CITY OF SURREY

South Westminster Integrated Stormwater Management Plan (ISMP)

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EB3779

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Executive Summary

The City of Surrey has made a commitment to the principles of integrated stormwater management and is in the process of completing Integrated Stormwater Management Plans (ISMPs) for the municipality. Since this program was initiated in the 1990s, the role and objectives of an ISMP have evolved, and as a major municipality in the region, the City of Surrey has played a significant role in this evolution. Nowadays, ISMPs take an ecosystem-based approach to rainwater management with linkages to other planning documents, such as Official Community Plans (OCPs), and in Surrey's case, the recently produced Biodiversity Conservation Strategy (BCS).

This ISMP is specific to the watersheds in the South Westminster area. Its goals are to provide recommendations on actions to protect and restore water quality and stream health within the watersheds and to carefully manage habitat resources for protection and enhancement of sensitive ecosystems, as well as addressing issues such as flooding risks to public and private property, erosion in the creeks, future development standards, and deficiencies in drainage infrastructure.

The preparation of this ISMP follows the basic format proposed for the most recent plans:

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 – Monitoring and Adapting: "*How do we stay on target?*"

Section 2 – Watershed Existing Conditions provides details of watershed features relevant to plan objectives. The section begins with a review of background reports. These reports, ranging from engineering studies dealing with problems with ongoing stormwater infrastructure to the more recent OCP and BCS, are essential to understanding the history and evolution of development within South Westminster. South Westminster developed mainly as two separate areas, with urban residential development in the uplands and industrial development in the lowlands. Significantly, of the total of 5861 private lots in the study area, 65% were created prior to 1960.

The ISMP study area contains four separate watersheds, each with an outlet to the Fraser River. Of the four, the Manson Catchment is the largest; the others are Gunderson, Old Yale and Pattullo. The conveyance systems draining each watershed consist of a combination of open channels and creeks as well as underground storm drains. Significant features of the watersheds are the three pump stations which are the outlet points for the Manson, Old Yale and Pattullo watersheds. The design and operation of these pump stations are the subject of ongoing studies since they are an essential component of flood protection of the watersheds. The Gunderson watershed flows directly to the Fraser River.

Flows derived from pumping records during storm events, and data and records of flooding were used to set up, calibrate and validate hydrological models for each watershed. Once calibrated and validated, the models were used to identify areas where the drainage infrastructure is deficient for both current and future development scenarios. The results of this modelling were the basis for recommendations for infrastructure improvements presented later in the ISMP.

Parsons retained Phoenix Environmental Services to provide environmental assessments of the vegetation and ecological communities within the watersheds, watercourses and fish habitat, and wildlife corridors. As to be expected in an older developed area, the report identified several issues related to the watercourses including stream erosion, fish migration barriers, riparian habitat damage, and water quality degradation. Also, as expected given the history and density of development, the report found the wildlife corridors seriously impaired. The full report is provided as **Appendix B** to the ISMP.

A Vision statement answering the question "*What do we want?*" is provided in **Section 3 – Vision.** This was developed by reviewing the existing conditions in the watersheds and linking the specific ISMP objectives with the appropriate planning documents – the Sustainability Charter, the OCP and the South Westminster NCP. No wide scale public consultation was conducted since experience to date in ISMP preparation has shown the vision for the study area is primarily outlined by the City's policy documents and infrastructure. The Vision Statement as stated in the plan is *to provide distinct and efficient stormwater management systems for the upland and lowland areas that accommodate future development growth, protect the remaining natural areas, and provide opportunities to enhance the overall watershed.*

Section 4 – Implementation recommends actions and projects that the City could undertake to meet the objectives of the ISMP. Sixteen recommendations are made, and for each recommendation, the appropriate next steps are proposed; barriers, obstacles and challenges are identified; cost estimates are provided; and potential funding sources for the recommended action are noted. Additionally, a relative priority (on a scale of 1 to 5) is assigned to each recommendation, and key players and their roles in implementation are identified. At least one City department has a key role in all recommendations, while roles for the province and developers are also identified.

The sixteen recommendations can be categorized as follows:

- ***Six relate to drainage infrastructure improvements.*** Of these, several are directed at improving the level of service provided by the pumping systems at the outlets to three of the watersheds and at resolving issues at locations of known flooding within the watersheds. After further feasibility studies, as well as preliminary and detailed design of the improvements, these recommendations can be expected to lead to capital projects in the near term.
- ***Two are directed at developing updated design criteria to account for climate change.*** There is general agreement that climate change is occurring and extreme events are becoming more extreme. The ISMP recommends review and revision of the current IDF curves to account for this phenomenon. Also, the ISMP recommends development of design criteria to account for the expected sea level rise in order to facilitate a more rational basis for design of pump stations discharging to the Fraser River.
- ***Three are recommendations for on-lot controls for quantity and quality of runoff.*** This will be the responsibility of the developer/owner, most likely of lots being redeveloped, with the City as the mandating and enforcing entity.

- ***Two are directed at protection and enhancement of existing ecological resources.*** Because of past history of development in the study area, natural habitat and wild life corridors are severely compromised. However, these recommendations refer to examining opportunities where improvements can be made to habitat and where wildlife corridors can be restored during redevelopment.
- ***Three are recommendations for improving water quality in the watersheds.*** These recommendations are in recognition of improved water quality in conveyance systems and receiving bodies being a primary objective of effective integrated stormwater management. They also emphasize the importance of discharges from highways and roads as being the source of significant contaminants impacting water quality. The recommendations are to implement stormwater BMPs for new roads and for existing roads when they are being rehabilitated or expanded. Also, recommended is the assessment of the City's street cleaning programs and the availability of modern street cleaning equipment that collect and remove road contaminants and prevent them from entering the stormwater conveyance systems.

Section 5 – Monitoring and Assessment discusses the monitoring and ongoing assessment of the recommendations so that the success of the implementation plan can be tracked. From this, a basis for adaptive measures can be developed and a framework for future updates to the ISMP established. It recognizes that the City's current monitoring includes erosion monitoring on the creeks, benthic monitoring at two locations on Delta Creek, and automatic recording of levels and flows at the three pump stations from which continuous flows into the stations can be derived. This ISMP uses Metro Vancouver's *Adaptive Management Framework* to expand on the existing monitoring program and develop a monitoring framework specific to South Westminster.

1. Introduction

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 increasingly 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 and the South Westminster ISMP is one of 25 watersheds for which Surrey is completing ISMPs.

Before the 1970s, comprehensive urban drainage planning was not completely 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 traditionally used tools such as Master Drainage Plans (MDPs). At this time, Integrated Stormwater Management Plans (ISMPs) are the primary planning tool used to manage the City's water resources. Currently 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 South Westminster ISMP study area covers approximately 1250ha between 96th Avenue, 112th Avenue and 132nd Street south-west of the Fraser River. The Study Area includes both urban and industrial land uses with predominately single-family residential areas to the south on the escarpment and mixed industrial uses within the lowland floodplain of the Fraser River.

This ISMP applies the principles of integrated stormwater management planning to provide the City with guidance in three areas:

1. ***Directing Future Growth:*** Provide policy and planning directions for future development and land-use changes to reduce or offset negative impacts of these changes;
2. ***Solve Existing Problems:*** Existing flooding, drainage and infrastructure deficiencies need to be identified and potential solutions mapped out; and
3. ***Identifying Improvement Opportunities:*** Identify potential projects that could improve the watershed health that could be implemented in the short and long term.

The study is being 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?*"

1.1 ISMP Principles

Stormwater Planning: A Guidebook for British Columbia **(May 2002)** and the ***Metro Vancouver Template for Integrated Stormwater Management Planning*** **(December 2005)** provide a framework for effective stormwater management throughout the Province. They 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 will guide the analyses, discussion and implementation of this 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.

1.1.1 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. This 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	24 hour Rainfall 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'

1.1.2 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.

1.1.3 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 do not 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.

1.1.4 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 South Westminster ISMP to be linked to other planning documents, the plan will identify inconsistencies with the other planning documents and will provide recommendations for changes to those documents. ISMPs are most appropriately linked to a municipality's key planning documents such as: the Official Community Plan (OCP) and the Neighbourhood Concept Plans (NCP). The OCP describes the fundamental philosophy and principles behind the policies for future growth in the community. The NCP reflects 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.

The analyses and details presented in the ISMP must be consistent with the objectives outlined in other planning and policy documents. The concept is that 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, the Sustainability Charter is shown as the overarching document governing all planning in Surrey, and the OCP already provides some direction for the watershed.

2. Watershed Existing Conditions

The ISMP Study Area (**Figure 2.1**) can be divided into two general classifications: the upland residential areas and the lowland industrial and commercial areas. The uplands and the lowlands present very different challenges for the ISMP and are linked through drainage. The upland drainage is directed through a number of creeks and storm sewers into the lowland drainage system. The lowland drainage system is made up of a number of low gradient open channels and storm sewers. The eventual outlet for the drainage is the Fraser River either through flood boxes or pump stations. There are four named creeks that carry water from the upland area to the lowland: Robson, Scott, Delta, and Armstrong. Within the Lowlands are a number of open channels including Manson Canal, Colliers Canal and Pattullo Creek.

The ISMP Study area includes four major catchments: Old Yale, Pattullo, Manson and Gunderson. Delta and Scott Creeks are located in the Manson catchment area and enter the stormwater drainage system near South Fraser Perimeter Road (SFPR) eventually reaching Manson Pump Station via the canal system (Colliers and Manson Canals). Much of Robson Creek is located in the Manson catchment area, and is a Class A (Red) watercourse, meaning that it is inhabited, or potentially inhabited, by salmonids year round. It flows directly into the Manson Canal prior to reaching the Manson Pump Station.

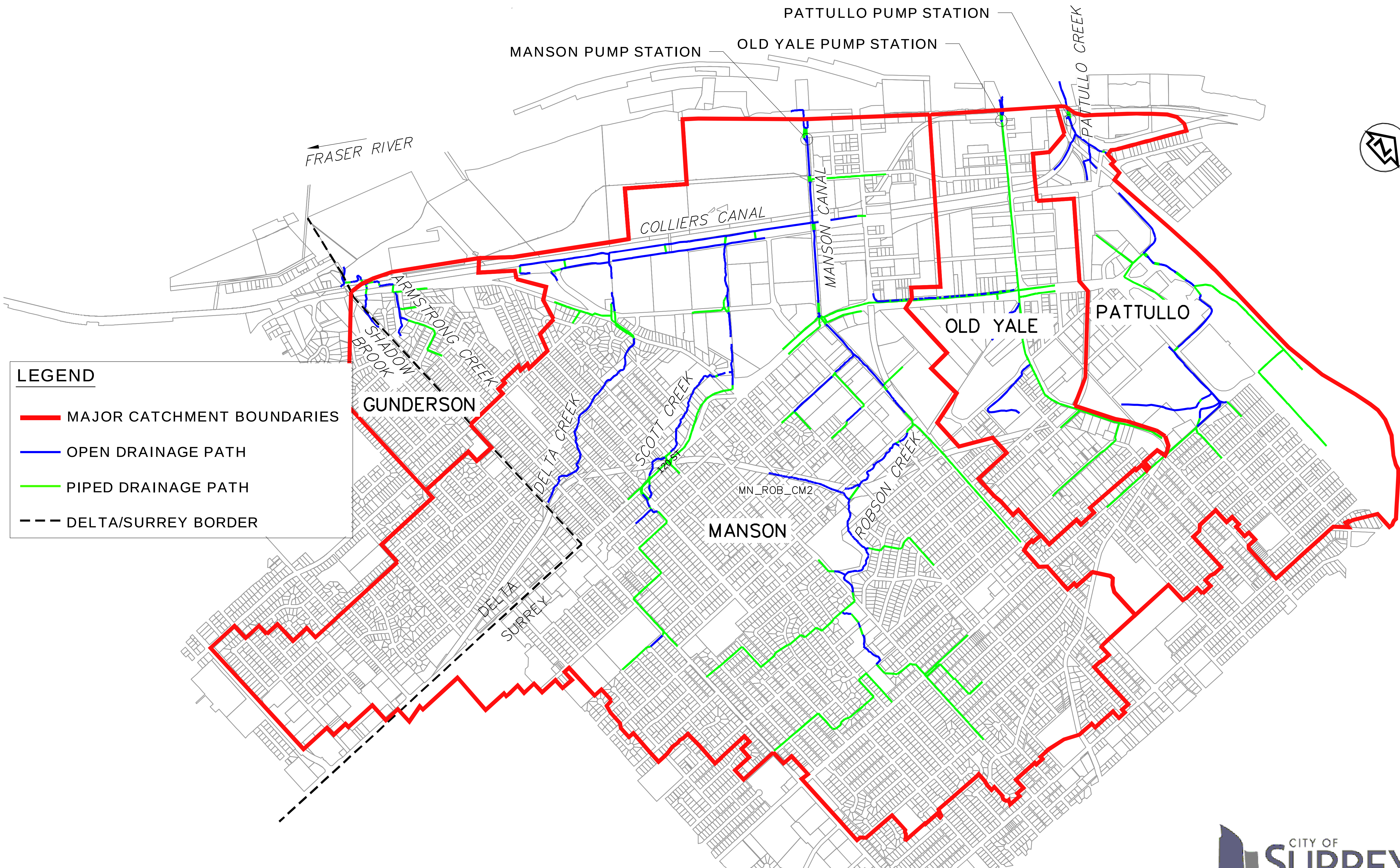
The stormwater drainage in the Old Yale catchment area eventually reaches the Fraser River via the Old Yale Pump Station. Much of the Old Yale drainage system is enclosed. Pattullo Creek discharges into the Fraser River via the Pattullo Pump Station. There is a connection between the Pattullo and Old Yale Pump stations that was constructed in 2009. Armstrong Creek and Shadow Brook are sub-catchments located in the Gunderson Slough catchment area and are both considered to be Class A watercourses. These watercourses eventually discharge into the Fraser River.

The lowland area is within the 500 year (or 1894 flood or record) flood plain of the Fraser River, but it is protected by a dyke system. The system is intended to protect to the 1:500 year flood elevation of approximately 4.4 metres (including a 0.6 metre freeboard) but there are some known gaps. Even if this flood protection is working, flooding could occur in a major storm event. Storm flooding is mitigated through open channel drainage to provide conveyance and storage and with the operation of pump stations and flood boxes along the Fraser River. In the future, the flooding and drainage problems have a potential to increase due to a number of factors:

- A portion of the new development proposed in the South Westminster ISMP is moving from low value, light industrial to high value commercial, residential and mixed use development. A key impact from a drainage perspective is that the new land uses will have a much lower tolerance for both nuisance (minor) and hazard (major) flooding; and
- Another pressure that will increase the chance of flooding in the future is sea level rise. Estimates for the future rate of sea level rise vary, but the area of South Westminster will be impacted over the next 50 to 100 years and beyond.

FIGURE 2.1

MAJOR CATCHMENT AREAS



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2.1 Background Reports

A number of background reports are available for the study area. These documents, listed in the Reference section, were reviewed to determine what relevant information should be used for the ISMP. The main reports are discussed below.

2.1.1 Stormwater Management Review Pattullo Drainage System (Associated Engineering, 1996)

The Pattullo Creek catchment experiences localized flooding, erosion and sedimentation issues. Furthermore, significant development is occurring in this catchment, particularly in the low lying Fraser River floodplain areas. A stormwater management review of Pattullo catchment was completed to determine the impacts of proposed modifications to the Old Yale catchment on the Pattullo system. It found that under existing development conditions, and with the existing drainage system, flooding could be expected in several areas within the Pattullo lowland areas on a regular basis. Flood protection and erosion control measures were recommended.

2.1.2 Old Yale Drainage System Stormwater Management Review (Associated Engineering, 1997)

The Old Yale catchment experiences localized flooding, erosion and sedimentation issues. Furthermore, significant development is occurring in this catchment, particularly in the low lying Fraser River floodplain areas. The report confirmed that under existing development conditions and with the existing drainage system, flooding can be expected on Old Yale Road, at the base of the upland area, on a regular basis. Moreover, the five year rainfall event results in a surcharged condition along the entire lowland sewer system. This situation is not a concern unless the hydraulic grade line exceeds the ground elevation, or causes basement flooding. However, the hydraulic grade line exceeded the ground elevation at 124th Street and Old Yale Road. The conclusion was that flooding is not a result of inadequate pumping capacity, but rather the limited hydraulic grade which limits conveyance of peak flows. This report included various improvements to be considered, which are as follows:

- Replacement of storm sewer located immediately upstream of the Old Yale pump station on Old Yale Road with a 2100 mm pipe; *(completed);*
- Replacement of storm sewer located between 124th and 125th Street on Old Yale Road, with a 1050 mm dia. pipe; *(not completed);*
- Replacement of storm sewers, located between 125th and 125A Street on Old Yale Road, with 900 mm dia. pipe; *(not completed);*
- Relocation of the water main near the intersection of Scott Road and Old Yale Road;
- Introduction of a control gate in the interconnection ditch between the two pump stations; *(completed);*
- Provision of a detention pond at the base of the upland areas in the vicinity of 124th St. and Old Yale Road; (unknown status); and

- Culvert modifications within the interconnection ditch between the Old Yale and Pattullo pump stations; *(completed).*

2.1.3 Creek Management Alternatives for Lower Delta Creek (KWL-CH2M, 1998)

The main objective of this report was to develop a long term strategy for creek management of the lower Delta Creek system with a focus on the River Road drainage system. About 70% of the Delta Creek watershed at the upstream end is located within the Corporation of Delta, thus creek management is inter-jurisdictional on a watershed basis. The River Road drainage inlet has a history of sedimentation and flooding problems and as such has been subject to blockage during storm events for the last several years. On October 28, 1996, it became blocked and overflowed, resulting in inundation of the road, damage to vehicles and some damage to adjacent properties.

The key findings in the report are as follows:

- Ravine instability delivers significant sediment and debris to the Delta Creek system, providing the potential for debris-laden floods which could exceed 1,000 m^3 in volume in an event;
- Delta Creek supports salmonids below Grace Road, although, habitat values are relatively poor;
- Soil quality investigations have determined that poor quality soil is present on the west side of Delta Creek below Grace Road as a result of historical wood waste fill, resulting in leachate to the creek system which is a significant water quality concern;
- Soil on the east side of the creek is not expected to be contaminated; and
- An existing GVS&DD sanitary sewer parallels the creek corridor below Grace Road and sewer overflows represent a periodic water quality impact. However, as shown on COSMOS, in November 1999 improvement works were carried out for Delta Creek at Grace Road.

2.1.4 Manson and Gunderson's Slough Watersheds Stormwater Management Review and Feasibility/Functional Plan (Associated Engineering, 1999)

The existing drainage networks of the Manson and Gunderson Slough Watersheds were modelled for the following scenarios: 2, 5, and 100 year spring/summer and fall/winter type storms for both existing and future development conditions. These watersheds were modelled free of any accumulated sediment and with varying seasonal 2-year Fraser River tidal conditions. The report found that the lowland drainage networks of the two watersheds service a 5-year storm event under existing conditions. However, the model illustrates local flooding of low lying areas adjacent to the Manson Canal from the pump station to 122 Street, Colliers Canal and the lowland reaches of Scott Creek. The 103A Avenue storm sewer from 122 Street to 121 Street floods under the 2-year storm event.

The existing undersized storm systems in the upland areas of the two watersheds for the 5-year storm event that cause local flooding are as follows:

- Several sections of 121 Street between 92A Avenue and 95A Avenue, 95A Avenue from 121 Street to 122 Street, and 122 Street from 95A Avenue to north of 96 Avenue;
- 97 Avenue from 124A Street to 125A Street, 125A Street from 97 Avenue to 97B Avenue, and 125A Street from 99 Avenue to Robson Creek upstream of 100 Avenue;
- From 128 Street at 99 Avenue through Robson Park to 127 Street;
- From 127B Street south of 100 Avenue through Robson Park to 127 Street;
- 128 Street between 100 Avenue and 100A Avenue, 129 St. from approximately 100A Avenue to 102 Avenue, and midway between 129 Street and 129A Street from 102 Avenue to 103 Avenue; and
- 122 Street from 102 Avenue to 102A Avenue.

The following storm sewers where highlighted by the model as potentially having capacity issues during the future 5-year storm event or greater:

- The Grace Road storm sewer from northeast of Robson Road to the Manson Canal;
- The Tannery Road storm sewer system outlet into the ditch between the Burlington Northern Railway (BNR) tracks and the SFPR; and
- The Scott Road storm sewer system from 101 Avenue to the Manson Canal.

Flooding of the lowland areas and surcharging of the upland storm sewer systems would be widespread during the 100-year storm events.

2.1.5 Manson Canal Drainage Improvements Post Construction Monitoring Program (New East Consulting, 2000)

A monitoring program was carried out in the Manson Canal area before and after drainage improvements in the canal were constructed. Groundwater levels and ground movement were monitored for 18 months prior to construction and 12 months after. No substantial ground movement was observed after construction.

2.1.6 South Westminster Neighbourhood Concept Plan (2003)

Surrey has a number of secondary land use plans that supplement the OCP. Secondary plans such as Neighbourhood Concept Plans (NCPs) provide detailed neighbourhood-level land use planning for developing areas throughout the city. For this study area there is one NCP: South Westminster NCP that was completed in 2003. The following summarises some main points that are discussed in the NCP.

The land area covered by this NCP is approximately 514 hectares located in the lowland floodplain of the Fraser River. This area is designated as “industrial” in the OCP. The ISMP Study Area includes both lowland and upland area. The re-development of the industrial area was the primary focus in the NCP. The area covered by the NCP also encompasses the Fraser River Port Authority (now Port Metro

Vancouver) and associated lands where a multi-berth port facility known as the Fraser Port is located. It is the largest industry and the most active use in the area. In addition to the Fraser Port, South Westminster's industrial area currently includes auto salvage yards and other industries requiring outdoor storage. The salvage yard areas have recently declined and several new commercial developments have occurred in the area such as a Chevron Station on Scott Road and a Home Depot on 128 Street at 110 Avenue.

The NCP states that the South Westminster area remains relatively undeveloped and under-utilized, the current industries located in this area were regarded as interim uses, and these industries neither provide large employment opportunities nor are a catalyst for new business growth.

The NCP includes a Land Use Plan that has been formulated for the South Westminster area, which is illustrated in **Figure 2.2**. This plan shows five distinct districts characterized by the different types of land uses they will support, which are as follows:

Area 1 - Fraser River Waterfront;

Area 2 - Yale Street Commercial;

Area 3 - Transit-Oriented Urban Village;

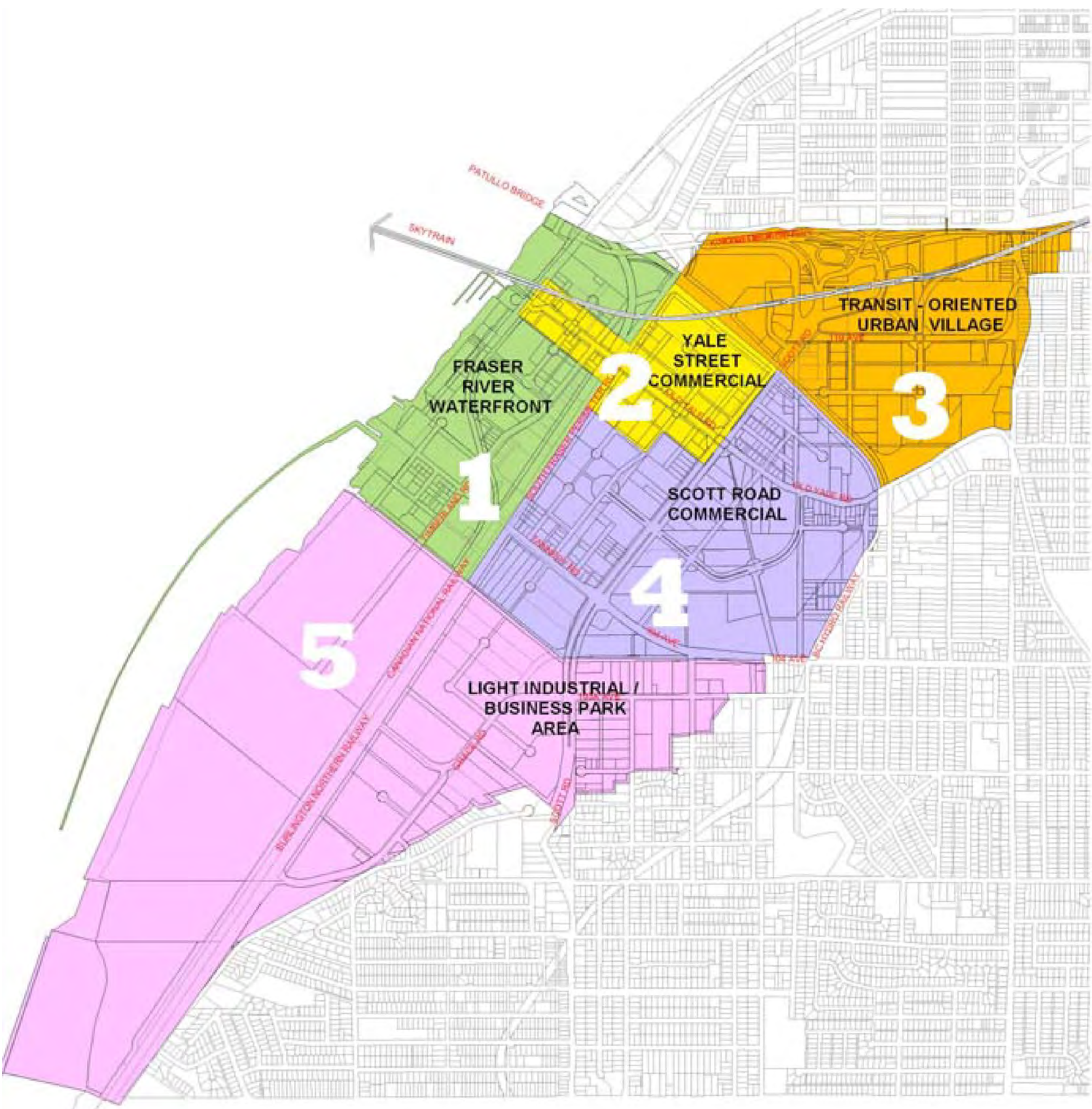
Area 4 - Scott Road Commercial; and

Area 5 - Light Industrial/Business Park Area.

The area is protected by a dyke system along the Fraser River designed to the 1:500 year flood elevation at approximately 4.40 metres (plus a 0.6 metre freeboard). It is stated in the NCP that Provincial flood proofing regulations will apply to new development in the area. Incremental filling to achieve flood protection standards may lead to increased flooding in some areas. Any comprehensive fill and pre-load plan will need to take into account potential flooding impacts.

The creeks in the low-lying area are generally considered to be Class A watercourses. It is stated in the NCP that this has posed a limitation on maintenance activities needed to maintain capacity in the canal. Therefore, there is a limitation on the capacity of the Manson Canal and pump station to protect the area from flooding. This is investigated further in this ISMP. The Colliers and Scott Creeks formally had their own outlets to the Fraser River, but have since been filled. The NCP recommended that the former open channel outlet for Colliers Creek be reinstated to relieve the Manson Canal. In addition, the NCP describes how riparian habitat enhancement along Scott and Colliers Creeks will likely be necessary to enable the Manson pump station to be upgraded, which may be accomplished for the Manson Canal and other channels through a long-term maintenance agreement with the Federal and Provincial governments. The opportunities and constraints from a drainage perspective are presented in the South Westminster Servicing Study which will be discussed in the subsequent section.

FIGURE 2.2
LAND USE PLAN



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2.1.7 Manson and Gunderson's Slough Watersheds Stormwater Diversion to the Fraser River (Associated Engineering, 2004)

In 2004 Associated Engineering re-investigated the Stormwater Management Review and Feasibility/Functional Plan in letter form. It was found that the options of a New Open Channel through the Port lands to be the most successful alternative in terms of mitigating lowland flooding in the study area.

2.1.8 125th Street Functional Stormwater Review Project (Stantec, 2006)

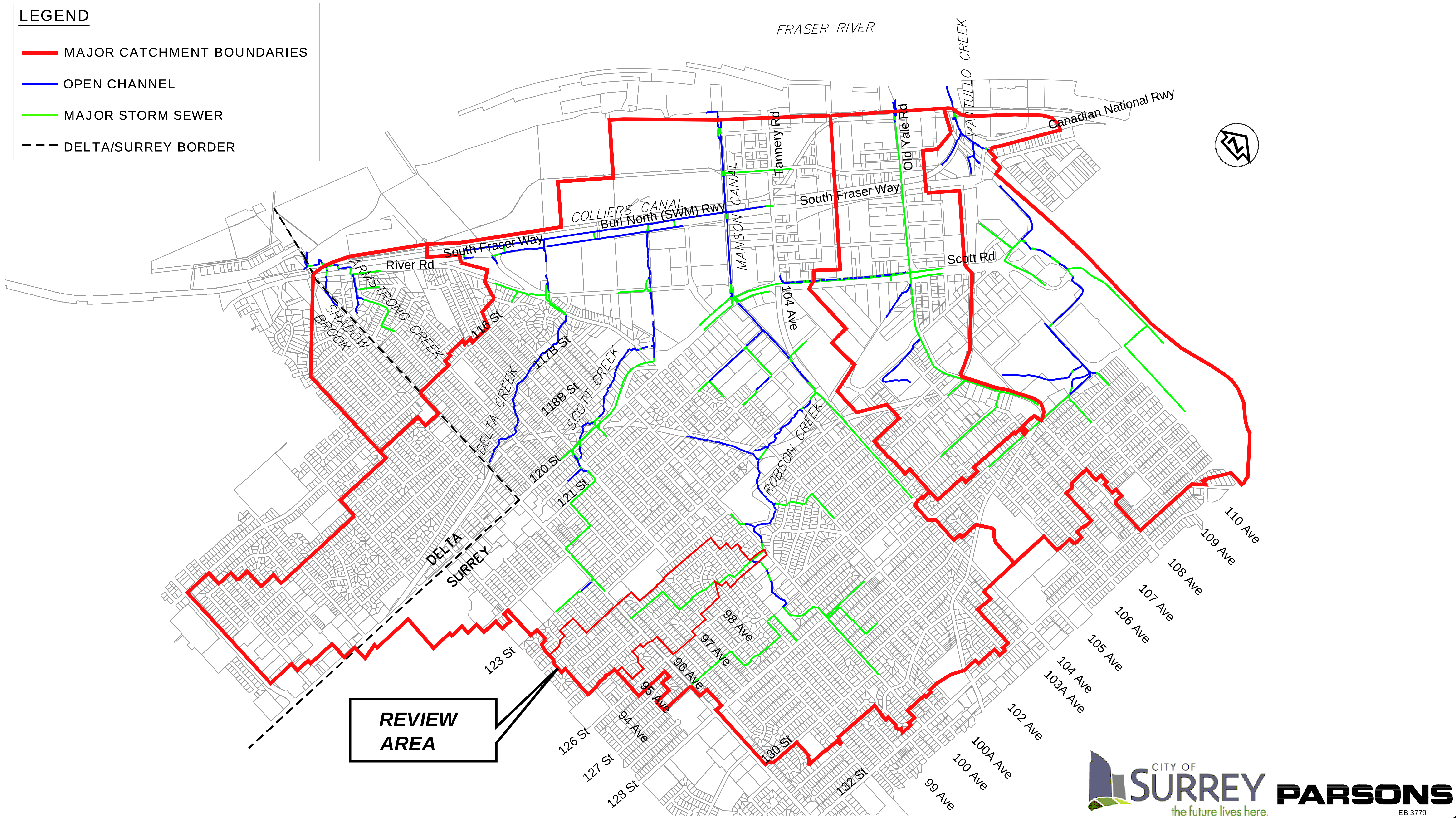
This report was initiated due to property flooding on 125th Street. It provided a preliminary review of the existing and proposed stormwater management features associated with the 125th Street Functional Stormwater Review Project. The location is shown in **Figure 2.3**.

The report recommended that the City of Surrey consider the following drainage improvement works:

- Upgrade 81 metres of 200 mm diameter storm sewer to 375 mm along 124th Street (just north of Iona Place);
- Upgrade 3.5 metres of 300 mm diameter storm sewer to 900 mm along 125th Street (just south of 96th Avenue);
- Upgrade 89 metres of 250 mm diameter storm sewer to 900 mm along 96th Avenue (west of 125th street);
- Upgrade 11 metres of 600 mm diameter storm sewer to 750 mm at 12515 97A Avenue *(not completed);*
- Upgrade 87.5 metres of 250 mm diameter storm sewer to 375 mm along 125A Street from 97 to 97A Avenue;
- Upgrade 12.5 metres of 600 mm diameter storm sewer to 750 mm at 12527 97B Avenue;
- Upgrade 15 metres of 600 mm φ storm sewer to 750 mm at 12546 99A Avenue;

FIGURE 2.3

125TH ST FUNCTIONAL STORMWATER REVIEW LOCATION PLAN



- A video inspection program should be put in place for all side yard storm sewer system plus existing storm sewers along 124A Street (96A Avenue to 97A Avenue, and 97A Avenue (124A Street east of 12515 97A Avenue);
- Proposed storm sewer works along 96th Avenue should be coordinated with the pending roadway improvements for the area; and
- The City of Surrey should do a detailed review to confirm which side yard sewer systems are located in either a registered Right-of-Way or an easement.

A review of the information available indicated that none of the sewer upgrades have been completed to date.

City staff reports that a more detailed study of this area will be undertaken this year.

2.1.9 Sustainability Charter (2008)

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 ISMP are the goals that could impact creeks and drainage systems; among them the general goals to respect natural areas and minimize the impacts of economic activities on the environment and to promote environmentally friendly businesses and "green" building practices. Some of the more specific rainwater / stormwater goals that influence the ISMP are listed below:

- ***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:
    - Minimize the impacts of development on the natural environment;
    - Promote the use of native species and reduce the impact of invasive species;
    - Promote permeable surfaces where possible in new developments;
    - Incorporate opportunities for natural areas and urban wildlife; and
    - 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.

2.1.10 10-Year (2012 – 2021) Servicing Plan (2011)

The objective of the 10-Year Servicing Plan is to establish a program of municipal engineering infrastructure works and services that are required to meet the needs identified under the Official Community Plan and Neighbourhood Concept Plans approved by Council. The Servicing Plan identifies the costs to provide transportation, drainage, water, and sanitary sewer services for both the existing population and the projected growth in population over the next 10 years (2012-2021). The 10-Year Servicing plan contains recommendations from past plans and the next update of the servicing plan will consider any new recommendations that have come forward.

The Ten Year Servicing Plan also includes a section on Stormwater and Environmental Works. According to this Plan, the majority of the replacement of the aging drainage mains will not be required for at least another 35-40 years. About 98% of the drainage main inventory are concrete or PVC, and have an estimated service life of 75 years, assuming they were installed using good construction practices. Therefore, the replacement demand from these mains will arise together and start by year 2045 and span the following 40 years. **Table 2.1.1** below includes the existing system upgrades in the New Westminster drainage area. **Figure 2.3** shows the locations of these upgrades.

Table 2.1.1: Program 1662 – Existing System Upgrades in New South Westminster

Project ID	Project Name	Project Location	Priority	Total Cost
6330	Robson Creek High Flow Diversion	123A St / 101 Ave	Long Term (7 – 10 years)	-
6331	Culvert Upgrade	120A St – 98 Ave	Short Term (1 - 3 years)	$133,000
6340	Upgrade 122 St. Sewer	122 St: 92 – 96 Ave	Short Term (1 - 3 years)	$393,000
7006	60m of 400mm diameter culvert upgrade and 360m ditch work	114 Ave: 123 St – 124 St	Long Term (7 – 10 years)	$40,000
7007	40m of 400mm diameter culvert upgrade and 160m ditch work	113 Ave: 124 St – 125 St	Long Term (7 – 10 years)	$284,000
7224	Robson Park Trunk Upgrades	99 Ave from 128 St to Robson Park Outlet	Medium Term (4 – 6 years)	$15,000
11655	Storm sewer upgrade	124 St: 99 – 100 Ave	Long Term (7 – 10 years)	$709,468
11656	Storm sewer upgrade	107 Ave: Old Yale Rd – 132 St	Long Term (7 – 10 years)	$709,306
11658	Storm sewer upgrade	96A Ave: 116 St – Townline Division	Long Term (7 – 10 years)	$422,625

Project ID	Project Name	Project Location	Priority	Total Cost
11659	Storm sewer upgrade	96A Ave: 116 – 120 St	Long Term (7 – 10 years)	$841,766
11660	Storm sewer upgrade	126 St:102 – 104 Ave	Long Term (7 – 10 years)	$1,458,804
11663	Storm sewer upgrade	122 St: 100 A – 100 Ave	Long Term (7 – 10 years)	$73,198
11994	Upland Pattullo and Bolivar Drainage Works	Area bounded by 108 Ave, 132 St, 106 Ave, 128 St	Short Term (1 - 3 years)	$3,000,000
12157	Storm sewer extension	118B St: 98 Ave to 97A Ave	Medium Term (4 – 6 years)	$70,000
12189	112A Ave Drainage Upgrades	112A Ave, west of 124 St	Short Term (1 - 3 years)	$155,000

The Creeks form an integral part of the City's drainage system. Stormwater management practices are implemented in order to reduce impacts of peak flows but because of the history of past development, damage still occurs. The City carries out detailed assessments of problem areas and the projects to address medium and high risk areas are part of the 10 Year Servicing Plan under the Erosion and Ravine Stabilization Program. **Table 2.1.2** illustrates the Erosion and Ravine Stabilization programs that are planned in South Westminster, including their total cost, growth and non-growth components.

Table 2.1.2: Program 1678 & 1679 - Erosion and Ravine Stabilization Programs in South Westminster

Project ID	Project Name	Project Location	Priority	Total Cost
6337	Scott Creek Ravine Erosion Protection Works	Scott Creek: 99 Ave / 120 St to River Rd	Medium Term (4 – 6 years)	$331,000
6338	Robson Creek Ravine Erosion Protection Works	Robson Creek: 127 St / 99 Ave – 104 Ave / 123 St	Medium Term (4 – 6 years)	$271,000
6735	Erosion Protection	128: 109 – 110 Ave	Medium Term (4 – 6 years)	$20,000
12847	Ravine Assessment in year 2012	Throughout Surrey	Short Term (1 – 3 years)	$1,000,000

There are two proposed road widening projects that may present an opportunity for the ISMP. They are listed in the 10 year servicing plan, and are shown in the below table.

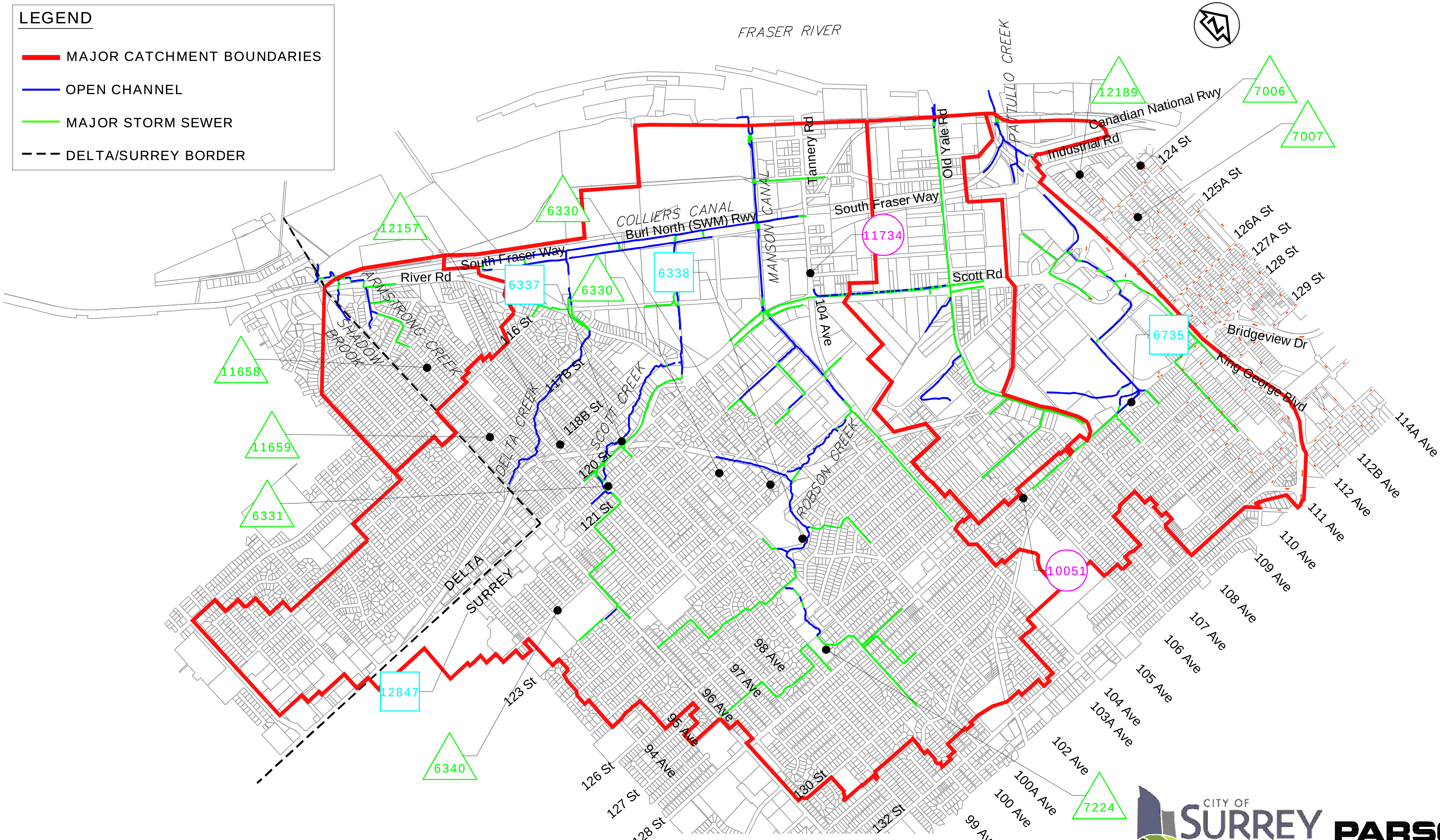
Table 2.1.3: Transportation Projects in the 10-Year plan

Project ID	Project Name	Project Location	Priority	Total Cost
10051	Ultimate Arterial Widening	128 St: 104 Ave – 108 Ave	Medium Term (4 – 6 Yrs)	$5,700,000
11734	Ultimate Arterial Widening	Tannery Rd: SFPR – Scott Rd	Short Term (1 - 3 Yrs)	$3,210,000

Understanding of these projects and awareness of their proposed timing could allow for some coordination of ISMP recommendations with these projects when they go to construction. **Figure 2.4** compiles all three programs: Existing Drainage Upgrades, Erosion and Ravine Stabilization and Transportation, onto a single plan showing their locations in the South Westminster area.

FIGURE 2.4

10 YEAR SERVICING PLAN PROGRAMS (2012-2021)



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2.1.11 Ravine Stability Assessments (Various 2011, 2009, 2006, 2002)

The City of Surrey completes a ravine stability assessment every two years where all ravines in the City are inspected and all erosion zones are documented and classified. Any sites that have significant erosion are further examined by a Professional Engineer, and remedial actions recommended by the Engineer are undertaken. The City's latest report was for 2011. It identified 48 sites within the study area, five were deemed medium risk and the remaining were considered low risk. The state of erosion within the study area is discussed in **Section 2.5** of this plan.

2.1.12 Official Community Plan (OCP) (2014)

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*. 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 ISMP must incorporate these principles in order to stay aligned with the City's priorities.

2.1.13 Sustainability Charter – Progress Report (2014)

In 2014, the City of Surrey updated City Council on the progress made on the goals outlined in the Sustainability Charter. In this report it was noted that an increase of 100 km of greenways, park pathways and other "active" transportation infrastructure was completed since 2011. It also identified the completion of remaining ISMPs was on schedule and noted that ISMPs covering 100% of the City's land area will be completed by the end of 2016. In a previous progress report, it was noted that the City had introduced standards for absorbent top soil cover on private yards in new development and rainwater infiltration systems in city boulevards.

2.1.14 Biodiversity Conservation Strategy (Diamond Head Consulting, 2014)

The goal of this report is to document the strategy to preserve the City's biodiversity over the long term. Consultation with stakeholders and the public was a key component of the process in identifying the values, places and challenges associated with preserving biodiversity. The current state of diversity was evaluated, options for conservation were prioritised and appropriate management strategies and policies were developed. While many of the recommendations in this document naturally focus on biodiversity, some relate to climate change, infrastructure, and site design.

2.2 Land Use

A critical component of any ISMP is to understand how past, present and future land use impact hydrology.

2.2.1 Past and Present

South Westminster is predominantly developed with urban residential in the uplands that accounts for approximately 57% of the land, and industrial in the lowlands which accounts for approximately 38%. **Table 2.2.1** presents the breakdown of zoning in the Study Area.

Table 2.2.1: Land Use in the Study Area

Land use	Area (ha)	Percentage
Urban Residential	652	57%
Multiple Residential	38	3%
Industrial	433	39%
Commercial	12	1%
Total	1135.7	

There are 5821 private lots in the study area. As illustrated in **Table 2.2.2**, the majority of these lots (65%) were created prior to 1960. In the late 19th century, South Westminster was a thriving residential community. However, following the collapse of the building boom in 1913, development of South Westminster idled until the mid-20th century when industrial uses gradually began to replace the residential community in the lowlands.

Table 2.2.2: Age of Lots

Age of Development	Percentage of Lots Created
Before 1950	26%
1950s	39%
1960s	9%
1970s	8%
1980s	7%
1990s	5%
2000 to present	6%

The age of residential development is also very important for understanding the overall impervious area within the watershed. The South Westminster study area is one of the older areas of Surrey. Most lots are between 700 and 900 square metre. If the original house is still there, they tend to take up 20-25% of the in area. If the lot is developed, 40% coverage is more normal. **Figure 2.5** shows two neighbouring properties where the original smaller footprint is to the north and the redeveloped home is to the south. The difference in lot coverage is apparent. When other impervious areas such as driveways, patios and sheds are added, the percentage of lot impervious area increases.

Figure 2.5 Typical House Before and After Re-Development

Re-development represents a potential future change in the watershed characteristics. A visual air-photo review indicated that this area of Surrey is not re-developing as quickly as other areas but neighbourhood demographics and market trends could change that in the future.

2.3 Watershed Features Overview

ISMPs are generally prepared and implemented on a watershed or sub-watershed basis. As previously stated, hydrologically the South Westminster ISMP study area can be broken into four catchments, each with an outlet that drains to the Fraser River. Of the four catchments, Manson is the largest and contains some distinct features. The others are Gunderson, Old Yale, and Pattullo. Refer to **Figure 2.1** for location and extent of each catchment.

The creeks and open channels that flow within each catchment are in most cases the catchment's most defining water resources feature. The following is a brief overview of the characteristics of some of the major creeks and open channels within the study area. **Figure 2.2** following shows location and routing of these creeks within the individual catchments.

As noted in Section 2.1.4, most of the recommendations from the *Manson and Gunderson's Slough Watersheds Stormwater Management Review and Feasibility/Functional Plan* have been implemented, including, and specific improvements are noted in the watercourse descriptions below.

2.3.1 Delta Creek (Manson Catchment)

Delta Creek is an urban stream situated on the north facing slope of Surrey and is contained in a steep ravine between 96 Avenue and River Road. The upper watershed is above 96 Avenue in the Corporation of Delta and the lower watershed is within the City of Surrey. Delta Creek discharges to the Fraser River via Manson Canal, and is divided as shown in **Table 2.3.1**.

Table 2.3.1: Delta Creek's Drainage Area

Portion	Area
Upper Watershed – District of Delta	112 ha
Upper Watershed – City of Surrey	45 ha
Lower Watershed – City of Surrey	28 ha
Total (above River Road)	184 ha

Delta Creek within the City of Surrey is a Class A (or red-coded) watercourse which means that it is inhabited or potentially inhabited by salmonids year round. **Section 2.8** will further examine the wildlife and fisheries aspects of this creek.

The soils in the watershed are comprised of Capilano sediments overlying Vashon drift sediments. The creek is actively eroding the Capilano sediments through down-cutting of the creek channel and toe erosion of the ravine side slopes in the upper part of the ravine. The lower ravine is less erodible as the creek encounters Vashon drift and the channel is shallower.

As documented in the *Report on Creek Management Alternatives for Lower Delta Creek (KWL-CH2M, 1998)*, this watercourse has a history of sedimentation and flood problems and the River Road drainage inlet has been subject to blockage during storm events for the last several years. This report also includes various options for improving sediment and debris management on lower Delta Creek. Two of the alternatives included an upstream debris basin which would be capable of retaining 500 m^3 to 2,000 m^3 of debris during a debris-laden flood, and these have been installed.

Delta Creek at 98A Avenue showing signs of erosion.

Delta Creek's ravine at 96A Avenue illustrating many trees which have fallen into the channel.

2.3.2 Colliers Canal (Manson Catchment)

The channel adjacent to the BNR tracks is known as Colliers Canal, and is part of Delta Creek. It was created to divert flows to accommodate development of Port lands. It is a Class A (or red-coded) watercourse which means that it is inhabited or potentially inhabited by salmonids year round. Historically, Delta Creek continued flowing northwest through culverts crossing the Burlington Northern and Santa Fe (BNSF) Railway and CNR tracks. A private ditch on the Port property then conveyed the flow northwest toward the Fraser River. An existing small ditch on Port property which drains runoff from Timberland Road lies to the east of the approximate location of the historical Delta Creek outlet to the Fraser River.

Scott Creek flows into Colliers Canal, and at one time flowed north from the base of its ravine, at River Road west of Scott Road toward the Manson Canal. However, there is no trace remaining of the historical Scott Creek channel from River Road to Manson Canal due to infilling after completion of the 1982 northwestern diversion to Colliers Canal. Upgrades to the canal between Delta Creek and Manson Canal have been implemented, as recommended in the *Manson and Gunderson's Slough Watersheds Stormwater Management Review and Feasibility/Functional Plan*.

2.3.3 Scott Creek (Manson Catchment)

Scott Creek is an urban stream located in South Westminster that drains to Manson Canal and Manson Pump Station near the Fraser River. Originally, it had its own outlet to the Fraser River. Its drainage area is 124ha in size and it has an imperviousness of approximately 61%.

Scott Creek is a Class A (or red-coded) watercourse which means that it is inhabited or potentially inhabited by salmonids year round. **Section 2.8** will further examine the wildlife and fisheries aspects of this creek.

A detention pond is shown on COSMOS at the end of River Road and the as-built drawings are dated March 15, 2006. During a site investigation in January 2013 beaver activity was apparent which had caused the entire area to flood as depicted in the photo below.

A high flow diversion and upgrades to the creek as recommended in the *Manson and Gunderson's Slough Watersheds Stormwater Management Review and Feasibility/Functional Plan* have been implemented.

Evidence of beaver activity along Scott Creek at the end of River Road.

Scott Creek downstream of culvert at 99 Ave and Scott Road Diversion. Right bank showing signs of erosion.

2.3.4 Robson Creek (Manson Catchment)

Robson Creek is an urban stream much of which is a Class A (or red-coded) watercourse which means that it is inhabited or potentially inhabited by salmonids year round. The upper reach is a Class B (or yellow-coded) which means that although fish are not present, this watercourse contains significant food/nutrient value. **Section 2.5** will further examine the wildlife and fisheries aspects of this creek.

Robson Creek's watershed has a total area of 287ha and approximately 57% of it is considered to be impervious. At the upstream end of Robson Creek four detention ponds are shown on COSMOS in Robson Park. The photos below depict the pond south of 100 Avenue as well as an eroded section behind Prince Charles Elementary School in Robson Ravine.

Installation of a culvert between 103A and 104 Ave, a sediment basin upstream of 103A Ave, and upgrades to Robson Park pond have been implemented as recommended in the *Manson and Gunderson's Slough Watersheds Stormwater Management Review and Feasibility/Functional Plan*.

Detention pond at upstream end of Robson Creek in Robson Park.

Robson Creek and signs of erosion behind Prince Charles Elementary School.

2.3.5 Manson Canal (Manson Catchment)

Manson Canal is part of Robson Creek, and was created to divert flows to accommodate development of Port lands. It is a Class A (or red-coded) watercourse which means that it is inhabited or potentially inhabited by salmonids year round It flows west along the south side of 104 Avenue to Scott Road where it turns northwest toward the Fraser River. Historically, Robson Creek continued flowing north into the Old Yale Watershed from the intersection of 123A Street and 104 Avenue toward the intersection of Scott Road and Old Yale Road.

Manson Canal collects drainage from approximately 827 hectares which represents 66% of the study area. As can be seen from some of the adjacent photos, the downstream portion of the channel can have significant width (over 10 metres). This channel width provides an important storage component in the system to store water during large events while Manson Pump Station is working at full capacity to discharge water to the Fraser River.

Upstream of the SFPR the wetted channel width gets smaller, although the overall corridor remains the same. Upstream of Scott Road, Manson Canal gets smaller and during site visits (summer 2013) was heavily vegetated with blackberry.

Upgrades to Manson Pump Station, upgrading of Scott Road drainage between 101 Ave & Manson Canal, and upgrades to the Tannery Road storm system between BNR & SFPR have been implemented, as

recommended in the *Manson and Gunderson's Slough Watersheds Stormwater Management Review and Feasibility/Functional Plan*.

2.3.6 Pattullo Creek (Pattullo Catchment)

Pattullo Creek is an urban stream located in South Westminster. It is a Class A (or red-coded) watercourse which means that it is inhabited or potentially inhabited by salmonids year round. Its drainage area is approximately 215ha with an imperviousness of 46%.

Pattullo Creek on 110 Avenue opposite Home Depot.

Pattullo Creek on 110 Avenue showing signs of erosion.

2.3.7 Armstrong Creek and Shadow Brook (Gunderson Catchment)

Armstrong Creek and Shadow Brook are urban streams located in South Westminster. The entire length of Shadow Brook and the lower-reach of Armstrong Creek are Class A (or red-coded) watercourses. The upper-reaches of Armstrong Creek in Ravine Park are Class B (or yellow-coded).

Armstrong Creek and Shadow Brook are both part of the Gunderson catchment area. The drainage area is approximately 78ha with 60% of it being impervious.

Armstrong Creek Near Regal Drive

Armstrong Creek and culvert at Regal Drive.

2.4 Hydrology and Hydraulics

Stormwater modelling is an important part of ISMP development. It is a tool used to highlight and confirm problem areas, as well as a platform on which to test possible solutions. A hydrologic and hydraulic model has been built for the South Westminster Study Area using XPSWMM. The model has been constructed to mimic the current condition of the major flow routes and identify deficiencies. Once the model has been calibrated and proven to effectively predict the impacts and responses to different levels of rainfall events, it can be used to derive options for solving issues such as sewer system overload, flooding, etc. Solutions to mitigate problem areas can be tested to determine the effectiveness and acceptability of potential upgrades.

2.4.1 Model Set-Up

XPSWMM has been used to model the South Westminster watersheds under existing conditions. Peak flows were modeled for the 2-year, 5-year, and 100-year storm events. The 5-year and 100-year return period are based on City of Surrey's design criteria for flow in-pipe and overland flow. The 2-year return period storms are included to see the system response during more frequently occurring rainfall events. Additionally, when sea-level rise and climate change are considered, the 2-year rainfall events will have a larger impact than when using current day criteria. The catchments and sub-catchments, as imported into XPSWMM, are shown in **Figure 2.6**.

The following information was input to the model:

- Catchment and sub-catchment physical parameters;
- Hydrological and infiltration parameters for each sub-catchment, including imperviousness;
- Storm network data including creeks, ditches, storm sewers and culverts;
- Pump station data and settings; and
- Rainfall & tidal data.

2.4.1.1 Catchment Data

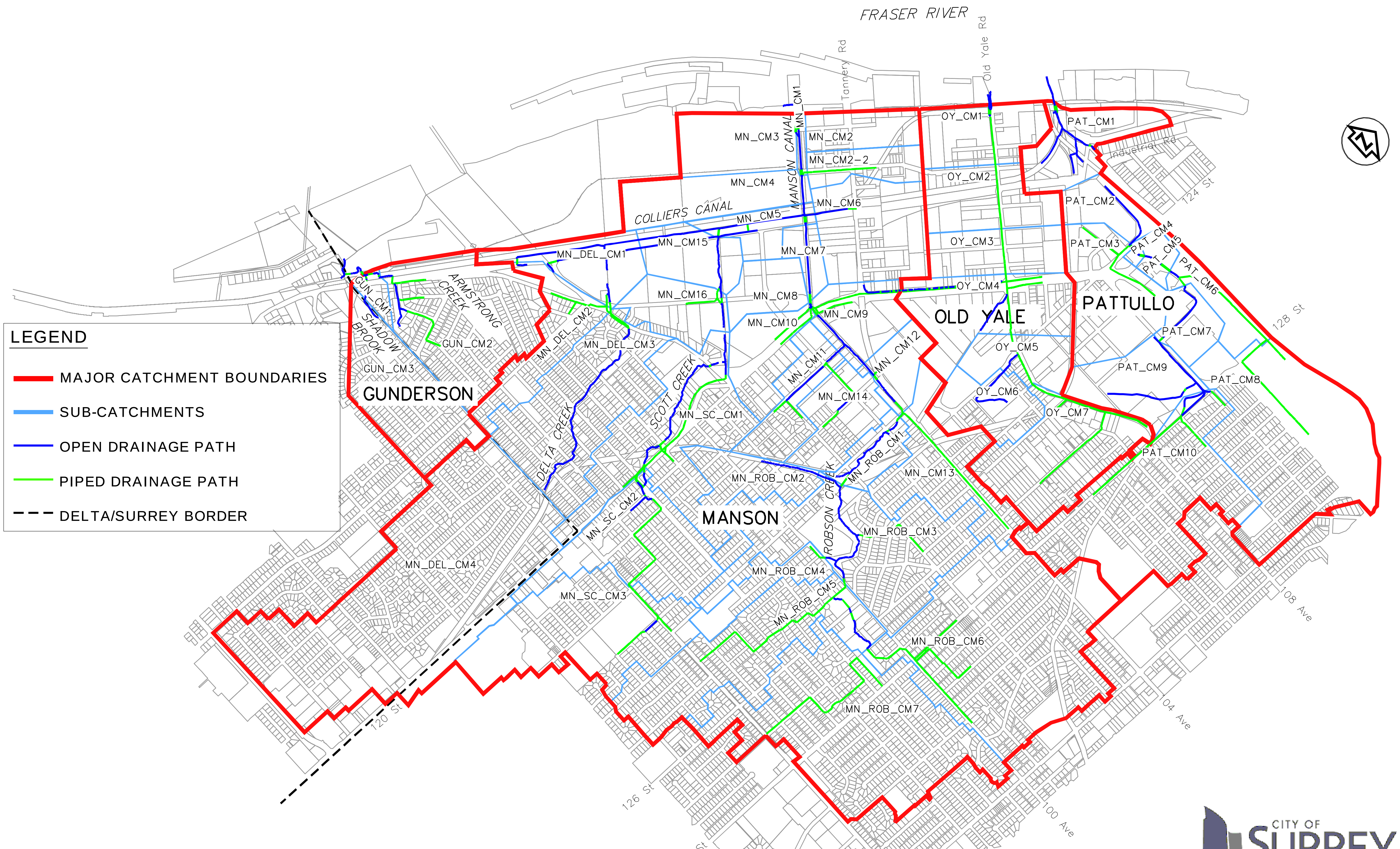
Topographic data provided the starting point to create catchment and sub-catchment boundaries, and the GIS data of existing storm sewers were used to solidify and confirm exact divides between catchments. Following creation of sub-catchments, areas, slopes, widths, and percent impervious were estimated. These parameters were obtained using land-use shape files, topographic data, AutoCAD, and aerial photos. Imperviousness is an important factor and is further discussed below.

Table 2.4.1: Catchment Overview

Catchment	Total Area (Ha)	# of Sub-Catchments	Imperviousness (%)
Manson	837.7	30	60.8
Gunderson	77.6	3	60.2
Old Yale	142.8	7	46.2
Pattullo	215.2	10	46.7

FIGURE 2.6

DRAINAGE SUB-CATCHMENTS



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2.4.1.2 Imperviousness

The imperviousness percentage drives changes in a stormwater runoff regime. Impervious surfaces are areas that have been covered by any material that impedes the infiltration of water into the soil. Areas of land covered by pavement or buildings are considered impervious to rain water. Concrete, asphalt, rooftops and even severely compacted areas of soil are considered impervious. For the modelling in each sub-catchment the percentage of impervious area was determined using a weighted area calculation. The assumed impervious areas per lot type were based on sample air photo analysis as to pick the most representative lot coverage for each land use type. Assumed design values for land use sometimes differ. The percentage of impervious area for the urban residential lots can vary depending on the size of the lots, age of construction and demographics of the area. For this study, we have reviewed typical lot types, sizes and ages to estimate the overall impervious area of the residential area.

Overall, the impervious area of the study area is estimated at 57%. This is an important indicator for overall health of the watershed. Although it can differ with factors such as soil type, slope, etc, studies of other watersheds have found that significant impairment to streams often occurs when more than 10% of the land within a watershed is covered with impervious surfaces. When these levels exceed 25%, most watersheds experience more severe ecosystem and water quality impairment

2.4.1.3 Other Catchment Parameters

The Horton infiltration method was used to model the exponential decay of infiltration capacity during heavy storms. Parameters required for the Horton method include depression storage, zero detention %, maximum infiltration rate, minimum (asymptotic) infiltration, decay rate of infiltration, and maximum infiltration volume. Additional hydrological parameters input for each catchment include Manning's n and groundwater base flows. These parameters were input based on each sub-catchment's classification as either upland or lowland.

Upland sub-catchments have average slopes ranging from 3% to 15%, while average slopes in lowland sub-catchments are typically less than 1%. Flatter grades generally allow for more detention and infiltration than steeper terrain.

Constant base flows for each catchment were input, based on the expected base flows during winter conditions. Groundwater flow depends on soil conditions and recent weather conditions. A detailed investigation into the variation of groundwater throughout the study area is out of the scope for this study. Constant base flows varying from 5 mm/Ha/day to 8 mm/Ha/day were input and adjusted during model calibration.

A complete list of all hydrological inputs is included in **Appendix A**.

2.4.1.4 Creeks and Open Drainage

A total of 9,770 metres of open drainage channels were input into the XPSWMM model. The majority of open channels are from the Manson catchment, which includes Colliers and Manson Canals, and Robson, Scott and Delta Creeks. Data input for each section of open drainage includes lengths, slopes, roughness coefficients, depth, bottom width and side slopes. The data was obtained from the City of Surrey's GIS information and record drawings. Site visits confirmed geometry at key locations.

Typically, average channel dimensions were used for a given length of channel. Channels in the lowland areas are generally consistent along their lengths, while steeper sections of creeks in the upland area had more variable cross sections.

Manson Canal at Timberland Rd. *13m width, 2.4m height, 2H:1V Side Slopes.*

Manson Canal at Manson Pump Station. *11m width, 2.5 m height, 2H:1V Side Slopes*

Colliers Canal. *10m width, 2.0 m height, 2H:1V & 1H:1V Side Slopes*

Scott Creek. *6.0m width, 3 m height, 2H:1V Side Slopes*

2.4.1.5 Storm Sewer and Culvert Data

A total of 3,530 metres of pipe storm sewer were input into the XPSWMM model. This network is shown in **Figure 2.7**. Data included lengths, slopes, pipe size, material, and roughness coefficients. Culvert pipe data were obtained from the City of Surrey's GIS and record drawings, and were confirmed at key locations, particularly the culverts along Manson Canal.

The pipe invert data often showed pipes with negative slopes (lower inverts on the upstream end), particularly within the Manson catchment. These culverts were partially full with water during inspection and it was difficult to accurately measure water depths, however, we have assumed that inverts included in the GIS are accurate and have used them in our model.

Catchment nodes have typically been set to drain upstream of the major culverts along the flow routes. This allows the model to captures all flow into these culverts to highlight any locations requiring upgrades.

2.4.1.6 Pump Station Data & Settings

Three pump stations were modeled in the study area: Manson, Old Yale and Pattullo. Data for the pump stations was found in record drawings, previous engineering reports and review of manufacturer specifications where applicable. Using this information, pump discharge vs. depth curves were developed for each pump in the three stations.

On/Off settings for Old Yale and Manson Pump Stations were provided by the City of Surrey. Pattullo On/Off settings shown are as recommended by Stantec, the Design Engineers of the pump station. **Table 2.4.2** shows the current pumps, their settings and information on the discharge pipes.

FIGURE 2.7

PIPED/OPEN DRAINAGE NETWORK

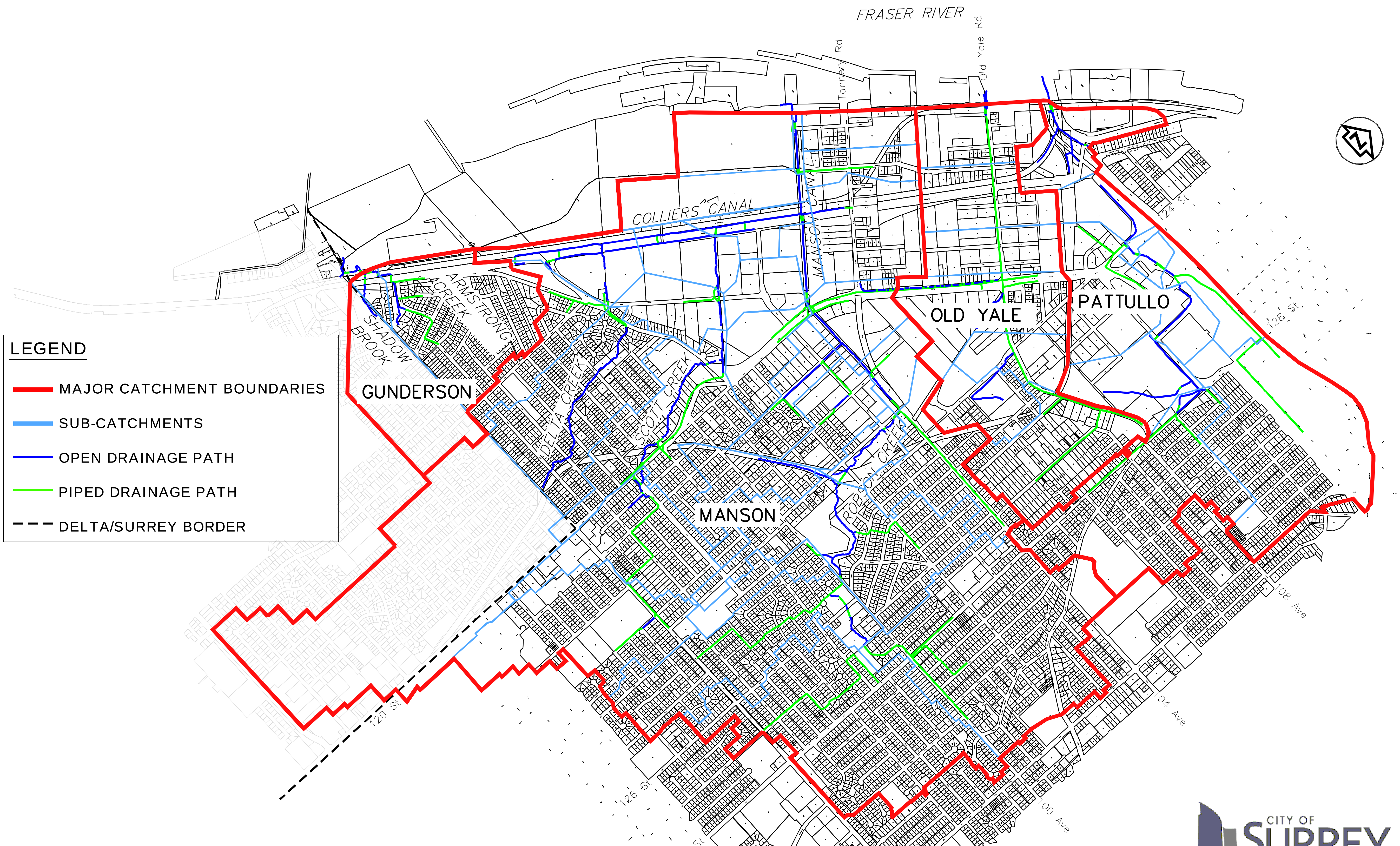

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Table 2.4.2: Pump Station Data

Pump Station	Catchment Area (Ha)	Description	Discharge Pipes	U/S Invert (m)	D/S Invert (m)
Manson	837.7	Pump 1: Capacity: 0.63 m³/s Pump On elevation: -0.050m Pump Off elevation: -0.200m *Flygt Model 7050*	Gravity: 2 x 2100Ø Concrete F/M: 2 x 2150Ø CSP	G: -0.22 F: 0.73	G: -0.77 F: -0.09
		Pump 2: Capacity: 0.67 m³/s Pump On elevation: 0.100m Pump Off elevation: -0.200m *Mod 60Hp Vert Propeller Pump*			
		Pump 3: Capacity: 2.11 m³/s Pump On elevation: 0.740m Pump Off elevation: 0.590m *Mod 150Hp Vert Propeller Pump*			
		Pump 4: Capacity: 3.88 m³/s Pump On elevation: 0.810m Pump Off elevation: 0.660m *Flygt Model 7140*			
		Pump 5: Capacity: 3.88 m³/s Pump On elevation: 0.950m Pump Off elevation: 0.780m *Flygt Model 7140*			
Old Yale	142.8	Pump 1: Capacity: 0.93 m³/s Pump On elevation: 0.101m Pump Off elevation: -0.280m	Gravity: 1200 x 2000 Concrete F/M: 2 x 600Ø CMP	G: 0.07 F: 2.33	G: 0.07 F: 0.25
		Pump 2: Capacity: 0.93 m³/s Pump On elevation: 0.406m Pump Off elevation: -0.280m			
Pattullo	215.2	Pump 1: Capacity: 0.67 m³/s Pump On elevation: 0.80m Pump Off elevation: 0.55m	Gravity: 2 x 1800Ø Concrete F/M: 3 x 750Ø Steel	G: -0.87 F: 0.90	G: -0.90 F: 0.80
		Pump 2: Capacity: 0.67 m³/s Pump On elevation: 1.05m Pump Off elevation: 0.80m			
		Pump 3: Capacity: 0.67 m³/s Pump On elevation: 1.30m Pump Off elevation: 1.05m			

2.4.1.7 Climate & Rainfall

South Westminster lies within the Lower Mainland Ecosystem. According to British Columbia Ministry of Environment's Ecoregion Unit Descriptions, *Pacific air passing over this area can stall against the mountains bringing intense rain or snow to the adjacent mountains. In the summer hot, dry air from the south can advect over this lowland bringing in warm temperatures and very dry conditions that are Mediterranean in effect. Winter storms can result from cold Arctic air moving through wide valleys in the Pacific Ranges and across the lowlands bringing cold conditions and deep snow to this lowland; such storms are infrequent and of a short duration. Vegetation zonation varies with elevation, distance from the Strait of Georgia and the corresponding nearness of the mountains. In the lowest portion of the Fraser Delta dry Coastal Western Hemlock forests occur, which gives way to the dry maritime Coastal Western Hemlock forests on the highest areas.*

The climate is characterized by periods of heavy rain during October to March and drier summer conditions. There is significant variation in precipitation throughout the lower mainland. **Figure 2.8** shows the mean annual precipitation of the Metro Vancouver area from 1961 to 1990, with locations of rainfall gauges shown. The rainfall contours show an increase in precipitation heading North and East into the more mountainous areas. The Westminster ISMP area is closest to the City of Surrey Kwantlen Park gauge, data from which was used for the modelled rainfall events.

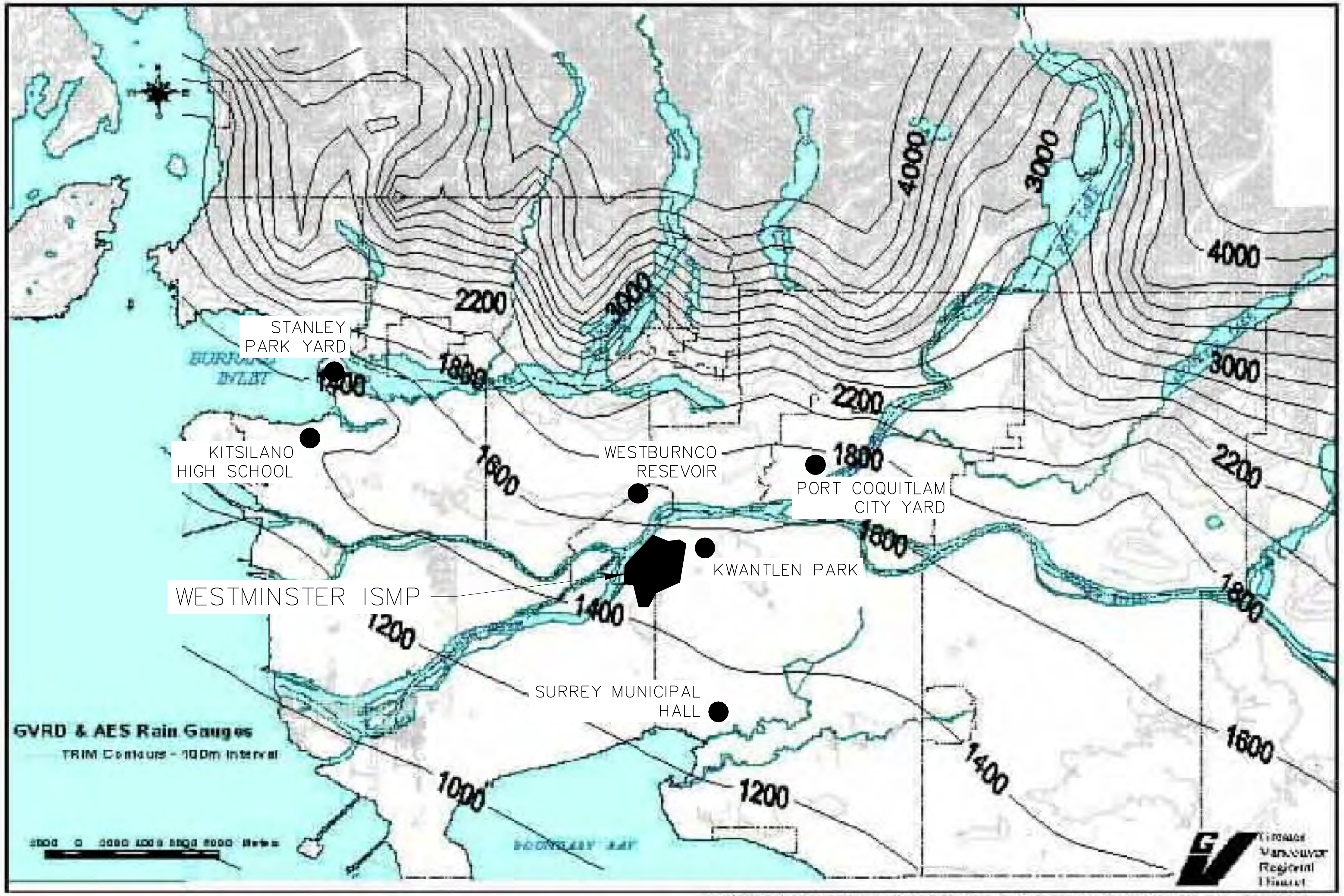
Environment Canada provides average climate data, taken from the 1971 to 2000 period. **Table 2.4.3** shows average annual data provided for Kwantlen Park. **Table 2.4.4** shows how the rainfall, snowfall and precipitation vary by month at the Kwantlen Park gauge.

Table 2.4.3: Rainfall Summary Data

Precipitation Data	Average Annual Quantity
Average Annual Rainfall	1527.9 mm
Average Annual Snowfall	58.1 cm
Average Annual Precipitation	1585.9 mm
Average # of Days with Precipitation >=0.2mm	179.7
Average # of Days with Precipitation >=5.0mm	94.7
Average # of Days with Precipitation >=10mm	56.9
Average # of Days with Precipitation >=25mm	14

FIGURE 2.8

GVRD MEAN ANNUAL PRECIPITATION 1961-1990



Prepared by Aquatic & Atmospheric Sciences Division, Environment Canada, Pacific & Yukon Region. May 2000
Note: Precipitation in millimetres. Precipitation amounts in the mountains are estimated.

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Table 2.4.4: Monthly Precipitation Data

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Rainfall (mm)	179.4	147.3	143.2	116.2	92.3	73.6	52.9	50.7	71.7	152.3	235.5	212.7
Average Snowfall (cm)	22.7	11.2	3.1	0.1	0	0	0	0	0	0.2	4.4	16.3
Average Precipitation (mm)	202.2	158.5	146.3	116.4	92.3	73.6	52.9	50.7	71.7	152.5	239.9	228.9

Rainfall data used in the XPSWMM model was based on the 2004 City of Surrey Design Criteria Manual. Design storms for 1, 2, 6, 12 and 24 hours were based on data from the Kwantlen Park gauge. All five durations of storm events were run to determine peak flows of the 2-year, 5-year and 100-year return period events. Graphs of design storms used are shown in **Appendix A**. In addition to return period rainfall events, gauge data from the past 11 years was used during model calibration described below.

2.4.1.8 Tidal Data

Because the lowland areas of South Westminster are drained by pump station and flood boxes, the level of the Fraser River at the time of the event is a critical component of the model. Fraser River levels were obtained from two sources:

- River levels at the Manson Pump Station from the City of Surrey (2002 to 2007); and
- River levels at Port Mann Bridge from Water Survey Canada (1987 to 2007).

The reason the Port Mann Bridge Levels were used is the Manson Pump station data had some errors (incorrect readings and data gaps). The Port Mann levels were compared to key data points within the Manson data to confirm their validity.

During non-freshet times the Port Mann Bridge data and the Manson data were virtually the same. **Figure 2.9** illustrates the tidal cycle for a typical day in January.

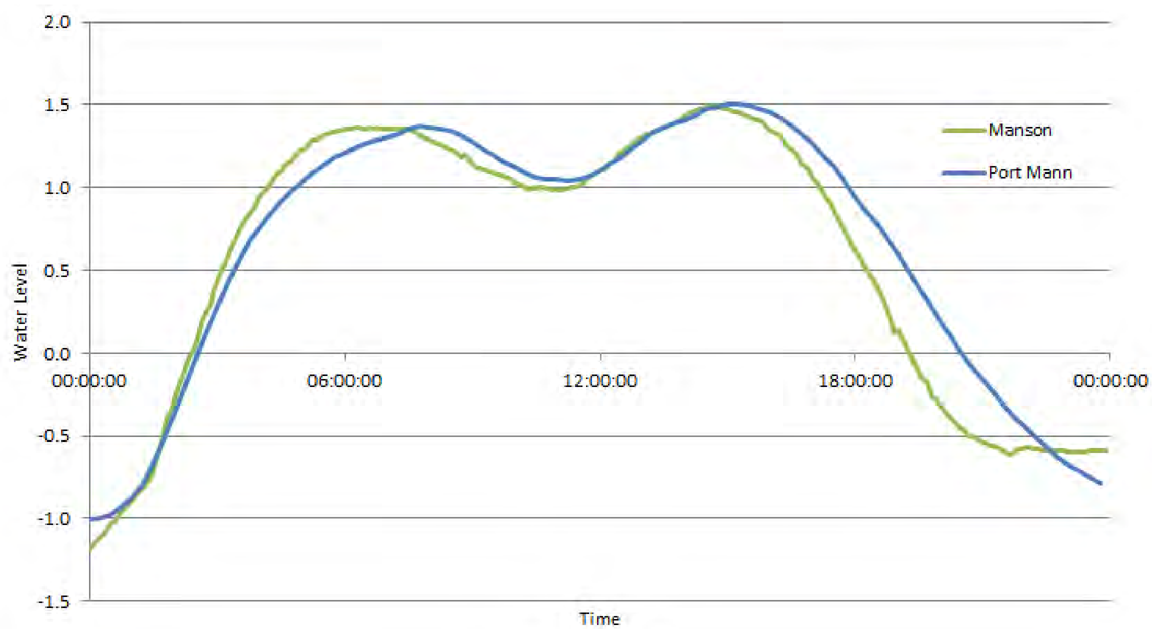

Figure 2.9: Normal Tidal Cycle

During a freshet the Fraser River develops more of a 'slope' as the upstream portions in Surrey are more influenced by the freshet, while the lower portions are more influenced by tides. **Figure 2.10** shows the two gauge stations during the freshet. As can be seen the biggest difference is in the lower portion of the tidal periods. It is an important graph because it conveys what could happen in a sea level rise scenario. The difference between the Port Mann and Manson locations is indicative of what 0.3 metres of sea level rise would mean for the South Westminster pump stations and flood boxes. 0.3 metres of rise is currently predicted before 2050.

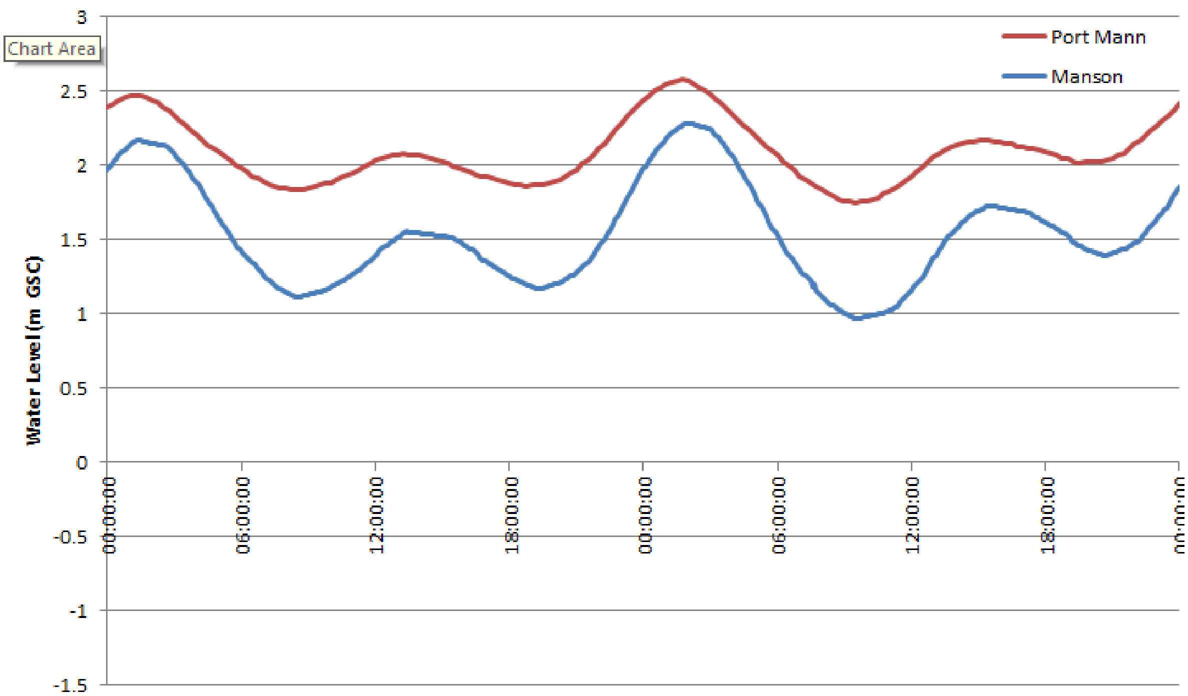

Figure 2.10: Freshet Tidal Cycle

Ultimately three different boundary conditions were used for the model: A normal tide cycle, a storm surge event and a freshet event. **Figure 2.11** below shows the three different events over 48 hours.

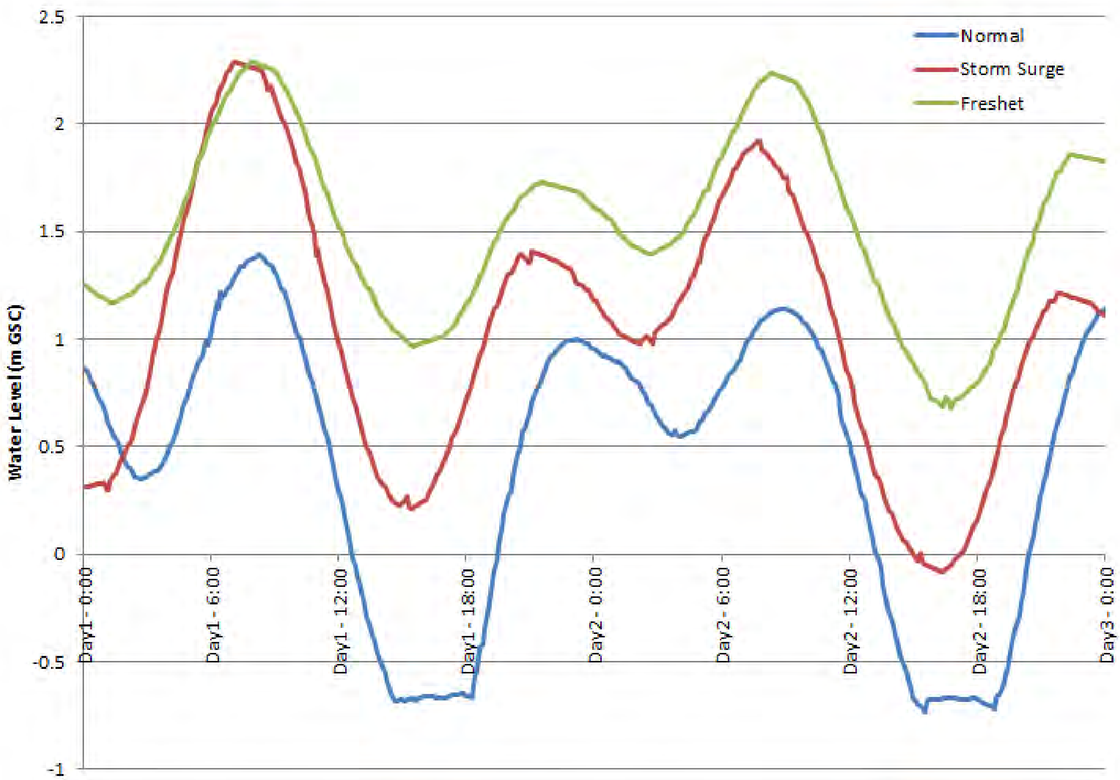

Figure 2.11: Comparison of Tidal Cycles

2.4.2 Model Calibration

Measured ditch levels between 2002 and 2012 have been used to calibrate the XPSWMM model. The model was run with rainfall events from periods of time between 2002 and 2012. Measured vs modeled ditch levels were compared for multiple rainfall periods and the following parameters were modified to calibrate the model:

- ***Constant Base Flows:*** Base flows vary throughout the year and even within a short period of time; and
- ***Maximum and Minimum Infiltration Rates:*** Like base flows, these vary throughout the study area and the season and were modified during model calibration.

Appendix A contains some output graphs for the modeled ditch levels and levels measured at Manson Pump Station for a 7 day period.

2.4.3 Model Results

XPSWMM has been used to model the South Westminster watershed under existing conditions. The following information has been obtained by modelling multiple scenarios:

- Peak flows;
- Capacity of pipe and open channels for the four catchments; and
- Areas of interest.

2.4.3.1 Peak Flows

Maximum peak flows have been modeled for the four catchments. Maximum flows will occur in an open outfall scenario. **Table 2.4.5** provides the peak flows at the outlets of the four catchments. The model was run with 2, 12 and 24 hour rainfall events for the three return periods. The maximum peak flows of the three rainfall events are shown.

Table 2.4.5: Outlet Peak Flow Rates

Catchment	2 Year Peak Flow at Outlet (m^3/s)	5 Year Peak Flow at Outlet (m^3/s)	100 Year Peak Flow at Outlet (m^3/s)
Manson	15.8 (12)	19.8 (12)	31.5 (12)
Gunderson Slough	1.8 (2, 12)	2.1 (2, 12)	3.7 (2hr)
Old Yale	2.9 (2)	3.7 (12)	4.8 (12)
Pattullo	3.6 (12)	4.5 (12)	6.6 (12)

2.4.3.2 Undersized Pipes and Open Channels

One purpose of the Modelling is to find infrastructure elements that require further investigation and possible upgrade. The model has been run with the 2, 5 and 100 year return period 12 hour rainfall events at Kwantlan Park Gauge. Graphs of the rainfall events are shown in **Appendix A**. The 12 hour events were chosen as they generally had the highest peak flows and capacity issues compared to other durations. In cases where this was not the case, the differences were negligible.

Three tide scenarios were modeled: freshet, storm surge and normal tide. Graphs of the three tides input were shown previously in **Figure 2.11**. Using specific tidal events affects the return period of the storm events being considered. For example, a 2-year return period rainfall event will occur during a freshet less than once every 2 years, because the freshet only occurs over a few weeks of the year. By running storms with different tidal conditions, we can observe and quantify the effect river levels have on the drainage systems. This will be particularly important when discussing the effect of sea level rise.

Modelling these scenarios, the four catchments have been divided into sections to highlight areas lacking conveyance capacity. The results are summarized in the following **Tables (2.4.6** to **2.4.8**) and the attached **Figures (2.12** to **2.17**). The Manson catchment has been divided into five sections, while the other three catchments remain classified exclusively. The pipes and channels have been classified as flowing 0-75% full, 75-99% full or >100% capacity. The percentage of pipes/channels that fit into the three classifications is listed in the following three tables.

Table 2.4.6: 2 Year, 12 hour Storm; Percentage of Pipes/Channels by % Capacity

		Normal			Storm Surge / Freshet		
Location	No of Pipes / Channels	0-75%	75-100%	> 100%	0-75%	75-100%	> 100%
Manson Canal	12	67%	8%	25%	42%	25%	33%
Colliers Canal	2	50%	50%			50%	50%
Delta Creek	4	100%			100%		
Scott Creek	4	75%	25%		75%	25%	
Robson Creek	9	89%	11%		89%	11%	
Gunderson	9	22%	22%	56%	22%	22%	56%
Old Yale	8	38%	13%	50%	13%	38%	50%
Pattullo	13	69%	15%	15%	69%	15%	15%

Table 2.4.7: 5 Year, 12 hour Storm; Percentage of Pipes/Channels by % Capacity

		Normal			Storm Surge / Freshet		
Location	No of Pipes / Channels	0-75%	75-100%	> 100%	0-75%	75-100%	> 100%
Manson Canal	12	33	33	33	8	25	67
Colliers Canal	2		50	50			100
Delta Creek	4	100			100		
Scott Creek	4	50	25	25	50	25	25
Robson Creek	9	89	11	0	89	11	
Gunderson	9	22		78	22		78
Old Yale	8	13		88	13		88
Pattullo	13	54	23	23	31	46	23

Table 2.4.8: 100 Year, 12 hour Storm; Percentage of Pipes/Channels by % Capacity

		Normal			Storm Surge / Freshet		
Location	No of Pipes / Channels	0-75%	75-100%	> 100%	0-75%	75-100%	> 100%
Manson Canal	12	0	8	92	0	8	92
Colliers Canal	2	0	0	100	0	0	100
Delta Creek	4	100	0	0	100	0	0
Scott Creek	4	50	0	50	50	0	50
Robson Creek	9	89	0	11	89	0	11
Gunderson	9	0	22	78	0	22	78
Old Yale	8	0	13	88	0	13	88
Pattullo	13	38	38	23	8	8	85

FIGURE 2.12

DRAINAGE CAPACITIES - 2 YEAR, 12 HR RAINFALL: NORMAL TIDE

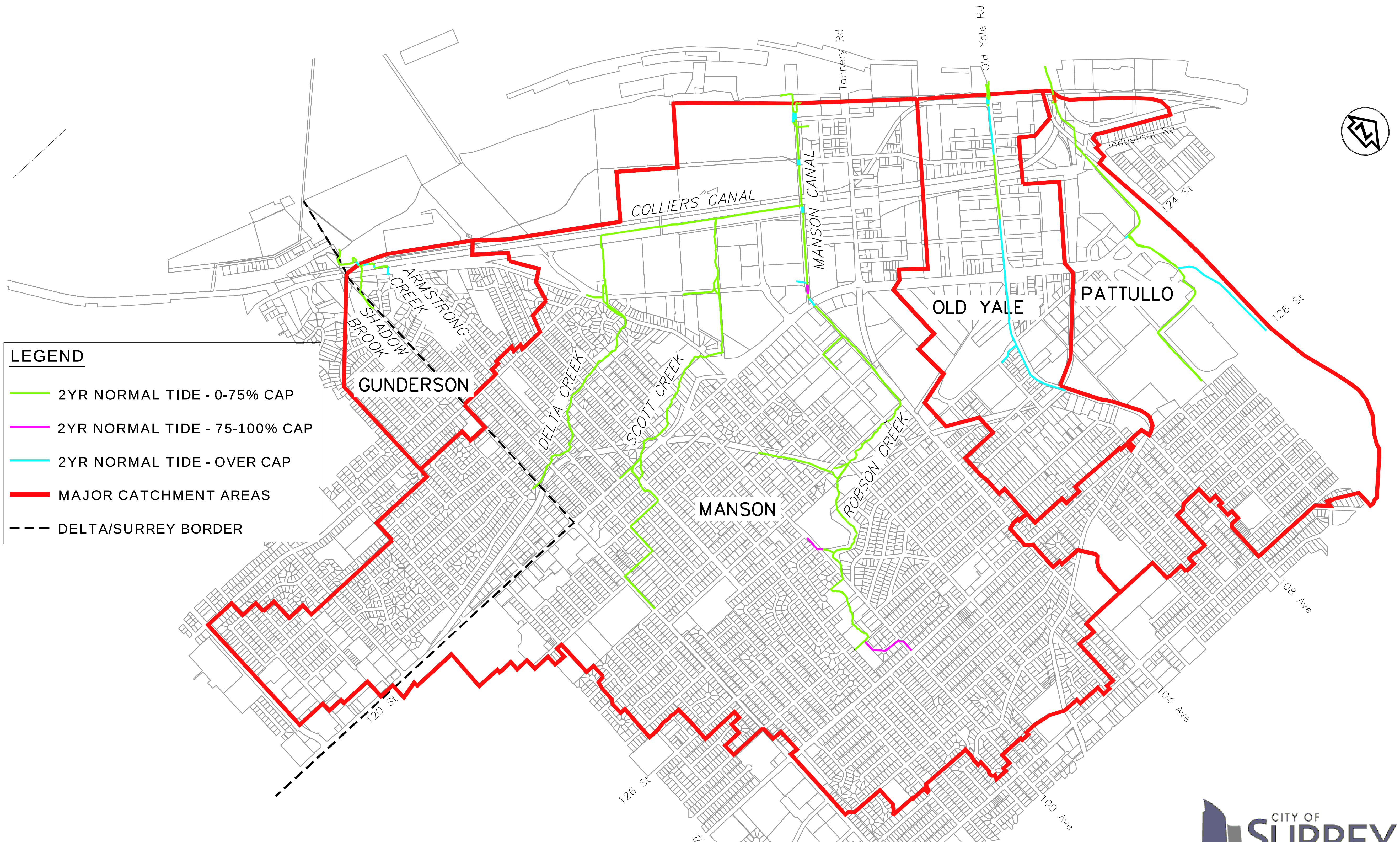

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FIGURE 2.13

DRAINAGE CAPACITIES - 2 YEAR, 12 HR RAINFALL: STORM SURGE

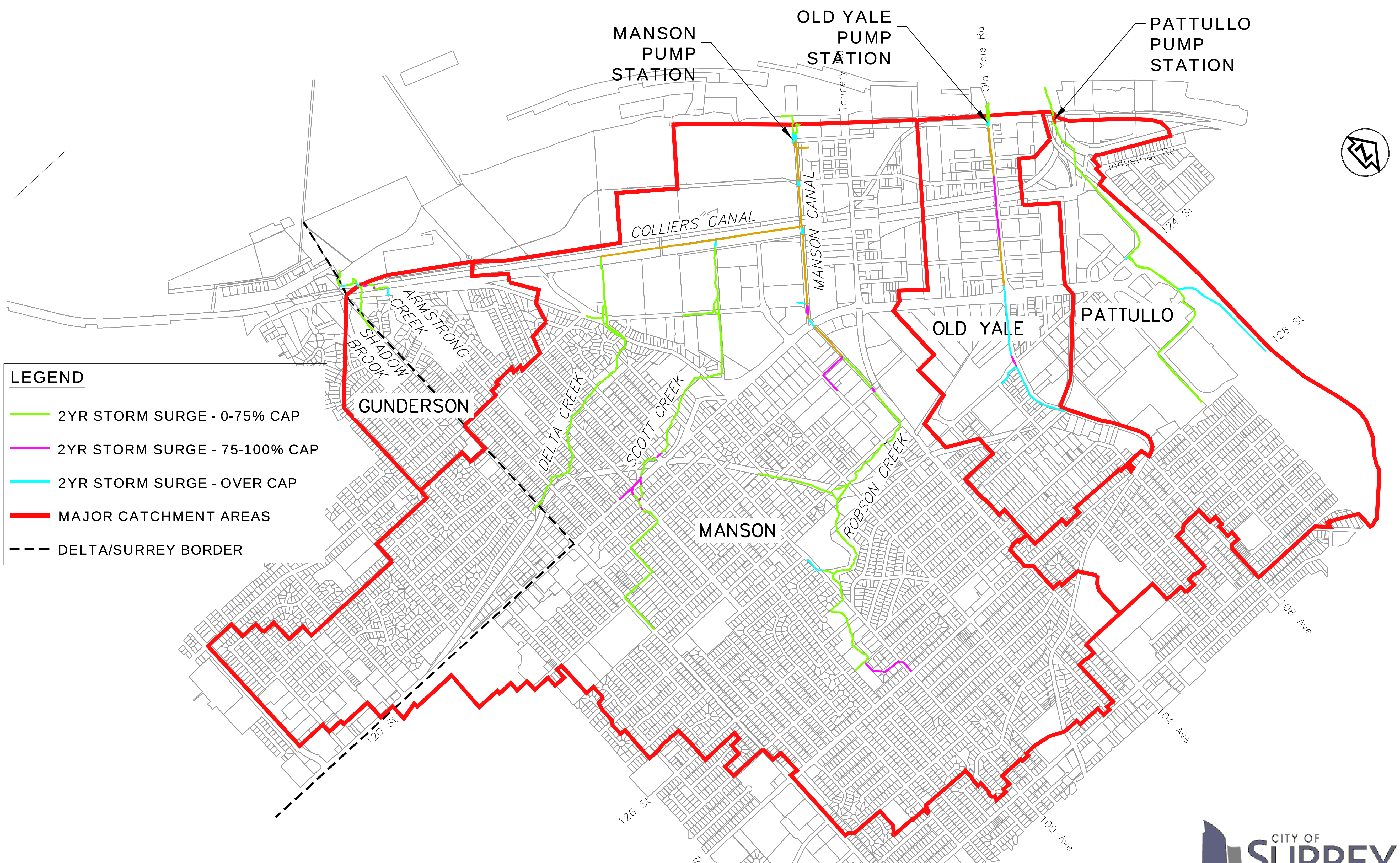

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FIGURE 2.14

DRAINAGE CAPACITIES - 5 YEAR, 12 HR RAINFALL: NORMAL TIDE

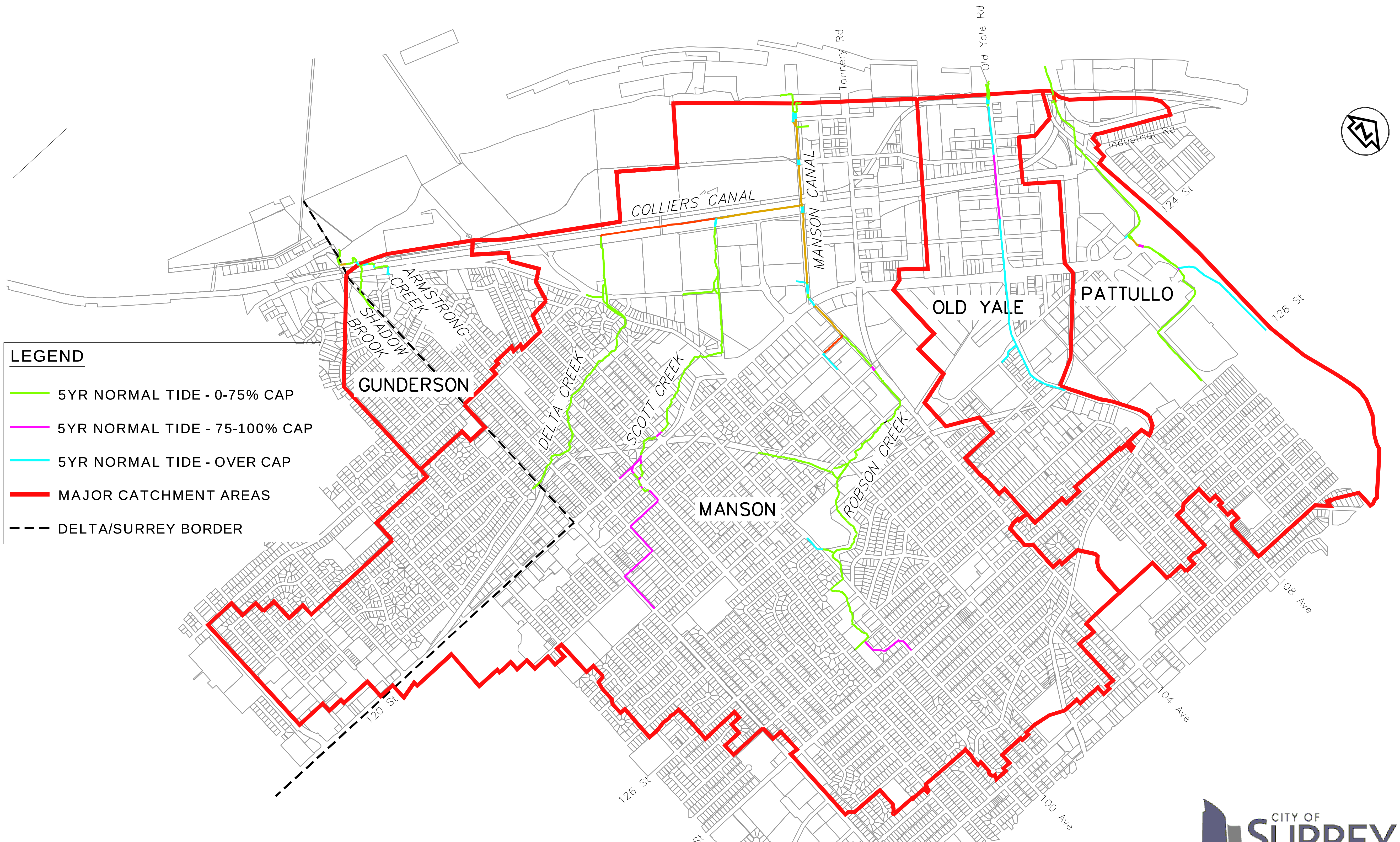

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FIGURE 2.15

DRAINAGE CAPACITIES - 5 YEAR, 12 HR RAINFALL: STORM SURGE

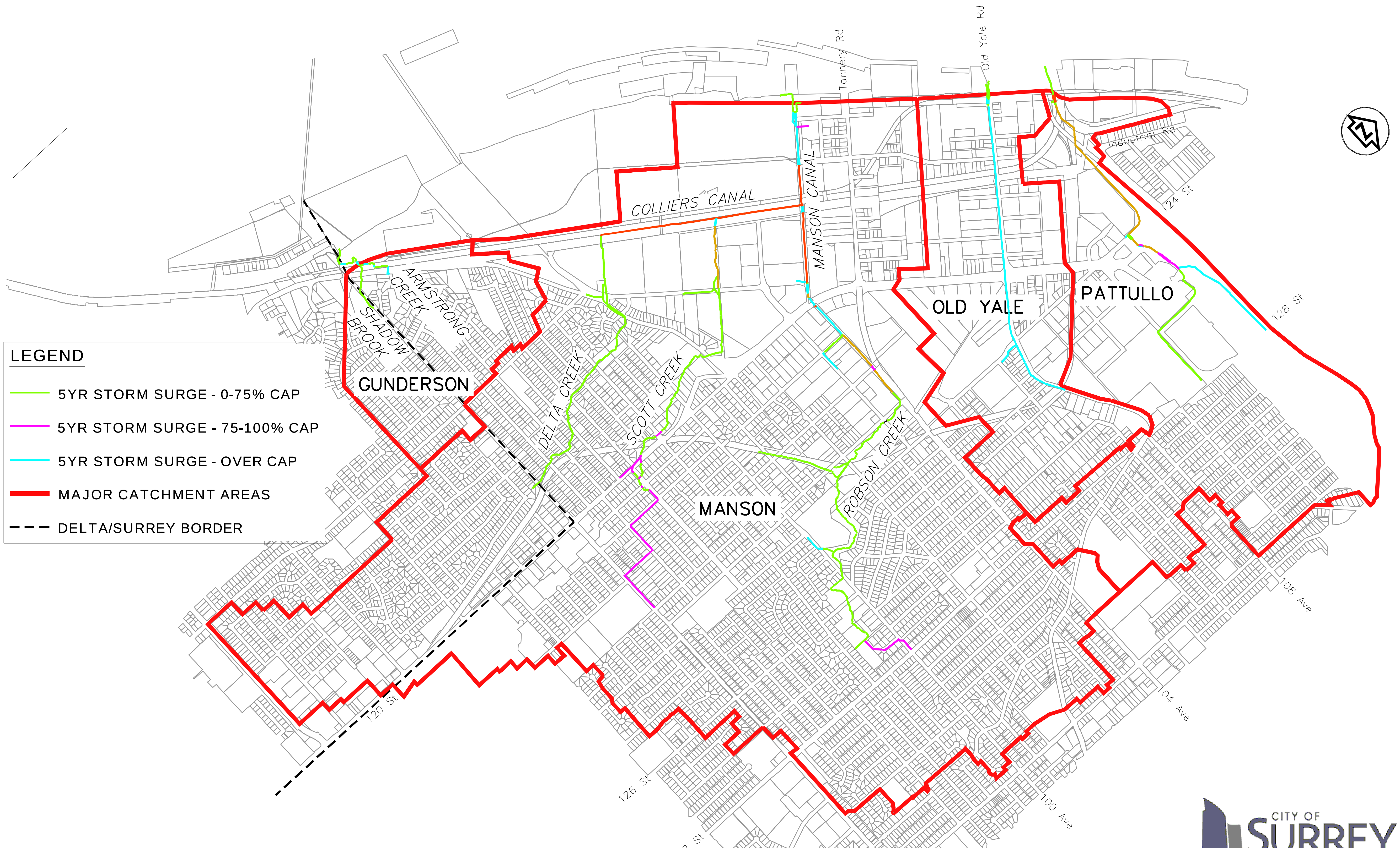

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FIGURE 2.16

DRAINAGE CAPACITIES - 100 YEAR, 12 HR RAINFALL: NORMAL TIDE

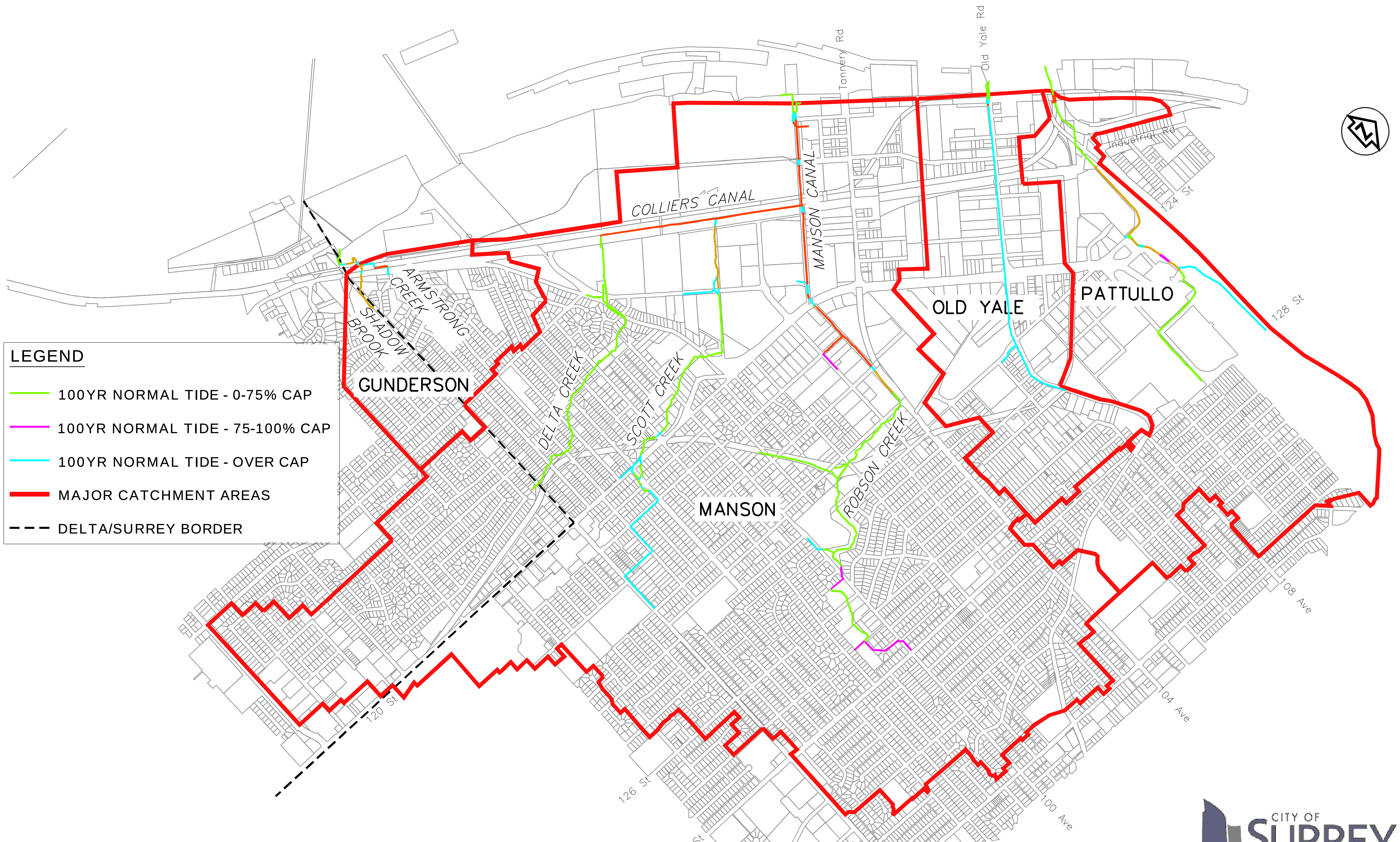

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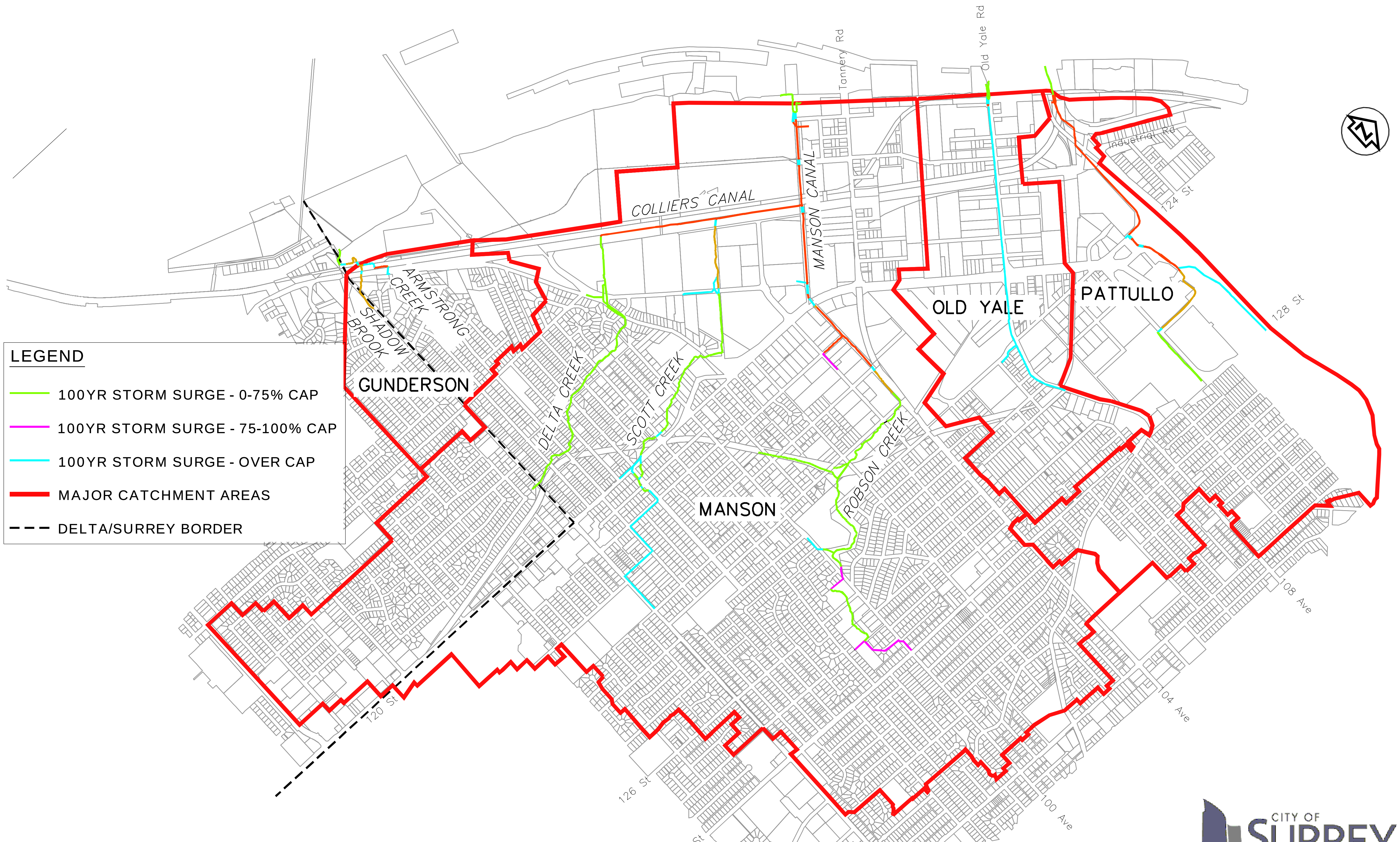
FIGURE 2.17

DRAINAGE CAPACITIES - 100 YEAR, 12 HR RAINFALL: STORM SURGE



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It should be noted that pipes flowing over capacity do not necessarily result in flooding on the road. For example, if a culvert is over capacity, there may be an upstream channel that can store the additional volume. Based on the results listed above, areas with capacity concerns include Colliers Canal, Manson Canal, Gunderson Slough Catchment, Old Yale Catchment and the Pattullo Catchment.

2.4.4 Discussion of Modelling Results

2.4.4.1 Colliers Canal

Colliers Canal is approximately 1 km long and begins at the downstream end of Delta Creek. The canal flows to the north-east picking up flow from Scott Creek before discharging into Manson Canal. The overall slope of Colliers Canal is roughly 0.2% and the bottom of channel is at less than 0.0m elevation for the majority of its length. As the channel bottom is lower than the Fraser river level during some high tides, Collier Canal's conveyance capacity is influenced by storm surges, freshets and high tides.

Based on the model results, a 2-year return period rainfall event will cause water to rise close to top of bank level if the event occurs during a freshet or storm surge, but not during regular tide levels. The canal could experience flooding in a combination of rainfall events and tidal condition. During this event, water levels are expected to be 200mm from the top of bank, which may result in overtopping the canal at low points or impact to the railway ballast.

During a 5-year, 12 hour rainfall event, flooding is expected in the downstream half of Colliers Canal. Flood levels are expected to be just over 2 metres in elevation. The photo below shows Colliers Canal with the rough flooding elevation shown in blue.

Colliers Canal with approximate flood elevation during 5 year, 12 hour rainfall event.

Floods of this level should remain within the railway and SFPR right of way; however, minor drainage system pipes discharging in Colliers Canal may be backed up during this event. Erosion is possible during any tidal condition, but the extent of overtopping will be increased to the upstream half of the canal during higher river level conditions.

2.4.4.2 Manson Canal

Manson Canal begins at the downstream end of Scott Creek and flows west toward the Manson Pump Station and the Fraser River. The total length of the canal is approximately 1500m and its average slope is roughly 0.1%. Similar to Colliers Canal, the Manson Canal is influenced by river levels resulting from storm surges, freshets and high tides.

During 2-year return period storms, culverts are expected to be under capacity, but the canals have sufficient size to store the additional volume. Providing the pump capacity remains and the system does not experience major blockage, flooding is not expected along the canal. However, high water levels in the canal impact the smaller, typically piped drainage systems discharging into the canal.

Increased surcharging is expected during a 5-year return period rainfall event. The elevation and extent of possible flooding is dependent on river level conditions during the event. The photo below shows Manson Canal with approximate expected elevations during a 5-year return period rainfall event during normal tide. It should be noted that the flood levels do not include freeboard so a flood level close to the top of bank may result in localized overtopping due to wave action.

Manson Canal with approximate flood elevation of a 5 year rainfall event during normal tide

A 5-year return period rainfall event that occurs during a freshet or a storm surge is expected to cause flooding in Manson Canal. Due to the joint probability of a 5-year event occurring during these tidal occurrences, the frequency of the events coinciding is less than once every 5 years.

The water level in the Fraser River affects Manson Canal because Manson Pump Station does not have the capacity to pump peak flows for storm event of a 2-year return period or later. Currently, this may be considered manageable due to the lower probability of a major storm event occurring at the same time as a large storm surge or freshet. As Surrey plans for sea level rise, increasing pump capacity may be considered as an option for sea level adaptation. This will be discussed in detail in future in **Section 4 – Implementation.**

2.4.4.3 Gunderson Catchment

The Gunderson catchment is in the south west of the study area. The catchment does not include a pump station so the catchment is unable to drain during river levels higher than 1 metre elevation. During a spring freshet, it is possible that river levels can remain above this level for days at a time.

During 2-year return period storms, the majority of culverts are expected to be under capacity while the open channels generally have sufficient capacity. Despite surcharging culverts, water levels are not expected to be high enough to result in flooding during 2-year events.

Flooding in multiple areas of the catchment is expected during 5-year return period rainfall events. The flooding should remain localized as the catchment terrain has steep enough grades to allow positive overland flow, however, property damage is still likely. Tide levels of approximately 1 metre elevation or greater during a rainfall event will increase the extent of flooding.

Looking upstream for outlet of Gunderson Catchment.

2.4.4.4 Old Yale Catchment

The Old Yale Catchment consists primarily of piped drainage, flowing towards Old Yale Pump Station and the Fraser River. The piped system limits storage capacity compared with open channels or canals.

During 2-year return period rainfall events approximately half the stormwater piping conduits input into the model were flowing at or above capacity. The expected surcharging of the major flow route is not expected to result in major flooding; however, localized flooding may occur along low-lying side streets.

The 5 year flooding will result in additional pipes surcharging within the system, but assuming no blockages occur and the pump station continues to operate, flooding is not expected along the major storm route during regular tide conditions. During freshet conditions, the HGL of the stormwater system is at roughly the existing ground elevation. Localized flooding is to be expected during 5-year events occurring during freshet or storm surge conditions.

The photo below shows Old Yale Pump Station with approximate expected elevations during a 5-year return period rainfall event during normal tide.

Old Yale Pump Station with approximate flood elevation of a 5 year rainfall event.

2.4.4.5 Pattullo Catchment

The Pattullo Catchment is a mixture of piped and open drainage in the north of the project area. The catchment drains to the Pattullo Pump Station, which was constructed in 2011. As the pump station is relatively new, there was not sufficient data to calibrate this portion of the model.

During 2 year return period storms, two culverts are at or over capacity, one near King George & 128 St and the other at Scott Road near King George.

The 5-year return period storm results in additional capacity issues in the Pattullo Catchment. The overcapacity culvert along King George Blvd results in flooding during the 5-year storm.

Pattullo Pump Station. Constructed in 2011.

2.4.5 Modelling for Improvement Options

As an important part of the completion of the ISMP future scenarios are modeled based on possible and/or expected future conditions. This is a necessary analytical exercise to develop improvement programs for the study area.

Scenarios modeled include:

- ***Sea Level Rise:*** Communities are planning for potential increases in sea level over the next 50 to 100 years. Anticipated increases in sea level will be input and the effects determined. Improvements to mitigate these effects, such as increased ditch storage or increase pump capacity, are considered for inclusion in plan recommendations;
- ***Drainage System Connections:*** Changes to the stormwater system that may improve performance are proposed and assessed. These include a potential connection between the Manson Catchment and the Old Yale Catchment. Currently, a channel exists between the Old Yale and Pattullo pump stations that provides redundancy for both systems; and
- ***Pump Station Upgrades:*** Increasing pumping capacities are assessed for potentially providing cost effective solutions to current deficiencies.

2.4.6 Continuous Stormwater Modelling

The current best practice in stormwater management is that designed systems should mimic nature as closely as possible. Continuous simulation recognizes that the majority of annual rainfall volume falls in frequent small events. As can be seen in **Figure 2.18** more than 80% of the rainfall is from 30 mm events or smaller. Therefore, managing the smaller events will have a benefit to the downstream watercourse by reducing the potential for minor but frequent erosion.

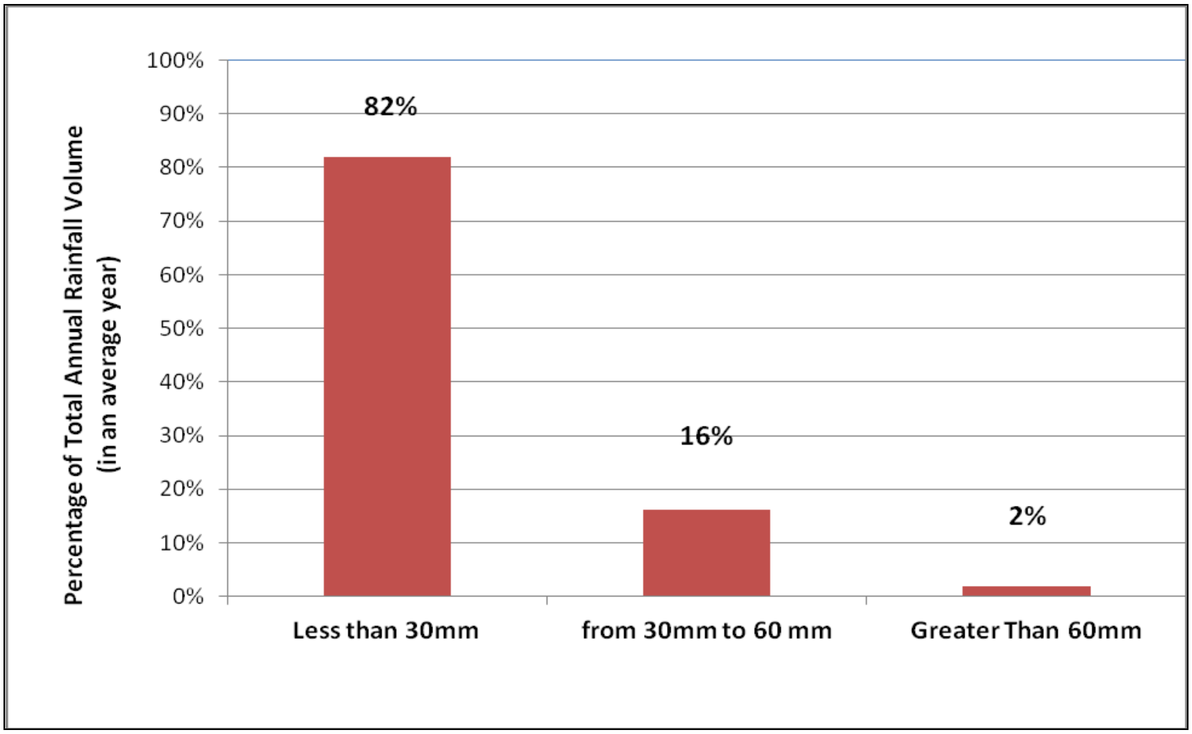


Figure 2.18: Rainfall Distribution for the Surrey Municipal Hall Rainfall Gauge

The Water Balance Model has been integrated with QUALHYMO in order to provide a “runoff-based tool” for source control evaluation and stream health assessment. The “runoff-based approach” holds the key to assessing environmental impacts in watercourses and the effectiveness of mitigation techniques. The Water Balance Model enables an understanding of the past and the ability to compare it to many possible future scenarios. This tool can give a good picture to how the overall water balance in an urban area like South Westminster is being affected by past development.

The graph in **Figure 2.19** shows the flow exceedance curve for a sample urban residential area in upper Robson Creek where storm flows run uncontrolled into the creek. **Figure 2.19** the vertical scale is logarithmic. It shows what to expect for the change in flow regime from a natural condition to a developed condition: fewer hours of smaller flows (i.e. loss of baseflow) and an increase in higher flows.

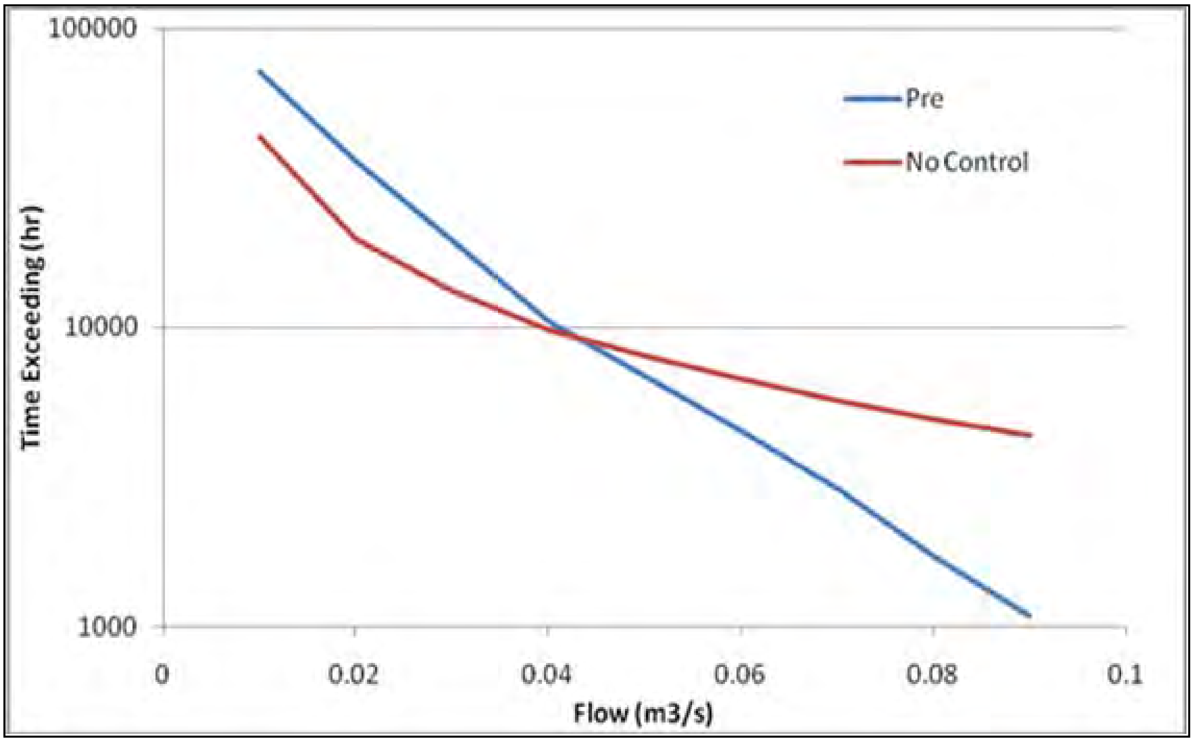


Figure 2.19 – Flow Exceedance Curve for a Typical Pre-Development (Pre) and Post-Development with no BMPs or Ponds (No Controls)

Current goals of stormwater design are to move the current situation back towards the pre-development condition, where use of appropriate BMPs makes this feasible. These BMPs would be directed at capturing, infiltrating and retaining small rainfall events.

2.5 Erosion and Sedimentation

Erosion plays an important role in the transformation of the landscape by moving soil, in the form of sediment. Sediment is eroded from the landscape, transported by river systems, and eventually deposited downstream. For example, the Fraser River carries an average of 20 million tonnes of sediment a year into the marine environment. Sedimentation occurs once the sediment or eroded material eventually settles or is deposited within the watercourse.

Natural, or geologic, erosion takes place slowly, over centuries or millennia. Erosion that occurs as a result of human activity may take place much faster. The greater the discharge, or rate of flow, the higher the capacity for sediment transport. When there is not enough energy to transport the sediment, it comes to rest. Sinks, or depositional areas, can be visible as newly deposited material on a flood plain or as bars and islands in a channel.

There are various types of erosion; however, the more common ones are listed below:

- ***Raindrop:*** Movement of soil particles caused by the direct impact of raindrops on bare soil;
- ***Sheet:*** Runoff which flows over the ground surface as a thin, even layer;
- ***Rill:*** A small, intermittent water course with steep sides, usually only a few inches deep;
- ***Gully:*** A channel caused by concentrated flow of surface and stormwater runoff over unprotected, erodible soil; and
- ***Stream & Channel Bank:*** Bank and bed erosion of existing stream channel caused by increased peak flows.

As an example, the photos below illustrate stream bank erosion found at Delta, Robson, Scott and Pattullo creeks.

Delta Creek: Evidence of erosion near 96A Avenue.

Robson Creek: Evidence of erosion north of 100 Avenue behind Prince Charles Elementary.

Scott Creek: Evidence of erosion near River Road.

Pattullo Creek: Evidence of erosion near 100 Avenue near Home Depot

Erosion, both natural and human induced, has the potential to cause problems to development or infrastructure near the creek. Furthermore, erosion can be dramatically accelerated by changes in land use, such as removal of shoreline vegetation. Without the presence of a healthy vegetated buffer, banks have reduced resistance against erosion, potentially resulting in a loss of habitat, soil stability and land.

Erosion with the potential to cause slope failure and property damage is not the only kind of erosion to cause concern. Accelerated erosion rates also have an impact on fish habitat and stream health. Field verification observations revealed numerous locations in the upper tributaries and headwaters where scour and erosion from excessive flow velocities in stormwater discharges have and continue to have a deleterious impact on the habitat values in the watersheds.

Generally, impacts of excessive scour and erosion from stormwater discharges in stream receiving environments include:

- Scour and often distant re-deposition of substrates, and invertebrate populations inhabiting those substrates, and progressively exposing fine-textured soils (e.g. clay chutes);
- Down-cutting (erosion) the stream channel;
- Coincident bank instability;
- Channel meandering-induced bank failures;
- Increased frequency and duration of high turbidity (i.e. suspended sediments);
- Loss of instream habitat complexity and niche habitat for aquatic populations;
- Increased downstream sediment deposition and flooding in lower gradient reaches; and
- An overall decline in the productivity and aquatic health of the stream.

Erosion and Sediment Control Association of BC (ESCA BC) lists various impacts of erosion and sediment on the aquatic environment. These include but are not limited to the following:

- Decrease of food-chain organisms;
- Impaired feeding;
- Clogged gills;
- Reduced photosynthesis;
- Diminished spawning; and
- Smothered eggs and fry.

Best Management Practices such as preservation and restoration of riparian forests, onsite infiltration, biofiltration, stormwater detention facilities, source controls for commercial oil / water separators and catch basins, and other innovative stormwater management facilities are essential to reversing the degradation of water quality and nutrient production and loss of the existing aquatic and riparian habitats in the South Westminster watershed.

2.5.1 Ravine Stability Assessment

The City of Surrey monitors all their river and creek systems for such erosion every two years with the Ravine Stability Assessment. The Ravine Stability Assessment is an extensive field study that looks for:

- Erosion;
- Bank Instability;
- Exposed Pipes;
- Failing or Damaged Headwalls;
- Damaged or Plugged Culverts;
- Debris Accumulation; and
- Damaged Erosion Protection Works.

A relative risk designation is assigned to each site:

- ***High Risk:*** Likely or immediate risk (within 1 year) to public safety, or damage to structures or infrastructure;
- ***Medium Risk:*** No anticipated risk to structures and no significant risk to public safety, but increasing risk may develop over time (beyond 1 year). May involve some impact to yard area, but no immediate risk to structures; and
- ***Low Risk:*** Minimal risk of impact to private property or public safety in the near or foreseeable future.

The most recent Ravine Stability Assessment was conducted in 2011 by WEB Engineering Ltd. Four watercourses within the South Westminster that were assessed: Delta Creek, Scott Creek, Robson Creek and Pattullo Creek. The following summarizes the findings of the Ravine Stability Assessment.

2.5.1.1 Delta Creek

As discussed in the *Report on Creek Management Alternatives for Lower Delta Creek* (KWL-CH2M 1998), ravine instability delivers significant sediment and debris to the Delta Creek system, providing the potential for debris-laden floods which could exceed 1,000 m^3 in volume. Therefore, any upgrading of the existing drainage system must consider such extreme creek processes in addition to flood flow.

Thirteen instability sites were identified on this watercourse, but none were identified as “high risk”. Three were found to be “medium risk” and the remaining sections along Delta Creek were considered to be “low risk”. The table below, which is an excerpt from the 2011 Ravine Stability Assessment, summarizes the data collected for Delta Creek. **Figure 2.20** shows the locations of the assessment locations.

Table 2.5.1: Ravine Stability Assessment (2011) for Delta Creek

	Location		Point Type	Risk	
	Northing	Easting		2011	2009
1	5447254	507702	Erosion	Medium	Medium
2	5447297	507694	Erosion	Low	Low
3	5447351	507720	Erosion	Low	Low
4	5447622	507535	Erosion	Medium	Medium
5	5447675	507519	Erosion	Low	Low
6	5447724	507507	Erosion	Low	Low
7	5447959	507455	Erosion	Low	Low
8	5447358	507716	Erosion	Low	Low
9	5447405	507710	Erosion	Medium	Medium
10	5447473	507625	Erosion	Low	Low
11	5447578	507533	Erosion	Low	Low
12	5447377	507717	Erosion	Low	Low
13	5447424	507687	Erosion	Low	Low

2.5.1.2 Scott Creek

Ten instability sites were identified on this watercourse, but none were identified as “high risk”. All sites were considered to be “low risk”; however, one new site was identified since the 2009 assessment. The table below, which is an excerpt from the 2011 Ravine Stability Assessment, summarizes the data collected for Scott Creek.

Table 2.5.2: Ravine Stability Assessment (2011) for Scott Creek

	Location		Point Type	Risk	
	Northing	Easting		2011	2009
1	5447803	507971	Erosion	Low	Low
2	5447848	507949	Erosion	Low	Low
3	5447953	507880	Erosion	Low	Low
4	5448078	507823	Erosion	Low	Low

	Location		Point Type	Risk	
	Northing	Easting		2011	2009
5	5448129	507810	Erosion	Low	Low
6	5447868	507915	Erosion	Low	Low
7	5447859	507932	Erosion	Low	Low
8	5447976	507887	Erosion	Low	Low
9	5448020	507853	Erosion	Low	Low
10	5447790	507969	Culvert	Low	N/A

2.5.1.3 Robson Creek

Twenty-five instability sites were identified on this watercourse, but none were identified as "high risk". Two were found to be "medium risk" and the remaining sections along Robson Creek were considered to be "low risk". However, seven new sites were identified since the 2009 assessment. The table below, which is an excerpt from the 2011 Ravine Stability Assessment, summarizes the data collected for Robson Creek.

Table 2.5.3: Ravine Stability Assessment (2011) for Robson Creek

	Location		Point Type	Risk	
	Northing	Easting		2011	2009
1	5447882	509286	Exposed Pipe	Low	Low
2	5447930	509191	Erosion	Low	Low
3	5448092	509040	Erosion	Low	Low
4	5448112	509051	Erosion	Low	Low
5	5448110	509040	Erosion	Low	Low
6	5448132	509045	Erosion	Low	Low
7	5448129	509028	Erosion	Low	Low
8	5448176	508940	Erosion	Low	Low
9	5448178	508870	Erosion	Low	Low
10	5448390	508721	Erosion	Medium	Medium
11	5448047	509013	Blockage	Low	Low
12	5448170	509016	Blockage	Medium	Medium
13	5448204	508815	Erosion	Low	Low
14	5448229	508806	Blockage	Low	Low
15	5448506	508696	Erosion	Low	Low
16	5448181	508997	Erosion	Low	Low
17	5448469	508703	Erosion	Low	Low
18	5448408	508707	Erosion	Low	Low
19	5448152	509009	Erosion	Low	N/A
20	5448425	508713	Erosion	Low	N/A
21	5448460	508703	Erosion	Low	N/A

22	5448366	508721	Culvert	Low	N/A
23	5448484	508691	Culvert	Low	N/A
24	5448186	508978	Culvert	Low	N/A
25	5447985	509092	Culvert	Low	N/A

2.5.1.4 Pattullo Creek

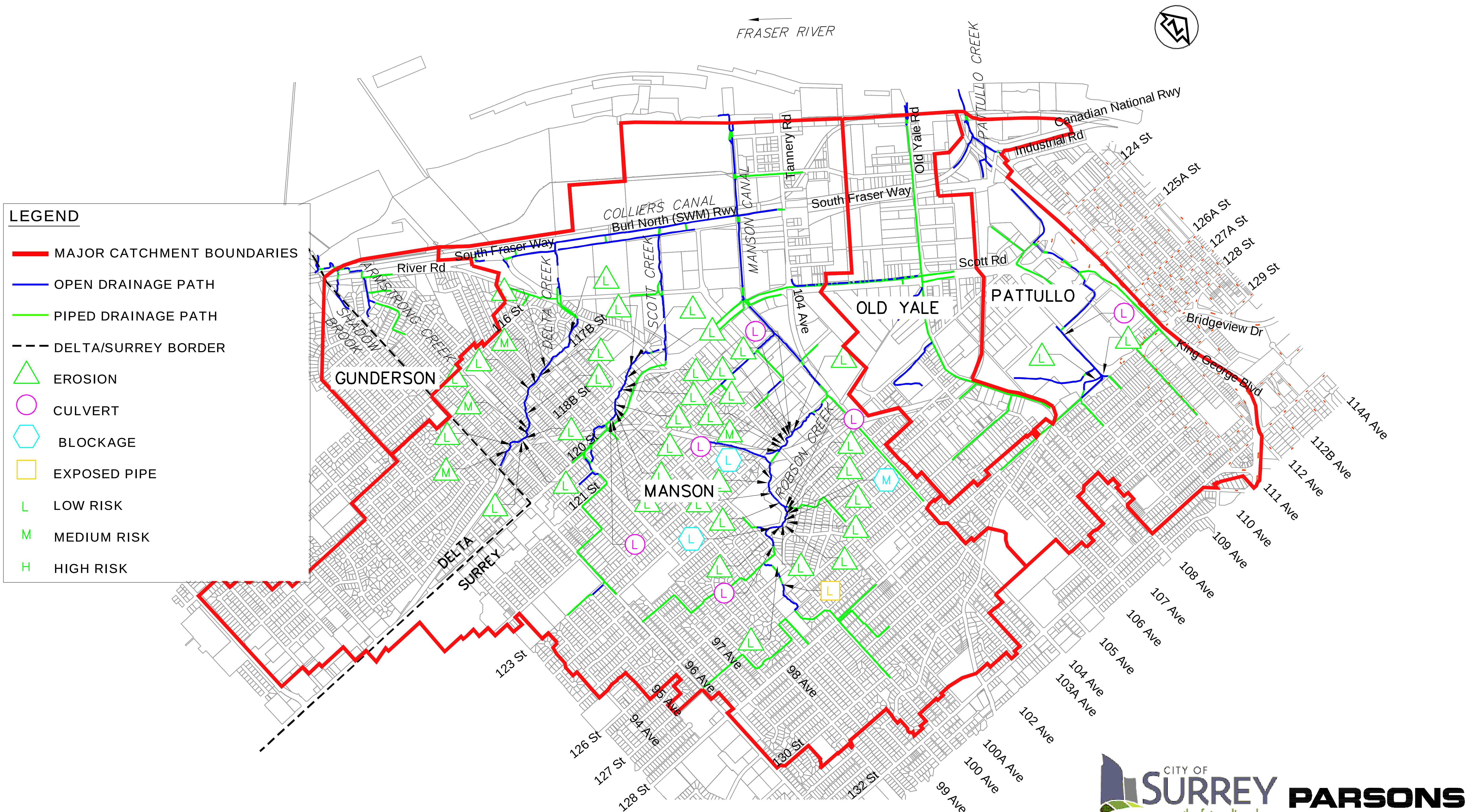
Pattullo Creek (110 Avenue Creek) is located in the northwest portion of the City and drains to the west before eventually discharging to the Fraser River. Three instability sites were identified as "low risk". However, one new site was identified since the 2009 assessment. The table below, which is an excerpt from the 2011 Ravine Stability Assessment, summarizes the data collected for Pattullo Creek.

Table 2.5.4: Ravine Stability Assessment (2011) for Pattullo Creek

	Location		Point Type	Risk	
	Northing	Easting		2011	2009
1	5449935	509622	Erosion	Low	Low
2	5449970	509319	Culvert Inlet	Low	Medium
3	5449985	509630	Erosion	Low	N/A

FIGURE 2.20

RAVINE STABILTY ASSESSMENT (2011)



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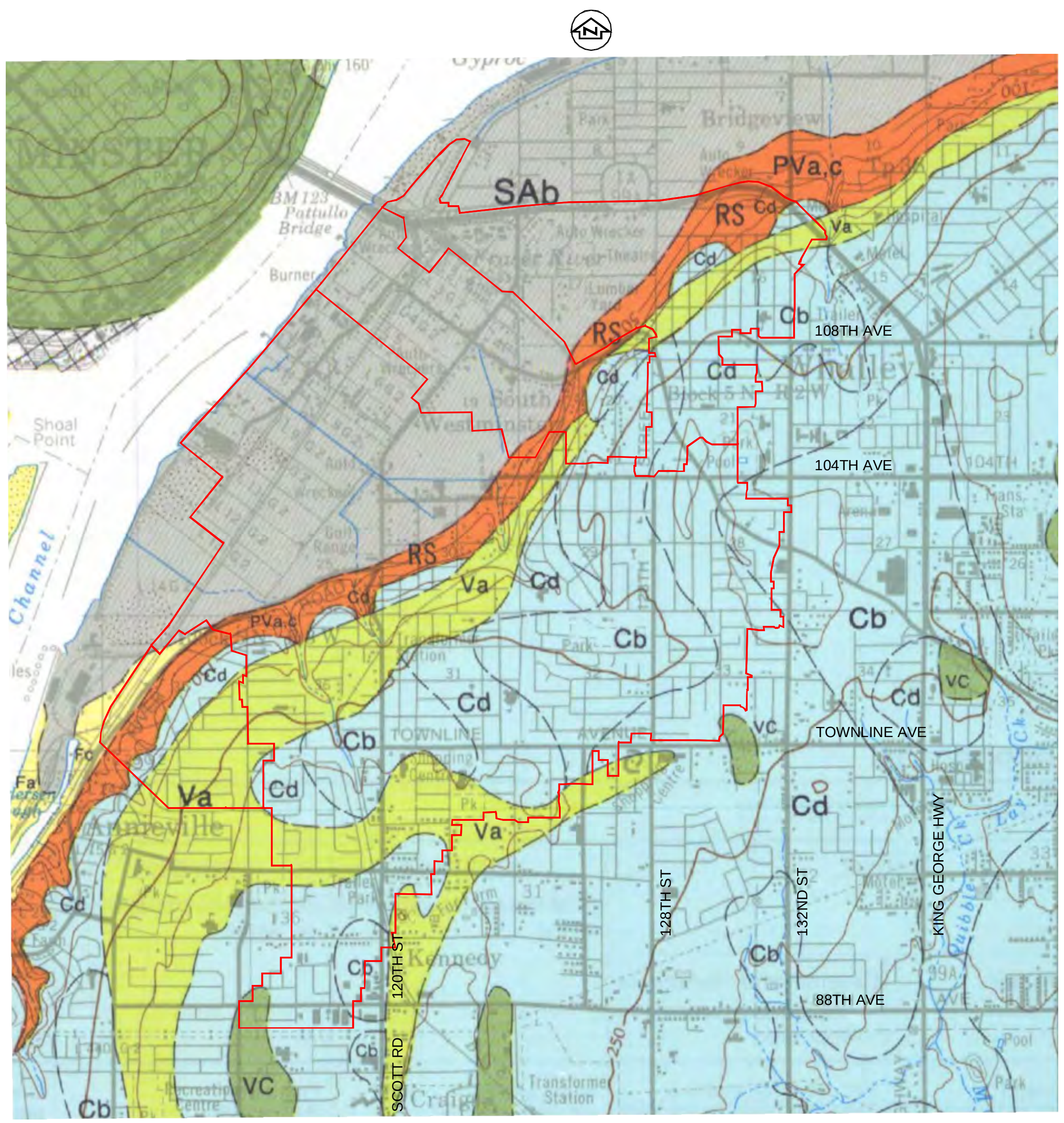
2.6 Soil

The study area is divided into two main soil area, the uplands and lowlands. The lowlands are peats and river sediments. The soils present challenges for maintenance of infrastructure and infiltration of rainwater. Much of this area is also vulnerable to seismic events.

The uplands are generally underlain by low permeability marine silts and clay to stony silt and clay deposits. This layer is between 20 and 40 metres thick. The soil map for the study area is attached as **Figure 2.21**.

FIGURE 2.21
SOIL MAPPING



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 glaciaomarine 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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2.7 Water Quality

Stormwater is influenced by human activities and contains contaminants such as hydrocarbons and heavy metals that are derived from vehicles, as well as nutrients, pesticides and bacteria resulting from urban and agricultural land uses. Furthermore, when stormwater flows over paved surfaces on warm days, for example it can increase temperature to levels unsuitable for cold-water fish such as salmon.

Heavy metals are a particular concern because they do not degrade in the environment and can cause serious harm to the aquatic environment. Heavy metals within stormwater are dominated by discharges from impervious areas such as highways, road surfaces and roofs.

There are three water quality sampling points that have been identified: Pattullo Pump Station, Manson Pump Station and Old Yale Pump Station. The following section of this report will compare the water quality results to the Water Quality Guidelines (B.C. Ministry of Environment (MOE)) in order to obtain a better understanding of the potential pollutants discharging into receiving water courses in South Westminster.

2.7.1 Existing Conditions

2.7.1.1 Land Use and Potential Sources of Pollution

South Westminster consists of approximately 514 hectares of land designated as “industrial” in the Official Community Plan (OCP). Is also encompasses the Port Metro Vancouver and associated lands. As a multi-berth port facility the Fraser Port is the largest industry and the most active use in the area. In addition to the Fraser Port, South Westminster has been home to many auto salvage yards and other industries requiring outdoor storage. The salvage yard areas have recently declined and several new commercial developments have occurred in the area such as a Chevron Station on Scott Road and a Home Depot on 128 Street at 110 Avenue.

Poor water quality from point sources and non-point sources can undermine other efforts to manage watercourse and habitat. Water quality, in terms of both parameters and the concentration of such parameters, varies dramatically throughout the City according to the predominant land use. Water quality is often predicated upon land use, and the contaminant loading associated with each use. The light industrial areas of South Westminster are expected to contribute different pollutant sources than the upland areas.

Potential sources of pollution are as follows:

- ***Nutrients***
  - The main potentially-polluting nutrients in relation to water are nitrogen, ammonia, phosphorus and sulphur;
  - They arise from the natural breakdown of crop residues and soil organic matter, rainfall, fertilisers, urine and manure, silage, landfill sites, wastewater and industrial effluents, power generation and other fuel-burning activities; and

   - Nutrients are the primary cause of eutrophication of lakes, rivers and the marine environment.

- ***Pesticides***
   - These include herbicides, insecticides and fungicides that are used in gardens, in agriculture, in roadside and trackside (railway) maintenance, and in parkland and golf courses.
- ***Heavy Metals***
   - Heavy metals are widely-used ingredients for chemical compounds used in industry;
   - Industrial contaminated land can be a source of heavy metals leaching into the environment;
   - They also exist naturally in soils at low concentrations;
   - They can be found in fuel, chemicals, waste materials and batteries; and
   - In high concentrations they are toxic to humans, animals, fish and plants.
- ***Suspended Solids***
   - Suspended solids are mineral and organic particles that remain suspended in water;
   - They sink only very slowly or are easily re-suspended by water turbulence;
   - Suspended solids might be eroded soil or decayed leaves;
   - Wastewater from sewage works and industry might also carry suspended solids into water bodies;
   - Suspended solids cause water to be turbid and this cloudiness reduces light levels; and
   - Turbidity can also be a sign of other pollution since nutrients, pesticides and metals can be attached to the suspended particles.
- ***Settleable Solids***
   - These are mineral or organic solids which can settle onto the beds of rivers and lakes where they can prevent fish spawning.
- ***Oxygen Depleting Substances***
   - Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) tests are analytical methods for measuring the amount of oxygen consumed during the microbial or chemical breakdown of oxygen-depleting substances in water, such as sewage and farm slurry; and
   - High levels of BOD and COD indicate a heavily polluted water body making it less suitable for aquatic life.
- ***Pathogens***
   - These are present in faeces from human and animal sources, including wildlife;
   - They can enter water through poor wastewater management or poor handling of manures, slurry and other farm wastes; and

- They may also be carried directly off fields by heavy rainfall or enter water bodies where stock and wildlife have direct access for drinking purposes.

- ***Temperature***
  - Temperature is not strictly a pollutant in the general meaning of the term but is included here because it can affect the health of the aquatic environment; and
  - When stormwater flows over paved surfaces on warm days, it can increase to temperatures that are unsuitable for cold-water fish like salmon or trout.
- ***Hydrocarbons***
  - These include vegetable and mineral oils (including petrol, diesel, white spirit, heating and lubricating oil), and chlorinated solvents such as dry cleaning fluids.
- ***Persistent Organic Pollutants (POPs)***
  - These are chemicals that are capable of long-range transport, accumulate in human and animal tissue, and have a significant impact on human health and the environment, even at low concentrations; and
  - They include such substances as dioxin and PCBs.

2.7.1.2 Water Quality Data

Water quality sampling has been conducted at the following locations: Pattullo Pump Station (last sample date March 3, 2010), Manson Pump Station (last sample date March 9, 2011) and Old Yale Pump Station (last sample date March 9, 2011). Water Quality Guidelines were obtained from MOE as a primary source and the Canadian Council of Ministers of the Environment as a secondary source. The table below illustrates the results. **Table 2.7.1** show the water quality sample results and highlights in red the readings that exceed standards.

Table 2.7.1: Water Quality Data

Sample Description		Water Quality Guidelines*	Pattullo Pump Station	Manson Pump Station	Old Yale Pump Station
Sampled Date			2010/03/03 15:00:00	2011/03/09 13:20:00	2011/03/09 13:00:00
Sample Type			GRAB	GRAB	GRAB
Aluminium Dissolved	mg/L	0.1	0.03	0.07	0.21
Aluminum Total	mg/L	No Data	0.53	1.45	5.81
Arsenic Dissolved	mg/L	0.005	<0.01	<0.01	<0.01
Arsenic Total	mg/L	No Data	0.001	0.001	0.003
Barium Dissolved	mg/L	No Data	0.06	0.019	0.028
Barium Total	mg/L	No Data	0.037	0.034	0.084
Boron Dissolved	mg/L	1.2	0.03	<0.02	0.02
Boron Total	mg/L	No Data	0.03	<0.02	0.03
Cadmium Dissolved	mg/L	No Data	<0.0005	<0.0005	<0.0005

Sample Description		Water Quality Guidelines*	Pattullo Pump Station	Manson Pump Station	Old Yale Pump Station
Cadmium Total	mg/L	No Data	<0.0005	<0.0005	0.0006
Calcium Dissolved	mg/L	No Data	25.1	15.3	28.8
Calcium Total	mg/L	No Data	25.5	16.4	33.6
Chromium Dissolved	mg/L	No Data	<0.001	<0.001	<0.001
Chromium Total	mg/L	No Data	0.001	0.002	0.009
Cobalt Dissolved	mg/L	No Data	<0.001	<0.001	<0.001
Cobalt Total	mg/L	110	<0.001	0.001	0.003
Conductivity	µmhos/cm	No Data	292	168	233
Copper Dissolved	mg/L	No Data	0.003	<0.002	0.003
Copper Total	mg/L	0.009/0.007/0.012**	0.003	0.005	0.024
Hardness as CACO3	mg/L	No Data	70.3	50.4	103
Iron Dissolved	mg/L	0.3	2.59	0.33	0.53
Iron Total	mg/L	1.0	4.45	2.3	7.67
Lead Dissolved	mg/L	0.001	<0.001	<0.001	0.001
Lead Total	mg/L	0.223/0.145/0.364**	0.001	0.004	0.022
Magnesium Dissolved	mg/L	No Data	4.63	1.75	2.53
Magnesium Total	mg/L	No Data	1.61	2.27	4.6
Manganese Dissolved	mg/L	No Data	0.353	0.126	0.249
Manganese Total	mg/L	1.3/1.1/1.6**	0.368	0.155	0.376
Mercury Total	µg/L	0.026	<0.05	<0.05	<0.05
Molybdenum Dissolved	mg/L	No Data	<0.002	<0.002	<0.002
Molybdenum Total	mg/L	2.0	<0.002	<0.002	<0.002
Nickel Dissolved	mg/L	No Data	0.001	<0.001	0.002
Nickel Total	mg/L	0.025	0.002	0.003	0.007
Nitrogen - Ammonia as N	mg/L	25.1 / 24.8 / 24.8***	0.4	<0.2	<0.2
Nitrogen - Nitrate as N	mg/L	32.8	0.6	0.35	0.32
Nitrogen - Nitrite as N	mg/L	0.06	0.03	0.03	0.03
Nitrogen - Total Kjeldahl	mg/L	No Data	<2	<2	2
pH	pH units	6.5 to 9.0	6.8	6.9	6.9
Phosphorus Dissolved	mg/L	No Data	0.02	<0.01	0.02
Phosphorus Total	mg/L	No Data	0.04	0.05	0.18
Selenium Dissolved	mg/L	No Data	<0.01	<0.01	<0.01
Selenium Total	mg/L	0.001	<0.001	<0.001	<0.001
Silver Dissolved	mg/L	No Data	<0.001	<0.001	<0.001
Silver Total	mg/L	0.0001	<0.001	<0.001	<0.001
Sodium Dissolved	mg/L	No Data	20.4	12	10.4
Sodium Total	mg/L	No Data	20.4	12.2	11.9

Sample Description		Water Quality Guidelines*	Pattullo Pump Station	Manson Pump Station	Old Yale Pump Station
Total Suspended Solids	mg/L	See below text for TSS	16	24	98
Zinc Dissolved	mg/L	No Data	0.038	0.012	0.028
Zinc Total	mg/L	0.033/0.033/0.040**	0.019	0.036	0.113

**Water Quality for the Protection of Aquatic Life*

***Water quality guideline depends on hardness*

****Water quality guideline depends on pH and water temperature*

2.7.2 Discussion on Water Quality Data

As indicated in the above table, the following exceeds the Water Quality Guidelines for come contaminants:

- ***Pattullo Pump Station***
    - Iron (Total); and
    - Iron (Dissolved).
- ***Manson Pump Station***
    - Iron (Total);
    - Iron (Dissolved); and
    - Zinc (Total).
- ***Old Yale Pump Station***
    - Aluminium (Dissolved);
    - Copper (Total);
    - Iron (Total);
    - Iron (Dissolved); and
    - Zinc (Total).

2.7.2.1 Iron

As shown in the above table, iron noticeably exceeds the water quality guidelines at all three water sampling points. As examples, at Pattullo Pump Station the concentration is 863% higher than the limit for *dissolved iron* and 767% higher for *total iron* at Old Yale Pump Station. Iron naturally occurs in the environment and a median level of 0.7 mg/L has been reported in rivers (World Health Organization, 2003). At all three sample locations the total iron exceeds what would be deemed natural in rivers, however, it is unknown whether the high iron content is naturally occurring or due to an upstream source.

Iron is a dietary requirement for most organisms and plays an important role in natural processes in binary and tertiary form. Iron may be harmful to plants at feed concentrations of between 5 and 200 ppm.

Iron is applied worldwide for commercial purposes, and is produced in amounts of 500 million tons annually. Iron is used as construction material, including for drinking-water pipes. Iron oxides are used as pigments in paints and plastics. Other compounds are used as food colours and for the treatment of iron deficiency in humans. Various iron salts are used as coagulants in water treatment (WHO, 2003).

2.7.2.2 Aluminum

Dissolved aluminum exceeds the water quality guideline at Old Yale Pump Station. Dissolved aluminium concentrations in waters with near-neutral pH values usually range from 0.001 to 0.05 mg/litre but rise to 0.5–1 mg/litre in more acidic waters or water rich in organic matter. At the extreme acidity of waters affected by acid mine drainage, dissolved aluminium concentrations of up to 90 mg/litre have been measured (WHO, 1997). Dissolved aluminum exceeds what would be deemed natural in rivers at the Old Yale Pump Station sampling location. However, it is unknown whether the high aluminum content is naturally occurring or due to an upstream source.

Dissolved Al^{3+}-ions are toxic to plants, which affect roots and decrease phosphate intake. Aluminum is toxic to fish in acidic, unbuffered waters starting at a concentration of 0.1 mg/L. Simultaneous electrolyte shortages influence gill permeability, and damage surface gill cells. Aluminum is mainly toxic to fish at pH values 5.0-5.5. Aluminum ions accumulate on the gills and clog these with a slimy layer, which limits breathing.

Aluminum metal is used as a structural material in the construction, automotive, and aircraft industries, in the production of metal alloys, in the electric industry, in cooking utensils, and in food packaging. Other examples of aluminum application include aluminum sulphate use as a basic material in paper glue, tanners, mordants and synthetic rubber, and aluminum hydrogen as a reduction and hydration agent.

2.7.2.3 Copper

As shown in the above table, total copper exceed water quality guidelines at the Old Yale Pump Station. Copper is found in surface water, groundwater, seawater and drinking-water, but it is primarily present in complexes or as particulate matter. Copper concentrations in surface waters ranged from 0.0005 to 1 mg/litre in several studies in the USA with a median value of 0.01 mg/litre.

Metallic copper is malleable, ductile and a good thermal and electrical conductor. It has many commercial uses because of its versatility. Copper is used to make electrical wiring, pipes, valves, fittings, coins, cooking utensils and building materials. It is present in munitions, alloys (brass, bronze) and coatings. Copper compounds are used as or in fungicides, algicides, insecticides and wood preservatives and in electroplating, azo dye manufacture, engraving, lithography, petroleum refining and pyrotechnics. Copper compounds can be added to fertilizers and animal feeds as a nutrient to support plant and animal growth. Copper compounds are also used as food additives such as a colouring agent. Copper sulfate pentahydrate is sometimes added to surface water for the control of algae.

2.7.2.4 Zinc

Total zinc levels at the Manson and Old Yale Pump Stations sampling points exceed water quality guidelines. In natural surface waters, the concentration of zinc is usually below 10 µg/litre, and in groundwater, 10–40 µg/litre. Therefore, it could be presumed that source of zinc may come from discharges upstream.

Zinc was not attributed a water hazard class since it is not considered a hazard (Lenntech, 2013). However, some zinc compounds (such as zinc arsenate and zinc cyanide) may be extremely hazardous. Although zinc is a dietary mineral for humans and animals, overdoses may negatively influence human and animal health and over a certain boundary concentration, zinc is quite toxic.

About three-quarters of the total zinc supply is used in metal form and the remainder is applied as various zinc compounds in various industries. Industrial wastewaters containing zinc stem from galvanic industries such as battery production. Zinc compounds are applied for many different purposes. Zinc chloride is applied for parchment production, zinc oxide is a constituent of salves, paints and catalysers, zinc vitriol is applied as a fertilizer, and zinc bacitracine is applied as a growth stimulant in animal husbandry. Zinc leaks from zinc pipes and rain pipes, consequential to circulation of carbon rich water. Car tires containing zinc and motor oil from zinc tanks release zinc compounds on roads. Zinc compounds are present in fungicides and insecticides, and consequently end up in water. When inadequate safety measures are taken, zinc may be emitted from chemical waste dumps and landfills, or from dredge mortar.

2.7.2.5 Total Suspended Solids (TSS)

This is a measure of the particulate matter that is suspended within a water body. High concentrations of non-filterable residue can increase turbidity, which could result in the restriction of light penetrating the water body thus hindering photosynthetic activity. Furthermore, suspended material can result in damage to fish gills. Settling suspended solids can cause impairment to spawning habitat by smothering fish eggs (MOE, 1998).

The water quality results in **Table 2.6.1** indicate that TSS is much higher (98 mg/l) at Old Yale Pump Station than at Pattullo Pump Station (16 mg/l) and Manson Pump Station (24 mg/l). However, interpreting these results is not as straightforward as other contaminants as the guideline is not a specific concentration but instead is based on background levels.

The Water Quality Guidelines produced by Canadian Council of Ministers of the Environment includes guidance to protect aquatic life in freshwater, which are as follows:

- ***Clear Flow***
    - Maximum increase of 25 mg/L from background levels for any short-term exposure (e.g., 24-h period); and
    - Maximum average increase of 5 mg/L from background levels for longer term exposures (e.g., inputs lasting between 24 hours and 30 days).

- ***High Flow***
  - Maximum increase of 25 mg/L from background levels at any time when background levels are between 25 and 250 mg/L; and
  - Should not increase more than 10% of background levels when background is ≥ 250 mg/L.

Suspended solids (SS) is a common pollutant in urban stormwater and has varying concentrations depending on land use. The major sources of SS (including sediment and floatables) are streets, lawns, driveways, roads, construction activities, atmospheric deposition, and drainage channel erosion. Median event mean concentrations for TSS which are as follows (EPA, 1983):

- ***Residential:*** 101 mg/l;
- ***Mixed:*** 67 mg/l; and
- ***Commercial:*** 69 mg/l.

Based on these concentrations, the TSS concentration that was measured at Old Yale Pump Station is in-line with the EPA's median event mean concentration for a residential area.

TSS is an important factor when considering the treatment of stormwater runoff. Treatment facilities such as detention ponds, swales, wetlands and other Best Management Practices (BMPs) are often used to treat stormwater and their performance is dependent on the TSS removal rate. Although there are many pollutants in urban runoff, including heavy metals, the reason for focusing on the removal of TSS is that the other pollutants will bind to particulates and settle to the bottom of a BMP.

2.8 Environment

Phoenix Environmental Services Ltd. (Phoenix) was retained by Parsons to provide the environmental assessment components for the South Westminster Integrated Stormwater Management Plan (ISMP). A summary of the key findings are presented below and a more detailed environmental assessment can be found attached in the **Appendix B**.

The study area is characterized by urban and industrial land uses with predominately single-family residential areas to the south, on the escarpment, and mixed industrial and commercial uses within the lowland floodplain areas near the Fraser River. The area has been largely built-out with negligible undeveloped lands. Features such as remaining streams, forested and environmentally sensitive areas have become a scarcity. These features still have significant retention value, even where degraded by urban activities.

The watershed within the ISMP study area includes three major drainage catchment areas including the Pattullo, Old Yale, Gunderson and Manson catchments as well as the sub-catchment of Armstrong Creek and Shadow Brook. The South Westminster ISMP study area is within the Georgia Depression Ecoprovince, Lower Mainland Ecoregion, Fraser Lowland Ecosection. The Study Area is within the Very Dry Maritime Coastal Western Hemlock (CWHxm1) Biogeoclimatic (BGC) subzone and the Dry Maritime Coastal Western Hemlock (CWHdm) BGC subzone.

2.8.1 Vegetation and Ecological Communities

No sensitive plant or animal species were detected during the field program, although several sensitive species are likely, including Great Blue Heron (Ardea Herodias), Trowbridge's Shrew (Sorex trowbridgii), Pacific Water Shrew (Sorex benderii), Streambank lupine (Lupinus rivularis) and Vancouver Island beggarticks (Bidens amplissima). Invasive vegetation species were regularly encountered along interfaces of forested and disturbed or developed sites. These invasive species included Himalayan blackberry (Rubus discolor), Japanese knotweed (Polygonum cuspidatum), Scotch broom (Cytisus scoparius) and English ivy (Hedera helix). Removal of these invasive plant species at strategic sites would benefit many native wildlife and vegetation species and improve existing wildlife corridors.

The riparian habitats, forested blocks, ponds and ROWs in the Study Area were identified as having high wildlife values and provided moderate to high rated habitat for a number of federally listed wildlife species including Pacific water shrew (Sorex benderii), red-legged frog (Rana aurora) and Western Screech-owl (Megascops kennicottii kennicottii). These riparian areas and forested stands also provided important nesting habitat for other wildlife including raptors such as Bald Eagle (Haliaeetus leucocephalus), Red-tailed Hawk (Buteo jamaicensis) and Cooper's Hawk (Accipiter cooperii). Wildlife sign encountered during the field program included coyote (Canis lantrans) and beaver (Castor canadensis). The ponds, watercourses and associated terrestrial habitats provided important habitat for many waterfowl, songbird and amphibian species. The riparian zones of all creeks provided moderate to high rated habitat for the provincially listed Trowbridge's shrew (Sorex trowbridgii) and Pacific sideband snail (Monadenia fidelis).

2.8.2 Watercourses and Fish Habitat

The watercourses in the ISMP Study can be separated roughly into three categories:

- Ravine Streams and tributaries;
- Constructed Fish Habitat Drainage Watercourses; and
- Constructed drainage ditches (not fish habitat).

Storm sewers and roadside ditches direct runoff from the upland areas within the Study Area toward Robson Creek, Scott Creek, Delta Creek, Armstrong Creek or Shadow Brook. These creeks convey flow down the steep escarpment into the lowland floodplain where connectivity to the Fraser River occurs through constructed (channelized) watercourses offering fish habitat. Phoenix Environmental identified a number of issues relating to the watercourses, which include: stream erosion, fish migration barriers, riparian habitat damage, and degraded water quality.

Development in upland areas of the Manson and Pattullo catchments has contributed to increased peak flows and run off volumes during storm events and the concentration of flows at storm sewer outlets. Changes to flow patterns due to land development accelerate naturally occurring erosion processes, by exposing the ravine channels to more frequent, longer duration, high flow events. Construction of detention ponds in Robson Creek has likely limited the erosion potential within that watercourse; however, ravine stability assessments (2002 – 2009) indicate that numerous localized bank erosion problems persist within the South Westminster ravine streams.

Phoenix Environmental observed potential obstructions to fish passage in the upper reaches of Scott and Robson Creek; however, the lower reaches of these streams and the other ravine streams within the Study Area are accessible to fish. Culvert extensions due to the construction of the SFPR could decrease potential for fish migration upstream, therefore, maintaining fish passage in Class A and Class A(O) watercourses has been critically important during design and construction. The installation of fish passable culverts and fish ladders under the SFPR into Shadow Brook and Armstrong Creek has potentially improved fish access into the upper reaches of those watercourses. Watercourses affected by SFPR construction require further assessment after completion of the highway.

Riparian habitat damage from refuse disposal and long-term structures built at or very close to watercourse banks and ravine crests occurs extensively throughout the Study Area. Water quality issues are most prevalent in the lowland floodplain and industrialized areas of the ISMP Study Area. To provide an indicator of aquatic health, benthic invertebrate community monitoring has been seasonally conducted at two locations in Delta Creek between 1999 and 2008. The results indicate that Delta Creek is consistently in the ‘Very Poor’ to “Poor” range.

2.8.3 Reclassification of Watercourses

Several changes in the City's online mapping (COSMOS) are proposed to address unmapped watercourses, inaccurately mapped watercourses, and to address proposed re-classifications of watercourses. The following table summarizes the recommendations of the Phoenix report.

Table 2.8 Watercourse Reclassification Recommendations

Location	Current Class	New Class	Comments
Pattullo			
Pattullo Bridge (South arm where watercourse splits into a "Y")	Class A	Class B	Low water levels, stagnant flow, no connectivity
Pattullo Bridge (Channel connected to watercourse along 111A Ave.)	Class A(O)	Class B	Very low water levels, no flow, no connectivity
109th Ave. to 110th Ave.	Class A	No Watercourse	Pedestrian trail only
Old Yale			
Scott Rd. and Old Yale Rd. (upstream extent north of 104 Ave. near 125A St.)	Class A	Must be reviewed	Fish movement deemed difficult due to >1km culvert but obstacle could be removed
Scott Rd. and Old Yale Rd. (124 St.)	Class A(O)	Must be reviewed	Fish movement deemed difficult due to >1km culvert but obstacle could be removed
Manson			
124th St. to 125A St.	Class A(O)	Class B	Overgrown channels, very low water levels, no connectivity, impaired fish access (long culvert)
Old Yale Rd. to 104 Ave.	Class A	Class B	Limitation to fish access, and poor habitat conditions
123A St. and BC Hydro Railway (123A St. between 100A Ave. and the end of 123A St.)	Class B	No Watercourse	Enclosed in a storm sewer
123A St. and BC Hydro Railway (ditches along the west side of 123A St. and on the south of 100A Ave. on the south side of 100A Ave. west of 123A)	Class C	Class B	Groundwater-fed and watercourse substrate observed.
102 Ave.	Class C	Class B	Gravel substrate and groundwater flow connection to an existing Class B watercourse.

Location	Current Class	New Class	Comments
Timberland Rd. and Tannery Rd. (on either side of Tannery Rd. northwest of Timberland Rd.)	Class A(O)	No Watercourse	Watercourses have been filled due to construction of SFPR.
Timberland Rd. and Tannery Rd. (unmapped channel on the south side of Timberland Rd. just east of CN Railway)	Class A(O)	Class C	Habitat Impact Assessment completed by Coast Environmental (2006) observed Class C ditches
Timberland Rd. and Tannery Rd. (east of Tannery Rd. on the south side of Timberland Rd. and on either side of the CN Railway)	Unmapped	Class A(O)	High water levels
Timberland Rd. and Tannery Rd. (west side of Tannery Rd. between South Fraser Way and Scott Rd.)	Class A	Altered by SFPR Construction	Stagnant water and fish passage was not maintained
103A and South Fraser Way	Class A(O)	Altered by SFPR Construction	Fish passage was not maintained
103A Ave. (east side of 121 St. between 103A Ave. and 102 Ave.)	Class A(O)	Class B	Very low water levels, no connectivity, contains algae on the substrate
103A Ave. (west side of 121 St. between 103A Ave. and 102 Ave.)	Class A	Class A(O)	Sufficient water levels with potential to support fish during winter periods
Scott Creek and 99th Ave.	Class A	Must be reviewed	Fish movement deemed difficult due to 1 meter high weir but obstacle could be removed
Grace Rd.	Class B	Class C	Dry due to flow changes from SFPR construction.

2.8.4 Wildlife Corridors

The ROWs, Armstrong Creek, Delta Creek, Scott Creek, Robson Creek and Manson Creek and their tributaries provided important wildlife corridors for many listed wildlife species including Red-legged Frog (Rana aurora) and Pacific water shrew (Sorex benderii) as well other wildlife. The relatively few and fragmented forested areas remaining in the Study Area have not changed substantially over many years, given the long history and density of urban development in the Study Area. Remaining forest patches need to be protected and wildlife movement corridors need to be maintained or established to improve the ecological integrity of the Study Area and to provide suitable living habitats for sensitive species. Provision of natural habitats that have protected corridors will result in increased biodiversity within the Study Area.

2.8.5 Recommended Improvements

Recommendations related to environmental resources in the study area are contained in **Section 4** of this plan. Descriptions are provided as follows:

- Habitat Improvements in **Section 4.4**; and
- Water Quality Improvements in **Section 4.5**.

3. Vision

Having investigated the existing conditions of the watershed and identified and assessed the environmental and other resources and conditions within the watershed, the next task is to determine "What do we want?" for the watershed, thereby creating a Vision for the South Westminster watersheds.

There are two components required to create this Vision:

- Understanding the larger, overarching objectives outlined in the City of Surrey's planning documents; and
- Understanding the current conditions within the watershed and identifying opportunities to implement positive change consistent with specific needs and requirements.

A watershed Vision should not be solely dictated by a consultant or other single party as it is a value decision that should be made by those with something at stake in the watershed and by those responsible for implementing changes. Not every watershed vision needs wide scale public consultation as often the reality is that existing bylaws, policies and infrastructure dictate the larger vision. This is the case for South Westminster where current City of Surrey policy documents already outline a desire to make sustainable decisions with regards to watershed health and stormwater management. What does need to be decided is how the existing documented policy/philosophy should be applied to this watershed.

In the following **Section 3.1**, we summarize several overarching City planning documents to provide an understanding of the larger vision. As well, we examine the specific challenges facing water infrastructure, habitat and other resources in the study area and develop key objectives (**Section 3.2**). In **Section 3.3**, a Watershed Vision statement is presented together with goals to support it.

3.1 Overarching Planning Documents

The watershed Vision must be in line with planning objectives and documents followed by the City. ISMPs need to have a two-way link with the relevant municipal planning documents, whereby the 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.

A detailed discussion of several key City planning documents was provided in the Stage 1 Draft: Existing Conditions Report (Delcan, June 2013). In this section, we provide a brief summary of the City's Sustainability Charter, OCP and South Westminster NCP, as they provide the context for the larger municipal vision related to integrated stormwater management within this watershed.

3.1.1 City of Surrey 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. Most relevant to the ISMP are the goals that could impact creeks and drainage systems, such as:

- Respect natural areas and minimize the impacts of economic activities on the environment;
- Promote environmentally friendly businesses and "green" building practices;
- Create a balance between the needs of Surrey's human population and the protection of terrestrial ecosystems;
- Protect Surrey's groundwater and aquatic ecosystems for current and future generations; and
- Establish a built environment that is balanced with the City's role as a good steward of the environment.

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.

3.1.2 Official Community Plan

The OCP is a statement of objectives and policies to guide City planning decisions with respect to land use and development in Surrey in order to achieve orderly growth for complete sustainable communities with sensitivity to the environment.

The OCP contains several policies that relate to ISMPs. 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 ISMP must incorporate these principles in order to stay aligned with the City's priorities.

3.1.3 South Westminster Neighbourhood Concept Plan (2003)

Surrey has a number of secondary land use plans that supplement the OCP. Secondary plans such as Neighbourhood Concept Plans (NCP) provide detailed neighbourhood-level land use planning for developing areas throughout the city. Following are several key points discussed in the NCP:

- The NCP of approximately 514 hectares of land is designated as "industrial" in the OCP and is located in the lowland floodplain of the Fraser River. The ISMP Study Area includes both lowland and upland areas. The re-development of the lowland industrial area was the primary focus in the NCP;
- The NCP stated that the South Westminster area remains relatively undeveloped and underutilized, and that the current industries located in this area were regarded as interim uses and they neither provide large employment opportunities nor are a catalyst for new business growth;
- The NCP included a Land Use Plan that has been formulated for the South Westminster area;
- The NCP included information regarding Drainage and Flood Management. Much of the lowland areas are protected by a dyke system along the Fraser River designed to the 1894 flood of record (approximately 1:500 return period) elevation at approximately 4.4 metres (plus a 0.6 metre freeboard). It is stated in the NCP that Provincial flood proofing regulations will apply to new developments in the area; and
- A major development since the NCP was completed is the construction of the South Fraser Perimeter Road. This new highway runs parallel to the Fraser River, widening and realigning the previous road rights-of-way, and therefore changes the previously established drainage patterns.

3.1.4 Other Plans and Documents

In addition to the above plans and policy documents developed by the City, there are other documents and reports developed by consultants that identify key requirements and management guidelines for specific areas and infrastructure within the watershed. Although more focused in nature, these documents still influence the overall vision for the watershed and have been reviewed in detail in **Section 2 – Existing Watershed Conditions** of this document.

3.2 Key Watershed Objectives

The South Westminster watershed poses a distinct challenge for the development of a single ISMP for the watershed, as the ISMP Study Area is composed of two very different components: the upland residential areas and the lowland industrial and commercial areas. Although linked by drainage infrastructure, both areas have their own area specific issues and concerns.

The upland area directs the majority of storm drainage through a number of creeks and storm sewers into the lowland drainage system. With predominantly urban residential developments occurring in the upland areas and development / re-development of lots having higher impervious lot coverage areas, the upland hydrology is changing. With the increase in impervious percentage, higher runoff rates and volumes are being directed to the natural creek systems, thereby increasing the potential for stream bank erosion, slope instability and increased sediment load within these systems.

The lowland area is within the approximate 500-year (1894 flood of record) floodplain of the Fraser River but is protected by a dyke system and several pump stations (Manson, Old Yale and Pattullo). Most of the area is made up of industrial / commercial developments; however, there is a move from low-value, light industrial to high-value, commercial, residential and mixed-used developments in portions of the lowland area. The lowland drainage system, which is made up of low-gradient channels, storm sewers, flood boxes and pump stations, is susceptible to major storm events (local area flooding behind the dyke) and Fraser River flood events. An additional pressure that may increase the potential flooding within the lowland area is sea level rise and the extent that it is accounted for in the design and construction of infrastructure within this area.

In this section, we provide commentary on various key watershed objectives and areas where we have identified opportunities that are addressed in **Section 4 – Implementation** of this report. For each of the key objectives, we describe the current situation, provide questions for consideration in terms of ISMP direction and objectives, and provide a recommended next step that will be detailed further in **Section 4**.

Our commentary has been organized based on the following four criteria, which we used to develop the overall vision and operational goals within the watershed:

- Determine Operational Criteria for Flooding (Lowland);
- Determine Responsibilities for Developers (Development);
- Determine Current Commitments and Goals for Habitat (Habitat); and
- Define Water Quality Goals (Water Quality).

3.2.1 Determine Operational Criteria for Flooding

The lowland area is at risk of flooding both from the Fraser River and from local rainfall events. The level of risk will be determined by the infrastructure and operational measures implemented by the City. In developing the overall vision for the watershed, it is important to reflect the City's objectives with respect to flood risk in this area.

3.2.1.1 Lowland Drainage Service Level

Situation: Our modelling showed that there were few significant deficiencies in the system for normal design events. There are some areas where local infrastructure capacity, either culverts or ditches, are exceeded, but the magnitude of the problem is generally minor. In the future, sea level rise could make these problems more frequent and more widespread.

Question: The following are options for the lowland drainage system:

a. *Do we maintain the existing level of service, while targeting specific deficiencies?*
b. *Do we make system improvements that increase the level of service?*

c. *Do we proactively increase storage and discharge capacity to account for sea level rise now, and if so in what increments?*

Recommended Goal: Improvement of the lowland drainage system to provide an increase in capacity and account for sea level rise.

3.2.2 Determine Responsibilities for Developers

One of the ways where changes in the watershed can be made is by requiring private land owners, at time of development, to implement changes to their land use or implement source controls in a way that improves the stormwater management within a development area. There is a current framework within the City that dictates the requirements for developers; however, through this ISMP, there is an opportunity to make key changes to the current framework that will provide developers with updated direction on how to address stormwater management components related to their proposed developments.

3.2.2.1 NCP development

Situation: The NCP for South Westminster (the lowland area) does not provide specific guidance with regard to stormwater management. This ISMP is an opportunity to provide that guidance.

Question: *The ISMP will recommend storm infrastructure and source controls for new development. Should they be performance based (e.g. storage/area targets) or prescriptive (e.g. dedicating set % of area for green surfaces)?*

Recommended Goal: Define stormwater infrastructure design requirements that influence new lowland developments and are consistent with the watershed stormwater management goals.

3.2.2.2 Single Lot Redevelopment

Situation: Upland single lot re-development is expected to increase, especially with the redevelopment of the City Centre.

Question: *Should the ISMP recommend that single lot redevelopments include stormwater BMPs? How should this be structured to be most effectively implemented?*

Recommended Goal: Define stormwater infrastructure design requirements that influence single lot redevelopment and are consistent with the watershed stormwater management goals.

3.2.3 Determine Current Commitments and Goals for Habitat

There are several overarching regulatory agencies focused on habitat preservation and enhancement.

Specifically with Fisheries and Oceans Canada (DFO), the City has a Memorandum of Understanding that habitat credits will always be positive. However, beyond the regulatory requirements, there should be a clear goal for habitat protection and creation within the watershed.

3.2.3.1 Watercourse Erosion

Situation: Most of the creeks show signs of heavy erosion in the upland area. Generally the erosion is not endangering public or private infrastructure, but it is causing damage to the environmental value of the creeks and contributing to sediment problems downstream.

Question: *For "non-hazardous erosion", how should resources be expended to reduce environmental damage? The infrastructure options for reducing erosion are to construct bypass pipes and upstream storage. The land-use options for reducing erosion are to reduce effective impervious area and capture more rainwater where it falls.*

Recommended Goal: Reduction of erosive impacts to the existing natural channel systems through the implementation of specific infrastructure projects and development design requirements.

3.2.3.2 Lowland Habitat

Situation: Because of the creek/valley systems in the upland area there are good habitat areas in that part of the study area. In the lowland area the ditches provide most of the habitat corridors at varying levels of habitat value (both aquatic and terrestrial). There exists potential to improve the wildlife connectivity through the lowlands.

Question: *Should creek/ditch setbacks be increased or enhanced? Should options that require additional land purchase be considered?*

Recommended Goal: Protection and enhancement of existing habitat areas within the lowlands.

3.2.4 Define Water Quality Goals

The study area offers plenty of scope to improve water quality from stormwater runoff and point-source pollution.

3.2.4.1 Water Quality

Situation: The water quality data indicated some areas of concern, likely from a combination of point-source and non-point source pollutants. The City can influence water quality through a number of means, such as development policies, BMP requirements and operational procedures.

Question: *What types of pollutants should be addressed by the ISMP? BMPs to address street runoff should be included, and, given the nature of the existing South Westminster land-use, a program to identify and stop point-source pollutants may be appropriate.*

Recommended Goal: Improved water quality within the watershed through the use of BMPs and development guidelines.

3.3 Watershed Vision

This Vision statement was developed by reviewing the existing conditions in the watershed and linking to specific objectives with the City's overarching planning documents – the Sustainability Charter and OCP, as well as the NCP.

South Westminster ISMP Vision:
To provide distinct and efficient stormwater management systems for the upland and lowland areas that accommodate future development growth, protect the remaining natural areas, and provide opportunities to enhance the overall watershed.

The watershed Vision will require goals to support it, and our recommendations are below:

South Westminster ISMP Goals:
1. Improve lowland drainage system level of service in order to reduce flood and drainage impacts, and account for sea level rise.
2. Provide stormwater management requirements for new development and re-development projects.
3. Reduce erosion and improve or increase habitat, including riparian and wildlife corridors.
4. Improve water quality of stormwater runoff.

The Vision and Goals outline our recommendations for the watershed. **Section 4 – Implementation** describes implementation in detail, and is structured around the following three channels, through which the City is able to influence stormwater management:

- As a regulator and approval authority;
- As a land owner and infrastructure manager; and
- As an educator and through the promotion of ideas.

The ISMP must both work within the context of current implementation mechanisms and recommend changes where appropriate, in order to be effective. For example, implementation items related to the City's role as a regulator should be linked with current regulatory tools. Where current tools are insufficient, to meet the goals, recommendations on potential changes to the tools should be made.

4. Implementation

Building upon the key watershed objectives discussed in **Section 1 – Introduction** and overall watershed vision presented in **Section 3 – Vision** of this document, we identify specific components of our proposed ISMP implementation plan that focus on the following overarching themes consistent with the proposed goals within the watershed:

Theme	Goal
Lowland – Determine Operational Criteria for Flooding	Improve lowland drainage system level of service in order to reduce flood and drainage impacts, and account for sea level rise.
Development – Determine Responsibilities for Developers	Provide stormwater management requirements for new development and re-development projects.
Habitat – Determine Current Commitments and Goals	Reduce erosion and improve or increase habitat, including riparian and wildlife corridors.
Water Quality – Define Goals	Improve water quality of stormwater runoff.

The implementation plan will identify and recommend potential projects and actions that the City of Surrey (City) can undertake. These recommendations will be structured around the following three channels, through which the City is able to influence stormwater management:

1. ***Regulator and Approval Authority* –** The City has the power to influence the activities of developers and private land owners through the Municipal Act which allows the City to control land form. Typically this influence can be applied at time of application for land use changes or building changes. This role is fundamental in the application of integrated stormwater management principles because managing water where it falls is essential; therefore, controlling land form plays a large role in watershed management.
2. ***Land Owner and Infrastructure Manager* –** The City owns significant portions of land within the catchment, making the City the single, most influential and visible land owner in the catchment. This is a huge opportunity for the City to provide good examples of how managing stormwater is an important City priority.
3. ***Educator and through the Promotion of Ideas* –** The City has made a commitment to make the principles of social, environmental and economic sustainability the foundation of all major decisions. As part of this commitment, the City should promote the principles of integrated stormwater management through education and awareness programs, and by practices that highlight how human activities are linked to stream health.

The final part of this **Section 4 – Implementation** provides a summary of all the recommendations together with cost estimates and the key players to be involved in their implementation. Recommendations are prioritized based on a proposed prioritization grouping from high-priority items addressing risk to public safety to those addressing aesthetic concerns.

4.1 Flood Control Criteria

Stormwater modeling is an important part of ISMP development and a hydrologic and hydraulic model was built for the South Westminster Study Area using XPSWMM. A total of 3,540 metres of piped and open channels and three pump stations were included in the model of the conveyance system. Peak flows were modeled for the following six storm events:

- 2-Year, 12-Hour Rainfall: Normal Tide Condition and Design River Condition;
- 5-Year, 12-Hour Rainfall: Normal Tide Condition and Design River Condition; and
- 100-Year, 12-Hour Rainfall: Normal Tide Condition and Design River Condition.

Full details of the model and modeling results are described in Section 2 and further details are provided in **Appendix A**.

The Fraser River data shown in ***Figure 2.1*** were considered when determining the appropriate boundary conditions for modeling the operational performance of the existing pump stations and major drainage canals within the watershed. The levels and level variations corresponding to the Storm Surge were selected as the Design River Conditions since selection of freshet conditions would represent the elevated probability of an extreme storm event over the catchment and freshet flows in the river occurring at the same time.

4.2 Identified Drainage Infrastructure Problems

One of the most prominent features of the ISMP study area is the divide between the upland residential areas and the lowland industrial and commercial areas. There are often drainage problems where the steep upland areas drop in elevation towards the flat lowlands. This is a result of runoff transitioning from steep-sloped creeks, ditches and pipes into low-gradient open channels and storm sewers. The change in grade also results in sediment accumulation, which reduces storage and further strains the drainage system.

Based on modelling results, field observations and discussions with City operational and engineering staff, operational deficiencies of the system, known areas of serious flooding, and other problems associated with catchment hydrology and system hydraulics were identified. Problem areas identified included:

- Intersection of 111th Avenue and 128th Street experienced widespread flooding in January 2014;
- Scott Road, between Old Yale Road and Tannery Road experienced flooding at two locations in January 2014;
- Repeated flooding has been reported at the intersection of 103A Avenue and 121 Street; and

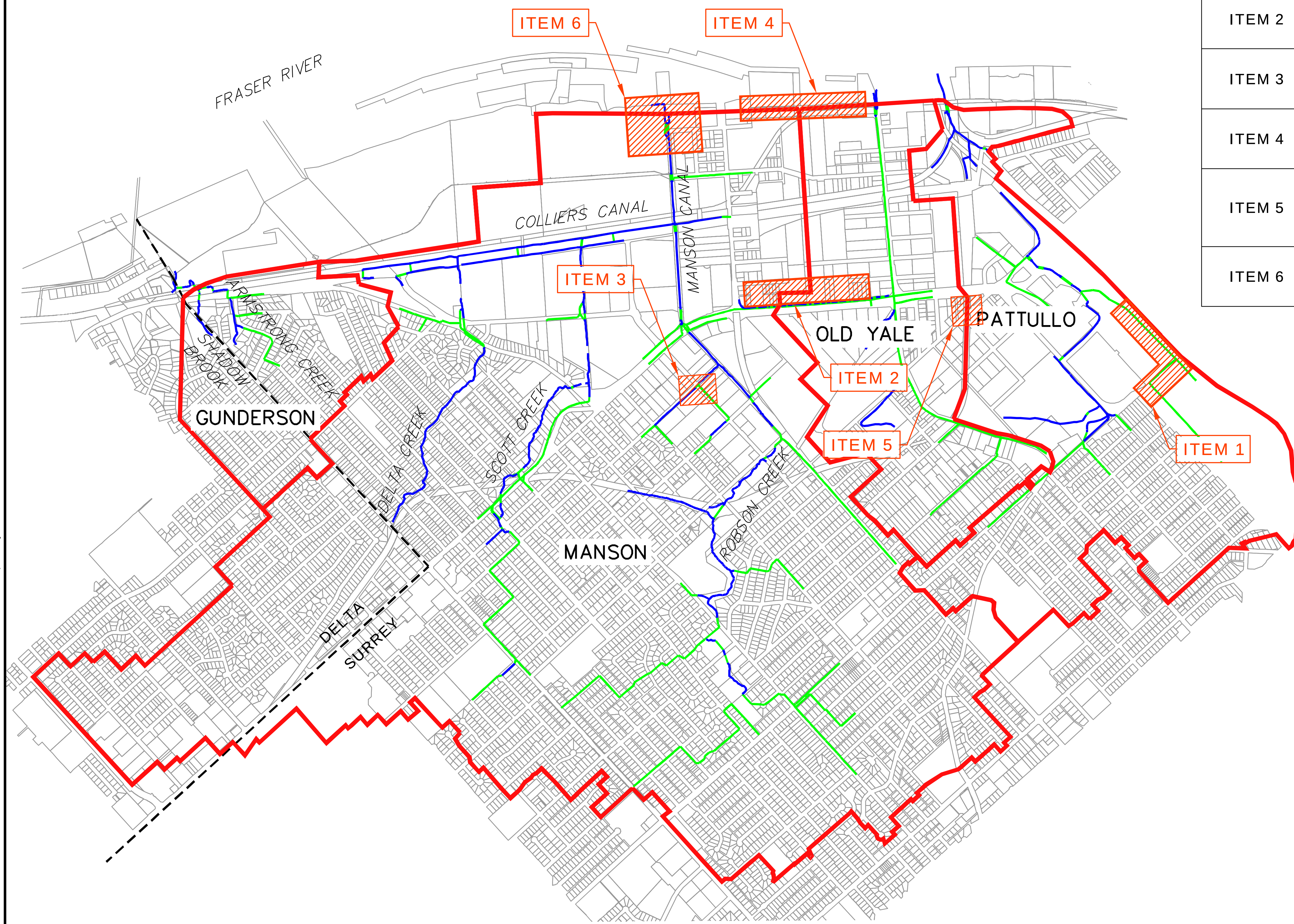
- Drainage problems have been reported adjacent to rail tracks, near the intersection of 124 Street and 109 Avenue.

Figure 4.1 provides the location and description of six infrastructure improvements proposed as part of this ISMP.

FIGURE 4.1

DRAINAGE INFRASTRUCTURE IMPROVEMENTS

ITEM 1	REPLACE 900mm AND 1050 DIAMETER STORM SEWERS ALONG KING GEORGE BLVD WITH A 1200mm PIPE
ITEM 2	INCREASE STORAGE AND IMPROVE DRAINAGE CONVEYANCE ALONG SCOTT ROAD BETWEEN TANNERY AND OLD YALE
ITEM 3	IMPROVE HYDRAULIC EFFICIENCY AT THE INTERSECTION OF 121ST STREET AND 103A AVENUE
ITEM 4	INVESTIGATE FEASIBILITY OF A CONDUIT BETWEEN MANSON AND OLD YALE PUMP STATIONS
ITEM 5	INVESTIGATE IDENTIFIED LOCATIONS OF LOCALIZED FLOODING, SUCH AS NEAR THE INTERSECTION OF 124TH STREET AND 109TH AVENUE
ITEM 6	ESTABLISH FUTURE DESIGN CRITERIA FOR THE SOUTH WESTMINSTER PUMP STATIONS



LEGEND

- MAJOR CATCHMENT BOUNDARIES
- OPEN CHANNEL
- MAJOR STORM SEWER
- DELTA/SURREY BORDER
- DRAINAGE IMPROVEMENT LOCATION

CITY OF SURREY the future lives here. PARSONS

EB 3779

4.2.1 Drainage Infrastructure Improvements

Following identification of drainage issues, modelling of the system was performed to confirm and size the improvements necessary to eliminate the deficiencies and to improve the levels of service provided by the existing drainage infrastructure. Improvements to the identified problems were proposed which were based on the modelled catchment resulted in a minor drainage system that was capable of conveying a 5-Year, 12-Hour Storm under Design River Conditions without causing flooding due to lack of pipe or conveyance channel capacities.

Item 1 – Replace 900mm and 1050mm Storm Pipe along King George Blvd with a 1200mm pipe

The intersection of 111 Avenue and 128 Street was flooded on the morning of January 11, 2014. The flooding was the result of a 1 in 6 year return period rainfall. **Photo 1** shows the extent of flooding at the intersection of 111 Avenue and 128 Street during the morning of January 11.

111 Avenue Looking East, at 128 Street (Jan 2014 Storm)

At the intersection of 111 Avenue and 128 Streets, drainage flows north along 128 Street to King George Boulevard and then west in a 900mm diameter pipe towards the Pattullo Pump Station. Modelling showed that the storm sewer along King George Boulevard was over-capacity during 2 year and 5 year return period rainfall events. The flooding event and modelling results confirm that the 900mm and 1050mm diameter storm sewers along the South side of King George Boulevard are undersized. Modelling during this phase indicates these pipes need to be repalced with 1200mm pipes.

Following the flooding, a detailed review of the Pattullo Pump Station settings was completed. The results of this assessment are presented in a technical memorandum included as **Appendix C** to this document.

Figure 4.2 shows the drainage route and infrastructure along the south side of King George Blvd.

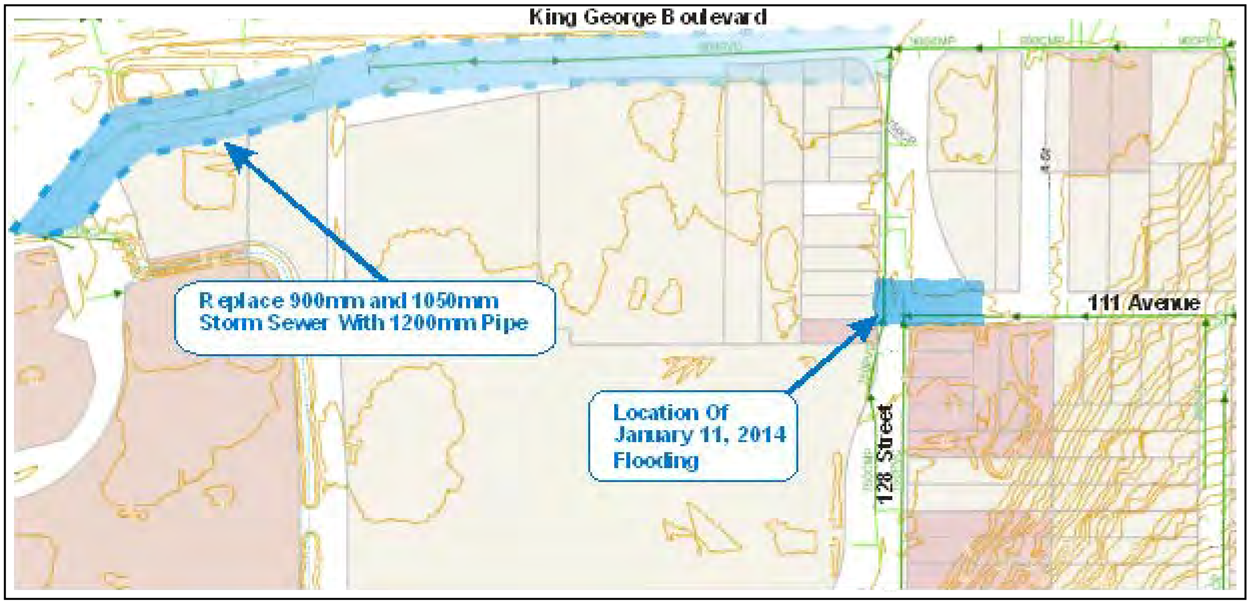


Figure 4.2 – Infrastructure along South Side of King George Blvd

Recommendation – Item 1: Replace 900mm and 1050mm storm sewer along King George Blvd with a 1200mm culvert. Works should be based on a detailed evaluation of drainage infrastructure at the intersection of 128th Street and 111th Avenue.

City's Role: Infrastructure Manager during infrastructure design.

Item 2 –Scott Road Drainage between Tannery Road and Old Yale Road

Flooding has been reported along the west side of Scott Road, between Tannery Road and Old Yale Road. The area in question is partly in the Old Yale Catchment and partly in the Manson Catchment. Based on modelling, photos of the flooding, and discussions with City staff, flooding along Scott Road on January 11th was due to:

- Manson and Old Yale Pump Stations were unable to drain their catchments fast enough during this rainfall event;
- The water levels in the downstream trunk canals and sewers rose and the storm sewers along Scott Road became surcharged; and
- The low lying properties are at a lower elevation than Scott Road and were unable to drain by overland flow.

As properties develop and raise their building/lots to the Flood Construction Level, these problems will be less frequent and instances of flooding will be reduced. In the interim, the following solutions are proposed:

- As part of ongoing road and other infrastructure improvements in the area, evaluate ways to increase drainage system storage along Scott Road, in particular near properties prone to flooding; and

- Add and maintain drainage connections to the stormwater system. Additional catch basins will improve drainage conveyance for properties along Scott Road.

Appendix D contains a Technical Memorandum detailing the analysis and results of this review.

Recommendation – Item 2: Improve drainage conveyance along Scott Road as part of the multi-use path installation. City's Role: Infrastructure Manager during infrastructure design.

Item 3 – Improve Hydraulic Efficiency of Drainage at the Intersection of 103A Avenue and 121st St

Repeated drainage problems have been reported at the intersection of 103A Avenue and 121 Street.

Drainage from 121 street is conveyed in two roadside ditches that inlet to a 600mm culvert running along 103A Avenue. This west-east culvert then turns north and crosses 103A Avenue, increasing to a 1350mm diameter storm pipe that runs parallel to a ditch before an outlet to Manson Canal. The east roadside ditch of 121 Street also has a 500mm overflow pipe that crosses 103A Avenue directly into the ditch. ***Figure 4.3*** shows the storm pipe configuration.

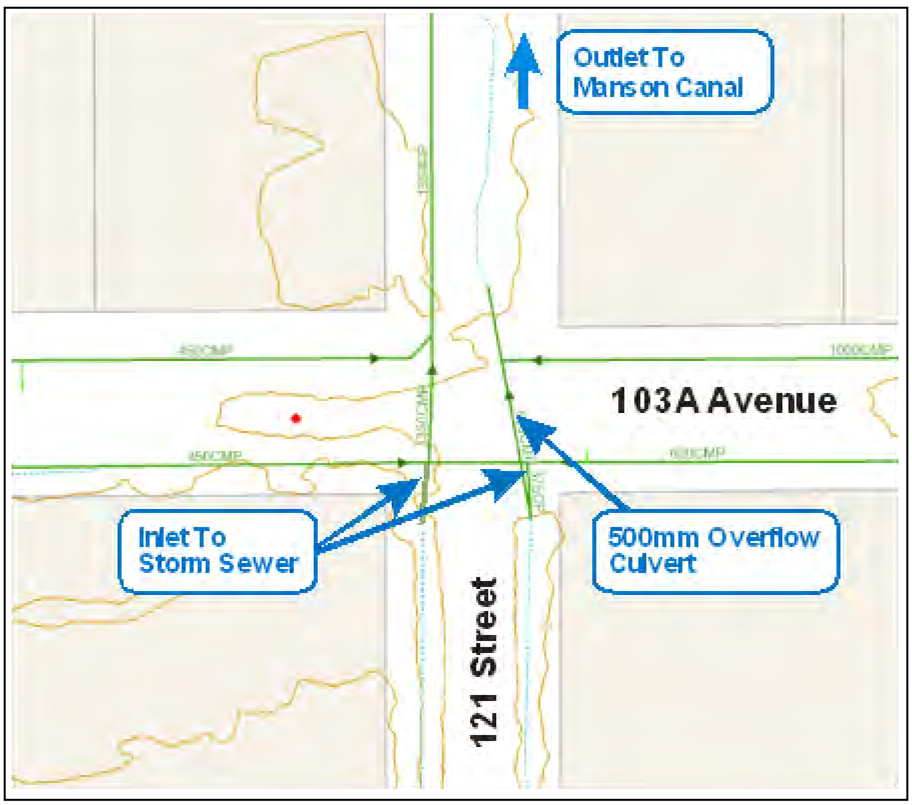


Figure 4.3 - Conveyance Piping at Intersection of 121 St and 103A Avenue

121 Street drops from 55 metres elevation to roughly 2 metres elevation upstream from 103A Avenue. The steep hillside transitioning to flat roadside ditches results in sediment deposits accumulating at the intersection. The photo on the left side below shows the west side ditch with silt filling more than half the

storm sewer connection. The photo to the right shows the east side ditch with a 500mm overflow culvert visible, but the 375mm storm sewer connection is not visible because sediment has accumulated and blocked its view.

121st St at 103A Ave -West Side Ditch Inlet

121st St at 103A Ave -East Side Ditch Inlet

While the modelling has indicated that the 1350mm pipe is surcharged during certain storm and high tide conditions, the overall conveyance system at the intersection appears inefficient, including inlets and piping connections. This, and the build-up of sedimentation close to and at the inlets shown in the photos are significant contributors to local flooding in this area.

Reducing flooding at the intersection first requires a condition assessment of underground drainage infrastructure at the intersection and removal of existing sediment.

Recommendation – Item 3: Improve hydraulic efficiency of drainage configuration at the intersection of 121st Street and 103A Avenue

City's Role: Infrastructure Manager during infrastructure design.

Item 4 – Investigate the Feasibility and Value of a Conduit between Manson and Old Yale Pump Stations

Currently the Manson and Old-Yale Pump Station Catchments are not interconnected. Constructing a conduit that connects the two pump stations would provide the following benefits:

- Adding Redundancy to the System. Should one or more pumps at Old Yale or Manson require shut down for emergencies or maintenance, the other station could act as a backup. In contrast to the Old Yale – Pattullo Pump Station Conduit, Manson and Old Yale Pump Stations have similar On/Off pump setting elevations;
- Increasing Storage in the System. The connection would be open channel where possible, to provide stormwater storage during major rainfall events; and

- Reducing flooding during rainfall events greater than the 1 in 5 year event by enabling the two stations to act together in dewatering the combined area served by the stations. The actual impact on system flooding is discussed below.

Parsons performed modeling to compare operation of the pump stations with and without the connection for 2-year, 5-year and 100-year return period events. The conduit assumed was a combination of open channel and enclosed 2000 mm pipe. As the On/Off settings of Manson and Old Yale pump stations are at a similar elevation, an interconnection allows flows in both directions between the two catchments. This is in contrast to the conduit between Old Yale and Pattullo Pump Stations, which only flows from Pattullo to Old Yale.

Table 4.2.1 shows the difference in peak water levels during design rainfall events due to the interconnection.

Table 4.2.1: Rainfall Events Peak Water Levels

Rainfall Events	Manson Catchment	Old Yale Catchment
2-Year Return Period, 12 hour	Peak water level **54cm** lower at Manson PS Peak water level **12cm** lower upstream at 122nd Street	Peak water level **3cm** higher at Old Yale PS No difference upstream
5-Year Return Period, 12 hour	Peak water level **65cm** lower at Manson PS Peak water level **33cm** lower upstream at 122nd Street	Peak water level **5cm** higher at Old Yale PS No difference upstream
100-Year Return Period, 12 hour	Peak water level **46cm** lower at Manson PS Peak water level **32cm** lower upstream at 122nd Street	Peak water level **55cm** higher at Old Yale PS Peak water level **18cm** higher upstream at Scott Road.

Based on the above preliminary evaluation, an uncontrolled connection would reduce peak water levels at the Manson station and result in a slight increase in the peak water levels at Old Yale for the two higher probability events noted in the table. It should be noted that lower water levels along Manson Canal are due in part from additional storage in the system near to the Manson Pump Station.

For the 1 in 100 event, modeling shows a significant increase in the peak level at the Old Yale station. The negative impact of this should be taken into account during any feasibility evaluation.

Recommendation – Item 4: Investigate in more detail the feasibility and value of a connection between Manson and Old Yale Pump Stations. Investigation should include impacts for extreme rainfall events.

City's Role: Infrastructure Manager during Feasibility Study.

Item 5 – Investigate and resolve locations of recurring localized flooding, for example near the intersection of 124 Street and 109 Avenue

Low-lying areas of South Westminster without natural or constructed overland flow routes can experience recurring drainage problems and localized flooding, even for very high frequency storm events.

As an example, flooding has been reported along the railway tracks near to the intersection of 124 Street and 109 Avenue. A review of COSMOS indicates that there are no record drawings available at this location. The photo below and ***Figure 4.4*** show the open drainage that exists along the railway tracks at this location.

Low area along railway at 124 Avenue-109 Street Intersection

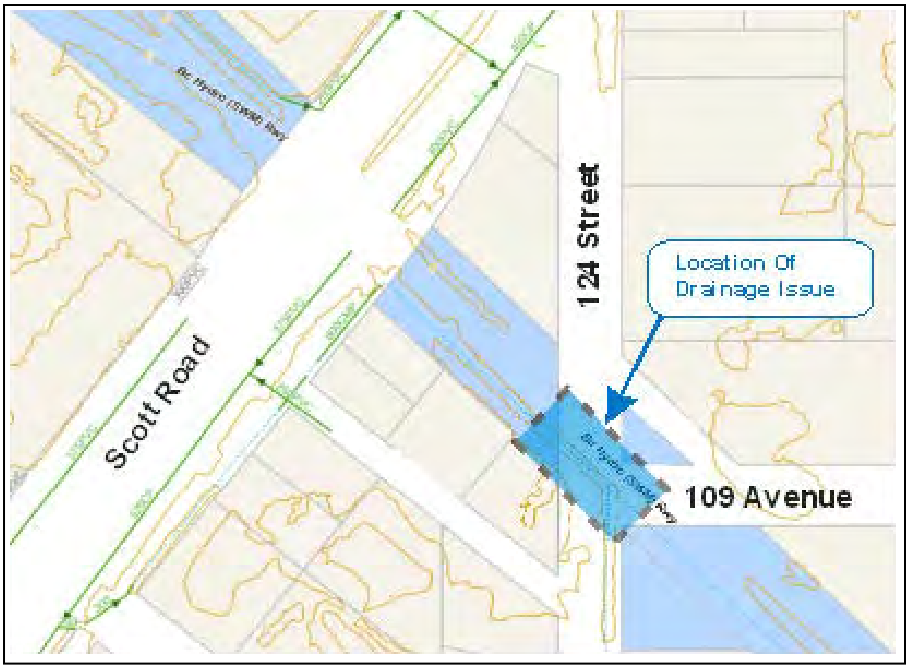


Figure 4.4 – Location of Localized Flooding along Railway at 124 Ave-109 St Intersection

Based on our site visits and discussions with operations staff, such instances of localized flooding can be frequent in older areas where drainage infrastructure is not designed on the basis of updated standards. They are typically identified by residents and maintenance staff during and after storms.

Recommendation – Item 5: Identify and investigate locations of localized flooding, such as near the intersection of 124 Street and 109 Avenue, that can be brought up to standard. City's Role: Infrastructure Manager during infrastructure design.

Item 6 – Establish pump station capacity design criteria to account for anticipated impacts of climate change

Required capacities, performance and operating costs of Fraser River pump stations are sensitive to water levels in the river. When water levels in the Fraser River are above the elevation of the Manson, Old Yale and Pattullo flood boxes, their catchment areas are drained exclusively by pumps. Under normal tidal conditions, river levels are not above the floodbox for more than about six hours before the tide retreats and flood boxes are able to drain the system. However, during freshet or storm-surge conditions the high river levels can persist for longer increasing pump run time and the risk of upstream flooding.

To quantify the impact of increased pump capacity, we modelled the existing Manson catchment with an additional **3.9 m^3/sec** capacity pump at the Manson Pump Station. The pump capacity was chosen to match the existing Manson Pump No. 5, Flygt Model 7140, set with the same On/Off settings. The model was run with 12 hour, 2-year, 5-year and 100-year rainfall events under storm surge conditions to mimic a time that the system is dependent on pump capacity. The additional pump lowered peak water levels at the Manson Pump Station forebay by **63cm** during a 2-year event, **47cm** during a 5-year event and **31cm** during a 100-year event.

Increasing pump capacity at any of the three pump stations would be expensive and should not be undertaken without a detailed analysis of the future design criteria for South Westminster that account for increased rainfall, sea level rise, and land-use conditions.

Recommendation – Item 6: Establish future design criteria for the three South Westminster pump stations that account for future development and impact of climate change. City's Role: Infrastructure Manager during infrastructure design.

4.2.2 Impacts of Climate Change on Drainage System

Rainfall and stormwater are essentially a climatic phenomenon and it is important to consider climate change in long-term infrastructure planning. In 2013, the City of Surrey released the Climate Adaptation Strategy that outlined the City's existing and future strategies to plan for a changing climate. These strategies included goals and policies that can help shape stormwater infrastructure in both the lowlands and uplands of South Westminster, including:

- Incorporate climate change into the City's Integrated Stormwater Management Plans (ISMPs) and other efforts to integrate land use planning and stormwater management; and
- Review and revise regulatory and design standards to account for and minimize the impacts of climate change.

The policies are supported by a January 2014 APEGBC Position Paper that identified the need for engineers to carry out work with appreciation of the changing climate.

The impact climate change will have on the design and stability of the City's dyking infrastructure is outside the scope of this ISMP as its design is for protection from the Fraser River. Climate change will mainly affect South Westminster's drainage systems due to major precipitation events becoming more extreme and more frequent, and the increase in river levels anticipated from sea level rise.

4.2.2.1 Precipitation

Extreme precipitation events are the primary driver and design basis for stormwater planning and flood control. Recent anecdotal evidence, such of Calgary's flooding in 2013, indicate rainfall events are becoming more "extreme", and current intensity-duration-frequency calculations may be underestimates that don't account for the impact of climate change.

Using the 1961-1990 timeframe as a historical baseline, the plan2adapt tool developed by the Pacific Climate Impacts Consortium shows median increases in winter precipitation for Metro Vancouver. In the 2020s, the median scenario projected a 3% precipitation increase, the 2050s median scenario projected a 6% precipitation increase and the 2080s median scenario projected a 9% precipitation increase.

Additionally, peak precipitation events are expected to be more frequent and more intense than current design rainfall events. Summer rainfall is expected to decrease which would lower creek flows and groundwater tables and possibly harm aquatic life.

Stormwater infrastructure is designed based on precipitation data typically from the past half century. In South Westminster, precipitation data from Surrey Kwantlen Park rainfall gauge is used to design drainage infrastructure. The short duration rainfall Intensity Duration Frequency (IDF) curve data at Kwantlen Park are provided in the City of Surrey's Design Criteria Manual is for the period 1962 to 1996. Surrey's Climate Adaptation Strategy stated that "*historic analysis showed that Surrey is experiencing increases in both the frequency and intensity of moderate and heavy precipitation events",* while cautioning "*More detailed modelling and analysis is necessary to complement the climate models and develop Surrey-specific design standards"*.

Recommendation – I Item 7: Review the most recent data and reports on extreme rainfall events, revise the City's design IDF curves and incorporate these revisions into the Design Criteria Manual, thereby establishing future design criteria for planning and designing infrastructure to account for the impact of climate change.

City's Role: Infrastructure Manager during infrastructure design.

4.2.2.2 Sea Level Rise

Currently, floodboxes drain the system during low tides and pump stations and stormwater storage drain the system and prevent flooding during high tides. A rise in sea levels will impact the outflow from South Westminster by reducing pump outputs (if capacities are not increased) and decreasing the periods of time the catchment is drained by its floodboxes.

Accurately estimating the future water levels of the Fraser River's requires a detailed study of the sea levels, tidal fluctuations, and wave run-up. Additionally, predicted future ground subsidence also needs consideration. In January 2011, The Ministry of Environment released a *Sea Dike Guidelines* report that recommended planning for a 0.5m sea level rise by 2050 and 1.0m in 2100. **Figure 4.5** displays the projected rise.

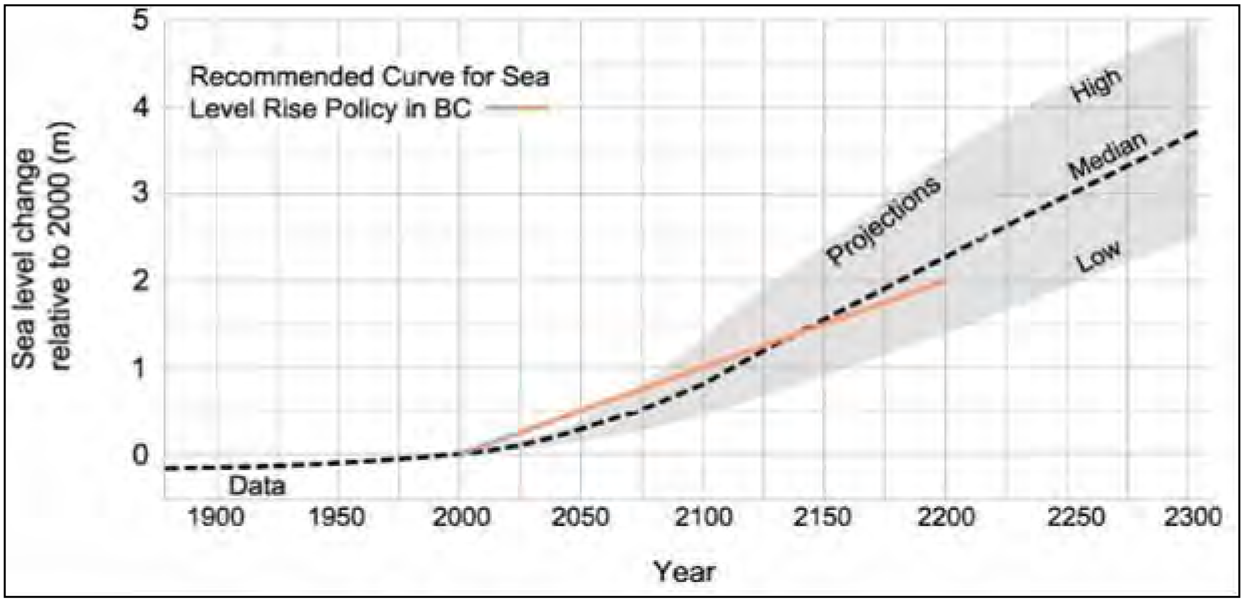


Figure 4.5 - Projected Sea Level Rise (Source: MoE Sea Dike Guidelines)

In the absence of a detailed study predicting sea level rise at South Westminster's location along the Fraser River, two future scenarios were modeled: a 0.5 metre and 1.0 metre rise in the Fraser River water levels at Manson Canal, under normal tidal conditions show in **Figure 2.11**. For the 2-year return period 12-hr storm, 0.5m sea level rise resulted in a 0.35m water level increase at Manson Pump Station. A 1.0m sea level rise resulted in a 0.53m water level increase. Increased flooding levels resulting from sea level rise depend on assumed tidal conditions and return period rainfall event used. The results above provide an estimate of the magnitude of flooding increase that can be expected by sea level rise.

Recommendation – Item 8: Develop an updated design boundary condition for riverside drainage infrastructure taking into account the expected sea level rise. This is most likely to be a province-led update of the NHC Fraser River model.

City's Role: Stakeholder

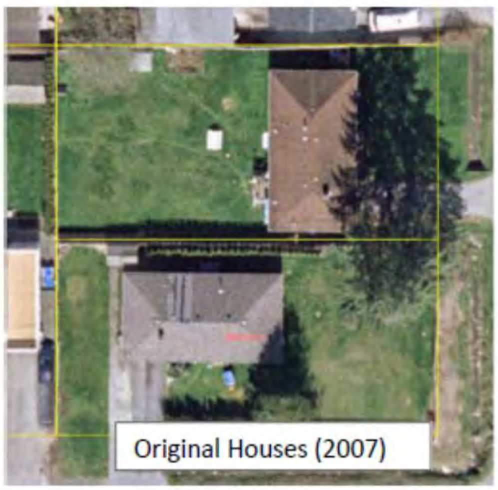
4.3 Development – Responsibilities of Developers

South Westminster is predominantly urban residential in the uplands that accounts for approximately 57% of the land area, and the remaining lands are heavily industrial/commercial in the lowlands.

4.3.1 Uplands Development

The upland area of South Westminster is predominately residential with a wide range of lot development. In the existing residential lots created prior to 1960, the original house typically accounts for approximately 20%-30% of lot coverage. When a new house is developed on the same lot, the new house often accounts for over 50% of the lot. The overall lot imperviousness also increases due to additional asphalt and concrete landscaping more common in lot re-developments.

It is important to begin to develop a framework for dealing with these developments from a stormwater management perspective. Implementation of on-lot Best Management Practices (BMPs) could reduce the adverse impacts to the overall system over time. ***Figure 4.6*** shows two lots in 2007 and the same two lots in 2013 after redevelopment with larger homes and wider driveways. The areas for each scenario were measured and the figure shows the differences between these two development conditions.



Previous Development (2007)

Surface	Area (m^2)
Impervious (asphalt)	120
Impervious (roof)	315
Pervious (grassed)	1165

Percent Impervious **27%**

Current Development (2013)

Surface	Area (m^2)
Impervious (asphalt)	480
Impervious (roof)	720
Pervious (grassed)	400

Percent Impervious **75%**

Figure 4.6 Comparison of Residential Lot Impervious Areas

The values for this example were used to create a single-lot model within the www.waterbalance.ca model. The model was used to compare a number of scenarios ***(Table 4.2.2)***.

Table 4.2.2: Single Lot Redevelopment Water Balance Scenarios

#	Name	Characteristics
1	Natural	This scenario represents the lot prior to any urbanization. The land was assumed to be free of impervious area. The scenario is an important point for comparison as it represents the ideal runoff pattern.
2	Previous Development (2007)	The houses that existed in 2007 prior to redevelopment as shown in the image above.
3	Current Development (2013)	The current larger house as shown in Figure 4.6 above, assuming that no BMPs were applied.
4	300 mm topsoil	This scenario models the existing larger house with absorbent topsoil applied to a depth of 300 mm.
5	Pervious Pavement	This scenario models the existing larger house with all paved surfaces being pervious pavement.
6	Rain Garden	This scenario models the existing larger house with 50% of the roof area being directed to a large rain garden.
7	All BMPs	Application of all of the three above BMPs applied to the existing larger house.

Figure 4.7 below shows the water balance volume for each scenario.

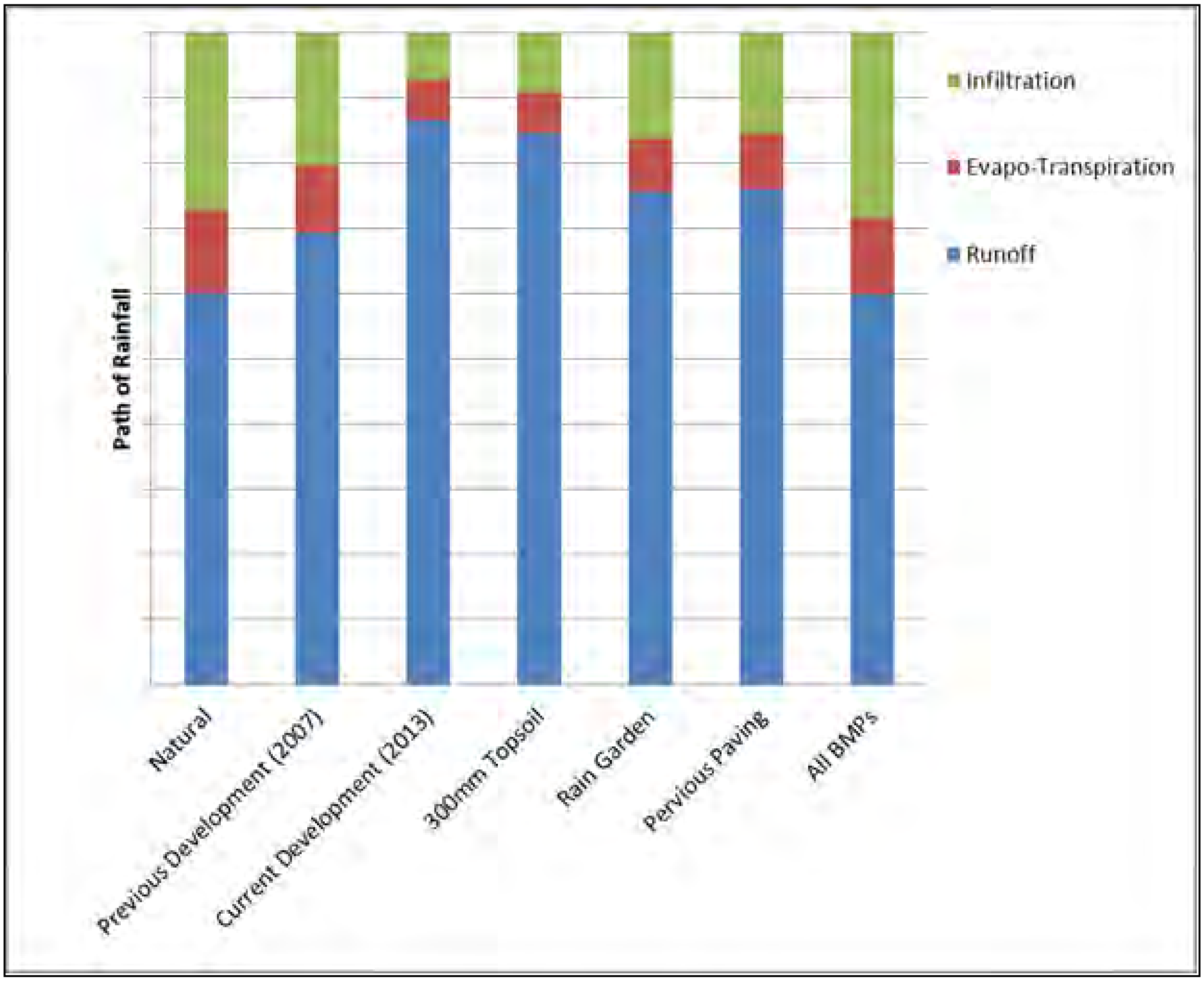


Figure 4.7 - Uplands Residential Development - Water Balance Scenario Results

The first scenario on the left defines the runoff regime prior to development (i.e. if the lot did not have any pavement or house on it) and, in integrated stormwater management, is considered an optimal runoff scenario for protection of downstream watercourses because it is the natural condition. For this condition approximately 60% of the water falling on the site runs off. This is an optimal target that would be reached in an ideal scenario.

The second scenario is that of the small houses before redevelopment. During this scenario 69% of the water runs off. Although this target will not restore natural flow conditions, future development scenarios that meet it would at least not be making the situation worse.

The third scenario, the new larger home, has 87% of the water running off the site. This is what would happen in a normal scenario without BMPs.

The remaining scenarios show how the application of BMPs can reduce the runoff volume and meet the optimal and 'hold the line' target. The results show that as BMPs are applied, they can have a positive impact. When all BMPs are applied the runoff meets the optimal target of a pre-urban development condition.

The implementation of on-lot BMPs at the single lot level is challenging for a number of reasons:

- Single lot redevelopment only goes through a building permit process, no planning process is required;
- To require those involved in single lot residential re-development to hire a professional to design a stormwater BMP system(s) would generate more cost to home owners and developers;
- The success of BMPs in reducing stormwater runoff is highly dependent on the quality of construction. The development world is not widely implementing these measures, particularly at the single lot level; and
- The success of BMPs is also tied to regular and correct maintenance of those BMPs which can be difficult to achieve if individual home owners are not aware of how to keep the BMPs operating efficiently.

The implementation of residential lot BMPs will need to be a long-term goal achieved with public participation, and should not be confined to the area of this ISMP, but rather be a City-wide program.

Recommendation – Item 9: Prepare for densification within the upper South Westminster catchment by requiring development to mitigate the impacts of stormwater runoff by meeting performance requirements.

1. Target of no net increase in volume of runoff from conditions prevailing before re-development. Require developers to demonstrate how this will be achieved.
2. Require developers to demonstrate that they have provided water quality treatment by removing 80% of total suspended solids from stormwater, using such methods as' equivalent grass swale area' to quantify.

This is in addition to stormwater management requirements outlined in the existing City of Surrey guidelines.

City's Role: City has a general role as **Educator** and as **Regulator** for specific developments.

Land developers involved in densification will have the resources and expertise to bring these requirements to current state-of-practice. This could be achieved using a tool such as www.waterbalance.ca or by using other engineering tools.

Recommendation – Item 10: Implementation of a long-term program that will move towards requiring single residential lots to implement BMPs on site at time of redevelopment. This long term program should be developed with involvement of City of Surrey staff from all affected departments.

City's Role: Educator and **Regulator**

The first stage of implementation is to form a working committee to develop an overall lot-level BMP program. This committee should consist of City of Surrey staff but could be facilitated by an outside expert. This committee would develop the policy and next steps for implementing BMPs at the site level. Stages would include:

- The first stage would be education of City staff and interested public on implementing BMPs. This would include providing written and staff resources to the public and contractors on how to implement BMPs. This could begin with easy-to-implement BMPs like absorbent topsoil and soak-away pits for roof drainage (where appropriate);
- Then a voluntary / pilot program on implementing BMPs would need to be created. At this time the City would also want to promote demonstration projects so that home owners and contractors could see the benefits of BMPs in action; and
- And finally, once the institutional framework and public knowledge are at an acceptable level some form of mandatory BMPs program can begin. The City would need to develop prescriptive requirements to be implemented through the building permit process.

4.3.2 Lowlands Development

In addition to residential development, the lowlands of South Westminster have been developing into business parks and light-industrial land use. The City of Surrey is actively promoting the redevelopment of South Westminster and, driven by the recently constructed South Fraser Perimeter Road (SFPR) and new businesses coming into the area, the low-lying areas of South Westminster will continue development in the near future. These land use changes will impact the stormwater regime and potentially increase imperviousness. The 2003 *Neighbourhood Concept Plan for South Westminster (NCP)* outlines potential land-use changes for the low-lying area of South Westminster. Among other recommendations, these changes include:

- Conversion of existing industrial land use to a combination of Light Industrial Use and Business Parks in areas south of Manson Canal;
- Higher density multiple residential uses and mixed-use retail/residential properties in a Transit-Oriented Urban Village within the vicinity of Scott Road Skytrain Station;
- Transit oriented low density commercial area along Old Yale Road and Scott Road; and
- Future parks and better connections between existing parkland.

Some of these changes, including adding Business Parks, are already being implemented while others will happen over time. Further implementation of the NCP will impact stormwater in South Westminster. The extent of this impact will be determined by the extent and type of development and onsite detention/infiltration measures that are implemented.

Similar to the uplands residential properties already described, a representative lot was selected and aerial photos pre-development and post-development shown below in ***Figure 4.8***. The areas for each scenario were measured.

Previous Development (2004)

Surface	Area (m²)
Impervious (asphalt)	6650
Pervious (grassed)	16850

Percent Impervious 28%

Current Development (2013)

Surface	Area (m²)
Impervious (asphalt)	14110
Impervious (roof)	6190
Pervious (grassed)	3200

Percent Impervious 86%

Figure 4.8 Comparison of Industrial Lot Impervious Areas

The values for this example were used to create a single-lot model within the www.waterbalance.ca model. The scenarios modelled are the same of those listed above in ***Table 4.2.1***.

Figure 4.9 below shows the water balance volume for each scenario.

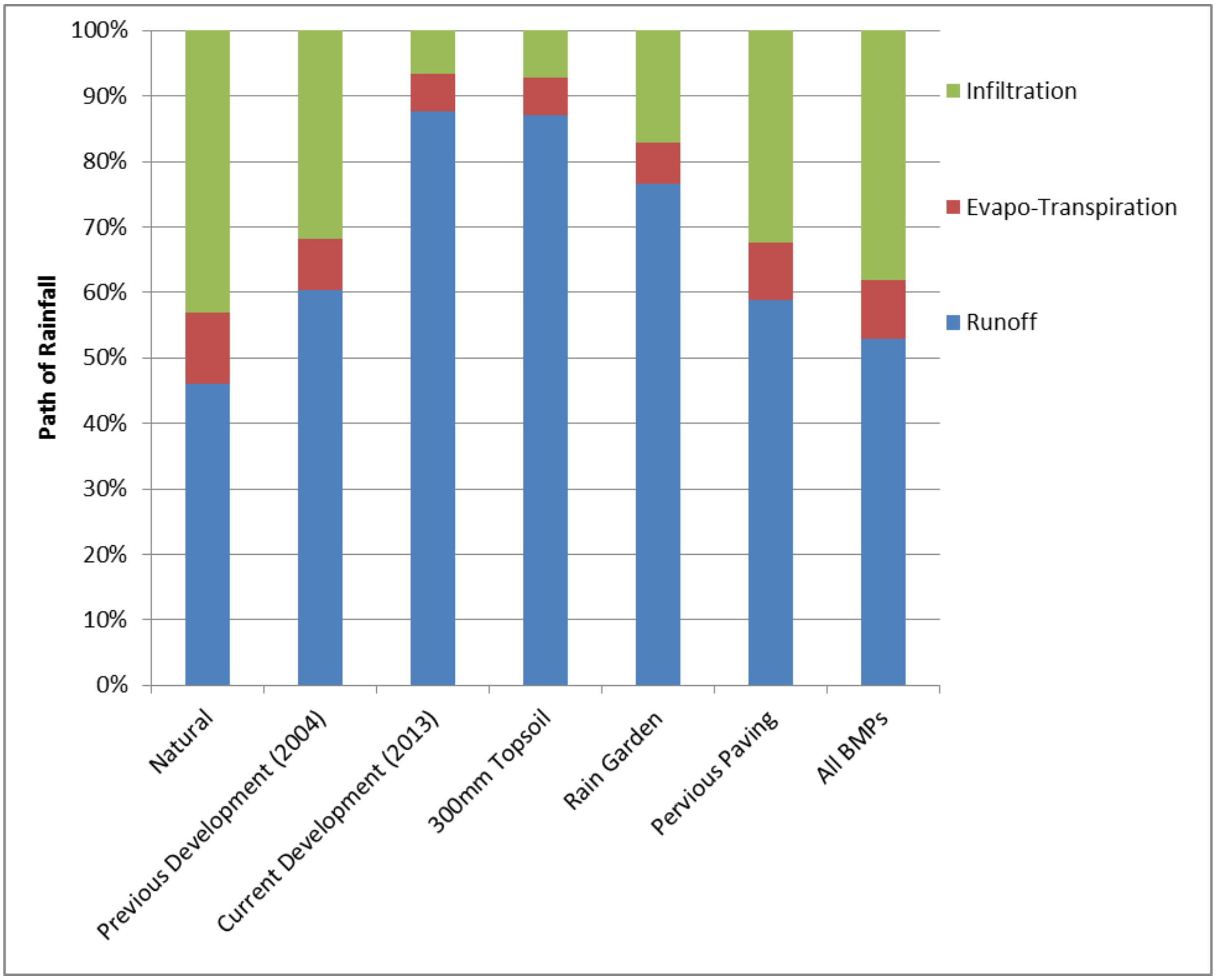


Figure 4.9 - Lowlands Development - Water Balance Scenario Results

The **Section 4.1** discussion of BMP application in the uplands of South Westminster generally applies to the lowland area; however there are key differences to be noted:

- Natural run-off in the lowlands is lower than the uplands. This is due to a flatter topography;
- Application of BMPs in the lowlands does not fully restore the natural runoff regime. Infiltration in the lowlands is more difficult due to soil conditions. This difficulty is generally mitigated where new developments raise the lot with sand/gravel;
- The industrial/commercial developments in South Westminster have included large areas of asphalt for parking. BMPs that target asphalt will have the biggest impact on run-off; and
- The relatively small areas of grassed, pervious areas reduce the impact of enhanced landscaping (300mm topsoil).

Recommendation – Item 11: Take advantage of the re-development of South Westminster to improve the on-site stormwater infrastructure in the lowlands of South Westminster. Specifically, industrial and business development should mitigate the impacts of stormwater runoff by meeting performance requirements.

1. Target of no net increase in volume of runoff from conditions prevailing before re-development. Require developers to demonstrate how this will be achieved.
2. Require developers to demonstrate that they have provided water quality treatment by removing 80% of total suspended solids from stormwater, using such methods as' equivalent grass swale area' to quantify.

This is in addition to stormwater management requirements outlined in the existing City of Surrey guidelines.

City's Role: City has a general role as Educator; for specific developments, Regulator

4.4 Habitat Improvements

The City's Ecosystem Management Study and Biodiversity Conservation Strategy (January, 2014) are key planning and management documents that provide a framework for the City in identifying key areas of interest and a consistent habitat management direction. Surrey's Green Infrastructure Network is composed of hubs and potential corridors. Hubs are larger areas of contiguous natural landscape that support ecological processes. Potential corridors delineate connections between hubs that are critical to the long-term function of the overall network. Corridors allow for animal movement and seed dispersal between hubs. Corridors often incorporate sites and these inter-connections further complement network success.

This study area is characterized by urban/industrial land uses with predominantly single-family residential areas to the south and on the escarpment, and mixed industrial and commercial uses within the lower floodplain areas near the Fraser River. The area has been largely built-out with negligible undeveloped lands. Features such as remaining streams, forested stands and environmentally sensitive areas have become rare. However, these features where they exist have significant retention value, even where degraded by urban activities.

Barriers to species movement such as road crossings should be minimized in the wildlife corridors. Where roads or other barriers are being constructed or rebuilt, provision for ease of passage of the fish or wildlife species that the corridor serves should be provided.

Where increases to the riparian buffer widths from ravine top of bank along watercourses are implemented, where possible the following should be carried out:

- Remove refuse and restore damaged habitat;
- Erect fences to deter encroachment into protected riparian habitat;
- Deter refuse disposal into streams through public education (e.g. newspaper articles, small displays); and
- Remove invasive species at strategic sites, such as Class A stream banks where invasive plant communities are relatively isolated, and re-vegetate these areas with native tree and shrubs.

The weir at the Robson Creek detention ponds could possibly be augmented with a fishway, while still enabling water level controls between the detention ponds. Further field investigation should be conducted to determine if fish are currently able to navigate into the upper reaches of Scott Creek, and identify opportunities to increase access around the 1-m weir observed during the February 2013 Environmental Assessment.

Recommendation – Item 12: Within existing wildlife corridors remove barriers or allow for improved movement when the area is impacted by new construction or infrastructural renewal. Avoid creation of new barriers to wildlife movement. To improve fish migration and remove existing barriers, review items identified in environmental report and consider a program for implementing improvements. Protect habitat by reducing human impacts such as waste disposal and unrestricted public entry

City's Role: Regulator where new construction requires City approvals; Infrastructure Manager for infrastructure renewal programs; Proponent for minor improvements for fish migration

In cases where potential corridors have been highlighted but no corridor exists, it is difficult to create corridors without property acquisition. In some cases it may be defensible to provide some site densification incentives to developers in exchange for intensive restoration efforts on an impaired corridor. Since densification in the industrial area is likely in the future, it is anticipated that these opportunities will arise.

Recommendation – Item 13: Be aware of the potential for improvement of existing impaired wildlife corridors where identified generally in the Biodiversity Conservation Strategy and more specifically in the Environmental Assessment Report (Appendix B to this report) when redevelopment begins to occur in the area.

City's Role: Regulator

4.5 Water Quality Improvements

Review of the water quality data gathered by the City at the pump stations was carried out as part of this study. Tables were prepared based on the analytical results, indicating where the recorded data were not compliant with the applicable water quality guidelines. Since a large proportion of the land area is designated as "industrial" in the OCP, it is not surprising that some compromise of the water quality of surface waters is being experienced. Additionally, the study area encompasses the lands owned and administered by Port Metro Vancouver which contain an active multi-berth facility, and also is home to many auto salvage operations which have the potential to become major sources of pollution of surface water and groundwater. Conclusions resulting from the review indicated:

- Iron (both total and dissolved), aluminum (dissolved),copper (total), lead (total) and zinc (total) exceed the guidelines in one or more of the samples taken; and
- Total suspended solids (TSS) levels as high as 98 mg/L have been recorded. High concentrations typically increase turbidity which hinder photosynthetic activity and cause damage to fish.

Poor stormwater quality caused by point and non-point sources is dependent on many factors such as land use and the water quality risks associated with each use. The light industrial areas of South Westminster are expected to contribute more and different pollutants than the upland areas. Common to all areas is the presence of roads and highways which continue to be the sources of many pollutants. Of significance to the study area is the recent construction and opening of the South Fraser Perimeter Road, which runs the length of the northern edge of South Westminster.

The redevelopment of the lowlands into light industrial and commercial zones will have a positive impact on water quality in the study area as long as established best management practices are designed into the facilities at lot level. This means that potential discharges from industrial developments are retained and treated before being discharged to City storm sewers or open channel parts of the stormwater conveyance system.

From an environmental viewpoint, retention of open drainage channels would have a positive impact on aquatic productivity and mitigation of water quality impacts by in-stream vegetation biofiltration. Groundwater recharge to the ravines has been severely impacted by development in the uplands so any opportunity to redirect groundwater to ravine streams, through infiltration or protection of springs present along the escarpment slopes, should be considered.

Recommendation – Item 14: In all redevelopments implemented in the lowland area, apply the City's water quality standards regarding stormwater discharges from each and every lot. In all redevelopments across the study area, examine ways to protect and enhance aquatic productivity

City's Role: Regulator

Streets and roads are typically the largest single source of non-point source pollution under the control of the municipality. Additionally, the types of pollution from this source are among the most deleterious to water quality (heavy metals, hydrocarbons, suspended solids containing solvents and lubrication substances). Pavements can also be a significant source of pollutants not directly associated with transportation, such as nutrients and pesticides, due to washing down from landscapes and atmospheric deposition.

All major municipalities have street sweeping/cleaning program. Historically driving forces behind these programs have been:

- ***Aesthetic:*** residents do not like to see trash and grit lying around the streets; and
- ***Cost-effectiveness:*** it is a cheaper way of keeping the material out of the catch basins and stormwater pipes before it reaches open channels, rivers and lakes.

However, little thought has been given until recent times as to how a street sweeping/cleaning program can be effective in creating a cleaner stormwater environment before runoff enters the conveyance systems.

The material that is most likely to cause impairment of water quality is the smaller particles and dust-like substances that can easily be transported by surface runoff. This material is seldom picked up by sweeping; in fact there is evidence in the literature that sweeping loosens this on the surface thereby potentially increasing the quantity eventually transported to the conveyance system. New sweeping/cleaning equipment designs are now available that uses vacuum systems and other improvements to more fully clean the pavement surfaces.

Recommendation – Item 15: Upgrade the street sweeping/cleaning program to include program components that reduce the level of contaminants in pavement runoff that causes impairment of stormwater quality by investigating the availability of suitable modern street cleaning equipment and developing a pilot program for its potential use in the City

City's Role: Infrastructure Manager

4.6 Transportation/Highways

There are many roads and City rights-of-way in South Westminster. This land area, if developed without consideration for stormwater management, will lead to stormwater problems in terms of quality and quantity. Contaminants from vehicles and from activities associated with road and highway construction and maintenance are washed from roads and roadsides as runoff. Consequently many pollutants are delivered to water courses, including pathogens, nutrients, sediment, and heavy metals.

By retaining rainfall from small storms, the implementation of BMPs reduces stormwater discharge volumes, which translates into reduced combined sewer overflows and lower pollutant loads. Additionally, BMPs treat stormwater that is not retained; these BMPs should be as close to source as possible and preferably always within the ROW corridor.

Future road projects within South Westminster, including general infrastructure replacement and rehabilitation projects will create an opportunity to implement good stormwater management practices. The following section will consider various green technologies that could enhance the water quality and quantity regime within the study area.

4.6.1 Green Roads vs. Conventional Roads

Conventional roads usually consist of an impervious surface such as asphalt and concrete that sheds rainfall and associated surface pollutants forcing the water to run off paved surfaces directly into nearby storm drains and then into streams and lakes. However, by implementing green infrastructure technologies such as grassed or vegetated filter strips, grass swales and pervious paving, enhancement of stormwater quality and control quantity can be achieved.

4.6.1.1 Water Quality Enhancement

Quality enhancement options that are relevant for new developments are:

- Grass swales are a vegetated, open-channel designed specifically to filter and attenuate stormwater runoff. There are various different types of swales such as enhanced grass swales, dry swales and wet swales with varying pollutant removal rates; and

- Grassed filter strips are vegetated areas that are intended to treat sheet flow from adjacent impervious areas. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils. Filter strips can provide a relatively high pollutant removal rate with proper design and maintenance. Filter strips are well suited to treating runoff from roads and highways, roof downspouts, very small parking lots, and other pervious surfaces. They are also ideal components of the "outer zone" of a stream buffer or as pre-treatment to another stormwater treatment practice such as grass swales.

Many stormwater BMP manuals recommend the use of filter strips as a secondary device to complement the function of grass swales. A filter strip would typically be located between edge of travel lane, or edge of parking lot, and a grass swale. It functions as pre-treatment to reduce pollutant loading prior to entering a grass swale.

Filter strips and swales can perform well as a first-flush BMP because they capture and treat the early part of the storm runoff which is generally the highest in stormwater contaminants. Since grass vegetation is generally part of a landscaped area, grass filter strips and swales are relatively easy to incorporate into many BMP strategies.

4.6.1.2 Water Quantity Control

There are various green infrastructure technologies that can help control water quantity by reducing runoff generated by the impervious road and by further increasing infiltration and evapotranspiration rates. A water balance model was developed for South Westminster using www.waterbalance.ca. The model can be used to compare a number of scenarios. These were applied to an example residential roadway to show the potential impact. The scenarios were created as outlined in ***Table 4.6.1****.*

In order to compare the effectiveness of each scenario in terms of runoff, evapotranspiration and infiltration, the same road area was applied throughout the water balance model. The results are shown in ***Figure 4.10***, which show the path of rainfall as a percentage.

Table 4.6.1: Green Road Infrastructure Water Balance Scenarios

#	Name	Characteristics
1	Conventional Road	Consists of an impervious surface such as asphalt and concrete that sheds rainfall and associated surface pollutants forcing the water to run directly into nearby storm drains and then into streams and lakes.
2	Filter Strip (1m wide)	1m wide filter strip treating runoff generated from the adjacent road.
3	Filter Strip (2m wide)	2m wide filter strip treating runoff generated from the adjacent road.
4	Grass Swale	Grassed open channel treating runoff generated from the adjacent road without an underdrain.
5	Grass Swale & Filter Strip (1m wide)	Combines scenario #2 and #4.
6	Grass Swale & Filter Strip (2m wide)	Combines scenario #3 and #4.
7	Pervious Paving	Type of hard surfacing that allows rainfall to percolate to an underlying reservoir base where rainfall is either infiltrated to underlying soils or removed by a subsurface drain. The scenario assumed that the entire modelled impervious road network was replaced with pervious paving and would infiltrate to the underlying soil (silty loam).

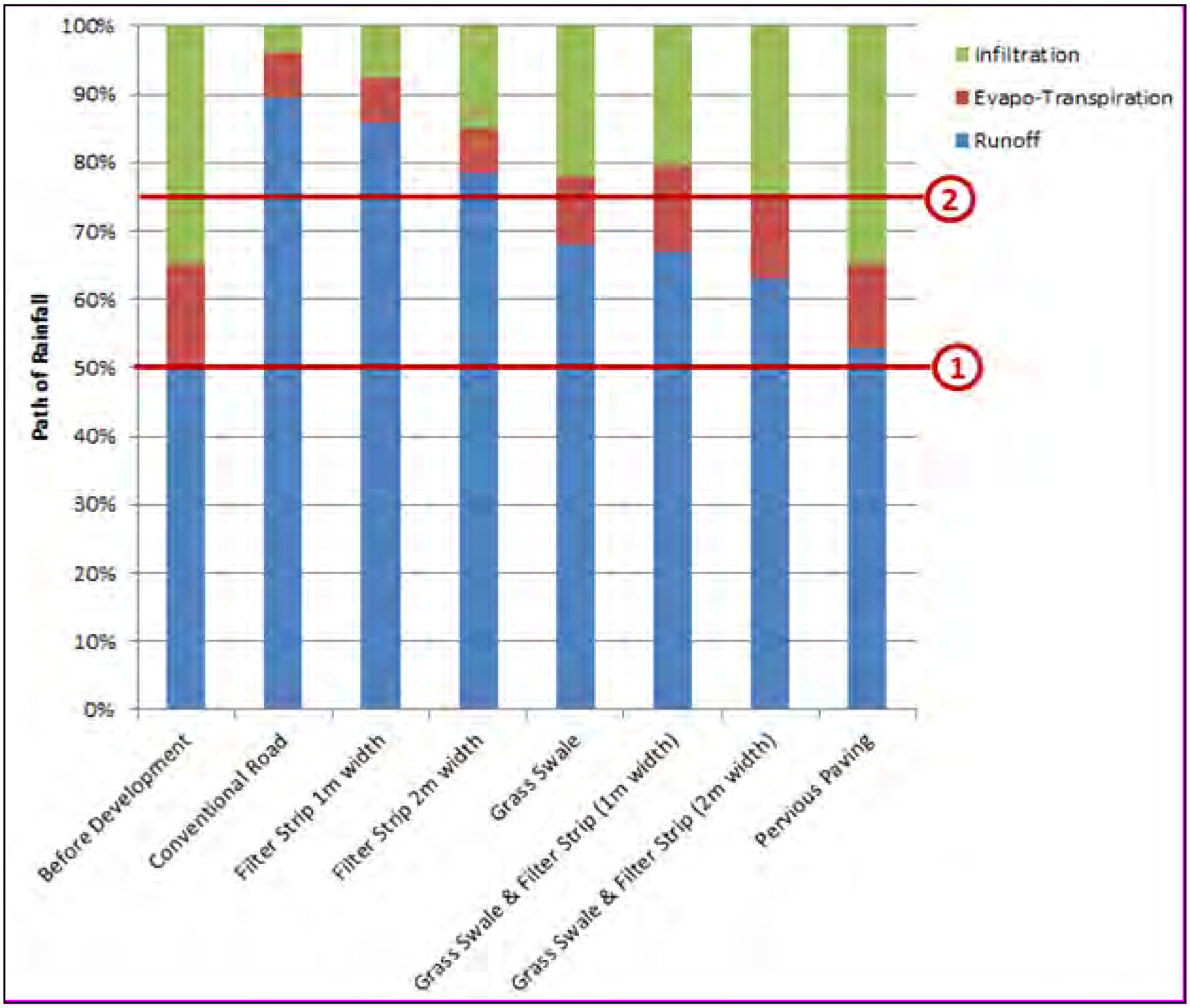


Figure 4.10 – Results from Water Balance Scenarios

Because of the high impervious area of roadways, it is difficult within a right of way to provide enough source controls to meet the ideal target of a predevelopment water balance (Line #1). However, within residential roadways with a typical 20 metre ROW, it is reasonable to expect a target of 75% runoff to be met (Line #2).

Recommendation – Item 16: Implement stormwater BMPs in new roads and when rehabilitating or upgrading existing road networks. Implementation should be achieved by including a standard requirement in Surrey design criteria that all streets must include green infrastructure to reduce annual runoff volumes to 75% of the total water balance. Stormwater quality BMPs would be required to reduce total suspended solids by 80%, using methods such as equivalent grass swale area.

City's Role: Regulator for roads in redeveloped areas; Infrastructure Manager for City constructed roads

4.7 Implementation Plan

The foregoing sections provide discussion and recommendations for the proposed improvements. 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 how the items should be prioritized, who will be responsible for implementation, and how the implementation items might be funded. Order-of-magnitude cost-estimates are also presented. The implementation items are presented in **Table 4.7.2** at the end of this section.

4.7.1 Key Players

Although the role for the City has been already identified in the previous sections, a critical aspect of the implementation plan is to identify the other key players that will be involved in implementing the plan. The linkage between the ISMP and the OCP and subsequent more detailed planning documents has already been highlighted. All the players and stakeholders with responsibility for revising the OCP and enforcing its requirements in subsequent more detailed planning documents and in managing the development of city infrastructure will also have key roles in implementing ISMP recommendations.

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 City staff in order to effectively implement recommended site level BMPs and other aspects of low impact development;
- ***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 should become one of the approved plans that applications must be consistent with. They will require support from the Engineering staff on technical issues;
- ***City of Surrey Engineering:*** The ISMP process is led by the Engineering Department within the City of Surrey. Once completed, the Engineering Department will rely on the Planning Department to implement the plan but will always be involved in supporting and monitoring the plan. In keeping with the importance of highways and roads to the quantity and quality of stormwater runoff in urban areas, this ISMP includes several recommendations in relation to the design and management of this infrastructure. The Transportation Department will have significant involvement and responsibility in this; and
- ***Community Groups:*** In previous sections of the document the role of the City as educator has been highlighted. In many cases, the most effective ways to progress in this area are through community groups. Members of organized community groups are typically leaders and influencers in their communities and can become sustaining supporters of the recommended improvements and, as importantly, become responsible for not allowing installed BMPs to fail

due to lack of maintenance. Such groups can be effective in providing feedback on demonstration projects and initiatives such as green streets or habitat improvement projects.

4.7.2 Funding Sources

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

4.7.2.1 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.

4.7.2.2 Development Cost Charges

The City of Surrey funds some growth related improvement out of development cost charges (DCCs). These DCCs vary by zoning and locations and can me collected through a front ending agreement or other mechanisms. The principle is that growth should pay for growth. Generally, these improvements would service larger areas, so the funds from multiple developments are combined to complete the necessary construction.

4.7.2.3 Utility Funding

The City of Surrey collects a Drainage Parcel Tax as part of City of Surrey property tax collection. 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.

4.7.2.4 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.

4.7.2.5 New Building Canada Fund

In the first quarter of 2014 the federal government launched the New Canada Building Fund, which is a continuation of an already established infrastructure financing assistance program. Over the next ten years a total of $14 billion dollars is being made available to invest in provincial, territorial and municipal infrastructure.

The Provincial-Territorial Infrastructure Component is one of three components within the program and is likely to be most applicable and useful to entities like the City of Surrey. It will involve a two-step process. The first step will require the municipal applicants to prepare a project description for purposes of initial screening to ensure that the proposed project meets eligibility criteria and objectives of the program. The second step is the submittal of a more detailed business case highlighting the regional benefits of the project.

Website: http://www.infrastructure.gc.ca/plan/nbcf-nfcc-eng.html

4.7.2.6 Federation of Canadian Municipalities - 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/

4.7.2.7 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; and
    - *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/

4.7.3 Prioritizing Of Projects

The implementation items have been classified in terms of their level of priority. The levels of priority are as presented in ***Table 4.7.1***.

Table 4.7.1: 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 nuisance flooding or improve the overall drainage system, and items that address aquatic environmental protection of existing resources
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.

4.7.4 Cost Estimates

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 designs of the projects are implemented.

4.7.5 Implementation Plan Items

The implementation plan items for this ISMP are presented in **Table 4.7.2** in the order in which they are detailed in the foregoing sections of this report. For each item, the key players and their roles are shown with the recommended next steps for the City. Also included are potential funding sources, estimated costs and priority level based on the system outlined in **Section 4.7.3** above.

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. Understanding and acceptance of this plan will be the first step towards implementation of the final recommendations.

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.

Table 4.7.2: Summary of Implementation Plan Items

	Location/Type	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Cost (future)	Priority
1	Lowlands/Infrastructure Improvements	Replace 900mm and 1050mm storm sewers along King George Blvd with a 1200mm diameter pipe.	City Engineering to lead	Update hydrologic/hydraulic model for this sub-catchment and confirm sizing Perform design of stormwater system in this area using more detailed information	Availability of funds Traffic Management along King George Blvd	City, through utility funding	$800,000	1
2	Lowlands/Infrastructure Improvements	Improve conveyance along Scott Road between Tannery and Old Yale	City Engineering to lead	Incorporate recommendation into detailed design of proposed multi-use path	Lack of space available Poor soil conditions	City through utility funding and Translink	$50,000	1
3	Lowlands/Infrastructure Improvements	Improve hydraulic efficiency at the intersection of 121 Street and 103A Avenue	City Engineering to lead	Site survey all channel dimensions, pipe inverts, rail elevations, etc Update hydraulic model with proposed drainage works Prepare preliminary design of intersection improvements	Poor soil conditions Flat topography limits drainage solutions Existing utilities under 103A Ave	City, through utility funding	$60,000	2
4	Lowlands/Infrastructure Improvements	Investigate feasibility and value of a conduit between Manson and Old Yale Pump Stations	City Engineering to lead City Planning to support	Using a more detailed model, analyze impacts of conduit for a wide range of events Prepare a conceptual study including conduit alternatives Establish feasibility including costs and benefits	Adequacy of existing ROW for conduit System may require complicated and expensive flow management system	City, through utility funding	$40,000 (study only)	3
5	Lowlands/Infrastructure Improvements	Investigate and resolve locations of recurring localized flooding, such as near the intersection of 124 Street and 109 Avenue	City Engineering to lead	Identify locations based on reports of flooding during storms and feedback from public Survey sites and develop remedial designs based on updated hydraulic model Prioritize based on impacts on public and traffic and implement as funds become available	Flat topography may limit options Coordination with property owners	City, through utility funding	$20,000 (per site)	2

Table 4.7.2: Summary of Implementation Plan Items

	Location/Type	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Cost (future)	Priority
6	Lowlands/Infrastructure Improvements	Establish future design criteria for the South Westminster pump stations accounting for future development and impact of climate change	City Engineering to lead	Review existing recommendations regarding climate change impacts on precipitation and sea level rise and draft specific guidelines	Uncertainty in science of prediction Level of understanding of climate change implications on the part of non-technical decision makers	City, through utility funding	$30,000	2
7	Revision/update of the City's design IDF curves	Review most recent data on extreme rainfall events, revise the City's design IDF curves and incorporate revisions into the Design Criteria Manual	City Engineering	Review most recent data from the Kwantlen monitoring station and estimate using appropriate statistical analyses new IDF relationships Revise Design Criteria Manual accordingly	Uncertainty in science of prediction Level of understanding of climate change implications on the part of non-technical decision makers	City, through utility funding	$15,000	2
8	Riverside Drainage Infrastructure	Develop a design boundary condition for riverside drainage infrastructure to account for expected sea level rise	Province to lead City Engineering to support as stakeholder	Most likely, an update of the Fraser River model by NHC	Uncertainty in the science of prediction Range of projected increase in peak precipitation	Province, with possible contribution by stakeholders	$100,000	2
9	Uplands Runoff Quantity and Quality	Modify existing stormwater management requirements for new residential developments to include: Target of no net increase in volume of runoff Lot development to include facilities to remove 80% of TSS from stormwater, such as equivalent grass swale area.	Developer – to demonstrate appropriate controls in development plans City Planning – to ensure such controls are on approved plans City Building Inspectors to ensure work meets specifications	City Planning to become familiar with controls City to continue to educate developers on BMPs and LID	Level of knowledge of BMPs and LID design	Developer / Applicant	N/A	3
10	City-wide/ Implementation of on-lot BMPs	Implement a long-term program of on-lot BMPs on all single-lot redevelopment	City Departments as educators and regulators	Form working group to develop program Develop outreach and education plan Emphasize success by pilot and demonstration projects Make requirements mandatory	Time constraints on City staff Level of knowledge on the part of property owners and developers	City and Participating Stakeholders	N/A	3

Table 4.7.2: Summary of Implementation Plan Items

	Location/Type	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Cost (future)	Priority
11	Lowlands/Runoff Quantity and Quality	Modify existing stormwater management requirements for industrial and commercial developments to include: Target of no net increase in volume of runoff Lot development to include facilities to remove 80% of TSS from stormwater, such as equivalent grass swale area.	Developer – to demonstrate appropriate controls in development plans City Planning – to ensure such controls are on approved plans City Building Inspectors to ensure work meets specifications	City Planning to become familiar with controls City to continue to educate developers on BMPs and LID	Lack of knowledge of and confidence in BMPs on the part of designers	Developer/ Applicant	N/A	3
12	Improvements to Existing Habitat	Within existing wildlife corridors, remove barriers when the area is impacted by new construction Avoid creation of new barriers to wildlife movement Protect habitat by reducing human impacts such as waste disposal and unrestricted public entry	City Departments as educators and regulators Developers, where redevelopments occur	Select pilot programs for implementation Use success of such programs as means of education stakeholders	Time constraints on City staff Engaging public and stakeholders	City Developers Funding agencies identified in Section 4	N/A	3
13	Restoration of Impaired Wildlife Corridors	Investigate opportunities during redevelopment for restoring corridors where identified in the Biodiversity Conservation Strategy and the Environmental Assessment Report (Appendix B)	Developers for land acquisition issues City Departments for approvals	Identify impaired corridors	Entails land acquisition	Developers	N/A	3
14	Study Area/ Apply upgraded standards regarding quality of stormwater discharges to all redevelopments	In redevelopments implemented in the lowland area, apply Surrey's water quality standards regarding stormwater discharges from each lot	City Planning City Engineering	City Planning become familiar with controls Communication with developers by Planning and Engineering	Time constraints on City staff	Developers City	N/A	4

Table 4.7.2: Summary of Implementation Plan Items

	Location/Type	Recommendations	Key Players and Roles	Next Steps	Barriers, Obstacles and Challenges	Funding	Cost (future)	Priority
15	Study Area/Water Quality Improvements	Upgrade street sweeping/cleaning program to include program components that reduce the level of contaminants in pavement runoff that causes impairment of stormwater quality by investigating the availability of suitable modern street cleaning equipment and developing a pilot program	City Engineering and O&M departments	Arrange a presentation to Transportation Dept on experience in other jurisdictions Select a sponsor/leader for assessment of value in study area Investigate availability and costs of equipment required	Anticipated costs required Personnel time constraints	City	$50,000	4
16	Study Area/Highways and Roads BMPs	Implement stormwater BMPs in new roads or when rehabilitating or upgrading existing roads. Implementation should be achieved by including a standard requirement in Surrey design criteria that all streets must include green infrastructure to reduce annual runoff volumes to 75% of the total water balance Stormwater quality BMPs would be required to reduce total suspended solids by 80%, using methods such as equivalent grass swale area.	City Engineering and O&M departments City as educators and regulators	Revise City's Design Criteria manual	Additional capital costs (land and construction) Potential increase in operations and maintenance	City	N/A	4

5. Monitoring and Assessment

Monitoring and ongoing assessment are an essential part of an ISMP. It allows for long-term strategies to be tracked and adapted as the plan moves forward and determines the extent to which the implementation of an ISMP has achieved its objectives. It provides as basis for adaptive measures for more effective actions and a framework for future updates to the ISMP.

Monitoring that is currently occurring within the South Westminster watersheds includes:

- Erosion monitoring every two years in the Scott, Delta, and Robson creeks as part of the City's Ravine Stability Program;
- Benthic Monitoring in two locations within Delta Creek; and
- Pump Station and water level data is recorded at Manson, Old Yale and Pattullo Pump Stations. This can be used to calculate pumped flow and estimated actual flows into the stations.

The proposed Monitoring Program provided below enhances the existing monitoring to cover more of the South Westminster area and provide a greater amount of data to assess the system over time.

5.1 Monitoring Framework

Metro Vancouver has released a report – the *Adaptive Management Framework (AMF)* - which is intended for use by Metro Vancouver and its member municipalities. The AMF provides an approach for, among others, monitoring watershed health and tracking ISMP implementation and effectiveness. The document covers five major areas:

- Monitoring framework;
- Data collection methodology;
- Assessing and reporting results;
- Adaptive management actions; and
- Supporting information.

It provides the basis for the Proposed Monitoring Program described in **Section 5.2**.

The proposed monitoring program classifies watercourses of the drainage system as:

1. ***Lower Gradient Stream:*** Generally a watercourse is considered lower gradient when the grade is less than one percent. Most ditches and canals of the lowlands are classified as lower gradient streams. Possible monitoring includes flow monitoring, water quality monitoring and erosion monitoring.
2. ***Higher Gradient Stream:*** Generally a watercourse is considered higher gradient when the grade is greater than one percent. Drainage in the uplands, including Scott, Delta, and Robson Creeks are considered higher gradient streams. Possible monitoring includes flow monitoring, water quality monitoring, benthic invertebrates monitoring and erosion monitoring.

3. ***Piped System:*** Piped sections exist throughout South Westminster; however, we will consider only the downstream section of the primarily enclosed Old Yale Catchment in the proposed monitoring program. Possible monitoring includes flow monitoring and water quality monitoring.

5.2 Proposed Monitoring Program

The frequency of monitoring depends on what is being monitored and whether it's a potential hazard to people, property or the aquatic environment. **Table 5.2.1** provides a recommended minimum frequency for the proposed monitoring program:

Table 5.2.1: Frequency of Proposed Monitoring

Monitoring Program	Water Quality Monitoring	Flow Monitoring	Benthic Invertebrates Monitoring	Erosion Monitoring
Monitoring Frequency	• Every 5 years; • Case-by-case basis (eg after spills)	• Case-by-case only • Where data is needed for model calibration	• Every 5 years; more where water quality is a concern	• Every 2 years (as part of Ravine Stability Program and along vulnerable sections of lowland open channels)

The proposed monitoring program, shown in **Figure 5.1** and below in **Table 5.2.1,** differs from the existing monitoring in the following ways:

- Water quality monitoring is recommended for all major watercourses; and
- Erosion monitoring is recommended in the low-lying canals. The City of Surrey's Ravine Stability Assessment program typically targets higher gradient streams likely to undergo erosion. The lowlands of Westminster are flat; however, due to the soft soils sloughing can occur.

5.3 Ongoing Assessment

The results of the monitoring program outlined in **Section 5.2** will indicate how changes in the watersheds are impacting the following parameters:

- ***Water Quality:*** Water quality monitoring results should show ongoing improvements in stream water quality. If this is not so, the reasons for deteriorating results should be investigated immediately and corrective actions and potentially more detailed and frequent monitoring undertaken. Water quality improvement is one of the basic objectives of integrated stormwater management planning.
- ***Stream Health:*** Monitoring of benthic invertebrates provides us with indications of stream health. These organisms live in the streams for several years, and some of them require excellent water quality to survive while others are more tolerant of polluted waters. By looking at the species present we can identify the quality of the stream.

- ***Sediment Transport:*** The City's Ravine Stability Assessment program has identified areas in the creeks that are subject to erosion. The effects of erosion can be felt downstream as well as at locations where the erosion is occurring. Downstream sediment deposition impacts the habitat value of the streams and can cause reductions in conveyance capacities. Locally the focus is on creek stability and protection of private and public property.

Many of the recommendations presented in this plan consist of improvements to drainage infrastructure, and several relate to the pumping systems at the Fraser River. Implementation of these will require further investigations/feasibility studies, approvals for incorporation into City capital planning, design and construction. From an ISMP perspective, a 5-year assessment cycle is suggested. It is expected that some of the recommendations, particularly those directed at preventing flooding, will have been implemented within five years following ISMP approval. Since flood control is a primary objective of integrated stormwater planning, incidences of flooding should be monitored and itemized on an ongoing basis. The results should be assessed on the same 5-year cycle as noted above. ISMP implementation should be seen to reduce frequency of flooding over the cycle.

Some recommendations will be difficult to implement without cooperation from senior governments and other municipalities. Unilateral decisions by the City on revising IDF graphs or development of new design criteria for sea level rise are not advisable. However, the City can use its leverage as a fast-growing major municipality to motivate other stakeholders to arrive multilaterally at agreed solutions.

This ISMP recommends new requirements for site redevelopments, both in the upland and lowland areas. When implemented as directed these requirements will control the stormwater discharged from the individual sites and improve its quality. Ongoing assessment should be identification of each site redevelopment and assessment of the extent to which each one meets the requirements recommended in this plan. Reporting on a 5-year cycle is recommended.

Recommendations on improvements to existing habitat and restoration of impaired wildlife corridors should be coordinated with staff members responsible for implementing the recommendations in the Biodiversity Conservation Strategy (January 2014).

Table 5.2: Proposed Monitoring Program

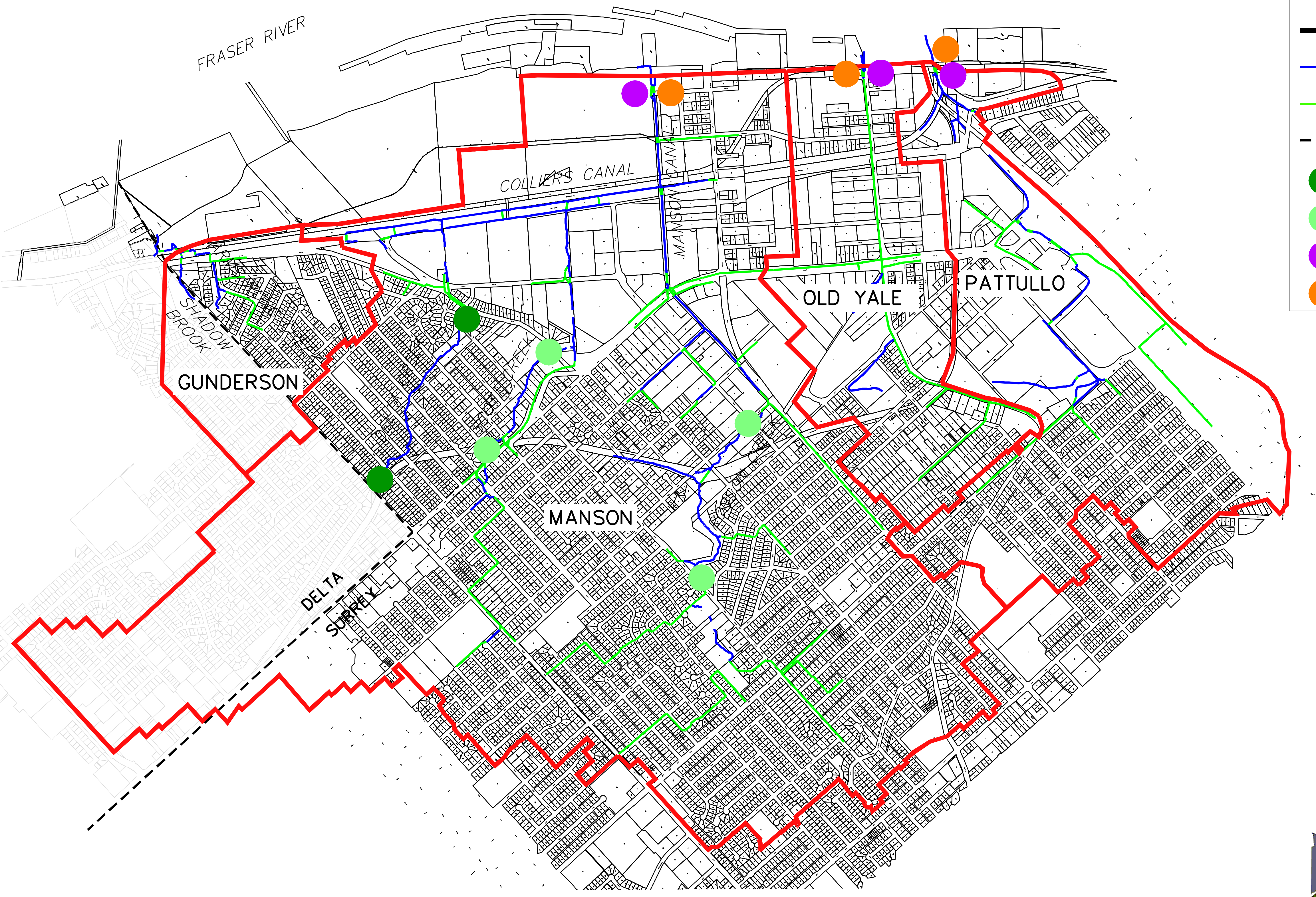
Creek / Location	Stream Type	Water Quality Monitoring	Flow Monitoring*	Benthic Invertebrates Monitoring	Erosion Monitoring
Scott Creek - Uplands	Higher Gradient Stream	Recommended	No	Recommended	Exists
Delta Creek - Uplands	Higher Gradient Stream	Recommended	No	Exists	Exists
Robson Creek - Uplands	Higher Gradient Stream	Recommended	No	Recommended	Exists

Creek / Location	Stream Type	Water Quality Monitoring	Flow Monitoring*	Benthic Invertebrates Monitoring	Erosion Monitoring
Colliers Canal - Lowlands	Lower Gradient Stream	Recommended	No	No	Recommended
Manson Canal - Lowlands	Lower Gradient Stream	Recommended	No	No	Recommended
Pattullo Channel - Lowlands	Lower Gradient Stream	Recommended	No	Recommended	Recommended
Old Yale Pipe - Lowlands	Piped System	Recommended	No	No	No

* Flow monitoring is recommended on a case-by-case basis only, for instance where data is needed to calibrate or recalibrate models or in demonstration projects. Incoming flow at pump stations can be estimated from recorded pumping data.

FIGURE 5.1

SOUTH WESTMINSTER MONITORING PLAN



LEGEND

- MAJOR CATCHMENT BOUNDARIES
- OPEN DRAINAGE PATH
- PIPED DRAINAGE PATH
- DELTA/SURREY BORDER
- EXISTING BENTHIC MONITORING
- PROPOSED BENTHIC MONITORING
- EXISTING FLOW MONITORING
- PROPOSED WATER QUALITY MONITORING

EB 3779

6. References

Title	Date	Author
2002 Ravine Stability Assessment	2002	Urban Systems
2005 Ravine Stability Assessment Update	2006	Associated Engineering
2009 Ravine Stability Assessment	2009	Web Engineering
2011 Ravine Stability Assessment	2011	Web Engineering
Stormwater Planning: A Guidebook for British Columbia	2002	MOE
Metro Vancouver Template for Integrated Stormwater Management Planning	2005	Metro Vancouver
City of Surrey's 2012-2021 Ten Year Servicing Plan	2012	City of Surrey
A Neighbourhood Concept Plan for South Westminster	2003	City of Surrey
Official Community Plan	2002	City of Surrey
Biodiversity Conservation Strategy	2014	Diamond Head Consulting
Report on Creek Management Alternatives for Lower Delta Creek	1998	KWL CH2M
125th Street Functional Stormwater Review Project	2006	Stantec
Manson and Gunderson's Slough Watersheds: Storm Water Management Review and Feasibility/Functional Plan Project: 4897-731	1999	Associated Engineering
Manson and Gunderson's Slough Watersheds Stormwater Diversion to the Fraser River	2004	Associated Engineering
Manson Canal Drainage Improvements Post Construction Monitoring Report	2000	New East Consulting Services Ltd.
Stormwater Management Review Pattullo Drainage System	1996	Associated Engineering
Old Yale Drainage System SWM Review	1997	Associated Engineering
Manson Pump Station Preliminary Review and Design Concept	1989	Delcan

PARSONS

Title	Date	Author
Water Quality Guidelines	Accessed website 2013	MOE BC
Water Quality Index	Accessed website 2013	Canadian Council of Ministers of the Environment
Health Canada Review of Dietary Exposure to Aluminum	1993	Health Canada
Iron in Drinking Water	2003	WHO
Aluminium in Drinking Water	1997	WHO
Aluminum: Potential for Human Exposure	1992	Agency for Toxic Substances and Disease Registry
Toxicological Profile for Copper	2004	Agency for Toxic Substances and Disease Registry
Copper in society and in the environment.	1999	Landner L., & Lindestrom L.
Zinc in Drinking Water	2003	WHO
Code of Federal Regulations	1994	US FDA
Drinking water treatment chemicals – Heath effects	2000	NSF
Water Treatment Solutions - Zinc	Accessed website 2013	Lenntech
Guidelines for Interpreting Water Quality Data (TSS)	1998	Ministry of Forests, Lands and Natural Resource Operations

APPENDIX A

Modeling Data and Results

Appendix A

XPSWMM Hydraulic and Hydrologic Tables – Catchments & Links

The tables show data that has been input into the XPSMM for multiple sub-catchments, pipes and open drainage.

Rainfall Graphs – 2, 5, & 100 Year Return Period Events

The graphs show rainfall data at the Kwantlen Park gauge. Included are the 1, 2, 6, 12 and 24 hour events for each of the 2, 5 and 100 year return period events

Measured Ditch Levels vs Modeled Ditch Levels

Measured ditch levels were used to calibrate the XPSWMM model. The model was run with a 7-day rainfall event in November 2006.   The graph shows the measured and modeled ditch levels were for this period.

CATCHMENT	AREA (m^2)	AREA (Ha)	IMPERV (%)	WIDTH (m)	SLOPE (m/m)	DEPRESSION		MANNINGS n		ZERO DETENTION(	MAX INFILTRATION RATE (mm/hr)	MIN (ASYMPTOTIC) INFILTRATION (mm/hr)	DECAY RATE (1/SEC)	MAX INFILTRATION	GROUNDWATER BASEFLOW	
						IMPERV	PERVIOUS	IMPERV	PERVIOU						mm/day	m/s
OY_CM1	182979	18.3	40	650	0.001	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0106
OY_CM2	196123	19.6	60	500	0.001	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0113
OY_CM3	160550	16.1	55	545	0.001	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0093
OY_CM4	290021	29.0	55	890	0.002	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0168
OY_CM5	126289	12.6	50	690	0.005	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0073
OY_CM6	149245	14.9	30	600	0.149	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0086
OY_CM7	322473	32.2	35	600	0.110	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0187
Total	**1427680**	**142.8**	**46.2**													

CATCHMENT	AREA (m^2)	AREA (Ha)	IMPERV (%)	WIDTH (m)	SLOPE (m/m)	DEPRESSION		MANNINGS n		ZERO DETENTION(	MAX INFILTRATION RATE (mm/hr)	MIN (ASYMPTOTIC) INFILTRATION (mm/hr)	DECAY RATE (1/SEC)	MAX INFILTRATION	GROUNDWATER BASEFLOW	
						IMPERV	PERVIOUS	IMPERV	PERVIOU						mm/day	m/s
PAT_CM1	180994	18.1	60	360	0.001	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0105
PAT_CM2	94194	9.4	60	260	0.002	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0055
PAT_CM3	263013	26.3	55	480	0.002	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0152
PAT_CM4	13770	1.4	50	240	0.002	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0008
PAT_CM5	32665	3.3	62	230	0.004	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0019
PAT_CM6	93548	9.4	50	170	0.002	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0054
PAT_CM7	86349	8.6	50	300	0.002	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0050
PAT_CM8	626822	62.7	40	500	0.048	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0363
PAT_CM9	185467	18.5	25	480	0.098	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0107
PAT_CM10	575023	57.5	45	505	0.071	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0333
Total	**2151845**	**215.2**	**45.7**													

CATCHMENT	AREA (m^2)	AREA (Ha)	IMPERV (%)	WIDTH (m)	SLOPE (m/m)	DEPRESSION		MANNINGS n		ZERO DETENTION(	MAX INFILTRATION RATE (mm/hr)	MIN (ASYMPTOTIC) INFILTRATION (mm/hr)	DECAY RATE (1/SEC)	MAX INFILTRATION	GROUNDWATER BASEFLOW	
						IMPERV	PERVIOUS	IMPERV	PERVIOU						mm/day	m/s
MN_CM1	15209	1.5	70	50	0.003	1.5	5	0.015	0.2	0	4	0.5	0.00115	0	5	0.0009
MN_CM2	207889	20.8	81	350	0.001	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0120
MN_CM3	182108	18.2	65	300	0.004	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0105
MN_CM4	201280	20.1	60	196	0.003	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0116
MN_CM5	94162	9.4	75	170	0.006	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0054
MN_CM6	277550	27.8	84	516	0.003	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0161
MN_CM7	52688	5.3	90	162	0.009	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0030
MN_CM8	99471	9.9	80	270	0.005	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0058
MN_CM9	150745	15.1	60	313	0.047	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0087
MN_CM10	148856	14.9	66	320	0.079	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0086
MN_CM11	146254	14.6	58	166	0.005	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0085
MN_CM12	91868	9.2	72	280	0.005	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0053
MN_CM13	270076	27.0	77	400	0.101	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0156
MN_CM14	159496	15.9	50	315	0.068	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0092
MN_CM15	135849	13.6	60	550	0.004	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0079
MN_CM16	137264	13.7	55	500	0.011	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0079
MN_DEL_CM1	159917	16.0	40	366	0.013	1.5	4	0.015	0.2	0	4	0.5	0.00115	0	5	0.0093
MN_DEL_CM2	177630	17.8	60	210	0.088	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0103
MN_DEL_CM3	445570	44.6	60	570	0.080	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0258
MN_DEL_CM4	1119772	112.0	57	600	0.037	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0648
MN_SC_CM1	454023	45.4	55	450	0.069	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0263
MN_SC_CM2	320159	32.0	65	540	0.033	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0185
MN_SC_CM3	462182	46.2	65	535	0.025	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0267
MN_ROB_CM1	84147	8.4	30	190	0.116	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0049
MN_ROB_CM2	161850	16.2	50	165	0.042	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0094
MN_ROB_CM3	530011	53.0	55	880	0.064	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0307
MN_ROB_CM4	100905	10.1	60	115	0.030	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0058
MN_ROB_CM5	445380	44.5	55	270	0.023	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0258
MN_ROB_CM6	812438	81.2	60	965	0.019	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0470
MN_ROB_CM7	732349	73.2	60	940	0.025	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0424
Total	**8377098**	**837.7**	**60.9**													

CATCHMENT	AREA (m^2)	AREA (Ha)	IMPERV (%)	WIDTH (m)	SLOPE (m/m)	DEPRESSION		MANNINGS n		ZERO DETENTION(	MAX INFILTRATION RATE (mm/hr)	MIN (ASYMPTOTIC) INFILTRATION (mm/hr)	DECAY RATE (1/SEC)	MAX INFILTRATION	GROUNDWATER BASEFLOW	
						IMPERV	PERVIOUS	IMPERV	PERVIOU						mm/day	m/s
GUN_CM1	36073	3.6	65	90.1	0.124	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0021
GUN_CM2	435563	43.6	60	700	0.096	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0252
GUN_CM3	304658	30.5	60	430	0.093	0.4	3	0.015	0.2	0	3	0.4	0.00115	0	5	0.0176
Total	**776294**	**77.6**	**60.2**													

OLD YALE PS

									Channel				Pipe				
Name	Length (m)	Upstream Node	Upstream Inv (m)	Upstream Ground (m)	Downstream Node	Downstream Inv (m)	Downstream Ground (m)	Slope (%)	Height	Bottom Width (m)	Side Slopes H:V	Man n	Material	Manning n	Diameter (m)	Height (m)	Width (m)
LinkOY10	275	OY_CM7	1.27	4.5	Node128	0.23	3	0.378					PVC	0.011	0.75		
O_LinkOY10	275	OY_CM7	3.5	4.5	Node128	2	3	0.545	1.000	30	2	0.2					
LinkOY9	175	OY_CM6	1.36	5	Node128	0.23	3	0.646					CONC	0.013	0.9		
O_LinkOY9	175	OY_CM6	4	5	Node128	2	3	1.143	1.000	30	2	0.2					
LinkOY8	75	Node128	0.23	3	OY_CM5	0.14	2.5	0.120					CONC	0.013	1.2		
O_LinkOY8	75	Node128	2	3	OY_CM5	2	2.5	0.000	0.500	30	2	0.2					
LinkOY7	308	OY_CM5	0.14	2.5	OY_CM4	-0.11	2	0.081					CONC	0.013	1.2		
O_LinkOY7	308	OY_CM5	2	2.5	OY_CM4	1.9	2	0.032	0.100	30	2	0.2					
LinkOY6	235	OY_CM4	-0.11	2	OY_CM3	-0.33	2	0.094					CONC	0.013	1.35		
O_LinkOY6	235	OY_CM4	1.9	2	OY_CM3	1.85	2	0.021	0.100	30	2	0.2					
LinkOY5	327	OY_CM3	-0.33	2	OY_CM2	-0.94	2	0.187					CONC	0.013	1.8		
O_LinkOY5	327	OY_CM3	1.85	2	OY_CM2	1.8	2	0.015	0.150	30	2	0.2					
LinkOY4	248	OY_CM2	-0.94	2	OY_CM1	-1.14	3	0.081					CONC	0.013	1.8		
O_LinkOY4	248	OY_CM2	1.8	2	OY_CM1	1.7	3	0.040	0.200	30	2	0.2					
LinkOY3	11	OY_CM1	-1.14	2.5	Node129	-1.2	4	0.545	3.640	5	2	0.03		0.2			

GUNDERSON

									Channel				Pipe				
Name	Length (m)	Upstream Node	Upstream Inv (m)	Upstream Ground (m)	Downstream Node	Downstream Inv (m)	Downstream Ground (m)	Slope (%)	Height	Bottom Width (m)	Side Slopes H:V	Man n	Material	Manning n	Diameter (m)	Height (m)	Width (m)
Link_G9	9	GUN_CM3	3.45	9	Node_G7	3.22	9	2.556					CONC	0.013	0.75		
O_Link_G9	9	GUN_CM3	5.5	9	Node_G7	5	9	5.556	2.000	30	2	0.2					
Link_G8	50	Node_G7	3.22	9	GUN_CM1	1.56	9	3.320					CONC	0.013	1.2		
O_Link_G8	50	Node_G7	5	9	GUN_CM1	3.6	9	2.800	2.000	30	2	0.2					
Link_G7	40	GUN_CM2	5.23	9	Node_G6	4.92	9	0.775					CSP	0.025	0.9		
O_Link_G7	40	GUN_CM2	7.5	9	Node_G6	4.92	9	6.450	1.500	30	2	0.2					
Link_G6	120	Node_G6	4.92	9	Node_G5	1.78	9	2.617	2.000	1	2	0.03					
Link_G5	25	Node_G5	1.78	9	Node_G4	1.7	9	0.320					CSP	0.025	0.9		
O_Link_G5	25	Node_G5	3.7	9	Node_G4	3.6	9	0.400	5.300	30	2	0.2					
Link_G4	22	Node_G4	1.7	9	GUN_CM1	1.56	9	0.636	2.000	1	2	0.03					
Link_G3_c1	22	GUN_CM1	1.56	9	Node_G3	1.45	9	0.500					CSP	0.025	0.8		
Link_G3_c2	22	GUN_CM1	1.56	9	Node_G3	1.45	9	0.500					CSP	0.025	0.8		
O_Link_G3	22	GUN_CM1	3.6	9	Node_G3	3.5	9	0.455	5.400	30	2	0.2					
Link_G2	90	Node_G3	1.45	9	Node_G2	1.25	9	0.222	2.000	1	2.5	0.03					
Link_G1	27.5	Node_G2	1.25	9	Node_G1	0.98	9	0.982					CSP	0.025	1.22		
O_Link_G1	27.5	Node_G2	3.1	9	Node_G1	3	9	0.364	2.000	30	2	0.2					

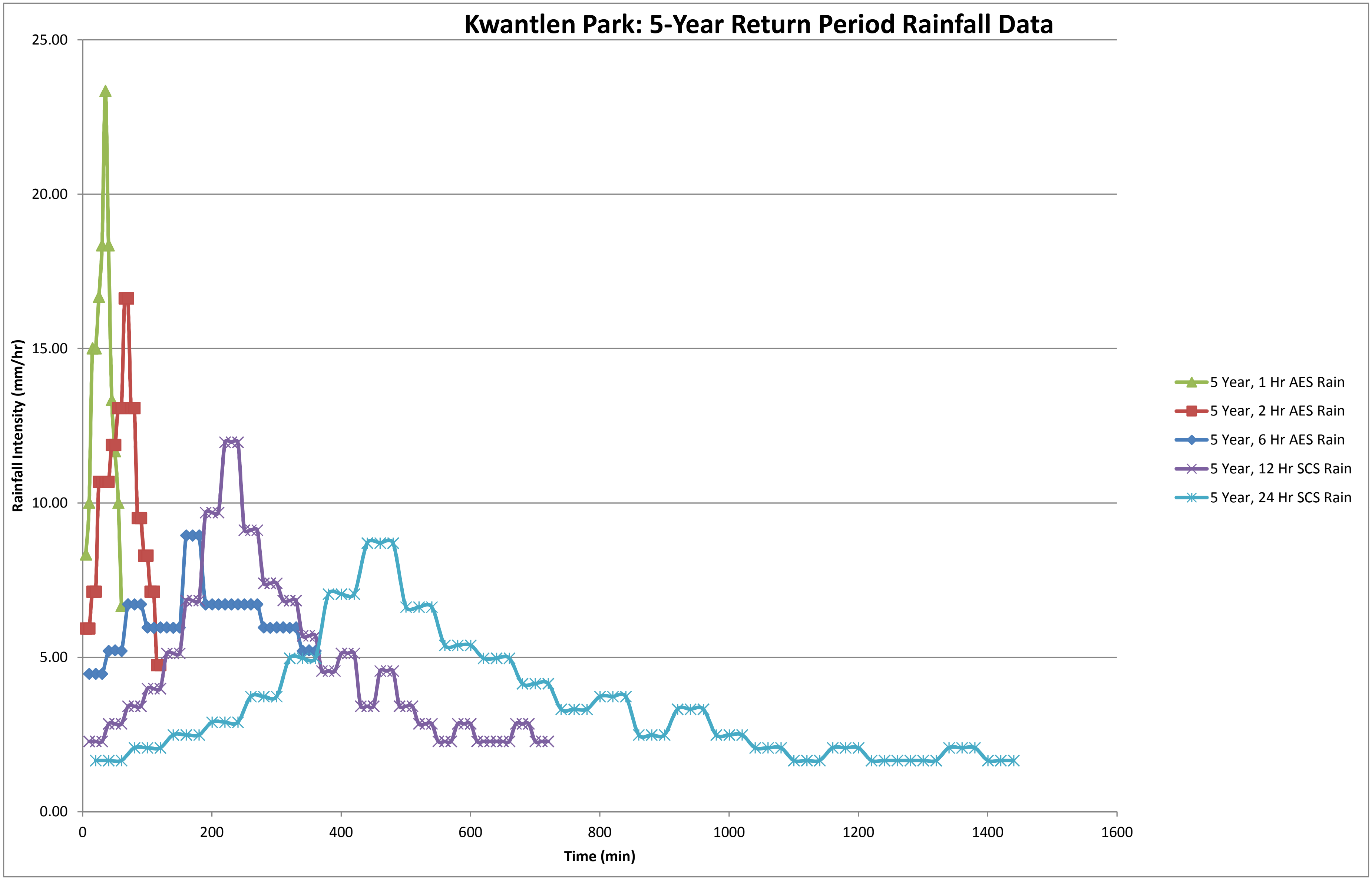
PATTULLO

									Channel				Pipe				
Name	Length (m)	Upstream Node	Upstream Inv (m)	Upstream Ground (m)	Downstream Node	Downstream Inv (m)	Downstream Ground (m)	Slope (%)	Height	Bottom Width (m)	Side Slopes H:V	Man n	Material	Manning n	Diameter (m)	Height (m)	Width (m)
Link P16	350	PAT_CM10	3	5	PAT_CM9	1.71	4	0.369	2.000	6	2	0.03					
Link P15	31.3	PAT_CM9	1.71	4	Node P7	1.37	3.5	1.086					CONC	0.013		0.8	1.8
O.Link P15	31.3	PAT_CM9	2.7	4	Node P7	2.65	3.5	0.160	0.850	12	2	0.2					
Link P14	360	Node P7	1.37	3.5	PAT_CM7	0.55	3	0.228	2.000	8	2	0.03					
Link P13	45	PAT_CM7	0.55	3	PAT_CM6	0.15	2.5	0.889					CONC	0.013		1.5	3
O.Link P13	45	PAT_CM7	2.55	3	PAT_CM6	2.4	2.5	0.333	0.100	12	2	0.2					
Link P12	560	PAT_CM8	1.54	3	PAT_CM6	0.15	2.5	0.248					PVC	0.011	0.9		
O.Link P12	560	PAT_CM8	2.7	3	PAT_CM6	2.2	2.5	0.089	0.300	12	2	0.2					
Link P11-1	60	PAT_CM6	0.33	2.5	Node P6	0.12	2.5	0.350					CONC	0.013		1.5	2.4
Link P11-2	60	PAT_CM6	0.33	2.5	Node P6	0.19	2.5	0.233					CONC	0.013		1.5	2.4
O.Link P11	60	PAT_CM6	2.2	2.5	Node P6	2.2	2.5	0.000	0.300	12	2	0.2					
Link P10	96	Node P6	0.12	2.5	PAT_CM5	-0.17	2	0.302	2.000	6	2	0.03					
Link P9-1	28	PAT_CM5	-0.17	2	Node P5	-0.3	2	0.464					CONC	0.013		1.5	2.4
Link P9-2	28	PAT_CM5	-0.17	2	Node P5	-0.19	2	0.071					CONC	0.013		1.5	2.4
O.Link P9	28	PAT_CM5	1.7	2	Node P5	1.7	2	0.000	0.300	12	2	0.2					
Link P8	50	Node P5	-0.3	2	PAT_CM4	0.28	2.3	-1.160	2.000	8	2	0.03					
Link P7	22.5	PAT_CM4	0.28	2.3	Node P4	0.25	2.3	0.133					CSP	0.025	1.8		
Link P7	22.5	PAT_CM4	0.28	2.3	Node P4	0.25	2.3	0.133					CSP	0.025	1.8		
Link P7	22.5	PAT_CM4	0.28	2.3	Node P4	0.25	2.3	0.133					CSP	0.025	1.8		
Link P7	22.5	PAT_CM4	0.28	2.3	Node P4	0.25	2.3	0.133					CSP	0.025	1.2		
O.Link P7	22.5	PAT_CM4	1.7	2.3	Node P4	1.7	2.3	0.000	0.600	12	2	0.2					
Link P6	28	PAT_CM3	-0.14	2.5	Node P4	-0.14	2	0.000					CONC	0.013		0.9	1.8
O.Link P6	28	PAT_CM3	1.7	2.5	Node P4	1.7	2	0.000	0.300	12	2	0.2					
Link P5	450	Node P4	-0.14	2.3	PAT_CM2	-0.45	3	0.069	2.440	4	2	0.03					
Link P4	390	PAT_CM2	-0.45	3	PAT_CM1	-0.8	4	0.090	3.000	8	2	0.03					
Link P3	15	PAT_CM1	-0.8	4	Node P3 St	-0.87	4	0.467	2.000	8	2	0.03					
Link P2 PS	39	Node P3 St	-0.87	4	Node P2	-0.9	4	0.077					CONC	0.013	1.2		
O.Link P2 PS	39	Node P3 St	2	4	Node P2	1.9	4	0.256	2.000	12	2	0.2					
Link P1	15	Node P2	-0.9	4	Node P1	-1	4	0.667	4.000	8	2	0.2	CONC	0.013	1.2		

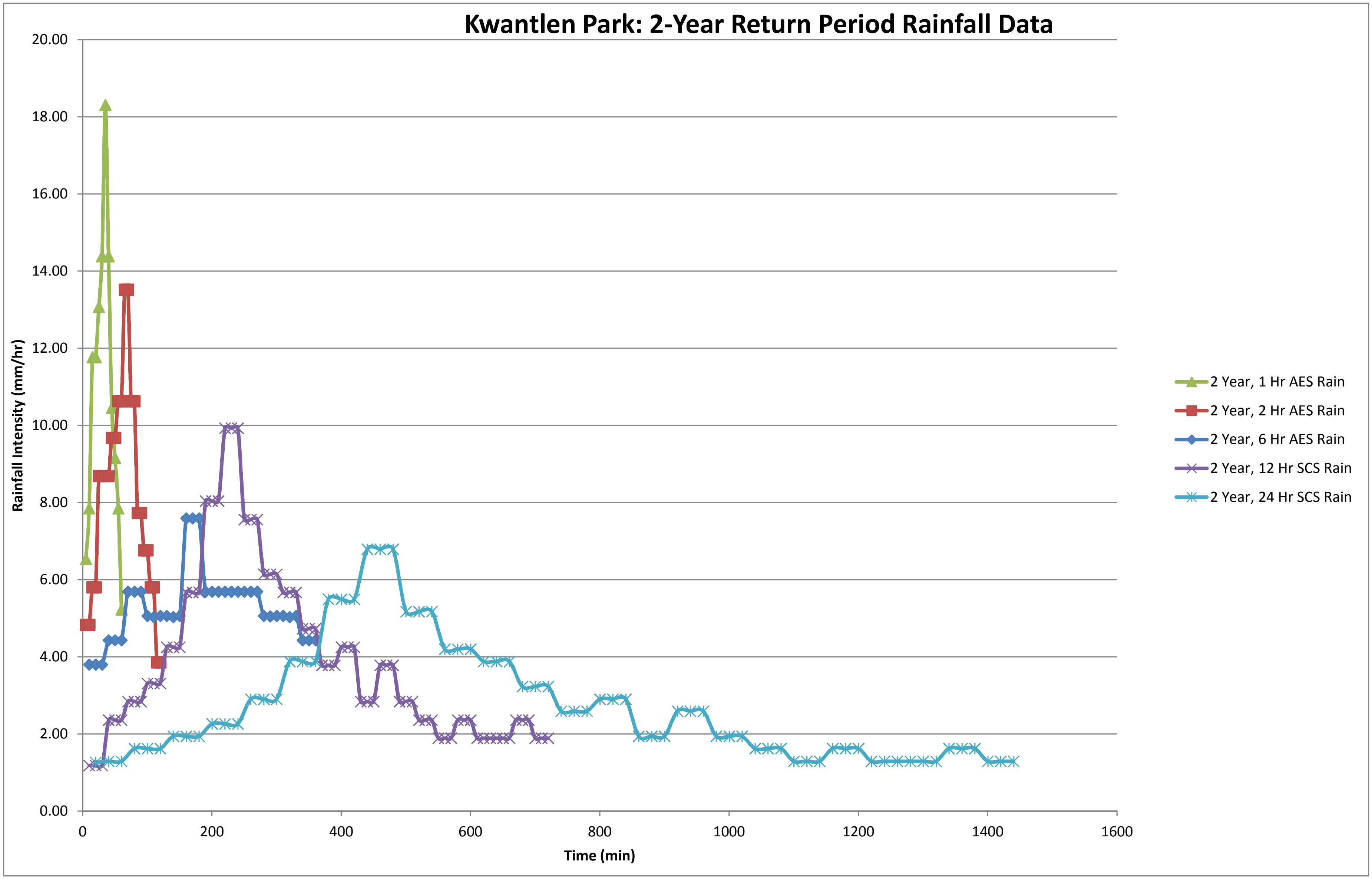
MANSON

									Channel				Pipe				
Name	Length (m)	Upstream Node	Upstream Inv (m)	Upstream Ground (m)	Downstream Node	Downstream Inv (m)	Downstream Ground (m)	Slope (%)	Height	Bottom Width (m)	Side Slopes H:V	Man n	Material	Manning n	Diameter (m)	Height (m)	Width (m)
LinkD5	15	MN_DEL_CM4	84	88	NodeD2	83	88	6.667					CONC	0.013	1.5		
O.LinkD5	15	MN_DEL_CM4	86.5	88	NodeD2	86.4	88	0.667	1.500	12	2	0.2					
LinkD4	1070	NodeD2	83	88	MN_DEL_CM3	5.85	10	7.210	4.000	6	2	0.03					
LinkD3	74.5	MN_DEL_CM3	5.85	10	NodeD1	4.5	9	1.812					CONC	0.013		1.5	2.4
O.LinkD3	74.5	MN_DEL_CM3	8.5	10	NodeD1	7	9	2.013	1.500	8	2	0.2					
LinkD2	31	MN_DEL_CM2	4.89	10	NodeD1	4.5	9	1.258					CONC	0.013		1.5	2.4
O.LinkD2	31	MN_DEL_CM2	8.5	10	NodeD1	7	9	4.839	1.500	8	2	0.2					
LinkD1	330	NodeD1	4.5	9	MN_DEL_CM1	2.5	4	0.606	1.500	12	2	0.03					
LinkM11	588	MN_DEL_CM1	2.5	4	NodeM4	-0.15	2.5	0.451	1.500	12	2	0.03					
LinkS4	757	MN_SC_CM3	83.07	86	MN_SC_CM2	68.86	72	1.877	2.000	3	2	0.03					
LinkS3	29.6	MN_SC_CM2	68.86	72	NodeS1	68.31	72	1.858					CONC	0.013	0.9		
O.LinkS3	29.6	MN_SC_CM2	71	72	NodeS1	70.9	72	0.338	1.000	12	2	0.2					
LinkS2	905	NodeS1	68.31	72	MN_SC_CM1	4	8	7.106	2.000	12	2	0.03					
LinkS1	160	MN_SC_CM1	4	8	NodeM7	2.43	4	0.981	1.500	8	2	0.03					
LinkM16-1	27	NodeM7	2.02	4	NodeM6	1.47	4	2.037					CONC	0.013		1.5	3.05
O.LinkM16	27	NodeM7	3.5	4	NodeM6	3.4	4	0.370	0.500	12	2	0.2					
LinkM16-2	33	NodeM7	2.43	4	NodeM6	2.3	4	0.394					CONC	0.013	0.45		
O.LinkM16-2	33	NodeM7	3.4	4	NodeM6	3.4	4	0.000	0.600	12	2	0.2					
LinkM15	58	NodeM6	1.47	4	NodeM5	1.35	4	0.207	2.000	10	2	0.03					
LinkM14	20	MN_CM16	1.59	5	NodeM5-2	1.47	4	0.600					CONC	0.013	1.05		
O.LinkM14	20	MN_CM16	3.5	5	NodeM5-2	3.5	4	0.000	0.500	12	2	0.2					
LinkM14-2	52	NodeM5-2	1.47	4	NodeM5	1.35	4	0.231					CONC	0.013	1.05		
O.LinkM14-2	52	NodeM5-2	3.5	4	NodeM5	3.5	4	0.000	0.500	12	2	0.2					
LinkM13	277	NodeM5	1.35	4	MN_CM15	0.2	3	0.415	2.650	10	2	0.03					
LinkM12-1	34	MN_CM15	0.2	3	NodeM4	-0.15	2.5	1.029					CONC	0.013		1.2	1.8
LinkM12-2	34	MN_CM15	0.2	3	NodeM4	-0.15	2.5	1.029					CONC	0.013		1.2	1.8
O.LinkM12	34	MN_CM15	2.8	3	NodeM4	2.3	2.5	1.471	0.200	12	2	0.2					
LinkM10	440	NodeM4	-0.15	2.5	MN_CM6	-0.46	2	0.070	2.460	15	2	0.03					

									Channel				Pipe				
Name	Length (m)	Upstream Node	Upstream Inv (m)	Upstream Ground (m)	Downstream Node	Downstream Inv (m)	Downstream Ground (m)	Slope (%)	Height	Bottom Width (m)	Side Slopes H:V	Man n	Material	Manning n	Diameter (m)	Height (m)	Width (m)
LinkR12	20	MN_ROB_CM7	65.85	70	NodeR5	65.2	70	3.250					CONC	0.013	1.2		
O.LinkR12	20	MN_ROB_CM7	69	70	NodeR5	68.9	70	0.500	1.000	12	2	0.2					
LinkR11	60.6	MN_ROB_CM6	66.15	70	NodeR5	65.2	70	1.568					CONC	0.013	0.9		
O.LinkR11	60.6	MN_ROB_CM6	69	70	NodeR5	68.9	70	0.165	1.000	12	2	0.2					
LinkR10	473	NodeR5	65.2	70	MN_ROB_CM5	63.02	68	0.461	3.000	4	2	0.03					
LinkR9	23	MN_ROB_CM5	63.02	68	NodeR4	62.92	68	0.435					CONC	0.013		1.4	2.1
O.LinkR9	23	MN_ROB_CM5	67	68	NodeR4	66.9	68	0.435	1.000	12	2	0.2					
LinkR8	105	NodeR4	62.92	68	NodeR2	61	68	1.829	3.000	8	2	0.03					
LinkR7	11.5	MN_ROB_CM4	66.79	70	NodeR3	66.7	70	0.783					CONC	0.013	0.45		
O.LinkR7	11.5	MN_ROB_CM4	69	70	NodeR3	68.9	70	0.870	1.000	12	2	0.2					
LinkR6	65	NodeR3	66.7	70	NodeR2	61	68	8.769	3.000	4	2	0.03					
LinkR5	491	NodeR2	61	68	MN_ROB_CM3	27.73	32	6.776	5.000	15	2	0.03					
LinkR4	80	MN_ROB_CM2	30	35	MN_ROB_CM3	27.73	32	2.838	4.000	12	2	0.03					
LinkR3	73	MN_ROB_CM3	27.73	32	NodeR1	21.11	25	9.068					CONC	0.013		1.4	1.5
O.LinkR3	73	MN_ROB_CM3	31	32	NodeR1	24	25	9.589	1.000	12	2	0.2					
LinkR2	400	NodeR1	21.11	25	MN_ROB_CM1	2.92	8	4.548	3.000	10	2	0.03					
LinkR1	47	MN_ROB_CM1	2.92	8	MN_CM13	2.69	7	0.489					CSP	0.025		2	3.1
O.LinkR1	47	MN_ROB_CM1	6	8	MN_CM13	5.9	7	0.213	1.100	12	2	0.2					
LinkM29	16	MN_CM13	2.69	7	NodeM12	2.64	7	0.312					CSP	0.025		2	3.1
O.LinkM29	16	MN_CM13	5.9	7	NodeM12	5.8	7	0.625	1.100	12	2	0.2					
LinkM28	194	NodeM12	2.64	7	NodeM11	0.65	4	1.026	2.500	3.5	2	0.03					
LinkM27-1	28.3	NodeM11	0.53	4	MN_CM12	0.52	4	0.035					CSP	0.025	1.8		
LinkM27-2	28.3	NodeM11	0.65	4	MN_CM12	0.46	4	0.671					CSP	0.025	1.8		
O.LinkM27	28.3	NodeM11	3.9	4	MN_CM12	3.8	4	0.353	0.100	12	2	0.2					
LinkM26	217	MN_CM12	0.46	4	NodeM10	-0.95	2.5	0.650	3.450	5	2	0.03					
LinkM25	105	MN_CM14	0.72	3	MN_CM11	0.62	3	0.095					CSP	0.025	1.05		
O.LinkM25	105	MN_CM14	2.9	3	MN_CM11	2.9	3	0.000	0.100	12	2	0.2					
LinkM24	134	MN_CM11	0.62	3	NodeM10	-0.95	2.5	1.172	2.380	3	2	0.03					
LinkM23	201	NodeM10	-0.95	2.5	MN_CM9	-0.54	2.5	-0.204	3.040	12	2	0.03					
LinkM22-1	48	MN_CM9	-0.54	2.5	MN_CM10	-0.55	2.5	0.021					Conc	0.013		1.5	3
LinkM22-2	48	MN_CM9	-0.24	2.5	MN_CM10	-0.25	2.5	0.021					Conc	0.013		1.5	3
O.LinkM22	48	MN_CM9	2.4	2.5	MN_CM10	2.4	2.5	0.000	0.100	12	2	0.2					
LinkM21	24	MN_CM10	-0.55	2.5	NodeM9	-0.67	2.5	0.500	3.050	8	2	0.03					
LinkM20	54	NodeM9	-0.67	2.5	NodeM8	-0.67	3	0.000					CSP	0.025		2	3
LinkM20-2	54	NodeM9	-0.68	2.5	NodeM8	-0.71	3	0.056					CSP	0.025		2	3
O.LinkM20	54	NodeM9	2.4	2.5	NodeM8	2.4	3	0.000	0.100	12	2	0.2					
LinkM19	20	MN_CM8	-0.05	3	NodeM8	-0.2	3	0.750					Conc	0.013	0.75		
O.LinkM19	20	MN_CM8	2.9	3	NodeM8	2.8	3	0.500	0.100	12	2	0.2					
LinkM18	360	NodeM8	-0.2	3	MN_CM7	-0.46	2	0.072	2.460	12	2	0.03					
LinkM17-1	32	MN_CM7	-0.46	2	MN_CM6	-0.46	2	0.000					Conc	0.013		1.5	3
LinkM17-2	32	MN_CM7	-0.46	2	MN_CM6	-0.46	2	0.000					Conc	0.013		1.5	3
LinkM17-3	32	MN_CM7	-0.46	2	MN_CM6	-0.46	2	0.000					Conc	0.013		1.5	3
O.LinkM17	32	MN_CM7	1.9	2	MN_CM6	1.9	2	0.000	0.100	12	2	0.2					
LinkM9	44	MN_CM6	-0.46	2	MN_CM5	-0.46	2	0.000	2.460	10	2	0.03					
LinkM8	165	MN_CM5	-0.46	2	MN_CM4	-0.32	2	-0.085	2.320	10	2	0.03					
LinkM7-1	30	MN_CM4	-0.32	2	MN_CM3	-0.34	2	0.067					Conc	0.013		1.5	3
LinkM7-2	30	MN_CM4	-0.32	2	MN_CM3	-0.34	2	0.067					Conc	0.013		1.5	3
LinkM7-3	30	MN_CM4	-0.32	2	MN_CM3	-0.34	2	0.067					Conc	0.013		1.5	3
O.LinkM7	30	MN_CM4	1.9	2	MN_CM3	1.9	2	0.000	0.100	12	2	0.2					
LinkM6	173	MN_CM3	-0.34	2	MN_CM1	-0.36	4	0.012	2.340	13	2	0.03					
LinkM5	50	MN_CM2	0	4	MN_CM1	-0.36	4	0.720	4.000	2.5	2	0.03					
LinkM4	20	MN_CM1	-0.22	4	NodeM3	-0.38	4.2	0.800	4.220	13	2	0.03					
LinkM3	15	NodeM3	-0.38	4.2	NodeM2	-0.77	4.2	2.600					Conc	0.013	2.1		
O.LinkM3	15	NodeM3	2.6	4.2	NodeM2	2.6	4.2	0.000	1.600	12	2	0.2					
LinkM1	20	NodeM2	-0.77	4.2	NodeM1	-2	4	6.150	4.000	15	2	0.03					



Kwantlen Park: 5-Year Return Period Rainfall Data
Rainfall Intensity (mm/hr)
25.00
20.00
15.00
10.00
5.00
0.00
0
200
400
600
800
1000
1200
1400
1600
Time (min)
5 Year, 1 Hr AES Rain
5 Year, 2 Hr AES Rain
5 Year, 6 Hr AES Rain
5 Year, 12 Hr SCS Rain
5 Year, 24 Hr SCS Rain



Kwantlen Park: 2-Year Return Period Rainfall Data
Rainfall Intensity (mm/hr)
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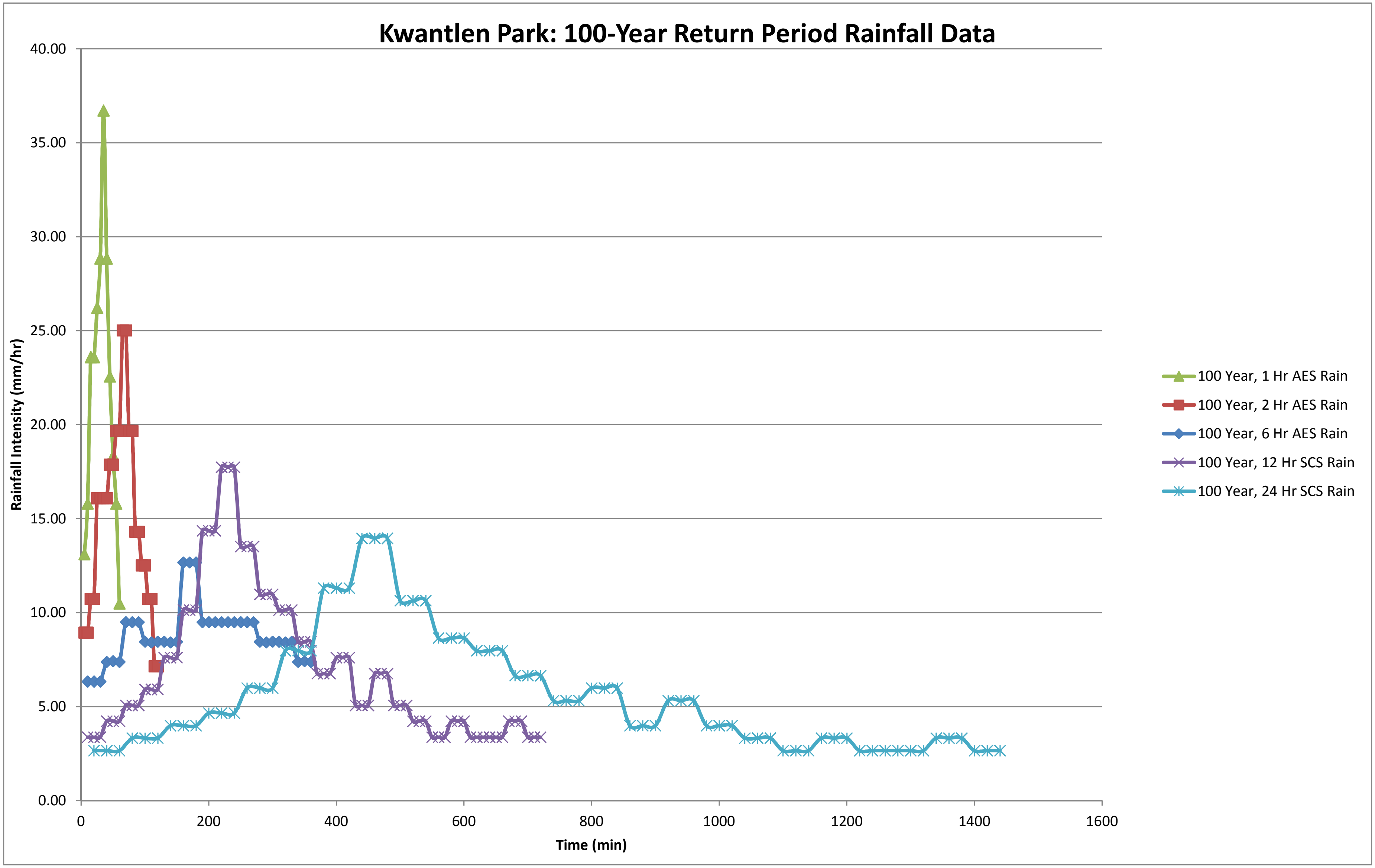
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
0
200
400
600
800
1000
1200
1400
1600
Time (min)
2 Year, 1 Hr AES Rain
2 Year, 2 Hr AES Rain
2 Year, 6 Hr AES Rain
2 Year, 12 Hr SCS Rain
2 Year, 24 Hr SCS Rain



Kwantlen Park: 100-Year Return Period Rainfall Data
Rainfall Intensity (mm/hr)
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
0
200
400
600
800
1000
1200
1400
1600
Time (min)
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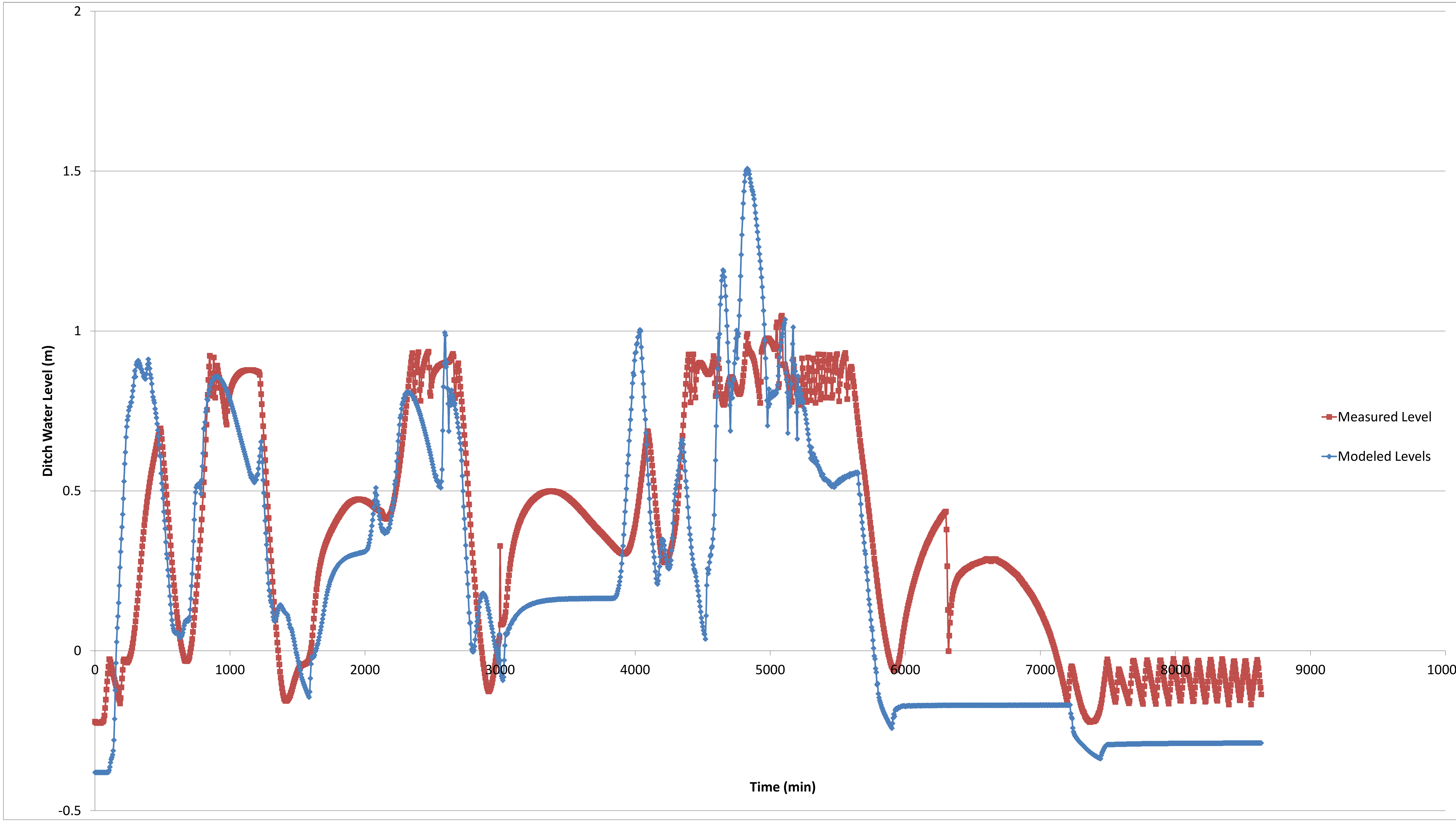
100 Year, 2 Hr AES Rain
100 Year, 6 Hr AES Rain
100 Year, 12 Hr SCS Rain
100 Year, 24 Hr SCS Rain



2
1.5
1
0.5
0
-0.5
Ditch Water Level (m)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Time (min)
Measured Level
Modeled Levels

APPENDIX B

Environmental Assessment Report

ENVIRONMENTAL ASSESSMENT REPORT

Stage 1: South Westminster Integrated Stormwater Management Plan

Surrey, B.C.

Prepared for:

Parsons Corporation and City of Surrey

Prepared by:

PHOENIX ENVIRONMENTAL SERVICES LTD.

February 2013

(February 2015 edition)

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EXECUTIVE SUMMARY

Phoenix Environmental Services Ltd. (Phoenix), in collaboration with Sartori Environmental Services and Bianchini Biological Services, has conducted an environmental assessment of the Study Area for the South Westminster Integrated Stormwater Management Plan (ISMP) that Parsons Corporation (formerly 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 South Westminster 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 priority areas for protection and enhancement include the Class A and Class B streams and their riparian areas, improved fish access into some of the watercourses, any groundwater springs and wetland areas within remaining forested or residential areas along the escarpment, and remaining forest stands along steep slopes and in the lower floodplain area.

The watercourses within the ISMP Study Area can be separated roughly into three categories: Ravine Streams and tributaries, Constructed Fish Habitat Drainage Watercourses, and Constructed drainage ditches (not fish habitat). Several changes in the City's online mapping (COSMOS) are proposed to address unmapped watercourses, inaccurately mapped watercourses, and to address proposed re-classifications of watercourses. These are discussed in detail in section 2.3 of this report and are shown on Figures 2-5 in Appendix A.

A number of issues relating to watercourses in the ISMP Study Area have been identified, including: stream erosion, fish migration barriers, riparian habitat damage, and degraded water quality.

Storm sewers and roadside ditches direct runoff from the upland areas within the Study Area toward Robson Creek, Scott Creek, Delta Creek, Armstrong Creek or Shadow Brook. These creeks convey flow down the steep escarpment into the lowland floodplain where connectivity to the Fraser River occurs through constructed (channelized) watercourses offering fish habitat.

Development in upland areas of the Manson and Pattullo catchments has contributed to increased peak flows and run off volumes during storm events and the concentration of flows at storm sewer outlets. Changes to flow patterns due to land development accelerate naturally occurring erosion processes, by exposing the ravine channels to more frequent, longer duration, high flow events. Construction of detention ponds in Robson Creek has likely limited erosion the erosion potential within that watercourse; however, ravine stability assessments (2002 – 2009) indicate that numerous localized bank erosion problems persist within the South Westminster ravine streams.

Phoenix Environmental observed potential obstructions to fish passage in the upper reaches of Scott and Robson Creek; however, the lower reaches of these streams and the other ravine streams within the Study Area are accessible to fish, and spawning coho have migrated into upper Robson Creek in Robson Park for the first time in 2013. Culvert extensions due to the

construction of the South Fraser Perimeter Road (SFPR)/Highway 17 could decrease potential for fish migration upstream, therefore, maintaining fish passage in Class A and Class A(O) watercourses has been critically important during design and construction. The installation of fish passable culverts and fish ladders under the SFPR into Shadow Brook and Armstrong Creek have potentially improved fish access into the upper reaches of those watercourses.

Riparian habitat damage from refuse disposal and long-term structures built at or very close to watercourse banks and ravine crests occurs extensively throughout the Study Area. Water quality issues are most prevalent in the lowland floodplain and industrialized areas of the ISMP Study Area. To provide an indicator of aquatic health, benthic invertebrate community monitoring has been seasonally conducted at two locations win Delta Creek between 1999-2008. The B-IBI results indicate that Delta Creek is consistently in the 'Very Poor' to "Poor" range. These issues are discussed in greater detail in section 2.4 of this report.

No sensitive plant or animal species were detected during the field program, although several sensitive species are likely, including Great Blue Heron (*Ardea Herodias*), Trowbridge's Shrew (*Sorex trowbridgii*), Pacific Water Shrew (*Sorex benderii),* Streambank lupine (*Lupinus rivularis*) and Vancouver Island beggarticks (*Bidens amplissima*). Invasive vegetation species were regularly encountered along interfaces of forested and disturbed or developed sites. These invasive species included Himalayan blackberry (*Rubus discolor*), Japanese knotweed (*Polygonum cuspidatum*), Scotch broom (*Cytisus scoparius*) and English ivy (*Hedera helix*). Removal of these invasive plant species at strategic sites would benefit many native wildlife and vegetation species and improve existing wildlife corridors.

The riparian habitats, forested blocks, ponds and ROWs in the Study Area were identified as having high wildlife values and provided moderate to high rated habitat for a number of federally listed wildlife species including Pacific water shrew (*Sorex benderii*), red-legged frog (*Rana aurora*) and Western Screech-owl (*Megascops kennicottii kennicottii*). These riparian areas and forested stands also provided important nesting habitat for other wildlife including raptors such as Bald Eagle (*Haliaeetus leucocephalus*), Red-tailed Hawk (*Buteo jamaicensis*) and Cooper's Hawk (*Accipiter cooperii*). Wildlife sign encountered during the field program included coyote (*Canis lantrans*) and beaver (*Castor canadensis*). The ponds, watercourses and associated terrestrial habitats provided important habitat for many waterfowl, songbird and amphibian species. The riparian zones of all creeks provided moderate to high rated habitat for the provincially listed Trowbridge's shrew (*Sorex trowbridgii*) and Pacific sideband snail (*Monadenia fidelis*).

The ROWs, Armstrong Creek, Delta Creek, Scott Creek, Robson Creek and Manson Creek and their tributaries provided important wildlife corridors for many listed wildlife species including Red-legged Frog (*Rana aurora*) and Pacific water shrew (*Sorex benderii)* as well other wildlife. The relatively few and fragmented forested areas remaining in the Study Area have not changed substantially over many years, given the long history and density of urban development in the Study Area. Remaining forest patches need to be protected and wildlife movement corridors need to be maintained or established to improve the ecological integrity of the Study Area and to provide suitable living habitats for sensitive species. Provision of natural habitats that have protected corridors will result in increased biodiversity within the Study Area.

1. INTRODUCTION

Phoenix Environmental Services Ltd. (Phoenix) has been retained by Parsons Corporation (formally Delcan) to provide the environmental assessment components for Stage 1 of the South Westminster Integrated Stormwater Management Plan (ISMP); which Parsons has been retained to prepare for the City of Surrey Engineering Department. This report has been completed in support of the formulation of the South Westminster ISMP.

This report has also been updated in February 2015 to include comments provided by the City's Environmental Coordinator regarding the initial February 2013 edition of this report.

1.1 ISMP Environmental Objectives

Based on the Terms of Reference issued by the City, the South Westminster ISMP is intended to be a comprehensive plan to balance land use planning, stormwater engineering, flood and erosion protection, and environmental protection in order to preserve and improve the overall health of the watershed.

The environmental objectives of the ISMP include:

- to protect and enhance the overall health of the Study Area watershed consisting of three major drainage catchment areas,
- to protect and enhance watercourses and aquatic life, to prevent pollution and maintain and improve water quality,
- to provide an inventory of watercourses and wildlife for the watershed, and
- to protect the environment, wildlife and wildlife habitat and corridors.

1.2 Study Area

The South Westminster ISMP Study Area covers an area of approximately 1250 hectares between 96 Avenue 112 Avenue and 132 Street west to the Fraser River ('Study Area'). The Study Area is characterized by urban and industrial land uses with predominately single-family residential areas south on the escarpment and mixed industrial and commercial uses within the lowland floodplain areas near the Fraser River. The Study Area has been largely built-out with negligible undeveloped lands, such that remaining streams, forested and environmentally sensitive areas have become a scarcity and of significant retention value, even where degraded by urban activities.

The watershed within the ISMP Study Area includes three (3) major drainage catchment areas including the Patullo, Old Yale and Manson catchments as well as the sub-catchment of Armstrong Creek and Shadow Brook (see Appendix A: Figure 1).

The South Westminster ISMP Study Area is within the Georgia Depression Ecoprovince, Lower Mainland Ecoregion, Fraser Lowland Ecosection. The Study Area is within the Very Dry

Maritime Coastal Western Hemlock (CWHxm1) Biogeoclimatic (BGC) subzone and the Dry Maritime Coastal Western Hemlock (CWHdm) BGC subzone.

1.3 Methodology

The methodology for this Stage 1 ISMP Environmental Assessment has included use of existing information resources, mapping and reports, as well as limited field reconnaissance, to conduct an assessment of the fish, aquatic and wildlife habitats within the ISMP Study Area.

1.3.1 Scope

The scope of work by Phoenix for Stage 1 of the ISMP has entailed:

- confirmation of fisheries classification for key watercourses and assessment of current health conditions of selected watercourses, including associated terrestrial habitats such as ravines, riparian areas, and wetlands;

- identification of significant terrestrial habitats including trees and forests, habitat hubs, wildlife corridors, and habitat restoration opportunities; and

- 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.

1.3.2 Background Information Search

Prior to field visits, pertinent background information and online mapping resources (COSMOS) provided by the City was reviewed in order to focus field observations on key watercourses, identified terrestrial habitats, and those species and habitats with a high potential for occurrence.

There has been an extensive collection of assessment reports previously completed for the City pertaining to the ISMP Study Area. Key reports reviewed for this environmental assessment include, but were not limited to: Manson and Gunderson's Slough Watersheds: Storm Water Management Review and Feasibility/Functional Plan, Ravine Slope Stability Assessments (2002, 2005, 2009), South Fraser Perimeter Road Environmental Impact Assessment reports (e.g. fish habitat, wildlife habitat), the City of Surrey Biodiversity Conservation Strategy (2014), Ecosystem Management Study (2011), and the Environmentally Sensitive Areas (ESA) database (Abs et al. 1990).

The BCCDC website was searched for all species listed under SARA, COSEWIC, Provincial Identified Wildlife and the Provincial *Wildlife Act* that are suspected to occur within habitats identified within the Study Area. In addition, species listed as Red and Blue-listed by the BCCDC but not specifically covered under legislation were also included. BCCDC data within the Study Area were also reviewed. Aerial photographs of the Study Area were examined and all potential habitats and wildlife corridors were stratified.

1.3.3 Field Surveys

Field observations of selected areas within the South Westminster ISMP Study Area have been conducted on January 11, 12 and 18, 2013 by Ken Lambertsen, R.P.Bio. (Senior Consultant), Claudio Bianchini, R.P.Bio. (Wildlife Biologist), Stephen Sims, R.P.Bio. (Fisheries Biologist) and Ivan Rossman B.I.T. (Biologist). Field surveys were completed during cold and dry conditions 48 hours after a significant rainfall event. The objectives of the field visits were to assess and classify watercourses, and to observe intact habitats and determine the potential to support wildlife, particularly rare and endangered species. Selected watercourses were observed for fish and aquatic habitat attributes and indicators of relative health (e.g. visual water quality).

The riparian habitats, forested blocks, fallow fields, wetted areas and right of ways within the Study Area were assessed for wildlife and vegetation values during field surveys. Transects were walked throughout the identified habitats. Due to survey timing (winter), only readily identifiable vegetation species within each site were identified and recorded. In addition, the presence of coarse woody debris (CWD), wildlife trees, dens, burrows and other habitat features were also recorded. All wildlife trees were classified according to methodologies identified by Backhouse (1993) and Fenger et al. (2006).

Pacific water shrew habitat was assessed following methodologies described by Craig and Vennesland 2008. Potential raptor/heron nest trees were scanned visually with binoculars. All wildlife and wildlife sign encountered was recorded.

2. WATERCOURSES

The following sections describe the types and features of watercourses in the ISMP Study Area, existing and proposed fisheries watercourse classifications, and key issues associated with the ecological function and health of the watercourses.

2.1 WATERCOURSE CLASSIFICATIONS

The City of Surrey has classified streams according to their ability to support fish populations:

- Class A – watercourses support fish populations year round or have the potential to support fish populations year round, if migration barriers are removed

- Class A(O) – watercourses support fish populations generally only during the winter months; often roadside ditches that have very low flows and warm temperatures in the summer

- Class B – do not support fish populations, but provide food and nutrients to downstream fish habitats and often are supported year-round by groundwater

- Class C – do not support fish populations and generally only convey flows associated with rainfall events; often shallow roadside ditches in headwater areas

Based on the background data, air photos, and limited ground-truthing, a majority of the streams in the watershed have been classified correctly, as shown on the City of Surrey GIS mapping system (COSMOS). Verification in the field primarily consisted of locating the reach breaks between Class A and Class B designations to see if fish barriers or flow restrictions were consistent with the classifications, as well as observations of flowing water (i.e. groundwater) during dry weather (e.g. ~48 hours following rainfall). Field surveys were conducted during dry conditions in order to facilitate differentiation between Class B and Class C watercourses. Fish sampling has not been conducted for this assessment.

2.2 General Description

The watercourses within the ISMP Study Area can be separated roughly into three categories:

- Ravine Streams and tributaries
- Constructed Fish Habitat Drainage Watercourses
- Constructed drainage ditches (not fish habitat)

2.2.1 Ravine Streams

The ravine streams and natural creeks within the Study Area generally originate along the north slope of the ISMP area and have formed ravines over the escarpment slopes. In the lower reaches within the South Westminster lowland floodplain areas, these creeks have typically become diverted into drainage channels offering fish habitat before discharging into the Fraser River.

The ravine streams in the ISMP Study Area (see Appendix A: Figures 2-5) include:

- Robson Creek
- Scott Creek
- Delta Creek
- Armstrong Creek
- Shadow Brook

Robson Creek flows into a culvert at the intersection of 103A Avenue and 123A Street, where it is directed to the south side of 104 Avenue which connects to the upstream end of Manson Canal and flows to the Fraser River. Robson Creek is Class A and is considered fish passable until the second pool in Robson Park, where a constructed weir potentially limits fish passage.

COSMOS analysis and limited field observations indicate Scott and Delta Creek are also fish passable, Class A watercourses. Connectivity to the Fraser River is via Colliers Canal (adjacent to the BNR tracks) and Manson's Canal. Armstrong Creek and Shadow Brook are Class A watercourses connected to Gunderson Slough through the Robson Road ditch. Further details regarding fish passage in the ravine streams can be found in section 2.4.2.

2.2.2 Constructed Fish Habitat Watercourses

Most of the constructed drainage watercourses that are either fish-bearing (Class A, Class A[O]), or provide flow and nutrients but are not fish-bearing (Class B), extend along the CN and BNR

Railway adjacent to the Fraser River, or roads near the Fraser River in the lowland floodplain area. These include Manson Canal, Colliers Canal, 110A Ave., Timberland Road, portions of Scott Road and 120A Street.

2.2.3 Constructed Drainage Ditches

These drainage ditches are typically shallow roadside drainage watercourses that primarily convey stormwater runoff for limited periods, and generally go dry quickly after rainfall ends. These ditches typically do not convey groundwater, and have insignificant fish habitat value. The majority of the Manson and Pattullo catchments contain these types of constructed roadside drainage ditches, particularly above the escarpment slope. Although some locations may intersect the high water table, the vast majority of the drainage ditches in the upper portions of the watersheds drain runoff only during rainfall events. The drainage ditches in the lowland floodplain portions of the watersheds provide conveyance and detention when the Fraser River water level is high. In most cases, however, these drainage ditches are not fish habitat, and are therefore classified as Class C watercourses.

2.3 PROPOSED WATERCOURSE RE-CLASSIFICATIONS

Through field observations at selected locations, and with reference to background reports, several changes to watercourse classifications are proposed, including mapping corrections. These are discussed by watershed/catchment area in the following sections, and are shown in Appendix A: Figures 2-5. Due to the size of the ISMP Study Area, and for scale purposes, 4 separate figures have been prepared to show watercourse classifications, and proposed changes.

2.3.1 Pattullo

2.3.1.1 Pattullo Bridge

Beneath the Pattullo Bridge at the intersection with the CN rail line, a Class A watercourse splits into a Y and one arm flows south (Figure 2, Location 1). The south arm is currently Class A, however, field observation on January 12 observed very low water levels, stagnant flow and no connectivity to the main open channel (Appendix B: Photo 1). This watercourse is also not included in the Fish Habitat Impact Assessment for the South Fraser Perimeter Road (SFPR) conducted by Coast River Environmental Services (2006). Re-classification from Class A to Class B should be considered.

In the same area beneath the Pattullo Bridge, on the northwest side of Bridge Road, a small channel connected to the constructed watercourse along 111A Avenue is classified as Class A(O). Very low water levels, no flow and no connectivity to the constructed channel were observed during field surveys; therefore re-classification from Class A(O) to Class B is recommended (Location 2, Photo 2).

2.3.1.2 109th Avenue to 110th Avenue

A Class A watercourse is mapped along the top of the escarpment between 109 Avenue and 110 Avenue. Field observations identified well-used access trail in this location, but no watercourse was located or appeared ever have been located here (Photo 3). Possible watercourse mapping by orthophoto analysis likely misinterpreted the pedestrian trail as a watercourse. It is therefore recommended that this watercourse be removed from fish classification maps (Location 3).

2.3.2 Old Yale

2.3.2.1 Scott Road and Old Yale Road

A watercourse is currently mapped as Class A with its downstream extent at the intersection of Scott Road and Old Yale, and upstream extent north of 104 Avenue near 125A Street (see Location 4, Figure 2). During field observations on January 12, the lower reach of the channel was difficult to locate and, in many areas, the mapped watercourse was not observed (Photo 4). Recent snowfall limited observation of the watercourse by flattening riparian vegetation (dense canary reedgrass) over the channel. However, previous observations of this watercourse by Phoenix and COSMOS aerial photography have confirmed a linear (constructed) open channel with sparse treed riparian along most of the length of this watercourse; except for the section just upstream of the Scott Road and Old Yale Road intersection, where remnant natural channel features have been observed and mapped on COSMOS.

Fish movement from the Fraser River into this channel likely may be limited by a ~1 km stretch of culvert through industrial land on Old Yale Road, which is considered to pose an obstacle to fish migration. Previously classified as Class B, this watercourse is now classified as Class A. Due to the length of storm sewer and numerous pollution-generating impervious surfaces draining to the storm sewer (i.e. water quality deterrent), the Class A classification may be questionable. Similarly, fish passage to the Class A(O) channel at 124 St. and Old Yale would obstructed by the >1 km length of culvert along Old Yale Road (Photo 5).

Phoenix did not confirm fish absence or presence for this report. However, fish access constraints suggest these channels could be re-classified; unless the current classifications are supported by the results of fish presence data, which has not been available for this report (Location 4). As both these watercourse straddle catchment boundaries, further details regarding their southern section can be found in sections 2.3.3.1 and 2.3.3.2.

2.3.3 Manson

2.3.3.1 124th Street to 125A Street

A network of Class A(O) watercourses connected to a storm sewer along Old Yale Road are mapped around land partially developed and appearing to be inactive between 124 Street and 125A Street (see Location 5, Figure 3). Field observations found overgrown channels, very low water levels and open channels lacking connectivity. Currently, it appears as though the mapped Class A(O) watercourses have yet to be constructed as aquatic habitats, and resemble ditches used for sediment control (Photo 6). Erosion from the surrounding development is also widespread, as is evidence of extensive vehicle use in the riparian area, construction debris and refuse.

As discussed in section 2.3.2.1, fish access to these watercourses is impaired by more than 1 km of culvert through industrial lands along Old Yale Road. Although no fish sampling was conducted, the present habitat conditions and water depths did not appear to be suitable over-wintering fish utilization. Therefore, re-classification from Class A(O) to Class B should be considered, pending confirmation that development and restoration will be completed.

2.3.3.2 Old Yale Road to 104 Avenue

The Class A linear (constructed) channel terminating in the Old Yale catchment at Scott Road and Old Yale Road originates in the Manson catchment, and flows north. Field observation (January 12 2013) of the south end of this channel identified an extensively overgrown channel with low and discontinuous channel flow during winter conditions (Photo 7). Given the limitations to fish access (i.e. discontinuous flow) and poor habitat conditions, re-classification from Class A to Class B for the section of channel along the steel fabrication plant site to 104 Avenue is recommended (see Location 6: Figure 3).

2.3.3.3 123A Street and BC Hydro Railway

An unmapped, flowing Class B watercourse was identified draining from a new storm sewer outfall at the north end of 123A Street to the existing Class B watercourse draining east to Robson Creek on the south side of the BC Hydro Railway (Location 7, Figure 3, Photo 8).

Due to recent residential subdivision development, a Class C ditch on the east side of 123A Street between 100A Avenue and the end of 123 A Street has been enclosed in a storm sewer, which outfalls to the above-noted, unmapped Class B watercourse. This ditch should be removed from drainage maps (Location 8, Figure 3).

Class C ditches along the west side of 123A Street south of 100A Avenue and on the south side of 100 A Avenue west of 123A were observed with flowing water and sorted small gravel substrates. Given the flow (i.e. groundwater-fed) and watercourse substrate observed during winter conditions, re-classification from Class C to Class B is recommended (Location 9, Figure 3, Photo 9). The downstream terminus of this watercourse enters a storm sewer, and the eventual outlet of the storm sewer receiving the Class B drainage could not be determined in the field (i.e. no nearby manholes or drainage channels) or by drainage mapping (COSMOS).

2.3.3.4 102 Avenue

A short section of Class C ditch west of 122 Street on the south side of 102 Avenue was observed with a sorted gravel substrate and groundwater flow connecting to an existing Class B watercourse. Re-classification of this short section of watercourse from Class C to Class B is recommended (Location 10, Figure 3, Photo 10).

2.3.3.5 Timberland Road and Tannery Road

The Class A(O) watercourses on either side of Tannery Road (Photo 11) northwest of Timberland Road have been filled in due to construction of the SFPR (Figure 4: Location 11). These watercourses should be removed from watercourse maps. Access to the area was limited to due to construction activities. Therefore, the current condition of the Class A(O) watercourse along Dyke Road is unknown.

COSMOS mapping indicates the watercourses east of Tannery Road on the south side Timberland Road and on either side of the CN railway between Tannery Road and Timberland Road are classified as Class A(O) habitat (Location 11, Figure 3, Photo 12). However, the Fish Habitat Impact Assessment completed by Coast Environmental (2006) for the SFPR indicates these are Class C ditches. Field observation of these areas was not completed due to access constraints as a result of SFPR construction.

A short unmapped, channel intersecting the Class A(O) constructed watercourse on the south side of Timberland Road was identified just east of the CN Railway (Location 12, Figure 4). High water levels were observed in the unmapped channel. Therefore, a Class A(O) classification consistent the current classification of the open channel on Timberland Road is recommended (Photo 13).

The Class A watercourse shown on the west side of Tannery Road between South Fraser Way and Scott Road, initially flows southwest and before turning northeast has been altered by SFPR construction at Tannery Road. Field observation found stagnant water present in the channel and fish passage does not appear to have been maintained (Location 13, Figure 4, Photo 14).

2.3.3.6 103A and South Fraser Way

The Class A(O) watercourse at the north end of 103A has been altered due to construction of the SFPR. Water was observed in some locations, however, it is unlikely fish passage or habitat has been maintained. Pending completion of SFPR construction, this channel should be reassessed to determine if it is still existent, and if it provides any suitable fish habitat or nutrients to fish habitat (Location 14, Photo 15).

2.3.3.7 103A Avenue

Watercourses mapped on the east and west side of 121 Street between 103A Avenue and 102 Avenue are currently classified as Class A(O) (west side) and Class A (east side). During the winter field visit, very low water levels lacking connectivity and containing algae on the substrate was observed on the west side of 121 Street (Photo 16), while on the east side, higher water levels were observed with slightly greater potential to support fish during winter periods (Photo 17). Potential re-classification of these watercourses from Class A(O) to Class B (west side) and Class A to Class A(O) (east side) should be considered (Location 15, Figure 4). In addition, low flows and an elevated inlet to the culvert under 103A Avenue pose a potential fish migration obstacle (Photo 18).

2.3.3.8 Scott Creek and 99th Avenue

Field observation of Scott Creek just upstream of the culvert at 99 Avenue identified an approximately 1 meter weir that potentially limits fish passage beyond this point (Location 16, Figure 4, Photo 19). Further investigation is required to determine if fish are currently able to navigate past this weir into the upper reaches of Scott Creek and to identify opportunities to increase access around this potential fish migration obstruction. Based on field observation, the current the Class A classification for the upper reaches of Scott Creek could be questionable.

2.3.3.9 Grace Road

The Class B watercourse on the north side of Grace Road, west of Colliers Creek was dry during winter field surveys (Photo 20 & Photo 21). Flow changes as a result of SFPR construction could be the cause. Winter field observations indicate potential for re-classification from Class B to Class C (Figure 5: Location 17).

2.4 WATERCOURSE IMPACTS AND MITIGATION

The ravine watercourses and some of the Class B constructed channels have been observed to provide good quality fish and wildlife habitat. However, detrimental impacts to watercourses continue to occur including: erosion and scour, barriers to fish migration, damaged riparian habitat and degraded water quality.

2.4.1 Stream Erosion

Development in upland areas of the Manson catchment has contributed to increased peak flows and run off volumes during storm events and the concentration of flows at storm sewer outlets. Changes to flow patterns due to land development accelerate naturally occurring erosion processes by exposing the channel to more frequent, longer duration, high flow events.

The City of Surrey commissioned the Manson and Gunderson Slough Watersheds Stormwater Management Review and Feasibility/Functional Plan (Manson and Gunderson Slough SWMRFP) in 1999, which addressed erosion and sedimentation concerns in Robson Creek, Scott Creek, Delta Creek, Armstrong Creek and Shadow Brook. In 1999, the creek beds of Robson Creek, Armstrong Creek and Shadow Brook were contained within erosion resistant soils of densely packed sands and gravels. Conversely, the creek beds of Delta and Scott Creek had penetrated into a highly erodible ravine soil layer that caused severe creek erosion, slope instability and sedimentation problems in the downstream lowlands.

Phoenix observed Robson Creek at the intersection with the BC Hydro (SWM) Railway and below the detention pond at 100 Avenue. In-stream mossy boulders and limited visible scour presented indications of relative stream flow and channel stability in the Robson Creek ravine (Photo 22), at least at that location. The recent construction of the detention ponds in Robson Park, as recommended in the Manson and Gunderson's Slough SWMRFP (1999), have evidently limited erosion potential by detaining peak flows during storm events (velocity control) and promoting infiltration (volume reduction). In addition, the series of detention ponds on Robson Creek are anticipated to provide water quality treatment and additional aquatic productivity.

Along the escarpment, Scott Creek and Delta Creek were observed at 99 Avenue and 98A Avenue respectively. At the outlet of the Scott Creek culvert under 99A Avenue, medium sized boulders (0.40m) appeared relatively unstable in the creek bed, indicating recent movement during periods of high flow (Photo 23). On the north side of the escarpment at River Road above the detention pond, small (0.10m), moss covered, in-stream cobbles as well as riffle pool and glide pool habitat features indicate greater signs of stability within Scott Creek. Recent Beaver activity is also abundant in the Scott Creek pond at 99A Avenue (Photo 24).

At 99A Avenue and 96A Avenue in Delta Creek, undercut banks were observed along the escarpment slope (Photo 25), and in the lower reaches no significant indications of creek instability were observed. Refuse accumulation within the creek and residential use of the riparian area was also observed.

Phoenix observed Shadow Brook from the culvert outlet at Queen's Place to the culvert under the SFPR. Evidence of high flow velocity (large unstable rocks) (Photo 26), and scour around trees was observed at the Queen's Place outlet, as was significant accumulation of refuse in the creek (Photo 27). In the lower reaches, signs of stability increased and a new, apparently fish passable culvert was in place for passage under the SFPR (Photo 28). Observations of Armstrong Creek were limited, although step-pool habitat in the lower reaches was noted.

While observations of channel stability in the ravine streams by Phoenix have been limited for this assessment, it is evident that scour and erosion problems persist. Ravine Stability Assessments have been carried out (2002 – 2009) for the City, including the main ravine streams in the South Westminster ISMP Study Area. Areas of continuing localized bank failure and erosion have been documented at numerous locations along Robson, Scott and Delta Creeks. None of the identified sites are classified as high risk; however, two sites in Robson Creek and three sites in Delta Creek are identified as medium risk. This suggests that further work with regard to stormwater management BMP (e.g. volume reduction, velocity control) would be beneficial, as would relocation of various existing residential and commercial structures along and within ravine areas as re-development opportunities arise.

2.4.2 Fish Migration Barriers

The ravine streams within the South Westminster ISMP are classified as Class A watercourses that, in the absence of fish migration barriers, provide or potentially provide year round habitat for fish populations.

Robson Creek flows into a fish passable culvert at the intersection of 103A Avenue and 123A Street, where it is directed to the south side of 104 Avenue which connects to the upstream end of Manson Canal and flows to the Fraser River. An approximately 0.75 meter constructed weir after the second detention pond in the upper reaches of Robson Creek is a potential obstacle to fish passage preventing movement further upstream to the third detention pond (Photo 29), and may be required for water level controls between ponds. The weir could be augmented with a fishway, while still enabling water level controls between the detention ponds.

Additional information provided by Stephen Godwin, R.P.Bio., Environmental Coordinator for the City, following a review of the February 2013 edition of this report, has clarified that the above-noted detention pond weir on Robson Creek was constructed in order to address the elevation (i.e. buried depth) of a natural gas line through the park under the watercourse. The weir was allowed to be built in consideration of the gas line constraint through negotiation with DFO. There is not any interest by the City, nor any capability, to construct a fishway at the weir, as discussed above, due to construction issues relating to the gas line. Mr. Godwin has noted that the first time spawning coho salmon have reached the lower detention pond in Robson Park was in 2013.

Scott Creek is connected to the Fraser River via the Colliers Canal (BNR ditch). Although a 5-meter culvert extension is required to facilitate widening of the SFPR, a fish passable culvert under the SFPR should maintain fish passage upstream. As discussed in Section 2.3.3.9, field observation of Scott Creek just upstream of the culvert at 99 Avenue identified an approximately 1 meter weir that potentially limits fish passage beyond this point (Figure 4: Location 17; Photo 16). Further investigation is required to determine if fish are currently able to navigate into the upper reaches of Scott Creek and to identify opportunities to increase access around this potential fish migration obstruction.

Delta Creek is connected to the Fraser River via Collier Creek, Collier Canal (BNR ditch) and Manson Canal. Field observations did not identify any fish migration barriers in Delta Creek and the Fish Habitat Assessment for the SFPR indicates that fish passage in Collier Creek and Canal are not to be affected due to construction of the SFPR (now Highway 17).

Armstrong Creek and Shadow Brook are connected to Gunderson Slough through the Robson Road ditch. In 2006, Coast River Environmental identified the culvert under River Road and the BNSF railway as a potential barrier to fish migration upstream into Armstrong Creek. Field observations noted the recent installation of a fish ladder (Photo 30) on the north side of the BNSF railway, facilitating fish passage from the Robson Ditch under the SFPR and into Armstrong Creek (Figure 5: Location 18). Further assessment is required to evaluate if this culvert is no longer an obstacle to upstream fish migration.

Similarly, in 2006, Coast River Environmental identified the culvert connecting the Robson Road Ditch and Shadow Brook as potentially limiting fish passage into Shadow Brook. At the time, sampling in Shadow Brook upstream of River Road found only cutthroat trout even though coho were present on the downstream side of River Road in the Robson Road ditch. Due to SFPR construction, an approximately 15-m culvert extension was required, potentially decreasing the likelihood of fish passage into Shadow Brook. Field observation noted the recent installation of a fish passable culvert under the SFPR. However, the effectiveness of the fish passage culvert installed for the SFPR project will need to be confirmed (e.g. by fish sampling) after completion of SFPR construction (Figure 5, Location 18).

2.4.3 Riparian Habitat Damage

Disposal of refuse along ravine banks and along and within lowland drainage watercourses has been observed by Phoenix in many locations, and is evidently quite extensive within the Study Area. Discarded styrofoam, household garbage and other flotsam have been observed in Shadow Brook, Scott Creek, Delta Creek and Robson Creek. In addition, extensive use of riparian areas to discard gardening debris has been observed where residential development has extended to the top of ravine banks along many locations on all of the ravine streams within the study area. Public education and establishing wider setbacks from top of ravine banks if and as re-development occurs can mitigate these impacts.

Along many of the Class A(O) and Class B open drainage watercourses, riparian vegetation is either absent or dominated by blackberry, knotweed, policeman's helmet and other invasive plants, together with extensive refuse disposal. There is much potential to restore and enhance open channel fish habitats in the lowland areas of the Study Area; much of which may probably await re-development of these areas.

2.4.4 Water Quality

An assessment of water quality within the ISMP Study Area by Phoenix has been limited to visual indicators, and has not been supplemented by water quality testing due to the limited timeframe available for such testing (i.e. no time for replication or adjustment for seasonal effects).

2.4.4.1 North Slope Ravine Streams

Phoenix field visits have revealed generally good visual indicators of water quality within the South Westminster ravine streams, where cool and clear flows were exhibited. However, field surveys were completed during cold and dry conditions and it is anticipated that during wet weather periods, stormwater contaminants from roadways, construction site siltation releases, and high flow event bank erosion result in episodes of diminished water quality. These impacts can be progressively mitigated over time by ongoing public education and stormwater quality BMP. Continued protection and potential expansion of groundwater resources to ravine streams will remain very important for sustaining fish and aquatic habitat quality in the South Westminster Study Area. For example, infiltration of source-separated stormwater, or use of utility trenches for groundwater preferential pathways to watercourses (which already occurs), are opportunities for consideration under the ISMP. While none were observed during field reconnaissance, protection of any springs along the escarpment slopes also should be maintained.

2.4.4.2 Lowland Floodplain Watercourses

Many of the existing classified open channel watercourses (i.e. Class A(O) and Class B) within the ISMP Study Area have exhibited visual indications of poor water quality during the Phoenix field visits, even under winter (high precipitation, cool temperature) conditions. Algae growth on substrate, evidence of petroleum contamination (sheen) and in-stream refuse disposal were observed in many locations within the Study Area. In particular, poor water quality was visually detected in: the open channels beneath the Pattullo Bridge at the intersection of the CN Railway, the ditches along Timberland Road, on either side of 121 Street between 103A Avenue and 102 Avenue, and in the apparently stalled subdivision south of Old Yale Road along 124 Street.

While there are many challenges, reduced pollution of stormwater and open channel drainage watercourses can be achieved over time through education, compliance monitoring and enforcement, and eventual re-development opportunities. Enclosing the existing open drainage watercourses in storm sewers is not a recommended approach, as geotechnical investigations for the Royal City pump station (Golder, 1996) have confirmed that maintaining open channels is advisable instead of storm sewers that are prone to subsidence in the soft, compressible soils in this part of the ISMP Study Area. While open drainage channels may be more susceptible to refuse accumulations and other contaminant sources, these are considered to be preferable for aquatic productivity and potential for mitigation of water quality impacts by instream vegetation biofiltration.

2.4.5 Benthic Macroinvertebrates

The City of Surrey has commissioned routine benthic invertebrate community monitoring in numerous watercourses throughout the City since 1999, which can provide indicators of aquatic health. Data and reports made available by the City of Surrey were reviewed in an effort to draw general conclusions on aquatic health monitored streams within the South Westminster Study Area and its tributaries. Upon review of available metrics data for the Study Area, it was deemed that analysis of resultant Benthic Index of Biotic Integrity (B-IBI) information provided the clearest indication of aquatic ecosystem health.

2.4.5.1 Benthic Index of Biotic Integrity (B-IBI)

B-IBI is a recognized standard method for quantitative indications of the health of the aquatic ecosystem of a stream using analysis of the benthic macroinvertebrate population composition. The B-IBI is most useful in comparing streams with different watershed conditions or to track changes over time. Ten metrics are used, each with a possible score of 1, 3, or 5 for a combined possible total of 50 points. For each sampling date, the mean B-IBI of three replicates is reported.

Two monitoring stations relevant to this report have been established within the Study Area by the City of Surrey to monitor the composition of the benthic macroinvertebrates. They are:

- *D1* – Located in Delta Creek in the lower portion of the ravine stream near River Road
- *D2* – Located in Delta Creek in the upper portion of the ravine stream near 96 Avenue.

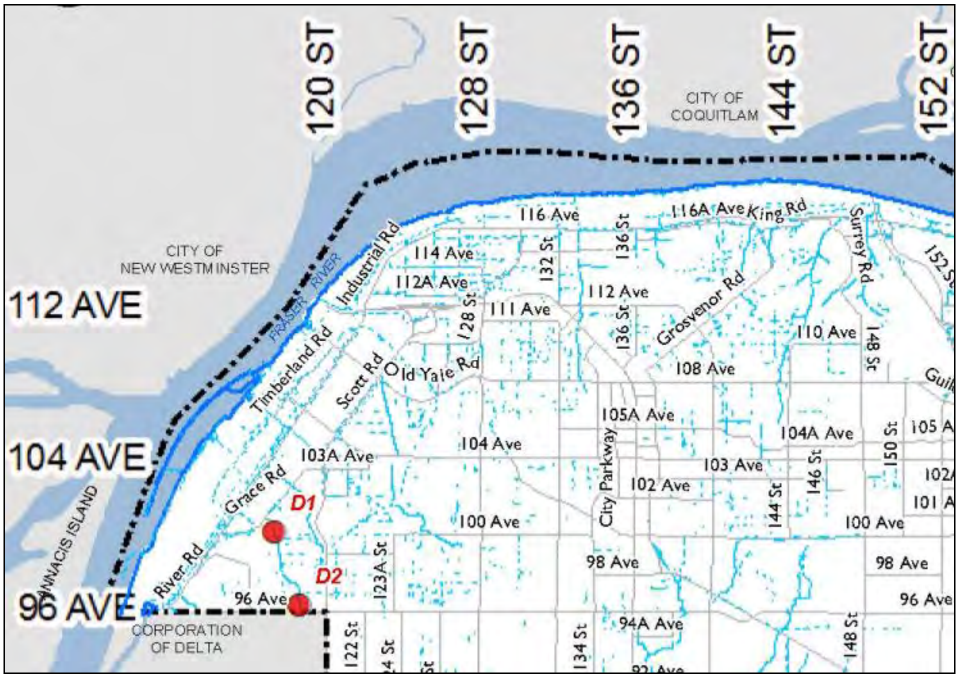


Figure: Approximate benthic community monitoring sites

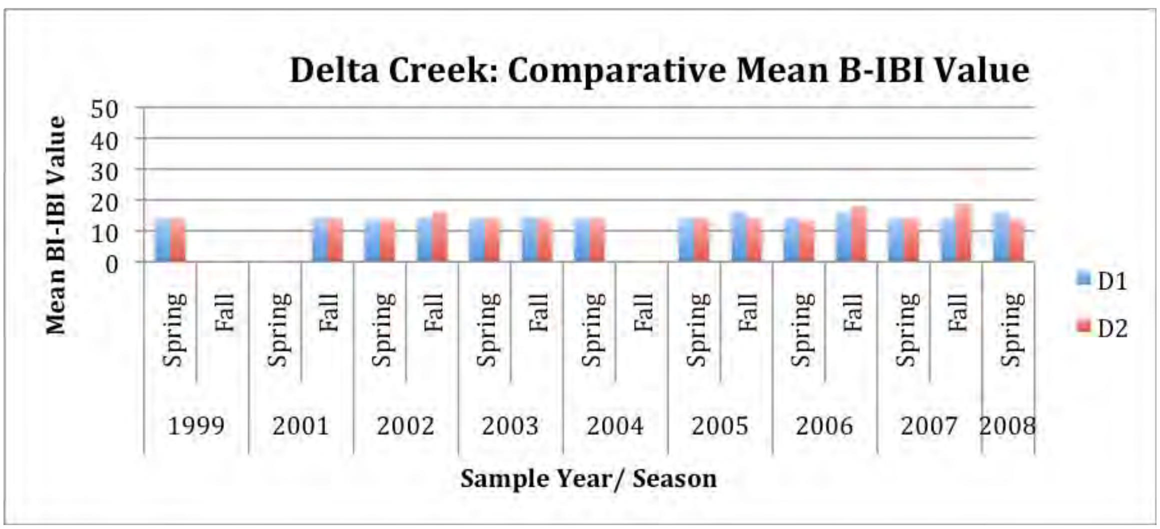


Table: Comparative mean B-IBI values for D1 and D2 sampling sites in Delta Creek between 1999 and 2008.

Data from D1 and D2 sampling stations comprising sampling results from 1999 to 2008 was provided by the City to Phoenix Environmental. At each sampling station, three benthic macroinvertebrate sample replicates were collected in the spring and fall of each year. Upon review of available data, it is apparent that Delta Creek has displayed consistently low B-IBI results with a minimum mean B-IBI of 13.8 and a maximum mean B-IBI of 18.6 since the commencement of monitoring in 1999.

2.4.5.2 Aquatic Ecosystem Health

Though available data is limited, the range of the entire mean B-IBI results (*n*=28) lies primarily within the "very poor" (10-16) range, with occasional results in the "poor" range (18-26) as defined for other large-scale comparative B-IBI studies in a similar geophysical settings (Morely, 2000).

From topical review of benthic macroinvertebrate data, it appears benthic communities in Delta Creek and its tributaries display symptoms of poor water quality and general anthropogenic pollution including (adopted from Morely, 2000):

- Depressed taxa richness,
- Dominance by a few pollution-tolerant species,
- Low presence and/or absence of longer living, pollution-intolerant species,
- Low relative abundance of predators.

Based on erosion and streambed scour issues documented at Delta Creek, supplementary benthic invertebrate community monitoring in Robson Creek would be helpful for comparison of streams with improved flow stability and those requiring greater flow stability.

3. TERRESTRIAL HABITATS

3.1 Vegetation Overview

Three vegetation types were identified within the Study Area:

1. Riparian Vegetation Type
2. Forested Blocks Vegetation Type
3. Right-of-ways and Fallow Fields Vegetation Type

Representative photographs of each of the vegetation types are in Appendix B. A list of observed vegetation within the vegetation types is included in Appendix C. The three vegetation types identified within the subject area are described below.

3.1.1 Riparian

The Riparian Vegetation Type occurred along all creeks and included the wetlands and ponds along Shadow Brook, Armstrong Creek, Delta Creek, Scott Creek, Robson Creek, Manson Canal and the vegetation along the treed portions of the banks of the Fraser River. The largest riparian zone occurred along the banks of Robson Creek, which originated near the centre of the Study Area and flowed northwest to the Fraser River. The developed upland areas surrounding these riparian habitats were typically developed to the top-of-bank (TOB). The vegetation composition along the sloped portions of all creeks were similar as they were generally dominated by western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*) with red alder (*Alnus rubra*) and bigleaf maple (*Acer macrophyllum*) (Attachment 2; Photograph 1). The shrub layer was mainly dominated by snowberry (*Symphoricarpos albus*) with salmonberry (*Rubus spectabilis*) dominating the ravine bottoms. Invasive species such as Himalayan blackberry (*Rubus discolour*) were regularly encountered. Sword fern (*Polystichum munitum*) typically dominated the herb layer.

The floodplain areas of the creeks were dominated by tree species including red alder and black cottonwood (*Populus balsamifera*). Salmonberry and reed canarygrass (*Phalaris arundinacea*) dominated the shrub and herb layers. Patches of Himalayan blackberry and red-osier dogwood (*Cornus stolonifera*) were also encountered.

The lowland portions of all creeks were all channelized forming either ditches or canals that eventually drained into the Fraser River (Photo 31). These channelized portions were typically dominated by young black cottonwood and red alder with Himalayan blackberry and reed canarygrass.

Three linear strips, approximately 500 m in length, of mature black cottonwoods were observed along the predominately developed banks of the Fraser River.

Three beaver (*Castor canadensis*) ponds were observed in these habitats. An active beaver pond was observed at the base of Scott Creek (Photo 33). In addition, active beaver ponds (Appendix A: Figure 6) were observed near the headwaters of Robson Creek (Photo 34) and Manson Creek (Photo 35). In addition to the beaver ponds, significant wetlands with open water and a large stormwater detention pond were observed near the base of the escarpment (Figure 6). Wetland vegetation species such as cattails (*Typha latifolia*) were commonly observed surrounding these waterbodies (Photo 36 & Photo 37).

3.1.2 Forested Blocks

The Forested Blocks Vegetation Type was associated mainly with the escarpment and a number of small parks within the Study Area. Most forested parks were conifer dominated with western redcedar, Douglas-fir (*Pseudotsuga menziesii*) and western hemlock commonly encountered. Patches of deciduous trees were also observed including red alder, bigleaf maple and paper birch (*Betula papyrifera*). The understorey was composed generally of sparse to moderate (5 - 50%) cover of shrubs including salmonberry, vine maple (*Acer circinatum*) and red huckleberry (*Vaccinium parvifolium*). Sword fern typically dominated the herb layer (Photo 38).

The forested portions of the escarpment were dominated by deciduous tree species such as black cottonwood, red alder and bigleaf maple. The moderate to dense (25 - 80%) shrub layer was dominated by salmonberry. Sword fern was commonly encountered in the sparse (2 - 10%) herb layer (Photo 39).

3.1.3 Right-of-Ways and Fallow Fields

The Right-of-ways and Fallow Fields Vegetation Type was situated mainly along the BC Hydro (SWM) Railway with the fallow fields portion generally associated with the lowland industrial areas.

The vegetation along the railways was dominated mainly by Himalayan blackberry (Photo 40).

The fallow field habitats were dominated by invasive species such as Himalayan blackberry as well as reed canary grass and other gramanoid species (Photo 41).

3.2 WILDLIFE TREES

A wildlife tree is any standing dead or living tree with special features that provides present or future critical habitats for the maintenance or enhancement of wildlife. There are nine classifications of coniferous and six classes of deciduous wildlife trees in various successions from live and healthy with no decay, to stumps and debris (Fenger et al. 2006). All of these wildlife tree stages provide important habitat, and are known to support more than 90 animal species in British Columbia, including cavity nesting birds and mammals (Backhouse 1993). Some of the uses include nesting, feeding, territoriality (i.e. bear mark trees, bird singing sites, etc.), roosting, shelter, and overwintering (Backhouse 1993).

There are nine decay classes of coniferous trees and six decay classes of deciduous trees within British Columbia (Fenger et al. 2006). Most of the trees observed in the Study Area were identified as Class 1 wildlife trees. Class 1 wildlife trees are described as live healthy trees with no decay. Class 2 to 9 wildlife trees were also identified within the Study Area. Most of the decayed trees were situated within the riparian areas of all watercourses (Photo 42). A figure with a description of each of the decay classes can be found in Appendix C.

Due to survey timing (winter), no active nests were observed within the Study Area during the field program. Nest cavities (likely from this breeding season) were detected in many of the wildlife trees observed. A number of old cavities were also observed in many of the wildlife trees encountered. Pileated Woodpecker (*Dryocopus pileatus*) foraging sign was observed on many of the wildlife trees. Three Common Flickers (*Colaptes auratus*) were observed within the riparian areas and forested blocks during the field assessment. These trees also provided habitat for many bird and mammal species including songbirds, squirrels and bats.

A Red-tailed Hawk was observed perched in a tree near Armstrong Creek and River Road during the field survey. One Bald Eagle nest was also observed (Photo 31). No Great Blue Heron nests were observed within the Study Area during the field investigation.

3.3 COARSE WOODY DEBRIS

CWD is typically described as woody debris greater than 0.3 m in diameter. CWD provides critical foraging, nesting, and cover components in the forested ecosystem for small mammals, amphibians, reptiles and invertebrates (Anonymous 1991). Many insectivorous small mammals, birds, and black bears feed on insects found in decomposing woody material. CWD provides a safe, moist environment in which species such as salamanders and shrews can forage and seek shelter.

Good CWD cover (5-15%) was recorded within most of the riparian habitats within the Study Area. CWD cover within the forested blocks varied from sparse to moderate (1-5%) (Photo 38). No CWD was observed within the ROWs and Fallow Fields Vegetation Type.

3.4 Sensitive Vegetation Species

Due to survey timing (winter) the presence of many herbaceous vegetation species could not be confirmed during the field survey. Table 1 lists federally and or provincially listed vegetation species that occur or may occur within the Study Area. Sections 3.4.1 to 3.4.6 present descriptions for federally and/or provincially listed species that have historically been recorded within the Study Area.

3.4.1 False-pimpernel

This provincially Blue-listed species occurs on wet, sandy or muddy banks and shores in the drier lowland and steppe subzones of the Bunch Grass (BG), CWH and Interior Douglas-fir (IDF) biogeoclimatic zones within British Columbia. It is considered rare in south-central British Columbia and the lower Fraser Valley (Douglas et al. 2002).

One BCCDC record for this species occurred within the Study Area along the Fraser River, near the Fraser Surrey Docks (Appendix A; Figure 6). The plants were situated in mud along the tidal foreshore (BCCDC 2013[1]). The current status of this population is unknown.

3.4.2 Pointed Broom Sedge

This provincially Blue-listed species typically occurs in moist to wet ditches, lakeshores, marshes and fallow fields. It is considered rare in southern British Columbia and the lower Fraser Valley (Douglas et al. 2002).

One BCCDC record for this species occurred within the Study Area along the Fraser River, near the Pattullo Bridge (Appendix B: Figure 7). The plants were situated in wet ground (BCCDC 2013[1]). The current status of this population is unknown. The banks of all creeks, ditches and ponds in the lowland portions of the Study Area provided potential habitat for this Blue-listed species.

3.4.3 Streambank Lupine

The streambank lupine is listed under Schedule 1 (part 4) of SARA. It is only found along the Pacific Coast of North America, from southwestern British Columbia to northwestern California. There are six known populations in the southwestern corner of British Columbia with five in the lower Fraser Valley and one is on Vancouver Island. The populations of these six sites ranged from 1 to 100 plants (EC 2013[1]).

One BCCDC record for this species occurred within the Study Area (Figure 7). This record is associated with three sites near Surrey Fraser Docks. These sites were situated beside railway tracks and/or roadsides (BCCDC 2013[1]). A follow up survey for this species was conducted in 2008 but presence of this species could not be confirmed (BCCDC 2013[1]). Portions of all rail right-of-ways within the lowland portion of the Study Area may provide habitat for this Blue-listed species.

Table 1: Federally and/or provincially listed plant species that may occur within the Study Area (SARA 2013; BCCDC 2013[1]).

Species	Federal/Provincial Status		Legislation			Site Occurrence
Common/Scientific Name	COSEWIC/SARA Status	BCCDC Status*	SARA	Provincial Identified Wildlife	Provincial Wildlife Act	Expected Onsite Habitat Use
Vegetation:						
False-pimpernel (*Linderniadubia anagallidea*)	-	Blue	-	-	-	**Suitable –** one record (3276) occurred within the tidal zone of the Fraser River. Two additional records occurred adjacent to the Study Area. The banks of all creeks provided potential habitat for this species.
Pointed Broom Sedge (*Carex scoparia*)	-	Blue	-	-	-	**Suitable** – one record (3412) occurred within the tidal zone of the Fraser River, beneath the Pattullo Bridge. The moist to wet ditches and fallow fields of the Study Area provided potential habitat for this species.
Streambank Lupine (*Lupinus rivularis*)	Endangered (November 2002)	Red	Y	-	-	**Suitable** – one record (3052) occurred along Timberland Road. The railway beds, wet to moist fallow fields and banks along area floodplains provided potential additional habitat for this species.
Three-flowered Waterwort (*Elatine rubella*)	-	Blue	-	-	-	**Suitable** – one record (3010) occurred within the tidal zone of the Fraser River, beneath the Pattullo Bridge.
Two-edged Water-starwort (*Callitriche heterophylla var. heterophylla*)	-	Blue	-	-	-	**Suitable** – one record (2994) occurred within the tidal zone of the Fraser River, near the Fraser Surrey Docks.
Vancouver Island Beggarticks (*Bidens amplissima*)	Special Concern (November 2001)	Blue	Y	-	-	**Suitable** – one historical record (40186) occurred near the foot of Grace Road. The moist to wet ditches, streambanks and pond edges, particularly along the Scott Creek and Manson Creek floodplain areas provided potential habitat for this species.

*Red= Extirpated, Endangered or Threatened *Blue= Special Concern

The City of Surrey (S. Godwin) has confirmed that there is a patch of streambank lupine located on the north side of Grace Rd. at Scott Creek, which is being actively managed by the City. Management efforts include: exclusion fencing, signage, and colony maintenance through on-going irrigation and weeding.

3.4.4 Three-flowered Waterwort

This provincially Blue-listed species typically occurs in wet ditches, mudflats and shallow ponds and shorelines. It is considered rare in southern British Columbia and the lower Fraser Valley (Douglas et al. 2002).

One BCCDC record for this species occurred within the Study Area. This record is associated with a site near Surrey Fraser Docks (Figure 6). The record is of a single small clump, submerged at high tide, along the muddy shore of the Fraser River (BCCDC 2013[1]). The current status of this population is unknown. The banks of the Fraser River, within the Study Area, provided potential habitat for this Blue-listed species.

3.4.5 Two-edged Water-starwort

This provincially Blue-listed species typically occurs in shallow ponds, slow-moving streams and shorelines in the CWHxm1. It is considered rare in coastal British Columbia (Douglas et al. 2002).

One BCCDC record for this species occurred within Study Area along the Fraser River, beneath the Pattullo Bridge (Figure 6). The plants were situated within the tidal zone (BCCDC 2013[1]). The current status of this population is unknown. The banks of the Fraser River, within the Study Area, provided potential habitat for this Blue-listed species.

3.4.6 Vancouver Island Beggarticks

The Vancouver Island beggarticks is listed under Schedule 1 (part 4) of SARA. Except for a single historical location on a research station in Brandon, Manitoba, the entire global range of the species occurs in the Pacific Northwest of North America. In Canada, it has been found in the Lower Fraser Valley and on Southern Vancouver Island, with one additional record on the mainland coast of British Columbia just north of Vancouver Island. The Vancouver Island beggarticks is a wetland species found occasionally in successional wetlands, but is generally limited to a very narrow band of habitat around pond, lake and stream margins, areas where annual and seasonal water level fluctuations are prevalent. It tends to occur in sites where waterfowl are common and shows a distinct preference for silty alluvial soils (EC 2013[2]).

One BCCDC record for this species occurred within the Study Area (Figure 7). The habitat for this record was described as a moist ditch bank near railroad tracks near the Surrey Fraser Docks (BCCDC 2013[1]). The current status of this population is unknown. The ditches, ponds and wetlands within the lowland portions of the study area may provide habitat for this Blue-listed species.

3.5 Sensitive Ecological Communities

The BCCDC defines listed ecological communities as natural plant communities and plant associations. These communities and associations include a wide range of known ecosystems with their environmental site requirements such as soil moisture and nutrients, climate, physiographic features and energy cycles. These sites are generally old growth stands that are usually 500 m^2 or greater. These ecosystems are often the remnants of the natural ecosystems that once occupied a much larger area. Typically, mature and old growth upland ecological communities are of concern to the BCCDC. In addition, all listed riparian, wetland and estuarine communities at any growth stage are also of concern to the BCCDC (K.A. McIntosh pers. comm.). The listed ecological communities are classified using methodologies and nomenclature developed by Green and Klinka (1994).

The forested portions within the Study Area were second to third growth stands. Of the 15 forested ecological communities identified within the CWHdm, fourteen have been identified as either Red or Blue-listed by the BCCDC. In addition, one non-forested site has also been listed. Of the 15 forested ecological communities identified within the CWHxm1, all fifteen have been identified as either Red or Blue-listed by the BCCDC. In addition, 8 non-forested ecological communities have also been listed.

The area southwest of Robson Creek fell within the CWHxm1. Robson Creek and the remaining portion of the Study Area to the northeast fell within the CWHdm.

Robson Creek ravine and the escarpment fell within the CWHdm. These forested areas were generally the Blue-listed Western Redcedar Sword Fern (Site Series 05) ecological community and the ravine bottom was identified as the Blue-listed Western Redcedar – Foamflower (Site Series 07). The cattail dominated ponds at the headwaters area of Robson Creek were classified as the Blue-listed Common Cattail Marsh (Site Series Wm 05).

Based on data collected during the field program the ravine slopes of Armstrong Creek, Delta Creek and Scott Creek fell within the CWHxm1 BGC subzone and were classified as the Blue-listed Western Redcedar Sword Fern (Site Series 05) ecological community. The bases of these ravines were dominated by the Red-listed Western Redcedar – Foamflower (Site Series 07). The Scott Creek floodplain, beaver pond and stormwater detention ponds and portions of Manson Canal within 12780 110th Street were classified as the Blue-listed Common Cattail Marsh (Site Series Wm 05).

Invasive vegetation species were encountered at many of the habitats and ecological communities observed within the Study Area and included species such as Himalayan blackberry, Japanese knotweed, scotch broom and English ivy. These invasive plant species were regularly encountered along interfaces of forested and disturbed or developed sites.

4. WILDLIFE INVENTORY AND HABITAT

Wildlife sign and activity was recorded throughout the Study Area. Songbirds were observed flying and feeding in vegetation throughout the site. Suitable nesting habitat for raptors such as

Bald Eagle, Red-tailed Hawk, Cooper's Hawk and owls were observed in most forested areas. Sign of coyote and beaver were detected within the Study Area. A Bald Eagle was observed along the Fraser River. All animal species detected are listed in Appendix C.

4.1 WILDLIFE SPECIES

No provincially listed wildlife species were detected during the field program. Sign of coyote, beaver, grey squirrel, woodpecker and passerines were detected within the Study Area. One Red-tailed Hawk was perched within the project area. Most of the treed portions within the Study Area provided potential breeding/roosting habitat for raptors, passerines, woodpeckers and a number of bat species.

4.2 FEDERALLY AND PROVINCIALLY LISTED WILDLIIFE SPECIES OF CONCERN

The BCCDC website was searched for all species listed under SARA, COSEWIC, Provincial Identified Wildlife and the Provincial *Wildlife Act* that are suspected to occur within habitats identified within the South Westminster ISMP Study Area. The following are the results of the habitat assessment for each of the six species. Habitats were assessed for six wildlife species listed in Table 2.

4.2.1 Red-legged Frog

In addition to being listed on Schedule 1 (Part 4) of SARA, the red-legged frog is also listed on the provincial Blue List (BCCDC 2013[1]). Red-legged frogs in BC are found in moist forests and in forested wetlands (Corkran and Thoms 1996). Adults will often wander far from standing water to forage on small insects or forest invertebrates (Nussbaum et al. 1983 in Ovaska and Sopuck 2004). Generally, they breed in cool, shaded temporary ponds where they attach their eggs to submerged woody debris or vegetation (Corkran and Thoms 1996). Critical habitats for the red-legged frog would include all temporary and permanent breeding ponds. CWD would also be considered a critical habitat element for cover and foraging.

No red-legged frogs were detected during the winter field survey. Red-legged frogs are generally not active in the winter which limits their detection. The stormwater detention ponds, beaver ponds and cattail marshes within the Study Area provided suitable breeding habitat for red-legged frog. The forested blocks and creeks provided suitable rearing habitat for red-legged frog and many other amphibian species.

4.2.2 Western Screech-owl

In addition to being listed on Schedule 1 (Special Concern) of SARA, the kennicottii subspecies of the Western Screech-owl is also listed on the provincial Blue List (BCCDC 20131). Along the coast the Western Screech-owl seems to be mostly found in either coniferous or mixed (deciduous or coniferous) forests, particularly near riparian areas. This owl prefers open forest for foraging and requires cavities in old, large trees for nesting and roosting. During the daytime it roosts in either coniferous or deciduous trees (COSEWIC 2002).

Table 2. Federally and/or provincially listed wildlife species that may occur within the Study Area (SARA 2013; BCCDC 2013[1]).

Species	Federal/Provincial Status		Legislation			Site Occurrence
Common/Scientific Name	COSEWIC/SARA Status	BCCDC Status*	SARA	Provincial Identified Wildlife	Provincial Wildlife Act	Expected Onsite Habitat Use
Vertebrates: Amphibians						
Red-legged Frog (*Rana aurora*)	Special Concern (November 2004)	Blue	**Y**	**Y**	**Y**	**Suitable** –Breeding habitat (ponds) occurred within Robson Creek, Scott Creek and Manson Creek beaver ponds, and stormwater detention ponds. Rearing habitat occurred along most riparian areas and forested blocks.
Western Screech-owl (*Megascops kennicottii kennicottii*)	Special Concern (May 2002)	Blue	**Y**	**Y**	**Y**	**Suitable** – The riparian habitat of all watercourses provided moderate to high rated nesting and roosting habitat.
Great Blue Heron (*Ardea herodias fannini*)	Special Concern (April 2008)	Blue	**Y**	**Y**	**Y**	**Suitable** – Potential nests sites occurred in the mature trees within the Study Area. Particularly along the Fraser River.
Vertebrates: Mammals						
Pacific Water Shrew (*Sorex bendirii*)	Endangered (April 2006)	Red	**Y**	**Y**	**Y**	**Suitable –** Moderate to high rated habitats were detected along all creeks within the Study Area.
Trowbridge's Shrew (*Sorex trowbridgii*)	-	Blue	**-**	-	**Y**	**Suitable** – Moderate to high rated habitats were detected along all creeks within the Study Area.
Invertebrates:						
Pacific Sideband (*Monadenia fidelis*)	-	Blue	-	-	-	**Suitable** – Moderate rated habitat occurred within the riparian and forested block of the Study Area.

*Red= Extirpated, Endangered or Threatened *Blue= Special Concern

Although Western Screech-owl was not detected during the field surveys, the forested riparian zones of all creeks within the Study Area provided potential breeding and roosting habitat for this owl species.

4.2.3 Great Blue Heron

In addition to being listed on Schedule 1 (Special Concern) of SARA the Great Blue Heron *fannini* subspecies is also listed on the Provincial Blue List (BCCDC[1] 2013). In British Columbia Great Blue Heron populations have been decreasing, resulting in the listing of this species (MELP 1998). Population decreases are believed to be the result of human disturbance (EC[3] 2013). Great Blue Herons nest in a wide variety of tree species. Foraging habitat does not appear to be limiting factor for this subspecies as not all available habitat is used by herons each year (Campbell et al. 1990). Critical nesting habitat includes both an established colony and a suite of alternative sites to retreat to should disturbance occur.

No Great Blue Heron nests were detected during the field survey. The mature trees within the Study Area, particularly along the Fraser River, provided potential nesting habitat for this subspecies.

4.2.4 Pacific Water Shrew

Pacific water shrews are usually associated with riparian areas (Nagorsen 1996; Craig 2003). Past studies have reported that the majority of water shrews were captured within 25 m of streams, however in moist forests, Pacific water shrews can be found up to 1 km from water (Pattie 1973 in Craig 2003). The home range of the Pacific water shrew is suspected to be 400 m along a waterbody (Craig 2003).

In British Columbia, capture sites appear to be primarily associated with coniferous or deciduous forest with capture sites located very close to water. Habitat components usually found at Pacific water shrew sites include the presence of red alder, bigleaf maple, western hemlock or western redcedar that border streams and skunk cabbage marshes (Nagorsen 1996). In addition, Pacific water shrews have also been captured in more open habitat, with dense marsh vegetation. These include reed canary grass vegetated roadside ditches and water bodies within highway medians (C. Schmidt, pers. comm.). CWD also seems to be an important habitat component. The presence of moist habitat appears to be more important than forest age (Craig 2003).

No Pacific water shrews were detected during the field survey. All creeks, ponds and wetlands within the Study Area provided moderate to high rated habitat for this species.

4.2.5 Trowbridge's Shrew

The Trowbridge's shrew is Blue-listed by the BCCDC (BCCDC 2013[1]). Trowbridge's shrew use both riparian and non-riparian forest (Zuleta and Galindo-Leal 1994). In non-riparian forests, the Trowbridge's shrew has shown a preference for areas with a high moisture regime (Nagorsen 1996).

Critical habitat elements for this species include rich soils and abundant decaying CWD and leaf litter on the forest floor (Nagorsen 1996). Ground litter, woody debris and shrub cover provides a secure environment for tunnelling and nesting.

All riparian habitats that provided moderate to high rated habitat for Pacific water shrew also provided moderate to high rated habitat for Trowbridge's shrew based on the presence of preferred vegetation and habitat features.

4.2.6 Pacific Sideband

The Pacific sideband snail is Blue-listed by the BCCDC (BCCDC 2013[1]). This large snail species is found from Alaska to California; west of the Coast and Cascade Mountains. Pacific sidebands live in deciduous, coniferous or mixed forests as well as in open forests and grassy areas (Forsyth 2004).

No Pacific sideband snails were detected within the Study Area. Pacific sideband snails are typically dormant in the winter which limits their detection. The riparian areas and forested blocks within the Study Area provided potential habitat for Pacific sideband snail.

4.3 Wildlife Corridors

Moderately used wildlife trails, attributed to coyotes, were detected within the Study Area. Coyote sign was particularly abundant along the escarpment area and along the SRY ROW. Grey squirrels (*Sciurus carolinensis*) were observed throughout the Study Area. Sign of beaver were observed within the ponds of Scott Creek, Robson Creek and Manson Creek. These animals appeared to travel mainly along the watercourses and riparian areas. In addition to coyotes and beaver, these corridors are likely used by many species of small mammals, birds, amphibians and reptiles.

5. SENSITIVE ENVIRONMENTAL AREAS

5.1 Watercourses and Riparian Habitats

The priority areas for protection include the Class A and B streams and their riparian areas and remaining forest stands of $\geq$ 1 hectare. Watercourses and their riparian areas in the City are currently protected by the Land Development Guidelines for the Protection of Aquatic Habitat. Under this regulation, setbacks for streams range from 15-30 meters from the high water mark or from the top of ravine (if slopes steeper than 3:1 exist) depending on the density of development at a site. Most of the existing development around streams in the Study Area occurred prior to the application of setbacks.

5.2 Interior Forest Habitat

Interior forests habitat are areas beyond the microclimatic and biotic effects of forest edges. Interior forests provide stable environmental conditions that are required for certain plant and animal communities. This habitat type can occur in any forest type of any age, however, as development continues, and large forested areas become fragmented, the quality and quantity of interior forest habitat decreases (Bannerman 1998). Although large forested blocks along the escarpments and Robson Creek Ravine are present, these are too narrow and disturbed (e.g. Old Yale Road traversing the escarpment) to provide interior forest habitat. Interior forest habitats are not present in the ISMP Study Area.

The City of Surrey's Biodiversity Conservation Strategy (BCS), adopted by the City in 2014, has identified several Green Infrastructure Network (GIN) Corridors within the ISMP study area. The Biodiversity Conservation Strategy, building on the 2011 Ecosystem Management Study prepared for the City, has identified key habitat areas across the City; which vary in type, size and condition. Large intact core habitat areas (Hubs) are essential to supporting and conserving biodiversity within the City. Smaller patches of habitat (<10 ha) have been identified as Sites; which provide habitat for fewer species with smaller home ranges, and often species tolerant of human disturbance. Corridors are linear habitat areas that encourage the movement of species between fragmented hubs and sites.

A substantial length of GIN Corridor extends southward along the escarpment within the ISMP study area from Bolivar Park and Poplar Park to the northeast, the forested slopes north of Old Yale Road and south of 110 Ave., and along the BC Hydro Railway to Delta Creek and its ravine. This corridor intersects a network of other corridors extending north and west along large ravines and watercourses through the extensively industrialized lowlands toward the Fraser River. The network of other GIN Corridors within the ISMP study area include Robson Creek, Manson Canal, Scott Creek, Delta Creek, and Colliers Canal to Shadow Brook at the boundary with Delta and nearby Gunderson Slough.

Further fragmentation of forested areas should be avoided to preserve the remaining forest habitat and corridor values identified under Biodiversity Conservation Strategy.

6. CONCLUSIONS

This Environmental Assessment for Stage 1 of the South Westminster ISMP has included use of existing research and reports, as well as limited field reconnaissance, to conduct an inventory and assessment of the fish, aquatic and wildlife habitats within the ISMP Study Area. The South Westminster ISMP Study Area is characterized by urban and industrial land uses with predominately single-family residential areas south of the escarpment and mixed industrial and commercial within the lowland floodplain areas near the Fraser River. The Study Area has been largely built-out with negligible undeveloped lands, such that remaining streams, forested and environmentally sensitive areas have become a scarcity and of significant retention value, even where degraded by urban activities.

The watercourses within the ISMP Study Area can be separated roughly into three categories: Ravine Streams and tributaries, Constructed Fish Habitat Drainage Watercourses, and Constructed drainage ditches (not fish habitat). The City of Surrey's Fisheries Watercourse Classification system has been applied to assess and classify watercourses in the Study Area. Several changes in the City's online mapping (COSMOS) are proposed to address unmapped watercourses, inaccurately mapped watercourses, and to address proposed re-classifications of watercourses. Numerous potential re-classifications of watercourses require further assessment after completion of the SFPR, as the nature of culvert crossings and habitat enhancement works have not been determined during this assessment.

A number of issues relating to watercourses in the ISMP Study Area have been identified, including: stream erosion, fish migration barriers, riparian habitat damage and water quality.

Development in upland areas of the Pattullo and Manson catchments has contributed to increased peak flows and run off volumes during storm events and the concentration of flows at storm sewer outlets. Changes to flow patterns due to land development accelerate naturally occurring erosion processes, by exposing the channel to more frequent, longer duration, high flow events. Construction of detention ponds in Robson Creek has likely limited the erosion potential within that watercourse. However, ravine stability assessments (2002 – 2009) indicate that numerous localized bank erosion problems persist within the South Westminster ravine streams. Further storm water management that aims reduce the volume and control the velocity of stormwater in the Study Area would help minimize the ongoing erosion within the ravine streams.

Phoenix has observed potential obstructions to fish passage in the upper reaches of Scott and Robson Creek (e.g. weir between detention ponds on Robson Creek). However, the lower reaches of these streams and the other ravine streams within the Study Area are accessible to fish, and spawning coho have reached the lower detention pond in Robson Creek at Robson Park for the first time in 2013. In the case of watercourses draining to Old Yale Road, while of low gradient and thereby passable, the length of storm sewer (>1 km) along extensively industrialized land uses with associated drainage water quality risks raises questions about the probability of fish migration from the Fraser River into two watercourses currently classified as Class A and Class A(O). Culvert extensions due to the construction of the South Fraser Perimeter Road (SFPR) could decrease potential for fish migration upstream, depending on completed design features following construction. It is expected that maintaining fish passage in Class A and Class A(O) watercourses has been critically important during design and construction. The installation of fish passable culverts and fish ladders under the SFPR into Shadow Brook and Armstrong Creek have likely improved fish access into the upper reaches of those watercourses. Re-assessment of watercourses affected by SFPR construction should be conducted now that construction of the SFPR/ Highway 17 is complete.

Riparian habitat damage from refuse disposal and long-term structures built at or very close to watercourse banks and ravine crests occurs extensively throughout the Study Area. Infill and re-development that may be proposed in the future should be used as an opportunity to increase the riparian buffer widths from the ravine top of the bank along watercourses, remove refuse and restore damaged habitat, and to include measures to avoid encroachment into protected riparian habitat. Water quality issues are most prevalent in the lowland floodplain and industrialized areas of the ISMP Study Area. Benthic invertebrate community monitoring has been seasonally conducted at two locations win Delta Creek from 1999-2008 to provide indicators of aquatic health. The B-IBI results indicate that Delta Creek is consistently in the ‘Very Poor’ to “Poor” range. Based on erosion and streambed scour issues documented at Delta Creek, supplementary benthic invertebrate community monitoring in Robson Creek would be helpful for comparison of streams with improved flow stability and those requiring greater flow stability.

Vegetation species listed under the *Species at Risk Act* (SARA) were not detected during the field program. Due to survey timing (winter), many herbaceous species could not be identified. The ISMP study area may provide habitat for at least six listed species, including the SARA listed Vancouver Island beggarticks (*Bidens amplissima*) and streambank lupine (*Lupinus rivularis*), as well as the provincially Blue-listed false-pimpernel, pointed broom sedge, three-flowered Waterwort and Two-edged Water-starwort. The City has confirmed the presence of a colony of streambank lupine at Grace Rd. and Scott Creek, which is being actively managed by the City. During the appropriate season and prior to clearing activities within the Study Area, a rare plant surveys for these species should be completed in the areas of documented occurrence and suitable habitats as described in this report. Invasive vegetation species were regularly encountered along interfaces of forested and disturbed or developed sites. These invasive species included Himalayan blackberry (*Rubus discolor*), Japanese knotweed (*Polygonum cuspidatum*), scotch broom (*Cytisus scoparius*) and English ivy (*Hedera helix*). Removal of these invasive plant species at strategic sites would benefit many native wildlife and vegetation species and improve existing wildlife corridors.

All riparian areas (creeks, ponds and wetlands), forested blocks, fallow fields and undeveloped right-of-ways (ROW) encountered were assessed during the field program. These areas were part of potential wildlife corridors and habitats that may be used by at least 12 federally or provincially listed terrestrial wildlife and vegetation species. The riparian habitats, forested blocks, ponds and ROWs were identified as having high wildlife values within the Study Area and provided moderate to high rated habitat for a number of federally listed wildlife species including Pacific water shrew (*Sorex benderii*), red-legged frog (*Rana aurora*) and Western Screech-owl (*Megascops kennicottii kennicottii*). These riparian areas and forested stands also provided important nesting habitat for other wildlife including raptors such as Bald Eagle (*Haliaeetus leucocephalus*), Red-tailed Hawk (*Buteo jamaicensis*) and Cooper's Hawk (*Accipiter cooperii*). Wildlife sign encountered during the field program included coyote (*Canis lantrans*) and beaver (*Castor canadensis*). The ponds, watercourses and associated terrestrial habitats provided important habitat for many waterfowl, songbird and amphibian species. The riparian zones of all creeks provided moderate to high rated habitat for the provincially listed Trowbridge's shrew (*Sorex trowbridgii*) and Pacific sideband snail (*Monadenia fidelis*).

The relatively few and fragmented forested areas remaining in the Study Area have not changed substantially over many years, given the long history and density of urban development in the Study Area. Remaining forest patches need to be protected and wildlife movement corridors need to be maintained or established to improve the ecological integrity of the Study Area and to provide suitable living habitats for sensitive species. Provision of natural habitats that have protected corridors will result in increased biodiversity within the Study Area, in support of the City's Biodiversity Conservation Strategy.

7. REFERENCES

Abs, S., et.al. 1990. Finding the balance: environmentally sensitive areas in Surrey. Rep. prep, for District of Surrey planning and development services, by Susan Abs and Assoc., Catherine Berris Assoc. Inc., Regional Consulting Ltd., Maclaren Plansearch Corp. July. 67 pp.

Anonymous. 1991. BC Environment planning for the future: Managing wildlife to 2001:a discussion paper. BC Environment, Wildlife Branch. 152 pp. (1993 update).

Associated Engineering (B.C.) Ltd. 1999. Manson and Gunderson's Slough and Watersheds Storm Water Management Review and Feasibility/Functional Plan, Project: 4897-731.

Associated Engineering Services Ltd. 2002. Surrey Ravine Stability Assessment.

Associated Engineering Services Ltd. 2006. City of Surrey Ravine Stability Assessment Update.

Backhouse, F. 1993. Wildlife tree management in British Columbia. BC Ministry of Environment, Lands and Parks, Worker's Compensation Board of BC, BC Silviculture Branch and Canada-BC Partnership Agreement on Forest Resource Development: FRDA II.

Bannerman, S. 1998. Biodiversity and Interior Habitats: The Need to Minimize Edge Effects. B.C. Ministry of Forests Research Program, Victoria, B.C. Extension note 21, pp. 1-8.

BC Conservation Data Centre (BCCDC) 2013[1]. BC Species and Ecosystems Explorer. Victoria, BC, Canada. http://srmapps.gov.bc.ca/apps/eswp/.

BC Conservation Data Centre (BCCDC) 2013[2]: Conservation Data Centre Mapping Service [web application]. Victoria, British Columbia, Canada. Available: http://maps.gov.bc.ca/imf50/imf.jsp?site=cdc.

Campbell, R.W., N.K. Dawe, I.McTarrart-Cowan, J.M. Cooper, G.W. Kaiser and M.C.E. McNall. 1990. The Birds of British Columbia. Volume 2. Nonpasserines. Diurnal birds of prey through woodpeckers. Royal British Columbia Museum, Victoria, B.C. 636 pp.

City of Surrey (CoS). 2013. Online Web Map: http://cosmos.surrey.ca/Geocortex/EssentialsExternal/web/Viewer.aspx?Site=City%20Map. (accessed January 15, 2013). City of Surrey. 55 pages + appendicies.

Coast River Environmental Services Ltd. 2006. Fish Habitat Impact Assessment, South Fraser Perimeter Road, Technical Volume 9 of the Environmental Assessment Application. Prepared for the Ministry of Transportation.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC) 2002. COSEWIC Assessment and Update Status Report on the Western Screech-owl *Otus kennicottii macfarlanei* subspecies *kennicottii* subspecies in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. vi + 31 pp.

Corkran, C.C. and C.R. Thoms. 1996. Amphibians of Oregon, Washington, and British Columbia. Lone Pine Publishing, Vancouver. 175 pages.

Craig, V. 2003. Species account and preliminary habitat ratings for Pacific water shrew (*Sorex bendirii*). Report tp Ministry of Water, Land and Air Protection. Surrey. 34pp.

Craig, V. 2003. Species account and preliminary habitat ratings for Pacific water shrew (*Sorex bendirii*). Report tp Ministry of Water, Land and Air Protection. Surrey. 34pp.

Craig, V., and R. Vennesland. 2008. The best management practices guidelines for Pacific water shrew in urban and rural areas: Working draft. September 2008. Unpublished report. 41pp.

Demarchi, M. and D. Bentley. Revised by L. Sopuck. 2005. Best Management Practices for Raptor Conservation during Urban and Rural Land Development in British Columbia. BC Ministry of Environment, Victoria, BC. 137 pp.

Diamond Head Consulting Ltd., et al. 2014. Biodiversity Conservation Strategy. Prepared for the City of Surrey.

Douglas, G.W., D.V. Meidinger, J.L. Penny. 2002. Rare Native Vascular Plants of British Columbia 2nd. ed. B.C. Ministry .Sustainable Resource Manage. and B.C. Ministry of Forests, Victoria, BC. 359pp.

Environment Canada (EC) 2013[1]. Species at Risk: Streambank Lupine. http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=746. Her Majesty the Queen in Right of Canada, 2011. Last update: 2010-01-11 (accessed January 15, 2013).

Environment Canada (EC) 2013[2]. Species at Risk: Vancouver Island Beggarticks. http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=688 the Queen in Right of Canada, 2011. Last update: 2010-01-11 (accessed January 13, 2013).

Environment Canada (EC) 2013[3]. Species at Risk: Great Blue Heron *fannini* subspecies. http://www.sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=292. Last updated 2010-01-11. Her Majesty the Queen in Right of Canada, (accessed January 13, 2013).

Fenger, M., T. Manning, J. Cooper, S. Guy and P. Bradford. 2006. Wildlife & Trees in British Columbia. Lone Pine Publishing. Edmonton. 336pp.

Forsyth, R.G. 2004. Land Snails of British Columbia. Royal BC Museum Handbook. Victoria: Royal BC Museum. 188 pages, [8] colour plates.

Golder Associates Ltd. 1993. Geotechnical Input to D5 Bridgeview Catchment Drainage Study, Surrey, B.C. Prepared for Kerr Wood Liedel Associates Ltd.

Green, R.N. and K. Klinka. 1994. A field guide for site identification and interpretation for the Vancouver forest region land management handbook Number 28. BC Ministry of Forests. Victoria, BC.

HB Lanarc and Raincoast Applied Ecology. 2011. City of Surrey Ecosystem Management Study.

Klinkenberg, Brian. (Editor) 2006. E-Flora BC: Electronic Atlas of the Plants of British Columbia [www.eflora.bc.ca]. Lab for Advanced Spatial Analysis, Department of Geography, University of British Columbia, Vancouver.

Ministry of Environment, Lands and Parks (MELP). 1998. Inventory methods for marsh birds: bitterns and rails. Standards for Components of British Columbia's Biodiversity No. 7. 37 pp.

Morley, S.A. Effects of urbanization on small stream in the Puget Sound lowland streams: restoration with a biological focus. Seattle, University of Washington. M.S. Thesis.

Nagorsen, D.W. 1996. Opossums shrews and moles of British Columbia. UBC Press. Vancouver.

Nagorsen, D.W. 1996. Opossums shrews and moles of British Columbia. UBC Press. Vancouver.

Ovaska K., L. Sopuck, C. Engelstoft, L. Matthias, E. Wind and J. MacGarvie. 2004. Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia. Report to BC Ministry of Water, Land and Air Protection Nanaimo, BC. 159pp.

Ovaska, K. and L. Sopuck. 2004. Update COSEWIC Status Report on the Red-legged Frog Rana aurora in Canada. Unpublished revised report prepared for COSEWIC. 63 pp.

Ovaska, K. and L. Sopuck. 2004. Update COSEWIC Status Report on the Red-legged Frog Rana aurora in Canada. Unpublished revised report prepared for COSEWIC. 63 pp.

Robertson Environmental Services Ltd. 2006. South Fraser Perimeter Road – Vegetation and Wildlife Impact Assessment. Technical Volume 12 of the Environmental Assessment Application. Prepared for the Ministry of Transportation.

Robertson Environmental Services. 2006. South Fraser Perimeter Road Vegetation and Wildlife Impact Assessment Technical Volume 12 of the Environmental Assessment Application. Report prepared for the Ministry of Transportation, Victoria, BC. 254pp.

Species At Risk Act (SARA). 2013. Species At Risk Act Public Registry. http://www.sararegistry.gc.ca/default_e.cfm.

Web Engineering Ltd. 2009. City of Surrey, 2009 Ravine Stability Assessment

Zuleta, G.A. and C. Galindo-Leal. 1994. Distribution and abundance of four small mammals at risk in a fragmented landscape. Wildlife Working Report No. WR-64. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC.

Personal Communications

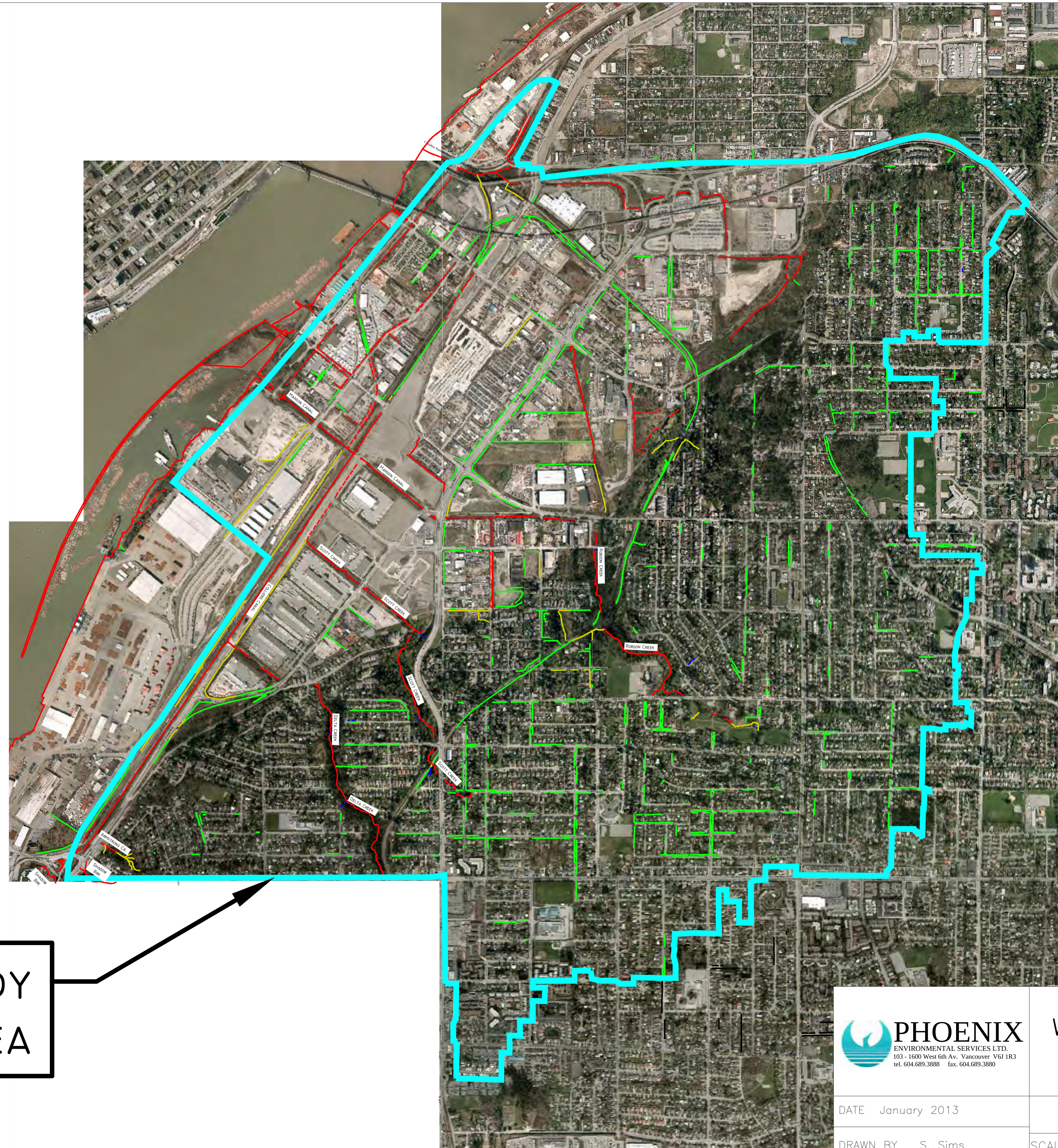
Godwin, Stephen. 2015. City of Surrey, Environmental Coordinator,

McIntosh, K. Anre. 2006. Bodega Environmental Services. White Rock, BC.

Schmidt, Chris. 2005. SEACOR Environmental Inc. Senior Project Manager. Vancouver, BC

APPENDIX A

Figures



Study Area

- Class "A" Watercourse
- Class "A(o)" Watercourse
- Class "B" Watercourse
- Class "C" Watercourse

Note Proposed reclassifications shown. Base layers, orthophotos and creek classifications courtesy of City of Surrey COSMOS mapping (2013).

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South Westminster ISMP
Watercourse Classification Map
Appendix A - Figure 1. Study Area

DATE January 2013		REV 00	
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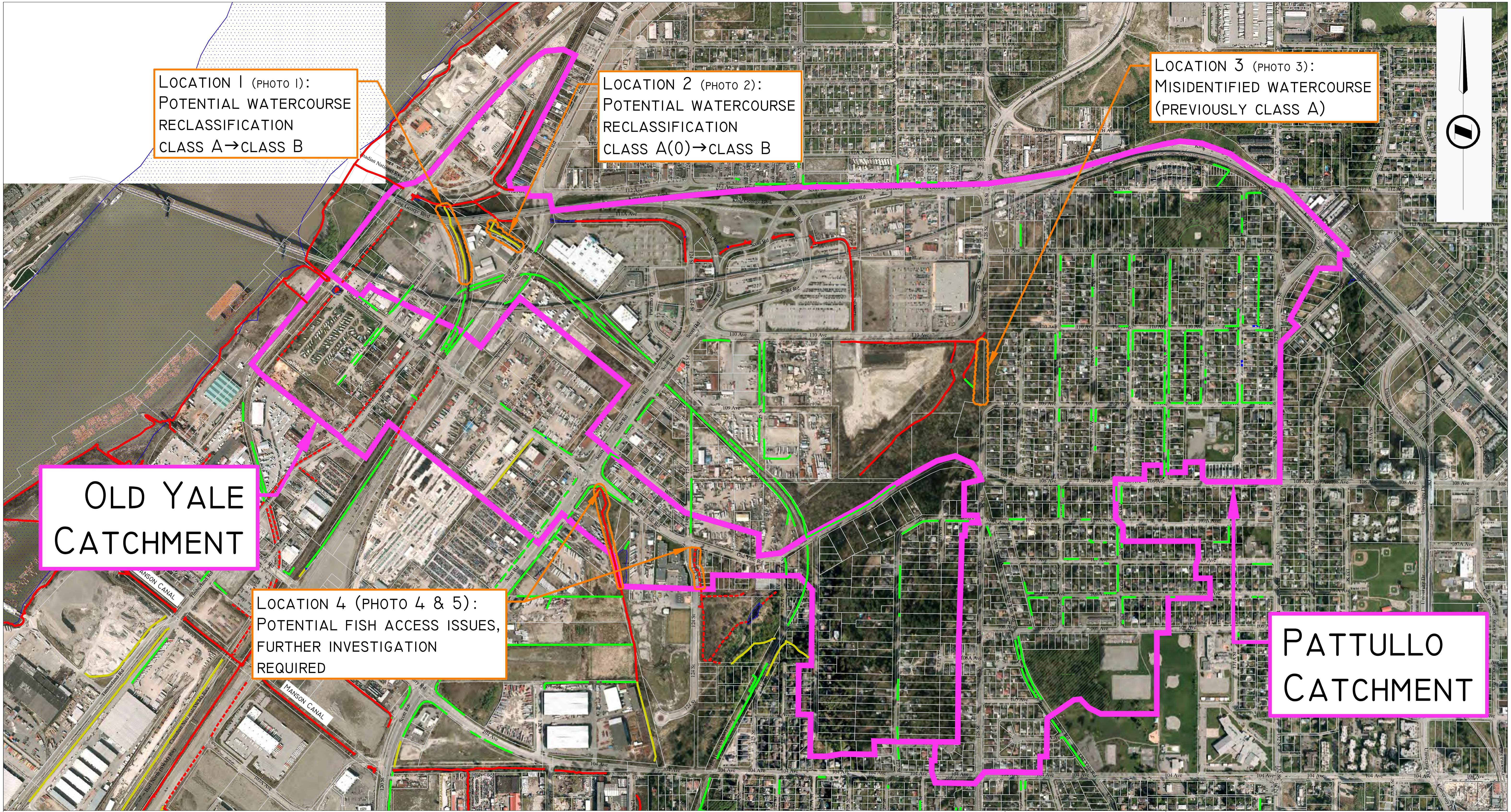

Class "A" Watercourse

Class "A(0)" Watercourse

Class "B" Watercourse

Class "C" Watercourse

Assessment & Potential Habitat Enhancement Location

City of Surrey Major Catchment Boundaries

Note Proposed reclassifications shown. Base layers and creek classifications courtesy of City of Surrey COSMOS mapping (2013).

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South Westminster ISMP
Watercourse Classification Map
Appendix A - Figure 2. Old Yale and Pattullo Catchments

DATE January 2013

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REV 00

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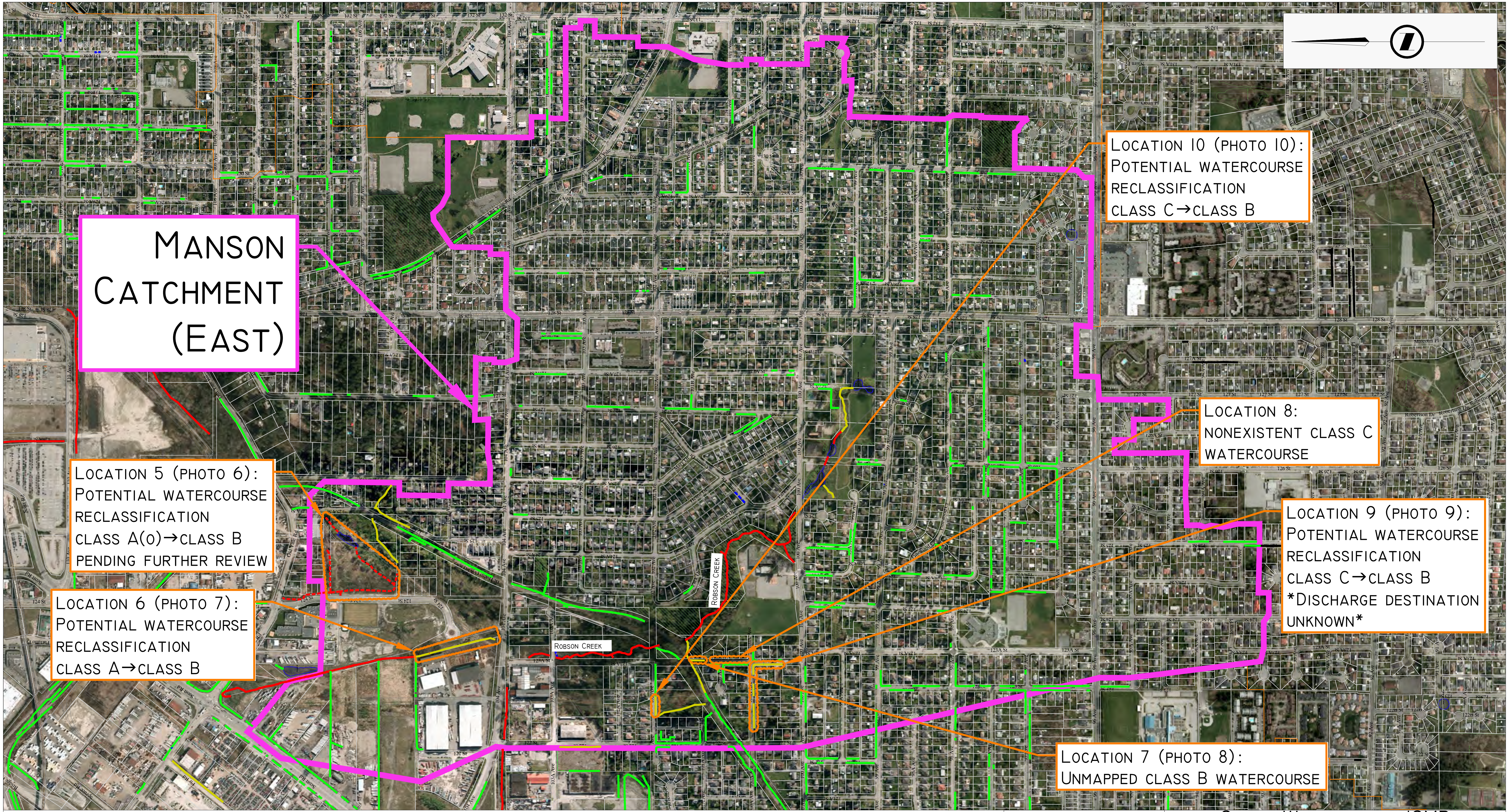

CLASS "A" WATERCOURSE

CLASS "AO" WATERCOURSE

CLASS "B" WATERCOURSE

CLASS "C" WATERCOURSE

ASSESSMENT & POTENTIAL HABITAT ENHANCEMENT LOCATION

CITY OF SURREY MAJOR CATCHMENT BOUNDARIES

NOTE PROPOSED RECLASSIFICATIONS SHOWN. BASE LAYERS AND CREEK CLASSIFICATIONS COURTESY OF CITY OF SURREY COSMOS MAPPING (2013).

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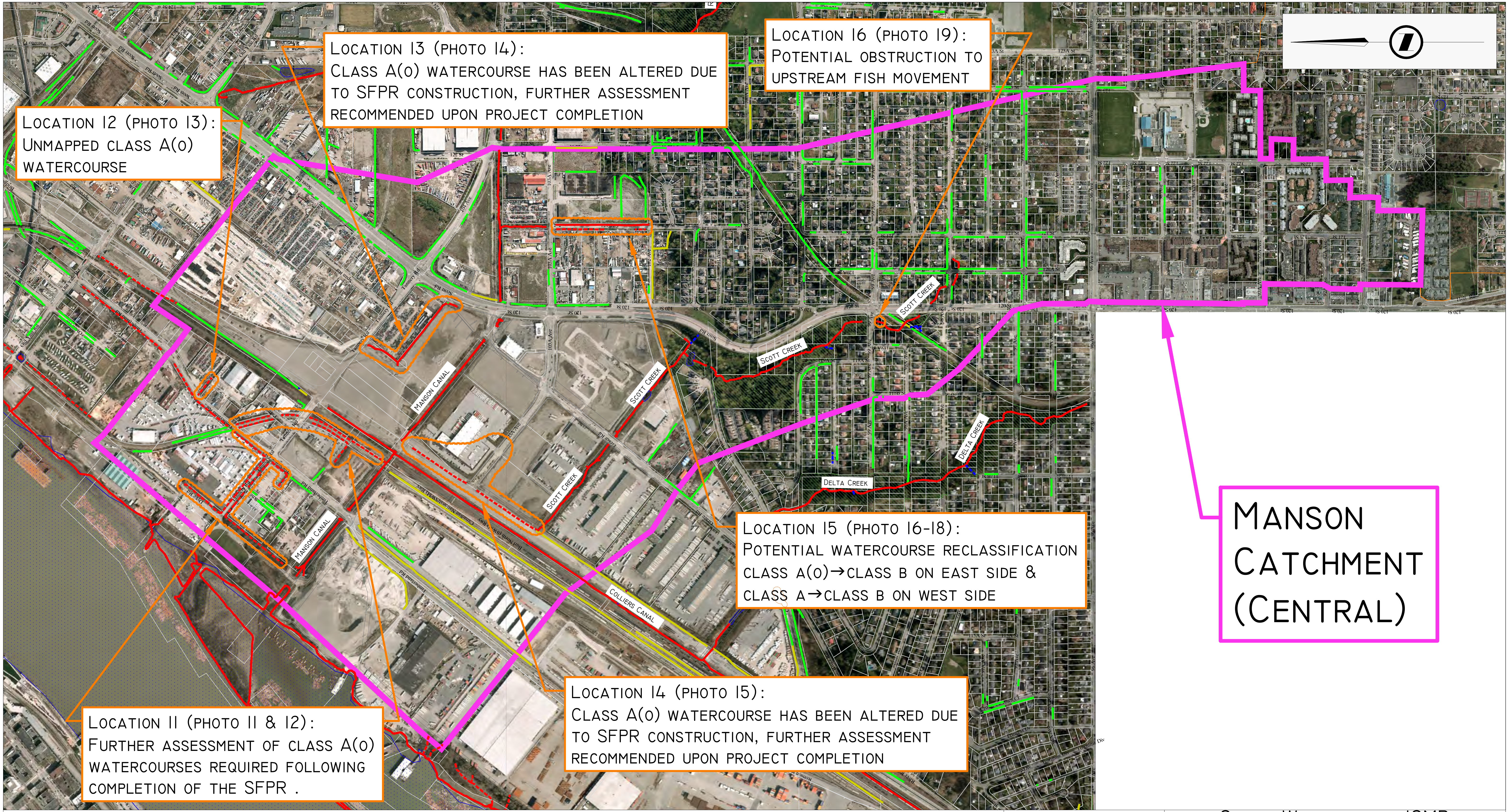
SOUTH WESTMINSTER ISMP
WATERCOURSE CLASSIFICATION MAP
APPENDIX A FIGURE 3. MANSON CATCHMENTS (EAST)

DATE	January 2013
DRAWN BY	S. Sims
SCALE	1:10,000
DRAWING NO.	SouthWestminsterISMP-WCM_AF3.dwg
REV	00



Class "A" Watercourse	Class "B" Watercourse	Assessment & Potential Habitat Enhancement Location	
Class "AO" Watercourse	Class "C" Watercourse	City of Surrey Major Catchment boundaries	

Note Proposed reclassifications shown. Base layers and creek classifications courtesy of City of Surrey COSMOS mapping (2013).

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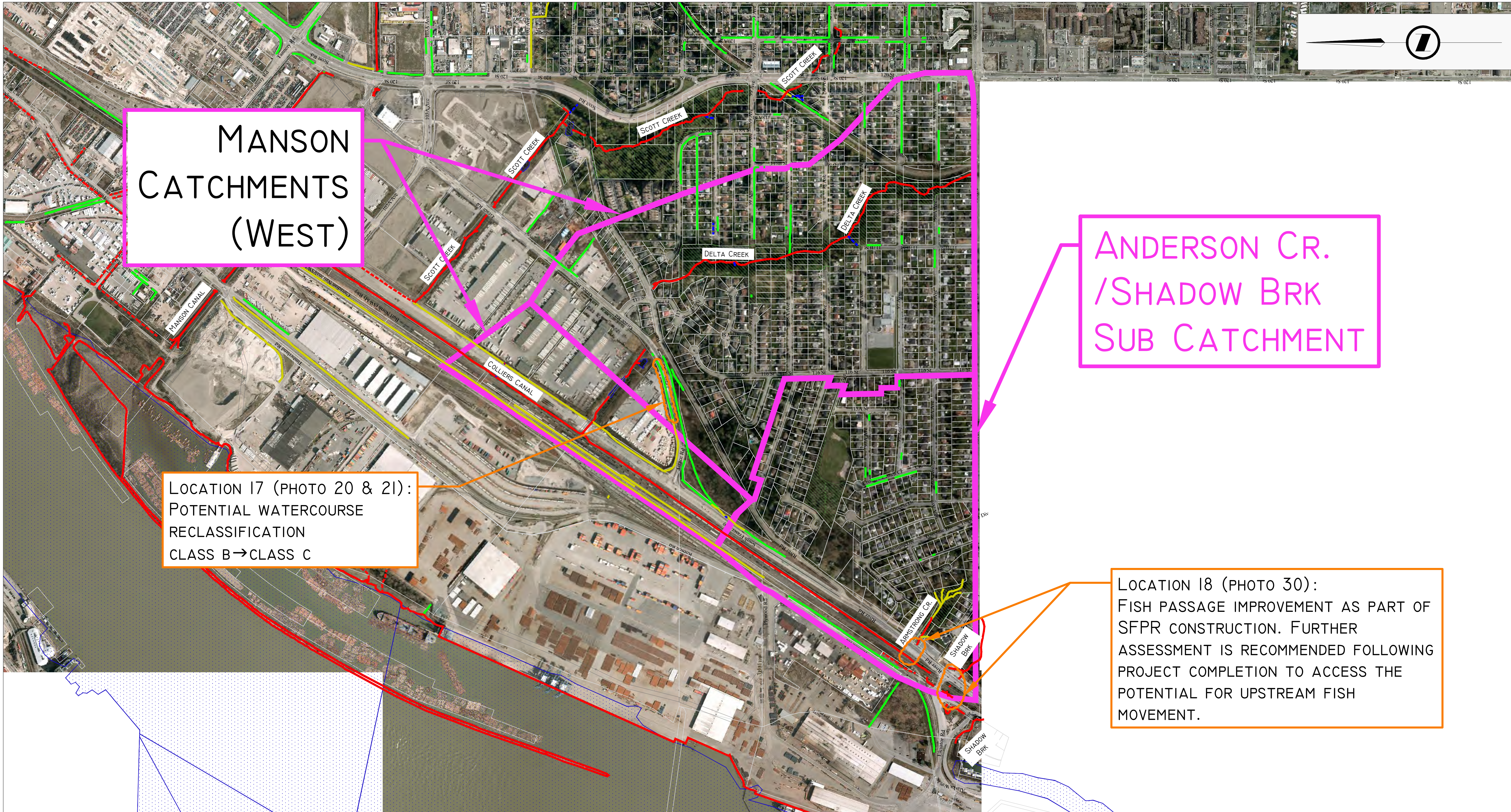
South Westminster ISMP
Watercourse Classification Map
Appendix A Figure 4. Manson Catchment (Central)

DATE January 2013
DRAWN BY S. Sims
REV 00
SCALE 1:10,000
DRAWING NO. SouthWestminsterISMP–WCM_AF4.dwg



Class "A" Watercourse

Class "AO" Watercourse

Class "B" Watercourse

Class "C" Watercourse

Assessment & Potential Habitat Enhancement Location

City of Surrey major and sub catchment boundaries

Note Proposed reclassifications shown. Base layers and creek classifications courtesy of City of Surrey COSMOS mapping (2013).

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South Westminster ISMP
Watercourse Classification Map
Appendix A Figure 5. Manson Catchments (West) & Anderson Cr./Shadow Brk Sub-Catchment

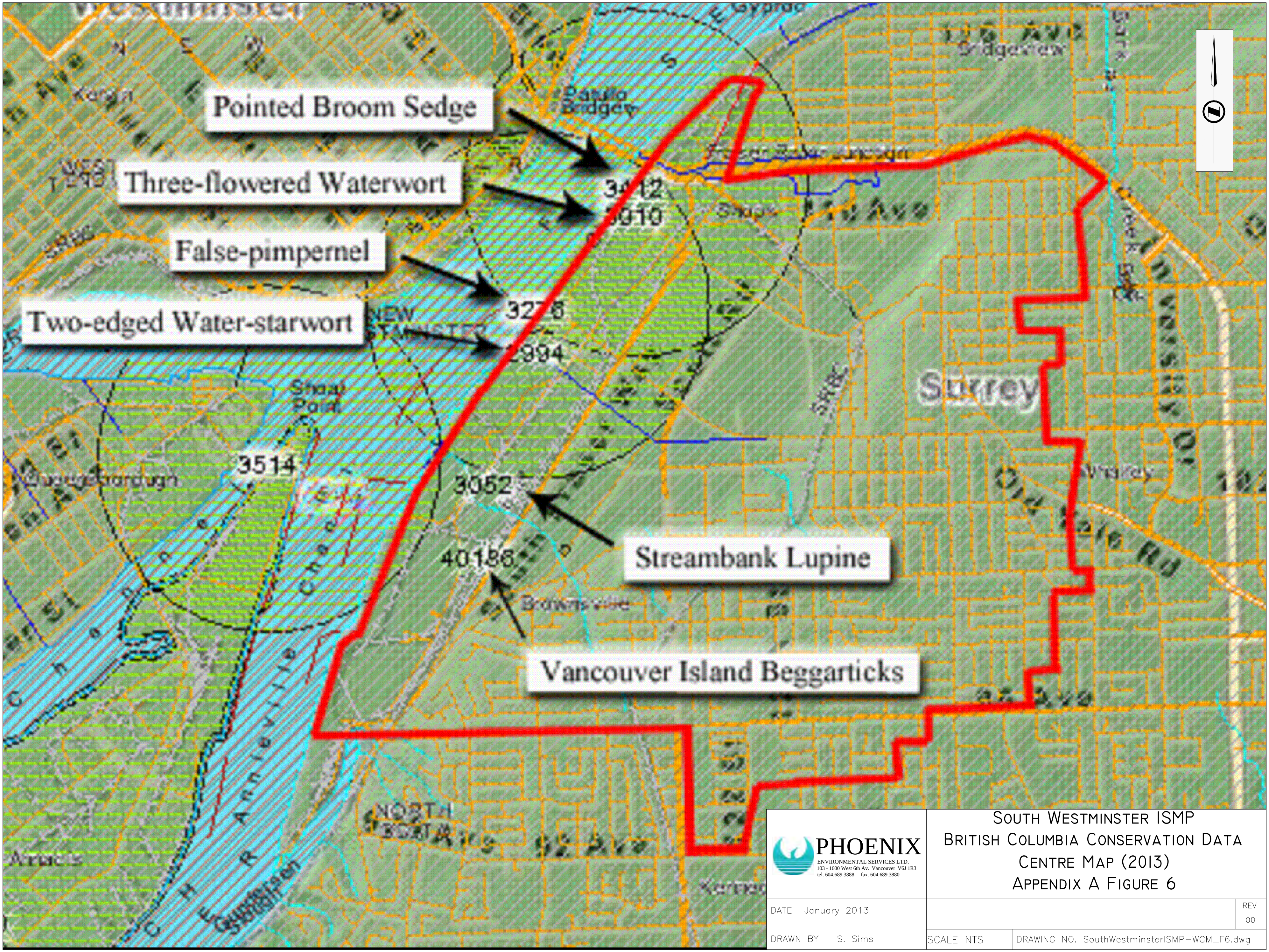
DATE January 2013

DRAWN BY S. Sims

REV 00

SCALE 1:10,000

DRAWING NO. SouthWestminsterISMP-WCM_AF5.dwg



PHOENIX ENVIRONMENTAL SERVICES LTD.

South Westminster ISMP
British Columbia Conservation Data Centre Map (2013)
Appendix A Figure 6

DATE January 2013		REV 00
DRAWN BY S. Sims	SCALE NTS	DRAWING NO. SouthWestminsterISMP-WCM_F6.dwg

APPENDIX B

Photo-documentation

Location 1 - Pattullo Bridge

Photo 1. Potential watercourse reclassification, class A → Class B.

Location 2 – Pattullo Bridge

Photo 2. Potential watercourse reclassification, Class A(O) → class B.

Location 3 – 109th to 110th Ave

Photo 3. Misidentified watercourse (previously mapped as Class A)

Location 4 – Scott Rd & Old Yale Rd

Photo 4. Potential fish access issue – Class A watercourse

Location 4 – Old Yale Rd & 124th St.

Photo 5. Potential fish access issue – Class A watercourse

Location 5 – 124th St. & 125A St.

Photo 6. Potential watercourse classification, Class A(O) → class B.

Location 6 – Old Yale Rd to 104th Ave

Photo 7. Potential watercourse reclassification, Class A → Class B.

Location 7 – North of 123A St, South of Railway

Photo 8. Unmapped Class B watercourse.

Location 9 – 123A St. to 101A Ave

Photo 9. Potential watercourse reclassification, Class C → Class B.

Location 10 – 102 Ave

Photo 10. Potential watercourse reclassification, Class C → Class B.

Location 11 – Timberland Rd & Tannery Rd

Photo 11. Further assessment of Class A(O) watercourses in the area required following completion of SFPR.

Location 11 – Timberland Rd & Tannery Rd

Photo 12. Further assessment of Class A(O) watercourses in the area required following completion of SFPR.

Location 12 – Tannery Rd, East of CN Railway

Location 13 – Tannery Rd b/w SFPR & Scott Rd

Location 14 – 103A St. & South Fraser Way

Photo 13. Unmapped Class A(O) watercourse.

Photo 14. Class A(O) watercourse has been altered, further assessment recommended following SFPR completion.

Photo 15. Class A(O) watercourse has been altered, further assessment recommended following SFPR completion.

Location 15 – 121st St. (East Side)

Photo 16. Potential watercourse reclassification, Class C → Class B.

Location 15 – 121st St. (East Side)

Photo 17. Potential watercourse reclassification, Class A → Class A(O).

Location 15 – 121st Ave @ 103A Ave

Photo 18. Potential obstruction to fish movement.

Location 16 – Grace Rd, West of Colliers Cr.

Photo 19. Potential obstruction to upstream fish movement.

Location 17 – Grace Rd, West of Colliers Cr.

Photo 20. Potential watercourse reclassification, Class B → Class C.

Location 17 – Grace Rd, West of Colliers Cr.

Photo 21. Potential watercourse reclassification, Class B → Class C.

Robson Creek & 100th Ave

Photo 22. Stream stability – Robson Creek downstream of 100th Ave.

Scott Creek @ 99A Ave.

Photo 23. Signs of instability – Scott Creek downstream of 99A Ave.

Scott Creek Rearing Pond

Photo 24. Observed beaver activity in Scott Creek pond at 99A Ave.

Delta Creek @ 99A & 96A Ave

Photo 25. Undercut banks – Delta Creek at 99A & 96A Ave.

Shadow Brook at Queen's Place

Photo 26. Unstable Boulders – Shadow Creek culvert outlet at Queen's Place.

Shadow Brook at Queen's Place

Photo 27. Refuse – Shadow Creek culvert outlet at Queen's Place.

Shadow Brook @ SFPR

Photo 28. New culver installed as part of SFPR construction.

Robson Creek Detention Pond

Photo 29. Obstruction to upstream fish movement in Robson Creek detention pond.

Location 18 – Armstrong Creek

Photo 30. Recently installed fish ladder installed during SFPR construction.

Robson Creek

Photo 31. Typical vegetation composition along Robson Creek.

Robson Creek

Photo 32. Channelized portion of Robson Creek as viewed from Timberland Road towards the Fraser River.

Scott Creek

Photo 33. Active beaver pond with lodge in background and dam on Scott Creek situated where the slope meets the lowland area.

Robson Creek

Photo 34. Active beaver pond and lodge near headwaters of Robson Creek.

Manson Creek

Photo 35. Active beaver pond located on Manson Creek situated near the base of the escarpment.

110^{th} Ave & 126A St.

Photo 36. Cattail dominated stormwater detention pond situated near the SE corner of 110 Ave and 125A St.

10677 124th St.

Photo 37. Restored pond associated with 10677 124th St.

Bog Park & Forested Block Vegetation Type

Photo 38. Typical stand composition of the Forested Block Vegetation Type.

Escarpment Area & Forested Block Vegetation Type

Photo 39. Deciduous dominated composition of the Forested Block Vegetation Type within the Escarpment area.

SRY ROW & Fallow Field Vegetation Type

Photo 40. Photograph of the SRY ROW within the ROW and Fallow Field Vegetation Type.

ROW & Fallow Field Vegetation Type

Photo 41. Active beaver pond located on Manson Creek situated near the base of the escarpment.

Scott Creek Beaver Pond

Photo 42. A Class 8 wildlife tree located along the banks on the beaver pond on Scott Creek.

APPENDIX C

Wildlife and Vegetation Species Detected

Species	Scientific Name*	Riparian (creeks & ponds)	Forested Blocks	ROWs and Fallow Fields
Tree Layer[1]:				
Bigleaf Maple	*Acer macrophyllum*	X	X	
Black Cottonwood	*Populus balsamifera*	X	X	
Douglas-fir	*Pseudotsuga menziesii*	X	X	
Paper Birch	*Betula papyrifera*	X	X	
Red Alder	*Alnus rubra*	X	X	
Sitka Spruce	*Picea sitchensis*	X		
Western Hemlock	*Tsuga heterophylla*	X	X	
Western Redcedar	*Thuja plicata*	X	X	
Shrub Layer[2]:				
Black Cottonwood	*Populus balsamifera*	X	X	X
Common Snowberry	*Symphoricarpos albus*	X	X	X
Devil's Club	*Oplopanax horridus*	X		
Douglas-fir	*Pseudotsuga menziesii*	X	X	
English Holly	*Ilex aquifolium*	X	X	X
Evergreen Blackberry	*Rubus laciniatus*		X	
Hardhack	*Spiraea douglasii*			X
Himalayan Blackberry	*Rubus discolor*	X	X	X
Indian-plum	*Oemleria cerasiformis*	X	X	
Japanese knotweed	*Polygonum cuspidatum*	X	X	X
Nootka Rose	*Rosa nutkana*			X
Paper Birch	*Betula papyrifera*	X	X	
Red Alder	*Alnus rubra*	X	X	X
Red Elderberry	*Sambucus racemosa*		X	
Red Huckleberry	*Vaccinium parvifolium*	X	X	
Red-osier Dogwood	*Cornus stolonifera*	X		
Rhododendron	*Rhododendron* spp.	X	X	
Salal	*Gaultheria shallon*	X	X	
Salmonberry	*Rubus spectabilis*	X	X	
Scotch Broom	*Cytisus scoparius*			X
Shore Pine	*Pinus contorta*		X	
Trailing Blackberry	*Rubus ursinus*	X		X
Vine Maple	*Acer circinatum*	X	X	
Weeping Willow	*Salix babylonica*	X		
Western Hemlock	*Tsuga heterophylla*	X	X	
Western Redcedar	*Thuja plicata*	X	X	
Willow	*Salix* spp.	X		
Herb Layer:				
American Bulrush	*Schoenoplectus pungens*	X		X
Bracken Fern	*Pteridium aquilinum*	X	X	X

Vegetation species detected within the study area (January 10 and 17, 2013).

Species	Scientific Name*	Riparian (creeks & ponds)	Forested Blocks	ROWs and Fallow Fields
Herb Layer (concluded):				
Canada Thistle	*Cirsium arvense*			X
Common Cattail	*Typha latifolia*	X		
Common Dandelion	*Taraxacum officinale*			X
Common Rush	*Juncus effusus*	X		X
Creeping Buttercup	*Ranunculus acris*	X		X
Curled Dock	*Rumex crispus*			X
Duckweed	*Lemna minor*	X		
English Ivy	*Hedera helix*	X	X	X
Grasses	*Graminoid* spp.	X	X	X
Great Mullein	*Verbascum thapsus*			X
Large-leaved Avens	*Geum macrophyllum*	X	X	
Licorice Fern	*Polypodium glycyrrhiza*	X	X	
Reed Canarygrass	*Phalaris arundinacea*	X		X
Sword Fern	*Polystichum munitum*	X	X	
Tall Oregon-grape	*Mahonia aquifolium*	X	X	

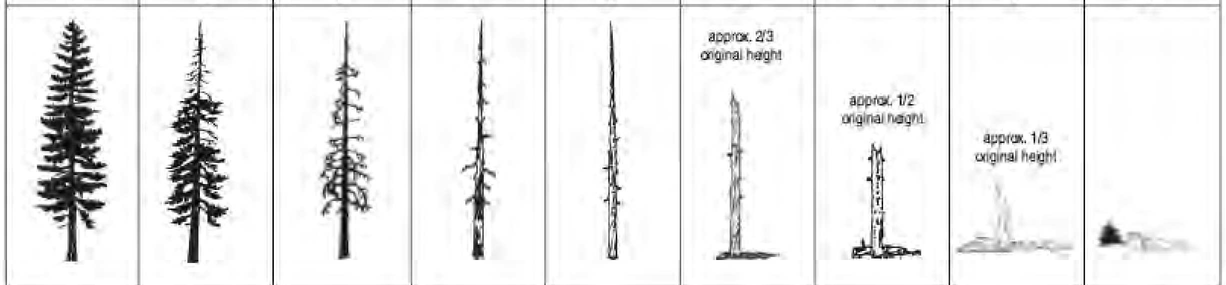
[1] Tree Layer: Woody plants >2m in height
[2] Shrub Layer: Woody plants 0-2m in height
* Scientific and common names from Klinkenberg 2006 (E-Flora BC)

Wildlife species detected within the study area (January 10 and 17, 2013).

Species	Scientific Name	Riparian (creeks & ponds)	Forested Blocks	ROWs and Fallow Fields
Birds:				
American Robin[1, 2]	*Turdus migratorius*	X	X	X
Bald Eagle[1, 2, 3]	*Haliaeetus leucocephalus*	X		
Bewick's Wren[1]	*Thryomanes bewickii*	X		
Black-capped Chickadee[1, 2]	*Poecile atricapillus*	X	X	X
Bufflehead[2]	*Bucephala albeola*	X		
Chestnut-backed Chickadee[1, 2]	*Poecile rufescens*	X	X	
Dark-eyed Junco[1, 2]	*Junco hyemalis*	X	X	X
European Starling[1, 2]	*Sturnus vulgaris*			X
Glaucous-winged Gull[1, 2]	*Larus glaucescens*			X
Golden-crowned Kinglet[1, 2]	*Regulus satrapa*	X	X	
Mallard[1, 2]	*Anas platyrhynchos*	X		
Northwestern Crow[1, 2, 3]	*Corvus caurinus*	X	X	X
Northern Flicker[1, 2]	*Colaptes auratus*	X	X	X
Pacific Wren[1]	*Troglodytes pacificus*	X		
Pileated Woodpecker[4]	*Dryocopus pileatus*	X	X	
Pine Siskin[1, 2]	*Spinus pinus*	X	X	
Red-tailed Hawk[2]	*Buteo jamaicensis*			X
Red-breasted Nuthatch[1]	*Sitta canadensis*	X	X	
Rock Pigeon[2]	*Columba livia*			X
Steller's Jay[1]	*Cyanocitta stelleri*	X	X	
Song Sparrow[1, 2]	*Melospiza melodia*	X	X	X
Spotted Towhee[1, 2]	*Pipilo maculatus*	X	X	X
Varied Thrush[1]	*Ixoreus naevius*		X	
White-winged Crossbill[1]	*Loxia leucoptera*		X	
Mammals:				
Beaver[4, 8]	*Castor canadensis*	X		
Coast Mole[5]	*Scapanus orarius*			X
Coyote [2, 6, 7]	*Canis lantrans*	X	X	X
Douglas Squirrel[1, 2]	*Tamiasciurus douglasii*	X	X	
Eastern Cottontail[7]	*Sylvilagus floridanus*			X
Eastern Grey Squirrel[1, 2]	*Sciurus carolinensis*	X	X	
Townsend's Vole[9]	*Microtus townsendii*			X

[1]Heard [2]Seen [3]Nest [4] Forage Sign [5] Mounds [6] Tracks [7] Scats [8] Lodge [9] Burrows

	LIVE		DEAD					DEAD FALLEN	
			Hard			Spongy	Soft		
Tree class	1	2	3	4	5	6	7	8	9
Description	Live/healthy; no decay; tree has valuable habitat characteristics such as large, clustered or gnarled branches, or horizontal, thickly moss-covered branches.*	Live/unhealthy; internal decay or growth deformities (including insect damage, broken tops); dying tree.*	Dead; needles or twigs may be present; roots sound.	Dead; no needles/twigs; 50% of branches lost; loose bark; top usually broken; roots stable.	Dead; most branches/bark absent; some internal decay; roots of larger trees stable.	Dead; no branches or bark; sapwood/ heartwood sloughing from upper bole; decay more advanced; lateral roots of larger trees softening; smaller ones unstable.	Dead; extensive internal decay; outer shell may be hard; lateral roots completely decomposed; hollow or nearly hollow shells.		Debris; downed trees or stumps.
Uses and users	Nesting (e.g., Bald Eagle, Great Blue Heron colonies, Marbled Murrelet); feeding; roosting; perching.	Nesting/roosting[1] —strong PCEs[2] (woodpeckers); SCUs[3]; large-limb and platform nests (Ospreys); insect feeders.	Nesting/roosting—strong PCEs; SCUs; bats.	Nesting/roosting —PCEs; SCUs; insect feeders.	Nesting/roosting—weak PCEs (nuthatches, chickadees); SCUs; bats; insect feeders.	Weaker PCEs; SCUs; insect feeders; salamanders; small mammals; hunting perches.	Insect feeders; salamanders; small mammals; hunting perches; occasionally used by weak cavity excavators such as chickadees.		Insect feeders; salamanders; small mammals; drumming logs for grouse; flicker foraging; nutrient source.



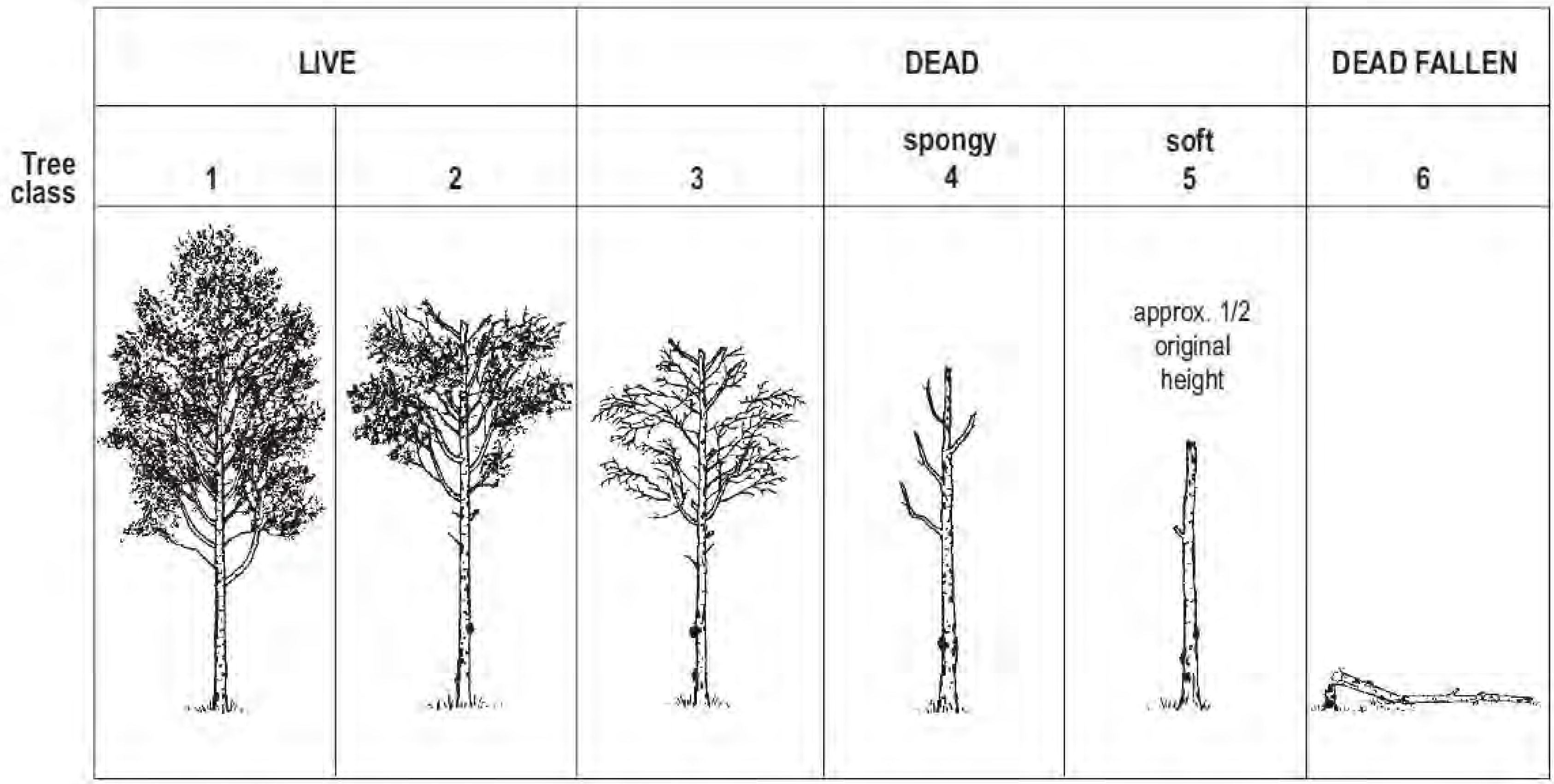
[1] Large witches' brooms provide nesting/denning habitat for some species (e.g., fisher, squirrels).

[2] PCE = primary cavity excavator

[3] SCU = secondary cavity user

* This classification system does not recognize root disease trees specifically. Such trees become unstable at or before death.

Nine decay classes of coniferous wildlife trees (Fenger et al 2006).



Six decay classes of deciduous wildlife trees (Fenger et al 2006).

APPENDIX C

Technical Memorandum:

Pattullo Pump Station Settings Review

Technical Memorandum

To:	Jeannie Lee, P.Eng	Date:	May 22, 2014
Copy:	Carrie Baron, P.Eng	Our Ref:	EB3779
From:	Barry Dinn, P.Eng Adrian Corlett, P.E.		

RE: City of Surrey – Pattullo Pump Station Settings and Conduit Review

Background

Delcan was retained by the City of Surrey to review the Pattullo Pump Station to:

- Confirm whether the On/Off pump settings are operating as expected;
- Determine whether lowering the On/Off settings will improve drainage in the catchment;
- Review the conduit connecting Pattullo and Old Yale pump stations and determine the impact of an open or closed sluice gate.

The driving force behind this Technical Memorandum is a major rainfall event that occurred on January 10th/11th, 2014 causing flooding in multiple areas throughout Surrey and the Lower Mainland. Within the Pattullo Catchment, flooding occurred at 128th Street and 111th Avenue. **Photo 1** and **Photo 2** show the flooding during the morning of January 11th.

Photo 1 – 111 Ave at 128 Street

Photo 4 – 111 Avenue (Facing East)

This memorandum addresses the rainfall event of January 10th/11th and determines whether lower On/Off settings would have reduced the flooding that occurred at 128th St and 111th Ave. In addition, design rainfall events will be modelled to determine the impact lower settings have on rainfall events with different duration and intensity.

Pattullo Pump Station Existing On/Off Settings

In a December 4th, 2013 email, The City of Surrey provided Delcan with the On/Off settings of the three pumps at Pattullo Pump Station. **Table 1** shows these settings:

Pattullo Pump Station	On Elevation (m)	Off Elevation (m)
Lead Pump (0.67 m^3/s)	0.753	0.144
Lag Pump (0.67 m^3/s)	0.830	0.144
Third Pump (0.67 m^3/s)	0.906	0.144

Table 1 - Pattullo Pump Station On/Off Settings

These On/Off settings are at a higher geodetic elevation than nearby Old Yale and Manson Pump Stations. The lead pump at Manson Pump Station turns on at **0.050m** and the lead pump at Old Yale Pump Station turns on at **0.101m**. Higher pump station settings for Pattullo Pump Station impacts the catchment in the following ways:

- The pumps turn on less frequently than if settings were lowered. The existing floodbox drains the catchment when river levels are below the outlet pipe. The lower the settings, the more likely the pumps will turn on before the river levels lower and the system is drained by floodbox.
- The groundwater levels along open drainage channels and ditches remain higher. This can reduce infiltration capacity of the ground; and
- The channels and ditches are more likely to be partially filled with water all year long. This impacts the ecological attributes of the drainage network as different species will prefer the constant water.

In order to confirm the above settings, wetwell levels and pump run times at Pattullo Pump Station from January 6th to 13th were provided to Delcan from the City's SCADA data. **Figure 1** shows measured wetwell water levels at Pattullo Pump Station for this time period. The data collector didn't record data during the January 10th/11th rainfall event.

Table 2 shows times that Pattullo's three pumps turned on during this seven day period. Due to the intensity of the rainfall, it is expected that all three pumps turned on during the January 10th/11th rainfall events.

Pump	Pump On Times (P_RUN)
Pump 1 - Run	1/11/2014 7:50
	1/11/2014 17:52

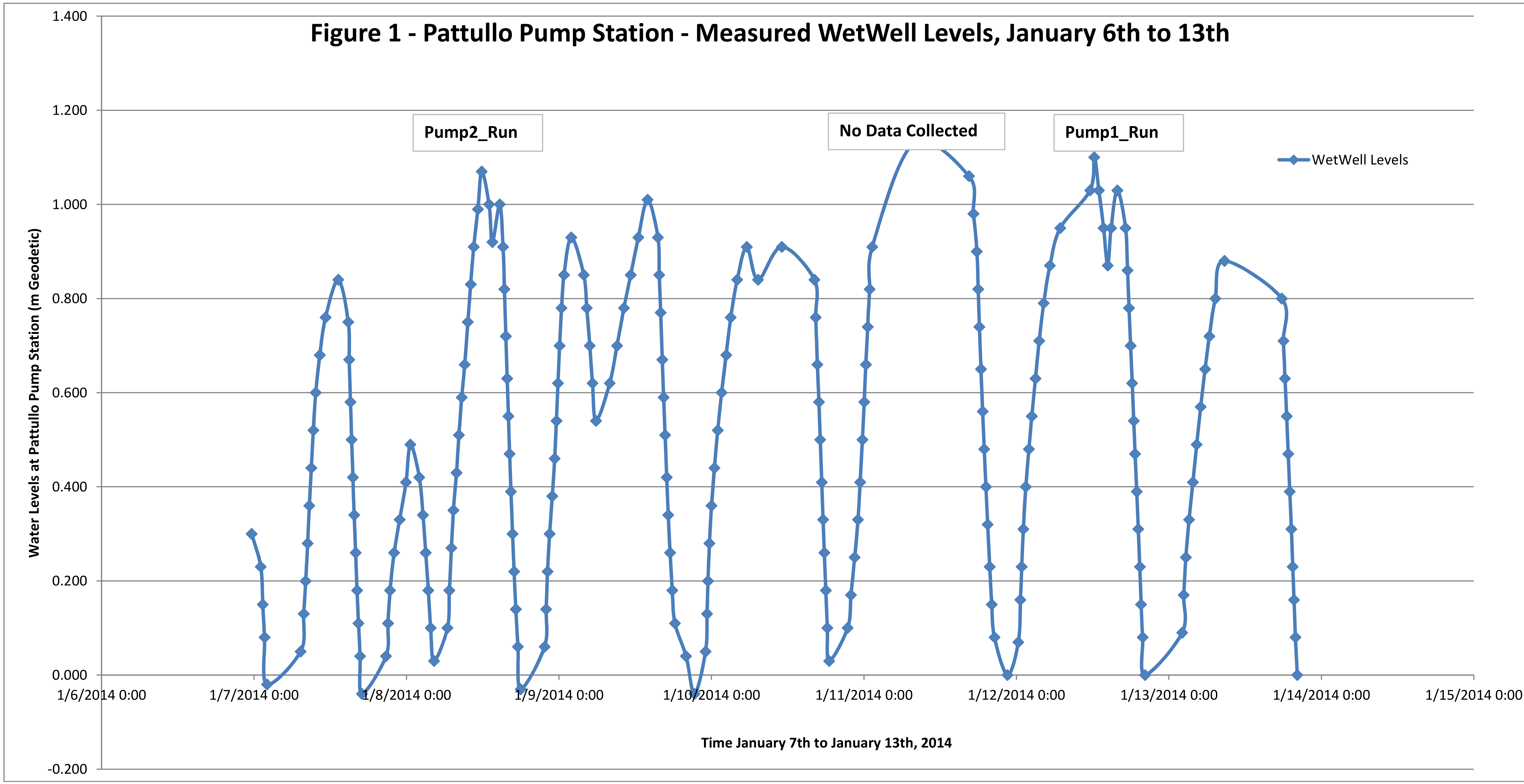


Figure 1 - Pattullo Pump Station - Measured WetWell Levels, January 6th to 13th
Pump2_Run
No Data Collected
Pump1_Run
WetWell Levels
Water Levels at Pattullo Pump Station (m Geodetic)
1.400
1.200
1.000
0.800
0.600
0.400
0.200
0.000
-0.200
1/6/2014 0:00
1/7/2014 0:00
1/8/2014 0:00
1/9/2014 0:00
1/10/2014 0:00
1/11/2014 0:00
1/12/2014 0:00
1/13/2014 0:00
1/14/2014 0:00
1/15/2014 0:00
Time January 7th to January 13th, 2014

Pump 2 - Run	11/19/2013 9:00
	1/8/2014 12:18
	1/8/2014 14:08
	1/11/2014 7:50
	1/11/2014 7:50
	1/12/2014 12:29
	1/12/2014 14:24
Pump 3 - Run	

Table 2 - Pattullo Pump Run Times

Upon review of the data provided and outlined above for the January 6th to 13th time period:

- The water levels at the Pattullo pump station closely follow the Fraser River water levels and are influenced by tide;
- The pumps were on three days out of seven, indicating that the majority of water is drained by the floodboxes;
- There are periods of time that water levels are above 0.75 metres elevation, but the lead pump did not turn on.

Following discussions between the City of Surrey and the Pattullo Pump Station Designer, Stantec, it was determined that the Pattullo Pump Station should be set with the on/off settings shown in **Table 3**:

Pattullo Pump Station	On Elevation (m)	Off Elevation (m)
Lead Pump (0.67 m^3/s)	0.80	0.55
Lag Pump (0.67 m^3/s)	1.05	0.80
Third Pump (0.67 m^3/s)	1.30	1.05

Table 3 - Recommended Pattullo Pump Station Settings

Lowering Pattullo Pump Station Settings – January 6th to 13th Model Analysis

Using the XPSWMM model created for the South Westminster ISMP, the Pattullo catchment was modelled by inputting rainfall and tidal data from January 6th to 13th.

To determine the impact of lowering the On/Off settings of the Pattullo Pump Station, the catchment was modelled for the January 6th to 13th time period using the provided settings and two additional scenarios:

Base Scenario – Provided On/Off Settings shown in **Table 1.**

Scenario 1 - On/Off Settings lowered 40cm

Scenario 2 - On Setting lowered 60cm and Off Settings Lowered 40cm. With these settings the lead pump at Pattullo turns on at roughly the same elevation as the lead pump at Old Yale Pump Station.

Table 4 shows the pump On/Off settings for the three modelled.

	Pump 1 Settings		Pump 2 Settings		Pump 3 Settings	
	On	Off	On	Off	On	Off
Base Scenario - Provided Settings	0.753	0.144	0.83	0.144	0.906	0.144
Scenario 1 - Lowered 40cm	0.353	-0.256	0.43	-0.256	0.506	-0.256
Scenario 2 – On Setting Lowered 60cm, Off Lowered 40cm	0.153	-0.256	0.23	-0.256	0.306	-0.256

Table 4 - On/Off Pump Settings for Three Modelled Scenarios

Figure 2 shows the Modelled Wet Well Water Levels during the January 6th and 13th period, using the provided pump On/Off settings and with Scenarios 1 and 2.

Results from modelling the January 6th to 13th rainfall event**:**

- Lower on/off settings results in lower the water levels at the Pattullo wet well during much of the week; however, the peak water level of January 11th was the same for all pump on/off settings
- The water levels at 128th Street and 111th Avenue, 1.9 kilometers upstream from the pump station, were the same for all three scenarios during the entire week. Lower settings had no impact that far upstream.

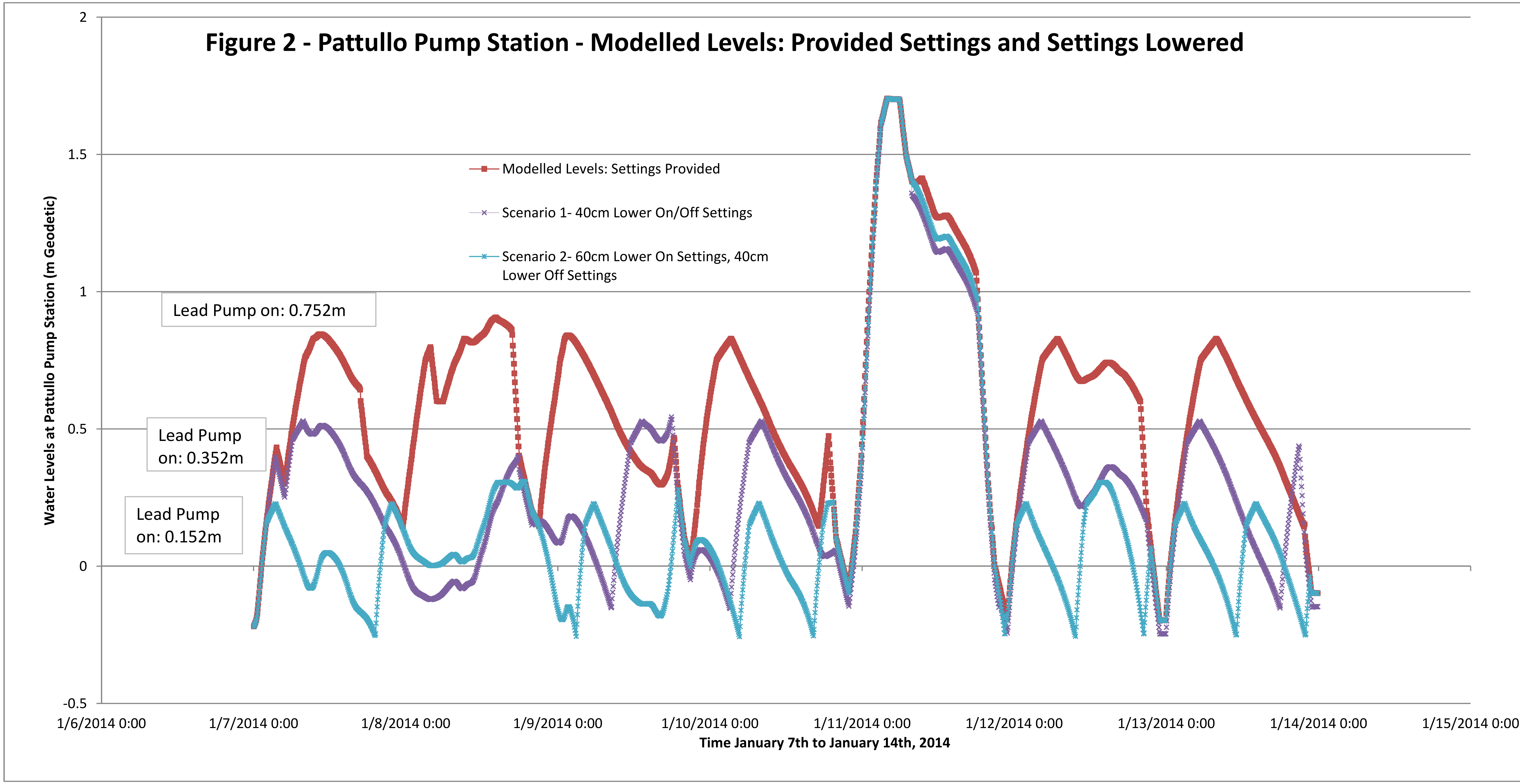


Figure 2 - Pattullo Pump Station - Modelled Levels: Provided Settings and Settings Lowered
Modelled Levels: Settings Provided
Scenario 1- 40cm Lower On/Off Settings
Scenario 2- 60cm Lower On Settings, 40cm Lower Off Settings
Lead Pump on: 0.752m
Lead Pump on: 0.352m
Lead Pump on: 0.152m
Water Levels at Pattullo Pump Station (m Geodetic)
2
1.5
1
0.5
0
-0.5
1/6/2014 0:00
1/7/2014 0:00
1/8/2014 0:00
1/9/2014 0:00
1/10/2014 0:00
1/11/2014 0:00
1/12/2014 0:00
1/13/2014 0:00
1/14/2014 0:00
1/15/2014 0:00
Time January 7th to January 14th, 2014

Lowering Pattullo Pump Station Settings – Design Rainfall Events

In addition to the January 6th to 13th period, the model was run with fifteen design rainfall events with 2-year, 5-year and 100 year return periods. The model was run using the provided **Base Scenario** On/Off settings and the **Scenario 2 –** On Settings Lowered 60cm, Off Settings Lowered 40cm pump settings. **Table 5** shows the Peak Water Levels at Pattullo Pump Station using these 2 settings.

Event	Provided Pump On/Off Settings - Peak Water Level (m)	On Settings 60cm Lower Off Setting 40cm Lower- Peak Water Level (m)	Difference (m)
2yr-1hr	0.83	0.35	0.48
2yr-2hr	0.83	0.44	0.39
2yr-6hr	1.12	1.10	0.02
2yr-12hr	1.38	1.38	0
2yr-24hr	1.33	1.13	0.20
5yr-1hr	0.83	0.49	0.34
5yr-2hr	0.83	0.48	0.35
5yr-6hr	1.17	1.17	0
5yr-12hr	1.39	1.39	0
5yr-24hr	1.39	1.32	0.07
100yr-1hr	0.86	0.60	0.26
100yr-2hr	0.90	0.74	0.16
100yr-6hr	1.39	1.39	0
100yr-12hr	1.40	1.40	0
100yr-24hr	1.41	1.41	0

Table 5 - Peak Water Levels, Base Scenario and Scenario 2 During Design Rainfall Events

Results show that lowering pump station settings will lower peak water levels at the Pattullo Pump Station during short duration (1hr and 2 hr) rainfall events. For 6 hr, 12 hr and 24 hour, the impact of lower settings diminishes.

At King George and 128th Street, 1.9 kilometers upstream of Pattullo Pump Station, lowering the settings had no impact on peak water levels during any modelled rainfall event. Lower pump settings will lower peak water levels for approximately 1 kilometer upstream from the Pattullo pump station.

Pattullo – Old Yale Conduit – Open or Closed Sluice Gate

The Pattullo – Old Yale Conduit was reopened in 2009 to enable the Old Yale pump station to drain the Pattullo pump station catchment in the event that the Pattullo pump station was submerged. Following upgrade, the Pattullo pump station is no longer at risk of flooding during the Fraser River 1894 flood levels and the Conduit now provides redundancy in both directions. A sluice gate exists at the Pattullo Pump Station that, when closed, prevents flow from Pattullo to Old Yale.

Our existing XPSWMM model was run with the sluice gate open and closed for 2-year, 5-year and 100-year return period rainfall events and for the period of January 7th to 13th.

Table 6 summarizes the Pattullo and Old Yale wet well peak water levels and the difference in elevation with the sluice gate open or closed.

	Pattullo Wet Well - Peak Water Levels			Old Yale Wet Well - Peak Water Levels		
Event	**Sluice Gate OPEN (m)**	**Sluice Gate CLOSED (m)**	**Difference (m)**	**Sluice Gate OPEN (m)**	**Sluice Gate CLOSED (m)**	**Difference (m)**
2yr-2hr	0.85	1.05	-0.20	0.58	0.50	0.08
2yr-12hr	1.67	1.94	-0.27	1.64	0.99	0.65
2yr-24hr	1.56	1.78	-0.22	1.54	0.68	0.86
		2 Year Average	**-0.23**		**2 Year Average**	**0.53**
5yr-2hr	0.90	1.05	-0.16	0.75	0.69	0.06
5yr-12hr	1.99	2.16	-0.17	1.95	1.63	0.32
5yr-24hr	1.85	1.99	-0.14	1.83	1.48	0.35
		5 Year Average	**-0.16**		**5 Year Average**	**0.24**
100yr-2hr	1.11	1.32	-0.21	1.07	1.07	0.00
100yr-12hr	2.31	2.37	-0.06	2.27	2.12	0.15
100yr-24hr	2.23	2.36	-0.13	2.20	2.00	0.20
		100 Year Average	**-0.13**		**100 Year Average**	**0.12**

Table 6 - Old Yale and Pattullo Wet Well Peak Water Levels, Sluice Gate Open or Closed

To summarize the results of the design rainfall events:

- In all scenarios modelled, water in the conduit flowed from Pattullo pump station to Old Yale pump station;
- During 2 year, 5 year and 100 year rainfall events, Pattullo peak water levels decrease with the sluice gate open and Old Yale peak water levels increase;
- Peak water levels in the Old Yale and Pattullo catchments are at roughly the same elevation when the sluice gate is open.

The rainfall and tidal conditions of January 7th to 13th were modelled and the following summarizes the results:

- During the peak rainfall of January 11th, modelling with an open sluice gate lowered the peak water level of the Pattullo wet well by **3cm**, and increased the peak water level of the Old Yale wet well by **3cm**.
- During the remainder of the week, when the sluice gate is open water levels in the Pattullo wet well were lower and the Old Yale wet well cycled more frequently to deal with the additional flow from the Pattullo catchment.

Based on the modelling done of the Pattullo-Old Yale conduit, we conclude:

- The channel provides important stormwater storage for the Old Yale pump station catchment and, when the sluice gate is open, storage for the Pattullo catchment as well;
- During major rainfall events, having the conduit open causes peak water levels in Pattullo and Old Yale catchments to become closer in elevation.

Keeping the sluice gate open creates redundancy in the system should a pump be out of service or one catchment be significantly more backed up than the other. It also results in similar peak water levels for the two catchments in major rainfall events. As both catchments service properties at comparable ground elevations, keeping the sluice gate open provides a more consistent level of service for the catchments and, therefore, it is recommended:

- The sluice gate remains closed during regular operation, in order to reduce pump cycling at the Old Yale pump station.
- The sluice gate may be opened when major rainfall events are expected.

Pattullo Pump Station Settings – Conclusions and Recommendations

Based on our modeling:

- The January 11th flooding at 128 Street and 111 Avenue would not have been affected by lowering the settings;
- The flooding at 128 Street and 111 Avenue was caused by an undersized 900mm Diameter storm sewer along the south side of King George Avenue from 128th Street to Scott Road;
- Lowering the settings will lower peak water levels at the Pattullo Pump Station for 2-year and 5-year return period, short duration rainfall events.

We do not recommend lowering the On/Off settings at Pattullo Pump Station at this time, but should be set as per **Table 3.**

APPENDIX D

Technical Memorandum:

Scott Road Drainage Review

Technical Memorandum

To:	Jeannie Lee, P.Eng	Date:	March 28, 2014
Copy:	Carrie Baron, P.Eng	Our Ref:	EB3779
From:	Barry Dinn, P.Eng Adrian Corlett, P.E.		

RE: City of Surrey - Scott Road Drainage Review

Background

Delcan has been retained by the City of Surrey to provide a drainage review of Scott Road, between Tannery and Old Yale Roads to assess the impact of a proposed multi-use pathway (MUP) along the west side of Scott Road. Between Tannery and Old Yale, the southern-most 120 metres of pathway is designed by Delcan and under construction, while the northern 590 metres has been conceptually designed by Binnie.

The driving force behind this Technical Memorandum is a major rainfall event that occurred on January 10th/11th, 2014 causing flooding in multiple areas throughout Surrey and the Lower Mainland. Along Scott Road, flooding occurred at two locations between Tannery and Old Yale Roads. **Figure 1** shows the two locations in relation to the Manson and Old Yale Pump Stations. The southern flooding location drains to the Manson Pump Station and the northern location drains to the Old Yale Pump Station. **Photo 1** and **Photo 2** show the flooding of January 11th.

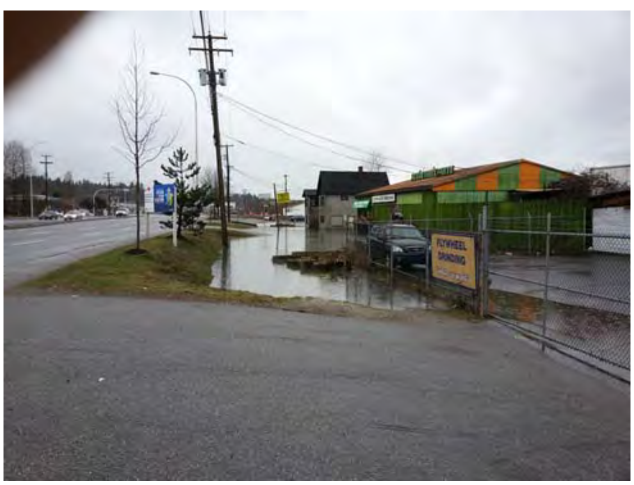
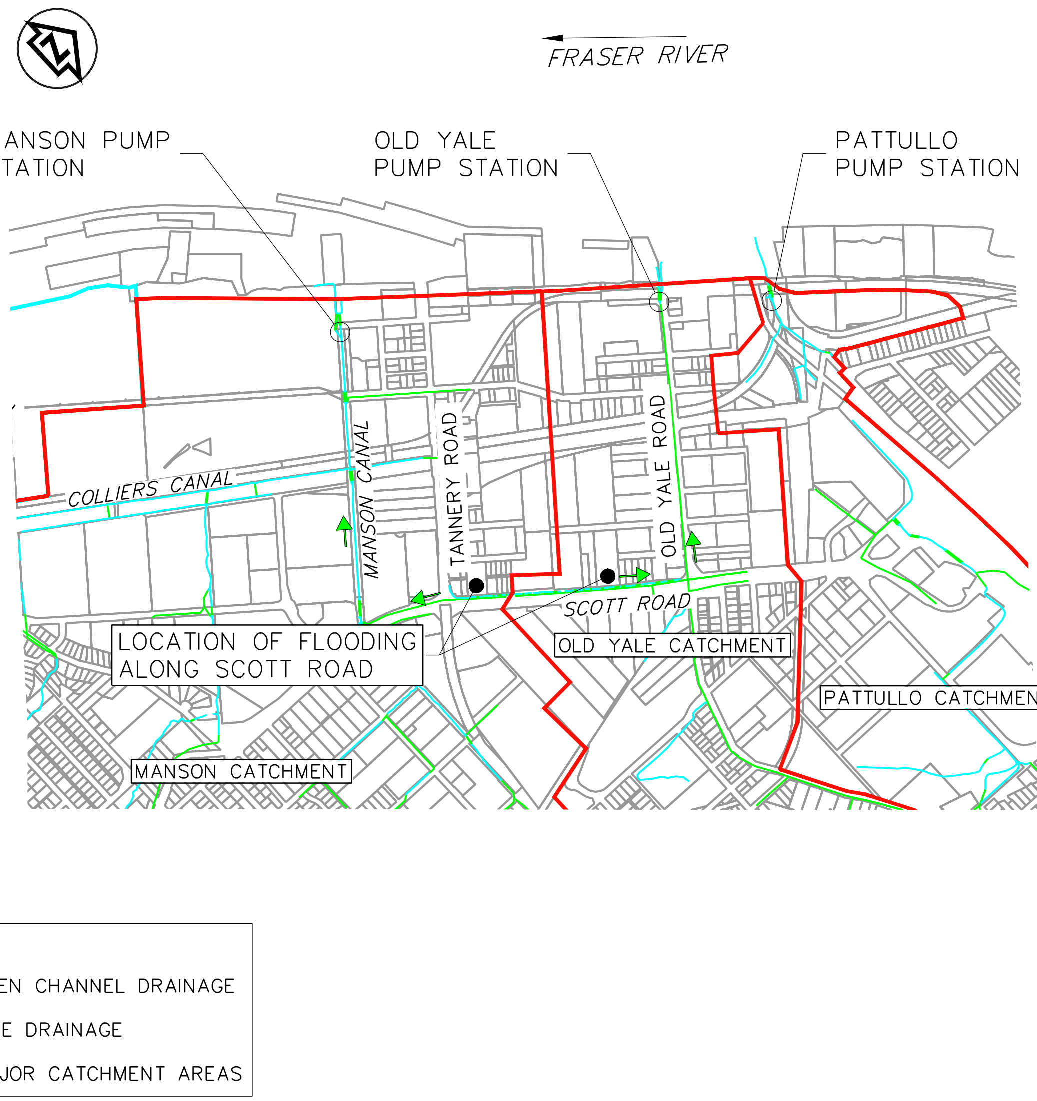


Photo 1 – Jan 11, 2014 - Scott Rd (Southern)

Photo 2 – Jan 11, 2014 - Scott Rd (Northern)

FIGURE 1

FLOODING LOCATION - SCOTT RD



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EB3779

Scott Road – Proposed Multi-Use Path (MUP)

Along the southern section of Scott Road, the path has been designed by Delcan and is under construction as of March 27, 2014. The design keeps the pathway adjacent to the road and ensures storage in the existing ditch is not reduced.

Along the northern portion along Scott Road, a conceptual design, *Drawing 13453-4.5 Issue Date 2013/10/23*, of the proposed MUP has been prepared by Binnie & Associates, and is attached with this memorandum. The existing ditches/swales are shown filled and a small swale installed at the toe of the path with connections to the existing storm sewer. The total project length is 590 metres with approximately 400 metres of ditches/swales being filled. The remaining length is driveway culverts, from 300mm to 450mm diameter that are shown removed in the conceptual design. **Photos 3 to 6** show the existing open drainage.

Photo 3 – Scott Rd (Facing North)

Photo 4 – Scott Rd (Facing North)

Photo 5 – Scott Rd (Facing South)

Photo 6 – Scott Rd (Facing South)

January 10th / 11th Rainfall – Event Description

During the evening of January 10th and morning of January 11th, 2014, a major rainfall event occurred in Metro Vancouver. **Table 1** shows the hourly rainfall recorded at City of Surrey's Kwantlen Park rainfall gauge and the approximate water levels of the Fraser River at the Manson Pump Station.

Time	Hourly Rainfall (mm)	Approx River Levels (m Geodetic)
1/10/2014 17:00	2	0.7
1/10/2014 18:00	1.4	0.3
1/10/2014 19:00	1.6	0.3
1/10/2014 20:00	3	-0.1
1/10/2014 21:00	4	-0.26
1/10/2014 22:00	5.6	-0.3
1/10/2014 23:00	6.8	-0.18
1/11/2014 0:00	10.8	0.28
1/11/2014 1:00	9.2	0.68
1/11/2014 2:00	7.4	1.08
1/11/2014 3:00	5	1.28
1/11/2014 4:00	3	1.28

Table 1 - Hourly Rainfall and Fraser River Water Levels

During the 12 hour rainfall interval, 59.8mm of rain was recorded. Based on Environment Canada's IDF data for Kwantlen Park, this 12 hour rainfall corresponds roughly to a **1 in 6 year** return period.

The significant rainfall was followed by a high tide that prevented the floodboxes from draining the catchments. Pumping capacity and storage in the system prevented overtopping and flooding along the major canals, however localized flooding occurred.

Based on our modelling, photos of the flooding, and discussions with City staff, flooding along Scott Road on January 11th was due to:

- Manson and Old Yale Pump Stations being unable to drain their catchments fast enough during this rainfall event as their floodboxes were closed due to high-tides.
- As water levels in the downstream trunk canals and sewers rose, the storm sewers along Scott Road became surcharged.
- As the low lying properties are unable to drain by overland flow, the backed-up storm sewers resulted in flooding.

Stormwater Model Analysis

As part of an on-going Integrated Stormwater Management Plan (ISMP) for the entire South Westminster neighbourhood, Delcan created a high-level drainage model along the trunk sewers & canals of Manson, Old Yale and Pattullo Pump Station catchments. For this assignment, drainage infrastructure along Scott Road was input to the existing XPSWMM model.

Data was obtained from City of Surrey Record Drawings and confirmed with a site visit. The west side of Scott Road has storm sewer (from 375mm to 750mm diameter), and a ditch/driveway culvert that runs along a parallel alignment. The ditch/driveway culvert alignment has connections to the storm sewer roughly every few hundred meters. At the northern Scott Road location of January 11^{th} flooding (**Photo 2)**, a 450mm diameter storm sewer exists as well as a ditch that runs parallel.

The model was run under the current condition and the future scenario with ditches filled by the proposed pathway. Results are as follows:

- Under free flow conditions, storm sewers along Scott Rd can convey 5-year return period events. However, during major events and periods of high tides, flow is limited by the existing trunk sewer along Old Yale Road, and surcharging can occur along Scott Road;
- Filling the existing ditches will reduce storage along Scott Road resulting in higher water levels during major storm events; and
- 2-year and 5-year return period events with 6 and 12 hour duration storms were modelled under existing & future scenarios. These rainfall events were selected to provide an indication of the impact of the proposed path. Infilling the ditch resulted in increased maximum water levels (Hydraulic Grade Line) in the ditch along Scott Rd. At the northern Scott Road flooding location, the increases in maximum water levels were are shown in **Table 2**:

Rainfall Event	Increase in Peak Water Level from Filling Swale
2-year, 6 hour Storm	2cm
2-year, 12 hour Storm	7cm
5-year, 6 hour Storm	7cm
5-year, 12 hour Storm	13cm

Table 2 - Flooding Location along Scott Road - Water Level Increase

Options for Mitigation Measures

As shown in the above table, peak water levels giving rise to surface flooding are expected to increase as a result of filling the ditches running along the west side of Scott Road. Options have been developed to offset the impact of the path installation. These options are intended to ensure that the proposed path does not worsen the drainage along Scott Road or downstream, but are not necessarily meant to improve the drainage situation. In order to mitigate this risk, the following options have been considered.

1. Replace the ditches with storm sewers along its existing alignment;
2. Construct small berm along the property line;
3. Install piped underground storage or proprietary stormwater storage system;
4. Design and build the multiuse pathway closer to Scott Road with near-vertical side-slopes;
5. Design and build the multiuse pathway with a swale grading towards Scott Road and construct a new ditch between Scott Road and the pathway;
6. Combination of the above depending on the cross section and utility conflicts.

Discussion of Options

Option 1: Replace Swale with Storm Pipe. The majority of lost storage could be replaced with this option, however it would result in two separate storm systems are running parallel along the west side of Scott Road. This increases maintenance requirements and makes this option unappealing in the long-term.

Option 2: Constructing Small Berms. Based on the current design, there is only a narrow width of property between the pathway and property line and therefore this solution is not feasible without changes to the path alignment.

Option 3: Underground Storage Chambers/Pipes. Underground storage chambers have been used throughout Surrey's Stormwater system and could be sized to replace the storage lost to the path. Due to soft soil conditions in the area, light-weight underground storage chambers, such as StormTech or an Armtec proprietary product, are preferred where settlement is expected. Additionally, PVC pipe could be used.

- The chambers or pipes could either form part of the conveyance system with active storage used during heavy rainfall events or be a storage tank with an inlet pipe that fills above a prescribed water level and a lower-elevation discharge pipe with a back-flow preventer to drain the system following a rainfall event. Either system requires that the active storage be above the bottom of the future ditch.
- The top elevation of the chamber/pipe should be as close to the proposed ground elevation as possible to maximize active storage. The storage can be either fully under or partially under the proposed pathway. We expect that the chambers won't be installed under driveways as the additional cover required will limit active storage.
- The underground chambers or pipes should be located at properties most at risk for flooding to maximize effectiveness.

Light-weight storage tanks or PVC pipes minimize the risks of settlement, but should be monitored as part of a maintenance program. A draw-back of this option is increased drainage maintenance of an enclosed system with unique infrastructure.

Option 4: Multi-use Path Closer to Scott Road. The existing ditch would be relocated closer to the property line rather than filled. Existing Hydro poles, if not relocated, would need to be integrated into the pathway and some sections of the path made wider to accommodate the poles. The ditch size varies along the length of Scott Road, and therefore, some sections, would need steeper walls to maintain storage. Existing driveway culverts may require replacement during MUP installation. A major draw-back of this option is that the MUP would no longer be separated from Scott Road. **Figure 2** schematically shows the path location and relocation of the existing ditch.

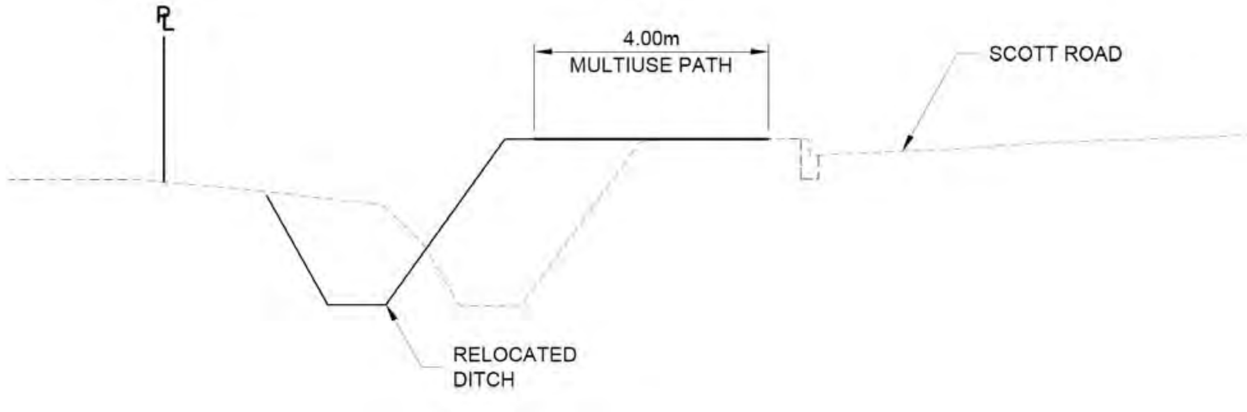

Figure 2 - Schematic MUP Closer to Scott Road

Option 5: Multi-use Path Closer to Property Line. The existing ditch would be relocated closer to Scott Road rather than filled. The ditch may require steeper side slopes in order to fit within the width. Grading the multiuse path towards Scott Road would eliminate the need for the swale shown on Binnie's typical section. As above, existing hydro poles would need to be relocated or integrated into the multi-use path. Where an existing pole is within the proposed ditch footprint and relocation is not cost-effective, a short section of culvert can be installed. The resulting loss of storage can be mitigated with wider ditch sections upstream or downstream.

A metal railing may be required between Scott Road and the relocated ditch, depending on the distance between top of ditch and the existing curb. **Figure 3** schematically shows the path location and relocation of the existing ditch.

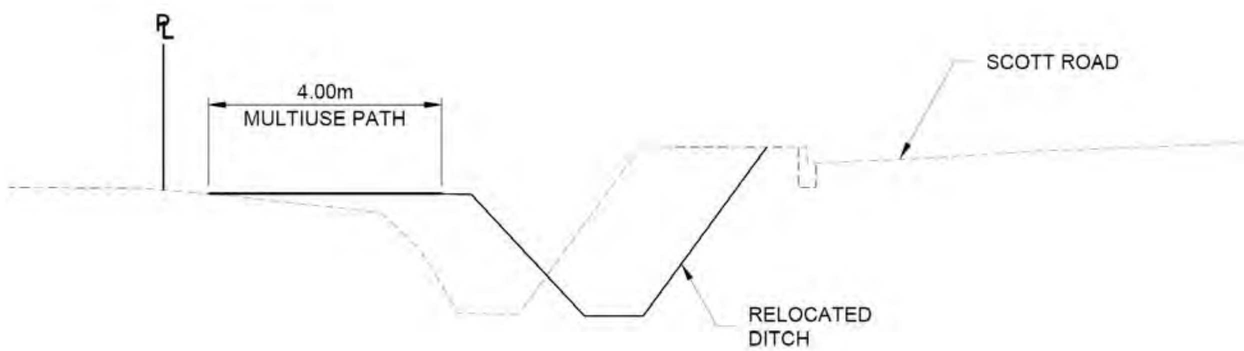

Figure 3 - Schematic MUP Closer to Property Line

Scott Road – Conclusions and Recommendations

Flooding along Scott Road was a result of:

- Low-lying properties were unable to drain by overland flow routes;
- The main storm trunk lines could not drain fast enough resulting to back-up along Scott Road's drainage pipe and flooding at low-lying areas that weren't able to drain.

For the 585 metres of proposed multi-use path, based on a site visit and a review of the property dimensions, it is technical feasible to provide the same or more volume of storage by considering the above options.

Of the above options, Options 3, 4 and 5 are viable solutions to maintain the existing volume of stormwater storage. We understand that keeping the path close to Scott Road is not preferred by the City's Transportation group so Option 4 is not recommended.

We recommend that:

- A criterion for the detailed design should be that active stormwater storage be no less than currently provided;
- In sections where space permits, Option 5 should be implemented with the new ditch sized to match existing. Where additional storage is needed, underground storage described in Option 3 should be implemented to maintain or increase storage;
- The decision of where to implement Option 5 and Option 3 or a combination of the two should be based on an evaluation during the detailed design.