railway ballast has been placed right into the creek. This should be removed and the bank should be restored with native planting.

Cummins Brook

Cummins Brook has the potential to be restored to a healthy red-coded watercourse by making some habitat improvements. The future development of the land surrounding Cummins Brook will play a large part in determining whether this watercourse continues to provide valuable food and nutrients to downstream fish habitats or degrades as a result of flow changes and water quality impacts from new developments and industrial activities. The impacts of those activities have been addressed as part of the setback and development recommendations above; however, some habitat improvement opportunities exist.

Recommendations:

- Restore riparian and stream habitat along Cummins Brook.
- Redefine the stream channel and restore the riparian area south of 52nd Avenue and the CPR tracks (just outside the Study Area).
- Replace or remove, if possible, the farm road culvert (just outside of the study area).

Habitat / BC Hydro Corridor

The BC Hydro corridor represents the largest green area within the study area. This area should be enhanced to provide better habitat. The land is not owned by the City of Surrey so the enhancement of any habitat would required

Recommendations:

- Enhance BC Hydro ROW with native shrubs and small trees, particularly along the edges.
- Where road or underground utility works occur at BC Hydro ROW street crossing, find opportunities for installing shallow wildlife tunnels.

4.2.3. Demonstration Projects

Greening Road ROWs

Typical residential neighbourhoods in the study area are made up of more than 20% road ROWs (including both asphalt and grassed area). The watershed vision calls for 'greener streets' and, since the road ROWs are owned and operated by the City, they provide opportunities for implementing stormwater source control measures in urban areas. 'Green streets' are designed to treat stormwater by encouraging infiltration and stormwater retention within the road ROW. Technically feasible options for stormwater source controls in road ROWs include:

- Rainwater gardens/infiltration swales within boulevards and medians;
- Pervious pavement for sidewalks;
- Exfiltration pipes in storm sewers systems; and
- Pervious pavement for parking and shoulders.

Using a typical road ROW with a 20 meter width, we have modeled two scenarios: one scenario using a conventional design and one scenario using a 'green street' design. The 'green street' design includes the features shown in **Figure 4.15**.

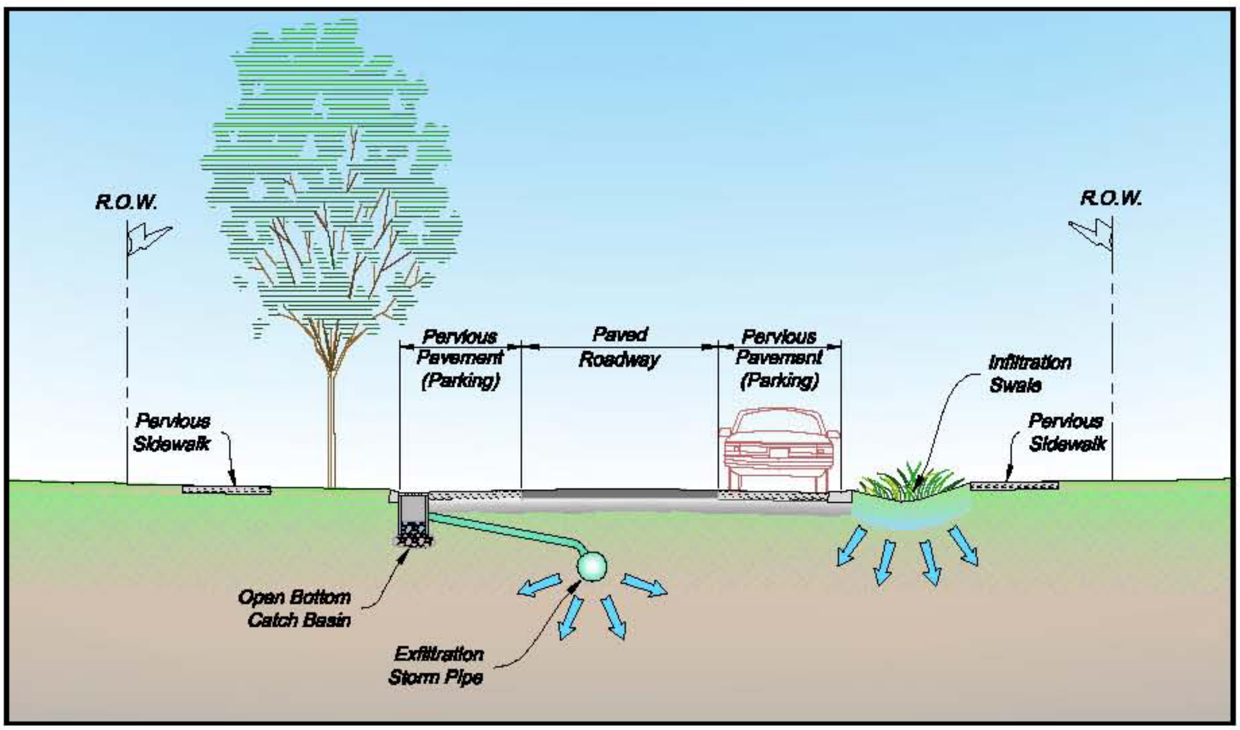

Figure 4.15: Typical Road ROW with BMPs

Modeling these two scenarios demonstrated the difference in the stormwater runoff. The results are shown in **Figure 4.16**.

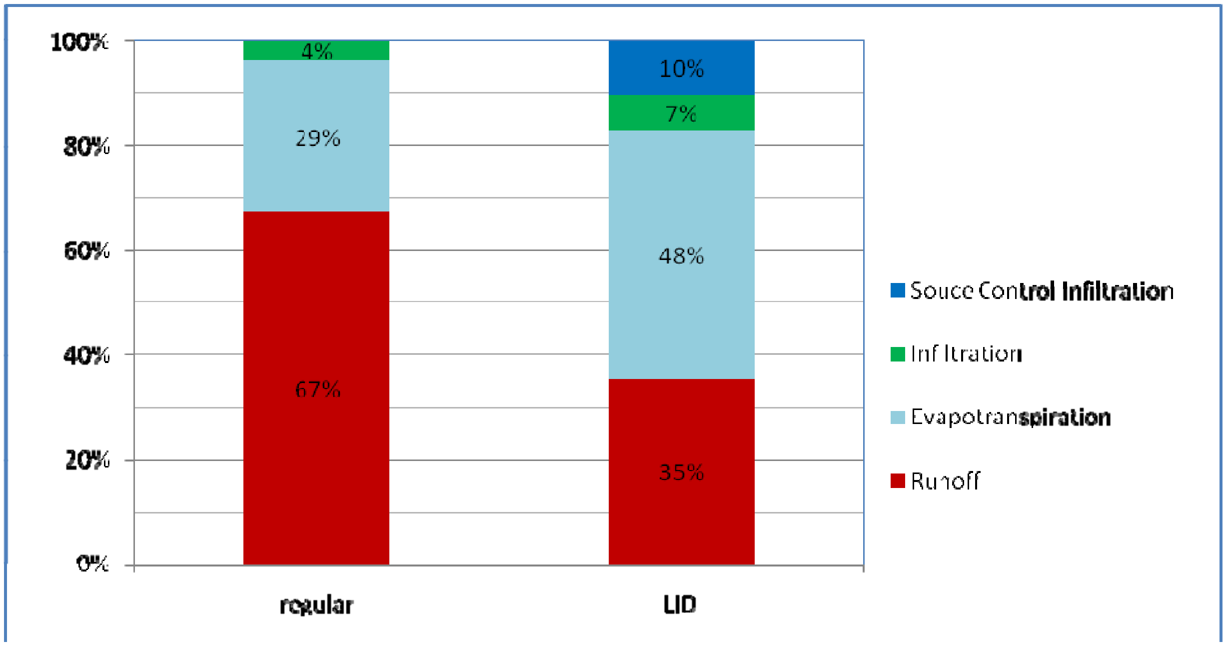

Figure 4.16: Water Balance comparison between conventional and green street.

As shown in **Figure 4.16,** the annual runoff from road ROWs can be reduced from 67% to 35% by switching from conventional stormwater design to 'green street' design; that is a reduction of almost 50%. This reduction would aid in shifting the water balance back towards more natural conditions.

'Green street' designs are becoming more common in North America, but they are still considered relatively new construction methods. Municipal staff responsible for road maintenance want to be certain of the maintenance requirements for 'green street' designs as well as the lifespan of the improvements and their effectiveness during various weather scenarios (heavy rain, freezing, etc.). The public may also have concerns with these projects because they change the look and operation of streets. However there is also an opportunity to include the public in maintaining some of the features like the rain gardens.

Recommendations:

- The City of Surrey implement a demonstration project within the catchment to test the application of the source control measures discussed in this section. The project should be designed to test each of the source control measures for performance, maintenance issues and public perception. The City should select a low traffic road on a low grade (less than 5%) and propose the idea to residents.

5. Implementation Plan

The section above provided the discussion and recommendations for the proposed improvement. This section takes the next step and outlines how to proceed with implementing the recommendations. The section outlines some of the considerations for implementation including who will be responsible for implementation, how the implementation items will be funded, how the items should be prioritized and what the costs are. The implementation items are presented in **Tables 5.2, 5.3** and **5.4**.

5.1. Key Players

One critical aspect of the implementation plan is to identify the key players that will be involved in implementing the plan. Although the ISMP outlines the work to be done, the implementation will rely on the following key players:

- **Developers/Property Owners:** Those developing private lands will be responsible for many of the implementation plan items. The implementation items will be a requirement of the development or permit process. In many cases this group will need support from the City of Surrey staff in order to effectively implement site level BMPs and LID.
- **City of Surrey Planning and Development**: One of the primary functions of the Planning and Development Department is managing application approval processes consistent with the approved plans, by-laws and policies. The ISMP will become one of the approved plans that applications must be consistent with. They may require support from the Engineering staff on technical issues.
- **City of Surrey Engineering**: The ISMP process is led by the Engineering group within the City of Surrey. Once completed, the engineering group will rely on the planners to implement the plan but will always be involved in supporting and monitoring the plan.
- **Community Groups**: In some cases, there may be an opportunity for members of the public and community to be involved in providing feedback such as green streets or habitat improvement projects.

5.2. Funding Sources

Below are potential funding sources for work recommended in the ISMP.

5.2.1. Cost carried by applicant

Many implementation items will be implemented in the form of conditions to be imposed at the time of development. These costs are generally borne by the applicant in the form of engineering and construction costs in meeting the City's requirements for developing the land. However, many source control BMPs have relatively small incidental costs compared to implementing standard development. For example, recent reports indicate installing pervious pavement can be cost neutral compared to conventional pavement when the reduction in requirement for underground storm infrastructure is considered.

5.2.2. Development Cost Charges

The City of Surrey funds some growth related improvement out of development cost charges (DCCs). The principle is that growth should pay for growth. Generally, these are improvements that are required to service larger areas so that the funds from multiple developments are required to complete the necessary construction.

5.2.3. Utility Funding

The City of Surrey collects a stormwater tax as part of City of Surrey property taxes. The money is available to spend on stormwater and flood control projects within the City of Surrey. It is used for infrastructure renewal and capital projects that fix existing problems.

5.2.4. External Funding Options

There are numerous external agencies that have fund and grant programs. Potential funding sources are listed in this section. We have briefly summarized some of the key characteristics including: who is eligible, what kinds of project are eligible, how much funding is available and where more information can be found.

Federation of Canadian Municipalities (FCM) – Green Municipal Fund (GMF)

Through GMF, FCM provides funding to three types of environmental initiatives: plans, studies and projects. Grants are available for sustainable community plans, feasibility studies and field tests, while a combination of grants and loans are available for capital projects. Funding is allocated in five sectors of municipal activity: brownfields, energy, transportation, waste and water. GMF funding is available to all municipal governments and their partners in eligible projects.

Website: http://gmf.fcm.ca/Funding-Opportunities/

Environment Canada – EcoAction Community Funding Program

This program provides financial support for projects that have measurable, positive impacts on the environment. Projects that are eligible for funding must address one on more of the following areas:

- Clean Air – reducing air emissions that contribute to air pollutants;
- Clean Water – diverting and reducing substances negatively affect water quality or focusing on water conservation and efficiency;
- Climate Change – reducing greenhouse gas emissions that contribute to climate change or dealing with the impacts of climate change; and

- Nature – protecting wildlife and plants, and protecting and improving the habitat where they live.

Groups eligible to receive funding through the EcoAction Community Funding Program are non-profit groups and organizations that are not part of federal, provincial, territorial, or municipal governments (with the exception of hamlet councils). Examples of eligible groups include:

- Environmental groups;
- Community groups;
- Youth and seniors groups;
- Community-based associations;
- Service clubs; and
- Aboriginal organizations, such as First Nations Councils, Inuit, Métis Associations.

Website: http://www.ec.gc.ca/ecoaction/default.asp?lang=En&n=FA475FEB-1

Evergreen Foundation

This program funds community and school greening projects. Grants are divided into the following categories:

- Common Grounds Grants – funding for protecting and restoring urban green spaces. Projects must be on publically accessible lands, have a strong volunteer-involvement component and open to the community.
    - Walmart – Evergreen Green Grants – Up to $10,000 for community based restoration and stewardship initiatives in urban and urbanizing areas, including naturalization, restoration and stewardship, and community food gardens
    - The Rebuilding Nature Grant Program – Up to $12,000 for community groups to cover the costs of tools and building projects, native plants and trees, and other expenses in support of environmental stewardship projects
    - Unilever – Evergreen Aquatic Stewardship and Conservation Grant – Up to $10,000 for community-driven restoration initiatives, as well as education projects that promote the wise use of water resources through educational and hands-on activities.
- Learning Grounds Grants
    - Toyota Evergreen Learning Grounds School Ground Greening Grants – Up to $3,500 for schools wishing to create outdoor classrooms and food gardens to provide students with a healthy place to play, learn and develop a genuine respect for nature.

Website: http://www.evergreen.ca/

TD Friends of the Environment Foundation

The TD Friends of the Environment Foundation has been able to help Canadians protect our country's natural beauty by providing environment funding for not-for-profit organizations across Canada. We're always looking for new and exciting initiatives, so submit your application to receive environmental funding for your community project. Eligibility requirements:

- Organizations must be Canadian, using the funds in Canada and they must be not-for-profit with a Charitable Registration Number;
- Schools, municipalities and First Nations groups are also eligible; and
- Organizations must be able to provide a charitable tax-receipt for the full amount of donation.

Website: http://www.fef.td.com/

Resources for Rethinking (R4R)

R4R provides funding for students' environmental initiatives through two programs:

- Project Flow – up to $3,000 in funding for school-based comprehensive water action plan projects; and
- EcoLeague Action Projects – up to $400 in funding for students engaging in community and school-based environmental action projects.

Website: http://r4r.ca/en/funding

5.3. Prioritizing of Project

The implementation items have been classified in terms of their level of priority. The levels of priority are as presented in **Table 5.1**. Projects are listed in **Tables 5.2, 5.3** and **5.4.**

Table 5.1: Prioritization Groups

Level	Description
Priority 1	Items which address a risk to public
Priority 2	Items that address a potential danger to property
Priority 3	Items that address aquatic environmental protection of existing resources Items that address nuisance flooding
Priority 4	Items that provide an environmental enhancement or improvement
Priority 5	Items that address aesthetic concerns

The prioritization system above and categorizing of the implementation plan items should be confirmed during review of this draft report or during development of the internal implementation discussions within the City of Surrey.

5.4. Costs

The financial costs of the implementation items have been estimated only where the implementation item is a specific infrastructure improvement. For other recommendations the costs have not been estimated. The costs are presented to provide an indication of the level of funding that may be required to address that item. A more detailed cost estimate should be performed as the projects are implemented.

5.5. Implementation Plan Items

The implementation plan items for this ISMP have been classified into categories as follows:

- **Policy and programs** that direct how development should occur in the futures
    - Green Field Development
    - Redevelopment
    - Watercourse Setbacks
- **Specific projects** that prescribe physical changes to the watershed such as infrastructure upgrades
    - Infrastructure Upgrades
    - Habitat Restoration
    - Demonstration Projects

More than any other aspects of the ISMP the implementation plan must be accepted by those City of Surrey staff that will be responsible for its implementation. Review of this draft ISMP will be the first step towards acceptance of the final recommendations.

5.5.1. Policy and Programs

Tables 5.2, 5.3 and **5.4** contain the implementation items for Green Field Development, Redevelopment and Watercourse Setbacks respectively. The implementation of new policies and programs requires the cooperation of City of Surrey planning department and engineering department to ensure that the resources, both in terms of staff and expertise are available. This draft ISMP should serve as the starting point for those discussions so that the implementation plan can be expanded for the final ISMP.

Table 5.2: Summary of Implementation Plan

Policies and Programs - Green Field Development

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
East Clayton Area	• Continue to apply stormwater criteria outlined in the NCP.	• Developers/Property Owners to implement • Planning to administer • Engineering to support	• Implementation by developers must be monitored and enforced. • Surrey staff must continue to support developers in implementing BMPs and LIDs.	Lack of confidence in BMPs by designers has lead to poor implementation, which can lessen future confidence in BMPs.	Developer / applicant funded	N/A	3
Outside East Clayton	The following performance criteria should be met with new developments: • Runoff control and flood mitigation as outlined in the City of Surrey Design Criteria; • Only 10% of annual runoff volume will be allowed to flow off-site in the form of runoff; and • Capture the first 25 mm of rainfall per day. In some cases, off-site stormwater facilities might already be sized to control runoff. If this is the case, a detailed review of the design and operational effectiveness analysis of those features must be done to confirm that they meet the above criteria.	• Developers/Property Owners to implement • Planning to administer • Engineering to support	• Surrey Planning staff must be brought up to date on these recommendations. • Surrey Engineering staff must continue to educate developers in successfully implementing BMPs and LIDs. This implementation must be monitored and enforced.	Lack of confidence in BMPs by designers has lead to poor implementation, which can lessen future confidence in BMPs.	Developer / applicant funded	N/A	3

Table 5.3: Summary of Implementation Plan

Policies and Programs - Single lot Redevelopment

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Commercial and Industrial	Performance criteria: • Meet the servicing objectives outlined in the Surrey Design Criteria Section 5.2; and • Provide on-lot source controls that control runoff to a maximum of 55% of the annual runoff.	• Developers/Property Owners to implement • Planning to administer • Engineering to support	• Surrey Planning staff must be brought up to date on these recommendations. • Developers and property owners must be informed of the requirements and pointed to the resources that will help them to implement.	Lack of confidence in BMPs by designers has lead to poor implementation, which can lessen future confidence in BMPs.	Developer / applicant funded	N/A	4
Residential	On-lot mitigation measures for single lot redevelopments: • Require the placement of 300 mm of absorbent topsoil with all new redevelopments; • Require that new paved areas be pervious or be directed to infiltration features such as infiltration trench or soak-away pit; • Require roof runoff to be directed to an infiltrationn swale, infiltration trench or soak-away pit.	• Developers/Property Owners to implement • Planning to administer • Engineering to support	• Developers, builders and home owners must be informed of the requirements. The City of Surrey can do this by modifying the development application and building permit approval process. • Surrey Building Permit staff need to be provided the resources to allow them to understand how to implement BMPs which they in turn will use to help the public understand how to implement BMPs on their property. Standard drawings may be required to aid in understanding.	Single family redevelopment may not have the technical expertise or resources to implement BMPs so technical support will need to be provided by the City.	Developer / applicant funded	N/A	4

Table 5.4: Summary of Implementation Plan

Policies and Programs - Watercourse Setbacks

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Upper McLellan	Setback recommendations are as follows: • For all undeveloped portions of the watercourse, 30 meters from the top of the bank on both sides of the creek. • This 30 meter setback should be publically owned and, where possible, fences should be used to control encroachment. • An additional setback easement of six meters from the publically owned land to allow for City maintenance access and minimize the potential for tree hazards to damage private property.	• Planning to lead • Engineering to support	• Inform planning and engineering staff of new development setback recommendations. • Require compliance at the site level at time of application	Setbacks can be challenging because of the implications to developable land area.	Developer / applicant funded	N/A	3
Middle McLellan	The City should, where applicable, make planning and development decisions that will facilitate future day-lighting. These steps would include: • Prohibiting the construction of new buildings on or within 15 meters of the potential creek centerline; • Acquiring property or easements along the corridor when the opportunity arises. This would be larger than the property/easement required for the maintenance of the storm drain; and • Include day-lighting of McLellan Creek in discussions when preparing future planning documents. • No further enclosures of the watercourse should take place.	• Planning to lead • Engineering to support	• Inform planning and engineering staff of new development setback recommendations • Require compliance at the site level at time of application	Because day-lighting is likely not a reality for the foreseeable future, getting buy-in to leave room for the creek may be difficult.	Developer / applicant funded	N/A	4

Table 5.4: Summary of Implementation Plan

Policies and Programs - Watercourse Setbacks

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Lower McLellan	Setback recommendations are as follows: • Allow no more encroachment within 30 meters and do not increase any existing encroachments; • Implement a policy of setback restoration by requiring an additional five meters off existing setbacks at the time of redevelopment to a maximum of 30 meters; and • Existing and additional riparian setbacks should be publically owned. Efforts should be made to have the land dedicated at the time of development or redevelopment.	• Planning to lead • Engineering to support	• Inform planning and engineering staff of new development setback recommendations • Require compliance at the site level at time of application	Setbacks can be challenging because of the implications to developable land area.	Developer / applicant funded	N/A	3
Cummins Brook	Setback recommendations are as follows: • Allow no more encroachment within 30 meters and do not increase any existing encroachments; • Implement a policy of setback restoration by requiring an additional five meters off existing setbacks at the time of redevelopment to a maximum of 30 meters; and • Existing and additional riparian setbacks should be publically owned. Efforts should be made to have the land dedicated at the time of development or redevelopment.	• Planning to lead • Engineering to support	• Inform planning and engineering staff of new development setback recommendations • Require compliance at the site level at time of application	Setbacks can be challenging because of the implications to developable land area.	Developer / applicant funded	N/A	3

Table 5.4: Summary of Implementation Plan

Policies and Programs - Watercourse Setbacks

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Cloverdale Canal	Do not allow encroachments on existing setback; Make the following improvements if feasible: • Require a 30 meter setback for new development with an additional six meter easement to allow for City maintenance access and limit the potential for tree hazards to damage private property; • Require an additional five meters off existing setbacks at the time of redevelopment to a maximum of 30 meters; and • Existing and additional riparian setbacks should be publically owned. Efforts should be made to have the land dedicated at the of development.	• Planning to lead • Engineering to support	• Inform planning and engineering staff of new development setback recommendations • Require compliance at the site level at time of application	Setbacks can be challenging because of the implications to developable land area.	Developer / applicant funded	N/A	3

5.5.2. Specific Projects

Tables 5.5, 5.6 and **5.7** on the next few pages contain the implementation items for Infrastructure Upgrades, Habitat Restoration and Demonstration Projects. This ISMP has highlighted a number of projects for implementation. This ISMP is only the first stage for implementing the project and further works will need to be undertaken for most implementation items.

To move from the ISMP stage to construction will generally require:

- Confirming the prioritization presented in this draft report
- Additional site investigation (survey or geotechnical investigation)
- Updated the analysis including options generation and evaluation
- Conceptual and preliminary design
- Confirmation of budget, property requirements, and stakeholder issues
- Design and construction

The specific project needs to be confirmed with City of Surrey staff prior to finalization of this ISMP. The schedule and priority ranking for the upgrades can also be developed draft report has been reviewed by those who will be responsible for implementing them.

Table 5.5: Summary of Implementation Plan

Specific Projects - Infrastructure Upgrades

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Cloverdale Canal and Racetrack Storm Sewer	• Continue to upgrade the Cloverdale Canal and associated storm system as outlined in this and previous reports, which includes upgrading pipes in the lower reaches and the crossing culvert at 57th. Ave. • Lands adjacent to the canal should not be developed until the potential for flooding has been mitigated. This includes flooding from the upland drainage and also flooding from the lowland or Nicomekl River. This study only covers the uplands.	• Engineering to lead	• Partial replacement will likely be a viable option once site analysis is complete. • Perform site survey and preliminary design. The modeling preformed as part of this study and past studies can serve as a basis for upgrade preliminary designs. • At the time of development application, the City of Surrey should require a detailed investigation of the flood levels and flow conveyance of the downstream structures. The reach should be studied as a whole. Upgrades will be required as part of the development. • Those improvements not associated with the development should continue to be implemented through the City of Surrey's capital plan. • Overland flow routes can serve as a backup to the underground system but should be assessed in more detail.	Because of the flat topography along this system, the pipe sizes required are relatively large and costly.	Developer / applicant funded Capital Improvement covered by the City's Utility Funding	$2.5-3.0 million if full replacement of the system is required.	1
175th Street Storm Sewer	• Upgrade the 175th Street Storm Sewer to a 1500 mm sewer and alternative routes should be considered.	• Engineering to lead	• Perform a site specific investigation of this system including site survey, additional modeling, route option investigation, option selection and design.		Capital Improvement covered by the City's Utility Funding	$500k-700k	2

Table 5.5: Summary of Implementation Plan

Specific Projects - Infrastructure Upgrades

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
57th Avenue Storm Sewer	• Upgrade the 57th Street storm sewer to 750 mm diameter.	• Engineering to lead	• Perform a site specific investigation of this system including site survey, additional modeling, route option investigation, option selection and design.	Preliminary design may find that the backwater in Cloverdale Canal will limit the effectiveness of the design.	Developer / applicant funded Capital Improvement covered by the City's Utility Funding	$200k-300k	2
Clover Square Village	• Study these reaches in more detail to determine the solution.	• Engineering to lead	• The site investigation should include site survey, discussions with property and city operations staff, additional modeling, and generation and evaluation of options. • Once this investigation is complete a better understanding of the problem should allow for recommendations on the solution to be made.	It is possible that no feasible infrastructure solution can be found in which case non structural measures may need to be considered.	Capital Improvement covered by the City's Utility Funding	N/A	2
176th Street Rail Crossing	• Upgrade the 176th Rail Crossing Street Storm Sewer to 1525 mm diameter.	• Engineering to lead • Rail Owner to implement	A site specific investigation of this area would include: • Site survey to pick channel dimensions, pipe inverts, rail elevations, • Update hydraulic model • Geotechnical investigation • Preliminary and Final Design Begin discussions on cost sharing and technical requirements with the railway owner (SRY)	Cooperation with the rail owner (SRY) will be required. Height restrictions may require that a twin culvert system be installed, and since it is under a railway, trenchless technology may be required for installation.		$175k-250k	2

Table 5.5: Summary of Implementation Plan

Specific Projects - Infrastructure Upgrades

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
185A Street Storm Sewer	• Clean the north rail ditch of vegetation and debris to provide a free flowing outlet.	• Engineering to lead	• The operator of this ditch (CPR/CN) should be contacted to discuss the ditch cleaning.	Cooperation with the rail owner (CPR/CN) will be required.	This item should be covered in a typical maintenance program.	N/A	3
192nd Street Storm Sewer	• Upgrade the 192nd outlet culvert to 750 mm diameter.	• Engineering to lead • Rail Owner to implement	• This work could be included in the 192nd Street overpass project. It should include a storm sewer investigation and upgrade for the system where required from 54th Avenue to the outlet into the Nicomekl River. Communicate the requirement to rail grade separation project manager	Cooperation with the rail owner (CPR/CN) will be required.	With Roberts Bank Rail Corridor Program	$350k-450k	3
55th Avenue Culvert	• Reset this culvert with the invert embedded to allow the natural movement of sediment through the bottom of the culvert.	• Engineering to lead	• A detailed site investigation may find that resetting the culvert is not required and sediment removal will be enough to increase capacity. • It is possible that this culvert could be removed completely, which is preferred from a capacity and environmental point of view.	Cooperation with the rail owner (CPR/CN) will be required as part of the works will be in their property.	Capital Improvement covered by the City's Utility Funding	$75k-100k	3
196th Avenue Storm Sewer and Culverts	• Require that the 196th Street overpass project include a storm sewer investigation and upgrade for the trunk sewer system from 60th Avenue to downstream of the railway culverts.	• Engineering to lead • Rail Owner to implement	• This work could be included in the 196th Street overpass project. Communicate the requirement to rail grade separation project manager	Cooperation with the rail owner (CPR/CN) will be required.	With Roberts Bank Rail Corridor Program	$500k-650k	3

Table 5.5: Summary of Implementation Plan

Specific Projects - Infrastructure Upgrades

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
188th Pond	• Upgrade the pond to provide water quality and water quantity control to the highest level possible given the property and infrastructure constraints of the site.	• Engineering to lead	• With further investigation it should be possible to reconfigure this pond to provide a more regular benefit to the system. That investigation should include site survey, geotechnical investigation, options generation and selection, preliminary design		Capital Improvement covered by the City's Utility Funding	$300k-400k	4
Rear lot Seepage	• The affected property owner should contact the school district to raise the issue and discuss potential solutions.		• No immediate action is required on this item. The solution must be found between the two property owners.	Because the City is sometimes viewed as responsible for all drainage, the City may be asked to become involved.	N/A	N/A	5
Fraser Downs Racetrack	• Develop the race track operation to include best management practices for water quality.	• Engineering to lead	• Contact should be established with the facility operators to begin to assess the nature and scale of the problem. • The City of Surrey should provide advice on how the issue can be resolved.	There may be issues about awareness of the issues from facilities operations staff. Perhaps they don't see a problem with current practices. Should there be resistance, bylaw enforcement action may be required.	Racetrack operator to fund. Support from the City may be required.	N/A	4
Cloverdale Ball Park	• Install an additional CB at the location of the flooding to facilitate drainage.	• Engineering to lead	• This small improvement project could likely be implemented by City staff.		Capital Improvement covered by the City's Utility Funding.	$5,000	3

Table 5.6: Summary of Implementation Plan

Specific Projects – Habitat Restoration

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Cloverdale Canal	• The riparian areas of the Cloverdale Canal should be assessed for potential restoration which would include removal of invasive species and planting the banks with native species that can provide shade to the watercourse.	• Planning to lead • Engineering to support	• Contact the race track stable operators to confirm they have, or help them develop, a management and maintenance plan that protects the stormwater quality. • Assess the riparian areas of the Cloverdale Canal for potential restoration which would include removal of invasive species and planting the banks with native species that can provide shade to the watercourse. Plantings would be required to consider future maintenance requirements for the channel which performs and important drainage function. • This project could be tied to the requirements for land development as part of the canal improvement project.	Plantings would be required to consider future maintenance requirements for the channel which performs and important drainage function.	Developer / applicant funded	N/A	4
Upper McLellan	• Enhance the unnamed tributaries of McLellan Creek (north of 64th Avenue) by restoring base flows to these channels.	• Planning to lead • Engineering to support	• Implementing source control measures in the East Clayton development should help restore base flows in the shallow soil layer. • This project should be tied to the development near upper McLellan creeks as part of the environmental requirements.		Developer / applicant funded	N/A	4
Lower McLellan	• There are portions in the lower McLellan Creek where railway ballast has been placed right into the creek. This should be removed and the bank should be restored with native planting.	• Engineering	• Discussions with the railway authority (CPR/CN) will be required to arrange access and discuss the scope of the work required. Some ballast might have to remain.	Cooperation with the rail authority (CPR/CN) will be required.	Capital Improvement covered by the City's Utility Funding	N/A	4

Table 5.6: Summary of Implementation Plan

Specific Projects – Habitat Restoration

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Cummins Brook	• Restore riparian and stream habitat along Cummins Brook. • Redefine the stream channel and restore the riparian area south of 52nd Avenue and the CPR tracks. • Replace or remove, if possible the farm road culvert.	• Planning to lead • Engineering to support	• Cummins Brook has the potential to be restored to a healthy red-coded watercourse by making some habitat improvements. • This project should be tied to the future development near the creeks as part of the environmental requirements.		Developer / applicant funded	N/A	4
Hydro Corridor	• Enhance BC Hydro right-of-way with native shrubs and small trees, particularly along the edges. • When road or underground utility works occur where the BC Hydro right-of-way crosses streets, find opportunities for installing shallow wildlife tunnels.	• Engineering	• Investigate interest of school or community groups in being a part of the corridor planting. • A part of this work is ideally suited to be implemented by school groups as part of environmental education or local non-government organizations (NGOs) for which habitat protection/restoration is a priority.	There will be property issues given the City does not own land.	External grant funding for community groups	N/A	4

Table 5.7: Summary of Implementation Plan

Specific Projects – Demonstration Project

Location	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Costs	Priority
Green Street Demonstration	Implement a demonstration project within the catchment to test the application of the source control measures discussed in this ISMP. A demonstration project should be designed to test each of the source control measures for performance, maintenance issues and public perception. The City should select a low traffic road on a low grade (less than 5%) and propose the idea to residents.	Engineering	A green street demonstration project would be a good tool to test potential BMPs for use in Surrey. A low traffic volume residential street should be selected for the project. A street that is scheduled for infrastructure renewal would be ideal because then the costs are only the incremental to go from a standard design to a green design which is generally less than 10%.	Because the aspects of green streets are not standard construction items, careful supervision will be required for the construction phase of the program.	Capital Improvement covered by the City's Utility Funding	$300k-500k	4

6. Monitoring Program

Monitoring forms an essential part of an ISMP. It helps us understand the watershed and identify opportunities that respect important environmental features. Monitoring is the link between science and planning policy. Information gathered from monitoring allows for long-term strategies to be tracked and adapted as the plan moves forward.

In general there are three types of monitoring:

- **Validation Monitoring** – Measures the extent to which completion of the objectives (actions) has been successful at achieving the goal
- **Effectiveness Monitoring** – Determines the extent to which the completed actions have achieved the objectives
- **Compliance Monitoring –** Identifies whether or not the implementation has been completed as planned

It is recommended that Surrey implement a monitoring program for the Cloverdale McLellan watershed.

6.1. Validation Monitoring

Validation monitoring can also be called monitoring of performance indicators. This is the monitoring that will tell us how well the ISMP implementation recommendations are impacting the watershed. For each aspect of the validation monitoring below, the first step is to establish baseline conditions based on existing conditions so that any future results can be compared to that condition. The basis for this ISMP is that all validation indicators should show either no change or improvement over time. If this is not the case, the implementation plan should be revisited. The results of the monitoring report should be presented in a validation monitoring report every three years.

6.1.1. Flooding

In the absence of a permanent stream flow gauge in the study area, flooding complaints serve as the best indication of system performance during high flow events. These complaints should be monitored as to their frequency and location to see if there is any reduction in flooding.

6.1.2. Water Quality

Stream water quality should be monitored to track how changes in the watershed are changing water quality. It is recommended that four water quality sites be established: upper McLellan, lower McLellan, Cummins Brook and Cloverdale Canal. The site should match those of the benthic sampling outlined below in section 6.1.3. These sites should be tested during low and moderate flow conditions at least twice a year. The parameters to be selected are dissolved oxygen, pH, coliforms, hydrocarbons, ammonia, nitrates / nitrites, temperature, salinity, and flow conditions.

6.1.3. Stream Health

Conventional water quality sampling consists of sampling at a specific point in time. Although this sampling provides great information for the specific time sampled, it does not necessarily tell us what is happening in the stream over the remainder of the year. Benthic invertebrates live in a stream for up to three years. During this time, they are exposed to the full range of water quality conditions present in the stream. Some species require excellent water quality to survive while others are quite tolerant of pollution. By looking at the different species present at a sampling site, we can identify whether stream health is good, fair or poor.

Two monitoring stations have already been established by the City of Surrey to monitor the composition of the benthic invertebrates of McLellan Creek. Station 1 is located in the upper reach of the Creek, north of 64th Avenue between 192nd and 194th Streets. Station 2 is located in the lower reach, south of the Langley Bypass. These two locations should continue to be monitored and two additional locations should be added: one in Cloverdale Canal and one in Cummins Brook. These sites should match the water quality sampling locations.

The stream health data should be collected two times per year.

6.2. Effectiveness Monitoring

There are a number of infrastructure improvements proposed as part of the ISMP implementation plan, which can be generally classified into two groups: those which increase conveyance and those that detain stormwater. The effectiveness of these upgrades should be monitored to ensure they achieve their proposed goal of reducing flooding and retaining stormwater. The exact details of the effectiveness monitoring plan should be developed as part of the specific project design but at a minimum should include the collection of flood complaint data from the public and City of Surrey maintenance staff both before and after implementation. An effectiveness monitoring report should be prepared three years after the completion of the improvement to report on its effectiveness.

For the recommendations related to development, redevelopment and setback it will be very difficult to measure there effectiveness on making changes to the watershed. That is because the implementation of these changes will be in the form of small incremental changes to the watershed. Although we know that changes which reduce effective imperviousness, reduce rainfall and increase infiltration should have a positive effect on the receiving watercourse the change will be too small to notice in any performance indicators.

6.3. Compliance Monitoring

Compliance monitoring is required to see that the items in the implementation plan are being implemented as specified. For the Cloverdale McLellan area the compliance monitoring program should address the site level redevelopment of residential and commercial/industrial redevelopment. The monitoring should include a review of past building permits to confirm if stormwater BMPs were included in the permit documents and on site.

Although this ISMP has recommended new requirements for site redevelopment, it is anticipated that the recommendations regarding site redevelopment will require changes within the City of Surrey building approval process. The changes will require City staff to agree to the recommendations of this ISMP and how is the best way to implement them. At this time it will also be important to outline the specific goals for compliance monitoring of site level redevelopment. Some examples to consider are measurements of % effective impervious or field review of implemented BMPs.

This monitoring should take place annually for the first three years of the program and after that period a compliance monitoring report should be prepared. That report should recommend future compliance monitoring which may need to increase or decrease depending on the level of compliance.

6.4. ISMP Adaptation

The primary purpose of the monitoring is to facilitate adaptation of the ISMP implementation plan to better achieve the watershed vision. This ISMP will not be the last stormwater planning activity for this watershed. In the future, as the science of stormwater management and the application new practices in Surrey changes, the recommendations in this report will need to be revisited. The ISMP monitoring results should be reviewed every 5 years to see if the plan is achieving the desired results. At this time the ISMP should be updated to reflect the results of the monitoring as well as any changes or development around in integrated stormwater planning.

One of the challenges of ISMPs is to solicit active interest from internal and external stakeholders. This was also a challenge faced by the Cloverdale-McLellan ISMP. One of the ways this showed in the level of involvement in review of the ISMP implementation recommendations in the draft report. This means, that although the project team has insured the recommendations are technically sound, there will be additional effort required to obtain buy-in and implementation of the ISMP. The exercise will partially define how this ISMP gets implemented. Because that has not taken place it is too early to begin to outline the details of the ISMP adaption.

7. References

Agriculture and Agri-food Canada, **Canadian Ecodistrict Climate Data**, 2010.

Associated Engineering, **Cloverdale Canal Hydraulic Analysis**, January 1996.

Kerr Wood Leidal Associates Ltd., **South Cloverdale Master Drainage Plan/Functional Plan (Draft**), May 2002.

McElhanney, **Fergus Creek ISMP**, 2007.

Stantec, **Upland Cloverdale Drainage Review**, November 2008.

Appendix A: Operations / Historical Issues

Appendix A –Operations/Historical Issues

Delcan has investigated stormwater issues within the study area. These issues are those identified in previous engineering reports, those raised by City of Surrey operations and engineering staff and those highlighted by Delcan's stormwater model. These issues have been summarized below and categorized into three categories: capacity issues (C), local drainage issues (L) and water quality issues (Q). The locations of each of the issues is shown on **Figure A.1**.

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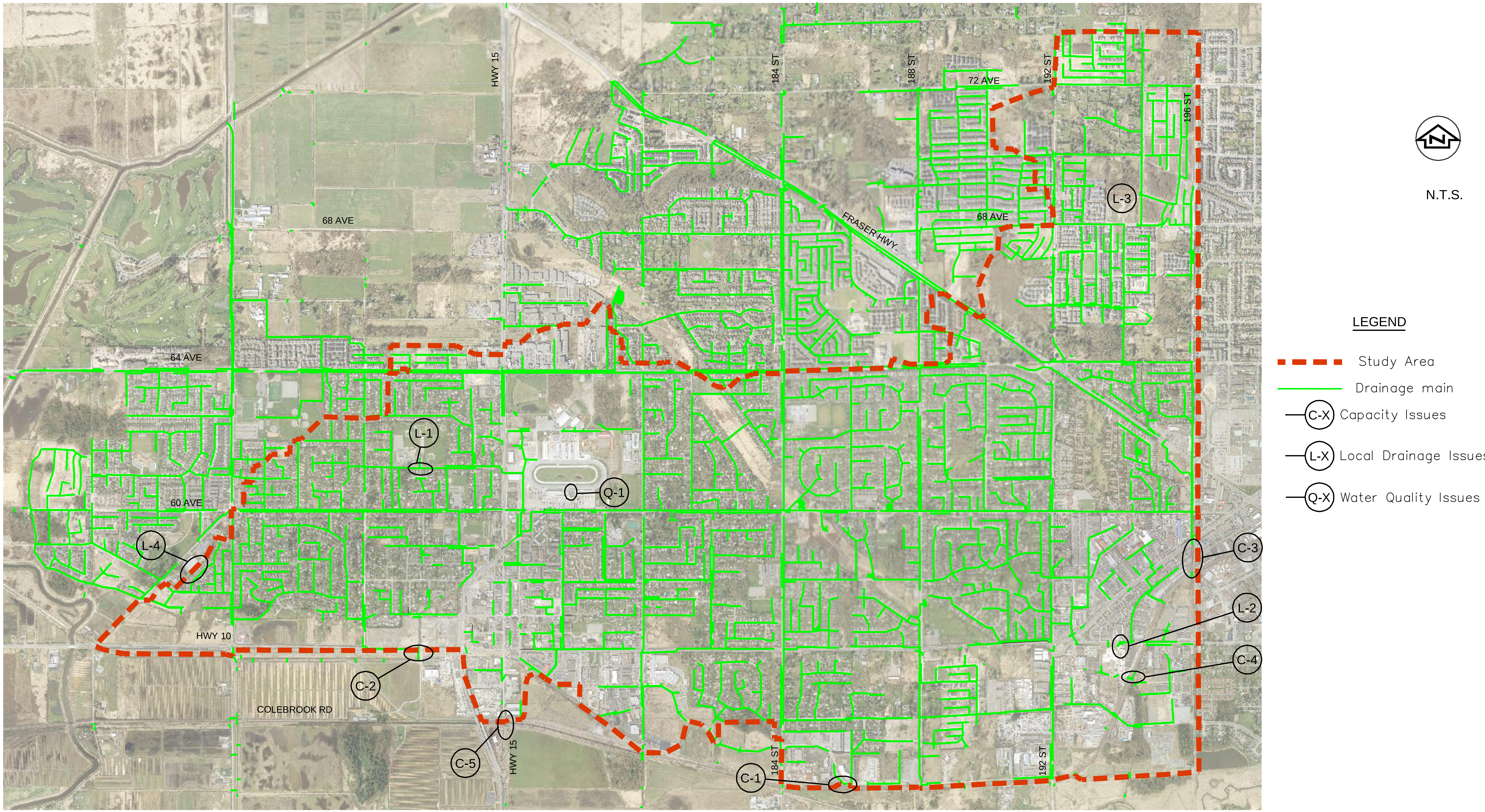
Figure A.1 - OPERATIONS / HISTORICAL ISSUES
Cloverdale McLellan ISMP



EB-3712

Issue C-1

City of Surrey operations staff have reported sewer surcharging in the area of 52nd Avenue and 185A (See **Figure A.1)**. At this location a storm sewer system provides drainage for approximately 15 hectares of residential and industrial area before out letting to the Canadian Pacific Railway to the south. Operations staff have reported that the rail ditch is not cleaned and as a result does not provide adequate drainage at the outlet. **Figures A.2** and **A.3** show the outlet ditch overgrown with vegetation and standing water at the outlet headwall. This ditch system was not fully modeled as part of the trunk sewer analysis but a short capacity calculation showed it was adequately sized.

Figure A.1: Location of sewer surcharging

Figure A.2: Outlet of storm sewer system

Figure A.3: Overgrown ditch outlet for storm sewer system

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Issue C-2

This is a drainage issue raised by both City of Surrey operations and engineering staff at Highway 10 west of the Cloverdale Bypass. During the highway 10 widening project, which involved the relocation of a portion of railway, some of the drainage channels south of Highway 10 were collected in new storm sewer and conveyed to the north side of the Highway 10 to avoid utility conflicts. See **Figures A.4** and **A.5** for the before and after using the 2009 and 2005 air photos. This re-direction of drainage puts additional flows into the drainage system on the north which must be conveyed via a siphon south across Highway 10.

Figure A.4: 2005 Air photo with drainage flow directions

Figure A.5: 2009 Air photo with drainage flow directions

Issue C-3

Operations staff have reported that McLellan Creek channel has capacity issues as it first outlets in the lower portion of the creek (see **Figure A.6**). At this location McLellan Creek runs along the Langley-Surrey border and north of the Langley Bypass is enclosed in two 900 mm concrete pipes (see **Figure A.7** below). After day-lighting, McLellan Creek runs in an open channel (see **Figure A.8** below) for 180 meters south before being conveyed under the Canadian Pacific Railway in a 900mm culvert. Operation staff suspect this culvert is undersized and causing a backwater affect or that the ditch is under capacity. The Delcan XPSWMM model shows that the downstream 900 culvert is right at capacity for the 5 year flow. However, the model cannot account for any sediment build-up or debris in the channel which is a possibility at this location.

Figure A.6: Lower McLellan Creek outlet channel

Figure A.7: outlet of McLellan Creek south of Langley Bypass

Figure A.8: McLellan Creek south of Langley Bypass

Issue C-4

There have also been operational concerns of reported flooding and blockage of the fish-friendly box culvert located along McLellan Creek just as McLellan Creek leaves the alignment of the railway (see **Figure A.9**). Delcan's XP SWMM model found that this culvert is sized adequately to convey the 5 and 100 year peak flows. However the open channel cross section is based on contour data and if there is a restriction at this location a field survey may be required to pick it up.

No debris or recent beaver activity was observed during visits to the site and extensive sedimentation was not noted (see **Figure A.10**). However, lower McLellan Creek is a low gradient portion of the watercourse and sediment deposition is a common occurrence where upstream areas have been developed without stormwater management ponds or BMPs to reduce peak flows.

Figure A.9: Lower McLellan Creek

Figure A.10: Box Culvert on lower McLellan Creek.

Issue C-5

Related to the Highway 10 improvement project, the BC Hydro (Cloverdale) Railway was relocated to go under the rail bridge for Hwy 15/Cloverdale Bypass (see **Figure A.11**). This involved the construction of a new set of rail track just north of a previously existing set of tracks. Conveyance capacity across the railway tracks has been reduced. Delcan's model showed that this 1.2 meter culvert is under capacity for the 5 year event even without considering the potential impacts of backwater from the agricultural channels.

Figure A.11: Conveyance across railway tracks

Issue L-1

There have been issues with poor surface drainage reported at the Cloverdale Ball Park near 61A Avenue to the south (see **Figure A.12**). During rainfall events surface ponding is observed along the north of 61A and the catchbasin inlet capacity appears to be insufficient. **Figure A.13** and **A.14** show that local grading does not convey the water directly to the catch basin and that there is a curb between the swale and catch basin. Delcan has modeled the 750 mm storm sewer running along 61A and found that the sewer has sufficient capacity at this location.

Figure A.12: Location of Surface Drainage Issue

Figure A.13: Shallow Grassed Swale along the North Side of 61A

Figure A.14: Swale Separated from Roadside Catch Basin by Curb.

Issue L-2

West of the railway, south of 56th Avenue, the private land owner has developed their property and filled in the existing ditch/creek without permission of DFO or the City of Surrey. This reach of the channel had an unknown fish habitat classification and its drainage function has not been replaced. This private property location was not visited, photographed or specifically identified during the preparation of this ISMP because of potential enforcement and legal issues.

Issue L-3

During the development of the East Clayton NCP the developer has implemented some traffic calming measures such as raised intersection and traffic humps. City of Surrey Operation Staff have reported that some of these measures have been poorly coordinated with stormwater drainage and local grades resulted in surface ponding and ice problems on the roadway. During site visits a few example of puddles related to incomplete asphalt and local drainage deficiencies were noted but overall there were not a lot of examples of this issue in the McLellan catchment portion of East Clayton (see **Figure A.15, and A.16**).

Figure A.15: Sediment buildup along curb

Figure A.16: ponding against curb

Issue L-4

During the open house one local property owner noted a drainage problem occurring at their lot which is located behind Surrey Centre Elementary School located on Old McLellan Road. They reported that the school playing fields are at a higher elevation then their backyard and that water seeps from the school onto their backyard frequently after storm events.

Issue Q-1

City of Surrey Engineering staff have reported water quality concerns in the Cloverdale Canal. City staff suspect that this could be related to the runoff generated by the Fraser Downs facility. It is unknown at this time if the Fraser Downs facility has a policy or plan in place to treat stormwater discharge from agricultural lands.

Appendix B: Event Modeling

Appendix B – Event Model

Summary

Delcan created an XPSWMM model to investigate the current and potential issues with the stormwater infrastructure in the Cloverdale McLellan Integrated Stormwater Management Plan (ISMP) study area. The model was also used to propose and test potential upgrades to the drainage system.

The XPSWMM modeling files that were previously created to update the South Cloverdale Master Drainage Plan/Function Plan (KWL, 2002) were provided as a starting point for the event modeling in this study. Delcan reviewed and updated all the input parameters provided and additional rainfall scenarios were created.

The updates included new infrastructure such as a new trunk sewer, culverts and infrastructure located north of 64th Avenue as part of the East Clayton development. The update to the hydrology reflected land use changes as a result of recent development. The model corrected known deficiencies in the system that had been raised by Surrey staff and we reviewed the model for inconsistencies with the GIS data received such as catchment delineation, storm drain connectivity and pipe sizing.

Once the XPSWMM model was reviewed and updated, different storm events were run in the model. The standard flood scenarios were run, which cover return periods from 5 year to 200 year ranging in duration from 2 hours to 24 hours. The flood level was determined using the XPSWMM model and applied to the contour data. These scenarios were run for the entire model and were used to highlight adequate and inadequate drainage infrastructure. Those pipes showing surcharging during a 5 year event are those which were highlighted for further review.

Model Set-up

The model was used to run two different land use scenarios: existing conditions and future conditions. The future conditions scenario assumed full build out of current OCP and NCP designations.

Hydrology

The key parameters required for the hydrologic input are listed in **Table B.1**. The methods used to determine the parameters are briefly described. For all parameters used, see the attachments to this memo.

Table B.1: Parameter and Method for Hydrology

Parameter	Method
Catchment Area	The catchment boundaries were determined from the GIS contour data and storm sewer network data provided by the City of Surrey. 155 Catchments were created (see **Figure 2.19**).
Infiltration	The Horton method was used for modeling infiltration. Initial infiltration of 25mm/hr with a minimum infiltration of 5mm/hr. Infiltration parameters were based on the City of Surrey template included in XPSWMM.
Slope	Average slopes of each sub-catchment were determined with Civil 3D based on a surface created with the contours.
Impervious Area (Existing Conditions)	Impervious percentages were determined from the zoning GIS layer and review of aerial photos. Zoning and sub-catchment layers were overlaid to determine each zoning area inside of each sub-catchment. Based on the Surrey design criteria, an impervious percentage was determined for each zoning code. 5% impervious area was used for undeveloped areas.
Impervious Area (Future Conditions)	Impervious percentages were determined from the aerial photo, zoning GIS layer, Surrey OCP and Clayton NCP. Zoning, OCP, NCP and sub-catchment were merged together to determined each zoning area inside of each sub-catchment. Based on the Surrey design criteria, an impervious percentage was determined for each zoning code. 5% impervious area was used for undeveloped areas.
Average Catchment Width	Average width of each catchment has been measured in AutoCAD

Hydraulics

The key parameters required for the hydraulic input are listed in **Table B.2**. The methods used to determine the parameters are briefly described. For all parameters used see **Appendix B-2** of this memo.

Table B.2: Parameter and Method for Hydraulics

Parameter	Method
Routing method	Storm Water Management Model (SWMM) has been used for routing. SWMM is a dynamic rainfall-runoff simulation model used for single event simulation of runoff quantity and quality from primarily urban areas. The runoff component of SWMM operates on a collection of sub-catchment areas that receive precipitation and generate runoff. The routing portion of SWMM transports this runoff through a system of pipes, channels, storage/treatment devices, pumps, and regulators. SWMM tracks the quantity and quality of runoff generated within each sub-catchment, and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprised of multiple time steps.
Diameter	The diameters for the pipes were included in the 2002 XPSWMM model provided; however, it was necessary to check and update them to account for recent construction and correct for changes in new information that has become available since the previous modeling. The XPSWMM model was compared with the GIS data provided by the City of Surrey. Where conflicts or data gaps existed the as-builts were downloaded from COSMOS to confirm. A number of field checks were also performed to check sewer sizes and connectivity where no data was available. Photos from the field visits can be seen in attached.
Length	The lengths for the pipes were included in the 2002 XPSWMM model provided; however, it was necessary to check and update to account for recent construction and correct for changes in new information that has become available since the previous modeling. The XPSWMM model was compared with the GIS data provided by the City of Surrey. Where conflicts or data gaps existed the as-builts were downloaded from COSMOS to confirm. A number of field checks were also preformed to check sewer sizes and connectivity where no data was available. Photos from the field visits can be seen in **Appendix B-4**.
Inverts/Slope	The inverts and slopes for the pipes were included in the 2002 XPSWMM model provided. However, it was required to check and update to account for recent construction and correct for changes in new information that has become available since the previous modeling. The XPSWMM model was compared with the GIS data provided by the City of Surrey. Where conflicts or data gaps existed the as-builts were downloaded from COSMOS to confirm. A number of field checks were also preformed to check

	sewer sizes and connectivity where no data was available. Photos from the field visits can be seen in **Appendix B-4**.
Roughness	The roughnesses for the pipes were included in the 2002 XPSWMM model provided. The following roughness coefficients were used: concrete = 0.013, CSP = 0.020 & natural channel = 0.04
Pond volume	The volumes for the pond were included in the 2002 XPSWMM model provided. However, it was required to check and update to account for recent construction and errors made in the previous modeling. The XPSWMM model was compared with the GIS data provided by the City of Surrey. Where conflicts or data gaps existed the as-builts were downloaded from COSMOS to confirm. A number of field checks were also preformed to check sewer sizes and connectivity where no data was available. Photos from the field visits can be seen in **Appendix B-4**.
Base Flow	Base flow added in the old model has been kept in place

Rainfall

The storms used for the analysis are shown in **Table B.3**. The storm analysis included all the storms outlined in the City of Surrey Design Criteria (May 2004). Graphs showing the storm distributions are found in **Appendix B-3** of this document.

Table B.3: Rainfall event used in the XPSWMM Model

Return Period	Duration	Distribution
5 year	2 hour	Atmospheric Environmental Service (AES)
5 year	6 hour	AES
5 year	24 hour	SCS Type 2
10 year	2 hour	AES
10 year	6 hour	AES
10 year	24 hour	SCS Type 2
25 year	2 hour	AES
25 year	24 hour	SCS Type 2
100 year	2 hour	AES
100 year	24 hour	SCS Type 2
200 year	2 hour	AES
200 year	24 hour	SCS Type 2
10 year	2 day	ARDSA
10 year	5 day	ARDSA

Those storms that were seen to be most critical for infrastructure design were the 2 hour duration events that produced the largest peak flows. Only the 2 hour events were further analyzed as they are a determinant factor for highlighting deficiencies and sizing proposed mitigation measures.

Time Step and Duration

A time step of 30 seconds was used for all catchments at the exception of West Cloverdale where a time step of 120 seconds was used to reduce the running time of the simulation. The duration of the model run was 1.5 days to cover from 2 hours to 24 hours rainfall.

Downstream Boundary Conditions

A key parameter in the model is the downstream boundary conditions. Because the outlet for this study is the lowland agricultural area, there is the potential for the water level in that area to influence the model upstream. The existing models were reviewed to determine the best boundary condition to use. Additionally, KWL was currently undertaking a more detailed study of the lowlands so recent results from their model were obtained from preliminary results of their modeling work. The peak downstream water levels ranged from 1.9 m (Hall's Prairie) to 0.7 m (West Cloverdale) and those values were used for the constant water elevation for the outlets of Delcan's upland model. This boundary condition does not consider the potential for a Nicomekl River flow due to breached or overtopped dikes.

Results

The results are available for each link. **Appendix B-1, table B6,** shows a sample of all the data available for a sample pipe. The parameter Max d/D (depth/diameter) is an indicator that a pipe might be running over capacity. For the existing and future conditions, this parameter was mapped for the 2 hour, 5 and 100 year events. The colour scheme indicates those pipes that are over capacity or approaching capacity.

The difference between the existing and future scenarios is primarily the extent of new development. Three scenarios have been modeled in XPSWMM:

- Existing storm network for the current development;
- Existing storm network for the future development; and
- Upgraded storm network for the future development.

The current development is based on existing land use GIS data and the 2009 aerial photo. The future development is based on the future land use also available in GIS. Moreover, the future development scenario is based on the Surrey OCP and the Clayton NCP. Clayton is located in the north of East Cloverdale and has the largest area yet to be developed in the study area. Fourteen storm events were run in the model. The 2 hour storms for the 5 and 100 year events have been extracted to GIS.

The Surrey design guide requires that any storm network meet the following criteria:

- A minor conveyance capacity up to the 5-year return period storm to minimize the inconvenience of frequent surface runoff.
- A major system conveyance capacity up to the 100-year return period storm to provide safe conveyance of flows to minimize damage to life and property.

To adequately analyze each storm network, each manhole or node in the model was capped to avoid any loss of the water outside of the system. The purpose of this assumption is primarily to ensure that 100% of the water flows from upstream to downstream without any loss. To evaluate any potential flooding in the model the hydraulic line was taken into consideration. When the hydraulic grade line is above existing ground elevation was taken as a potential flooding.

Upgrade Capacity Scenario

The results for the existing and future modeling highlight pipes that should be considered for upgrade. Delcan used the XPSWMM model to determine the new size of pipe that should be considered for that location.

A number of system upgrades are proposed for further investigation. **Figure B.1** shows the location where the pipe has been upgraded in the model. In total 28 pipe systems has been highlight as a problem. Each system can includes more than one pipe.

Furthermore, to visualize the overall of the stormsewer capacity, 6 figures (**Figure B.2-B.7**) has been generated. Each figure represents each scenario as mentioned above for 5 year and 100 year event. Each stormsewer has been divided in different categories:

- 0-75% of pipe capacity
- 75-100% of pipe capacity
- More that 100% of pipe capacity (potential flooding area or pipe surcharging)

For the upgraded capacity there are still links where are showing as running surcharged. In most cases these links are either only a minor surcharge and did not require upgrades. In a few of the cases in the lowland these surcharges links are not shown improved by the upgraded capacity because a simple enlargement of the infrastructure did not solve the problem and further site investigation is recommended in the main body of this ISMP.

Each upgraded infrastructure is included in forms below. Each table shows the ID linking table and the locations show in the **Figure B.1**. The tables show also all pipe details for each scenario:

- Location
- Pipe ID (link number in XPSWMM model)
- Diameter
- Slope
- Material
- Length
- FlowRatio of maximum depth of water on the diameter
- Estimate cost (high level cost of the upgrade)

This analysis was preformed as a screening level. Each pipe ID was then assessed to determine if it should be carried forward to the ISMP documents and included in the recommendations. Some of the links that were originally found to be a problem were determined to have only a minor impact and as a results not carried forward.

Those links that were carried forward were grouped together when neighbouring problem links so that the system as a whole would be assessed for potential improvement. Those areas are highlighted in Figure 4.13 of the main body of this ISMP.

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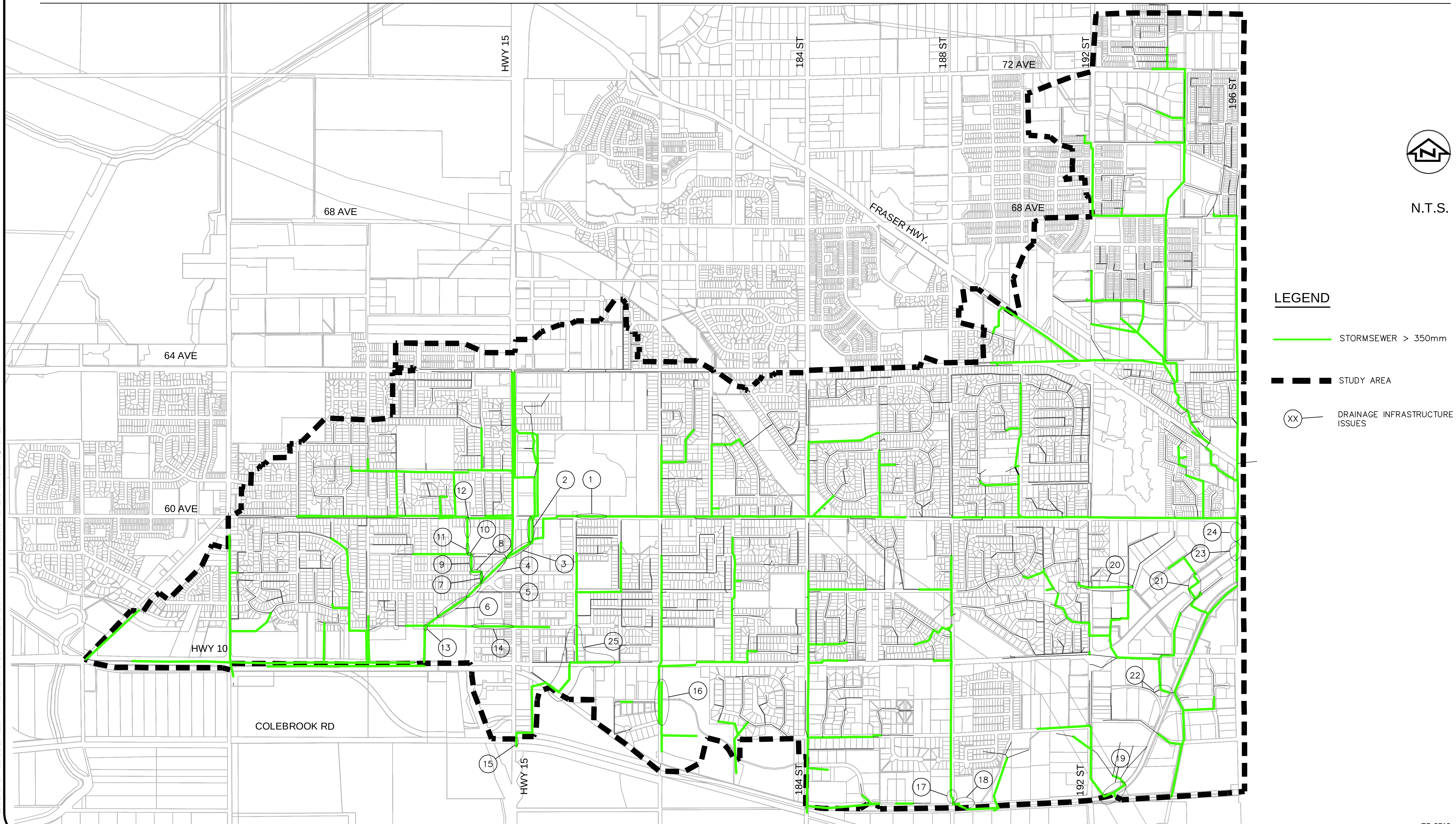
Figure B.1 - Infrastructure Upgrades
Cloverdale McLellan ISMP



EB-3712

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Figure B.2 - Existing Capacity - 5 Year Event
Cloverdale McLellan ISMP

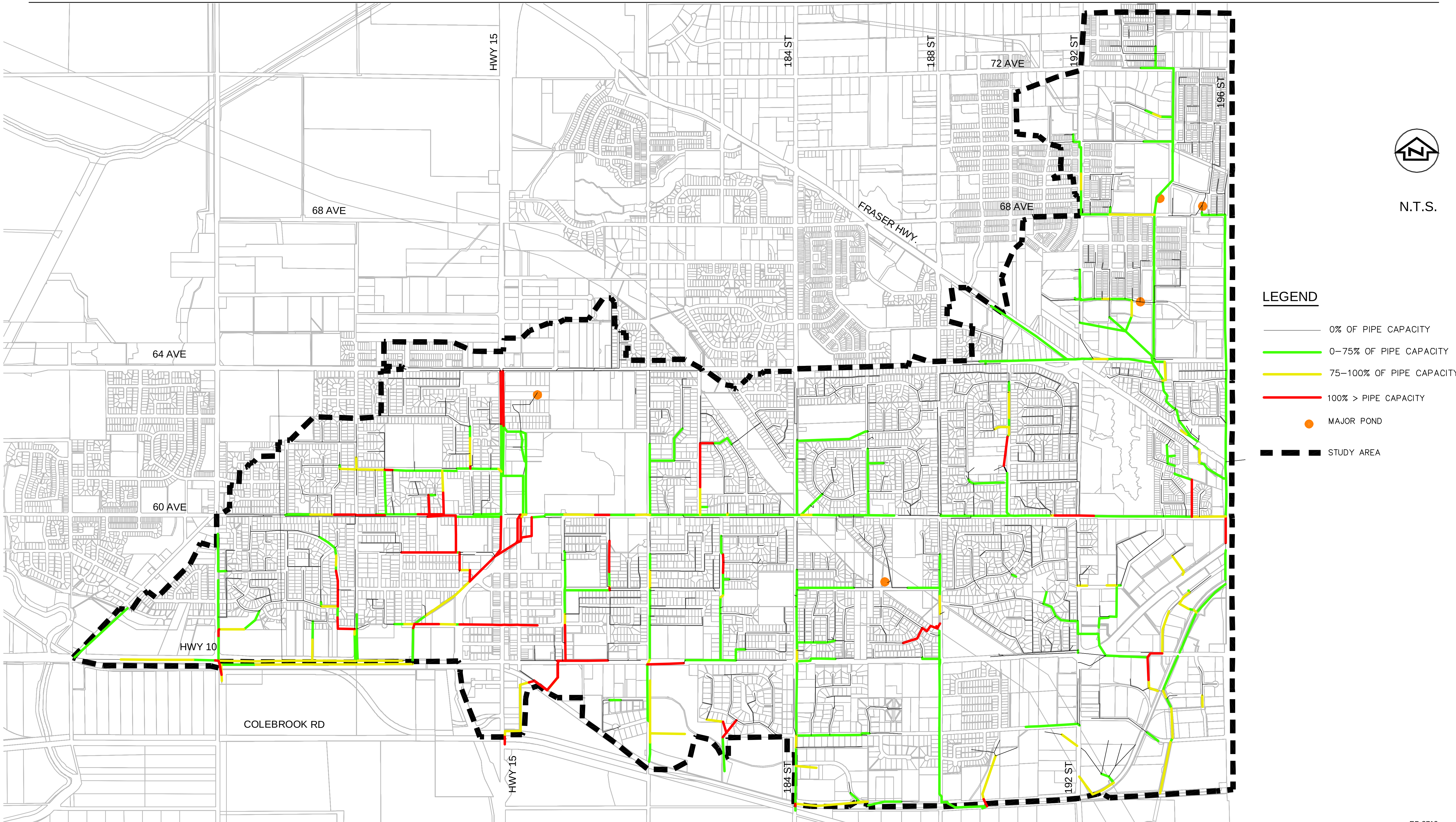

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Figure B.3 - Future Capacity - 5 Year Event
Cloverdale McLellan ISMP

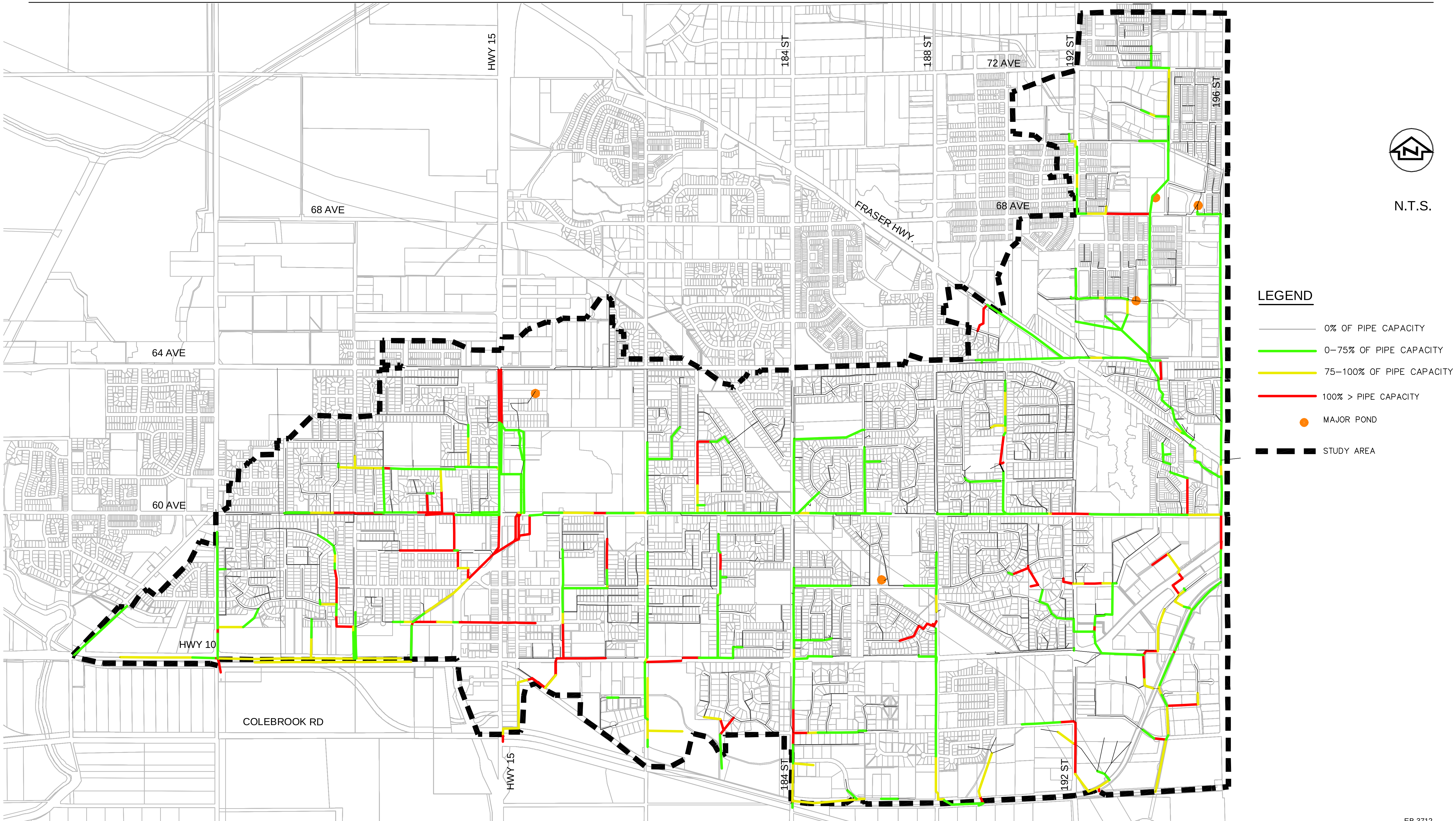

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Figure B.4 - Upgraded Capacity - 5 Year Event
Cloverdale McLellan ISMP

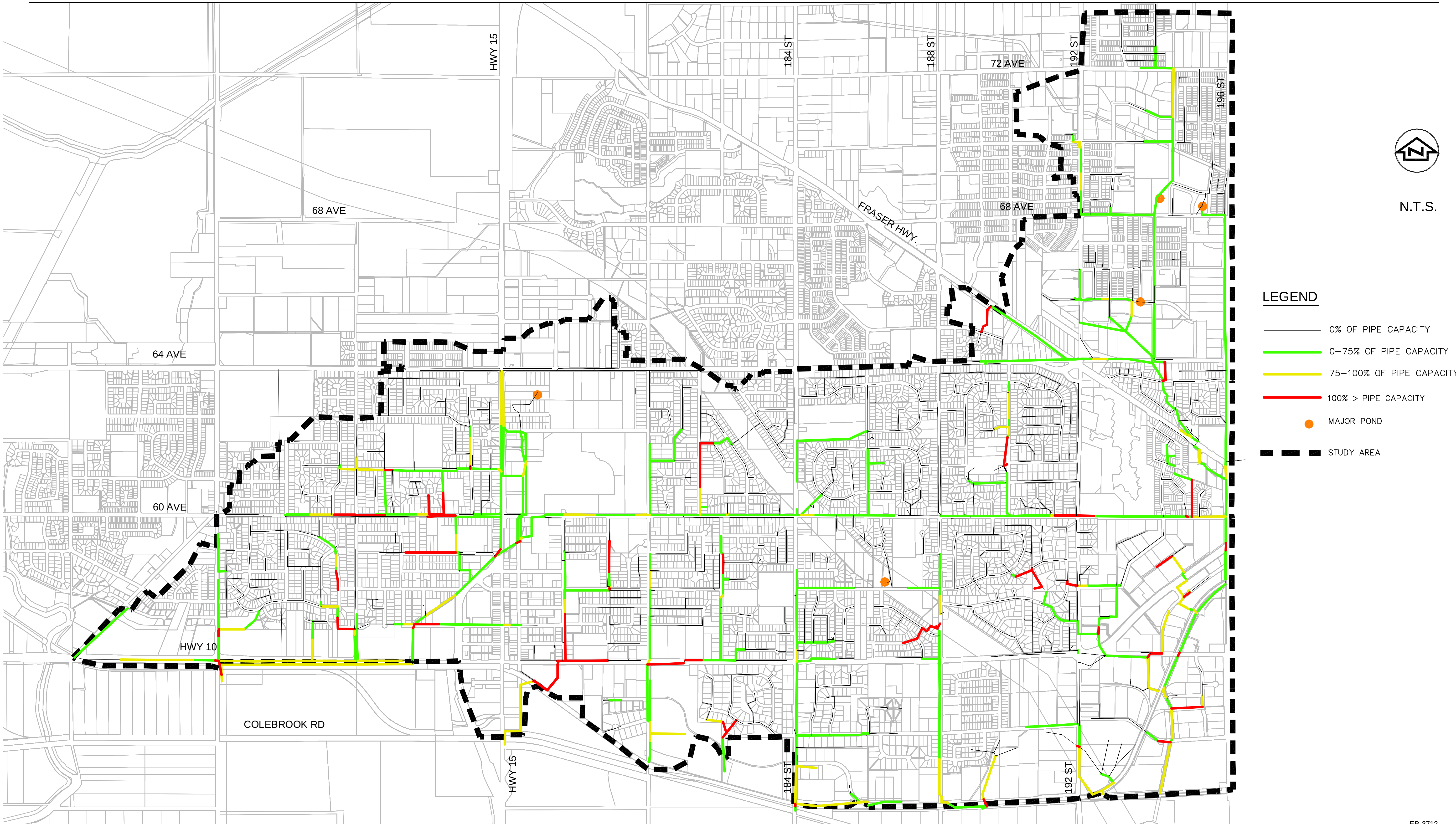

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Figure B.5 - Existing Capacity - 100 Year Event
Cloverdale McLellan ISMP

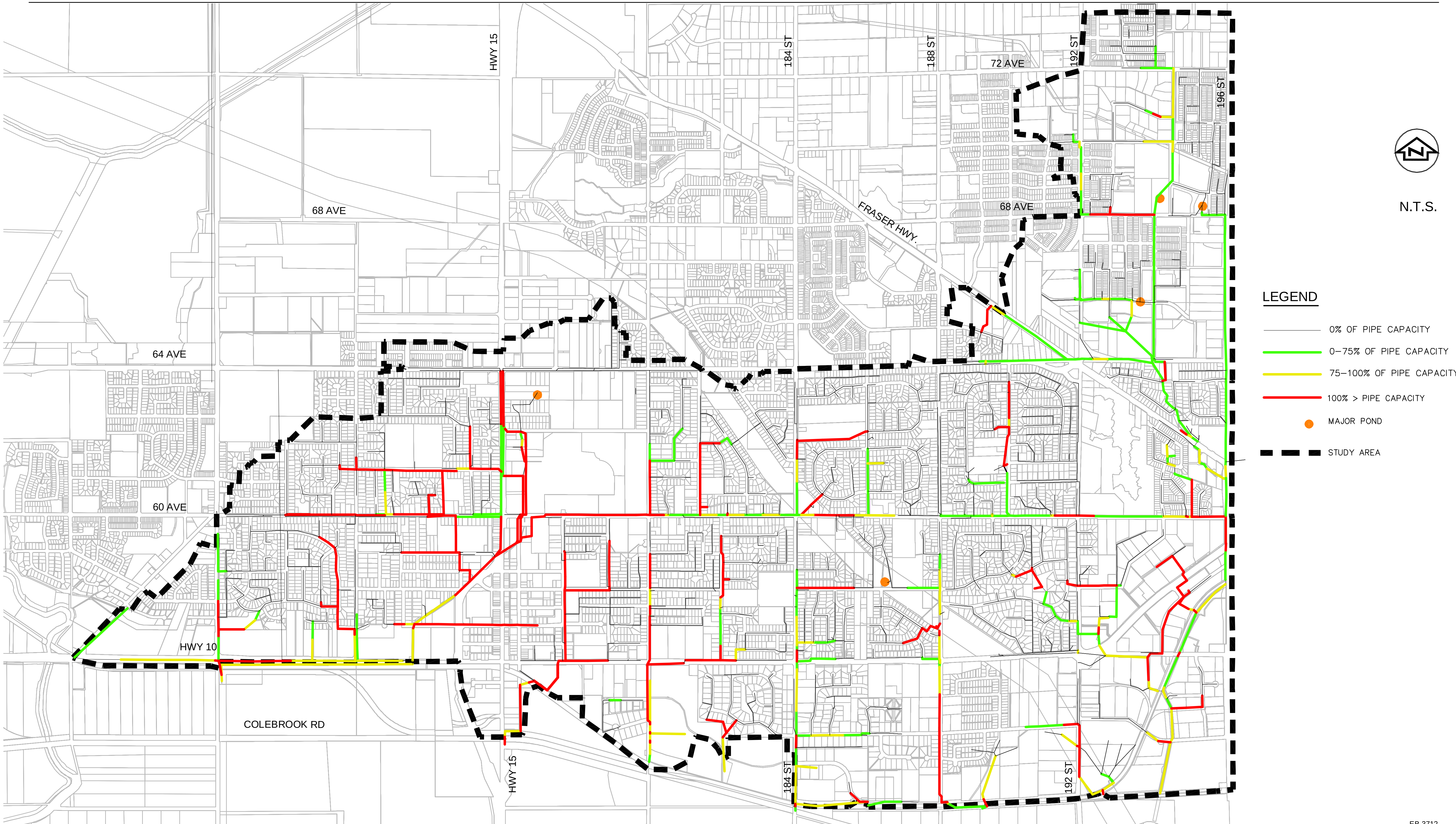

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Figure B.6 - Future Capacity - 100 Year Event
Cloverdale McLellan ISMP

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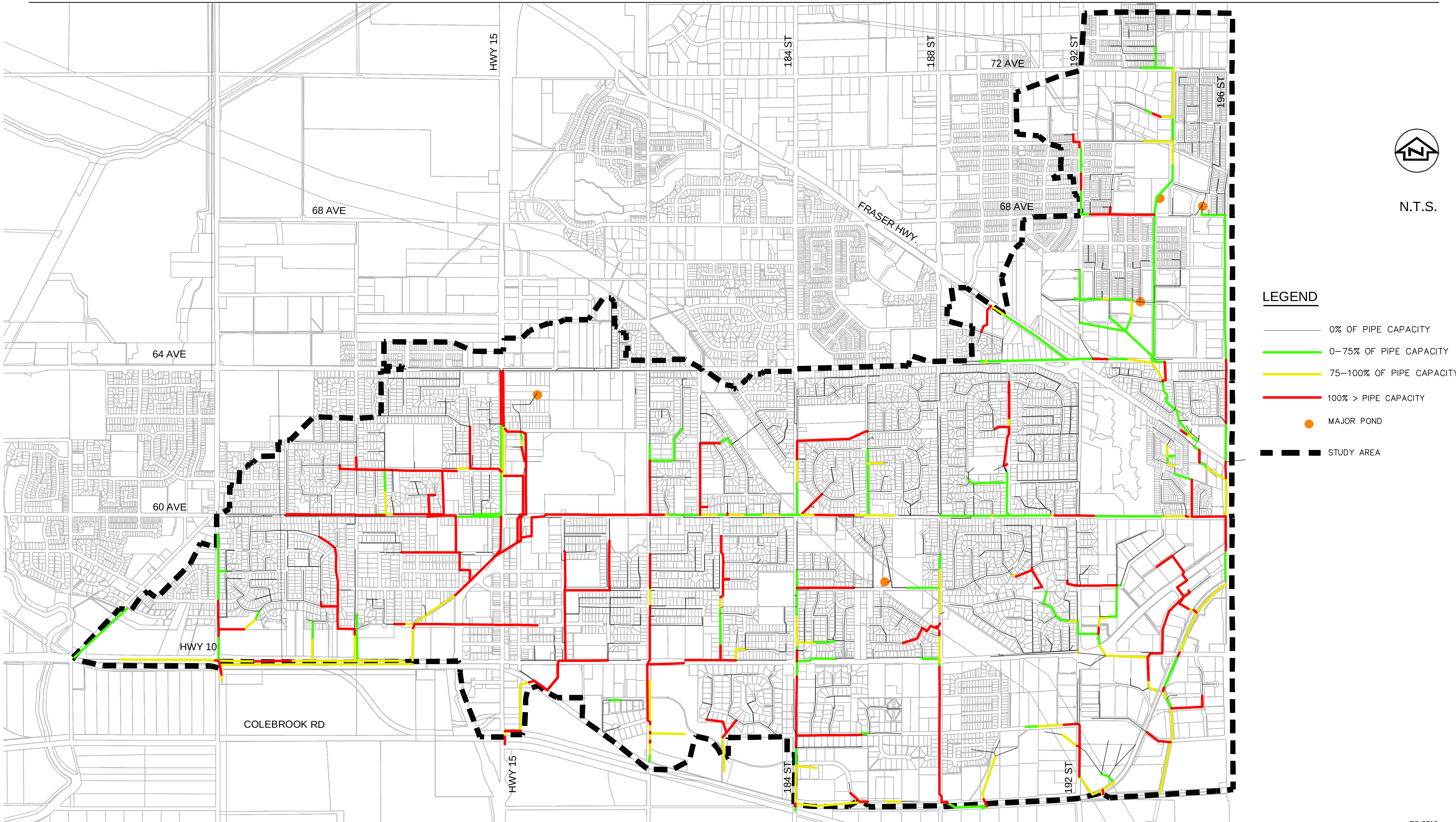

EB-3712

Figure B.7 - Upgraded Capacity - 100 Year Event
Cloverdale McLellan ISMP

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BURNABY, BRITISH COLUMBIA, CANADA V5H 4M2
TEL: 604-438-5300 FAX: 604-438-5350
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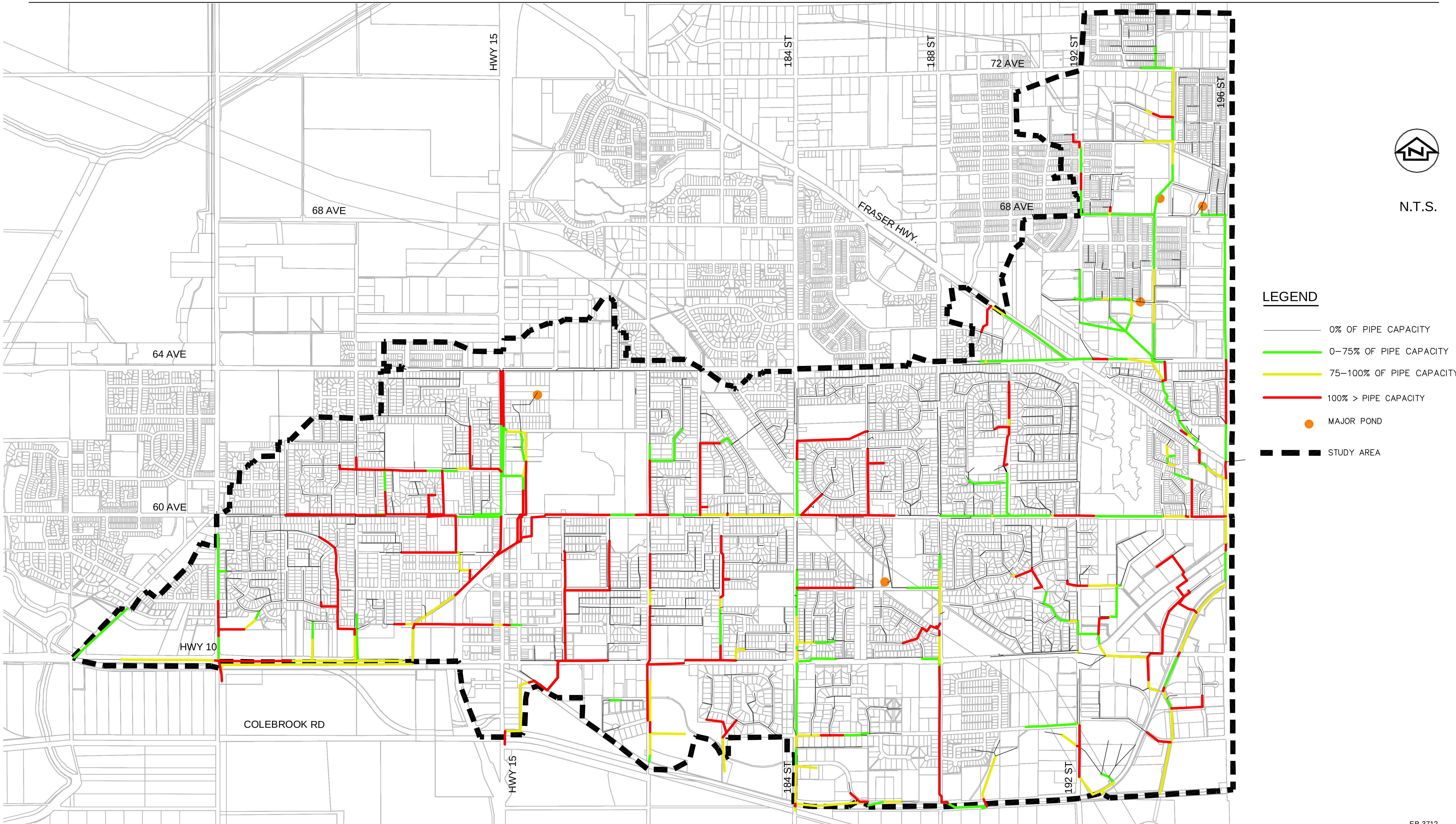


EB-3712

ID: 1		
Location: 60 Ave. between 177B St. and 160 St.		Pipe ID: 485, 486 & 488
Current Pipe (existing development)		
Diameter: 900mm	Slope: 7.50, 10.49 & 6.0%	Material: Concrete
Length**:** 54,23 & 94m		
Analysis		
	5 year	100 year
Flow Rate	485: 1.87 m^3/s 486: 1.87 m^3/s 487: 1.87 m^3/s	485: 3.83 m^3/s 486: 3.33 m^3/s 487: 3.37 m^3/s
Max depth/diameter (d/D)	485: 1.67 486: 1.67 487: 0.43	485: 8.17 486: 8.17 487: 6.90
Current Pipe (future development)		
Diameter: 900mm	Slope: 7.50, 10.49 & 6.0%	Material: Concrete
Length**:** 54,23 & 94m		
Analysis		
	5 year	100 year
Flow Rate	485: 1.87 m^3/s 486: 1.87 m^3/s 487: 1.87 m^3/s	485: 3.83 m^3/s 486: 3.33 m^3/s 487: 3.37 m^3/s
Max depth/diameter (d/D)	485: 1.67 486: 1.67 487: 0.43	485: 8.17 486: 8.17 487: 6.90
Proposed Pipe (future development)		
Diameter: 1050mm	Slope: 7.50, 10.49 & 6.0%	Material: Concrete
Length**:** 54,23 & 94m		
Analysis		

	5 year	100 year
Flow Rate	485: 1.92 m^3/s 486: 1.92 m^3/s 487: 1.92 m^3/s	485: 2.97 m^3/s 486: 2.97 m^3/s 487: 2.97 m^3/s
Max depth/diameter (d/D)	485: 0.66 486: 0.66 487: 0.35	485: 2.03 486: 2.03 487: 0.69
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 230, 000.00	

ID: 2		
Location: corner 176A St. and 60 Ave.		Pipe ID: 546 & 553
Current Pipe (existing development)		
Diameter: 1200mm	Slope: 0.78 & 2.69%	Material: Concrete
Length**:** 117 & 16m		
Analysis		
	5 year	100 year
Flow Rate	546: 2.30 m^3/s 553: 2.23 m^3/s	546: 3.41 m^3/s 553 3.41 m^3/s
Max depth/diameter (d/D)	546: 1.25 553: 1.58	546: 3.24 553: 3.59
Current Pipe (future development)		
Diameter: 1200mm	Slope: 0.78 & 2.69%	Material: Concrete
Length**:** 117 & 16m		
Analysis		
	5 year	100 year
Flow Rate	546: 2.30 m^3/s 553: 2.23 m^3/s	546: 3.41 m^3/s 553 3.41 m^3/s
Max depth/diameter (d/D)	546: 1.25 553: 1.58	546: 3.24 553: 3.59
Proposed Pipe (future development)		
Diameter: 1525mm	Slope: 0.78 & 2.69%	Material: Concrete
Length**:** 117 & 16m		
Analysis		
	5 year	100 year
Flow Rate	546: 2.50 m^3/s 553: 2.50 m^3/s	546: 3.37 m^3/s 553 3.45 m^3/s

Max depth/diameter (d/D)	546: 0.51 553: 0.67	546: 1.11 553: 1.36
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 220, 000.00	

ID: 3		
Location: between hwy. 15 and 176A St.		Pipe ID: 991287
Current Pipe (existing development)		
Diameter: 3050x1200mm	Slope: 0.09%	Material: Concrete
Length**:** 142m		
Analysis		
	5 year	100 year
Flow Rate	4.97 m^3/s	6.70 m^3/s
Max depth/diameter (d/D)	1.58	3.59
Current Pipe (future development)		
Diameter: 3050x1200mm	Slope: 0.09%	Material: Concrete
Length**:** 142m		
Analysis		
	5 year	100 year
Flow Rate	5.02 m^3/s	6.70 m^3/s
Max depth/diameter (d/D)	1.59	3.59
Proposed Pipe (future development)		
Diameter: 3600x1500mm	Slope: 0.09%	Material: Concrete
Length**:** 142m		
Analysis		
	5 year	100 year
Flow Rate	5.45 m^3/s	8.09 m^3/s
Max depth/diameter (d/D)	0.71	1.39
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 680, 000.00	

ID: 4		
Location: Cloverdale Bypass		Pipe ID: 991286
Current Pipe (existing development)		
Diameter: 3050x1200mm	Slope: 0.52%	Material: Concrete
Length**:** 196m		
Analysis		
	5 year	100 year
Flow Rate	5.58 m^3/s	7.41 m^3/s
Max depth/diameter (d/D)	1.56	3.45
Current Pipe (future development)		
Diameter: 3050x1200mm	Slope: 0.52%	Material: Concrete
Length**:** 196m		
Analysis		
	5 year	100 year
Flow Rate	5.62 m^3/s	7.44 m^3/s
Max depth/diameter (d/D)	1.59	3.46
Proposed Pipe (future development)		
Diameter: 3600x1500mm	Slope: 0.52%	Material: Concrete
Length**:** 196m		
Analysis		
	5 year	100 year
Flow Rate	6.08 m^3/s	9.00 m^3/s
Max depth/diameter (d/D)	0.72	1.39
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 950, 000.00	

ID: 5		
Location: Cloverdale Bypass		Pipe ID: 991281
Current Pipe (existing development)		
Diameter: 3050x1200mm	Slope: 0.55%	Material: Concrete
Length**:** 100m		
Analysis		
	5 year	100 year
Flow Rate	7.86 m^3/s	10.7 m^3/s
Max depth/diameter (d/D)	0.98	1.74
Current Pipe (future development)		
Diameter: 3050x1200mm	Slope: 0.55%	Material: Concrete
Length**:** 100m		
Analysis		
	5 year	100 year
Flow Rate	7.90 m^3/s	10.7 m^3/s
Max depth/diameter (d/D)	0.99	1.75
Proposed Pipe (future development)		
Diameter: 3600x1500mm	Slope: 0.55%	Material: Concrete
Length**:** 100m		
Analysis		
	5 year	100 year
Flow Rate	8.72 m^3/s	12.6 m^3/s
Max depth/diameter (d/D)	0.72	1.05
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 485, 000.00	

ID: 6		
Location: Cloverdale Bypass		Pipe ID: 18775
Current Pipe (existing development)		
Trapezoid channel: 3000mm Wide x 940mm height	Slope: 0.29%	Natural Channel
Length**:** 200m		
Analysis		
	5 year	100 year
Flow Rate	7.86 m^3/s	10.444 m^3/s
Max depth/diameter (d/D)	1.00	1.00
Current Pipe (future development)		
Trapezoid channel: 3000mm Wide x 940mm height	Slope: 0.29%	Natural Channel
Length**:** 200m		
Analysis		
	5 year	100 year
Flow Rate	7.90 m^3/s	10.7 m^3/s
Max depth/diameter (d/D)	0.99	1.75
Proposed Pipe (future development)		
Trapezoid channel: 3500mm Wide x 1200mm height	Slope: 0.29%	Natural Channel
Length**:** 200m		
Analysis		
	5 year	100 year
Flow Rate	8.52 m^3/s	12.22 m^3/s
Max depth/diameter (d/D)	0.97	0.99
Estimated Cost:	$ 200, 000.00	

ID: 7		
Location: Corner Cloverdale Bypass and 58A Ave.		Pipe ID: 302
Current Pipe (existing development)		
Diameter: 1050	Slope: 0.78%	Material: Concrete
Length**:** 62m		
Analysis		
	5 year	100 year
Flow Rate	2.22 m^3/s	3.32 m^3/s
Max depth/diameter (d/D)	1.14	2.30
Current Pipe (future development)		
Diameter: 1050	Slope: 0.78%	Material: Concrete
Length**:** 62m		
Analysis		
	5 year	100 year
Flow Rate	2.22 m^3/s	3.32 m^3/s
Max depth/diameter (d/D)	1.14	2.30
Proposed Pipe (future development)		
Diameter: 1525	Slope: 0.78%	Material: Concrete
Length**:** 62m		
Analysis		
	5 year	100 year
Flow Rate	2.33 m^3/s	3.55 m^3/s
Max depth/diameter (d/D)	0.70	1.03
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 112, 000.00	

ID: 8		
Location: Corner Cloverdale Bypass and 58A Ave.		Pipe ID: 283
Current Pipe (existing development)		
Diameter: 1200	Slope: 0.14%	Material: Concrete
Length**:** 56m		
Analysis		
	5 year	100 year
Flow Rate	2.22 m^3/s	3.32 m^3/s
Max depth/diameter (d/D)	0.96	2.26
Current Pipe (future development)		
Diameter: 1200	Slope: 0.14%	Material: Concrete
Length**:** 56m		
Analysis		
	5 year	100 year
Flow Rate	2.22 m^3/s	3.32 m^3/s
Max depth/diameter (d/D)	0.96	2.26
Proposed Pipe (future development)		
Diameter: 1525	Slope: 0.14%	Material: Concrete
Length**:** 56m		
Analysis		
	5 year	100 year
Flow Rate	2.33 m^3/s	3.55 m^3/s
Max depth/diameter (d/D)	0.54	0.80
Estimated Cost:	$ 103, 000.00	

ID: 9		
Location: 175 St. between 59 Ave. and 58A Ave.		Pipe ID: 3136
Current Pipe (existing development)		
Diameter: 1050	Slope: 0.46%	Material: Concrete
Length**:** 86m		
Analysis		
	5 year	100 year
Flow Rate	2.22 m^3/s	3.32 m^3/s
Max depth/diameter (d/D)	1.17	3.33
Current Pipe (future development)		
Diameter: 1050	Slope: 0.46%	Material: Concrete
Length**:** 86m		
Analysis		
	5 year	100 year
Flow Rate	2.22 m^3/s	3.32 m^3/s
Max depth/diameter (d/D)	1.17	3.33
Proposed Pipe (future development)		
Diameter: 1525	Slope: 0.46%	Material: Concrete
Length**:** 86m		
Analysis		
	5 year	100 year
Flow Rate	2.33 m^3/s	3.55 m^3/s
Max depth/diameter (d/D)	0.50	0.76
Estimated Cost:	$ 160, 000.00	

ID: 10		
Location: 175 St. between 59 Ave. and 58A Ave.		Pipe ID: 282
Current Pipe (existing development)		
Diameter: 1050	Slope: 0.54%	Material: Concrete
Length**:** 12m		
Analysis		
	5 year	100 year
Flow Rate	1.90 m^3/s	2.85 m^3/s
Max depth/diameter (d/D)	1.17	3.40
Current Pipe (future development)		
Diameter: 1050	Slope: 0.54%	Material: Concrete
Length**:** 12m		
Analysis		
	5 year	100 year
Flow Rate	1.90 m^3/s	2.85 m^3/s
Max depth/diameter (d/D)	1.17	3.40
Proposed Pipe (future development)		
Diameter: 1200	Slope: 0.54%	Material: Concrete
Length**:** 12m		
Analysis		
	5 year	100 year
Flow Rate	1.98 m^3/s	3.12 m^3/s
Max depth/diameter (d/D)	0.61	0.87
Estimated Cost:	$ 20, 000.00	

ID: 11		
Location: between 175A st. and 176A st.		Pipe ID: 255
Current Pipe (existing development)		
Diameter: 900	Slope: 0.73%	Material: Concrete
Length**:** 100m		
Analysis		
	5 year	100 year
Flow Rate	1.59 m^3/s	2.33 m^3/s
Max depth/diameter (d/D)	3.31	3.69
Current Pipe (future development)		
Diameter: 900	Slope: 0.73%	Material: Concrete
Length**:** 100m		
Analysis		
	5 year	100 year
Flow Rate	1.59 m^3/s	2.33 m^3/s
Max depth/diameter (d/D)	3.31	3.69
Proposed Pipe (future development)		
Diameter: 1050	Slope: 0.73%	Material: Concrete
Length**:** 100m		
Analysis		
	5 year	100 year
Flow Rate	1.63 m^3/s	2.51 m^3/s
Max depth/diameter (d/D)	0.76	1.58
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 140, 000.00	

ID: 12		
Location: between 175A st. and 176A st.		Pipe ID: 228
Current Pipe (existing development)		
Diameter: 900	Slope: 0.80%	Material: Concrete
Length**:** 107m		
Analysis		
	5 year	100 year
Flow Rate	1.59 m^3/s	2.33 m^3/s
Max depth/diameter (d/D)	3.30	4.40
Current Pipe (future development)		
Diameter: 900	Slope: 0.80%	Material: Concrete
Length**:** 107m		
Analysis		
	5 year	100 year
Flow Rate	1.59 m^3/s	2.33 m^3/s
Max depth/diameter (d/D)	3.30	4.40
Proposed Pipe (future development)		
Diameter: 1050	Slope: 0.80%	Material: Concrete
Length**:** 107m		
Analysis		
	5 year	100 year
Flow Rate	1.63 m^3/s	2.51 m^3/s
Max depth/diameter (d/D)	0.75	1.57
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 150, 000.00	

ID: 13		
Location: Across 57 Av.		Pipe ID: 18777
Current Pipe (existing development)		
3600 x 1200mm box culvert	Slope: 0.16%	Material: Concrete
Length**:** 31m		
Analysis		
	5 year	100 year
Flow Rate	8.20 m^3/s	10.86 m^3/s
Max depth/diameter (d/D)	1.46	2.09
Current Pipe (future development)		
3600 x 1200mm box culvert	Slope: 0.16%	Material: Concrete
Length**:** 31m		
Analysis		
	5 year	100 year
Flow Rate	8.22 m^3/s	10.92 m^3/s
Max depth/diameter (d/D)	1.49	2.12
Proposed Pipe (future development)		
4250 x 1500mm box culvert	Slope: 0.16%	Material: Concrete
Length**:** 31m		
Analysis		
	5 year	100 year
Flow Rate	8.97 m^3/s	12.53 m^3/s
Max depth/diameter (d/D)	1.07	1.60
Comments:	Proposed pipe for 5 and 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 150, 000.00	

ID: 14		
Location: 57 Av. Between 175 st. and 177B st.		Pipe ID: CW4,CW5,CW6 & CW7
Current Pipe (existing development)		
Diameter: 525mm	Slope: 0.51%, 0.49%, 0.56% & 0.35%	Material: Concrete
Length**:** 20, 165, 45 & 20m		
Analysis		
	5 year	100 year
Flow Rate	CW4: 0.55 m^3/s CW5: 0.41 m^3/s CW6: 0.41 m^3/s CW7: 0.41 m^3/s	CW4: 0.85 m^3/s CW5: 0.64 m^3/s CW6: 0.64 m^3/s CW7: 0.64 m^3/s
Max depth/diameter (d/D)	CW4: 1.19 CW5: 2.34 CW6: 2.61 CW7: 2.81	CW4: 3.63 CW5: 8.40 CW6: 9.62 CW7: 10.22
Current Pipe (future development)		
Diameter: 525mm	Slope: 0.51%, 0.49%, 0.56% & 0.35%	Material: Concrete
Length**:** 20, 165, 45 & 20m		
Analysis		
	5 year	100 year
Flow Rate	CW4: 0.55 m^3/s CW5: 0.41 m^3/s CW6: 0.41 m^3/s CW7: 0.41 m^3/s	CW4: 0.85 m^3/s CW5: 0.64 m^3/s CW6: 0.64 m^3/s CW7: 0.64 m^3/s
Max depth/diameter (d/D)	CW4: 1.19 CW5: 2.34	CW4: 3.63 CW5: 8.40

	CW6: 2.61 CW7: 2.81	CW6: 9.62 CW7: 10.22
Proposed Pipe (future development)		
Diameter: 750mm	Slope: 0.51%, 0.49%, 0.56% & 0.35%	Material: Concrete
Length: 20, 165, 45 & 20m		
Analysis		
	5 year	100 year
Flow Rate	CW4: 0.55 m^3/s CW5: 0.41 m^3/s CW6: 0.41 m^3/s CW7: 0.41 m^3/s	CW4: 0.85 m^3/s CW5: 0.64 m^3/s CW6: 0.64 m^3/s CW7: 0.64 m^3/s
Max depth/diameter (d/D)	CW4: 0.46 CW5: 0.55 CW6: 0.54 CW7: 0.58	CW4: 1.33 CW5: 1.50 CW6: 0.99 CW7: 0.82
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed.	
Estimated Cost:	$ 250, 000.00	

ID: 15		
Location: Corner 176 St. and BC railway		Pipe ID: 18777
Current Pipe (existing development)		
Diameter: 1200	Slope: 0.47%	Material: Corrugated steel
Length**:** 43m		
Analysis		
	5 year	100 year
Flow Rate	1.70 m^3/s	2.15 m^3/s
Max depth/diameter (d/D)	1.16	1.39
Current Pipe (future development)		
Diameter: 1200	Slope: 0.47%	Material: Corrugated steel
Length**:** 43m		
Analysis		
	5 year	100 year
Flow Rate	1.76 m^3/s	2.18 m^3/s
Max depth/diameter (d/D)	1.18	1.42
Proposed Pipe (future development)		
Diameter: 1525	Slope: 0.47%	Material: Corrugated steel
Length**:** 43m		
Analysis		
	5 year	100 year
Flow Rate	2.08 m^3/s	2.91 m^3/s
Max depth/diameter (d/D)	0.84	1.03
Comments:	Proposed pipe for 100 year event allow surcharge in the sewer. However, no flooding is observed. Culvert across the rail way	
Estimated Cost:	$ 210, 000.00 (trenchless under the track)	

ID: 16		
Location: 180 St. south of 56 Ave.		Pipe ID: 8094, 8095, 8087, 8098 8099, 8100 & 8101
Current Pipe (existing development)		
Diameter: 1350 culvert (8094, 8097, 8099 & 8101) Open Channel: 1.5x1.5m (8095, 8098 & 8100)	Slope: 0% for 8094,8095,8097,8099 8101. 0.01% for 8098 & 8100	Material: Concrete for culvert and natural cover for channel
Length**:** 13, 44, 7, 41, 10, 40 & 23m		
Analysis		
	5 year	100 year
Flow Rate	1.89 m^3/s	3.15 m^3/s
Max depth/diameter (d/D)	8094: 0.92 8095: 0.80 8097: 0.86 8098: 0.75 8099: 0.80 8100: 0.69 8101: 0.72	8094: 1.22 8095: 1.00 8097: 1.13 8098: 0.97 8099: 1.04 8100: 0.88 8101: 0.92
Current Pipe (future development)		
Diameter: 1350 culvert (8094, 8097, 8099 & 8101) Open Channel: 1.5x1.5m (8095, 8098 & 8100)	Slope: 0% for 8094,8095,8097,8099 8101. 0.01% for 8098 & 8100	Material: Concrete for culvert and natural cover for channel
Length**:** 13, 44, 7, 41, 10, 40 & 23m		
Analysis		
	5 year	100 year
Flow Rate	2.00 m^3/s	3.28 m^3/s
Max depth/diameter (d/D)	8094: 0.94	8094: 1.27

	8095: 0.82 8097: 0.88 8098: 0.77 8099: 0.82 8100: 0.71 8101: 0.74	8095: 1.00 8097: 1.17 8098: 1.00 8099: 1.07 8100: 0.91 8101: 0.95
Proposed Pipe (future development)		
2100x1200mm box culvert	Slope: 0.01%	Material: Concrete
Length**:** 178m		
Analysis		
	5 year	100 year
Flow Rate	2.05 m^3/s	3.42 m^3/s
Max depth/diameter (d/D)	0.79	0.99
Comments:	Box culvert is proposed by City of Surrey on the Cosmos GIS website	
Estimated Cost:	$ 470, 000.00	

ID: 17		
Location: Corner 188 St. and railway		Pipe ID: 1752 & 1756
Current Pipe (existing development)		
Diameter: 525	Slope: 1.98 & 3.16%	Material: Concrete
Length**:** 18 & 32m		
Analysis		
	5 year	100 year
Flow Rate	0.39 m^3/s	0.79 m^3/s
Max depth/diameter (d/D)	1752: 0.59 1756: 0.59	1752: 1.53 1756: 1.37
Current Pipe (future development)		
Diameter: 525	Slope: 1.98 & 3.16%	Material: Concrete
Length**:** 18 & 32m		
Analysis		
	5 year	100 year
Flow Rate	0.60 m^3/s	0.90 m^3/s
Max depth/diameter (d/D)	1752: 0.81 1756: 0.83	1752: 3.03 1756: 2.51
Proposed Pipe (future development)		
Diameter: 600	Slope: 1.98 & 3.16%	Material: Concrete
Length**:** 18 & 32m		
Analysis		
	5 year	100 year
Flow Rate	0.60 m^3/s	0.93 m^3/s
Max depth/diameter (d/D)	1752: 0.61 1756: 0.59	1752: 0.93 1756: 0.87
Estimated Cost:	$ 45, 000.00	

ID: 18		
Location: Corner 188 St. and railway		Pipe ID: 1755
Current Pipe (existing development)		
Diameter: 600	Slope: 1.06%	Material: Concrete
Length**:** 33m		
Analysis		
	5 year	100 year
Flow Rate	0.39 m^3/s	0.79 m^3/s
Max depth/diameter (d/D)	0.62	1.16
Current Pipe (future development)		
Diameter: 600	Slope: 1.06%	Material: Concrete
Length**:** 33m		
Analysis		
	5 year	100 year
Flow Rate	0.60 m^3/s	0.90 m^3/s
Max depth/diameter (d/D)	0.79	1.63
Proposed Pipe (future development)		
Diameter: 600	Slope: 1.06%	Material: Concrete
Length**:** 33m		
Analysis		
	5 year	100 year
Flow Rate	0.60 m^3/s	0.90 m^3/s
Max depth/diameter (d/D)	0.63	0.87
Estimated Cost:	$ 32, 000.00	

ID: 19		
Location: Canadian pacific railway between 52 Ave. 51B Ave.		Pipe ID: 8046
Current Pipe (existing development)		
Diameter: 725	Slope: 0.15%	Material: Corrugated Steel
Length**:** 21m		
Analysis		
	5 year	100 year
Flow Rate	0.92 m^3/s	1.19 m^3/s
Max depth/diameter (d/D)	1.33	1.74
Current Pipe (future development)		
Diameter: 725	Slope: 0.15%	Material: Corrugated Steel
Length**:** 21m		
Analysis		
	5 year	100 year
Flow Rate	1.02 m^3/s	1.21 m^3/s
Max depth/diameter (d/D)	1.47	1.77
Proposed Pipe (future development)		
Diameter: 1050	Slope: 0.15%	Material: Corrugated Steel
Length**:** 21m		
Analysis		
	5 year	100 year
Flow Rate	1.33 m^3/s	1.85m^3/s
Max depth/diameter (d/D)	0.80	0.97
Comments:	Culvert is across the rail	
Estimated Cost:	$ 75, 000.00	

ID: 20		
Location: 191A St. & Enterprise highway		Pipe ID: 1198, 1204, 1527, 1525, 1525 & 993157
Current Pipe (existing development)		
Diameter: 450	Slope: 1.0, 1.61, 3.34, 3.34, 3.34 & 3.3%	Material: Concrete
Length**:** 116, 19, 65, 29, 15 & 57m		
Analysis		
	5 year	100 year
Flow Rate	1198, 1204: 0.41 m^3/s 1527, 1526, 1525, 993157 : 0.57 m^3/s	1198, 1204: 0.57 m^3/s 1527, 1526, 1525, 993157 : 0.81 m^3/s
Max depth/diameter (d/D)	1198: 3.66 1204: 1.30 1527: 1.20 1526: 1.14 1525: 1.00 993157: 1.00	1198: 5.10 1204: 2.83 1527: 4.74 1526: 4.48 1525: 3.51 993157: 2.99
Current Pipe (future development)		
Diameter: 450	Slope: 1.0, 1.61, 3.34, 3.34, 3.34 & 3.3%	Material: Concrete
Length**:** 116, 19, 65, 29, 15 & 57m		
Analysis		
	5 year	100 year
Flow Rate	1198, 1204: 0.41 m^3/s 1527, 1526, 1525, 993157 : 0.57 m^3/s	1198, 1204: 0.57 m^3/s 1527, 1526, 1525, 993157 : 0.81 m^3/s
Max depth/diameter (d/D)	1198: 3.66 1204: 1.30 1527: 1.20 1526: 1.14	1198: 5.10 1204: 2.83 1527: 4.74 1526: 4.48

	1525: 1.00 993157: 1.00	1525: 3.51 993157: 2.99
Proposed Pipe (future development)		
Diameter: 525	Slope: 1.0, 1.61, 3.34, 3.34, 3.34 & 3.3%	Material: Concrete
Length**:** 116, 19, 65, 29, 15 & 57m		
Analysis		
	5 year	100 year
Flow Rate	1198, 1204: 0.41 m^3/s 1527, 1526, 1525, 993157 : 0.57 m^3/s	1198, 1204: 0.57 m^3/s 1527, 1526, 1525, 993157 : 0.81 m^3/s
Max depth/diameter (d/D)	1198: 0.78 1204: 1.00 1527: 0.63 1526: 0.63 1525: 0.63 993157: 0.73	1198: 3.74 1204: 2.28 1527: 0.85 1526: 0.85 1525: 0.85 993157: 0.92
Comments:		
Estimated Cost:	$ 220, 000.00	

ID: 21		
Location: Corner of Langley Bypass and Landmark gate		Pipe ID: 1518, 1534 & 1540
Current Pipe (existing development)		
Diameter: 600	Slope: 0.54, 0.18 & 0.52%	Material: concrete
Length**:** 40, 66 & 64m		
Analysis		
	5 year	100 year
Flow Rate	0.48 m^3/s	0.63 m^3/s
Max depth/diameter (d/D)	1518: 1.08 1534: 1.42 1540: 1.04	1518: 2.97 1534: 3.01 1540: 2.12
Current Pipe (future development)		
Diameter: 600	Slope: 0.54, 0.18 & 0.52%	Material: concrete
Length**:** 40, 66 & 64m		
Analysis		
	5 year	100 year
Flow Rate	0.49 m^3/s	0.63 m^3/s
Max depth/diameter (d/D)	1518: 1.04 1534: 1.43 1540: 1.06	1518: 2.97 1534: 3.01 1540: 2.12
Proposed Pipe (future development)		
Diameter: 750	Slope: 0.54, 0.18 & 0.52%	Material: concrete
Length**:** 40, 66 & 64m		
Analysis		
	5 year	100 year
Flow Rate	0.49 m^3/s	0.63 m^3/s
Max depth/diameter (d/D)	1518: 0.57	1518: 1.69

	1534: 0.76 1540: 0.82	1534: 1.98 1540:1.78
Comments:	Proposed pipe for 100 year event allow surcharge in the culvert. However, no flooding is observed.	
Estimated Cost:	$ 180, 000.00	

ID: 22		
Location: Between 54 Ave. & 56 Ave. west of production blvd		Pipe ID: 8017
Current Pipe (existing development)		
Diameter: twin 900	Slope: 0.18%	Material: corrugated steel
Length**:** 30m		
Analysis		
	5 year	100 year
Flow Rate	1.34 m^3/s	1.76 m^3/s
Max depth/diameter (d/D)	1.73	2.23
Current Pipe (future development)		
Diameter: twin 900	Slope: 0.18%	Material: corrugated steel
Length**:** 30m		
Analysis		
	5 year	100 year
Flow Rate	1.34 m^3/s	1.76 m^3/s
Max depth/diameter (d/D)	1.8	1.8
Proposed Pipe (future development)		
Diameter: twin 1350	Slope: 0.18%	Material: corrugated steel
Length**:** 30m		
Analysis		
	5 year	100 year
Flow Rate	1.36 m^3/s	1.90 m^3/s
Max depth/diameter (d/D)	0.94	1.11

Comments:	Proposed pipe for 100 year event allow surcharge in the culvert. However, no flooding is observed. Twin culvert cross the railway
Estimated Cost:	$ 250,000.00 (trenchless under the track)

ID: 23		
Location: South of Hwy 10 between 176 and 177B st.		Pipe ID: 8001, 8002
Current Pipe (existing development)		
Diameter: twin 900mm + 1500mm	Slope: 1.41 (900mm), 1.55 (900mm) 1.41% (1500mm)	Material: Corrugated Steel (2x900mm) Concrete (1500mm)
Length**:** 3 **x** 41m		
Analysis		
	5 year	100 year
Flow Rate	4.84 m^3/s	7.13 m^3/s
Max depth/diameter (d/D)	8001 (900mm): 1.47 8001 (1500mm): 0.89 8002 (900mm): 1.46	8001 (900mm): 1.71 8001 (1500mm): 1.03 8002 (900mm):1.70
Current Pipe (future development)		
Diameter: twin 900mm + 1500mm	Slope: 1.41 (900mm), 1.55 (900mm) 1.41% (1500mm)	Material: Corrugated Steel (2x900mm) Concrete (1500mm)
Length**:** 3 **x** 41m		
Analysis		
	5 year	100 year
Flow Rate	5.70 m^3/s	8.35 m^3/s
Max depth/diameter (d/D)	8001 (900mm): 1.57 8002 (1500mm): 0.94 8001 (900mm): 1.56	8001 (900mm): 1.82 8002 (1500mm): 1.10 8001 (900mm):1.81
Proposed Pipe (future development)		
Diameter: 1800mm	Slope: 1.41% (1800mm)	Material: Concrete (1800mm)
Length**:** 41m		
Analysis		
	5 year	100 year

Flow Rate	5.70 m^3/s	8.35 m^3/s
Max depth/diameter (d/D)	8001 (1800mm): 0.78	8001 (1800mm): 0.91
Comments:	Culvert crossing the railway	
Estimated Cost:	$ 300, 000.00 (trenchless under the railway track)	

ID: 24		
Location: Intersection of Langley Bypass and 196 St.		Pipe ID: 1497
Current Pipe (existing development)		
Diameter: 1350mm + 1500mm	Slope: 0.87% (1350mm) 0.87% (1500mm)	Material: Concrete (1350mm) Concrete (1500mm)
Length**:** 2 x 135m		
Analysis		
	5 year	100 year
Flow Rate	4.84 m^3/s	7.13 m^3/s
Max depth/diameter (d/D)	1497 (1350mm): 1.25 1497 (1500mm): 1.19	1497 (1350mm): 1.63 1497 (1500mm): 1.39
Current Pipe (future development)		
Diameter: 1350mm + 1500mm	Slope: 0.87% (1350mm) 0.87% (1500mm)	Material: Concrete (1350mm) Concrete (1500mm)
Length**:** 2 x 135m		
Analysis		
	5 year	100 year
Flow Rate	5.70 m^3/s	8.35 m^3/s
Max depth/diameter (d/D)	1497 (1350mm): 1.37 1497 (1500mm): 1.23	1497 (1350mm): 1.77 1497 (1500mm): 1.58
Proposed Pipe (future development)		
Diameter: 1800mm	Slope: 0.87% (1800mm)	Material: Concrete (1800mm)
Length**:** 135m		
Analysis		
	5 year	100 year
Flow Rate	5.70 m^3/s	8.35 m^3/s
Max depth/diameter (d/D)	1497 (1800mm): 0.70	1497 (1800mm): 0.91

Estimated Cost:	$ 310, 000.00	

ID: 25A		
Location: South of Hwy 10 between 176 and 177B St.		Pipe ID: 993073, 998004, 1611 1621,1622,998006, 3424
Current Pipe (existing development)		
Diameter: 1200mm (993073) 900mm (others)	Slope: 0.03, 0.11, 0.13, 0.13, 0.13, 0.09 & 0.04	Material: Corrugated (3424) Concrete (others)
Length**:** 14.7, 8.18, 72.1, 90.3, 90.3, 3.5 & 27.3m		
Analysis		
	5 year	100 year
Flow Rate	0.444 m^3/s 1.485 m^3/s (3424 & 993073)*	0.654 m^3/s 2.118 m^3/s (3424 & 993073)*
Max depth/diameter (d/D)	993073: 0.957 998004: 1.268 1611: 1.325 1621: 1.394 1622: 1.462 998006: 1.462 3424: 1.435	993073: 1.644 998004: 2.161 1611: 2.159 1621: 2.159 1622: 2.158 998006: 2.158 3424: 2.120
Current Pipe (future development)		
Diameter: 1200mm (993073) 900mm (others)	Slope: 0.03, 0.11, 0.13, 0.13, 0.13, 0.09 & 0.04%	Material: Corrugated (3424) Concrete (others)
Length**:** 14.7, 8.18, 72.1, 90.3, 90.3, 3.5 & 27.3m		
Analysis		

	5 year	100 year
Flow Rate	0.444 m^3/s 1.485 m^3/s (3424 & 993073)	0.654 m^3/s 2.118 m^3/s (3424 & 993073)
Max depth/diameter (d/D)	993073: 0.957 998004: 1.268 1611: 1.325 1621: 1.394 1622: 1.462 998006: 1.462 3424: 1.435	993073: 1.644 998004: 2.161 1611: 2.159 1621: 2.159 1622: 2.158 998006: 2.158 3424: 2.120
Proposed Pipe (future development)		
System is surcharged in multiple places near this location. Enlarging the underground infrastructure, although making an improvement, does not solve the problem enough to remove surface flooding during the 5 year event. Further investigation, analysis and option generation is required.		
Comments: Storm sewer 993073 & 3424 are located upstream and downstream of the system and are the location where the system is split and joint, respectively. Between these storm sewers the system is separate in 2 systems. The other system is shown at 28B		
Estimated Cost:	----	

ID: 25B		
Location: South of Hwy 10 between 176 and 177B St.		Pipe ID: 993073, 1608, 1612 1623,1624,998005, 3424
Current Pipe (existing development)		
Diameter:1200mm (993073,1608, 1623,1624, 998005) 900mm (others)	Slope: 0.03, 0.03, -0.65, 0.13 0.15, 2.03 & 0.04	Material: Corrugated (3424) Concrete (others)

Length: 14.7, 54.0, 26.2, 92.3, 90.2, 3.0 & 27.3m		
Analysis		
	5 year	100 year
Flow Rate	1.041 m^3/s 1.485 m^3/s (3424 & 993073)*	1.464 m^3/s 2.118 m^3/s (3424 & 993073)*
Max depth/diameter (d/D)	993073: 0.957 1608: 0.947 1612: 1.210 1623: 0.908 1624: 1.124 998005: 1.186 3424: 1.435	993073: 1.644 1608: 1.621 1612: 2.018 1623: 1.476 1624: 1.643 998005: 1.700 3424: 2.120
Current Pipe (future development)		
Diameter:1200mm (993073,1608, 1623,1624, 998005) 900mm (others)	Slope: 0.03, 0.03, -0.65, 0.13 0.15, 2.03 & 0.04	Material: Corrugated (3424) Concrete (others)
Length: 14.7, 54.0, 26.2, 92.3, 90.2, 3.0 & 27.3m		
Analysis		
	5 year	100 year
Flow Rate	1.041 m^3/s 1.485 m^3/s (3424 & 993073)*	1.464 m^3/s 2.118 m^3/s (3424 & 993073)*
Max depth/diameter (d/D)	993073: 0.957 1608: 0.947 1612: 1.210 1623: 0.908 1624: 1.124	993073: 1.644 1608: 1.621 1612: 2.018 1623: 1.476 1624: 1.643

	998005: 1.186 3424: 1.435	998005: 1.700 3424: 2.120
Proposed Pipe (future development)		
System is surcharged in multiple places near this location. Enlarging the underground infrastructure, although making an improvement, does not solve the problem enough to remove surface flooding during the 5 year event. Further investigation, analysis and option generation is required.		
Comments: Storm sewer 993073 & 3424 are located upstream and downstream of the system and are the location where the system is split and joint, respectively. Between these storm sewers the system is separate in 2 systems. The other system is shown at 28A		
Estimated Cost:	----	

Appendix B-1: Hydrology Model Inputs

This Appendix includes all the parameters used inside of the XPSWMM model. **Table B.4** shows the impervious percentage for each zoning. Each zoning description can be found inside of the City of Surrey bylaw. **Table B.5** and **Figure B.1** show the catchment parameter and the location of each of them, respectively. **Figure B.2** shows the parameter used for the infiltration.

Table B.4: Impervious percentage for each zoning

Zoning	% Imp.	Zoning	% Imp.
Agriculture (A-1)	20	Single family residential (R-F)	65
Town center commercial (C-15)	90	Single family residential (RF-12)	80
Local commercial (C-4)	90	Single residential coach house family (RF-12C)	65
Neighbourhood commercial (C-5)	90	Single residential coach house family (RF-9C)	65
Community commercial (C-8)	90	Special single family residential (RF-9S)	65
Child care zone (CCR)	80	Single family residential gross density (RF-G)	65
Comprehensive development (CD)	90	Semi-detached residential (RF-SD)	65
Comprehensive development (C-D)	90	Single family residential secondary suite (RF-SS)	65
Self-service gasoline station(CG-1)	90	Half acre residential (RH)	65
Combined service gasoline station (CG-2)	90	Half acre residential gross density (RH-G)	55
Highway commercial industrial (CHI)	90	Multiple Residential (RM-10)	65
Golf Course (CPG)	20	Multiple Residential (RM-15)	65
Business park (IB)	90	Multiple Residential (RM-30)	65
High impact industrial (IH)	80	Multiple Residential (RM-45)	65
Light impact industrial (IL)	90	Multiple Residential (RM-70)	65
Assembly hall (PA-1)	80	Duplex Residential (RM-D)	65

Assembly hall (PA-2)	80	Special care housing (RMS-1)	80
One acre residential (RA)	50	Special care housing (RMS-1A)	80
Single family residential (RF)	65	Rural family residential (RS)	54

Table B.5: Catchment statistic

ID	Tot. Area (Ha)	Ave. Slope (%)	Width (m)	Existing Impervious (%)	Proposed Impervious (%)
1	46.41	1.97	400	62.9%	65.1%
2	10.77	1.82	300	65.0%	65.0%
3	12.64	4.98	630	65.0%	65.0%
4	31.74	3.64	154	65.1%	65.1%
5	36.58	4.74	250	74.0%	76.0%
6	40.05	5.98	590	82.6%	83.6%
7	5.83	1.75	240	54.4%	65.0%
8	15.56	3.96	180	81.2%	81.2%
9	6.14	1.84	157	68.7%	68.7%
10	14.46	5.23	240	65.0%	65.0%
11	18.04	2.86	300	65.6%	65.6%
12	10.37	1.57	509	68.6%	68.6%
13	12.29	3.31	163	68.7%	68.7%
14	12.15	3	193	66.8%	66.8%
15	4.07	0.5	540	73.0%	73.0%
16	4.13	0.5	175	86.3%	86.3%
17	8.58	3.03	211	65.7%	65.7%
18	11.20	2.78	500	17.8%	86.3%
19	20.38	2.28	390	64.3%	64.3%

20	14.06	1.32	205	64.8%	64.8%
21	9.30	0.27	270	64.2%	64.2%
22	4.27	4.4	250	64.9%	64.9%
23	11.23	2.64	142	65.0%	65.0%
24	10.27	6.41	270	64.1%	64.1%
25	7.90	3.52	240	63.2%	63.2%
26	1.60	6.26	42	64.7%	64.7%
27	7.45	9.09	250	53.4%	53.4%
28	17.95	1.99	740	28.3%	28.3%
29	6.89	7.97	212	62.1%	62.1%
30	6.71	2.63	240	35.3%	35.3%
31	14.84	1.65	400	32.0%	32.0%
32	14.75	1.48	225	65.1%	65.1%
33	17.64	1.04	285	74.0%	74.0%
34	6.14	1.57	211	70.4%	70.4%
35	12.05	0.77	436	86.9%	86.9%
101	6.50	2.69	288	65.0%	65.0%
102	4.62	9.8	226	82.3%	82.3%
103	10.29	9.28	373	65.2%	65.2%
104	10.22	2.55	245	65.0%	65.0%
105	3.56	0.94	176	65.0%	65.0%
106	5.14	4.7	232	65.0%	65.0%
107	0.82	1.7	31	65.0%	65.0%
108	5.04	10.67	100	65.0%	65.0%
109	8.79	5.92	294	65.0%	65.0%
110	9.28	1.48	204	65.0%	65.0%
111	7.67	10.02	204	55.5%	65.0%
112	3.99	1.16	184	67.7%	67.7%
113	3.29	1.16	155	78.1%	78.1%

114	8.97	8.57	420	40.9%	66.8%
115	8.79	7.43	236	65.0%	65.0%
116	2.05	7.78	153	60.8%	60.8%
117	6.14	0.99	180	89.0%	89.0%
118	5.41	1.62	245	88.9%	88.9%
119	3.18	1.48	83	80.9%	80.9%
120	2.59	0.73	114	90.0%	90.0%
121	3.50	0.43	155	90.0%	90.0%
122	13.04	0.97	422	90.0%	90.0%
123	10.00	1.88	325	90.0%	90.0%
124	7.16	0.41	249	87.9%	87.9%
125	20.74	6.62	567	58.3%	58.3%
126	9.60	0.7	104	82.1%	82.1%
127	12.28	1.88	202	54.0%	90.0%
128	16.53	1.92	300	54.0%	90.0%
201	8.96	2.19	246	63.4%	63.4%
202	7.04	1.45	190	65.0%	65.0%
203	4.51	5.73	116	65.0%	65.0%
204	2.14	4.38	58	65.0%	65.0%
205	4.05	3.45	143	61.1%	61.1%
206	5.15	8.51	38	59.6%	59.6%
207	4.05	9.74	101	53.6%	53.6%
208	16.94	8.22	300	46.5%	56.6%
209	8.35	11.4	261	55.5%	55.5%
210	3.33	7.29	65	65.6%	81.5%
211	8.53	2.71	283	73.2%	90.0%
212	9.05	5.57	168	55.2%	79.1%
213	7.28	4.59	241	31.4%	84.9%
214	1.85	4.05	60	65.0%	65.0%

301	4.40	1.03	158	60.0%	60.0%
302	6.03	2.29	178	60.1%	60.1%
303	3.82	2.74	229	52.4%	52.4%
304	11.17	4.09	367	64.3%	64.3%
305	3.51	3.97	91	54.9%	54.9%
306	6.78	5.06	284	30.8%	50.6%
307	5.31	6.04	154	11.5%	81.0%
308	4.59	7.46	166	7.9%	65.0%
309	15.47	7.31	136	61.1%	86.1%
312	4.11	5.74	95	64.2%	64.2%
401	16.21	1.31	405	9.0%	62.4%
402	16.41	1.23	411	10.3%	53.1%
403	11.94	1.27	356	26.5%	54.3%
404	9.49	1.17	201	50.4%	50.4%
405	11.33	0.83	268	50.1%	50.1%
406	17.59	1.48	315	9.0%	64.8%
407	2.06	1.17	86	65.0%	65.0%
408	11.29	2.3	297	52.5%	64.7%
409	14.39	2.66	343	17.0%	53.2%
410	6.57	4.12	200	12.9%	62.1%
411	9.94	3.03	190	7.5%	90.0%
412	6.61	4	304	45.8%	61.9%
413	11.98	5.83	195	64.4%	64.4%
414	9.79	4.54	167	64.9%	64.9%
415	13.13	4.81	228	67.9%	67.9%
416	3.96	8.53	120	20.9%	60.9%
417	2.16	10.44	103	21.0%	65.0%
418	11.46	12.06	523	37.3%	65.9%
419	7.30	1.39	220	63.6%	65.0%

420	11.33	4.41	158	52.4%	55.0%
421	5.88	7.6	428	50.2%	33.5%
422	4.00	6.85	108	69.1%	69.3%
423	7.21	11.4	186	45.4%	73.4%
424	3.70	2.22	49	58.9%	58.9%
425	8.60	1.62	126	64.5%	64.5%
426	7.32	1.5	300	65.0%	65.0%
427	8.13	1.72	174	64.0%	64.0%
428	4.57	1.74	70	63.7%	63.7%
429	12.66	3.45	191	61.3%	65.0%
430	5.38	5.36	298	64.3%	64.3%
431	33.46	7.52	390	62.8%	63.1%
432	26.29	4.97	367	55.4%	55.4%
433	7.61	5.49	124	65.3%	65.3%
434	5.27	7.88	71	65.6%	65.6%
435	5.14	5.31	219	65.0%	65.0%
436	1.99	3.03	78	67.2%	67.2%
437	5.21	2.84	123	74.5%	74.5%
438	4.51	1.03	188	65.1%	65.1%
439	4.92	3.52	112	81.3%	81.3%
440	1.87	5.78	38	80.5%	80.5%
441	3.09	3.01	126	74.4%	74.4%
442	1.09	2.33	78	68.2%	68.2%
443	13.97	7.22	386	65.0%	65.0%
444	11.59	6.15	332	58.4%	58.4%
445	24.62	8.11	708	49.2%	49.2%
446	5.59	4.55	133	58.5%	58.5%
447	6.00	2.77	138	66.3%	66.3%
448	9.49	7.28	273	88.8%	88.8%

449	9.11	2.94	288	89.8%	89.8%
450	13.36	2.55	642	90.0%	90.0%
451	8.84	1.94	207	90.0%	90.0%
452	2.65	3.55	82	90.0%	90.0%
453	4.51	1.74	163	90.0%	90.0%
454	1.52	2.75	63	90.0%	90.0%
455	6.97	2.13	191	73.8%	90.0%
456	16.89	4.28	372	55.2%	73.3%
457	16.45	3.23	456	61.7%	79.8%
458	9.78	2.79	232	80.0%	80.0%
459	4.44	3.31	140	86.1%	86.1%
460	12.48	1.73	320	85.2%	85.2%
461	8.21	2.1	90	79.5%	83.5%
462	11.26	2.75	313	69.4%	88.9%
463	3.61	0.9	208	35.6%	80.0%
464	16.84	2.74	509	79.3%	79.3%
465	10.01	8.6	387	32.7%	66.1%
466	4.18	7.47	89	59.1%	59.1%

Appendix B-2: Hydraulic Model Inputs

Tables B.6 and **B.7** show an example of the data available for each link (sewer) and node (pond and manhole) inside of the model, respectively. Each data and node is related at a name or number. These can be found inside of the SWMM model and output file include inside of the CD ROM.

Table B.6: Data available for each link

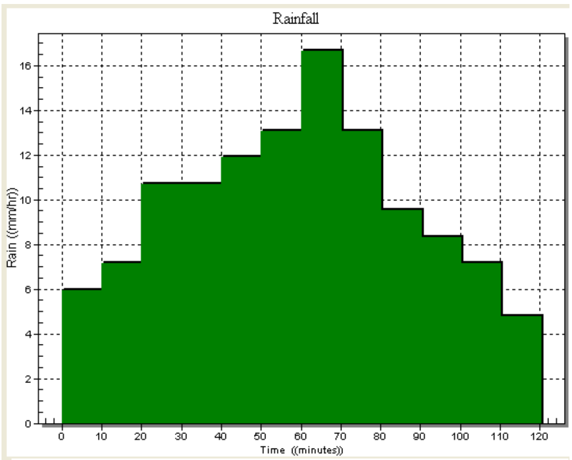
Scenario	Base Scenario	Future Development	Upgraded Scenario
Storm	5yr 2hr	5yr 2hr	5yr 2hr
Link Name	1805	1805	1805
Diameter (m)	0.6	0.6	0.75
Length (m)	118.052	118.052	118.052
Conduit Slope (%)	2.08	2.08	2.08
Roughness	0.013	0.013	0.013
Shape	Circular	Circular	Circular
Bottom Width (m)	0	0	0
Upstream Crown Elevation (m)	7.43	7.43	7.43
Downstream Crown Elevation (m)	4.97	4.97	4.97
Upstream Invert Elevation (m)	6.83	6.83	6.83
Downstream Invert Elevation (m)	4.37	4.37	4.37
Min Velocity (m/s)	0	0	0
Max Velocity (m/s)	2.92	3.07	3.19
Min Flow (m^3/s)	0	0	0
Max Flow (m^3)	0.663	0.875	0.905
Design Velocity (m/s)	3.13	3.13	3.64
Design Full Flow (m^3)	0.89	0.89	1.61
Max Depth (m)	1.099	1.69	0.547
Max Flow/Design Flow (%)	0.758	0.987	0.563
Max d/D (depth/diameter)	1.831	2.816	0.73
Time to Peak (hr)	1.192	1.225	1.192

Table B.7: Data available for each node

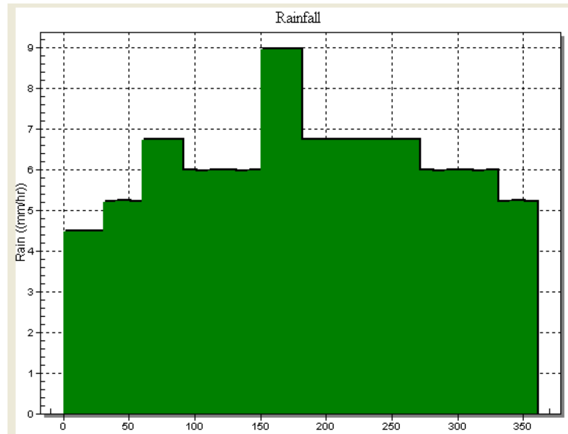
Scenario	Base Scenario		Future Development		Upgraded Scenario	
Storm	5yr 24hr	100yr 24hr	5yr 24hr	100yr 24hr	5yr 24hr	100yr 24hr
Node Name	Pond A	Pond A	Pond A	Pond A	Pond A	Pond A
Ponding Type	Allowed	Allowed	Allowed	Allowed	Allowed	Allowed
Ground Elevation (Spill Crest)	73	73	73	73	73	73
Invert Elevation (m)	68.5	68.5	68.5	68.5	68.5	68.5
Initial Depth (m)	2	2	2	2	2	2
Flood Loss (m^3)	0	0	0	0	0	0
Duration of Flooding (min)	0	0	0	0	0	0
Max Surface Area (m^2)	11633	11918	12164.72	12504.22	12164.37	12505.12
Max Water Depth (m)	2.306	2.333	2.356	2.388	2.356	2.388
Max Volume (m^3)	16659	16970	17244	17630	17244	17632

Appendix B-3: Rainfall Distribution

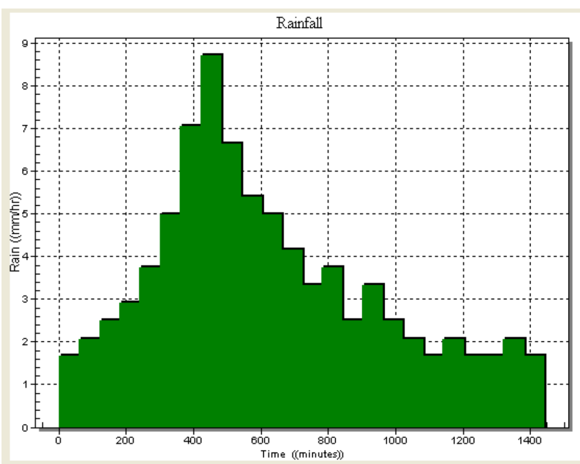
The following section shows the distribution of each rainfall run in the model.



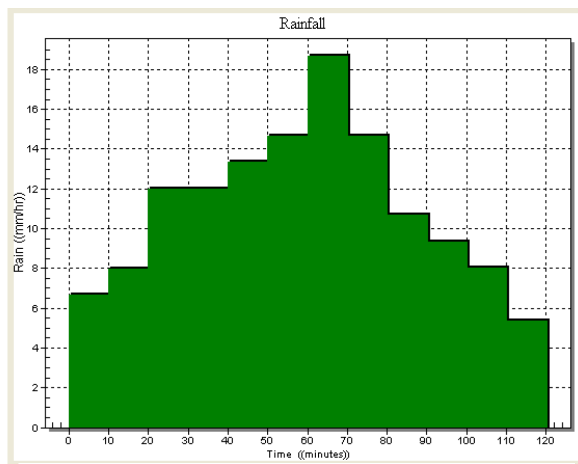
5 years – 2 hours – AES Kwantlen



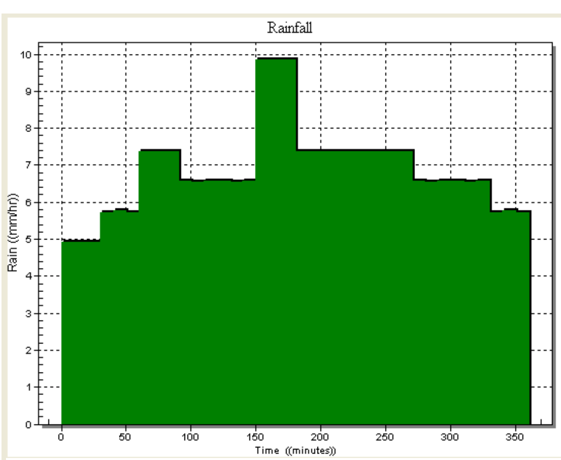
5 years – 6 hours – AES Kwantlen



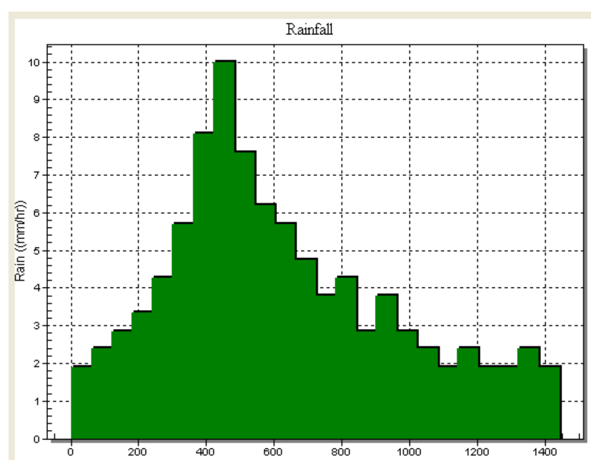
5 years – 24 hours – SCS Kwantlen



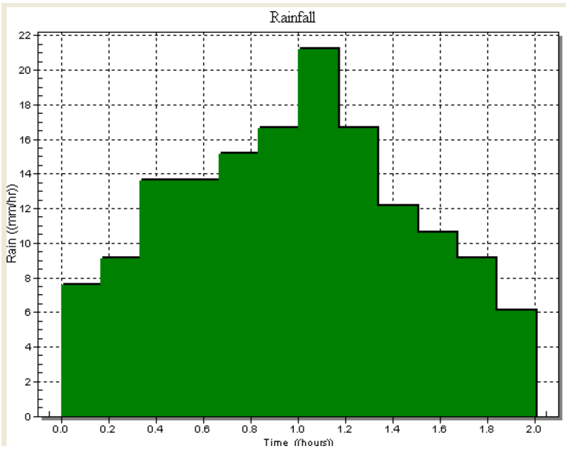
10 years – 2 hours – AES Kwantlen



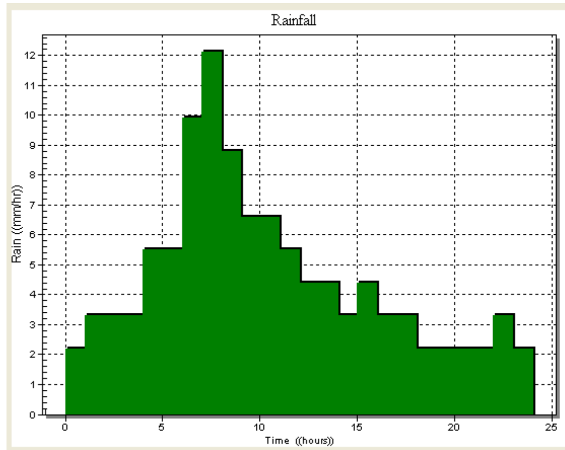
10 years – 6 hours – AES Kwantlen



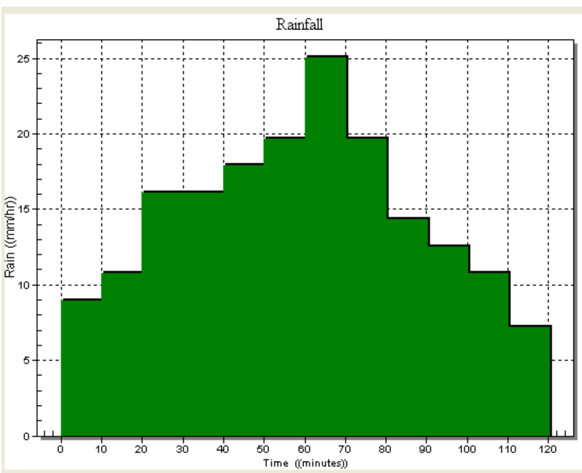
10 years – 24 hours – SCS Kwantlen



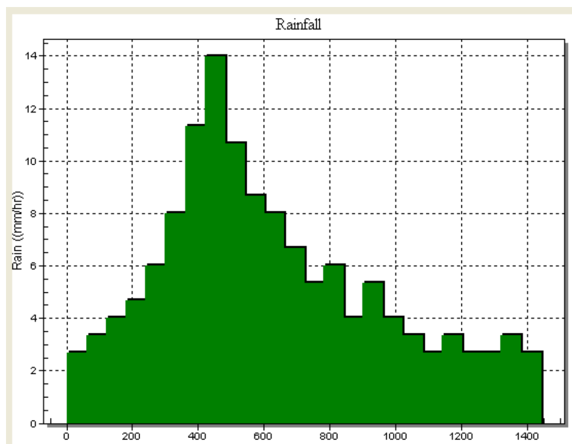
25 years – 2 hours – AES Kwantlen



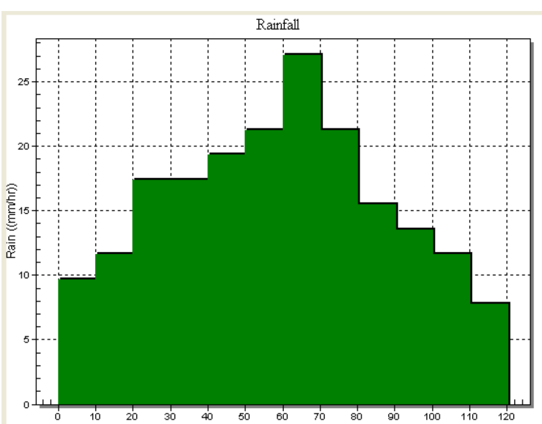
25 years – 24 hours – SCS Kwantlen



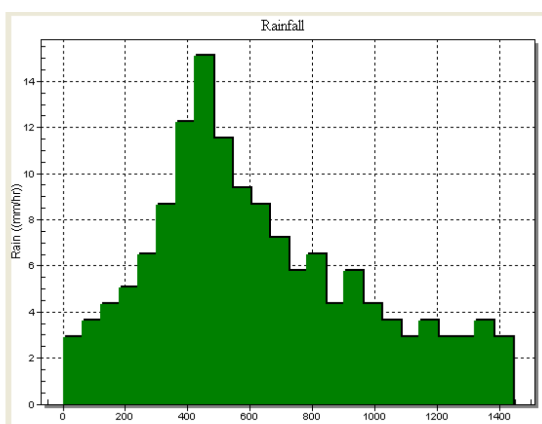
100 years – 2 hours – AES Kwantlen



100 years – 24 hours – SCS Kwantlen



200 years – 2 hours – AES Kwantlen



200 years – 24 hours – SCS Kwantlen

Appendix B-4: Photos from Field Visits

Photo 1: 1800mm Ellipse culvert with gate corner 64^e Avenue and 194^e St.

Photo 2: 1200mm x 3600m box culvert across 57 Avenue

Photo 3: 900mm CMP culvert across 56 Avenue on the east side of 168 St.

Photo 4: Culvert across the Railway along 176 St. (view from north side of the rail)

Photo 5: Culvert across the Railway along 176 St. (view from south side of the rail)

Photo 6: Drainage system along the Railway corner of 176 St. and Colebrook Rd (view from south side of the rail)

Photo 7: Drainage and pond system along 62 and 62a Avenue

Photo 8: Drainage and pond system along 62 and 62a Avenue

Appendix C: Continuous Modeling

Appendix C: Continuous Modeling of McLellan Creek

Summary

Stormwater management systems for new urban developments have traditionally been designed and analyzed with the aid of computer models employing design storm events rather than continuous modeling using long term historical rainfall data. It has generally been accepted that the latter method provides a more rigorous and realistic understanding of how a system behaves on a regular basis rather than just during infrequent major events. Through the ISMP process, the creation of a continuous model adds value by:

- Increasing our understanding of the system’s overall water balance;
- Quantifying the impact of changes in land use and stormwater practices;
- Providing annual flow exceedance curves to see the direct impact on erosion potential within receiving streams; and
- Demonstrate the benefits of stormwater Low Impact Development (LID) measures that target small, frequent rainfall events.

Continuous modeling differs from event modeling in that it quantifies more aspects of the hydrologic cycle. **Figure C.1** shows some of the common processes in hydrological studies. Event based models tend to focus on surface runoff and treat all other processes as losses. By including more detailed modeling of infiltration, inception interflows, evaporation, evapotranspiration and groundwater, a better understanding of the overall catchment can be obtained.

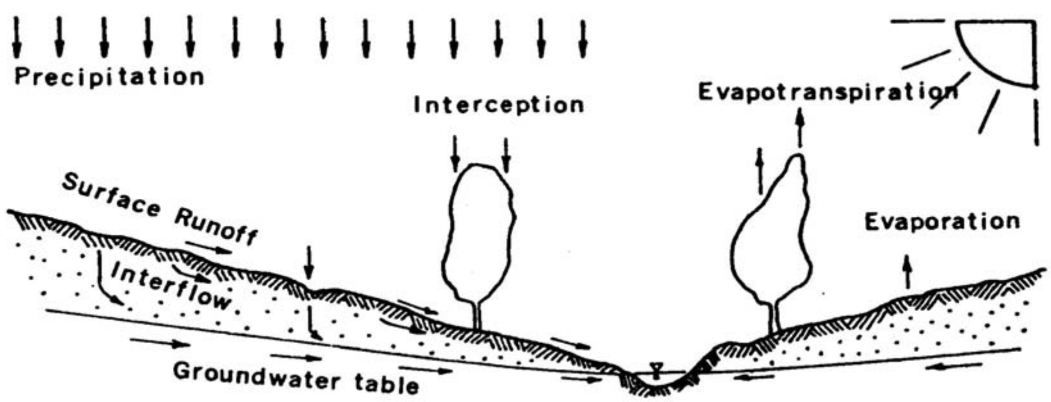


Figure C.1: Typical hydrologic processes

The computer simulation analysis of this study utilized the QUALHYMO computer model. The original QUALHYMO model was developed in 1983 during the creation of a methodology for analysis of stormwater detention ponds for water quality control and was funded by a grant from the Ontario Ministry of the Environment. QUALHYMO accounts for various hydrologic processes that produce runoff from urban areas. These include:

- Time-varying rainfall;
- Evaporation of standing surface water;
- Snow accumulation and melting;
- Rainfall interception from depression storage;
- Infiltration of rainfall into unsaturated soil layers;
- Percolation of infiltrated water into groundwater layers; and
- Interflow between groundwater and the surface water.

Scenarios

Three scenarios were run:

1. Existing conditions – based on air photo and current zoning.
2. Future land use – based on full build out of NCP land.
3. Pre-development – a forested condition with minimal impervious areas.

The pre-development scenario was included to provide an indication of what the conditions would have been for McLellan Creek prior to urban development.

McLellan Creek

The area of focus for the continuous modeling is McLellan Creek watershed. This area was selected for a focused study because it is the only area within the study area with a significant length of open channel.

The watershed is bounded by 74 Ave. on the north, 187 St. on the west, 196 St. on the east, and 54 Ave. and Canadian Pacific Rwy. on the south (**Figure C.2**). McLellan Creek also drains a small area on the Langley side of the municipal border, which is excluded from this study because it does not represent a large area.

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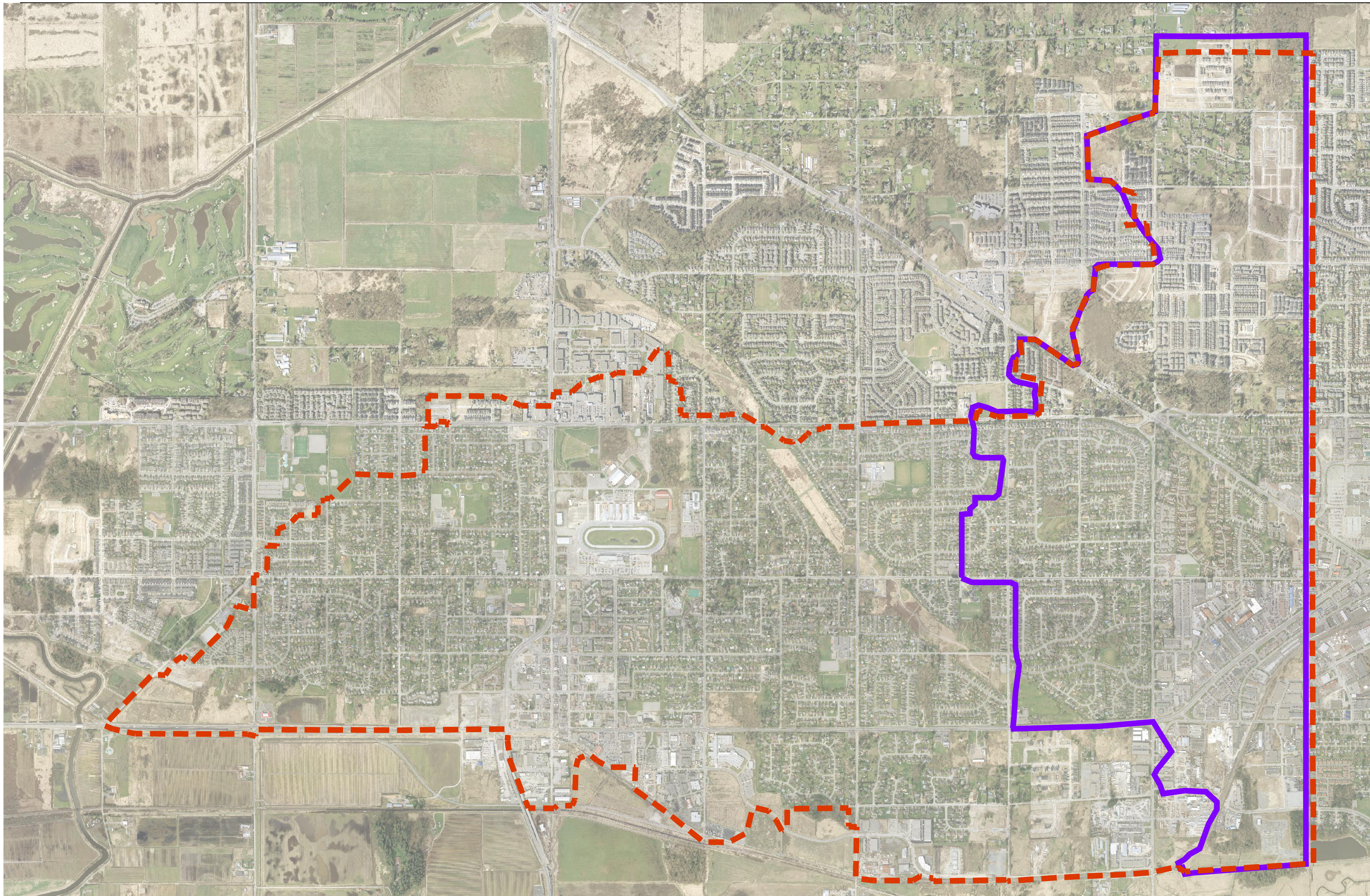
Figure C.2 McLellan Creek Watershed
Cloverdale McLellan ISMP



N.T.S.

LEGEND

McLELLAN CREEK

STUDY AREA

EB-3712

Q:\EB\3712 SURREY - CLOVERDALE MCLELLAN ISMP\EB\DWGS\FINAL REPORT\APPENDIX C\FIG C-2- MCLELLAN CREEK WATERSHED.DWG PLOTTED ON 2010/10/20 10:50am BY DELCANGUEST

Model Set-up

A single catchment model was created for the McLellan Creek catchment. A list of the input parameters is provided in **Table C.1.**

Table C.1: Model Parameters

Parameters	Description	Existing	Future	Pre-Development
GENERAL				
A	Basin Area (ha)	518.8	518.8	518.8
AB	Flag = 0	0	0	0
FRIMP	Fraction of directly connected impervious area	0.63	0.66	0.05
IMPERVIOUS AREA				
AA	Flag = 2 WILLIAMS UH	2	2	2
XK	Hydrograph Shape factor	5	5	5
TP	Hydrograph Shape factor	1.5	1	1.5
ABSIMP	Initial abstraction (mm)	2.5	2.5	2.5
RIMP	Volumetric runoff coefficient	0.99	0.99	0.99
CETIMP	Evaporation correction factor	1.0	1.0	1.0
PERVIOUS AREA				
AA	Flag = 2 WILLIAMS UH	2	2	2
XK	Hydrograph Shape factor	5	5	5
TP	Hydrograph Shape factor	1.5	1	1.5

Parameters	Description	Existing	Future	Pre-Development
SMIN	Minimum S (mm)	18.0	18.0	18.0
SMAX	Maximum S (mm)	118.0	118.0	118.0
SK	Variable for S calculation (1/mm)	0.01	0.01	0.01
APIK	API calculation parameter	0.9	0.9	0.9
APII	Starting API (mm)	20	20	20
ABSER	Initial abstraction (mm)	6.0	6.0	6.0
CETPER	Evaporation correction factor	1.0	1.0	1.0
BASEFLOW GROUP				
NSVOL	Recession Curve method	0	0	0
BASMIN	Minimum baseflow rate	0.02	0.02	0.02
BFACR	Baseflow calibration factor	1.5	1.5	1.5
SVOL	Starting Moisture (Groundwater reservoir) (mm)	20	20	20
SWILT	Soil Moisture Wilting Point (mm)	16	16	16
SFIELD	Soil moisture at filed capacity (mm)	150	150	150
SLOSKA	Base flow recession constant	0.00001	0.00001	0.00001
SLOSKB	Base flow reduction factor	0.15	0.15	0.15
CET	Evaporation correction factor	0.0005	0.0005	0.0005
SNOWMELT PARAMETERS				

Parameters	Description	Existing	Future	Pre-Development
ISNOW	Flag = 2 Reduced Heat Budget method	2	2	2
BASET	Temperature at which snowmelt begins	0.5	0.5	0.5
SNOFAC	Coefficient of calibration. Default value when ISNOW= 2	0.15	0.15	0.15
PACDEP	Initial snow pack depth in water equivalents (mm)	10.0	10.0	10.0
ALPHAA	Coefficient of calibration for upward ground heat flux	2.5	2.5	2.5
XKL	Ratio of soil thermal conductivity over The soil depth for which it applies	15	15	15
BCOEF	Proportionality constant for downward daily average soil heat flux	1.1	1.1	1.1
XNCOEF	Thermal insulation factor for snow pack	150	150	150
KFLAG	No snow removal operations	0	0	0
PSTATE	Temperature above which precipitation will occur as rain	0.0	0.0	0.0
COEFD	Wet day coefficient of calibration. Typically set at 0.012	0.012	0.012	0.012
COEFE	Temperature above which precipitation will occur as rain	1.2	1.2	1.2
CFACTR	Rain gauge catch correction factor	1.0	1.0	1.0
CFACTS	Snow gauge catch correction factor	1.1	1.1	1.1
IZFLAG	Anderson-Gray Seasonal melt coefficient	2	2	2

Soils

Examination of surficial soils is critical to understanding the hydrology of an area. From the geologic map, the study area is covered with raised marine, deltaic, and fluvial deposits: (80% Cd and 20% Cb). Cd, is a silt loam to clay loam with minor sand and silt.

Land use

The land use classification follows Surrey's manual. Existing land use information was identified based on the 2009 Airphotos of Surrey GIS COSMOS. The future land use was derived from the City's OCP and zoning information and is shown in **Figure C.3**. The input values used for the model are listed in **Table C.2**.It is noted that the study area is almost a fully developed area. Future development will not significantly change the land use.

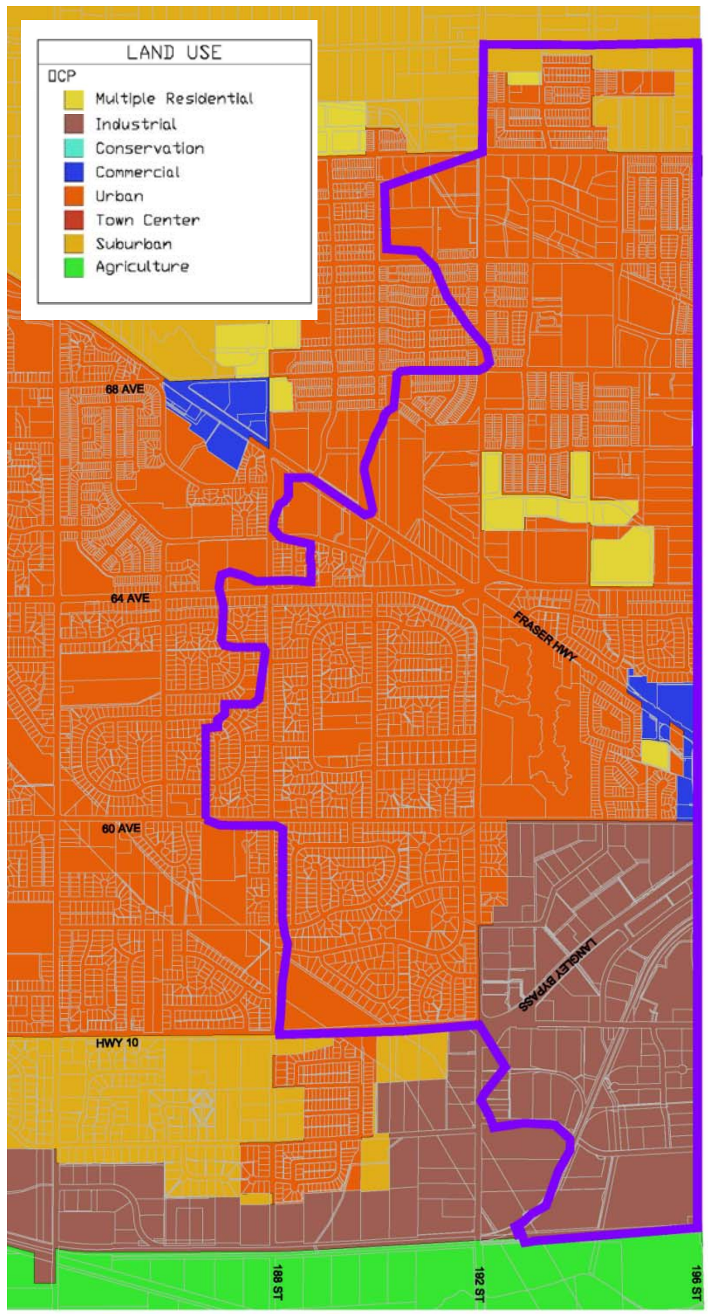


Figure C.3: OCP land use for McLellan Catchment

Table C.2: Land Use (Existing)

Description of Area	% Impervious ratio	Area (Ha)	Impervious Area (ha)	CN (soil C)	CN*Area (soil C)
Commercial	90	27.04	24.3	94	2542
Industrial	90	78.6	70.7	94	7388
Residential		0	0.0		
RA, RA-G	50	57.67	28.8	79	4556
RH, RH-G	55	16.75	9.2	80	1340
RF, RF-SS, RM-D	65	132.4	86.1	90	11916
RF-G,RM-M, RM-10, RM-15, RM-19, RM-30, RM-45, RM-70, RM-135, RMC-135	65	61.3	39.8	85	5211
RMC-150, RF-9, RF-12, RF-SD	80	62.9	50.3	85	5347
Parks, Playground, Cemeteries; Agricultural Land	20	77.92	15.6	74	5766
Institution; School; Church	80	4.27	3.4	90	384
SUM		**518.9**	**328.3**	**86**	**44449**
%			**63%**		

Table C.3: Land use (Future)

Description of Area	Impervious ratio %	Area (Ha)	Impervious Area (ha)	CN (soil C)	CN*Area (soil C)
Commercial	90	27.04	24.3	94	2542
Industrial	90	78.6	70.7	94	7388

Description of Area	Impervious ratio %	Area (Ha)	Impervious Area (ha)	CN (soil C)	CN*Area (soil C)
Residential		0	0.0		
RA, RA-G	50	99.87	49.9	79	7890
RH, RH-G	55	16.75	9.2	80	1340
RF, RF-SS, RM-D	65	132.4	86.1	90	11916
RF-G,RM-M, RM-10, RM-15, RM-19, RM-30, RM-45, RM-70, RM-135, RMC-135	65	63.3	41.1	85	5381
RMC-150, RF-9, RF-12, RF-SD	80	62.9	50.3	85	5347
Parks, Playground, Cemeteries; Agricultural Land	20	33.65	6.7	74	2490
Institution; School; Church	80	4.27	3.4	90	384
SUM		**518.8**	**341.9**	**86**	**44677**
%			**66%**		

Model Verification

QUALHYMO model parameters are usually determined through a calibration or verification process; however, as there are no short or long term discharge records for McLellan Creek, the parameters were determined based on local experience. McElhanney (2007) performed a study of some stream parameters in Surrey. It included the Salmon River at 72 Avenue with a watershed of 49 km^2 and West Creek near Fort Langley with a watershed area of 11.4 km^2. The results of this study provided input to the parameters.

Climate Data

Data Requirement

Continuous modeling with QUALHYMO requires the following recorded data:

- Hourly rainfall-precipitation data;
- Hourly air temperature data;

- Monthly evapotranspiration data; and
- Hourly flow data, if available, which is used for calibration of model parameters.

Hourly Rainfall-precipitation

The station and period that were used are shown in **Table C.4.**

Table C.4: Precipitation Data Stations

Station Name	Period
Chantrell Creek Elementary	2000-2009
Semiahmoo Fish & Game Club	2000-2009
Surrey Kwantlen Park	2000-2009
White Rock STP	2000-2009
Surrey Municipal Hall	2000-2009
Port Kells Pump Station	2000-2009

Hourly Air Temperature

According to Environment Canada, climate stations at Surrey Municipal Hall, Surrey Kwantlen Park and other locations in the Surrey municipal area only report daily data. There is no hourly temperature data available for these stations. However, hourly data was available the nearby stations shown in **Table C.5**.

Table C.5: Temperature Data

Station Name	Period
Vancouver International Airport	1980-2009
Pitt Meadows CS	1994-2009
Abbotsford Airport	1953-2009
White Rock CS	1994-2009

The closest climate station, located in Pitt Meadows, was selected and the data were downloaded for 2000-2009.

Monthly Potential Evapotranspiration

There are no climate stations in Surrey and the surrounding area that measure monthly potential evaportranspiration. However, evapotranspiration data can be calculated using other climate factors such as temperature and wind speed. Agriculture and Agri-food Canada provides the data estimated using the Penman and Thornthwaite methods for each eco-district. The data can be downloaded from the following link:

http:/sis.agr.gc.ca/cansis/nsdb/ecostrat/district/climate.html

Results

The results of the model outputs are in the form of hourly outflow for the duration of the model run. The complete results are available upon request. The results were used to see the change in runoff volume and the flow exceedance for each scenario.

Runoff Volume

The overall runoff volume is an important indication of the system's performance. **Table C.5** and **Figure C.4** below shows the average runoff rate per month. The change in average runoff rate per month is relatively small between the existing and future scenarios (3% or less in all months).

Table C.5: Runoff Volume for Existing and Future Land Use

Month	Runoff Volume (m^3 in thousands)		Change
	Existing Conditions	Future Conditions	
January	618	635	3%
February	232	238	3%
March	396	409	3%
April	234	242	3%
May	244	252	3%
June	171	176	3%
July	103	105	2%
August	149	153	3%
September	239	246	3%
October	549	564	3%
November	607	624	3%
December	484	498	3%
TOTAL	**4027**	**4142**	**3%**

To illustrate how the difference from the pre-development scenario the comparison of the pre-development to the existing condition range are generally between 100 and 150% increase.

Table C.6: Runoff Volume for Pre-development and Existing Land Use

Month	Runoff Volume (m^3 in thousands)		Change
	Pre Development	Existing Conditions	
Jan	304	618	104%
Feb	98	232	135%
Mar	158	396	151%
Apr	86	234	171%
May	93	244	161%
Jun	74	171	131%
Jul	60	103	71%
Aug	70	149	112%
Sep	100	239	138%
Oct	262	549	110%
Nov	284	607	113%
Dec	205	484	136%
TOTAL	**1796**	**4027**	**124%**

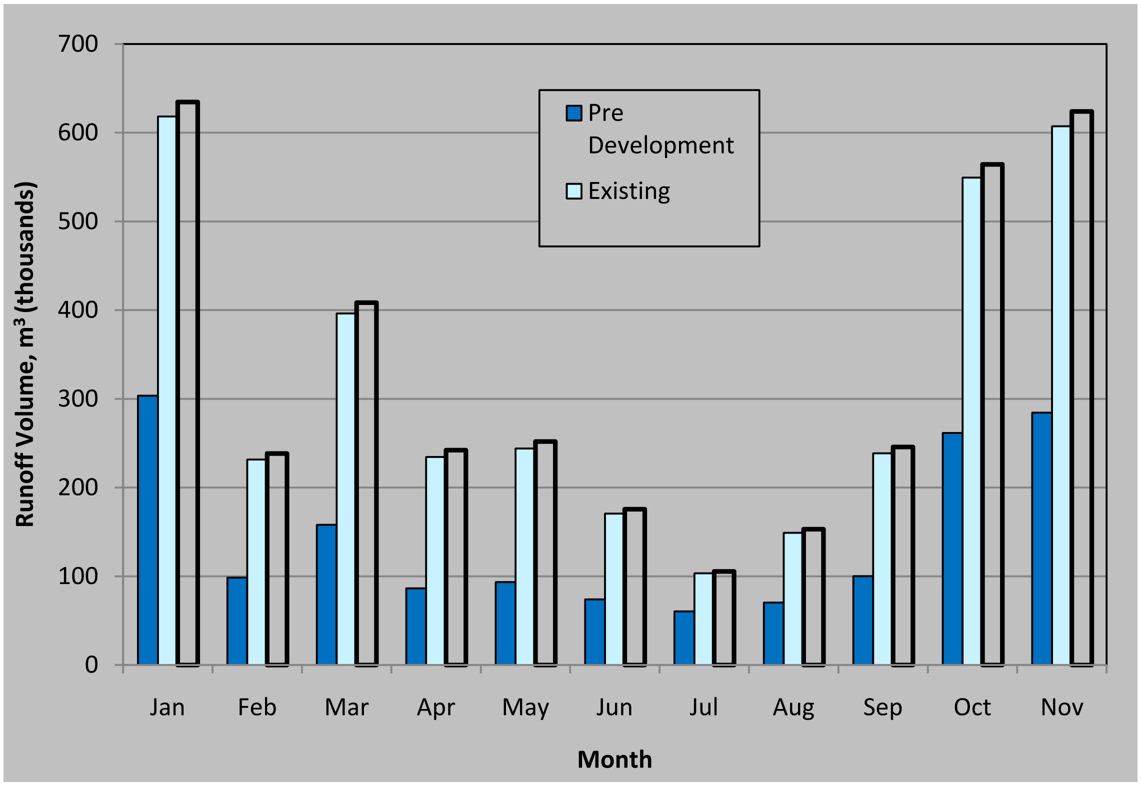


Figure C.4: Runoff Volume by month

Stream Flow Exceedance

The summary of stream flow discharge exceedance is shown in **Figure C.5**. The graph indicates that there is an impact on stream flow as the watershed develops from the existing condition to the full development condition if no mitigation measures are taken. The impact is an increase in the amount of time that any given stream discharge is exceeded.

As noted previously, the change in impervious area is not significant, so no significant change is seen in the stream flow exceedance curve. Again, the major impacts have already occurred when the catchment move from a pre-development state to the existing conditions.

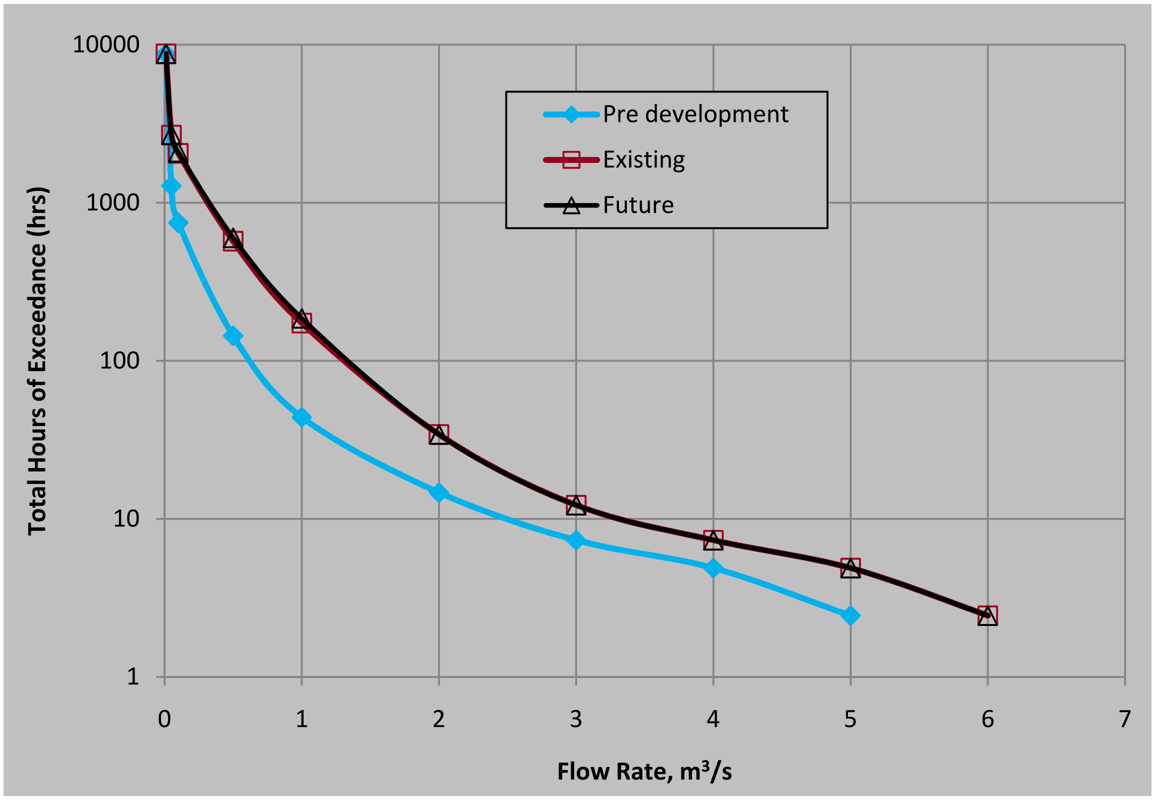


Figure C.5: Stream Flow Exceedance

Discussion

The continuous model provides a relative comparison between development scenarios. As can be seen in the results, with the increase in impervious area, the amount of surface runoff is also increased as less water is evaporated or infiltrated.

The number of times that any given peak flow rate is exceeded is higher in the developed scenario for every case except low flows. For example, in the pre-development scenario, 1 m^3/s is exceeded in 44 hours of the year while in the existing scenario that same flow rate is exceeded 173 hours of the year.

This result is significant for the ISMP because it shows that the changes to the flow regime that have already occurred represent a much more significant change than the changes that could occur in the future. This means that the if the vision for the watershed is to improve the aquatic environment to more natural conditions, the plan must include changes that not only maintain, but also make improvements on the existing conditions.

Appendix D: Water Balance Evaluation

Appendix D: Water Balance Model

The Water Balance Model is a tool to support decision making that was developed to help achieve desired urban stream health and environmental protection outcomes. The value of the tool lies in its ability to graph and report the differences between pre-development, post-development and mitigation scenarios for a study area by running detailed hydrology simulations and comparisons. The simulation is performed with historically accurate climate data that spans multiple decades and is recorded in hourly time steps.

The Water Balance Model tool is publicly available and accessible online (at www.waterbalance.ca). It can be operated through a series of online interactive interfaces. The overall operation includes two steps: 'Data Input' and 'Result Review'. In the 'Data Input' step, the required information and data are input to configure the catchment geometry, soil, surface condition, surface enhancement, and control measures. With information on enhancement and control measures, various scenarios of catchment conditions are configured and enclosed in one project. Once the required information is complete and the simulation function is triggered, the tool, powered by QUALHYMO, will provide various simulation results in the form of graphs and reports for review.

Commercial or Industrial

When new development or redevelopment occurs, it will be important to make stormwater management decisions to improve the water balance. The following performance criteria are proposed for the lower catchment:

- Meet the servicing objectives outlined in the Surrey Design Criteria section 5.2; and
- Provide on-lot source controls that infiltrate 40% of the annual runoff.

To demonstrate that these performance criteria are achievable, we have designed some stormwater Best Management Practices (BMPs) for a typical sample lot. **Figure D.1** shows a typical lot as it is today. **Figure D.2** shows possible BMPs applied to the site during redevelopment.

Figure D.1: Sample Existing Lot Conditions

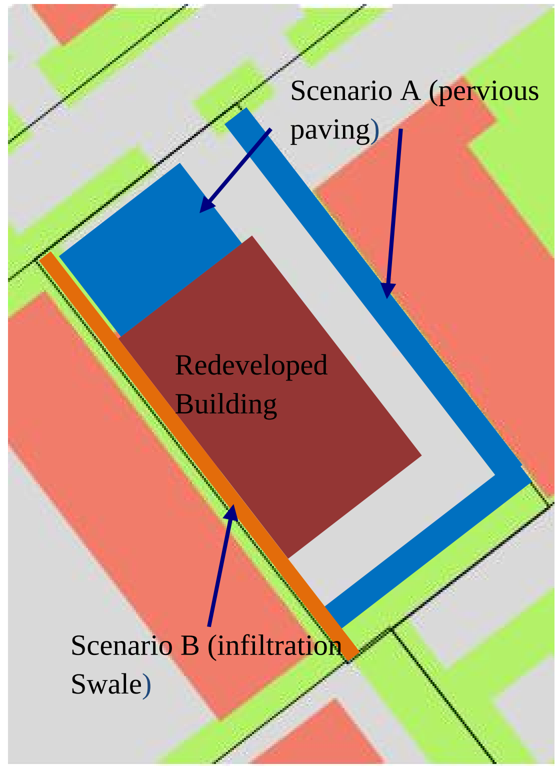


Figure D.2: Sample Proposed BMP Scenarios

The lot was assumed to be 95% total hard surfaces (building or paving). Two source control scenarios were run:

1. A pervious pavement scenario in which 35% of the lot was converted to pervious pavement.
2. An infiltration swale scenario where 5% of the land was used to provide an infiltration swale.

These BMPs were modeled using the Water Balance Model available at www.waterbalance.ca and the results of the annual water balance are shown in **Figure D.3**. The results show that in Scenario A 51% of the total rainfall on the site was generated to surface runoff. For Scenario B, only 33% of the water was surface runoff and the rest of the water was infiltrated on site. This confirms that a target to infiltrate 40% of the total available water is reasonable and achievable.

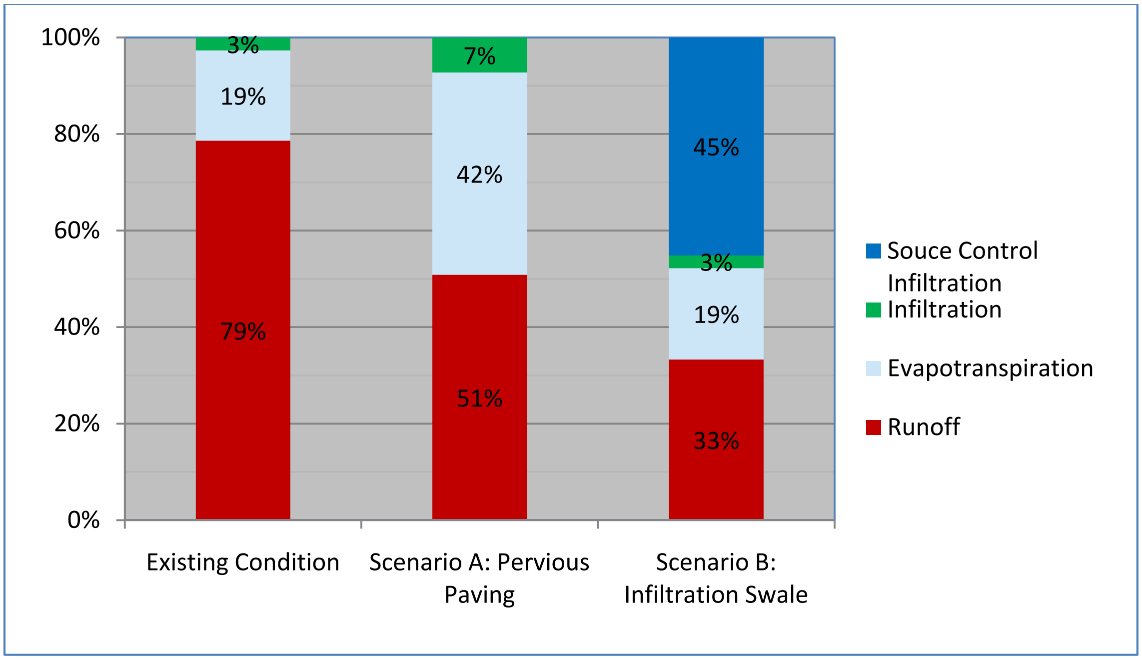


Figure D.3: Development Scenario Results

Residential - Single Lot Redevelopment

The majority of the single family residential development area in the catchment was constructed at a time when the portion of the lots covered by home and driving was lower than it is today. The zoning bylaw allows construction on single family lots to cover up to 60% of the total lot area. With the trend to redevelop older homes into a larger footprint comes the potential to increase the impervious area of the lot. To illustrate the impact of this increase in impervious area, a typical lot is shown in **Figure D.4**. This lot is located in a 1953 subdivision.

Figure D.4: Typical Residential Lot

Table D.1: Current Lot Area Distribution

Type	Area (m^2)	%
Roof	161	22
Paved	95	13
Lawn	492	65
Total	748	100

If the lot is developed to its full potential as allowed by zoning, the lot coverage could look like **Figure D.5**. **Table D.2** shows the assumed lot characteristics.

Figure D.5: Typical residential lot to maximum development

Table D.2: Proposed Lot Area Distribution

Type	Area (m^2)	%
Roof	448	60
Paved	150	20
Lawn	150	20
Total	748	100

The lot changes depicted in **Figure D.5** impact the water balance. The lot was modeled using a continuous model using 10 years of historical rainfall data. The results are illustrated in **Figure D.6.** The figure shows how rainwater leaves the site. There are generally three available routes: losses (evaporation, transpiration), infiltration, and runoff. In general, the more rainwater that is turned into losses or infiltration, the closer the site mimics natural conditions.

The total runoff is more than doubled as a result of the lot redevelopment. If the redevelopment of existing residential lots becomes widespread in the coming years, it will impact the stormwater conveyance infrastructure and downstream receiving waters. To counter the negative impacts on the water balance, we recommend that source control measures be implemented on the lot level at the time of redevelopment.

To illustrate the potential source control options available, the water balance model was used to simulate the potential source control options. The redevelopment scenario shown in **Figure D.5** was used as a basis to test the performance of some source control BMPs. The roof water runoff was directed to an infiltration swale, the paved area was converted to pervious paving and the lawn was converted to 300 mm of absorbent topsoil (including the area of the infiltration swale). The results of the changes are shown in the Figure x.

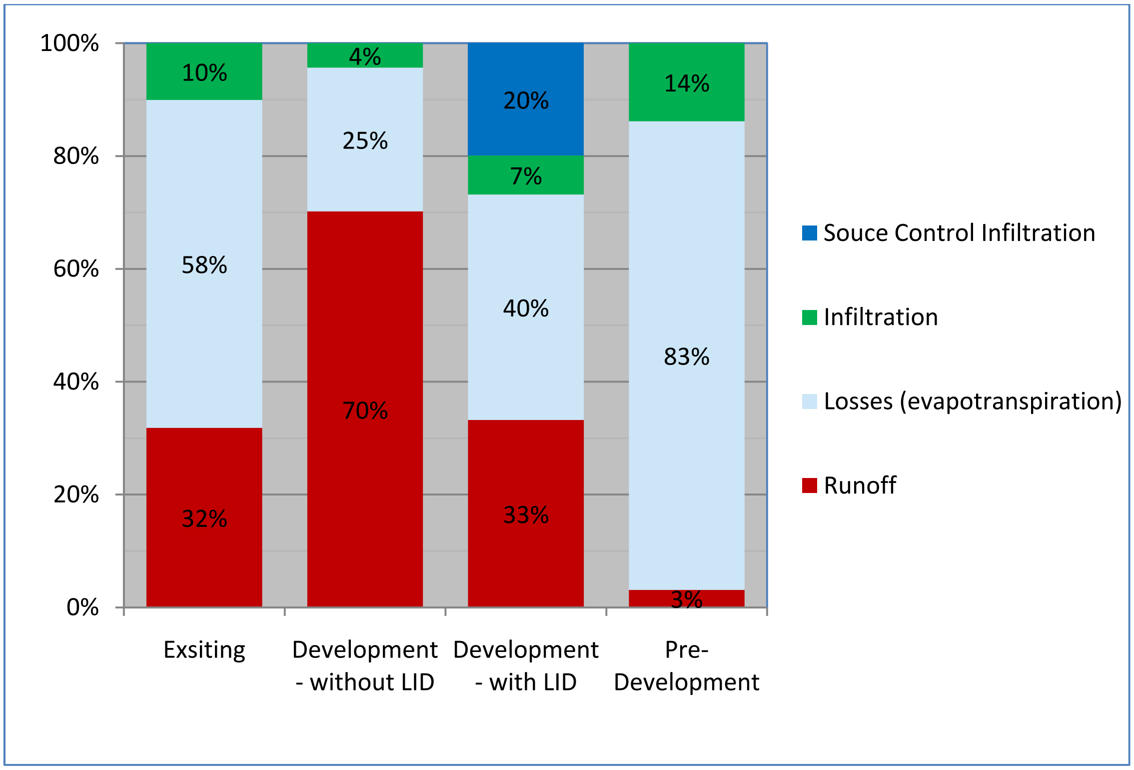


Figure D.6: Water balance of residential lot

If applied to all redeveloped lots the selected BMPs can mitigate the effects of the increased impervious area. The graph shows that development without mitigation will result in a 38% increase in runoff, and 6% loss of infiltration whereas implementing the LIDs allows new development and limits runoff to virtually the same level while improving infiltration by 17%. Infiltration can benefit the health of watercourses by increasing baseflows.

Without the implementation of source controls there will be an increase in the severity and frequency of downstream flooding, increased pressure on infrastructure and increased environmental damage in the receiving watercourses.

We recommend adopting the following on-lot mitigation measures:

- Require the placement of 300 mm of absorbent topsoil with all new redevelopments;
- Require that new paved areas that are part of the redevelopment be pervious; and
- Require roof runoff to be directed to an infiltration swale, infiltration trench or soak-away pit.

In order to implement the recommended measures, developers, builders and home owners must be informed of the requirements. The City of Surrey can do this by modifying the development application and building permit approval process.

Greening Road ROWs

Typical residential neighbourhoods in the study area are made up for more than 20% road ROWs (including both asphalt and grassed area). The watershed vision calls for 'greener streets' and, since the road ROWs are owned and operated by the City, they provide opportunities for implementing stormwater source control measures in urban areas. 'Green streets' are designed to treat stormwater by encouraging infiltration and stormwater retention within the road ROW. Technically feasible options for stormwater source controls in road ROWs include:

- Rainwater gardens/infiltration swales within boulevards and medians;
- Pervious pavement for sidewalks;
- Exfiltration pipes in storm sewers systems; and
- Pervious pavement for parking and shoulders.

Using a typical road ROW with a 20 meter width, we have modeled two scenarios: one scenario using a conventional design and one scenario using a 'green street' design. The 'green street' design includes the features shown in **Figure D.7**.

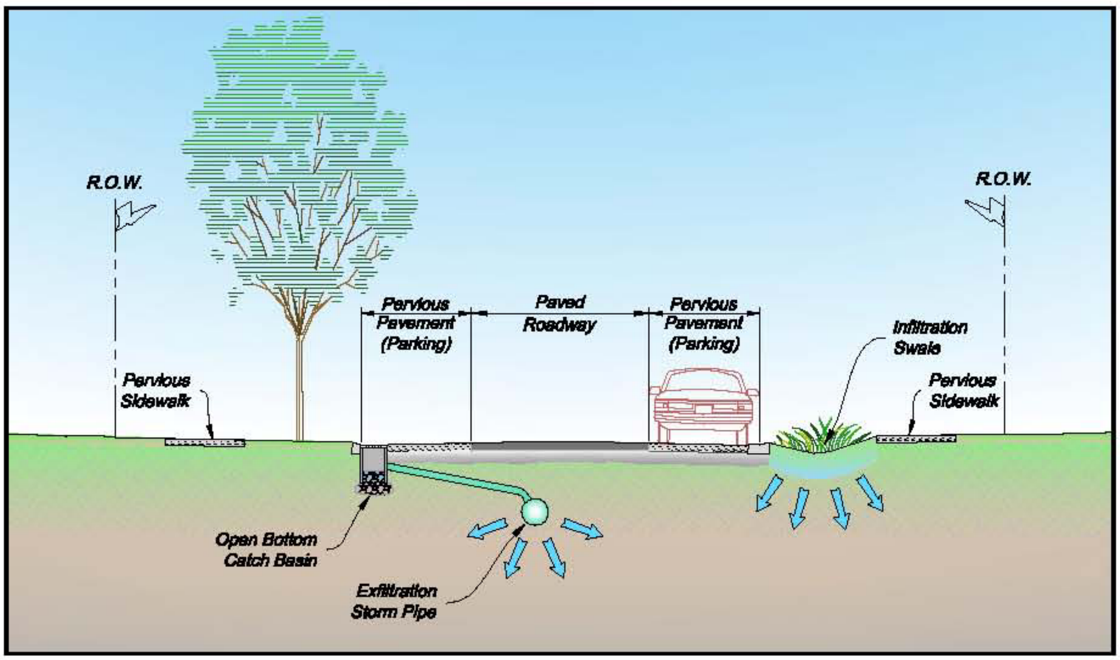


Figure D.7: Typical Green Street Section

Modeling these two scenarios demonstrated the difference in the stormwater runoff. The results are shown in **Figure D.8**.

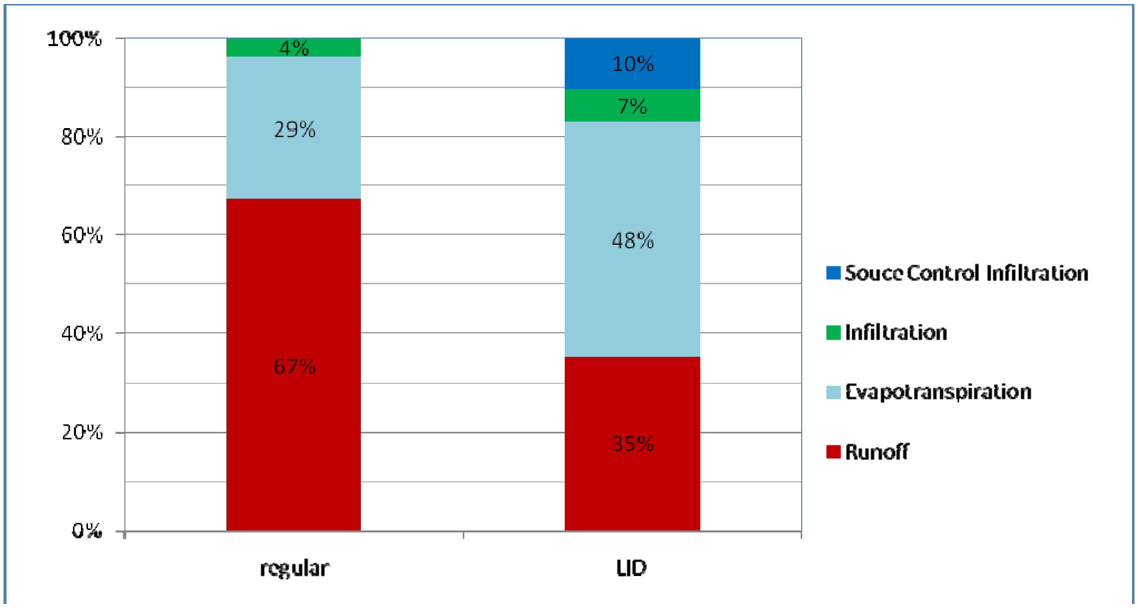


Figure D.8: Water Balance of Conventional and Green Streets

As shown in **Figure D.8**, the annual runoff from road ROWs can be reduced from 67% to 35% by switching from conventional stormwater design to 'green street' design; that is a reduction of almost 50%. This reduction would aid in shifting the water balance back towards more natural conditions.

Delcan recommends that the City of Surrey implement a demonstration project within the catchment to test the application of the source control measures discussed in this section. A demonstration project should be designed to test each of the source control measures for performance, maintenance issues and public perception.

Appendix E: Environmental Report

ENVIRONMENTAL ASSESSMENT REPORT

Stage 1: Cloverdale McLellan Integrated Stormwater Management Plan

Surrey, B.C.

Prepared for:

Delcan Corporation and City of Surrey

Prepared by:

PHOENIX ENVIRONMENTAL SERVICES LTD.

February, 2010

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EXECUTIVE SUMMARY

Phoenix Environmental Services Ltd. (Phoenix) has been retained by Delcan Corporation (Delcan) to provide the environmental components for the Cloverdale McLellan Integrated Stormwater Management Plan (ISMP) that Delcan has been retained to prepare for the City of Surrey Engineering Department. This report has been completed in support of Stage 1 of the formulation of the Cloverdale McLellan ISMP (the ISMP). The objective of Stage 1 is to provide an inventory and assessment of existing terrestrial (wildlife habitats and corridors) and aquatic habitats (watercourses, wetlands) within the Study Area using available information and limited "ground-truthing" site reconnaissance. The scope of work by Phoenix has included use of existing research and reports, as well as field verification where necessary. The primary aquatic and terrestrial habitats are Upper and Lower McLellan Creek, Cummins Brook, the riparian forests of both watercourses, remnant forest stands (generally those of $\geq$ 1 hectare), and the BC Hydro utility right-of-way.

McLellan Creek is the primary fish habitat within the watershed that still has portions of natural aquatic habitat. Upper McLellan Creek is currently considered Class A (fish bearing), but does not have an adequate watershed to support a resident fish population and is cut off from Lower McLellan Creek by more than a kilometer of storm sewer. Based on these factors, Phoenix has recommended that Upper McLellan Creek be reclassified to Class B.

Cummins Brook, a tributary of the Nicomekl River to the west of McLellan Creek, is the only other watercourse in the Study Area that flows partially within a natural channel (not channelized, ditched, or piped). However, recent modifications to Cummins Brook were observed in January 2010. The channel has been diverted as it passes through the industrial 18949 52nd Avenue. It was confirmed with DFO that the relocation of the watercourse was not authorized. Cummins Brook has the potential to provide fish habitat if restoration works included improvements to the stream channel, baseflow enhancements, as well as culvert replacements and barrier removals downstream of 52nd Avenue and the CPR tracks (outside of the Study Area).

Most other watercourses within the Study Area are unnamed roadside ditches or farm ditches that are tributaries of the Nicomekl River. Farm ditches along the southern boundary (near Highway 10) are primarily classified as either Class A or Class A(O), but are low quality aquatic habitats due to high summer water temperatures and limited habitat diversity. Restoration of the riparian area along these watercourses with large shrubs (willows, dogwood) would improve aquatic habitat by decreasing water temperatures and providing shade and nutrients. Restoration works should include aggressive and sustained control of invasive species in conjunction with increasing the channel complexity where possible (i.e. increase meandering, create planted floodplain benches and backwater habitats).

Peak flow volume and velocity, lack of base flow, water quality, and loss of biodiversity are the primary concerns for the aquatic habitats within the Study Area. Excessive peak flows threaten to undermine channel restoration activities. At the same time, base flows have been diverted into the storm sewer system, resulting in some remaining watercourses drying out.

The Study Area land use is primarily residential, commercial, and industrial with little contiguous forested land. As a result, there is little significant wildlife habitat within the Study Area. Based on previous studies, existing data, and field verification, the key wildlife habitats in the Study Area include

1) the remaining riparian forest at the headwaters of McLellan Creek, 2) the lower reach of McLellan Creek and the associated riparian area, and 3) the BC Hydro right of way that transects the site from northwest to southeast.

There are many impediments to movement of wildlife between the fragmented, relatively small habitat patches within and beyond the Study Area including roads, fences, buildings, culverts and impervious areas. Although most habitats in the Study Area are not significant independently, the remaining patches and corridors of habitat (i.e. forests and riparian areas) within the Study Area warrant protection and enhancement for their potential benefit to City- and region-wide biodiversity resilience.

Based on the inventory of existing aquatic and terrestrial habitats, the following issues and opportunities for restoration were identified:

- Pursue stormwater retrofits to improve water quality where no controls are present or where only standard oil/water separators are currently being used.
- Enhance the unnamed tributaries of McLellan Creek (north of 64th Avenue) by restoring base flows to these channels.
- Replace the lost forested wetland near Upper McLellan Creek by creating new streams and riparian areas.
- Remove excess railroad ballast from the lower reach of McLellan Creek, south of the Langley Bypass.
- Restore riparian and stream habitat along Cummins Brook and augment base flows through new stormwater facilities and retrofits, where appropriate.
- Enhance BC Hydro right-of-way with native shrubs and small trees, particularly along the edges. When road or underground utility works occur where the BC Hydro right-of-way crosses streets, find opportunities for installing shallow wildlife tunnels.

1. INTRODUCTION

Phoenix Environmental Services Ltd. (Phoenix) has been retained by Delcan Corporation (Delcan) to provide the environmental components for the Cloverdale McLellan Integrated Stormwater Management Plan (ISMP) that Delcan has been retained to prepare for the City of Surrey Engineering Department. This report has been completed in support of Stage 1 of the formulation of the Cloverdale McLellan ISMP (the ISMP).

1.1 ISMP Environmental Objectives

Based on the Terms of Reference issued by the City for this ISMP, it is clear that the ISMP requires a balance of stormwater engineering and environmental assessment (see References section). The City is interested in a holistic approach whereby environmental friendly designs and protection and restoration of natural features would be an integral component.

The environmental objectives for the ISMP to be addressed by Phoenix are:

- to provide an inventory and assessment of existing terrestrial (wildlife habitats and corridors) and aquatic habitats (watercourses, wetlands) within the Study Area using available information and limited "ground-truthing" site reconnaissance;
- to work with Delcan and with City of Surrey staff, Fisheries and Oceans Canada (DFO), and others (stakeholders) to identify environmental issues associated with existing and potential future stormwater infrastructure and development within the watershed;
- to work with Delcan and stakeholders to identify mitigation, enhancement and restoration opportunities associated with options for new or retrofitted stormwater infrastructure;
- to contribute to development of design criteria that will help achieve the long-term watershed goals of protecting and enhancing watercourses and aquatic life as well as preventing pollution and maintaining water quality;
- to contribute to and participate in the public consultation process for the Study;
- to contribute to the establishment of a monitoring and assessment strategy for long-term assessment of watershed health;
- and to contribute to the Final Integrated Stormwater Management Plan report and maps.

This report addresses the first of the above objectives, with the other objectives to be addressed in the future stages of the ISMP preparation.

1.2 METHODOLOGY

The scope of work by Phoenix for Stage 1 of the ISMP has included use of existing research and reports, as well as field verification where necessary, to conduct an inventory and assessment of the wildlife and aquatic habitats within the ISMP Study Area.

The methodology for this Stage 1 ISMP Environmental Assessment (Stage 1 EA) has entailed:

- Classification of all watercourses and assessment of current health conditions, including associated terrestrial habitats such as ravines, riparian areas, and wetlands;
- Identification of significant terrestrial habitats including trees and forests, old fields, and wildlife corridors;
- Identification of Sensitive Environmental Areas and areas of concern such as deteriorated watercourses (e.g. scour and erosion), potential sources of negative impacts to water quality, and degraded wildlife habitats.

2. WATERCOURSES

2.1 WATERCOURSE HEALTH

2.1.1 Unnamed Nicomekl Tributaries

Many watercourses within the Study Area are unnamed roadside ditches or farm ditches that are tributaries of the Nicomekl River. Farm ditches along the southern boundary (near Highway 10) are primarily classified as either Class A or Class A(O), but are low quality aquatic habitats due to high summer water temperatures and limited habitat diversity.

One of the most significant of these watercourses is a Class A segment (indicating possible year-round fish presence) starting from the Cloverdale Bypass at 58th Avenue and flowing southwest to 57th Avenue in an engineered channel (possibly an old farm ditch). The watercourse then turns directly south from 57th Avenue to Highway 10 (56th Avenue). This creek is not of high quality due to a lack of riparian vegetation (dominated by blackberry thickets), but has high potential for restoration between 56th and 57th Avenues, as it is not currently developed. The water quality is unknown, but may include untreated stormwater from the hectares of upstream development.

Use of the roadside and farm ditches in the dyked portion of the Study Area by fish is limited by summer water quality. The May 2002 South Cloverdale Master Drainage Plan Draft Report indicated that temperatures range between 17 and 22 degrees Celsius; high conductivity levels and dissolved solids; dissolved oxygen levels between 3.5 and 8.1 mg/L; and low pH values, indicating high microbial activity. In the 2002 fish inventory of the South Cloverdale ditches, no salmonid species were found.

Restoration of the riparian area along these watercourses with large shrubs (willows, dogwood) would improve aquatic habitat by decreasing water temperatures and providing shade and nutrients. Restoration works should include aggressive and sustained control of invasive species in conjunction with increasing the channel complexity where possible (i.e. increase meandering, create planted floodplain benches and backwater habitats).

2.1.2 McLellan Creek

McLellan Creek is the primary fish habitat that still has portions of natural habitat within the watershed. Site visits and research of the Fisheries Database and the South Cloverdale Master Drainage Plan Draft Report (May 2002) confirmed that the lower reaches of the creek support juvenile trout and salmon populations year round. Chum and Coho Salmon were observed in 1995 following restoration work; Chum and Coho Salmon, Cutthroat Trout, Rainbow Trout, and Steelhead were found during sampling in 1997; Coho were observed in 1999 (FISS); Coho were observed during the field visit by Phoenix in December 2009. Part of the upper reach is classified as fish habitat, but this is a theoretical designation that would only be realized if nearly a kilometer of storm sewer pipe was daylighted.

The headwaters of McLellan Creek are within a forested riparian area. The culverts appear to be appropriately sized and were not perched, as observed during field visits following a winter storm event. The portion of upper McLellan Creek located between 192nd and 194th (north of 64th Avenue) has a forested riparian zone and a well defined channel that does not show significant signs of erosion. The side channels that join the main stem at this location are currently classified as Class B. Very little flow was observed following a winter storm event. Both McLellan Creek and the tributaries would benefit from baseflow augmentation.

2.1.3 Cummins Brook

Cummins Brook is a tributary of the Nicomekl River to the west of McLellan Creek. The headwaters of this watercourse is a narrow channel that outfalls from a storm drain and flows south along a property line to 54th Avenue. The channel is bordered by suburban development to the west and industrial land to the east. The brook takes on a more natural form starting at the stormdrain outfall on the south side of 54th Avenue (at 189A Street), but has been impacted by surrounding residential and industrial development. The brook flows south into industrial zoned land, including areas of fill and parking/storage.

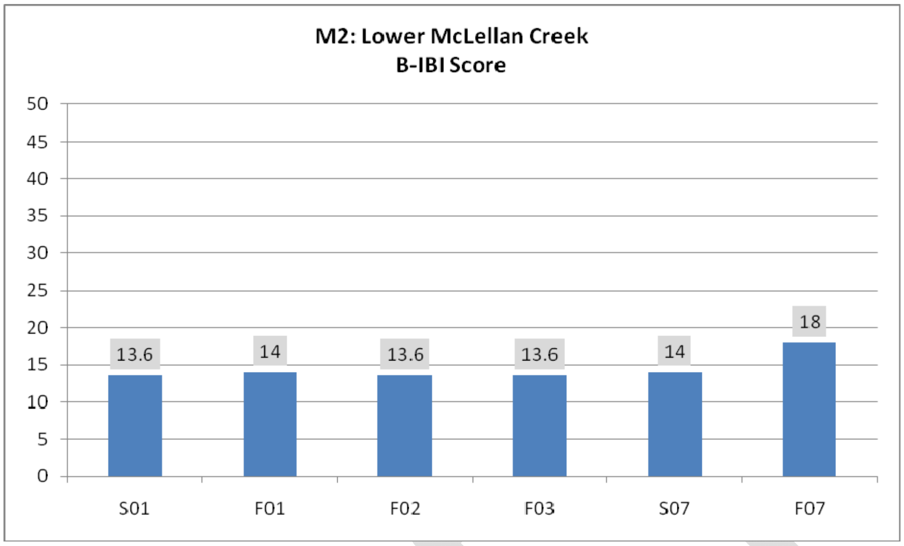
Recent modifications to Cummins Brook were observed in January 2010. The channel has been reconfigured as it passes through the industrial property on the north side of 52nd Avenue. Trees have been planted within the riparian area further to the north. The banks of the newly graded channel were not planted yet. It was confirmed with DFO that the relocation of the brook was not authorized.

The riparian area of Cummins Brook is primarily reed canary grass, with sparse tree cover within the Study Area. The lower reach beyond the Study Area, south the CPR tracks, enters a mixed deciduous/coniferous forest. The future development of the land surrounding Cummins Brook will play a large part in determining whether this watercourse continues to provide valuable food and nutrients to downstream fish habitats or degrades as a result of flow changes and water quality impacts from new developments and industrial activities.

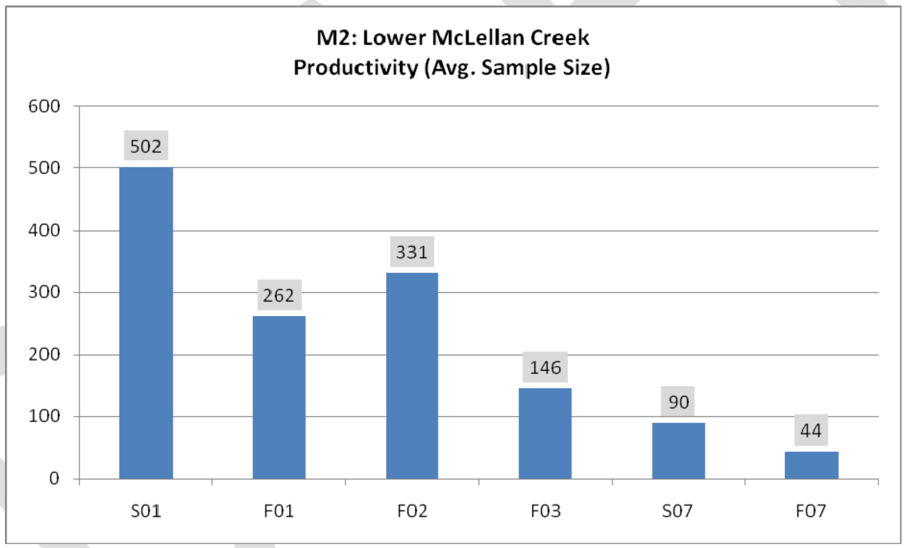
2.1.4 Benthic Index of Biotic Integrity (B-IBI)

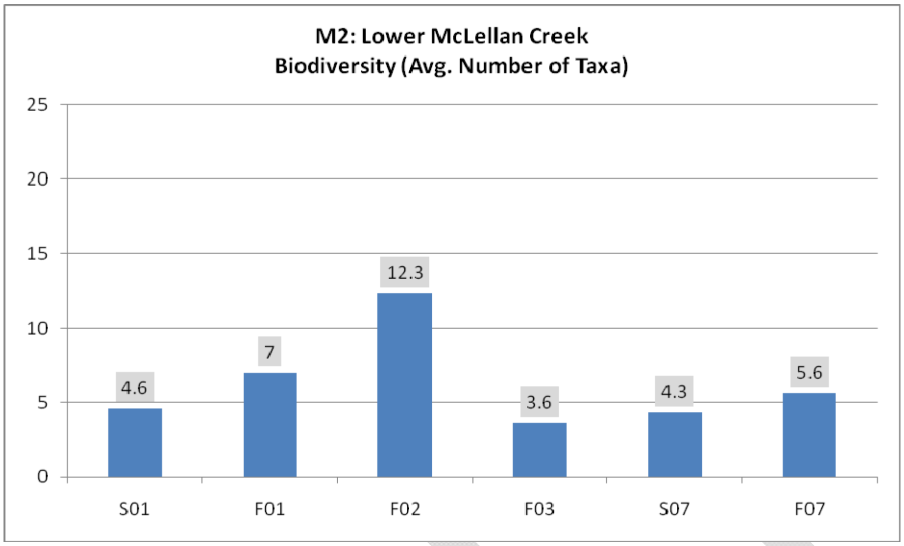
Two monitoring stations have been established by the City of Surrey to monitor the composition of the benthic macroinvertebrates of McLellan Creek. Station 1 is located in the upper reach of the Creek, north of 64th Avenue between 192nd and 194th Streets. Station 2 is located in the lower reach, south of the Langley Bypass. Data summaries were provided to by the City of Surrey.

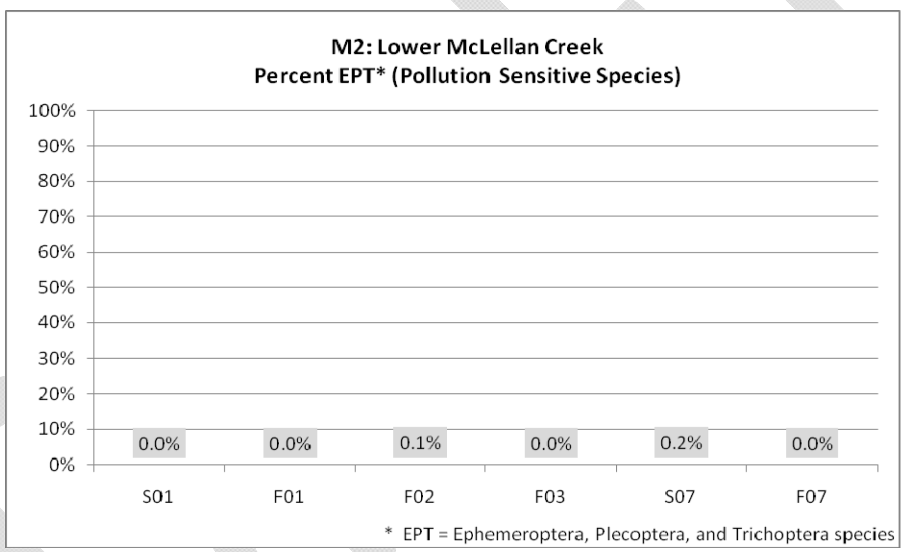
The Benthic – Index of Biotic Integrity (B-IBI) is a recognized standard method for determining the health of the aquatic ecosystem of a stream using analysis of the benthic macroinvertebrate population composition. Both sampling stations on McLellan Creek received scores indicating poor health (< 14 on a 35 point scale). No samples reached the threshold for “good health” at 21 points. Sampling done for the Lower McLellan Creek in 2007 showed a slight improvement in the overall metric scoring (B-IBI), but the average number of individuals in the sample significantly decreased (2001 – 502 individuals, 2007 – 30 individuals). Biodiversity and total sampling size have generally decreased since sampling began in 2001. Key data is summarized in the charts below.



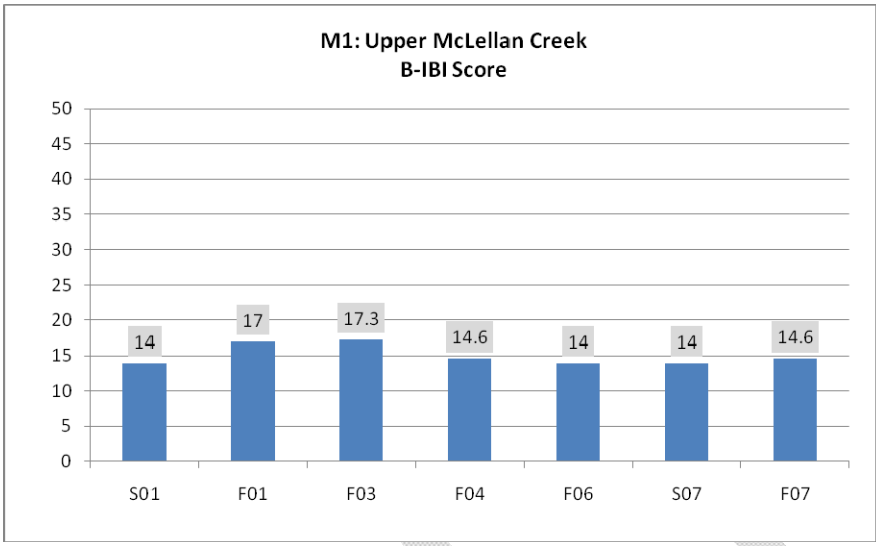
Note: S = Spring; F=Fall; Number refers to the year of sampling (ie. S01 = Spring 2001)

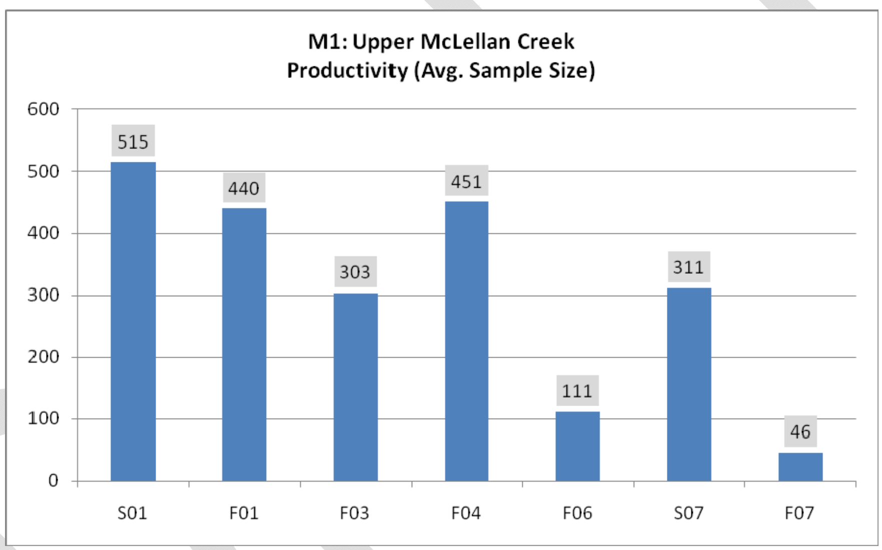


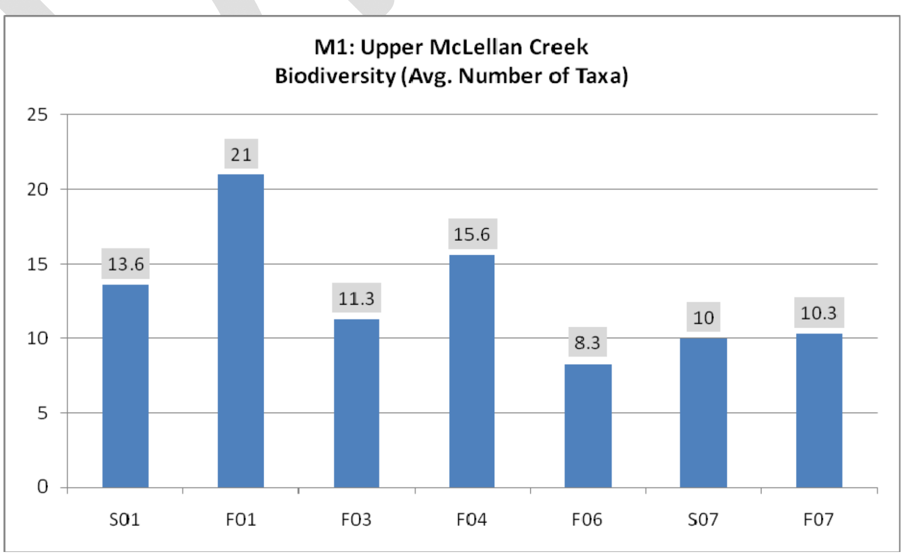


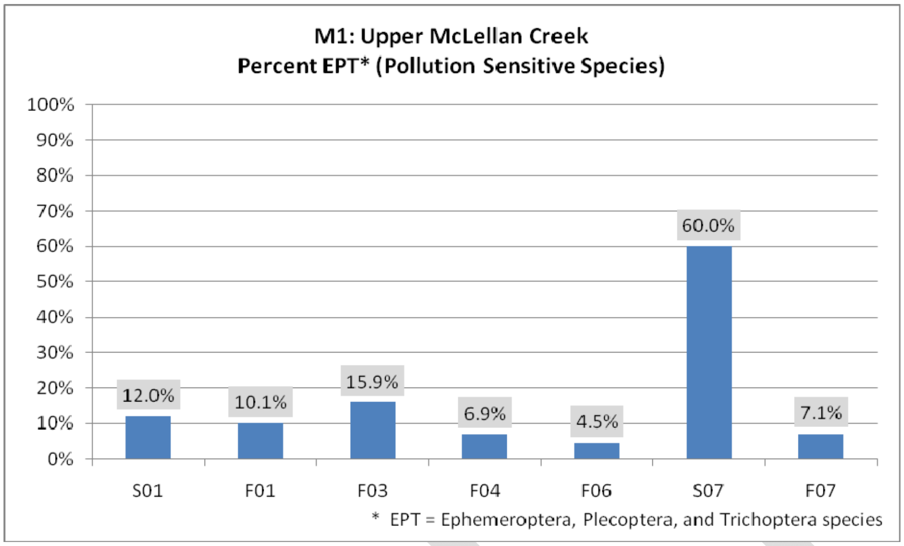


Samples for Upper McLellan Creek generally had greater biodiversity and a higher proportion of pollution-sensitive species, indicating better water quality and aquatic ecosystem health than the downstream segments. This is to be expected, as the upper reaches are primarily downstream of residential, while the lower reaches are downstream of heavily urbanized, industrial land. Key data is summarized in the charts below.


M1: Upper McLellan Creek
B-IBI Score
0
5
10
15
20
25
30
35
40
45
50
14
17
17.3
14.6
14
14
14.6
S01
F01
F03
F04
F06
S07
F07


M1: Upper McLellan Creek
Productivity (Avg. Sample Size)
0
100
200
300
400
500
600
515
440
303
451
111
311
46
S01
F01
F03
F04
F06
S07
F07


M1: Upper McLellan Creek
Biodiversity (Avg. Number of Taxa)
0
5
10
15
20
25
13.6
21
11.3
15.6
8.3
10
10.3
S01
F01
F03
F04
F06
S07
F07


M1: Upper McLellan Creek
Percent EPT* (Pollution Sensitive Species)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
12.0%
10.1%
15.9%
6.9%
4.5%
60.0%
7.1%
S01
F01
F03
F04
F06
S07
F07
* EPT = Ephemeroptera, Plecoptera, and Trichoptera species

2.2 WATERCOURSE CLASSIFICATIONS

The upper reaches of McLellan Creek (north of 64th Ave.) are currently classified as Class A with Class B tributaries. While this reach of McLellan Creek may have at one time supported a resident (e.g. trout) population, the low flows during late summer dry observed in this reach of McLellan Creek cannot support a resident population. The length of culvert enclosures downstream, the associated gradients within long runs of culverts, and velocity barriers during higher runoff events eliminate the potential for restoring fish access into the upper reaches of McLellan Creek without removing culverts (i.e. "day-lighting") on a massive scale. Consequently, the mainstem of the Mclellan Creek headwaters are proposed to be re-classified as Class B (see Appendix A, *Figure 1: Watercourse Classifications*).

There is a small side ravine to the northeast of mainstem McLellan Creek north of 64th Ave. During January 2010, the side ravine was essentially dry with no fluvial process evident in the leaf litter accumulation in the side ravine / tributary channel; even after several weeks of significant rainfall events (i.e. winter conditions). This watercourse is currently classified as Class B, but is currently exhibiting features of a Class C watercourse. If more baseflows were delivered to this side ravine (see Recommendations), then this side ravine tributary would have the ecological form and function of a Class B watercourse restored. Therefore, the Class B classification of this tributary is proposed to be retained.

The portions of Cummins Brook within the Study Area are currently classified as Class B. The headwaters of Cummins Brook is currently a 3-cell stormwater detention pond northwest of the intersection of 55A Avenue and 189A Street. There is a narrow v-notched channel downstream of the detention pond for about 15 m, after which Cummins Brook is conveyed by culvert to the west side of a large filled industrial lot adjacent to a recently constructed residential subdivision. During January 2010, very little flow was observed in the linear, shallow ditch-like channel north of 54 Avenue.

A short distance south of 54 Ave., Cummins Brook emerges from a recently constructed headwall and drains through an ill-defined, low gradient meandering channel(s) obscured by reed canary grass matting adjacent to the west of an agricultural field within a thin band of scattered cottonwood trees. However, evidence of short-term, high volume flows along sections of Cummins Brook has been observed in the reach upstream of a recent diversion. From the north end of a large recently filled lot at 18949 52nd Ave, Cummins Brook has been diverted into a large, steep-sided, V-shaped constructed channel. Evidence of sloughing of the lower banks along the fill slope has been observed along the (presently) unvegetated diversion channel. Until recently, this reach of Cummins Brook was a shallow, narrow meandering low-gradient stream through a wet meadow vacant farm field and a small stand of mature cottonwood at the south end of the diversion where Cummins Brook enters an adjacent lot to the west. On the north side of 52nd Ave., Cummins Brook flows by a wetland pond which is in part sustained by an abandoned well with artesian flow. (Note: the adjacent site to the west of Cummins Brook on the north side of 52nd Ave. has been previously assessed By Phoenix for an industrial land development application).

The culvert crossing 52nd Ave. for Cummins Brook is submerged, but open. It is suspected that this is also the case for the rail track crossing, which has not been observed due to vegetation cover (i.e. blackberry thicket). South of the tracks (just outside the Study Area), Cummins Brook flows through old field in an overgrown channel (i.e. reed canary grass), except where a small stand of cedar trees have shaded out the reed canary grass. Cummins Brrok is crossed by a farm access road with a slightly perched culvert and enters the large mature coniferous forest south of the Study Area. Cummins meanders through the forest with granular substrates further downstream. As such, the lower reaches of Cummins Brook offers very good over-wintering habitat with spawning potential for salmonids.

The current Class A classification of Cummins Brook south of the Study Area is supported by field observations by Phoenix. However, the currently shown location (within the forest outside the Study Area) where Cummins Brook changes to a Class B watercourse was not accessible during the field visit. As there was no obvious fish migration barrier south of the rail tracks, Phoenix proposes that the Class A classification extend at least as far north as the rail tracks or 52nd Ave. Upstream, lack of flow, depth, poor substrates and no bank vegetation along the recently constructed diversion channel cannot support upstream fish migration.

Within the Study Area, the current Class B classification for Cummins Brook is supported by Phoenix, provided the headwaters detention pond is converted and retained as a permanent bio-pond. Otherwise, Cummins Brook upstream of 54 Avenue now has the features of a Class C watercourse.

3. TERRESTRIAL HABITATS

A majority of the Study Area is developed and the dominant cover type is impervious surfaces (buildings, sidewalks, parking, roads). Based on the Ecosystem Management Study underway by HB Lanark, the Cloverdale area (not necessarily equivalent to this Study Area boundary) includes approximately 10% forest, 1.4% interior forest, 1.8% freshwater wetlands, and 8.6% old field habitat. During analysis of orthophotos and field reconnaissance of the Cloverdale-McLellan ISMP Study Area, no wetlands or interior forest (>100 m from edge) were identified by Phoenix.

3.1 TREES AND WOODED AREAS

The Ecosystem Management Study identifies that most forests in Surrey are deciduous, followed by mixed deciduous-coniferous, and a small percentage of forested area is dominated by coniferous species. This breakdown is consistent for forested areas within the Study Area. A majority of the Study Area is urbanized with very few and small stands of deciduous forest dominated by red alder (Alnus rubra) and black cottonwood (Populus balsamifera) remaining on undeveloped lots and along McLelllan Creek. However, a few areas of riparian forest and upland forest remain. These areas are young to mature forests and include a mix of deciduous and coniferous species such as red alder, big leaf maple (Acer macrophyllum), cottonwood, western redcedar (Thuja plicata), and Douglas fir (Pseudotsuga menziesii). The understory of these forests often includes invasive species due to the openness of the canopy and recent and ongoing disturbances along the edges (ie. blackberry).

Remaining forest stands of $\geq$ 1 hectare were identified by orthophoto (see Appendix A, *Figure 2: Sensitive Environmental Areas*). Many of these areas are within City parks or along the residential/agricultural edge. Due to the limited amount of habitat left in the Study Area, these forest stands are essential for providing refuge for birds and small mammals. Creating connections from these stands to the Nicomekl River or to the BC Hydro right-of-way would improve movement corridors for wildlife.

The largest forest within the Study Area is along the headwaters of McLellan Creek within the ravine northwest of 64th Ave. and 192nd Street. An area of forest is also present along the lower reach of McLellan Creek. Key habitat connections outside the Study Area are to the diverse and primarily coniferous riparian forest along Cummins Brook south of the CPR tracks outside of the Study Area and to the deciduous forest at Hi-Knoll Park. The B.C. Hydro right-of-way also provides a connection across the watershed divide to the north, joining with St. Gelais Brook, a tributary of the Serpentine River.

3.2 WILDLIFE INVENTORY AND HABITAT

The Study Area land use is primarily residential, commercial, and industrial with little contiguous forested land. As a result, there is little significant wildlife habitat within the Study Area. The remaining forested areas do not contain adequate interior forest habitat to support wildlife other than small mammals and birds. The existing background information, including the Ecological Management Study (HB Lanark), City of Surrey COSMOS mapping, and the B.C. Conservation Data Centre indicate that there are no known threatened or endangered species or interior forest habitats within the Study Area.

Based on previous studies, existing data, and field verification, the key wildlife habitats in the Study Area include 1) the remaining riparian forest at the headwaters of McLellan Creek, 2) the lower reach of McLellan Creek and the associated riparian area, and 3) the BC Hydro right of way that transects the site from northwest to southeast. The riparian forests south of the Study Area along Cummins Brook and McLellan Creek are also potentially important to maintain connectivity with the Nicomekl River and its floodplain.

The headwaters area of McLellan Creek includes roughly 4 hectares of young to mature mixed forest to the northwest of the intersection of 64th Avenue and 194nd Street. Although this stand is not large enough to provide habitat for sensitive interior bird species, it may provide adequate habitat to support populations of song birds and small mammals. Riparian habitats offer a variety of ecological functions and values due to their topographic variation and the availability of water and nutrients (Kennedy, et. al., 2003). This riparian forest likely supports amphibian populations, as well as providing food and nutrients for fish and amphibian populations downstream.

The lower reach of McLellan Creek is within a young to mature mixed forest. Although fairly narrow, this area is of particular value because of the creek, the connection to the deciduous forest at Hi-Knoll Park, and the proximity to the Nicomekl River. Multiple eagle nests have been documented just outside of the Study Area boundary in Hi-Knoll Park (COSMOS and HB

Lanark maps). McLellan Creek is one of the only remaining aquatic habitats where salmonid species are still present.

The BC Hydro right of way is approximately 140 meters wide and approximately 3.3 km long (within the Study Area) with above ground electrical transmission lines. The land uses under the power lines include a golf course, pedestrian paths, stormwater detention basins, and limited private land uses. The entire right-of-way has managed vegetation only, such as grasses and shrubs, since trees could interfere with the utility line. A majority of the edge condition of the right-of-way includes the back yards of single family homes, many of which have screened their property with trees and hedges. The right-of-way could be enhanced to provide better habitat conditions for small mammals and birds by the control of invasive species (i.e. blackberry, reed canary grass) and the addition of more native shrubs and small trees. For example, the existing outer edges of trees and shrubs could be widened without compromising the utility lines.

There are many impediments to movement of wildlife between the fragmented, relatively small habitat patches within and beyond the Study Area including roads, fences, buildings, culverts and impervious areas. Improvement to habitat quality and connectivity is possible, particularly along the edges of the BC Hydro right of way and where it crosses major streets. Although many habitats in the Study Area are not significant independently, the remaining patches and corridors of habitat (i.e. forests) within the Study Area warrant protection and enhancement for their potential benefit to City- and region-wide biodiversity resilience.

4. SENSITIVE ENVIRONMENTAL AREAS

There are no rare or unique environmental areas in the Study Area. However, due to the limited aquatic and terrestrial habitat, all remaining intact habitats are considered Sensitive Environmental Areas. The priority areas for protection include McLellan Creek and its riparian area, Cummins Brook and its riparian area, and the remaining forest stands of $\geq$ 1 hectare in parks and vacant lots. These areas are shown on *Figure 2: Sensitive Environmental Areas* in Appendix A.

5. CONCLUSIONS

5.1 KEY AREAS OF CONCERN

5.1.1 Deterioration of watercourses

Peak flow volume and velocity, lack of base flow, water quality, and loss of biodiversity are the primary concerns for the aquatic habitats within the Study Area. Reaches of lower McLellan Creek showed evidence of high peak flows such as bank scouring and flattened vegetation. A newly restored segment of the upper reach, just south of 64th Avenue, shows signs of significant erosion and bank scour. Excessive peak flows threaten to undermine channel restoration activities. At the same time, base flows have been diverted into the storm sewer system, resulting in some remaining watercourses drying out.

5.1.2 Loss of habitat (forests, streams, etc.) and habitat fragmentation

The Study Area is primarily covered with impervious surfaces, and the current road network and development pattern has significantly fragmented the habitat patches. Future road and storm sewer improvements should include consideration of box culverts with shelves for small mammal movement, fencing to funnel wildlife to appropriate culverts, and connection of these wildlife tunnels to greenways or other appropriate movement corridors. Remaining forest stands of $\geq$ 1 hectare should be protected to the greatest extent possible.

5.2 Opportunities for Restoration

Based on the inventory of existing aquatic and terrestrial habitats, the following opportunities for restoration were identified:

- Pursue stormwater retrofits to improve water quality where no controls are present or where only standard oil/water separators are currently being used.
- Enhance the unnamed tributaries of McLellan Creek (north of 64^{th} Avenue) by restoring base flows to these channels.
- Replace the lost forested wetland near Upper McLellan Creek by creating new streams and riparian areas.
- Remove excess railroad ballast from the lower reach of McLellan Creek, south of the Langley Bypass.
- Restore riparian and stream habitat along Cummins Brook and augment base flows through new stormwater facilities and retrofits, where appropriate.
- Redefine the stream channel and restore the riparian area south of 52nd Avenue and the CPR tracks (just outside the Study Area). Replace the farm road culvert (or remove, if possible).
- Enhance BC Hydro right-of-way with native shrubs and small trees, particularly along the edges. When road or underground utility works occur where the BC Hydro right-of-way crosses streets, find opportunities for installing shallow wildlife tunnels.

These potential opportunities for restoration are shown on *Figure 3: Opportunities for Restoration* in Appendix A.

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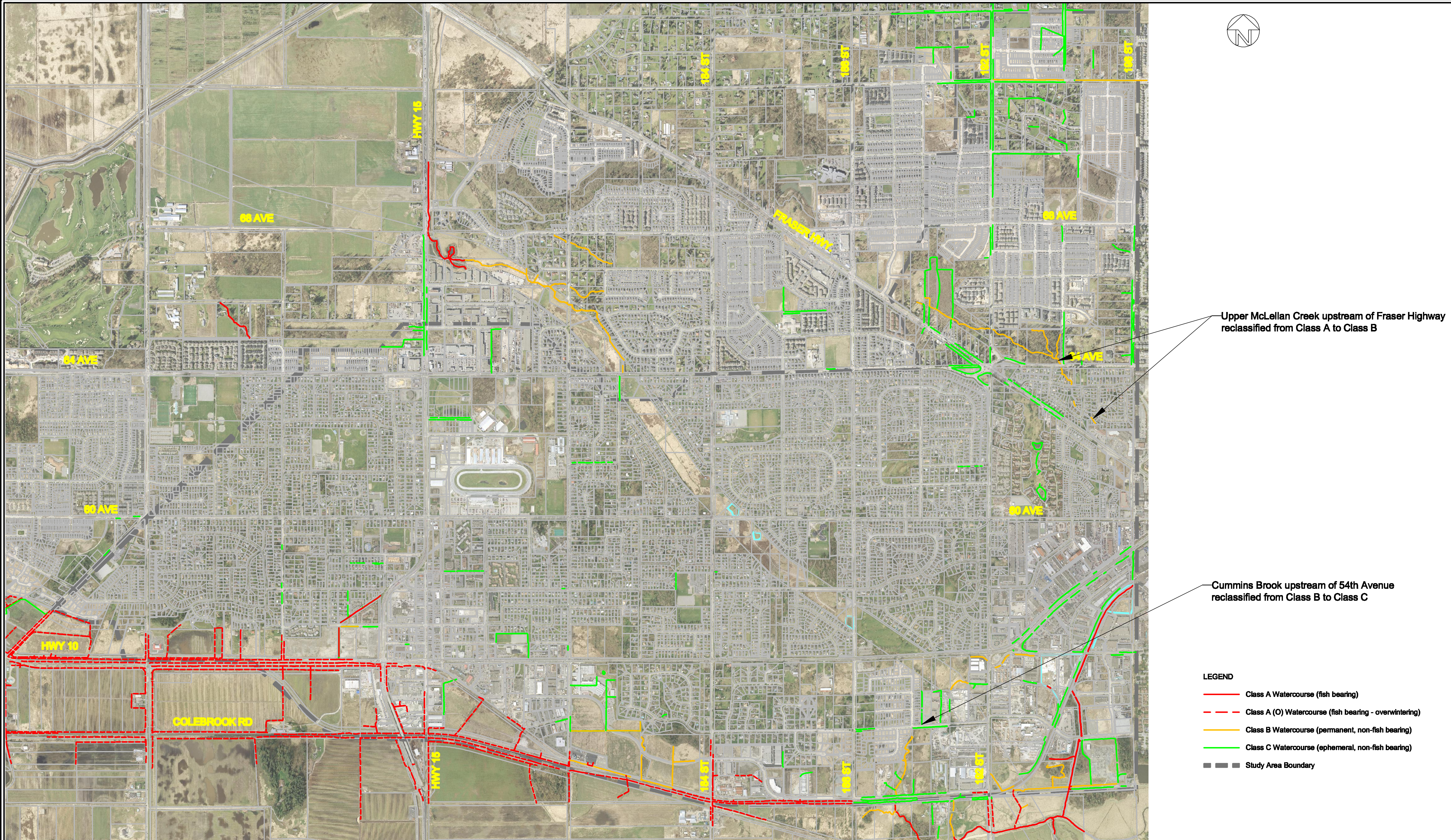

Figure 1: Watercourse Classifications

Cloverdale - McLellan Integrated Stormwater Management Plan
Surrey, BC

PHOENIX
ENVIRONMENTAL SERVICES LTD.
103 - 1600 West 6th Av. Vancouver V6J 1R3
tel. 604.689.3888 fax. 604.689.3880

DATE: Feb. 9, 2010	DRAWN BY: MBT	SCALE: As Shown	DWG: Stage 1 Maps.dwg

	Habitat Type	Approx. Size (ha)	Notes
1	Mixed Forest	0.8	
2	Old Field/Deciduous Forest	5.4	
3	Mixed Forest	1.2	
4	Mixed Forest	2.5	
5	Mixed Forest	1.0	
6	Mixed Forest	1.7	
7	Mixed Forest	2.3	
8	Riparian Forest	4.7	McLellan Creek
9	Mixed Forest	1.6	
10	Mixed Forest	2.5	
11	Riparian Forest	4.2	McLellan Creek
12	Old Field / Riparian Forest	9.8	McLellan Creek
13	Mixed Forest	4.1	Cloverdale Exhibition Grounds
14	Mixed Forest	2.1	Cloverdale Exhibition Grounds
15*	Mixed Forest	19.2	3.8 ha within Study Area
16*	Old Field/Deciduous Forest	2.8	Hi-Knoll Park
17*	Mixed Forest	13.3	Cummins Brook
18*	Mixed Forest	3.8	
19*	Coniferous Forest	9.0	

*All or partially outside of Study Boundary

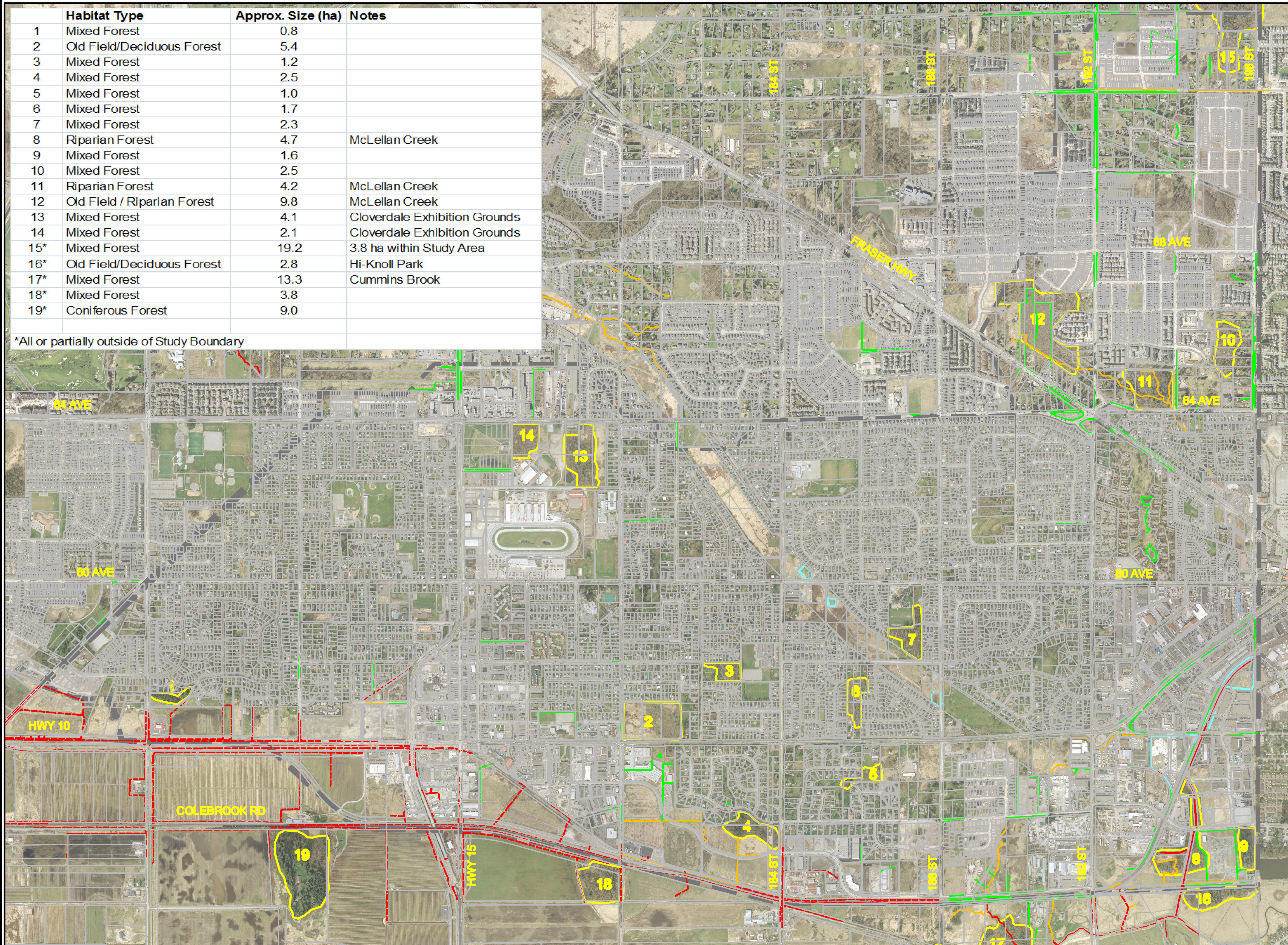

Figure 2: Significant Environmental Areas

Cloverdale - McLellan Integrated Stormwater Management Plan
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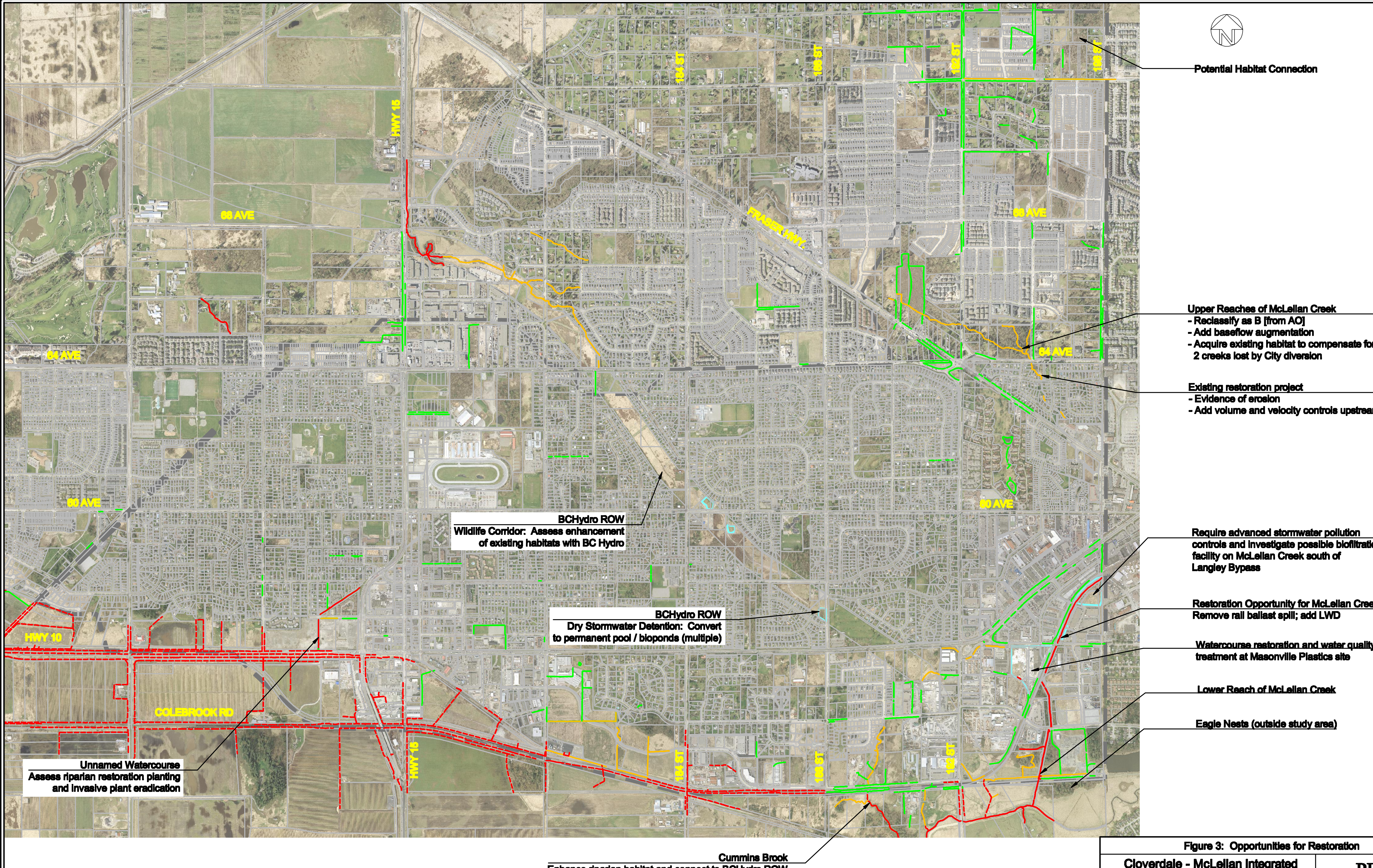

Figure 3: Opportunities for Restoration

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Surrey, BC

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