WILLBAND CREEK ISMP

FULL REPORT
October 18, 2019

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Willband Creek Integrated Stormwater Management Plan

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Nov 27, 2019

Acknowledgements

This report was prepared by Urban Systems Ltd. with subconsulting support from Dillon Consulting (environmental services), GeoAdvice (hydrologic/hydraulic modeling services), and Thurber Engineering (geological and hydrogeological services). Numerous City of Abbotsford staff also offered their experience and expertise to develop this report.

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EXECUTIVE SUMMARY

The City of Abbotsford (the City) has developed an Integrated Stormwater Management Plan (ISMP) for the Willband Creek watershed to allow for the continuation of viable development and redevelopment, while at the same time mitigating impacts to the environment and the existing drainage system and to plan for the effects of climate change.

The ISMP is developed and described in four parts:

- **Part 1** describes existing conditions, issues, and opportunities that need to be considered by the City in terms of integrated stormwater management;
- **Part 2** describes the future conditions, and an assessment of the potential impacts of development (if unmitigated) that need to be considered by the City;
- **Part 3** describes stormwater management strategy to address the issues, opportunities, and potential future impacts of development;
- **Part 4** describes the implementation strategy and adaptive management strategy.

Part 1: Existing Conditions

Land Use

The Willband Creek watershed is located within the heart of Abbotsford with a tremendous diversity of land uses. Major land uses include residential, commercial, industrial, agricultural, institutional, and park and school uses. The study area is already highly urbanized, and incorporates several neighbourhoods (or portions) including:

- City Centre;
- Fairfield;
- Marshall – McCallum;
- Historic Downtown;
- Hazelwood;
- South Clearbrook;
- Immel – McMillan, and
- Clayburn

With redevelopment in and around the South Fraser Way being a priority in the coming years, there is great opportunity for stormwater management, as it provides the opportunity to implement source controls where they do not currently exist. However, challenges also occur due to increased building footprints and less area for surface-based rainwater management. Based on the 2016 aerial photograph of the study area, approximately 45% of the total study area is currently impervious (ie. asphalt and roof tops) surface. However, in the highly urbanized centres the impervious surface is around 90% with very little tree canopy. While redevelopment poses on opportunity to change, a challenge is the relative slow speed at which that change will occur if left to redevelopment alone.

Environmental Conditions

Historic development has significantly altered the aquatic habitat, water quality, and terrestrial habitat. As part of the ISMP, an investigation of existing habitat conditions within the study are was completed and consisted of a review of background information supplemented by a series of field assessments.

Willband Creek and its various named tributary channels and waterbodies are the most significant habitat features of the study area. The most significant water bodies include:

Mill Lake and its creek through Ravine Park, Willband Creek, Boa Brook, Horn Creek, Prairie Street Creek, and although man-made the

Willband Creek Stormwater Detention Facility near Willband Creek's junction with Clayburn Creek.

Naturally, the terrestrial portion of the study area is dominated by coniferous forests with western hemlock and western red cedar being the most common tree species. Much of the coniferous forest within the study area has been removed and replaced with non-native species on landscape properties, and a large part of the terrestrial habitat within the watershed consisted of landscaped residential properties.

The Watershed Health Tracking Score in metro Vancouver's Template for Integrated Stormwater Management Planning 2005 was applied to measure watershed health. Using this template, Willband Creek would be indicated as an extremely impacted watershed, which can be expected given the loss of intact riparian forest and high imperviousness.

The conditions across the watershed are highly varied and the high-quality components are outweighed by the poor-quality components. Overall, the watershed health is considered poor based on Metro Vancouver standards.

While it is evident that the City is placing an increased emphasis on environmental planning and protection, this has not been a seamless effort. Developers and individual property owners often do not fully understand the purpose of the City's environmental protection measures, and instead see it as an increased expense and burden. Education to identify, understand, and address these gaps between policy direction and on-the-ground implementation will be essential to a successful ISMP.

Geotechnical & Hydrogeology Conditions

The surficial geology of the Study area was mapped at a regional scale by the Geological Survey of Canada and published in 1980. The geologic conditions within the Study area are complex and varied.

Most of the surficial sediments within the Study area are associated with the repeated advance and retreat of glaciers, but the modern-day river and hill-slope processes continue to shape the landscape by eroding and depositing sediments.

While some of the lower lying areas of the watershed have moderate to poor infiltration capabilities, 70% of the study area is considered good for infiltration which provides a significantly opportunity to return rainwater to the ground. However, doing so increases the need to consider water quality prior to return to ground in an urban setting.

Hydrologic and Hydraulic Conditions

In addition to natural features, the Willband Creek watershed's management system is comprised extensively of manmade features; storm sewers, detention ponds, culverts, and ditches. An important aspect of an ISMP is to understand the hydrology of the watershed, the working hydraulics of the management systems, and how it performs against established criteria. A hydrologic (relationship between rainfall and land) and hydraulic model (the performance of conveyance and management structures) was compiled to assess system performance, highlights of which are noted in the summary below.

Existing Condition Summary

- Both aquatic and terrestrial habitats have been significantly impacted by past development and watercourse encroachment. Overall, the watershed health is deemed to be poor.

- Despite the overall assessment noted above, there are some local cases where aquatic and riparian health is considered fair; including in Horn Creek, Boa Brook, and Thiessen Creek. Ironically, Horn Creek has also been identified as having the largest number of bank erosion sites.
- Erosion in Horn Creek, Boa Brook and Prairie Street Creek persist despite some instream repairs having been completed in Horn Creek. While source control through redevelopment provide an opportunity to improve the situation, the timeline with that approach is expected to be long, therefore the City will likely need to intervene with communal solutions more near term.
- Water quality is considered somewhat poor in the lowlands and in Mill Lake. In the case of lowland watercourses, mainly a result of urban runoff and likely insufficient water circulation and lack of riparian cover. In the case of Mill Lake, this is mainly attributed to stratification and insufficient water circulation.
- There is good infiltration potential for the majority of the upland study area; this opens a strong opportunity to apply low impact development techniques as redevelopment occurs.
- Modelling indicates that portions of the lowland system do not meet current conveyance criteria. System performance is hampered even further due to downstream effects of the broader Matsqui Prairie system.
- Generally, the performance of the storm sewer network appears to be reasonably good against established criteria; however, under the 100-year (major) event, the potential of flooding is widespread.
- Seven of 14 public upland detention facilities modelled (excluding Mill Lake and Willband Creek Park ponds) do not appear to be meeting criteria.

Part 2: Potential Future Conditions

Based on the City's 2016 Official Community Plan, the City has developed a "Build_35" GIS dataset, which represents a prediction of that extent of lands that may be redeveloped by year 2035. To represent the potential effects of future land use changes, three primary parameters were adjusted in the analysis; the total impervious fraction, the portion of the impervious fraction that is redirected to ground, and whether engineered controls are applied. In addition, the potential impacts of climate change area also considered.

Many different land use sub-scenarios were created to test the outcomes of different level of controls and influence of potential climate change, results of which are compared against existing conditions. For this ISMP, the following land use sub-scenarios have been created:

- Future Land Use (Build_35) with no controls and historic precipitation.
- Future Land Use (Build_35) with controls and historic precipitation.
- Future Land Use (Build_35) with no controls, but climate change precipitation.
- Future Land Use (Build_35) with controls and climate change precipitation.

Based on the analysis, is appears as though climate change will potentially be a more significant driver of erosion potential than future land use, but that implementing effective source controls through redevelopment can largely compensate for the impacts of climate change and redevelopment. As such, in this case redevelopment poses a significant opportunity for betterment rather than a detriment.

Within the historic downtown there is some aged piping infrastructure within private property to which the City does not have a right of way. Options exist to redirect City systems away from private property.

A critical component to the drainage system is a large diameter storm sewer pipe through the Historic Downtown that was installed to infill the original Mill Lake Ravine and settle the area. The current condition of this pipe is unknown and its considered high priority to assess. Hydraulic modeling suggests is marginally undersized to meet current criteria. The strategy for managing this critical piece of infrastructure will be determined through an assessment of its condition. The costs associated with its failure and its replacement are both very high.

The City's current design criteria for storm sewer infrastructure is different than what likely existed at the time when much of the historic infrastructure was installed. Despite the majority of trunk infrastructure currently meeting criteria, there are many segments which long term that will be replaced and upgraded; either to ensure capacity meets criteria under future conditions, that the infrastructure meets the minimum size requirement of current criteria, and that drainage infrastructure is installed in areas that currently don't have it.

Analysis does not indicate that flooding within the lowland floodplain to the north will worsen if successful source controls in the uplands are implemented. Again, redevelopment poses an opportunity for betterment. However, performance of the lowland floodplain is highly governed by downstream systems within the Matsqui Prairie and its outfall to the Fraser River. Performance of the floodplain will be governed more significantly by that system. The City has budgeted to conduct a more comprehensive study of ways to improve performance of the Matsqui Prairie system.

Part 3: Management Strategy

Based on the findings of Part 2, a number of recommended management strategies are identified, as follows:

Storm Sewer Capital Program and Priorities

Storm sewer and culvert improvements are grouped into one of three priority levels using the following logic:

Priority 1 – components that will fail against current criteria in the future even with the application of source controls.

Priority 2 – components that will fail against current criteria in the future only if successful source controls are not applied.

Priority 3 – components that will meet capacity criteria but do not meet minimum size requirements or where infrastructure does not currently exist.

The recommendations for storm sewer capital program and priorities are:

1 Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary.

2 Develop a strategy to redirect City infrastructure in Historic Downtown to Montrose Avenue and communicate service connection redirection and private sewer abandonment requirements to property owners (also flag these properties in the City data bases to ensure this requirement is not missed during any future building or development permit application).

3 Conduct a condition assessment of the trunk sewer downstream of Ravine Park (high priority), then as the results dictate, conduct a study to confirm the viability and cost effectiveness of creating on-line temporary storage within Ravine Park.

4 Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted flood loss of 100 m^3 or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 m^3 and 100 m^3.

5 Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study.

Environmental Opportunities

There are several opportunities available to the City to improve the habitat value in the study area. However, several constraints are associated with each of them. Opportunity areas included:

- riparian infill;
- fish access improvement;
- habitat construction;
- instream maintenance;
- channel daylighting;
- water quality improvements; and
- integration of habitat features into stormwater controls.

Based on the analysis, the following recommendations relating to environmental opportunities are provided:

1 Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road.

2 Replace or modify stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street.

3 Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation (collaboration with Fraser Valley Conservancy).

4 Removal of garbage and other anthropogenic debris from watercourses.

5 Recognized to have significant challenges, however, review the practicality of daylighting a portion of ravine previously infilled with piping downstream of Mill Lake.

6 Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged.

7 Subject to item 6 above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake.

8 Install “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators, yet more sophisticated treatment options exist at higher expense.

9 Develop necessary programs and regulations to increase the tree canopy in the City Centre and Historic Downtown area.

Geotechnical and Source Controls

It is expected that to protect a high vulnerability aquifer, runoff treatment should involve media filtration, either in the form of amended landscape growing media or with proprietary media filtration devices.

Recommendations and action items for Geotechnical and Source Controls include:

1 Further develop a mitigation strategy for high risk erosion sites in ravines.

2 Explore candidate sites for communal ponds that may arrest erosion in Horn Creek and Boa Brook. Further evaluate these pond sites against the alternative option of a high flow diversion that was previously identified in a 2009 study.

3 Implement source controls at Civic sites such as the parking lot at Five Corners and the Municipal Hall site to demonstrate leadership in source controls, however these facilities will not change the performance of local storm sewer conveyance in a design event.

4 The City has an established Stormwater Source Control Bylaw that currently applies to CICP Lands and the Abbotsford Airport Lands and is a supplement to the Development bylaw. Consistent with the recent Master Drainage Plan, its recommended that this Storm Water Source Control Bylaw be adopted as a City-wide document.

5 Develop criteria and standards for the application of roadside swales or other form of control in urban streets.

6 Conduct annual observation and evaluation of geotechnical stability in creek ravines.

7 Create a Development Permit Area for the application of infiltration system in proximity to steep slopes, under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose.

Mill Lake and Willband Creek Floodplain

The City has particular interest to understand the potential change in floodplain performance as a result of changes to the upland systems and climate change. The following recommendations or provided:

1 Conduct Phase 2 Matsqui Prairie Drainage Study.

2 Upon completion of the Phase 2 Matsqui Prairie Drainage Study, establish a new Flood Construction Level (FCL) as necessary.

3 Adjust operational protocols for Mill Lake to offer greater freeboard in the winter.

Actions and Capital Costs

Based on the recommendations above, the following table of actions, relative priority and planning level budgetary costs are provided for inclusion into the capital program. Costs are Class D and include 50% engineering and contingencies but exclude taxes.

Table ES-1
Summary of Actions, Priority and Budgetary Costs

Action	Priority	Budget Cost
LAND USE MANAGEMENT		
Explore the design of rainwater management facilities for both retention and water quality treatment in the Municipal Hall lands site and the City owned parking lot at West Railway Street and Essendene Avenue. Both facilities would serve local catchments and demonstrate the City as leaders.	Medium	$50,000 (pre-design study only)
Designate the 4 blocks of Historic Downtown between South Fraser Way to George Ferguson Way, Pauline Street to Montvue Avenue, as a special area exempting it from current stormwater site control criteria but pay cash-in-lieu for detention. However, onsite source controls are still encouraged where feasible.	High	N/A
Develop policy around service connections for subsurface floor space, both in terms of the mechanical requirements for the physical connection and statements to limit the City's liability.	High	$20,000 (excluding creation of regulatory documents)
Establish tree canopy targets and landscape standards to suit (both private and public spaces). Determine what regulatory processes would trigger implementation (eg. Building permit, re-development, capital reconstruction).	High	$30,000 (excluding creation of regulatory documents)
ENVIRONMENTAL OPPORTUNITIES		
Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road.	Low	$50,000 to develop a program $100,000 to $500,000 for planting
Modify or replace stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street.	Low	TBD through design review

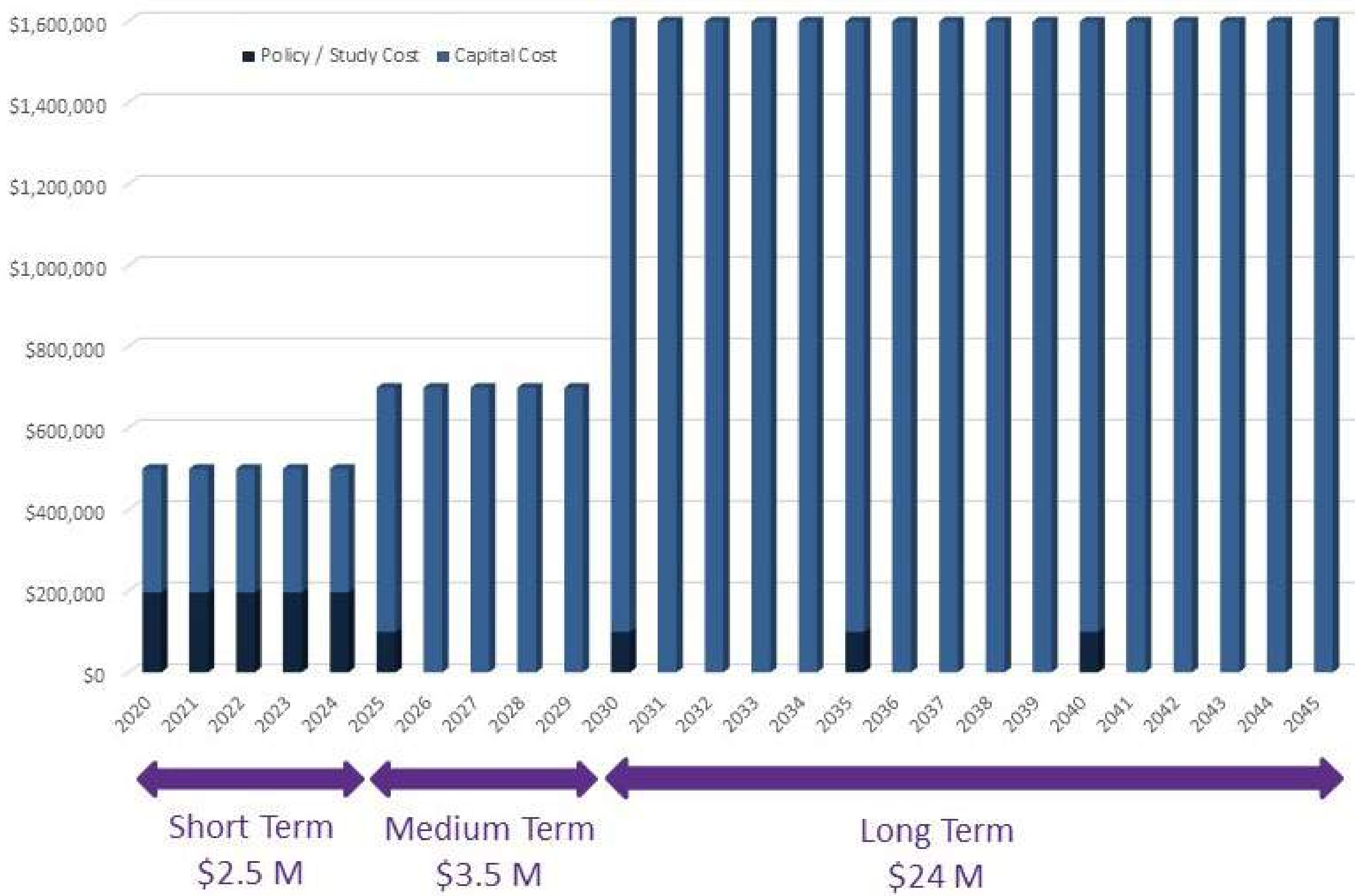
Action	Priority	Budget Cost
ENVIRONMENTAL OPPORTUNITIES Cont.		
Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation.	Low	$50,000 to develop a program Premature to offer an implementation budget, particularly if off-line pools are considered.
Removal of garbage and other anthropogenic debris from watercourses.	High	N/A
Recognized to have significant challenges, however review the practicality of daylighting a portion of ravine downstream of Mill Lake.	Low	$50,000 for investigation only
Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged.	Medium	$20,000
Subject to item above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake.	Medium	TBD
Consider “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators. (7 outfalls)	Medium	$1.5M to $3.0M assuming O/G, not media filltration
Apply landscaped based biofiltration site controls wherever possible.	High	N/A
GEOTECHNICAL AND SOURCE CONTROLS		
Expand Stormwater Source Control Bylaw to City-wide, and to ensure it is enforceable through the Development and Building Permit processes.	High	$50,000
Identify high risk sites (eg. auto-wreckers, service stations) which would be restricted from infiltration systems.	High	N/A

Action	Priority	Budget Cost
GEOTECHNICAL AND SOURCE CONTROLS Cont.		
Further develop an erosion mitigation strategy for Horn Creek and Boa Brook. Done in concert with the exploration of communal detention ponds discussed under "Infrastructure" below.	High	$50,000
Conduct an annual review and assessment of geotechnical stability in Horn Creek, Boa Brook and Prairie Street Creek.	High	$20,000 per year
Develop criteria and standards for the application of urban roadway Green Infrastructure. This would also include the potential application of perforated storm sewers provided water quality pre-treatment is provided.	High	$50,000
Develop a comprehensive tracking GIS database of public and private site controls.	High	TBD
Explore operating permit requirements for long term inspection and maintenance of private site controls.	Medium	$20,000
Create a Development Permit Area for the application of infiltration system in proximity to steep slopes under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose.	High	$20,000
INFRASTRUCTURE		
Video inspect trunk sewer downstream of Mill Lake Ravine Park and conduct condition assessment. It is also recommended that the City prepare a "criticality" map of the drainage system and assign operational policy on a priority basis.	**High**	$20,000
Subject to result of the above action, conduct a pre-design study to explore the potential for restricting flow at the storm sewer inlet at the downstream end of Mill Lake Ravine Park.	High	$50,000

Action	Priority	Budget Cost
INFRASTRUCTURE Cont.		
Subject to the findings of items above, decide to upgrade the trunk sewers downstream of Mill Lake Ravine Park, either through full replacement or supplemental capacity, or restrict flow at the inlet.	High	TBD
Proceed with a design process for the redirection of City sewers to Montrose Avenue through the Historic Downtown to direct City flows out of private lands. Require private lands to reconnect during redevelopment.	Low	$50,000
Notify private property owners in Historic Downtown that need to reconnect to realigned City infrastructure on Montrose Avenue and flag these properties in the City database to ensure reconnection is achieved through Building or Development permitting.	Low	N/A
Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary.	Priority 1 – Medium-High Priority 2 – Medium Priority 3 – Low	Priority 1 - $5,345,800 Priority 2 – $8,571,500 Priority 3 - $24,352,500
Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted floodloss of 100 m^3 or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 m^3 and 100 m^3.	Medium	$200,000 to $500,000 depending on the level of detail
Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study.	High	$100,000

Action	Priority	Budget Cost
INFRASTRUCTURE Cont.		
Monitor flows in storm sewer system to validate performance at most problematic (in theory) areas (see Figure 15.1) – based on seven sites monitored November to April. Then conduct an updated hydraulic assessment.	High	$100,000
Conduct a predesign study to further explore the potential of communal detention ponds to reduce erosion in Horn Creek and Boa Brook and compare to the diversion conceived by previous 2009 study.	High	$100,000
MILL LAKE AND WILLBAND CREEK FLOODPLAIN		
Conduct Phase 2 Matsqui Prairie floodplain assessment	High	N/A (budgeted by the City for 2020)
Initiate discussions with the Fraser Valley Conservancy regarding a floodplain storage and habitat facility west of Highway 11.	High	N/A
Review need to establish new Flood Construction Levels (FCL's) in the floodplain.	High	N/A
Adjust operational protocols for Mill Lake to offer greater freeboard in the winter.	High	N/A

Figure ES-1
Preliminary Capital Expenditures and Timelines



Part 4: Adaptive Management

Adaptive management is a process of monitoring, reviewing, learning, and adjusting.

Monitoring

Environmental health and flow monitoring are two important components of an Adaptive Management process, but the program needs to be expanded. Monitoring is broken into several categories, including physical (e.g. are the desired flows and quality of water being achieved?), regulatory (e.g. are the City's regulatory tools successfully guiding development?), and process (e.g. are City staff properly informed and are inter-departmental processes in place to successfully direct the plan's implementation).

Physical Monitoring

- It is recommended that the City implement some short term (at least one winter season) monitoring within the storm sewer system and existing detention ponds in order to validate performance.
- It is recommended that the City implement a semi-permanent water level (not flow) gauge on Willband Creek on the upstream side of Highway 11.
- It is recommended that the City require short term monitoring (one winter season) of all future stormwater source controls, private and public, to validate that their performance in accordance with design criteria.
- It is recommended that the City retain a qualified geotechnical professional to inspect Horn Creek, Boa Brook and Prairie Street Creek each year for soil instabilities and risk assessment.
- Finally, is recommended that water quality and benthic sampling be repeated on a 5-year cycle at the same locations as previously sampled.

Regulatory Monitoring

The most significant regulatory aspect to track is that source controls are being implemented in accordance with bylaws and criteria.

- It is recommended that the City set up appropriate record systems to track that source controls are in fact being implemented through both the Development and Building Permit processes, and in accordance with the bylaws. As an extension, also track that inspection and maintenance reporting is being done.
- It is anticipated that an Urban Forestry Management Strategy would include some form of regulation to guide development and private property owners. It is therefore recommended that if and when such regulation is created that tracking be implemented.
- And finally, it is recommended that inspection and monitoring occur at occupancy permit that a development / building has not exceeded the permissible site coverage as permitted by the zoning bylaw, and that directly connected impervious surface does not exceed those permitted by design criteria.

Process Monitoring

The most significant aspects of process monitoring are to ensure that City inspectors are knowledgeable of design criteria and standards of the Development Bylaw and Stormwater Source Control Bylaw. An equally important process to monitor is that implementation of controls is not "slipping through the cracks" during the Development or Building Permit process.

- It is recommended that a "checklist" field be created in the application registry to track whether or not controls are successfully implemented.

Assessment

It is recommended that an audit of all above monitoring be undertaken on a 5-year cycle. Physical monitoring data would be processed for evaluation by hydrologists and environmental professionals and evaluated against all preceding data. Its recommended that the City implement a central database to record and track data for each monitoring period. The fundamental goal is to see if the hydrologic response to rainfall of the built lands is reducing, and that the water quality and watershed health is improving.

Key Performance Indicators

Cost effective, measurable, and reliable key performance indicators allow the City to determine whether or not the watershed vision is being achieved. Performance indicators need to be selected for things that can be observed and measured frequently. In the context of Willband Creek, recommended key performance indicators are:

- Reduced sediment deposits at the base of Horn Creek, Boa Brook, and Prairie Street Creek
- Stability of creek bed and banks in Horn Creek, Boa Brood, and Prairie Street Creek
- Fewer annual service complaints due to flooding
- Increase in tree canopy as measured from aerial photos
- A positive differential between the number of trees planted to the number of trees removed
- No reduction in the riparian vegetation as measured from aerial photos
- Successful implementation of source controls with all development and building permits that require them
- Improved water quality as measured in Horn Creek
- Improved benthic health as measured in Horn Creek
- Successful implementation of the Capital Program.

Responses

The monitoring program is important to assess the specific failure mechanism, should failure occur. Was there a poor design(s)? Has there been a significant change in weather patterns? Was there a breakdown in approval process that prevented bylaws from being enforced? Was there an infrastructure failure due to insufficient maintenance? There can be many reasons why objectives may not be met. The response(s) need to align with the cause. It is therefore premature to articulate a specific response plan at this time, but some fundamental responses may be as follows:

1 If watercourse erosion and environmental health do not stabilize, or preferably improve, the City may need to accelerate the implementation of communal management infrastructure through its capital program; either with high flow diversions or stormwater detention ponds. As determined herein this ISMP, there are relatively few opportunities for effective ponds on lands where no buildings currently exist, therefore land acquisition and building demolition may be required.

2 If development or building permits are being completed without successful source controls, the City needs to evaluate whether this was a procedural failure, or if it needs to strengthen the enforcement and penalties of the bylaws, making amendments to them accordingly.

3 If service calls occur due to structural or maintenance failure, the City needs to strengthen its Asset Management Program.

4 If maintenance of private source controls is not validated, the City should consider implementing a formal Stormwater Source Control Operating Permit program.

5 If there is increased flooding in the upland urban area not caused by structural or maintenance failure, the City may consider accelerating its pipe replacement program on a priority basis or explore alternative mitigative measures.

6 If the funding for infrastructure change cannot keep up with demand (i.e. worsening conditions) the City needs to revisit its funding stream and look to a program that provides more reliable funding.

7 If the City is not leading by example in implementing and maintaining source controls in public spaces, the City needs to evaluate its interdepartmental collaboration and priorities.

PART 1 – EXISTING CONDITION

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1 INTRODUCTION

1.1 Purpose

The purpose of developing an Integrated Stormwater Management Plan (ISMP) for the Willband Creek watershed is to allow for the continuation of viable development and redevelopment, while at the same time mitigating impacts to the environment and the existing drainage system and to plan for the effects of climate change. This ISMP will inform the formulation of land use and infrastructure policies and guidelines that will be incorporated into future development and capital plans for the watershed.

The ISMP is developed and described in parts:

- Part 1 describes existing conditions, issues, and opportunities that need to be considered by the City in terms of integrated stormwater management;
- Part 2 describes the future conditions, and an assessment of the potential impacts of development (if unmitigated) that need to be considered by the City;
- Part 3 describes stormwater management strategy to address the issues, opportunities, and potential future impacts of development;
- Part 4 describes the implementation strategy and adaptive management strategy.

1.2 Study Area

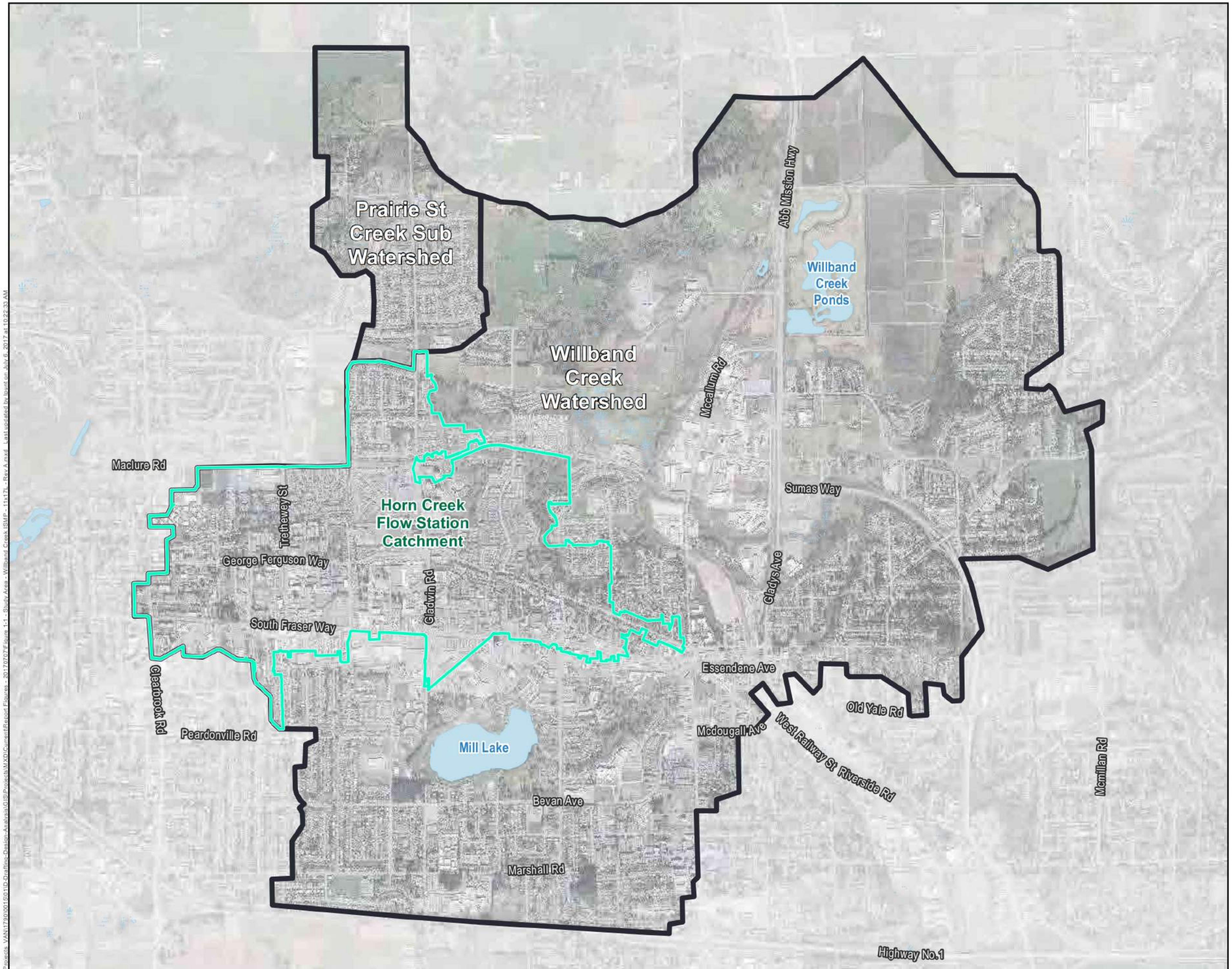
As shown on Figure 1.1, the Willband Creek watershed is located in the centre of the City and spans south to Highway 1, west as far as Clearbrook Road, north to Matsqui Prairie and east beyond McMillan Road. It includes Mill Lake. A sub-catchment of approximately 130 hectares (ha), defined as the Prairie Street Creek Sub-Catchment, is not tributary to Willband Creek but is included in the Study Area as it is of special interest to the City, as described further in this report. The total Study Area is an estimated 1,840 ha.

1.3 Known Issues

On January 23, 2017, the consultant team facilitated a workshop with a broad selection of City staff to discuss the scope of the ISMP and to identify issues pertinent to the watershed. The City identified specific areas of concerns and issues on the figures provide in Appendix A.

A generalized summary of known issues identified by the City includes:

- Increased flooding and wet conditions in the Matsqui Prairie floodplain, affecting the performance of the Willband Creek detention facility and influencing land usage;
- numerous sites of channel erosion and poor water quality;
- risk to flooding to properties around Mill Lake if water levels not actively managed;
- wide spread invasive species in creek corridors; and
- some critical trunk infrastructure in poor condition or not functioning properly.



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Study Area

Legend

- Willband Creek Watershed
- Horn Creek Flow Station Catchment

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 145 290 580 870
Metres

N

Coordinate System:
NAD 1983 UTM Zone 10N

Scale:
1:22,010

Data Sources:
Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2017 / 7 / 6

URBAN systems

FIGURE 1.1

A few comments from the City relate to potential strategies and management alternatives to address issues, including:

- improved development bylaw and a plan to guide infill development; and
- consideration for improving the function of Willband Creek detention facility east of Highway 11 and the potential to add new detention storage west of Highway 11.

1.4 Relationship to Matsqui Prairie and Clayburn Creek Studies

The City previously completed an ISMP for the Clayburn Creek watershed (KWL, 2012), with the terminus point being the confluence of Clayburn Creek with Willband Creek at Clayburn Road; this is therefore the same terminus of the Willband Creek ISMP. Design rainfall events and applicable criteria have been applied to the Willband Creek ISMP, consistent with the Clayburn ISMP. However, the terms of reference for this Willband ISMP notes ARDSA criteria are applied to the agricultural lands. While the Clayburn Creek ISMP acknowledges this standard, the process to develop it did not include specific analysis using the ARDSA criteria; rather, a recommendation of the Clayburn ISMP was that a separate Matsqui Prairie Study be undertaken.

Since completing the Clayburn Creek ISMP, the City completed a Phase 1 Matsqui Prairie Drainage Study (June 2013, KWL), and has intent to complete a more comprehensive Phase 2 Matsqui Prairie Drainage Study in 2019 following the completion of the Willband ISMP. The Phase 1 Matsqui Prairie Drainage Study computed flood cell acquired light detection and ranging (LiDAR) data. For this report, LiDAR data was used to measure storage within the Willband Creek detention facility and a storage zone on the west side of Highway 11 opposite the Willband Creek detention facility that was designed for MOTI as compensation associated with highway widening. Additionally, LiDAR data were used to create channel sections where other sources of information were limited.

For this report, modeling focused on assessing system performance against established municipal criteria. The adequacy of the Willband Creek Detention Ponds was not particularly assessed against that criteria. "[Its] design philosophy was that it would provide detention for storms less than a 10-year recurrence, to provide some protection of the Matsqui Prairie farmland. Since the site is low lying, storms greater than 10-year recurrence will tend to inundate the entire site, rendering the pond of marginal usefulness."[1]

[1] City of Abbotsford Willband Stormwater Detention Facility, Operation and Maintenance Manual, UMA, 2000

2 RELEVANT REGULATIONS AND GUIDELINES

2.1 Local Regulations and Guidelines

A number of City regulations and guidelines relate to stormwater management in the Study area. These are summarized in **Table 2.1** below.

Table 2.1 - Relevant City Regulations and Guidelines

Document	Date	Relevance to Stormwater Management
Waterways Protection Bylaw	1996	Prohibits fouling or obstructing water or sewer flow regardless of private or public property.
Consolidated Farm (Mushroom Growing Operation Stormwater and Waste Management and On-farm Composting) Bylaw	1998	Provides requirements when establishing or expanding a mushroom growing operation to include a storm water and waste water management plan and comply with setback requirements. Also addresses mushroom composting.
Watercourse Management Policy Manual	2001	Outlines policies the City abides by when maintaining watercourses within specified areas.
Petroleum Products Storage Tank Bylaw	2003	Regulations to protect water systems from contamination including location related to utilities and dispensing pumps located over a body of water.
Soil Removal and Deposit Bylaw	2003	Regulates soil removal as it affects natural watercourses and drainage.
Streamside Protection Bylaw	2005	Protects streams within the City that support fish habitat from harmful conditions associated with development, and to preserve, protect, restore and enhance the natural environment near streams that support fish habitat.
Sewer Rates and Regulations Bylaw	2009	Main regulatory instrument in achieving objectives of the Abbotsford/Mission Water & Sewer Commission Source Control Program (SCP) for the purpose of source control.
Tree Protection Bylaw	2009	Outlines tree cutting permits, exemptions and regulations.
Development Cost Charges Imposition Bylaw	2010	Outlines potential costs for drainage for different types of development.

Document	Date	Relevance to Stormwater Management
Erosion and Sediment Control Bylaw	2010	Outlines among other things: prohibition against discharge, ESC submission requirements; sign and plan requirements; monitoring and reporting
Development Bylaw 2070-2011	2011	Outlines rules for drainage collection and control and water distribution; requires rainwater management plan
Storm Water Source Control Bylaw	2011	Outlines provisions to control, manage, treat and dispose of runoff in specified areas.
Abbotsford Floodplain Ditch Maintenance	2013	Outlines details of Ditch Maintenance Program.
Zoning Bylaw	2014	Regulations: Floodproofing provisions; setbacks, and requires CICP and Abbotsford Airport lands conform to Stormwater Source Control Bylaw 2045-2011;
Erosion and Sediment Control (ESC) Bylaw: Best Management Practices	2014	Provides an overview of ESC requirements and best practices for compliance
Information Package for Developing Near Streams and Ravines	2016	Provides information to landowners and buildings about developing near streams and ravines.
Official Community Plan - Part 3	2016	Outlines the City's vision and policies for sustainable infrastructure such as stormwater and flood protection
Official Community Plan - Part 4	2016	Outlines the City's vision for neighbourhoods including considering the environment in areas such as streams, riparian area etc. Includes goal to update ISMPs.
Official Community Plan - Part 5, Chapter 5	2016	Provides development guidelines for rainwater management and landscape buffers
Official Community Plan - Part 5, Chapter 6	2016	Development guidelines for riparian habitat, flows, drainage and channel geometry, water quality, tree standards, crossings through natural environment areas etc.
Official Community Plan - Part 5, Chapter 7	2016	Development guidelines in relation to steep slopes including site drainage, vegetation maintenance and installment, tree removal, erosion and sediment control
Official Community Plan - Maps	2016	Maps for various uses including drainage + flood control, natural environment DP areas, steep slope DP areas etc.
Five-year Financial Plan Bylaw, 2017-2021	2017	Identifies water/drainage costs.

2.2 Regional

In addition to the City's regulations and guidelines, the regional documents outlined in **Table 2.2** are also relevant to the ISMP.

Table 2.2 - Relevant Regional Regulations and Guidelines

Document	Date	Relevance to Stormwater Management
FVRD Regional Growth Management Strategy	2003	Outlines sustainable planning initiatives when planning for growth including: protecting the natural environment and promoting environmental stewardship; and protecting and managing rural and recreational lands.
Fraser Valley - BC Agriculture & Climate Change Regional Adaptation Strategies Series (Climate Action Initiative)	-	Strategic document addressing agriculture and climate change in the Fraser Valley region. Issues of stormwater and runoff are addressed, and overall strategies and action items are addressed.

2.3 Senior Government Regulations and Guidelines

The following Provincial regulations and guidelines relate to stormwater management in the Study area:

- Agricultural Land Commission Act
- Dike Maintenance Act
- Drainage, Ditch and Dike Act
- Drinking Water Protection Act
- Environment and Land Use Act
- Environmental Assessment Act
- Environmental Management Act (including Waste Discharge Regulation)
- Fish Protection Act (and Riparian Areas Protection Act)
- Integrated Pest Management Act
- Water Protection Act
- Water Sustainability Act
- Stormwater Planning: A Guidebook for British Columbia (2002)
- Guidelines for Preparing Liquid Waste Management Plans (2011)
- Beyond the Guidebook 2010: Implementing a New Culture for Urban Watershed Protection and Restoration in British Columbia (2010)
- Develop with Care 2014: Environmental Guidelines for Urban and Rural Land Development in British Columbia
- Standards and Best Practices for Instream Works (2004)

The following Federal regulations and guidelines relate to stormwater management in the Study ***area***:

- Canadian Environmental Assessment Act
- Fisheries Act
- Canada Water Act
- Pest Products Control Act
- Canadian Environmental Protection Act
- Species at Risk Act
- Canada Wildlife Act
- Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat

3 LAND USE

3.1 General

The Willband Creek watershed is located within the heart of Abbotsford. It includes much of the City's core urbanized area, and also extends into the Agricultural Land Reserve (ALR). Existing developed areas are shown on **Figure 1.1** (Study area).

There is a tremendous diversity of land uses within the watershed. Major land uses include residential, commercial, industrial, agricultural, institutional, and park and school uses. Based on infrastructure records in the City's online mapping system, much of the urban development within the Study area was built in the 1970's and early 1980's, placing it around 30 to 45 years old; however, there are some older portions in the Historic Downtown north east of Mill Lake.

The study area is already heavily urbanized with a high impervious fraction; largely absent of stormwater controls. The City's future Land Use Plan, from the 2016 Official Community Plan (OCP), is shown on **Figure 3.1**. And within the OCP the City Centre and Historic Downtown area is envisioned as "the area with the most redevelopment and intensification of uses" as depicted in **Figure 3.2**.

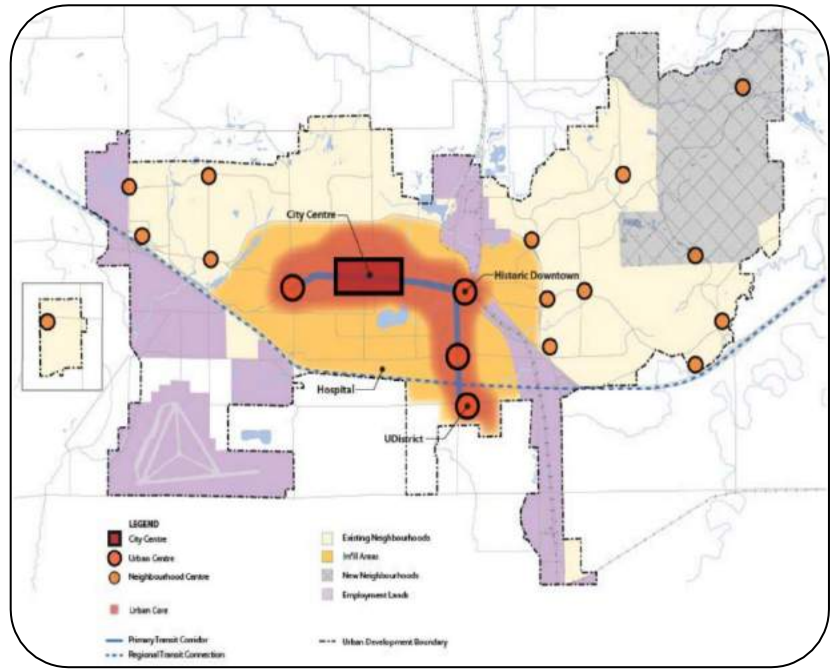
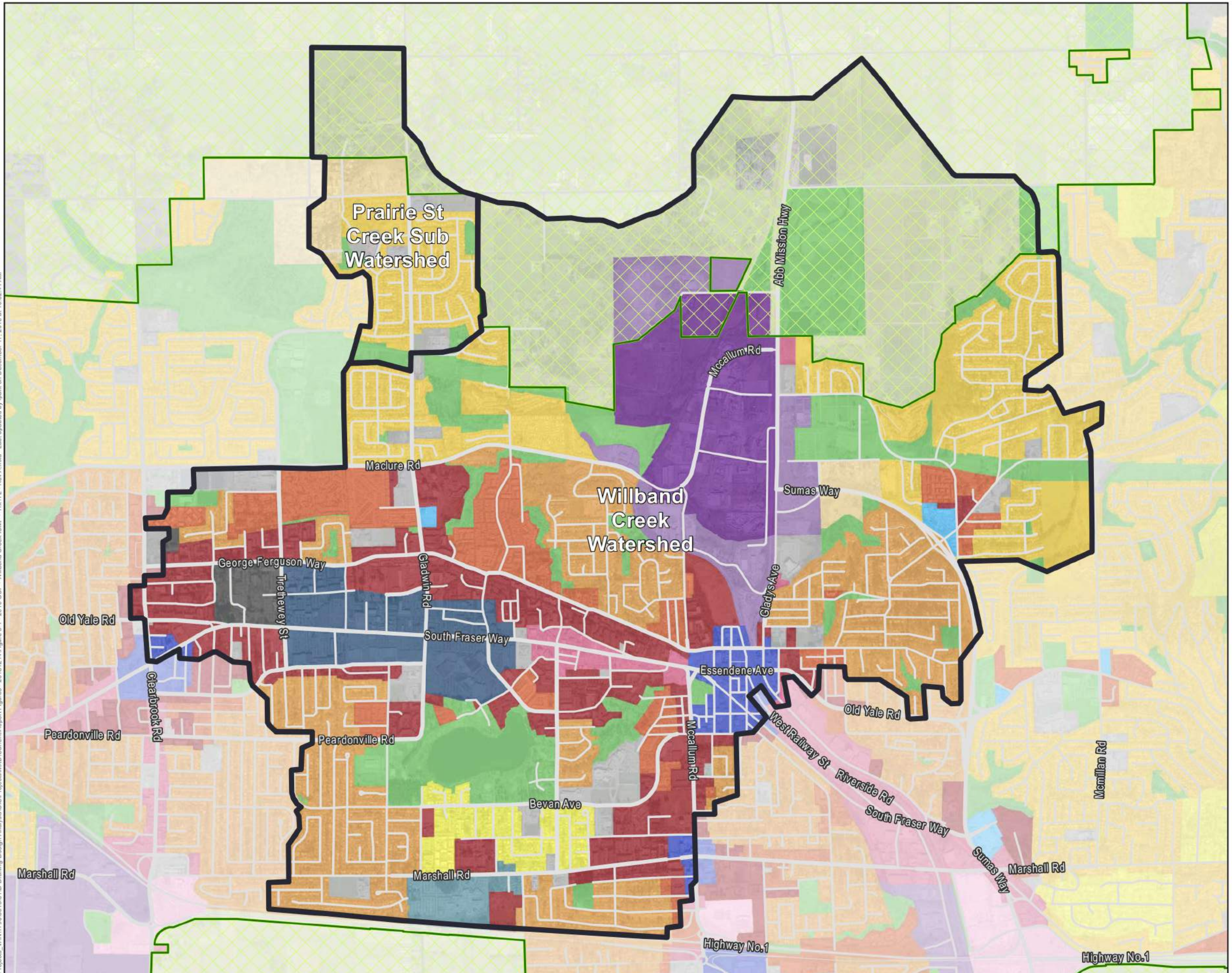


Figure 3.1 - Future Urban Structure Map (City of Abbotsford 2016 OCP)



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Willband Creek
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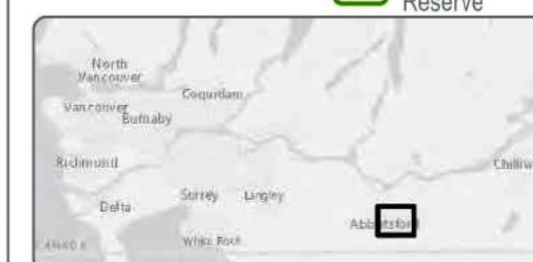
Management Plan

OCP (2016) Land Use Plan



The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 145 290 580 870
Metres

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Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,010

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

Project #: 1790.0015.01
Author: LP
Checked: GS
Status: FINAL
Revision: A
Date: 2018 / 12 / 17

URBAN systems

FIGURE 3.1

The Willband Creek watershed wholly or partially covers the following neighbourhoods:

- City Centre;
- Fairfield;
- Marshall – McCallum;
- Historic Downtown;
- Hazelwood;
- South Clearbrook;
- Immel – McMillian; and
- Clayburn

City Centre

City Centre is located at the western end of the watershed, northwest of Mill Lake. It is defined by its primary arterial, South Fraser Way, which runs east/west through the core of the neighbourhood. The predominant land use along South Fraser Way is low density, car-oriented, commercial development. On the ground, this takes the form of shopping centres, large parking lots, and large format retail stores. Due to the nature of the development, the area is heavily urbanized, with a significant amount of impermeable surface area with very few trees or natural areas. This core commercial area is surrounded by a mix of single-family infill development to the south and multi-family development to the north. It also includes some institutional uses, including City Hall.

Moving forward, this area is anticipated to experience significant change in its form, character, and land uses: the 2016 OCP has designated this area as the new 'city centre', envisioning a higher density, walkable, mixed-use form of development. This will occur through substantial redevelopment of the existing commercial sites, which will present a significant opportunity to influence stormwater management practices in this key area.

Additionally, the southern end of Clearbrook Centre has been identified for small-scale residential infill, which will moderately increase density in these existing single-family areas.

Marshall- McCallum, South Clearbrook

Along the south edge of the watershed is the Marshall – McCallum and South Clearbrook neighbourhoods which includes a hospital and mixed density residential between Highway 1 and Mill Lake.

This area is to see increased densification and residential infill. One of the few areas remaining the same will be the existing single-family area immediate south of Mill Lake, which has been designated for 'urban large lot' residential use.

Historic Downtown

This Historic Downtown is predominantly a walkable mix of urban shops, restaurants, and services. Beyond the downtown, the neighbourhood contains a substantial amount of moderate-to-low density residential development.

It is envisioned in the 2016 OCP that this area retains its general form and character, with moderate change coming in the form of residential infill in the existing single-family neighbourhoods to the south and east of the historic downtown. The historic downtown has been designated as an 'urban centre' under the OCP, which may include an introduction of higher density mixed use development (currently, development is predominantly one to two storeys). The existing commercial area along Highway 11 has been designated for 'secondary commercial' use and will therefore retain its general character.

The Historic Downtown has posed a particular challenge from a stormwater management perspective because zoning permits building coverage with zero setbacks from the property lines, not providing land space beyond the building footprint for on-lot management techniques.

Hazelwood

Hazelwood is the north central portion of the study area. From a land use perspective, Hazelwood is defined by its industrial area – a mix of general and high impact industrial and one of the largest in the City. The 2016 OCP has designated a substantial portion of land west of Willband Creek – currently undeveloped and designated as 'high impact' industrial uses.

From a natural perspective, this area is at a key intersection of the Willband Creek watershed, where many of the watershed's various creeks, brooks, and outflows converge on their way to Willband Creek Park, including an engineering detention and park facility.

Clayburn and Immel – McMillian

The north-eastern portion of the Willband Creek watershed includes portions of the Clayburn and Immel – McMillian neighbourhoods. These lands include ALR, industrial, and low density residential. Moving forward, it is envisioned in the OCP that the area within the ALR remains; however, 'general' industrial uses will be introduced across Highway 11, adjacent to the newly designated 'high impact industrial'.

3.2 Impervious Surfaces

Hydrologic functions are directly related to the relationship between impervious and pervious surfaces; therefore, it is important to consider the "total impervious area" (TIA) in the Study area. To compute this value, the 2016 aerial photograph for the study area was processed with GIS tools, the results of which are presented on **Figure 3.3** and summarized in **Table 3.1**.

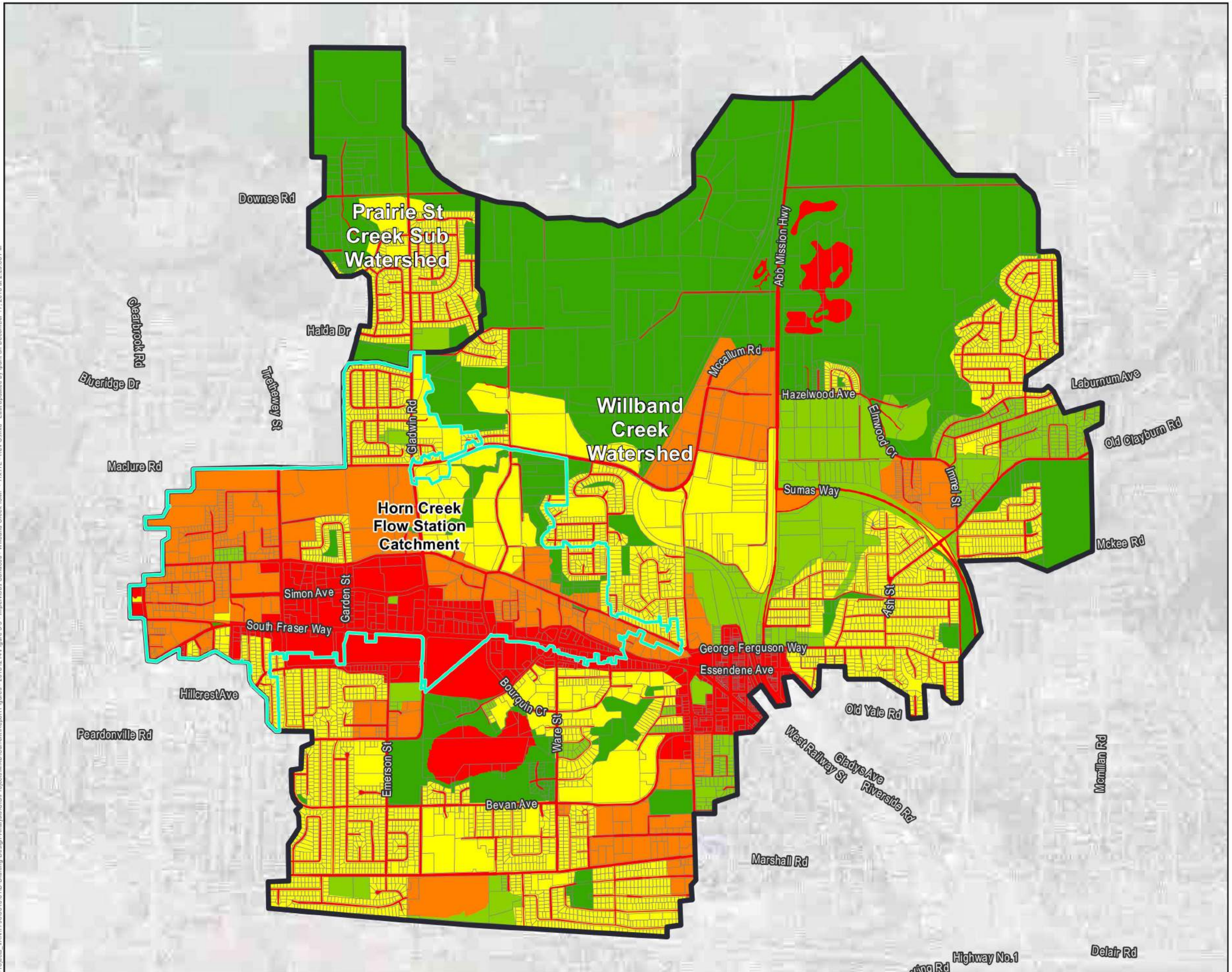
Table 3.1 - Total Impervious Area - Existing Land Use Conditions

Area	Total Area (ha)	Impervious Area (ha)	TIA (%)
Prairie Creek	130	37	28%
Horn Creek Flow Station Catchment	330	227	69%
Willband Creek Remained	1,380	558	40%
Total Study area	**1,840**	**822**	**45%**

3.3 Issues and Opportunities

Preliminary OCP directions indicate that in the coming years the City will be placing a strong emphasis on redevelopment, particularly in and around South Fraser Way. This involves shifting future development patterns away from the existing low-density, car-oriented development toward a more compact (i.e., dense), walkable, and sustainable form of development.

Such a shift presents a tremendous opportunity for stormwater management, as it provides the opportunity to implement source controls where they do not currently exist. However, challenges also occur due to increased building footprints and less area for surface-based rainwater management systems. Another challenge is the relative slow speed at which change will occur if left to redevelopment alone to address problems. For example, erosion persists in Horn Creek and Boa Brook, and while redevelopment within the catchment provides a great opportunity to improve conditions through the implementation of source controls, it will likely take many years to see enough redevelopment occur to significantly diminish the erosion. The City may need to intervene with communal solutions to address significant problems.



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Willband Creek
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Impervious Surfaces

Willband Creek Watershed
Horn Creek Flow Station Catchment
Parcel

Total Impervious Percentage

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

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Metres

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Coordinate System:
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URBAN systems

FIGURE 3.3

4 ENVIRONMENTAL CONDITIONS

4.1 Potential Impacts of Development on the Environment

Historic development has significantly altered the aquatic habitat, primarily due to the removal of riparian vegetation, a change in creek flow inducing channel erosion (eg. Horn Creek and Boa Brook), and in some cases channel infill with pipes, such as through the Historic Downtown.

In some cases, barriers restrict fish access (e.g., the Trafalgar Street culvert on Horn Creek). Additionally, development has impacted water quality. With exception to the Mill Lake Ravine system, barrier to fish can be removed with comparable ease. A summary of the aquatic habitat features is presented on Figure 4.1.

Many of the watercourses have groundwater inputs along the escarpment above Matsqui Prairie. As the watercourses move further away from the escarpment, the water quality reduces due to agricultural inputs and reduced riparian cover.

Development has also affected terrestrial habitat. As would be expected in an urban setting, the majority of the formerly forested areas have been removed. Some habitat value has been re-established with landscaping, but this habitat is fragmented and largely consists of non-native species. In turn, non-native vegetation can affect the conditions and diversity for native birds and wildlife.

4.2 Background Review and Field Investigations

The investigation of existing habitat conditions of the Study area consisted of a review of background information supplemented by a series of field assessments. Initially, a desktop review of compiled and summarized background information, specific to the Study area, was completed. This information was provided by the City and included studies for park master plans, drainage, water quality, and well assessments completed within and adjacent to creeks for infrastructure projects.

The background review also included a series of online databases and information sources to compile additional information available for the watershed. This included fish and wildlife inventories, ecosystem information and rare species databases.

The information obtained during the background review and from aerial photography was utilized to identify information gaps, identify watercourses and key natural areas, and prepare a series of maps to assist the field team in orienting to the watershed. Field investigations were conducted as follows:

- April 18, 2016 – Study area orientation with City staff;
- May 26 and 27, 2016 – Assessment of aquatic and terrestrial habitat;
- August 26, 2016 – Collection of water quality data; and
- May 17 and 18, 2017 – Detailed channel reach assessments.
- September 2017 – Benthic sampling

4.3 Conditions

The most significant habitat feature of the study area is Willband Creek and its various named tributary channels and waterbodies: Thiessen Creek, Blackham Brook, Bateman Brook, Horn Creek, Boa Brook, Scott Brook, Evans Brook, Mill Lake, and the Mill Creek outlet channel (see **Figure 4.1**). Significant terrestrial habitat is provided around Mill Lake, within local parks and within a retained woodlot at the north extent of the Study area. Prairie Street Creek is the main habitat feature in its sub-watershed.

A description of stream habitat quality is defined in **Table 4.1**.

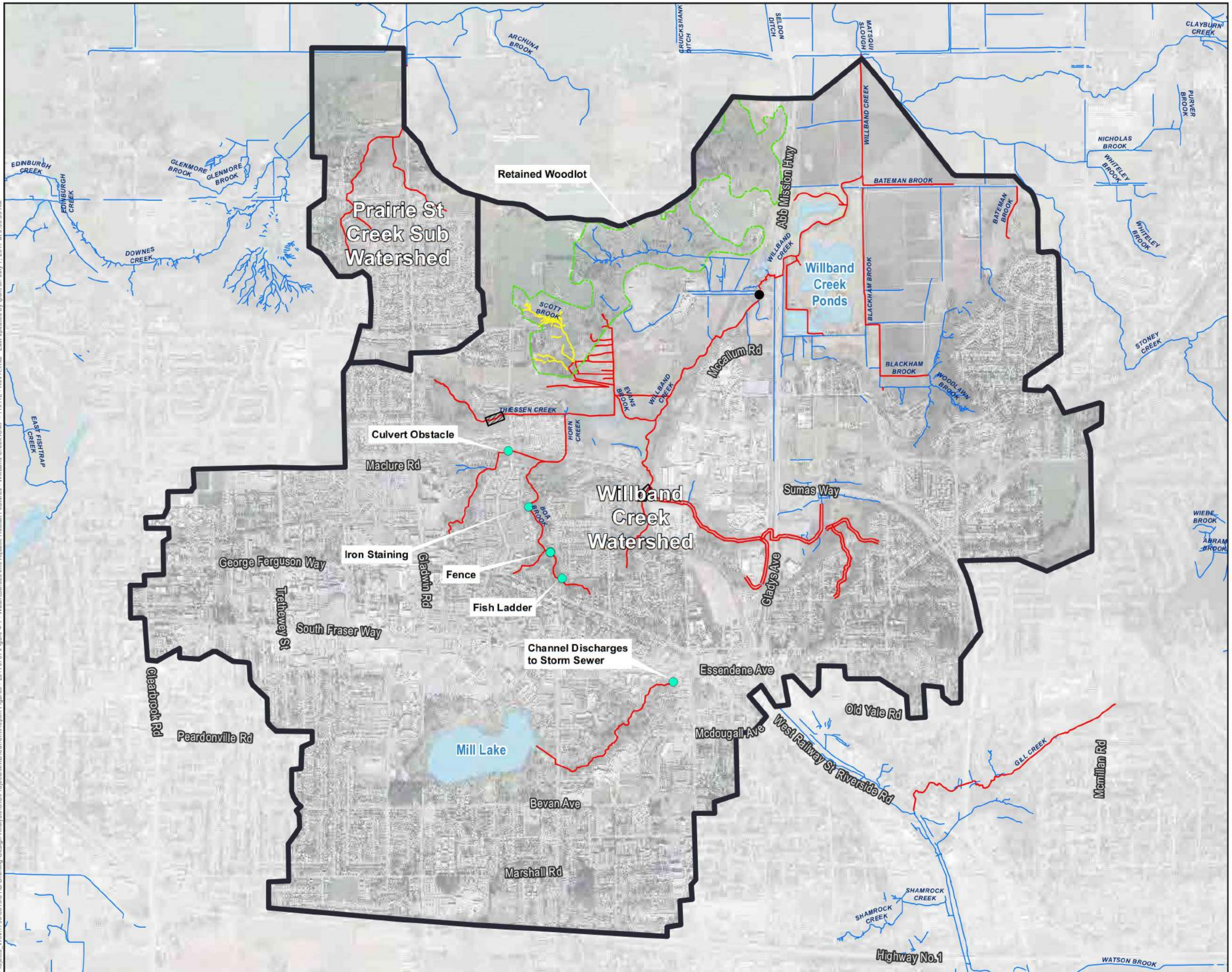
Table 4.1 - Description of Stream Habitat Quality

Description	Definition
Excellent	Channel displays a number of criteria that makes it highly suitable as fish habitat, particularly for salmonids. Typically the channel is highly complex, has a varied morphology, mixed cobble/gravel substrate, good water quality, and productive, well-established riparian vegetation.
Good	Channel still highly suitable as fish habitat but may lack one of the criteria characteristic of excellent habitat or may have the extent of these criteria reduced.
Fair	Channel can still support fish populations but generally lacking in several of the criteria for excellent habitat or may have all these criteria significantly reduced.
Poor	Channel generally exhibits low complexity, silt/organic substrate, uniform morphology, poor water quality and has significantly reduced riparian vegetation. Fish presence generally limited to tolerant species.

Watercourse classifications, as defined by the City, are presented on **Figure 4.1**. The definitions of watercourses that are represented in the Study area are provided in **Table 4.2**. The complete classification system is attached as Appendix B.

Table 4.2 - Watercourse Classification Relevant to the Willband Creek Watershed

Class	Sub-Class	Definition
Red (A)	Red (A)-P	Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply.
Red (A)	Red (A)-OW	Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species may be present year-round.
Red (A)	Red (A)-NP	Watercourses with non-permanent (*i.e.*, flow for <6 months) water supply that dry up in the summer months. Inhabited by fish during the over-wintering period.
Blue	N/A	Creeks, streams, and channels with unconfirmed classification



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Willband Creek
Integrated Storm Water
Management Plan

Watercourses and Aquatic Habitat Features

- Willband Creek Watershed
- Woodlot Extent
- Detailed Reach Assessment
- Water Quality Sampling Location
- Site Specific Features

Fish Classification

- Class 'A' - Fish-bearing watercourses with permanent (i.e. flow for >6 months)
- Class 'A(OW)' - Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid
- Class 'B' - Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Permanence is unknown.
- Creeks, Streams, Channels with Unknown Classifications

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URBAN systems

FIGURE 4.1

4.3.1 Willband Creek

Willband Creek is comprised of a number of tributaries. The western tributary of Willband Creek originates near Babich Place upstream of Maclure Road and is located within a ravine. It is characterized as a higher gradient system transitioning to a lower gradient section of channel to the north. The reach is a meandering, permanent channel exhibiting a high degree of complexity, particularly in its upper reach. Large Woody Debris is present in moderate amounts. Riparian vegetation was well-established with a mixture of mature and young growth stages. Invasive species presence was generally limited to the vicinity of Maclure Road. The tree canopy was predominantly deciduous. No records of fish presence in the western tributary were identified in the background review. One Chinook fry and lamprey were collected during the May 2017 detailed site assessments, which are attached in Appendix C. Based on this occurrence, the channel has been assigned a classification of Red (A) -P.

The channel provides good habitat value given its complexity. Given its relatively small dimensions, fish presence could be reduced which prevented the channel from receiving an excellent rating.

The eastern tributary has several sub-tributaries but originates to the southeast of Sumas Way and Gladys Avenue. The area is predominantly a wetland located north and east of Gateway Christian Reformed Church. The wetland discharges to the west under Gladys Avenue and subsequently to the Willband Creek mainstem. The wetland was entirely pool habitat with a substrate dominated by silt with some organic detritus. Complexity was generally low although a moderate amount of Large Woody Debris was present. Other than possibly the culvert conveying flow under Gladys Avenue, barriers to fish access were not observed. The riparian vegetation was largely deciduous. Tree presence and riparian quality are impacted by adjacent development.

Habitat quality of the eastern tributary network was considered fair to good overall.

The lower reaches of the Willband Creek mainstem (i.e., downstream of Maclure Road) can be characterized as a permanent, low-gradient, gently meandering channel. Complexity was generally low. Instream Large Woody Debris was limited, which is to be expected given that trees were only present in low numbers and were generally immature. Barriers or obstacles to fish access were not observed. The water was somewhat turbid which is typical for larger, lower gradient streams.

The detention pond system within Willband Creek Park are located within this reach. The ponds are exposed with limited riparian canopy coverage. As such, water quality could be compromised, particularly during the summer.

A number of the criteria for habitat quality have been impacted along this reach of the channel as a result of past land use activities. A significant tree canopy is generally lacking, water quality was observed to be turbid, and instream complexity was generally low. Riparian vegetation was established along the channel although in some places it had been cleared to the top-of-bank for agricultural use. Reed canary grass dominated the riparian zone along sections of the channel. Other invasive species dominated in other sections of the riparian zone. Instream vegetation consisted primarily of reed canary grass.

Based on past sampling efforts, the lower reach of Willband Creek provides habitat for many species of fish. As such, the channel has been assigned a classification of Red (A)-P. Despite the impacted riparian area, given the varied fish presence this reach has been assessed as providing fair habitat value.

4.3.2 Blackham Brook / Bateman Brook

Blackham Brook has been designated as fair habitat despite the limited complexity and reduced riparian zone. This is largely due to the size and depth of the channel which is anticipated to support species more tolerant of reduced habitat quality.

Bateman Brook has been channelized as a linear, roadside ditch along the south side of Bateman Road. Despite the generally low complexity and lack of significant riparian vegetation for large sections, Bateman Brook provides moderate quality fish habitat. This is largely due to the diverse fish species utilization as well as the presence of good water quality as indicated by the crayfish.

Given that salmonids have been sampled in previous summers, these channels have been classified as Red (A)-P.

4.3.3 Evans Brook

Evans Brook originates in a marshy area south of the terminus of Valley Road. It is conveys flow from both Thiessen Creek and Scott Brook into Willband Creek. Overall habitat quality within Evans Brook was observed to be fair. The channel was confirmed as being fish accessible and has sufficient depth for fish presence. However, the lack of significant complexity prevented it being given a higher rating.

A small, unnamed channel is confluent with Evans Brook immediately north of the Industrial Avenue right-of-way. The channel provides fair habitat based on its complexity and fairly well-established riparian zone, which would provide a significant food and nutrient contribution to downstream reaches. However, the small size and probable lack of fish access prevents it from being rated higher than fair.

4.3.4 Scott Brook

Scott Brook originates within a small ravine in a forested patch north of the Old Riverside Road alignment. Records of fish presence in Scott Brook are generally quite limited. However, a steelhead was captured immediately north of the Old Riverside Road unconstructed right-of-way in 2015. Flow was observed to be intermittent in the upper reaches of the channel. As such, the classification is considered to be Red(A)-NP. Overall, habitat value has been rated as moderate despite the well-developed riparian area and moderately complex channel.

4.3.5 Thiessen Creek

Thiessen Creek originates within a forested patch in Old Riverside Park. Flow is conveyed on its original alignment southeast, then east, prior to flowing into a marshy area east of Horn Street. From there, flow is conveyed east, then north within a channelized reach to its confluence with Evans Brook.

Its upper reaches are encompassed within a ravine prior to flowing into the low gradient marshy area. The channel is permanent with moderate sinuosity and gradient in its upper reaches. The upper reach is predominantly riffle habitat (80%) with the remainder equal areas of run and pool. Substrate consists of a mix of boulder (10%), cobble (10%), gravel (40%), sand (30%) and silt (10%). The upper reach is highly complex with significant cover from overhanging vegetation and a large amount of Large Woody Debris although it is quite shallow (0.2 m depth at the time of assessment). No barriers to fish access were observed. Water quality was observed to be clear with no sedimentation.

The riparian zone was predominantly deciduous forest. Tree species include red alder and bigleaf maple. The understory included immature western hemlock, vine maple, salmonberry, thimbleberry

(Rubus parviflorus), horsetail and ferns. Skunk cabbage was present at the margins of the channel.

Previous fish sampling efforts have identified threespine stickleback in the channel. The detailed assessment conducted for this project identified Chinook salmon, cutthroat trout and lamprey (see detailed reach assessment in Appendix C). As such, the channel has been classified as Class Red (A)-P (see Figure 4.1).

The upper reach of the channel provides excellent habitat despite its shallow nature due to its complexity and well-established riparian vegetation.

As referenced, the lower reach of Thiessen Creek has been channelized within a marshy area.

4.3.6 Horn Creek

The mainstem of Horn Creek originates in Horn Creek Park near Nelson Place. Flow is conveyed in a generally northern direction to Maclure Road. Coho salmon, cutthroat trout, rainbow trout, threespine stickleback, and lamprey have been collected during previous sampling efforts, the majority from the sediment basin immediately upstream of Maclure Road. Signal crayfish have also been sampled. The channel provides Class Red (A)-P habitat. Despite the possible restrictions on fish access, Horn Creek provides excellent value fish habitat. It should be noted that erosion is a concern within Horn Creek.

4.3.7 Boa Brook

Boa Brook originates on private properties immediately north of George Ferguson Way. The lower reaches of the channel appear to be accessible to fish with no obvious barriers observed and a number of deep pools to provide cover for fish. The tree canopy may be described as mixed forest with varying age classes. Coniferous species were more prevalent in the upper reaches. There has been limited fish sampling effort in Boa Brook. Current records indicate one cutthroat trout has been collected in the summer of 1998. As such, the channel provides Class Red (A)-P habitat. Boa Brook provides excellent habitat in its lower reaches due to its varied complexity and significant pool habitat to provide refugia for fish. The upper reach provides only fair habitat given the low depth and potentially restricted fish access. It should be noted that erosion is a concern within Boa Brook.

4.3.8 Mill Lake and Mill Lake Outlet Channel

Mill Lake is fed by ground water and the storm sewer system. It is approximately 18.5 hectares (ha) in area, with approximately 73% of the surface area less than 2.0 m in depth (CH2M Hill, 2003). It has a maximum depth of 10.5 m. It is anticipated that substrates would consist almost entirely of silt and decaying organic matter.

There are a number of factors that impact water quality, the primary being a high faecal coliform count from the waterfowl that frequent the lake. There is also a lack of oil/water separators for the storm sewer system. As a result, hydrocarbons are known to discharge directly to the lake (pers.comm.). Finally, the lack of depth through the majority of the lake would likely result in high summer water temperatures, which would significantly affect dissolved oxygen levels.

Fish species include largemouth bass and rainbow trout, both of which have previously been stocked. The bass is an aggressive, introduced species that can have a significant impact to native species of fish as a result of predation.

There is limited indication of fish presence within the outlet channel, with one record of a rainbow trout from June 2010. As such, the channel provides Class Red (A)-P habitat. Fish habitat quality is fair in the channel due to the comparatively low depth and complexity. It may be able to sustain a fish population in sections of the channel, particularly if larger pools were present., but given the lack of access from the bottom and poor water quality discharging from Mill Lake, it is expected that any resident fish population would be vulnerable to extirpation.

4.3.9 Prairie Street Creek

The Prairie Street Creek system originates as two secondary channels in a residential area south of Downes Road. Limited effort has been made to sample for fish within Prairie Street Creek. The only reports are for observations of unidentified species north of Downes Road. However, given the quality of the habitat and assumed fish access to this reach, the channel likely provides Class Red (A)-P habitat. Overall habitat quality has been rated as good. However, similar to Horn Creek and Boa Brook, erosion and sediment deposits in the lower reaches have been an issue.

4.4 Mill Lake Water Quality

Limited water quality data were available within the background information provided for the Study area. One report was provided for a Mill Lake Water Quality study (CH2M Hill, 2003). Samples were collected on two occasions during the summer of 2001 and included:

- Total Dissolved Solids;
- Total Suspended Solids;
- Hardness;
- Total Metals;
- Extractable Hydrocarbons;
- Biochemical Oxygen Demand; and
- pH.

The results indicated that each parameter was either at or below what is considered “typical” for urban stormwater runoff. However, the report indicated potential for metals to accumulate in the sediment where it could be taken up by bottom feeders and work into the tissues of aquatic life. A number of field parameters were also assessed.

Temperature in the top water mass (up to 2.5 m depth) was found to be 23.6 C. Despite this elevated temperature, dissolved oxygen (DO) was in the range of 6.5-8.0 mg/L. This meets the BC Water Quality Criteria (MoE, 1997) for all aquatic life stages other than buried embryos/alevins. As such, a self-sustaining population of aquatic life would need to hatch and enter the water column prior to the summer months to avoid peak temperatures and possible DO levels below their life requirements.

Temperature and DO in the lower water mass were 7.9 C and 0.0-1.5 mg/L, respectively. DO was significantly reduced at these lower depths, likely due to biochemical oxygen demand from decaying organic material in the lake bed material. Most aquatic organisms would not be expected to be able to survive under these conditions.

Two pH readings were taken with results of 7.01 and 7.70, both of which are well within the normal range. Total Suspended Solids (TSS) results were shown to be 4 mg/L at the surface and 233 mg/L in the lower water mass. The assessment indicated nitrates and phosphates were not at excessive concentrations. However, there was nutrient enrichment as evidenced by the emergent vegetation at the site.

Sampling for coliform bacteria indicated a low level of contamination in the lake (a maximum of 240 cnts/100 ml). However, faecal coliform levels are a concern due to the number of geese and other waterfowl utilizing the lake. It may be that these levels have become elevated subsequent to the 2003 study. There is no applicable standard for freshwater aquatic life for coliforms; it is primarily a concern if recreational contact is made with the water.

One round of water quality sampling was conducted on August 29, 2016, as part of this ISMP and compared against BC Approved or Working Water Quality Guidelines and the Canadian Council of Ministers of the Environment Water Quality Guidelines. The results indicate (refer to Appendix C) that very few of the parameters exceeded limits for freshwater aquatic life. Many were below detection limits. Two parameters exceeded standards. DO was lower than the standard for buried embryos/alevins. This is expected during the summer months when temperatures are elevated. Given that most embryos and alevins would be expected to have emerged by late summer when the sample was taken, this result is not indicative of water quality issues.

Coliforms were somewhat elevated. Given that there is no standard for freshwater aquatic life, this is not a concern unless the channel is used for recreational use. The data collected for this project are indicative of conditions at a single moment. Additional data collection may be warranted to obtain a more thorough understanding of conditions over time. However, these results indicate that water quality does not appear to be a concern for freshwater aquatic life.

4.5 Terrestrial Species and Habitat Inventory

The Study area is located in the Coastal Western Hemlock Very Dry Maritime Eastern variant (CWHxm1) biogeoclimatic zone (MFLRNO, 2016). The CWHxm1 is the driest of the CWH sub-regions.

In an undisturbed state, this zone is dominated by coniferous forests with western hemlock and western redcedar being the most common tree species. As is typical in a developed watershed, much of the coniferous forest within the Study area has been removed and replaced with non-native species on landscape properties. However, there are still blocks of contiguous forested habitat, particularly along upland watercourses within ravines and at the northern extent of the Study area west of Highway 11.

Terrestrial habitat within the Study area has been significantly impacted from urban development.

A large part of the terrestrial habitat within the watershed consists of landscaped residential properties. The extent and composition of this habitat varies considerably. Some properties retain larger sections of vegetation which includes native vegetation, non -native plant species, or a mixture of the two. Some properties are largely devoid of habitat value with lawn and ornamental shrubs being the primary vegetation. Regardless, given the size and lack of connectivity to larger sections of intact vegetation, these areas have limited value and can be expected to be primarily used by common wildlife habitat generalists that are well-adapted to urban/suburban environments.

4.5.1 Invasive Plant Species

The following plant species were observed during the site assessment or are listed in the provincial Invasive Alien Plant Program database and are considered invasive:

- Himalayan blackberry
- Lamium
- Scotch broom
- Policeman’s helmet
- Reed canary grass
- Yellow flag iris

While invasive, only one of these species, yellow flag iris, is considered noxious per the BC Weed Control Act. Property owners are required to take steps to avoid the spread of these weed species per the legislation.

Although invasive species were common throughout the Study area, they typically did not dominate the understory at any particular location. The one exception to this general trend was the lowland areas of Willband Creek north of Maclure Road. Reed canary grass tended to dominate the area, as is often the case in wet, open fields in the Lower Mainland.

4.6 Mammals

Small mammals such as voles and shrews are expected, particularly within the intact habitat of the forested block in the northern portion of the Study area or within intact riparian areas adjacent to Study area creeks. Other rodent species such as squirrels, rats, and mice are expected to be common throughout the watershed given their adaptability to urban/suburban environments. Species that are well-adapted to urban environments (e.g., raccoon, skunk, coyote) are also expected to be present.

Habitat for aquatic mammals such as beaver and muskrat is anticipated along some of the larger, lower gradient sections of watercourse, particularly along the Willband Creek mainstem.

It is likely that the large intact forested areas are the only terrestrial habitat in the Study area where it might be expected that larger mammals (e.g., mule deer) might be present on a regular basis. The lack of forested wildlife corridors may make access challenging. However, there is ample habitat available if access can be achieved. It should be noted that a recent black bear sighting north of Mill Lake (Abbotsford News, 2017) indicates that they could be present in the forested area.

Mammal sign was not observed in the Study area. Regardless, numerous mammal species are anticipated to be present.

4.7 Birds

Birds are the most common wildlife group within the Study area. This is to be expected given that they are best suited to disperse across developed areas that would normally constitute barriers or obstacles for many species restricted to movement on the ground.

In general, the best habitat for birds, particularly passerines (perching birds), is in the riparian areas with an intact tree canopy and the retained forested block west of Highway 11. The intact trees and well-established understories in these locations provide ample nesting and foraging opportunities. Waterfowl would tend to prefer more open bodies of water such as Mill Lake, the detention pond system in Willband Creek Park, and the wetland area on the Eastern Tributary of Upper Willband Creek. Raptor species would tend to prefer large trees on the edge of open areas to allow for nesting opportunities adjacent to their preferred foraging areas.

4.8 Herptiles (Amphibians and Reptiles)

Significant amphibian presence is anticipated in the lower gradient sections of the Willband Study area where flow would tend to be reduced and the exposure to the sun due to limited riparian vegetation would serve to increase water temperatures. Larger, ponded areas with emergent aquatic vegetation provide excellent habitat for amphibians. Open water habitats are preferred by many insect species that amphibians prey upon. These areas tend also to have silty or organic substrates which allow for burial during winter hibernation. Reptile presence is expected to largely be limited to garter snakes, primarily in proximity to areas occupied by amphibians which form a significant part of their diets (Gregory and Campbell, 1984).

Background information provided by the City indicated that bullfrog, northern red -legged frog and northwestern salamander have been collected in and around Willband Creek Park. The bullfrog is an aggressive invasive species that can have a significant impact on the ecosystem, particularly as adults prey upon native amphibians, birds, and fish (Green and Campbell, 1984). The northern red-legged frog is a provincially listed species. There are reports of presence of western painted turtle in Mill Lake. Pacific tree frogs were heard calling in the vicinity of Scott Creek during the site assessment. No additional herptile sign was observed.

4.9 Rare Species Presence and Potential

Through a review of the records and resources and Conservation Data Centre (CDC) mapping layers on iMapBC (Government of BC, 2017), rare species that have been identified or have the potential to occur in the Willband Study are outlined below in **Table 4.3** below.

Table 4.3 - Rare Species Presence or Potential

Common Name	Scientific Name	BC List [1]	SARA [2]
Western painted turtle	*Chrysemys picta pop 1*	Red	Endangered
Northern red-legged frog	*Rana aurora*	Blue	Special Concern
Pacific water shrew	*Sorex bendrii*	Red	Endangered
Oregon forestsnail	*Allogona townsendiana*	Red	Endangered
Roell's brotherella	*Brotherella roellii*	Red	No Status
Pacific waterleaf	*Hydrophyllum tenuipes*	Red	No Status
Batwing vinyl	*Leptogium platynum*	Red	Endangered

1 BC List Status - Red: Candidates for Extirpated, Endangered or Threatened stats in BC; Blue: Considered Special Concern in BC,

2 SARA – Listing under Schedule 1 of the Federal Species at Risk Act

4.10 Watershed Health

The Watershed Health Tracking Score in Metro Vancouver's Template for Integrated Stormwater Management Planning 2005 (KWL, 2005) was applied to measure watershed health. The score is assessed by plotting Total Impervious Area (TIA) against Riparian Forest Integrity (RFI). As previously described, TIA is a measure of the impervious surface in the watershed where there is no infiltration of storm water into the ground. RFI is calculated through aerial photograph interpretation and consists of determining the percentage of intact forested areas within 30 m of a creek. This calculation is based on the current alignments of the creeks and other watercourses in the watershed as well as historical alignments, if known. It includes those sections of a watercourse that have been enclosed in the storm sewer system. The resulting mapped riparian areas are presented on **Figure 4.2** as "intact forested area within buffer".

The RFI was estimated at 31% for the Willband Creek watershed, most of which is in the ravines in the upper reaches of the watershed. The Prairie Street Creek watershed was estimated as having an RFI of 54%. TIA was measured as 37% and 26% for Willband Creek and Prairie Creek, respectively. These values are plotted on **Figure 4.3**.

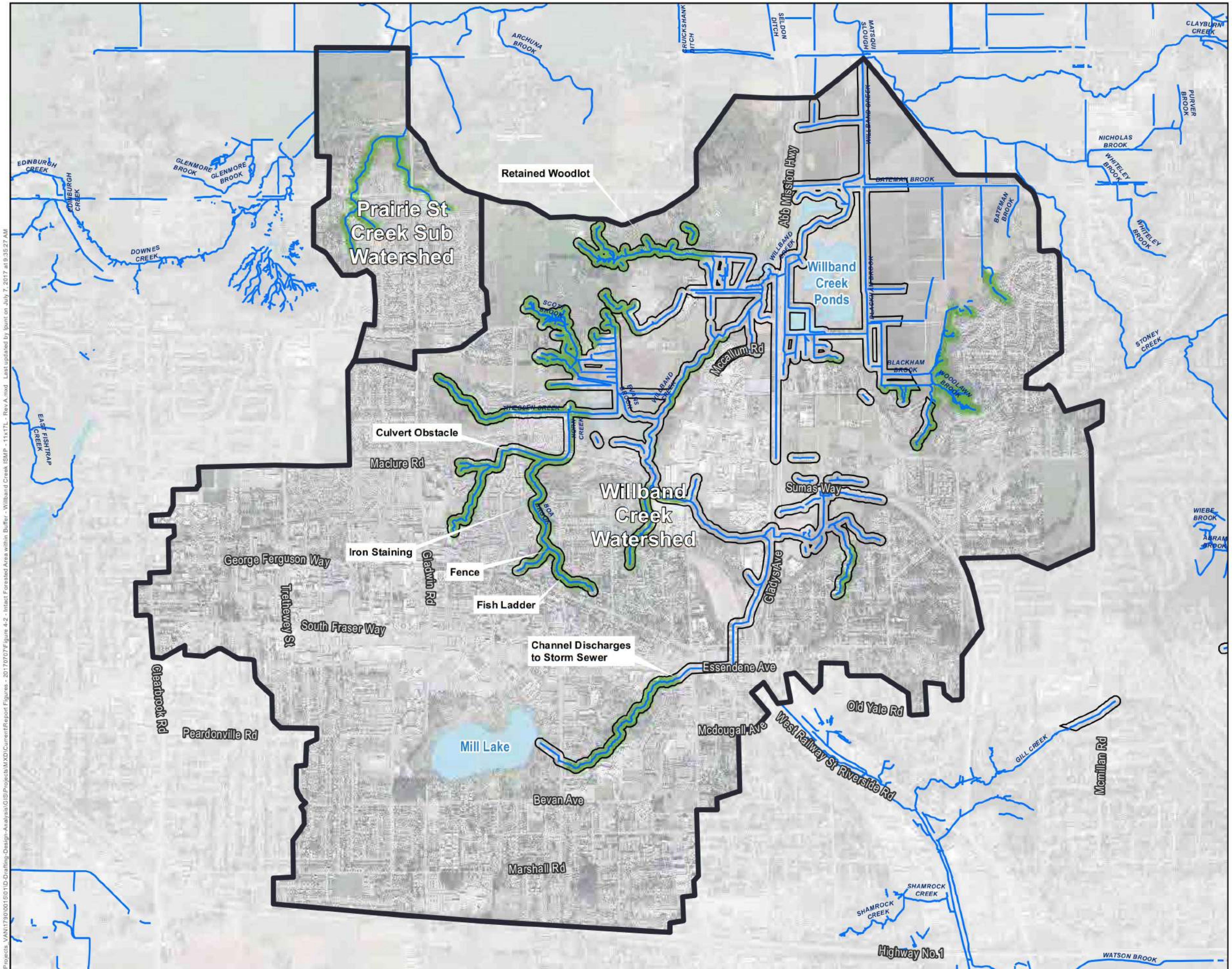
Figure 4.3 may also be used to predict the Benthic Index of Biotic Integrity (B -IBI) for the watershed. B-IBI is a 10-metric measure of the presence of benthic invertebrates in the watershed which ranges from a theoretical maximum of 50 (a pristine, undeveloped, old -growth watershed) to a minimum of 10 (severely impacted). In practice, a B-IBI score of 40 would be considered excellent.

As can be seen with **Figure 4.3**, following the diagonal access to the upper right from the intersection of the RFI and TIA for Willband Creek would result in a predicted B-IBI score of 13.9, which approaches the minimum. This is indicative of an extremely impacted watershed, which can be expected given the loss of over 70% of the original intact riparian forest and imperviousness over 35%. The predicted B-IBI score for the Prairie Street Creek sub-watershed is higher than Willband Creek, at 17.2%. According to the Greater Vancouver Regional District Benthic Macroinvertebrate B-IBI guide (GVRD, 2003), these results would be “poor” for Prairie Creek and “very poor” for Willband Creek.

In September 2017, benthic invertebrate samples were collected from four (4) distinct sampling locations in Horn Creek.

Various benthic metrics were calculated for each station to provide insight on community composition and overall stream health. Many of the metrics considered are included in the B-IBI and have predicted responses to human disturbance (*e.g.*, Ephemeroptera taxa are expected to decrease with increasing urbanization, agriculture, grazing and recreation).

Overall, the 2017 B-IBI scores for the four (4) Horn Creek benthic invertebrate survey sites were found to be in “poor” condition. The total B-IBI scores range from 18 to 24, with an average of 20. These scores indicate an overall “fair” stream condition (**Table 4.4**). Note that per the standard protocol, individual samples were combined to produce an aggregate score for the entirety of the sampled reach within Horn Creek. As such, while any one sample may indicate a "poor" condition, the aggregate for the creek indicated a "fair" result because of the diversity of taxa found at all sites.



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Willband Creek
Integrated Storm Water
Management Plan

Intact Forested Area Within Buffer

Legend

- Willband Creek Watershed
- Creeks and Streams
- Creek and Stream 30m Buffer
- Intact Forested Area within Buffer

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 145 290 580 870
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,010

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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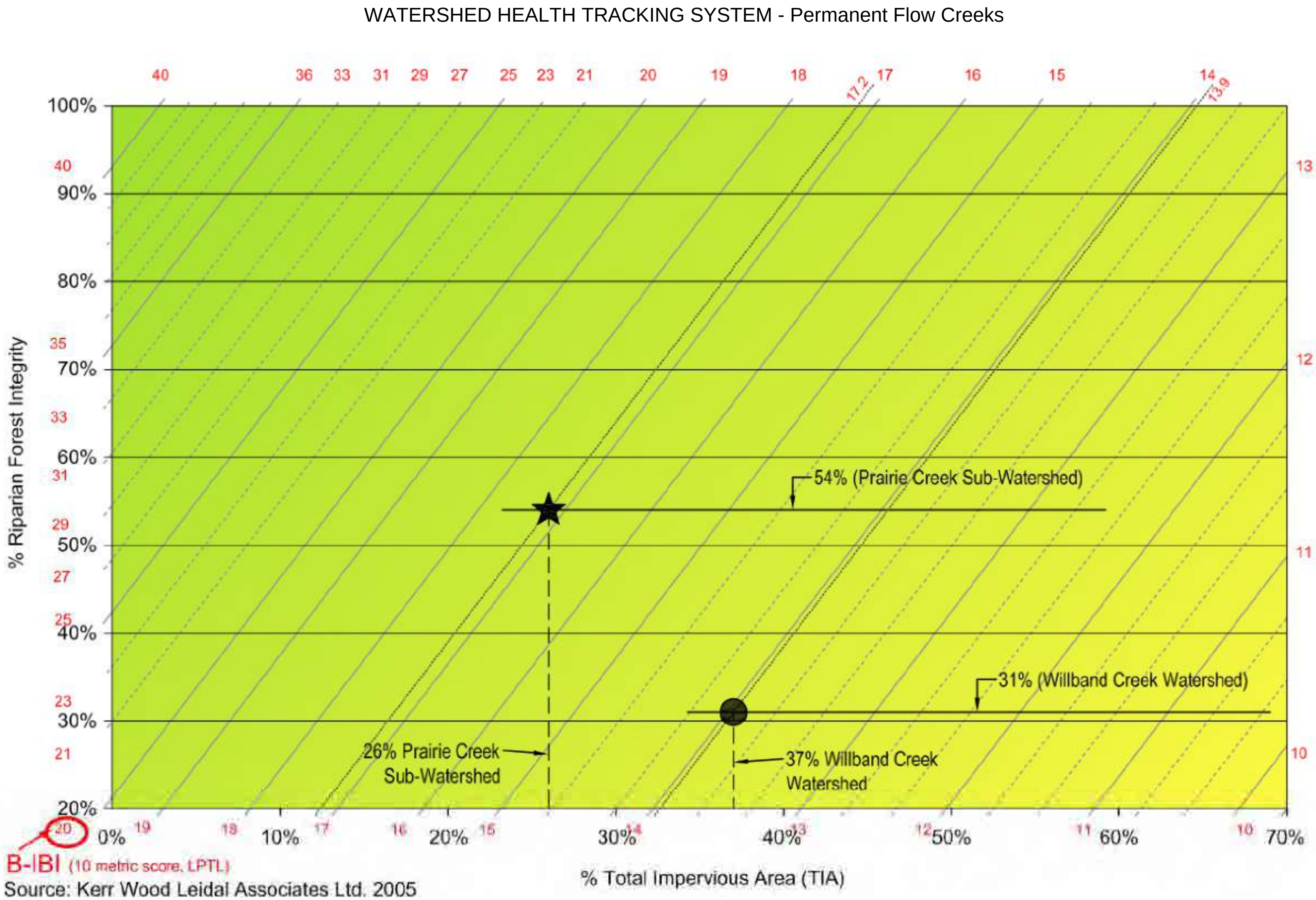
FIGURE 4.2



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

Watershed Health Tracking Score

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

Data Sources:

Data provided by Dillon (2017) and Kerr Wood Leidal Associates (2005).

Project #: 1790.0015.01
Author: LP
Checked: GS
Status: FINAL
Revision: A
Date: 2017 / 7 / 7

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FIGURE 4.3

Table 4.4 - Summary of B-IBI Scores for Horn Creek, 2017

Metric	Metric B-IBI Score (1,3 or 5)					Predicted response due to human impact
	H1	H2	H3	H4	Aggregate	
Total Taxa Richness	3	3	3	3	5	decrease
Number of Ephemeroptera Taxa	1	1	1	1	1	decrease
Number of Plecoptera Taxa	1	1	1	1	1	decrease
Number of Trichoptera Taxa	1	1	1	1	3	decrease
Number of Long-lived Taxa	1	1	1	1	3	decrease
Number of Intolerant Taxa	1	1	1	1	1	decrease
Number of Tolerant Taxa	5	5	5	5	5	increase
Percent of Predator Individuals	3	5	1	1	3	increase
Number of Clinger Taxa	1	1	1	1	3	decrease
Percent Dominance	3	5	3	3	5	increase
Total B-IBI	20	24	18	18	30	
Stream Condition	Poor	Poor	Poor	Poor	Fair	

Taxa richness, overall abundance and %EPT (Ephemeroptera, Plecoptera, Trichoptera) were also calculated for each Horn Creek survey sites (**Table 4.5**). In 2017, taxa richness within Horn Creek ranged from 20 to 25, with an average of 22.5. Overall abundance ranged from 404 to 427, with an average of 417, while %EPT (Richness) ranged from 14% to 28% throughout the creek.

Table 4.5 - Additional Analysis for Horn Creek, 2017

Station	Richness	Abundance	% EPT (Richness)
H1	20	404	20%
H2	25	420	28%
H3	24	417	21%
H4	21	427	14%

The overall community composition within Horn Creek has also been considered. **Figure 4.4** displays the benthic community composition of Horn Creek, with non-insects comprising 38.7% of the overall composition. Diptera comprised 28.4% and Ephemeroptera comprised 22.0%, while the remaining communities consisted of Trichoptera (10.1%) and traces of Coleoptera (0.3%), Plecoptera (0.2%), Arachnida (0.1%), and Collembola (0.1%).

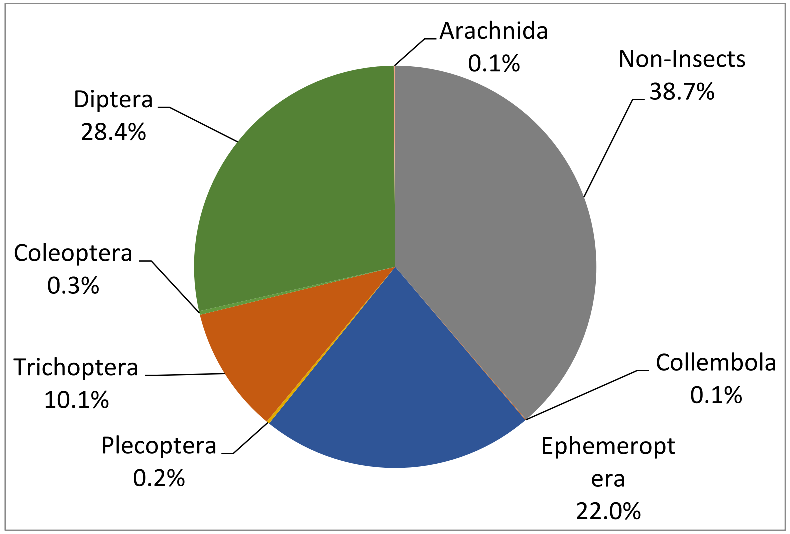


Figure 4.4 - Horn Creek Community Composition, 2017

Note: non-insects include annelida, mollusca, crustacea, and platyhelminthes

Discussion of 2017 Horn Creek Data

As outlined above, based on the Total B-IBI, the results of the 2017 benthic survey indicate that the overall stream conditions within Horn Creek are "fair" (although each individual sample sites resulted in a "poor" stream condition). This score is indicative of a system that has been influenced by human activity. The most abundant species in the combined sample locations was *Baetis sp.* (a member of *Baetidae* family, and *Ephemeroptera* order). In general, presence of *Ephemoptera* in a stream system is a positive indicator of stream health. However *Baetis sp.* in particular are one of the more pollution tolerant Ephemoptera taxa and can be found in higher numbers where organic pollution exists (with an organic pollution tolerance value of 6 on a scale of 10), (Mandaville, 1999). Furthermore, nutrient enrichment is known at times to increase the number of *Ephemeroptera* order species in a stream system (Page *et al.* 2008). As Horn Creek is located in close proximity to residential development, it is possible that this may be influencing nutrient loading to the creek system. Furthermore, the %EPT (Richness) found in Horn Creek was low (with an average of 20.75%); decreased rates of these taxa (Ephemeroptera, Plecoptera and Trichoptera) are an indication of disturbance or stress to the stream. The results of the benthic survey are only one (1) of many indicators of watershed health for the Horn Creek system.

As indicated, the theoretical B-IBI results for the Willband watershed would be "very poor" whereas Horn Creek is rated as "fair". This may be reflective of the lack of industrial discharges in the Horn Creek subwatershed as well as the intact riparian vegetation within the ravine.

It is important to note that basing the condition of a stream on one sampling period is not generally recommended and future examination of the watercourses should be considered. In addition, caution should be exercised in using one year of data to determine the aquatic integrity of a stream system. Long-term monitoring across the watershed would help facilitate separation of naturally occurring broad scale impacts (i.e., drought, etc.) from human-induced impacts (i.e., urbanization, tree removal, etc).

The benthic summary is attached as **Appendix C**.

4.11 Opportunities and Constraints

There are opportunities (and related constraints) available to the City to improve the habitat value in the Study area.

4.11.1 Riparian Infill

Riparian infill consists of the installation of native vegetation in areas currently lacking riparian vegetation. In particular, this consists of the Willband Creek lowlands north of Maclure Road. Native vegetation would significantly improve habitat for both aquatic and terrestrial species. Constraints and disadvantages include:

- Expense
- Limitations to plant trees within the BC Hydro corridor in Lower Willband Creek, and
- Land Owner and buy-in by property owners. Fish Access Improvements

4.11.2 Fish Access Improvements

A number of culverts in the watershed may restrict access for fish to upstream reaches. This can be addressed through replacement with a properly sized and situated culvert that promotes access. Culverts can also be baffled or retrofitted with fish ladders to improve access. Such improvements would only be done where the channel itself is not a barrier and offers good fish access.

Erosion and sediment deposition may also serve to restrict fish access. Sufficient accumulation can block culverts. The deposition of sediment into pool habitat can infill refugia and resting areas for fish which may compromise access. In addition, sufficient erosion can deposit large volumes of woody debris into the channel which can accumulate at culvert inlets and impede fish access.

4.11.3 Habitat Construction

Habitat could be constructed in areas where adequate land is available, such as on Lower Willband Creek. This could include instream enhancement such as the placement of log cover structures or the creation of offline pools. Constraints include:

- Land acquisition may be required;
- Construction of new habitat can be expensive; and
- Off-line pools can lead to localized increases in water temperature if not adequately buffered by riparian vegetation.

4.11.4 Instream Maintenance

The removal of garbage and other anthropogenic would serve to improve water quality. The primary constraint for this option is that it is an ongoing requirement although it can be comparatively inexpensive.

4.11.5 Mill Lake and Creek Daylighting

There are options for improving water quality within Mill Lake. For example, the installation of oil/water separators at select locations within the storm sewer system could reduce the volume of hydrocarbons reportedly discharging to the lake. Mechanized aerators and/or water circulation devices would serve to increase DO levels in the lake to the benefit of aquatic life. However, it should be noted that increased DO may also provide a benefit for the invasive largemouth bass reported to be present.

Another benefit would be the removal of accumulated sediment and organic detritus currently reducing water depth throughout much of the lake. Deeper water would serve to buffer the increased temperature typical during the summer months and would likely increase DO levels in the water column. However, as previously indicated, metals and hydrocarbons could have accumulated in the sediment and if confirmed through sampling, disposal at a designated facility would be required at a potentially significant cost.

Daylighting the Mill Lake outlet channel represents a significant opportunity, and also a significant challenge that is likely impractical to consider. The cost and impact to built land would be extreme. However, the culvert currently in place is critical piece of infrastructure that may be vulnerable and costly in itself to repair if in poor condition. This culvert is discussed further in subsequent sections.

4.12 Environmental Condition Summary

Aquatic habitat in the study area has been significantly impacted by past land use activities. Riparian forest has been removed, sections of channel have been enclosed, fish access has been restricted in places, and erosion persists in some streams. Despite these impacts, salmonid presence has been confirmed for every channel. Riparian forest is often intact with the upland ravines of Horn Creek, Boa Brook, and Thiessen Creek. These sections are retained on their original alignment and typically display high complexity and good to excellent fish habitat value. However, these sections represent relatively little of the overall watershed.

Terrestrial habitat has also been impacted by fragmentation, making access and migration challenging for some species. However, despite these drawbacks, there is a great diversity of habitat present is isolated patches. Invasive plants are widespread; however, there is a high percentage of native plants present with invasive species typically not dominating other than in parts of Lower Willband Creek. Rare species are known to occupy the watershed, and other species not previously noted may be present.

Overall, the conditions across the watershed are highly varied and the high-quality components are outweighed by the poor-quality components. Overall, the watershed health is considered poor based on Metro Vancouver standards.

4.13 Implementation Challenges to Consider

It is evident that the City is placing an increased emphasis on environmental planning and protection. This is demonstrated by the work of its dedicated Environmental Coordinators, its robust Natural Environment Development Permit process, a range of regulatory Bylaws (i.e. ESC, Streamside, Tree Protection), and an increased focus on enforcement by Building Department inspectors.

At the same time, this effort has not been seamless. Developers and individual property owners often do not fully understand the purpose of the City’s environmental protection measures – rather, they see it as an increased expense and burden. The emphasis on enforcement has placed additional strain on the Building Department inspectors, who must enforce measures they might not fully understand or feel comfortable with them. Further identifying, understanding, and addressing these ‘gaps’ between policy direction and on-the-ground implementation will be essential to a successful ISMP. The City recognizes the need for improved regulatory tools, such as broader application of stormwater source controls to guide infill development.

5 GEOTECHNICAL AND HYDROGEOLOGY CONDITIONS

5.1 General

The surficial geology of the Study area was mapped at a regional scale by the Geological Survey of Canada and published in 1980 (GSC Map 1485A). The geologic conditions within the Study area are complex and heterogenous. Surficial sediments are underlain by the Eocene-aged Kitsilano Formation. The Kitsilano Formation is a sedimentary bedrock sequence consisting of sandstone, siltstone, shale, conglomerate, and minor volcanic rocks.

Most of the surficial sediments within the Study area are associated with the repeated advance and retreat of glaciers. During glacial periods, sea levels were significantly higher relative to the land surface, which was depressed under the weight of the ice-sheet. During and following deglaciation, the land surface rebounded upward. Increased rates of sediment erosion and deposition were likely associated with this period of relatively rapid uplift and resulted in the initial formation of many of the ravines and alluvial fans observed today. The rates of erosion and deposition likely have subsided since the most recent deglaciation, as the rate of uplift decreased and mature forests developed.

Modern day river (Fluvial) and hill-slope (Colluvial) processes continue to shape the landscape by eroding and depositing sediments. Anthropogenic deposits (i.e. fill) is present near surface for some of the Study area.

5.1.1 Surficial Geology

Bedrock is generally overlain by thick glaciomarine and marine sediments composed predominantly of clay and silt from the Fort Langley Formation. This unit is present at depth throughout the Study area and is only mapped at surface in the southwest corner of the Study area.

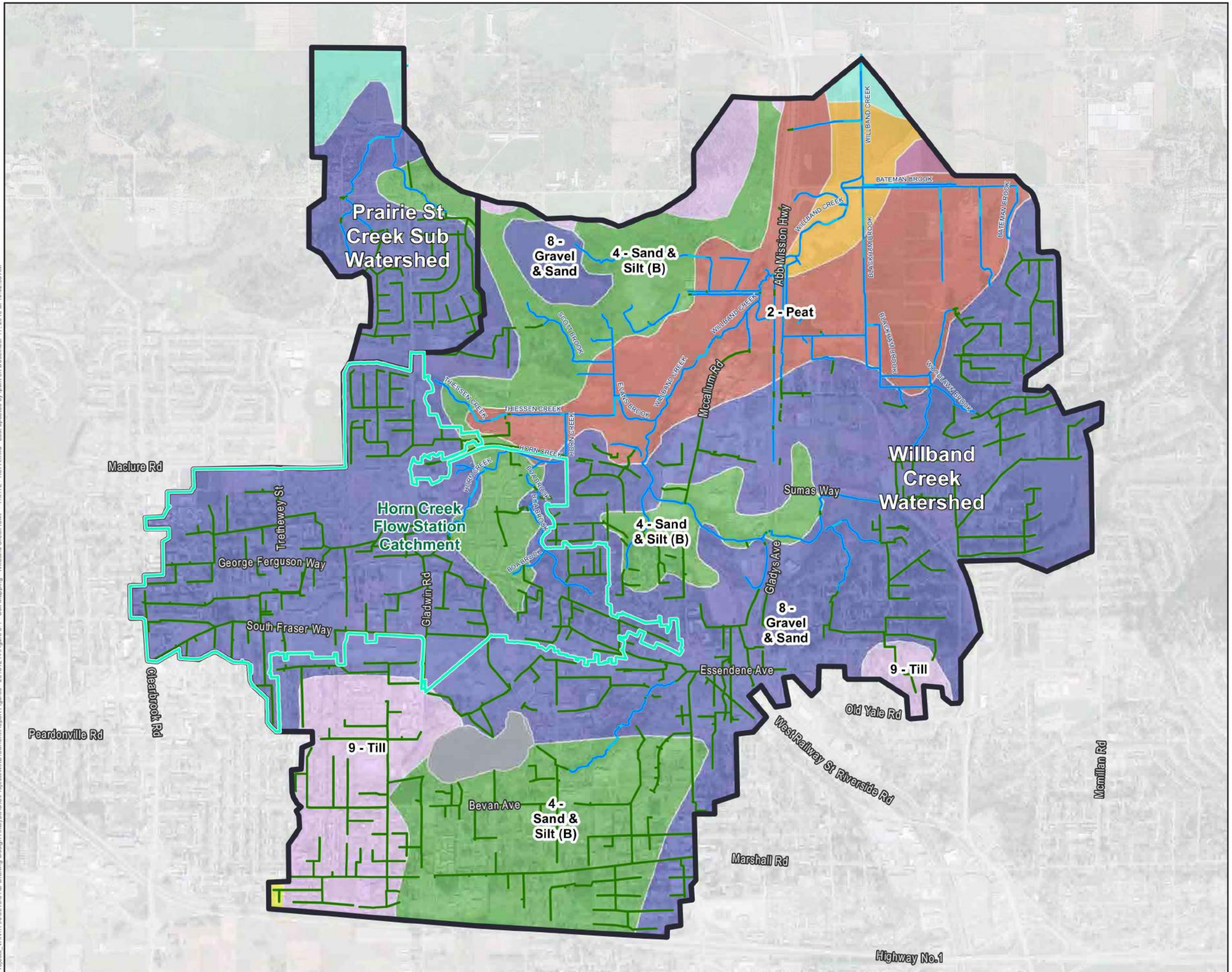
In the uplands, Fort Langley Formation is overlain by Sumas Drift, which consists of sequences of proglacial outwash sands and gravels up to 40 m thick. The area is mantled with eolian deposits consisting of windblown sand, silt, and silt loam. Lodgment and minor flow till composed of sandy till and sub-stratified drift between 2 and 10 m thick is mapped in the east portion of the Study area.

The lowlands consist of complex interfingering of postglacial Salish Sediments and Fraser River Sediments, which include of sequences of peat, organic silt loam and silty clay loam, and stratified clays, silts and sands, respectively.

5.1.2 General Hydrogeologic Conditions

A conceptual hydrogeological model is a qualitative representation of a Study area which is used to describe the flow of groundwater through the subsurface. In the context of the ISMP, a conceptual model provides an improved understanding of the interactions of surface and groundwater and can be used to identify opportunities for enhanced stormwater infiltration (groundwater recharge).

The process of developing a conceptual model includes subdividing the subsurface into hydrostratigraphic units (e.g., aquifers and aquitards) based on their relative estimated hydraulic properties. Conditions which bound the system are identified, including: established groundwater levels, surface water bodies, and watercourses, and areas of groundwater recharge and discharge.



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Soil Mapping

Legend

- Willband Creek Watershed
- Horn Creek Flow Station Catchment
- Creek
- Main

Soil Group*

- 2 - Peat
- 3 - Silt & Clay (A)
- 3 - Silt & Clay (B)
- 4 - Sand & Silt (A)
- 4 - Sand & Silt (B)
- 6 - Silt & Clay
- 8 - Gravel & Sand
- 9 - Till

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 145 290 580 870
Metres

N

Coordinate System:
NAD 1983 UTM Zone 10N

Scale:
1:22,019

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

Project #:	1790.0015.01
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Date:	2018 / 12 / 17

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FIGURE 5.1

can be correlated with Fort Langley Formation, and low permeable Salish and Fraser River Sediments located in the Lowlands. This hydrostratigraphic unit is present at surface in the lowlands and is locally overlain by the Lowland Aquifer.

Unit 2 – Upland Aquifer

The Upland Aquifer is a partially confined aquifer that can be correlated with Sumas Drift, eolian- deposited Salish Sediments and well drained Shallow Soils. This unit is mapped at surface and is unconfined through most of the Study area but is confined in some areas where it is capped by low permeable fill, till or colluvium.

Unit 3 – Intermediate Sand & Gravel Aquifer

This unit is defined as a partially confined aquifer. It consists of complex sequences of sand and gravel material interpreted as Sumas Drift glacial outwash and till. It is hydraulically connected to the Upland Aquifer. In some areas, the unit is partially confined between the Clay Aquitard and local till, and bedrock.

Unit 4 – Fractured Bedrock (Kitsilano)

This unit consists of fractured bedrock that underlies the other units within the Study area, and it consists of the Kitsilano Formation.

Unit 5 – Lowland Aquifer (Salish, Fraser River)

This unconfined- to-confined aquifer consists of surficial geological units interpreted to be composed of silts and sands from the Salish Sediments and Fraser River Sediments. The unit is complex, and its materials consist of poorly drained shallow soils, peat, and interbedded mixtures of sand and silt, and clay. There are no water wells reported to have been drilled into this unit. Locally perched water tables are present where permeable materials overlie less permeable soils.

5.1.5 Provincial Aquifer Mapping

The extents of the aquifers could not be mapped in detail within the scope of this study and due to limited available data. To support the management of groundwater, the British Columbia Ministry of Environment (MOE) has published an online tool (BC Aquifer Classification System), which provides limited two-dimensional (2D) mapping and aquifer classification. The boundaries of the aquifers mapped by the Province are likely based on limited data. Further, there are likely additional aquifers within the Study area that are unmapped.

5.2 Groundwater Hydrology

Water table elevations were compiled from water well records, provincial monitoring well data, and other consultant reports.

5.2.1 Uplands

Water well and geotechnical test hole data indicate that static groundwater elevations in the uplands vary between about El. 42 m to El. 70 m. Water well records from the BC Wells Database, and soils reports from the City indicate that groundwater is relatively shallow, usually less than 10 m below ground surface. Seasonal groundwater fluctuations range between 1.0 m and 3.0 m from static at Provincial Monitoring Wells located outside the Study area, and groundwater recharge response to precipitation events occurs within 1 to 2 days of rainfall events.

5.2.2 Lowlands

Geotechnical test hole data indicates that static ground water elevations in the lowlands vary between about El. 3 m to about El. 28 m. Groundwater depths in the lowlands are typically within 3 m of ground surface, and are often at or within 1 m of ground surface. There are few water well reports in the BC Wells database for wells located in the lowland areas. Static water level is shallow, and ponding occurs in areas during periods of high intensity rainfall.

Water levels may drop over the summer, but are quick to rise after continued rain. Ponding water is slow to dissipate, and has been observed by others to last longer than it has in the past. Regions mapped as having annual or seasonally high water tables, perched water tables, or those prone to flooding are unlikely to provide adequate drainage.

Groundwater levels in the lowlands may be artificially influenced through controls in the drainage system that force storage for the purposes of agricultural irrigation, which is typically done May 15 through September 15.

5.2.3 Groundwater Flow

An understanding of the interactions between groundwater and surface water is important to the effective management of the Study area. Precipitation and surface water are regarded to be the widespread sources of groundwater recharge in the area. In turn, surface water is likely recharged by precipitation and groundwater baseflow. Groundwater baseflow likely becomes the dominant source of recharge during longer periods with no precipitation.

The Upland area is drained by various creeks which have incised into the terrain draining into the Lowlands. These creeks are supplied with water from precipitation, and small wetlands and lakes distributed across the surface of the Uplands. The primary natural drainage in the lowlands is Willband Creek, which drains northward into Matsqui Slough. Willband Creek is supplied with water from tributary creeks. Mill Lake is likely supplied with contributions from groundwater and precipitation, which fluctuate seasonally.

Gradients suggest groundwater flows towards creeks in some areas. Precipitation is likely the dominant source of flow in the creeks for much of the year, and creek flow may contribute to the recharge of groundwater in upland areas where groundwater levels are deeper.

In the summer months when there is little precipitation, groundwater discharge is likely an important source of recharge to many creeks in the region (baseflow or gaining stream), especially in lower elevation areas where groundwater is relatively shallow. Watercourses may dry up when static water table deepens over the summer and when there are long periods with no precipitation.

Where shallow aquitards or local impermeable surficial soils are present, infiltrating precipitation may remain in local perched aquifer subunits and flow laterally as interflow or throughflow rather than recharging deep aquifers. Groundwater discharge in sloping areas in the form of surface seepage is possible due to throughflow in stratified aquifers (e.g. Upland Aquifer, Intermediate Sand & Gravel Aquifer). Deep aquifers may receive significant recharge from precipitation where they are unconfined. Upward and lateral flow of groundwater from bedrock may also contribute to the recharge of deep aquifers.

Inferred horizontal hydraulic gradients in the uplands suggest groundwater flow generally drains towards the lowlands. The horizontal hydraulic gradient in the lowlands indicate that groundwater flow is generally northward towards the Matsqui Prairie.

The available groundwater data indicate shallow regional groundwater flow is generally consistent with topography and watershed catchments. Data are insufficient to adequately assess vertical hydraulic gradients; however, they are generally inferred to promote the downward movement of water.

5.3 Infiltration Rates

Best attempts were made to assign infiltration rates. Areas where there is poor test hole coverage have been assigned a broader range of infiltration rates to account for uncertainty.

Non-native fill may be present in variable thickness overlying the mapped native surficial geology units but is not possible to quantify.

Infiltration rates were estimated for the geologic map units shown on Figure 5.1, and are summarized below in Table 5.1.

Table 5.1 - Estimated Infiltration Rates

Soil Group	Material Type	Estimated Minimum Infiltration Rate (mm/hr)	Estimated Maximum Infiltration Rate (mm/hr)
2	Peat	0.036	36
3	Silt & Clay (A)	0.0036	0.36
4	Silt & Clay (B)	0.0036	3.6
5	Sand & Silt (A)	0.036	36
6	Sand & Silt (B)	0.36	3600
7	Silt & Clay	0.00036	3.6
8	Gravel & Sand	3.6	3600
9	Till	3.6	360

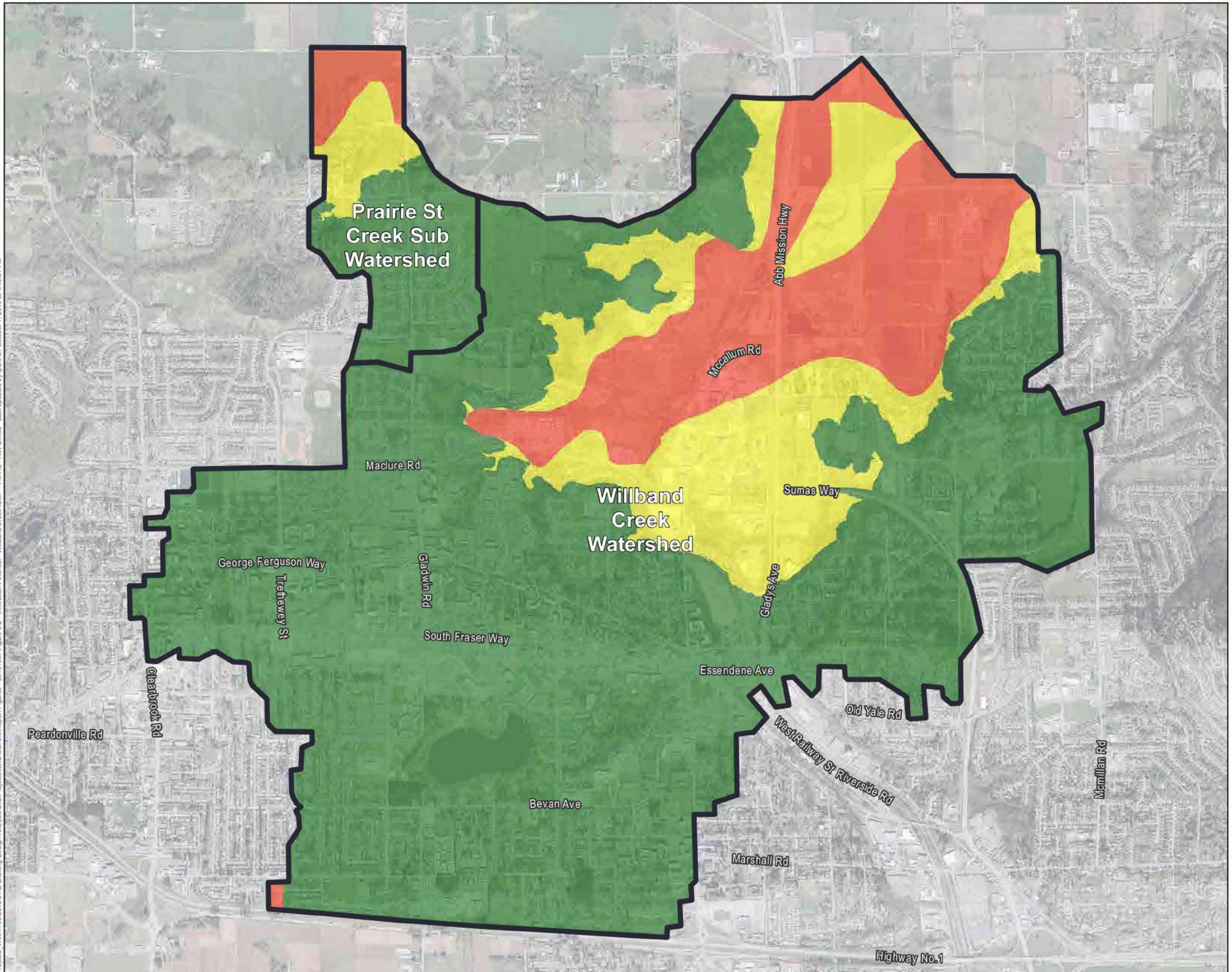
5.3.1 Infiltration Potential

One objective of stormwater management is to reduce stormwater runoff and demands on the storm water infrastructure system by implementing source controls. The conceptual hydrogeological model described above provides a framework for high-level screening of areas which have the potential for the enhancement of stormwater infiltration. Factors which influence the potential for infiltration enhancement include: the hydraulic properties of the near-surface sediments and soils, and the existing groundwater levels and soil saturation. In general, 70% of the Study area has good potential, as shown on **Figure 5.2**.

More detailed assessments should be carried out by a qualified professional in areas where stormwater infiltration enhancement measures are considered, however within the scope of this ISMP, the following is a brief discussion of areas where there is potential stormwater infiltration enhancement.

1 The soils and sediments underlying most of the Lowlands are relatively impermeable with shallow static water table. The area has poor potential for stormwater infiltration. In these locations, organic soils overlay poorly drained silts and clays. Wetlands, ponding surface water, and peat deposits are indicative of high water table and saturated conditions.

2 An exception is the area south of the Willband Storm Detention Facility near Hazelwood Avenue and Sumas Way which is mapped as Marble Hill soils overlying eolian deposits and/or Sumas Drift (Soil group 8 in Figure 5.1). Available data indicates that static water levels may be greater than 5 m depth within this area. This area may have potential for stormwater infiltration enhancement.



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Willband Creek Integrated Storm Water Management Plan

Infiltration Potential

Legend

- Willband Creek Watershed
- Good Infiltration Potential (70%)
- Marginal Infiltration Potential (15%)
- Poor Infiltration Potential (15%)

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Metres

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Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,010

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvise (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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Date:	2019 / 10 / 7

URBAN systems

FIGURE 5.2

3 Abbotsford, and Laxton soils overly well drained Sumas Drift. There is a substantial aquifer at depth to accept infiltrating stormwater, but static water depth is poorly constrained in this area. This means that despite the soils being conducive to infiltration, the high-water table will limit water movement through it.

4 Upland areas mapped as Lonzo Creek, Ryder and Calkins shallow soils may be subject to perched and shallow water table (less than 5 m depth), as they may overlay less permeable till-like material.

The investigation of stormwater infiltration enhancement must also consider the potential unintended consequences of causing changes to groundwater conditions. Specifically, concentrated stormwater infiltration measures can lead to geotechnical hazards. The best practice management of stormwater should include consideration of these issues. Infiltration enhancement may not be appropriate in some areas of the City, particularly close to steep slopes or where groundwater mounding may cause seepage failures or flooding elsewhere. Areas prone to perched water tables are more susceptible to risk.

5.4 Geotechnical Erosion Site Assessment

The City expressed concern for channel erosion at a number of creek segments throughout the Study area. Priority sites were selected for inspection and assessed by Thurber on April 13 and 25, 2017 within the following creeks:

- Boa Creek;
- Horn Creek;
- Thiessen Creek; and
- Willband Creek.

Singular sites were identified on Boa Brook, Thiessen Creek, and Willband Creek. Within Horn Creek there were number of reaches identified where multiple erosion sites existed.

Watercourse Stability Assessment Data Sheets (WSADS) record key information and photographs for each site and are provided in Appendix D.

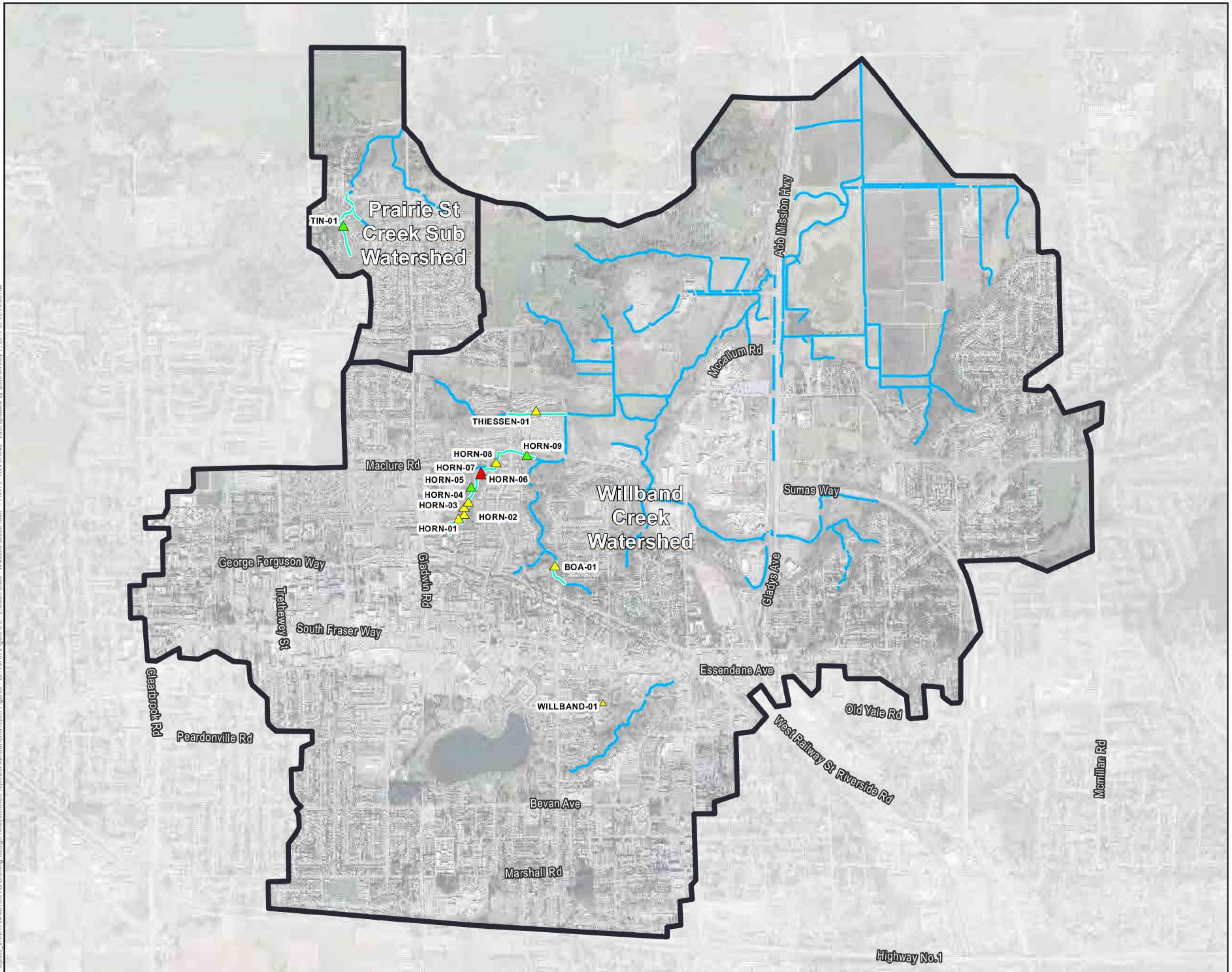
Creek bank erosion and channel migration are natural mechanisms in stream geomorphology and an eroded bank is not necessarily of concern. Conversely, excessive creek bank erosion in an urban environment is often a sign of increased creek flow, typically resulting from accelerated stormwater runoff discharging into the creek from the storm sewer system. Therefore, it was necessary to establish a criterion that would differentiate natural creek bank erosion and that likely caused by increased creek flow as these sites would be vulnerable to further rapid erosion which could lead to ravine slope instability and deposition of sediment into the creek. A 1 m vertical eroded face height on the channel bank was applied as the lower limit for identifying and recording potentially problematic erosion sites.

The overall risk rating is a qualitative assessment based only on visual observations made during the reconnaissance. The rating uses a combination of consequence and severity/likelihood based on engineering judgement and experience. It should be noted that the rating is subjective and may not be directly comparable to the ratings used by others. The rationale for the hazard rating used for this ISMP is described in Table 5.2. The erosion sites are shown on **Figure 5.3**.

The sites within Horn creek were often about 5 m high and in some cases extended 10 m to 20 m in length along the creek. Further, pedestrian walking paths and houses were often near the sites. Retrogression of the erosion features within Horn Creek may pose a risk to residents and infrastructure. No “very high risk” sites were observed during the assessment.

Table 5.2 - Geotechnical Hazard Risk Ratings

Risk	Description
Very Low	Site identified primarily for record keeping purposes. Generally, the site conditions are not severe, are not anticipated to change significantly with time, and/or the consequences of continued erosion are very low.
Low	Generally, the site conditions are not anticipated to change significantly with time and/or the consequences of continued erosion are low. Site should be checked periodically to reassess risk.
Medium	Erosion is moderate and erosion is ongoing. Site conditions anticipated to deteriorate with time but are currently not in urgent need of repair. Site should be inspected and a plan for remediation formulated. The exact details and timeline of the remediation will depend on risk tolerance and particulars of site.
High	Eroded creek channel faces are significant and continued erosion and deteriorating conditions should be anticipated. Site should be inspected regularly and a plan for remediation developed to address site issues in the near future. Potential for danger to public and/or infrastructure and/or severe environmental degradation if not remediated.
Very High	Eroded creek channel faces/ravine slopes are significant, and erosion is severe. Slope instability has already occurred or is anticipated imminently. Requires immediate response and remediation. Currently there is a danger to public and/or infrastructure and/or severe environmental degradation if not remediated. (no “Very High” risk sites have been identified within the Willband study area)



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Willband Creek
Integrated Storm Water
Management Plan

Erosion Sites

Legend

- Willband Creek Watershed
- Traversed Creek Section
- Low to Very Low Risk Level
- Medium Risk Level
- High Risk Level

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FIGURE 5.3

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20170707\Figure 5-3 - Erosion Sites - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on July 7, 2017 at 10:19:45 AM

6 HYDROLOGIC AND HYDRAULIC CONDITIONS

In addition to the natural systems described in prior sections of this report, the Willband Creek watershed's management system is comprised extensively of manmade features; storm sewers, detention ponds, culverts, and ditches. An important aspect of an ISMP is to understand the hydrology of the watershed, the working hydraulics of the management systems, and how it performs against established criteria.

6.1 Modeled System

The modeled system was determined through discussion with City staff. The hydrodynamic model was truncated to pipes with diameter of 300 mm or greater, plus the larger open channel streams which comprise the primary system. Pipes with smaller diameter are included only as required for system connectivity. Roadside ditches and catch basins were not included. Also, only a single private stormwater management facility at the hospital has been included in the model at this time. It was agreed with the City that an assessment would first be conducted for public infrastructure only, and that consideration for private infrastructure would be made based on the initial findings.

An inventory of the modeled system is presented on **Figure 6.1**. It is comprised of 30 km of open channels, 85 km of storm sewers, 1.6 km of culverts, 25 controls structures, 14 public storage facilities, excluding Mill Lake and multiple cells of the Willband Creek detention facilities, and 1 private pond at the Hospital.

All geometric information for the system was obtained from desktop sources, including City GIS databases, City record drawings, and LiDAR (for Creek transects and pond volumes). Early in the ISMP study process, initial records provided from the City were assessed for completeness and large anomalies identified. The City undertook the necessary field work to address the data gaps and anomalies and provided a verified GIS data base, which was applied to the model.

6.2 Mill Lake

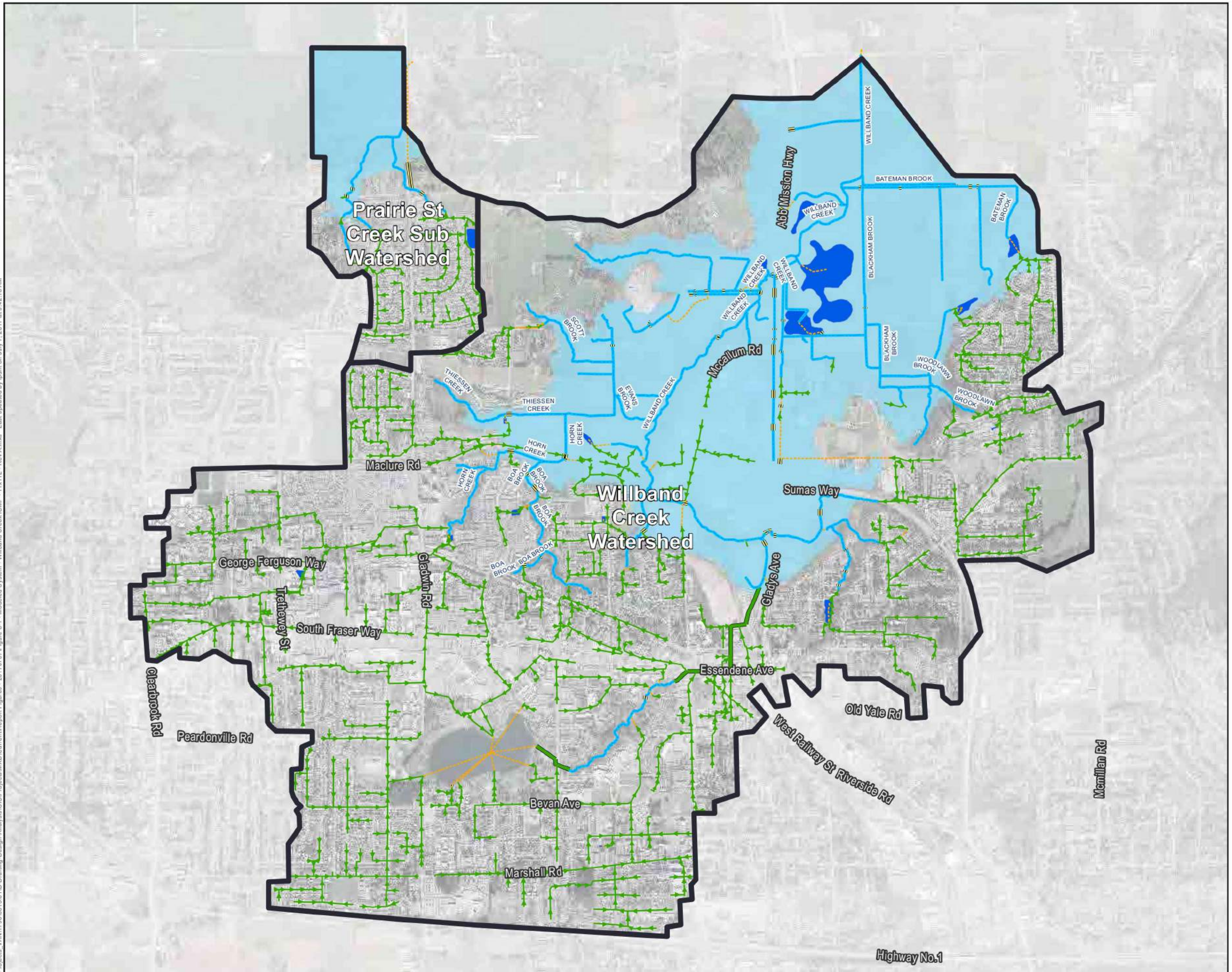
Mill Lake represents a very significant feature within the southern portion of the watershed. Its outflow is controlled by a sluice gate and stop log structure that is manually operated by City staff, but with no set protocol. Mill Lake is monitored with SCADA systems. Some basements have been known to flood adjacent to Mill Lake. The model was developed assuming a winter condition when the sluice gate is closed and the weir set to its maximum elevation of 51.65 m.

6.3 Land Use and Soils Parameters

To represent existing conditions, TIA percentages shown on **Figure 3.3** were applied. Soils infiltration rates were applied from **Table 5.1.**

6.4 Model Calibration

Only a single monitoring station, on Horn Creek, lies directly within the Willband Creek watershed that can provide data for model calibration. While this station has been collecting data since 2012, only data March 1, 2017 and April 1, 2017 were applied to model calibration because of anomalies in other data that did not allow for confident application. The 2017 dataset is limited, but offers reasonable



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Willband Creek Integrated Storm Water Management Plan

Modeled System

Legend

- Willband Creek Watershed
- Detention Facility
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)
- Conduit Added for Connectivity

Minor System

- Minor Storm Sewer

Major System

- Creek
- Culvert
- Major Storm Sewer

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Date: 2017 / 7 / 7

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FIGURE 6.1

confidence, as it was a wet month, yielding several precipitation events despite not being overly significant in intensity.

Corresponding precipitation data was obtained from the City's Flowworks account for the "City Hall" raingauge station. A total of nine precipitation events occurred; some single day events and some multi-day events. The magnitude of all events was below a 1:2 year return period level. A detailed table of these events, and the model calibration process, is provided in Appendix E. These events were modeled continuously, rather than in isolation for each event. This provides for both model calibration and validation. Results of the model calibration are also provided in Appendix E, but yielded very good with observed data, recognizing, however, the limited magnitude of the events.

The catchment for the Horn Creek flow monitoring station is shown on Figure 1.1. It represents 18% of the overall Willband Creek watershed and represents some of the most densely developed portions. One of the key calibration parameters was to adjust the directly connected impervious fraction, also known as the Effective Imperious Area (EIA). For Horn Creek, calibration yielded a total impervious area (TIA) of 69% and an EIA of 39%. As such, 30% of the impervious area appears disconnected to some degree from the conveyance system.

Even in a highly urbanized area, this value is not uncommon, particularly in older areas where rainwater capture is not always effective and with leakage out of aging storm sewers where infiltration is possible. In the absence of data for other parts of the watershed, this 30% reduction from TIA to EIA has been applied to all other areas.

The overall TIA for the entire Willband Creek watershed has been measured at 45%, with a resulting EIA of 32%.

6.5 Performance Criteria

Table 6.1 below summarizes the current City performance criteria consolidation from the City's bylaws and past studies.[2]

Table 6.1 - Performance Criteria

System Component	Performance Criteria
Peak Flow Attenuation (Detention)	10-year peak flow detained to 5 L/s/ha 100-year peak flow detained to 5 L/s/ha if major flow paths cannot be identified.
Upland Criteria	
Storm sewer	Safe conveyance of 10-year peak flows in minor systems. Safe conveyance of 100-year peak flows in major systems.
Culvert	Safe conveyance of 100-year peak flows.
Channel	200-year peak flow to be conveyed in upland creeks and without overtopping major roadways/railways in the lowlands.

[2] City of Abbotsford Storm Water Source Control Bylaw, 2011 (Bylaw No. 2045-2011)
City of Abbotsford Development Bylaw, 2011 (Bylaw No. 2070-2011)
Clayburn Creek Integrated Stormwater Management Plan, May 2012
Matsqui Prairie Drainage Study - Phase I, June 2013

Lowland Criteria	
Culvert	Safe conveyance of 10-year peak flows.
Channel	2-year peak flow to be contained within the lowland creek banks.
Agricultural Flooding	10-year ARDSA Summer and Winter Criteria

6.6 Design Storms

Design storm hyetographs as used in the Clayburn Creek ISMP and the Matsqui Prairie Drainage Study–Phase 1 were applied herein to ensure consistency and compatibility between models. **Table 6.2** summarizes the total rainfall volume for each single day design storm event.

Table 6.2 - Single Event Design Storm Precipitation

Duration (hr)	6-month (mm)	2-year (mm)	5-year (mm)	10-year (mm)	100-year (mm)
1	9.72	13.50	17.65	20.50	29.25
2	13.72	19.05	24.55	28.20	39.60
6	25.06	34.08	41.30	45.70	59.25
12	36.79	51.10	61.00	67.55	88.05
24	51.05	70.90	85.70	95.50	126.20

Developed by averaging the rainfall intensity values from the Abbotsford A AES station (1100030) and the Mission West Abby AES station (1105192).

Precipitation events for the evaluation of multi-day events are shown in **Table 6.3**.

Table 6.3 - Multi-Day Design Storm Precipitation

Duration (days)	10 year (mm) (ARDSA)	200 year (mm)
2 day (summer)	120.1	n/a
5 day (winter)	182.8	262.2

6.7 System Performance

Assessment of the conveyance systems was broken into its individual components of:

- Minor Storm Sewers;
- Major Storm Sewers;
- Creeks; and
- Culverts.

The inventory of these systems is presented on **Figure 6.1**.

Results presented under the 2-, 10-, and 100-year return period represent the worst case from all storm durations assessed (i.e., 1-, 2-, 6-, 12-, and 24-hour durations). The 5-day duration was run for the 200-year return period. The longer duration of the 200-year return period produced peak flows which were generally less than the peak flows of the 100-year duration because of lower peak intensity.

6.7.1 Winter Base Flow

The City's Flowworks account was used to obtain data from representative creeks, from which an estimated winter base flow value of 0.15 L/s/ha was judged, therefore applied to analysis herein.

Before describing the performance assessment of the individual components, **Table 6.4** on the following page presents some general findings of the hydrologic response at key points of interest.

Table 6.4 - Hydrologic Response Indicators

Point of Interest	Catchment Area (ha)	Average TIA (%)	Peak Flow Rate (L/s/ha)			
			2-year critical storm duration	10-year critical storm duration	100-year critical storm duration	200-year, 5-day
Willband Creek Outfall	1699	46	2.8	3.7	4.6	4.8
Prairie St Creek Outfall	130	28	6.6	10.4	15.2	8.2
Willband Creek at Maclure Road	735	44	6.5	9.7	12.3	10.0
Horn Creek at hydrometric station	330	69	16.0	24.1	30.8	18.8
Mill Lake Outlet	197	44	2.5	3.8	5.3	5.4
Boa Brook	67	48	11.2	16.6	23.3	13.9
			Runoff Coefficient			
Willband Creek Outfall	1699	46	0.32	0.34	0.35	0.37
Prairie St Creek Outfall	130	28	0.18	0.18	0.18	0.17
Willband Creek at Maclure Road	735	44	0.26	0.26	0.26	0.31
Horn Creek at hydrometric station	330	69	0.39	0.42	0.41	0.39
Mill Lake Outlet	197	44	0.27	0.32	0.29	0.32
Boa Brook	67	48	0.32	0.34	0.34	0.32

6.7.2 Unit Peak Flow

Unit peak flow is a function of many factors, therefore they cannot be compared with precision, but in general it is shown that as the impervious fraction goes up, so does flow rate, however as the size of the watershed goes up, the peak flow goes down.

As expected, being only of moderate size and having the highest impervious fraction, Horn Creek is generating the greatest peak flow response.

Mill Lake appears to be providing a very important role in protecting downstream systems with a significant attenuation of peak flows. This Lake is considered a very valuable natural asset. Should that lake be reduced in capacity or function, the impacts to downstream systems and lands would be significant.

Given the vast size of the overall Willband Creek watershed, lowland gradients, and available lowland storage, there is also a dramatic peak flow reduction in Willband Creek at Clayburn Road.

6.7.3 Storm Sewer Assessment

Within the uplands, the storm sewers of the minor system were assessed by simulating their ability to safely convey the ***minor*** flow, generated from the 10-year return period rainfall event. Storm sewers that convey stormwater flows from Mill Lake and infilled creek segments were considered as part of the ***major*** system. The major storm sewers were assessed by simulating their ability to safely convey the major flow, generated during the 100-year return period rainfall event.

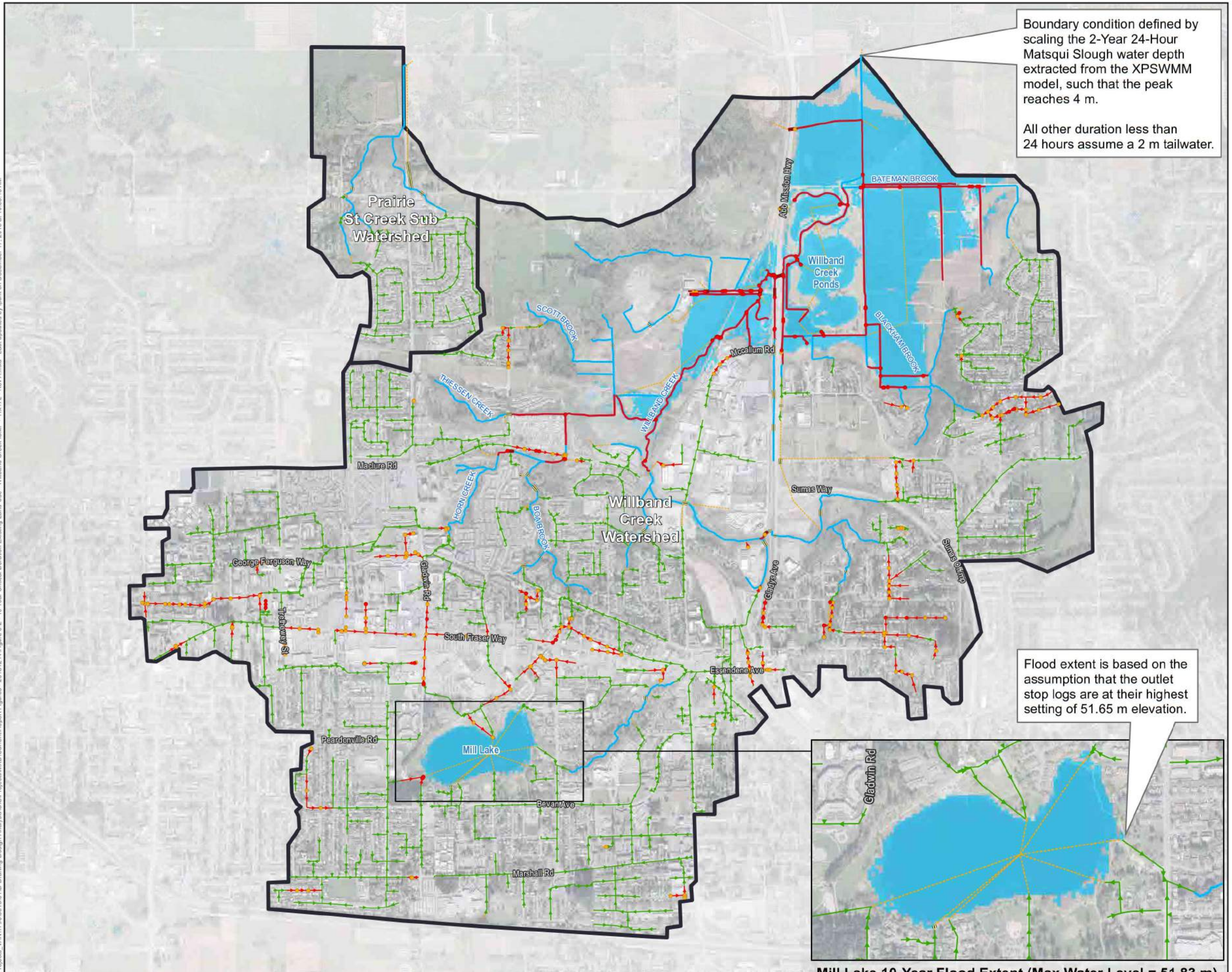
Storm sewers were flagged if any of the following criteria were met:

- Modeled peak flow is greater than full pipe capacity;
- Pipe surcharged for longer than 5 minutes; and
- Water surcharged higher than 0.3 m above the crown of the pipe.

Figure 6.2 shows the results of the storm sewer performance assessment for the existing land use condition against the 10-year design events, while **Figure 6.3** shows the results for the 100-year design events, both without considering the effects of private stormwater management systems; a conservative assessment.

Given the extent of conveyances assessed, system performance against the 10-year criteria look generally favourable. Given the criticality of Mill Lake, the predicted HGL and flood extent of it is shown. This depiction is based on the assumption of the control structure being set at its highest level. Results do indicate that the top of bank would breach, flooding landscaped area around the park, however no impact to adjacent building appears likely by surface waters. The predicted maximum level (51.82 m) may result in backwater into the storm sewer system and service connections, therefore if there is subsurface habitable space in surrounding buildings; it is possible they may be impacted. The City has indicated that flooding has occurred in the past.

As expected, conveyance performance worsens under the 100-year level, as shown on **Figure 6.3**. However, the minor system is not required to perform to that level. Generally, the portions of the system designated as “major” and required to perform to the 100-year level, do perform reasonably well. Only two major storm sewer reaches on Montrose Avenue have been found deficient against the 100-year criteria. Once again, flood level and extent in Mill Lake are shown, and given the relative size of the lake results are not significantly dissimilar to the 10-year event. The predicated maximum water level increases from 51.82 m in the 10-year event to 51.86 m in the 100-year event. The position of the discharge weir leaving the Lake is critical to the resulting lake level. Management of the weir is discussed in subsequent sections of the report.



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Willband Creek Integrated Storm Water Management Plan

10-Year, Critical Duration System Performance (Existing Land Use)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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Metres

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Coordinate System: NAD 1983 UTM Zone 10N

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Data Sources:
Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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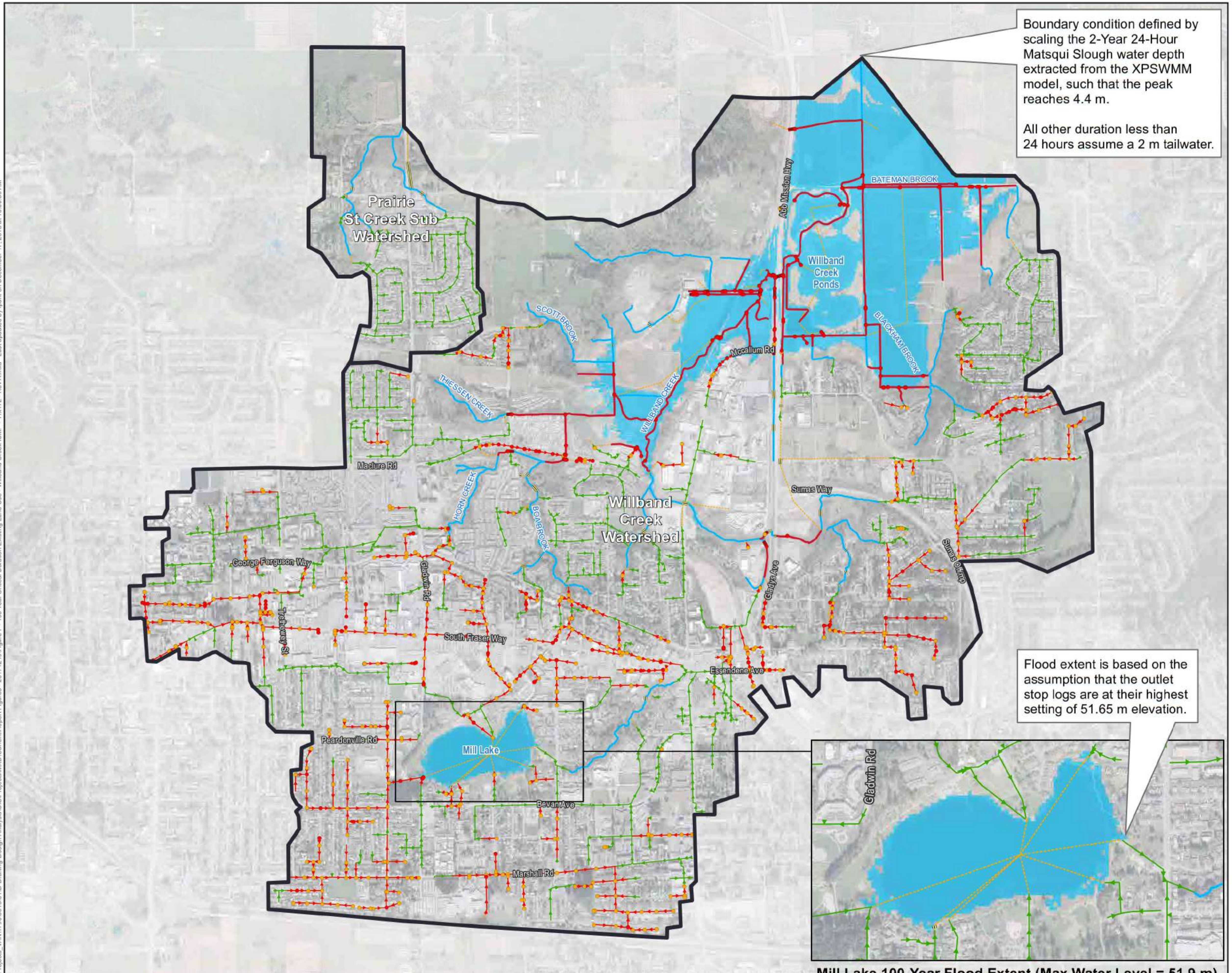
FIGURE 6-2

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 6-2 - 10 Year Critical Duration Existing Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:03:10 AM



U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20171219\Figure 7 - 100 Year Critical Duration Existing Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:03:30 AM

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Willband Creek Integrated Storm Water Management Plan

100-Year, Critical Duration System Performance (Existing Land Use)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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FIGURE 6.3

Assessment results for each storm sewer component, when measured against the established criteria, are presented on **Figure 6.4**.

6.7.4 Culverts and Bridges

The culverts were assessed by evaluating their ability to safely convey minor and major flows generated from the 10-year and 100-year return events.

Culverts were determined to be undersized if the following criteria were met:

- **Upland Culvert**: Modeled 100-year peak flow is greater than full-flow capacity and water surcharged higher than 50% of the culvert height above the crown of the culvert.
- **Lowland Culvert**: Modeled 10-year peak flow is greater than full-flow capacity and water surcharged higher than 50% of the culvert height above the crown of the culvert.

Using the criteria previously noted in Table 6.1 only two culverts have been identified deficient under current conditions. One upland culvert crossing Oxford Avenue (assessed against the 100-year event), and one lowland culvert crossing Highway 11 (assessed against the 10-year event).

Two road bridges and one rail bridge were identified within the Willband watershed; however, as-built drawings for these bridges were not available to formulate a complete assessment. Peak flows, maximum water depths, and hydraulic grade line elevations have been reported in the adjacent creek to each bridge in the detailed report contained in Appendix E.

A summary of culvert performance against criteria is presented on **Figure 6.5.**

6.7.5 Detention Facilities

The detention facilities were assessed by evaluating their ability to detain the 10-year flow and release at a rate of 5 L/s/ha, with exception to Mill Lake and the Willband Creek Park ponds, which were not designed to the same criteria.

A total of 14 upland public stormwater detention ponds or tanks have been assessed (excluding Mill Lake and Willband Creek detention facility). Based on the information available and the 5 L/s/ha criteria, 7 of them appear to meet criteria, while 7 do not. In 6 of the 7 cases, it appears that the control device needs to be revisited. The results also indicate relatively poor utilization of available storage. Of those ponds not meeting criteria, modeling suggests that on average only 12% of available storage is being utilized.

A summary of detention facility performance is presented on **Figure 6.6.**

6.7.6 Creeks

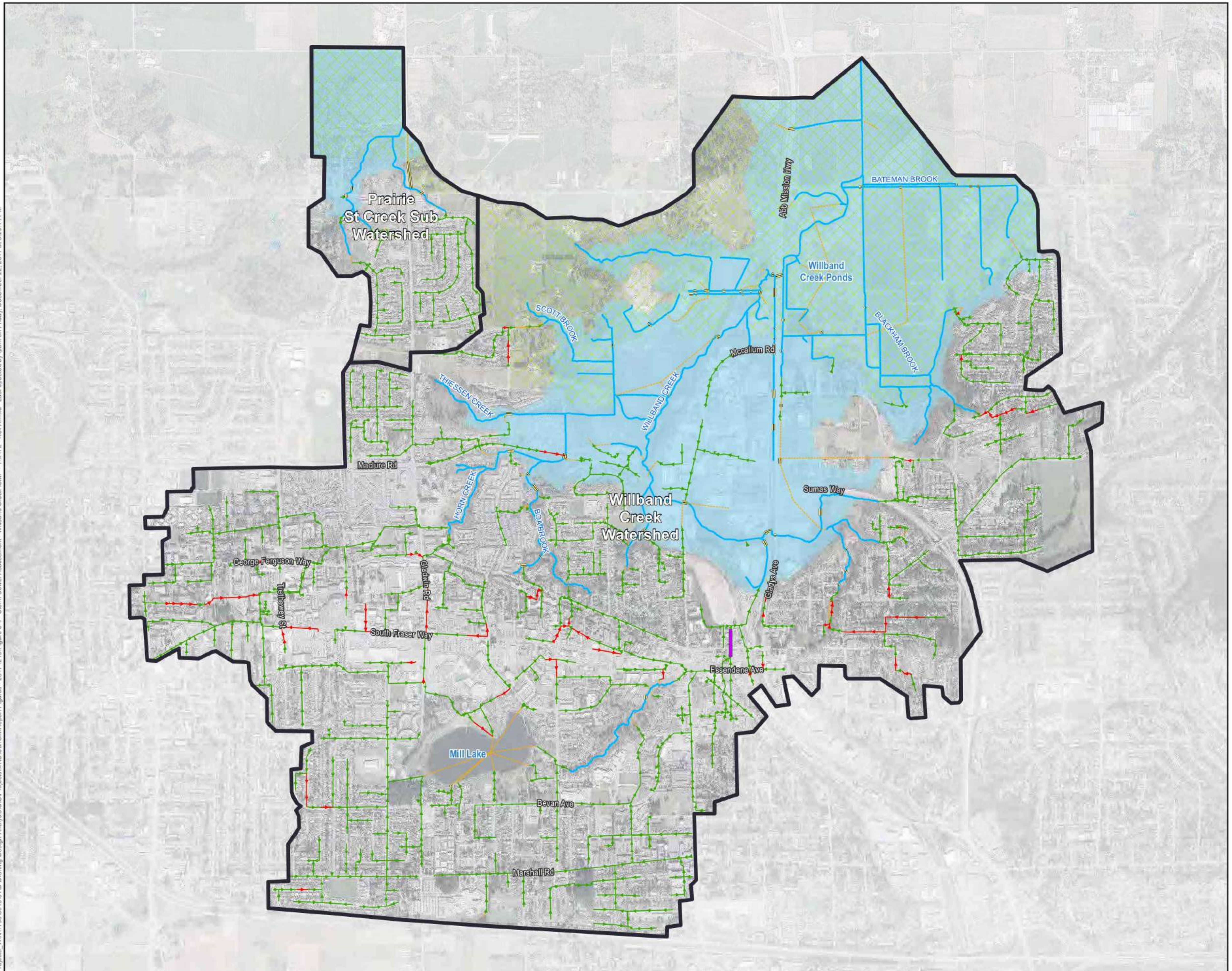
The creeks of the major system were assessed by simulating their ability to safely convey and contain the 2-year and 200-year flows. Creek capacity was assessed based on the criteria outlined in Table 6.1.

As creeks within the lowland region are influenced by the downstream water levels at Clayburn Creek, it was necessary to assess the system with downstream boundary conditions. For the purposes of this assessment, hydraulic grade line boundary conditions at Clayburn Road were provided from Kerr Wood Leidal who had previously completed the Clayburn Creek ISMP and the Phase 1 Matsqui Prairie Drainage Study.

The results of the creek assessment are presented on **Figure 6.7**. Overall the system appears to meet criteria, however there is a concentrated area in the lowlands, downstream of Maclure Road not meeting criteria that corresponds with the areas reported as problematic by the City.

6.7.7 Floodplains

Performance and the extent of flooding predicted in the City's 200 year 5-Day winter event is shown in **Figure 6.8.**



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Storm Sewer Assessed Against Established Criteria (Existing Land Use)

- Willband Creek Watershed
- Major Main (100-Year) Surcharge 0.3 m over Crown for > 15 min
- Minor Main (10-Year) Surcharge 0.3 m over Crown for > 5-min
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 145 290 580 870
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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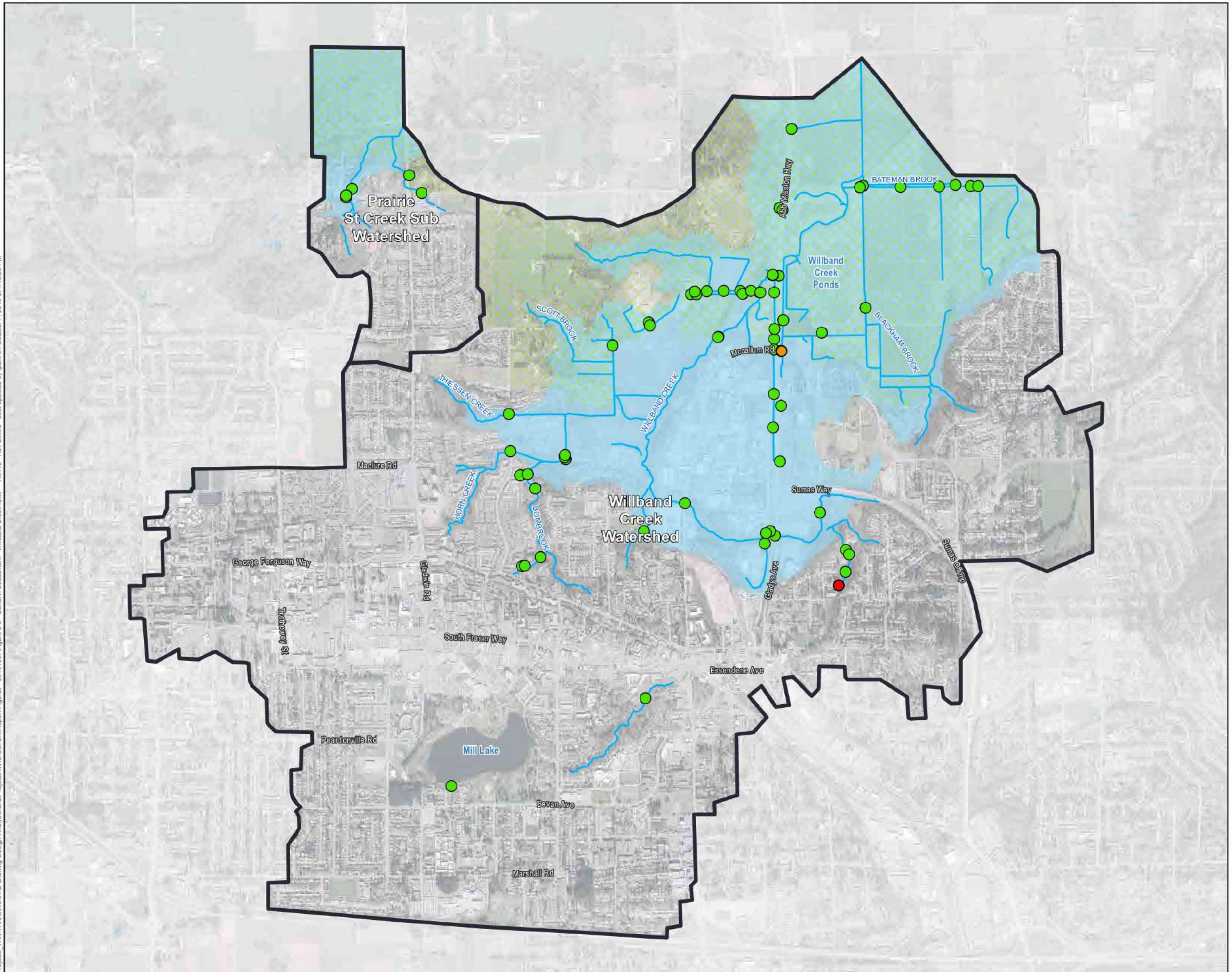
FIGURE 6.4



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Culverts Assessed Against Established Criteria (Existing Land Use)

- Willband Creek Watershed
- Creek
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

Culvert Assessment

- Meets Criteria
- Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown
- Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown

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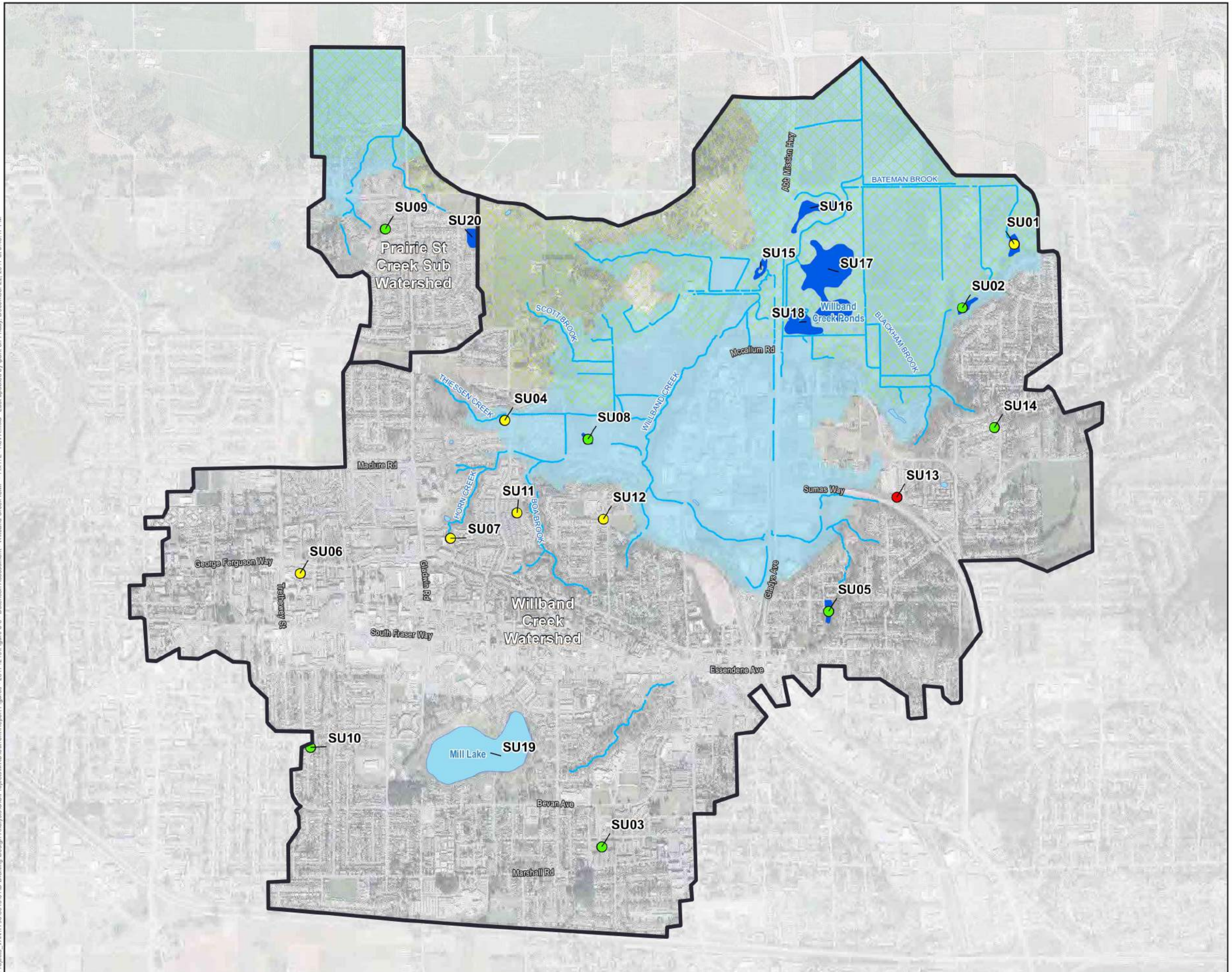
FIGURE 6.5



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Detention Facilities Assessed Against Established Criteria (Existing Land Use)

- Willband Creek Watershed
- Detention Facility
- Lake
- Creek
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

Detention Assessment

- Meets Criteria
- Outlet Modification Required to Meet Criteria
- Insufficient Storage Volume to Meet Criteria

North Vancouver, Coquitlam, Vancouver, Burnaby, Richmond, Surrey, Langley, Delta, White Rock, Abbotsford, Chilliwack

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Metres

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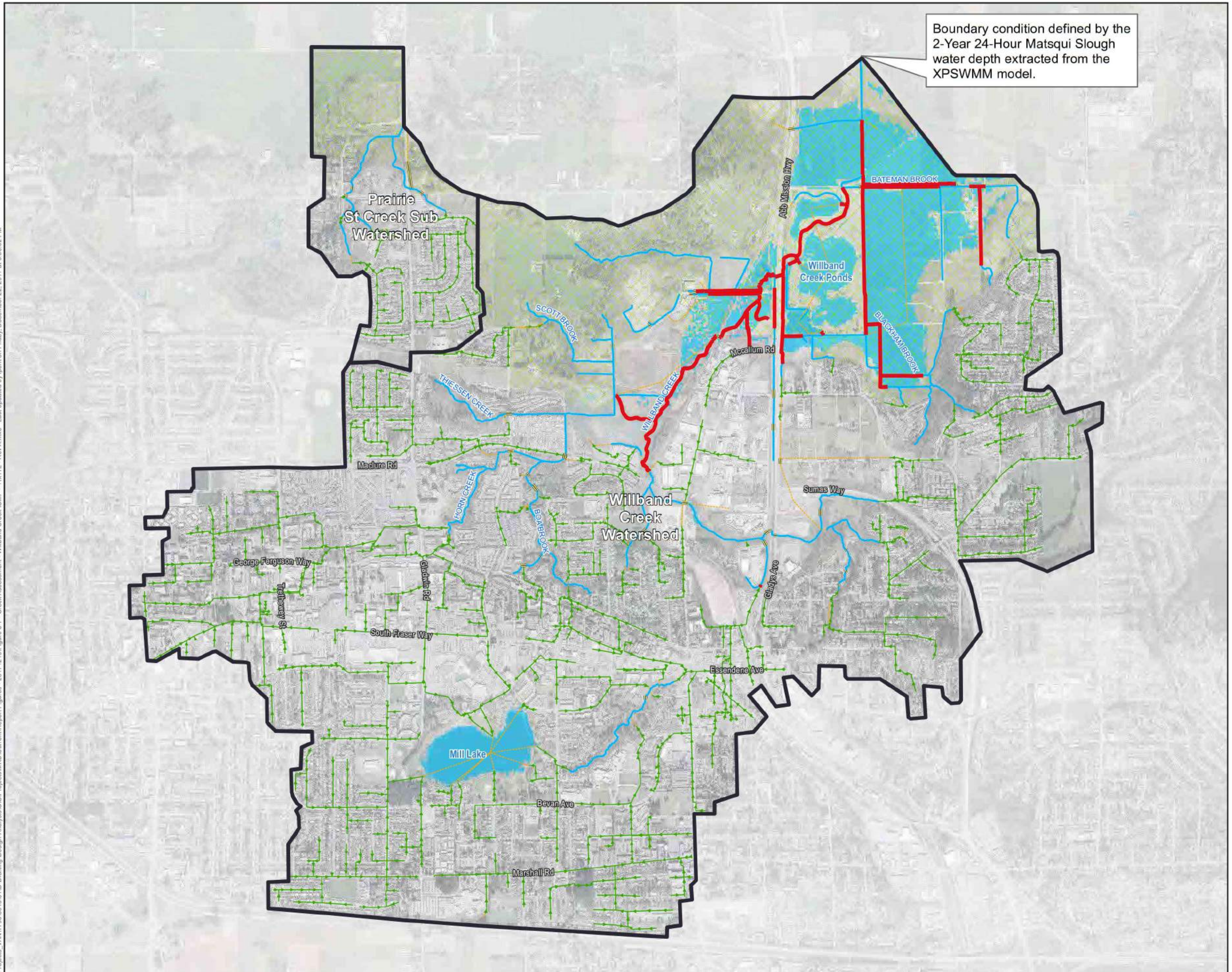
FIGURE 6.6



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Creeks Assessed Against Established Criteria (Existing Land Use)

- Willband Creek Watershed
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland and Mill Lake Flood Extent (2-Year, 24-Hour)

Creek Assessment

- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek

0 145 290 580 870
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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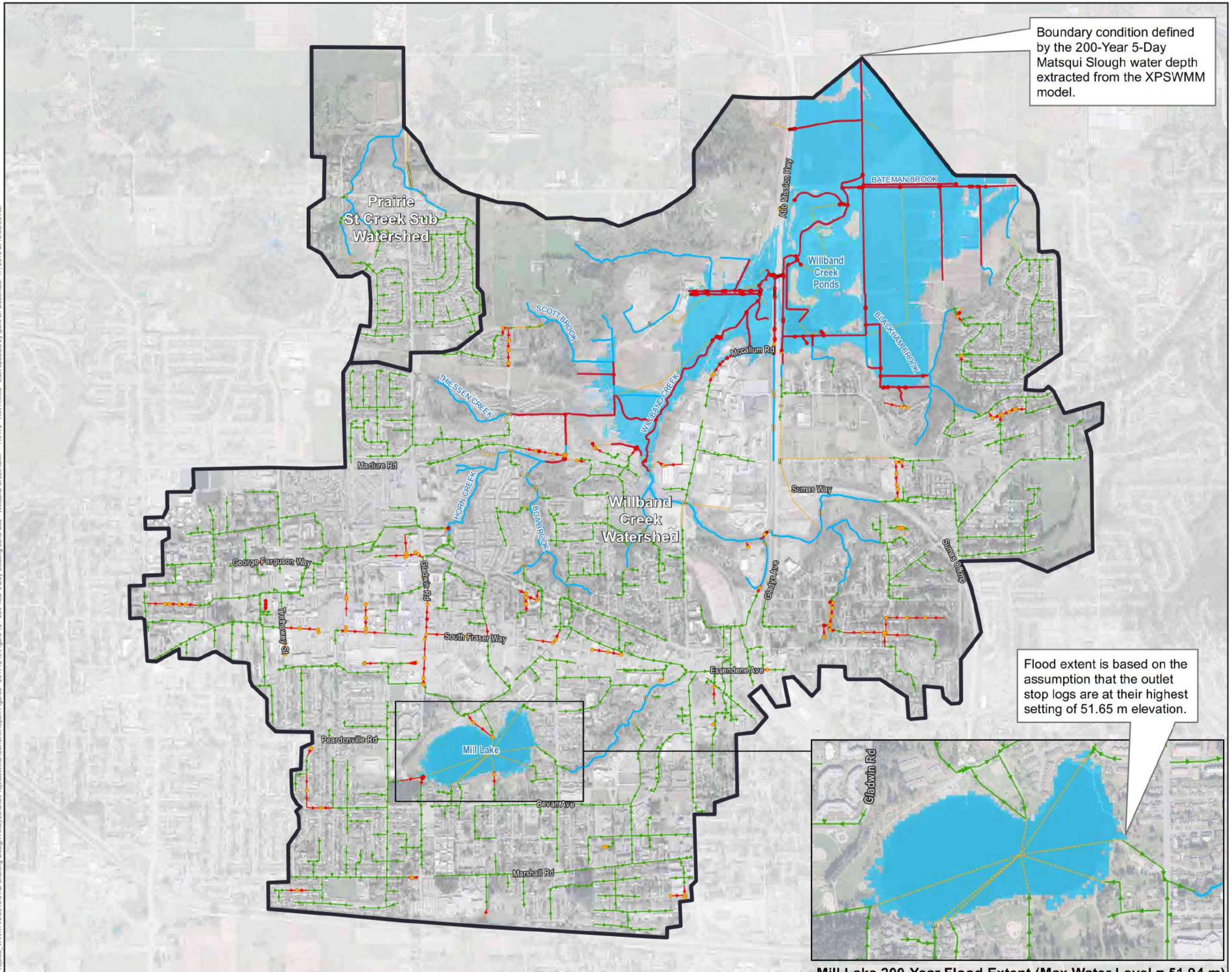
FIGURE 6.7



Mill Lake 200-Year Flood Extent (Max Water Level = 51.94 m)

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

200-Year, 5-Day
System Performance
(Existing Land Use)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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FIGURE 6.8

7 EXISTING CONDITION SUMMARY

Based on the preceding sections, the following summary statements are made to describe the existing systems.

1 Both aquatic and terrestrial habitats have been significantly impacted by past development and watercourse encroachment. Overall, the watershed health is deemed to be poor.

2 Despite the overall assessment noted in item 1 above, there are some local cases where aquatic and riparian health is considered fair; including in Horn Creek, Boa Brook, and Thiessen Creek. Ironically, Horn Creek has also been identified as having the largest number of bank erosion sites.

3 Erosion in Horn Creek, Boa Brook and Prairie Street Creek persist despite some instream repairs having been completed in Horn Creek. While source control through redevelopment provide an opportunity to improve the situation, the timeline with that approach is expected to be long, therefore the City will likely need to intervene with communal solutions more near term.

4 Water quality is considered somewhat poor in the lowlands and in Mill Lake. In the case of lowland watercourses, mainly a result of urban runoff and likely insufficient water circulation and lack of riparian cover. In the case of Mill Lake, this is mainly attributed to stratification and insufficient water circulation.

5 There is good infiltration potential for the majority of the upland study area; this opens a strong opportunity to apply low impact development techniques as redevelopment occurs.

6 Modeling indicates that portions of the lowland system do not meet current conveyance criteria. System performance is hampered even further due to downstream effects of the broader Matsqui Prairie system.

7 Generally, the performance of the storm sewer network appears to be reasonably good against established criteria; however, under the 100-year (major) event, the potential of flooding is widespread.

Seven of 14 public upland detention facilities modeled (excluding Mill Lake and Willband Creek Park ponds) do not appear to be meeting criteria.

Recommendations and actions to address these issues are discussion in following sections.

PART 2 – POTENTIAL FUTURE CONDITIONS

8 FUTURE CONDITIONS

8.1 Future Land Use Parameters

Based on the City's 2016 Official Community Plan (OCP), the City has developed a "Build_35" GIS dataset, which represents a portion lands that may redevelopment by year 2035. Through consultation with the City, this "Build_35" data set has been applied to the analysis rather than the OCP at full build out. The reason being that the timeline for complete redevelopment is considered too far out, and it's predicted that climate change will have a more significant impact on system performance than redevelopment.

To represent the potential effects of future land use changes, three primary parameters were adjusted; the total impervious fraction, the portion of the impervious fraction that is redirected to ground, and whether engineered controls are applied. Such parameters have been assigned for each land use type as described in Table 8.1 below.

8.2 Controls

For low density land uses where only rock-pits or drywells are applied, control is represented in the SWMM model by routing impervious area to pervious, however, 95.5 mm of depression storage is added to the pervious area to reflect the City's requirement to retain the 1:10 year, 24 hour rainfall volume.

For those land uses where on-site engineered controls are applied, controls were represented in the SWMM model using a "Rain Barrel" LID (low impact development) tool directly within the software. While full retention is desired, criteria permits storage and release to a maximum of 5 L/s/ha for the 1:10 year event at a minimum. The "Rain Barrel" LID tool in SWMM offers the best representation of this. It also permits analysis of this control on a lot-by-lot basis. Within the scope of this ISMP, the SWMM model does not permit the ability to first route impervious surface runoff to the pervious area prior to "Rain Barrel" controls. As such, the model is generally representative, but conservative from what the City seeks from developers.

Table 8.1 - Future Condition Land Use Parameters

Willband OCP Land Use Designations	Future Condition Total Impervious Area (%)	Portion of Total Impervious Area Redirected to Ground for Infiltration	Remaining Impervious Area Directly Connected to Control System or Storm Sewer	Are On-site Engineered Detention Control Applied?
FN Reserve	Maintain Existing	Maintain Existing	Maintain Existing	N
City Centre	90	50	50	Y
Urban Centre	90	50	50	Y
Neighbourhood Centre	90	50	50	Y
Urban 1 - Midrise	80	50	50	Y
Urban 2 - Ground	80	50	50	Y
Urban 3 - Infill	65	90	10	N
Urban 4 - Detached	60	90	10	N
Urban Large Lot	40	90	10	N
Suburban	40	90	10	N
Secondary Commercial	90	50	50	Y
Regional Commercial	90	50	50	Y
General Industrial	90	0	100	Y
High Impact Industrial	90	0	100	Y
Hospital	90	50	50	Y
Institutional Complex	90	50	50	Y
Institutional	90	50	50	Y
Agricultural	20	100	0	N
Open Space	Maintain Existing	Maintain Existing	Maintain Existing	N

8.3 Precipitation Event Sub-Scenarios

System performance is assessed for the same historic storms as described in previous sections for the Existing Condition, however, the design precipitation events are scaled up 10% to represent potential climate change impacts. This scaling factor was recommended by Kerr Wood Leidal (KWL) to be consistent with other analysis conducted in the City.

The future conditions have been analysed for three single event return periods, namely:

- 1:10 year (range of storm durations up to 24 hours)
- 1:100 year (range of storm durations up to 24 hours)
- 1:200 year 5 day event which is for agricultural areas only
- Continuous simulation

8.4 Land Use Sub-Scenarios

At this stage, many different land use sub-scenarios have been created to test the outcomes of different level of controls and influence of potential climate change, results of which are compared against existing conditions.

The following land use sub-scenarios have been created:

- Future Land Use (Build_35) with no controls and historic precipitation.
- Future Land Use (Build_35) with controls and historic precipitation.
- Future Land Use (Build_35) with no controls, but climate change precipitation.
- Future Land Use (Build_35) with controls and climate change precipitation.

8.5 Summary of System Performance

Inserted below are **Figures 8.1** through **Figure 8.12**; a collection of figures representing the outcomes of the above noted sub-scenarios in various combinations, with a summary statement provided in the sub-sections below:

8.5.1 Future Land Use (No Controls)

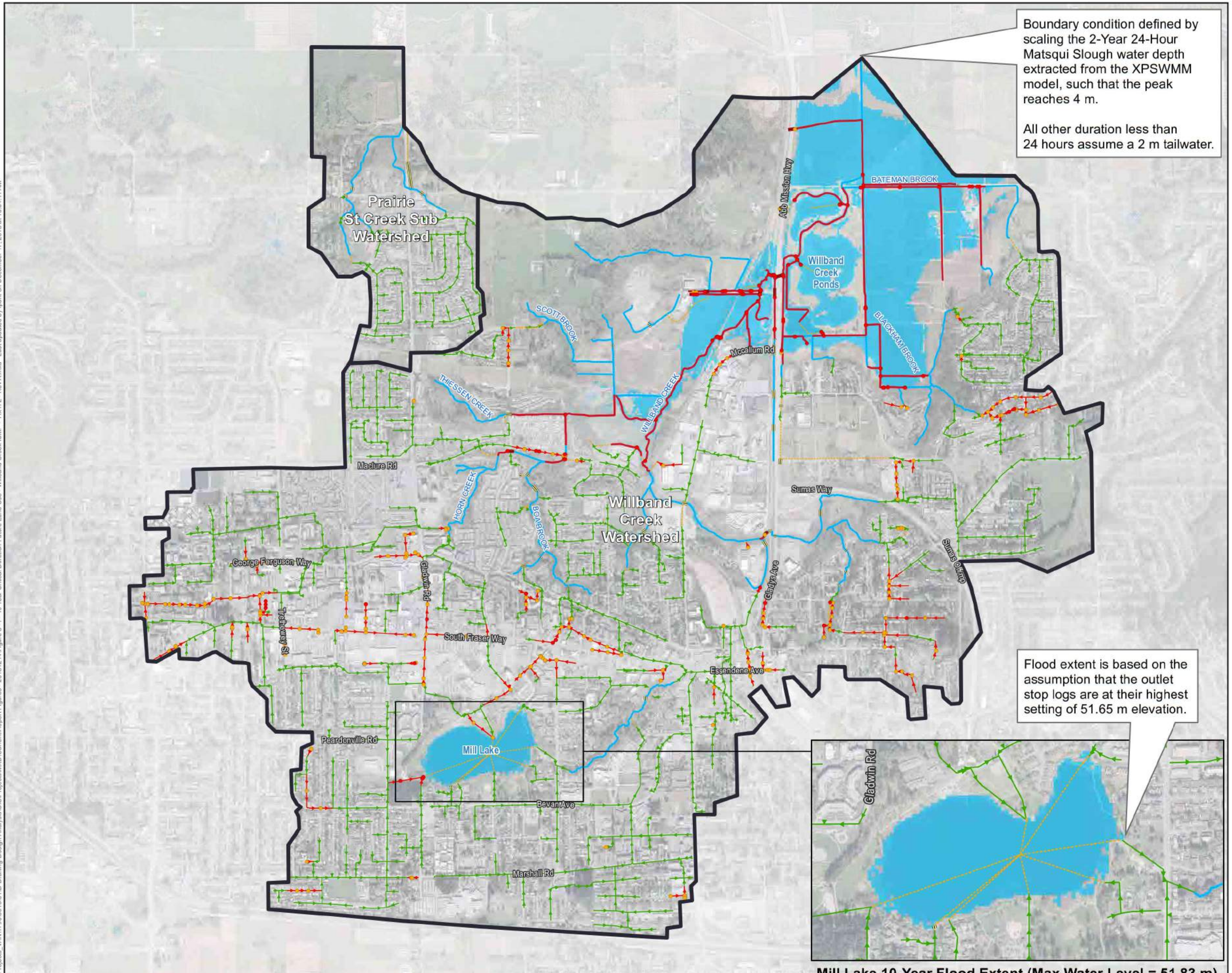
Regardless of what precipitation event is considered, at a watershed scale the extent of development in the Build_35 layer does not result is a dramatic change in system performance, but some local systems in vicinity of the land use change do worsen if development occurs in absence of any controls.

8.5.2 Future Land Use (With Controls)

For all design events, analysis shows the application of controls to Build_35 properties can provide a significant reduction in system surcharging; not only in mitigating the impacts of redevelopment but improving over existing conditions. This is particularly the case in the higher density areas in the central and southern portions of the watershed. This affirms that the application of controls through redevelopment provides an opportunity to improve over current conditions. Not only will this reduce flood risk, but it will improve overall watershed health.

8.5.3 Future Land Use (No Controls with Climate Change)

As one would expect, scaling design flows up by 10% to represent climate change, along with developing without controls, results in a noticeable increase in system surcharging. This represents the potential worst case and conservative scenario. For comparison, systems were once again assessed against established criteria,



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

10-Year, Critical Duration System Performance (Future Land Use)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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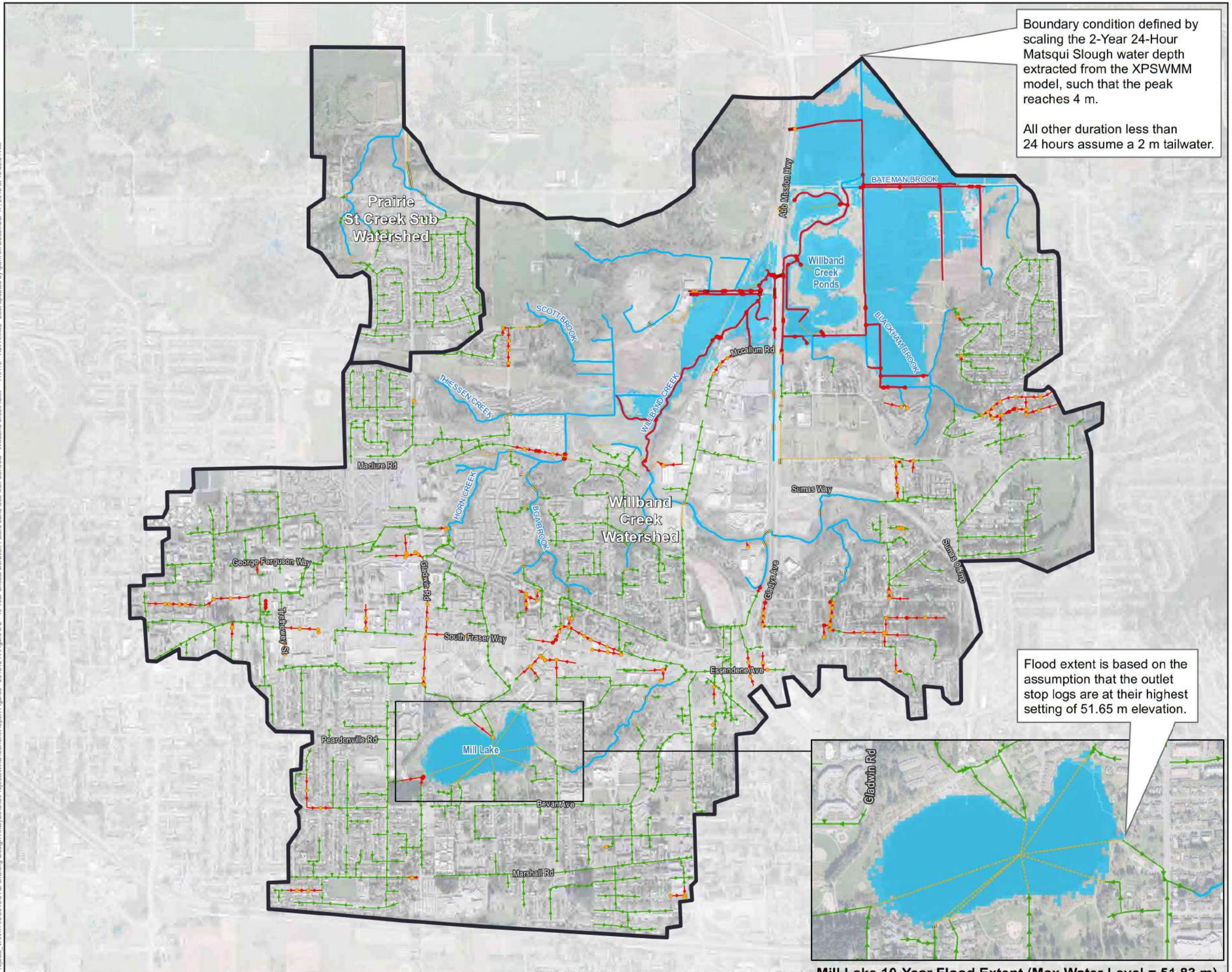
FIGURE 8.1



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

10-Year, Critical Duration System Performance (Future Land Use With Controls)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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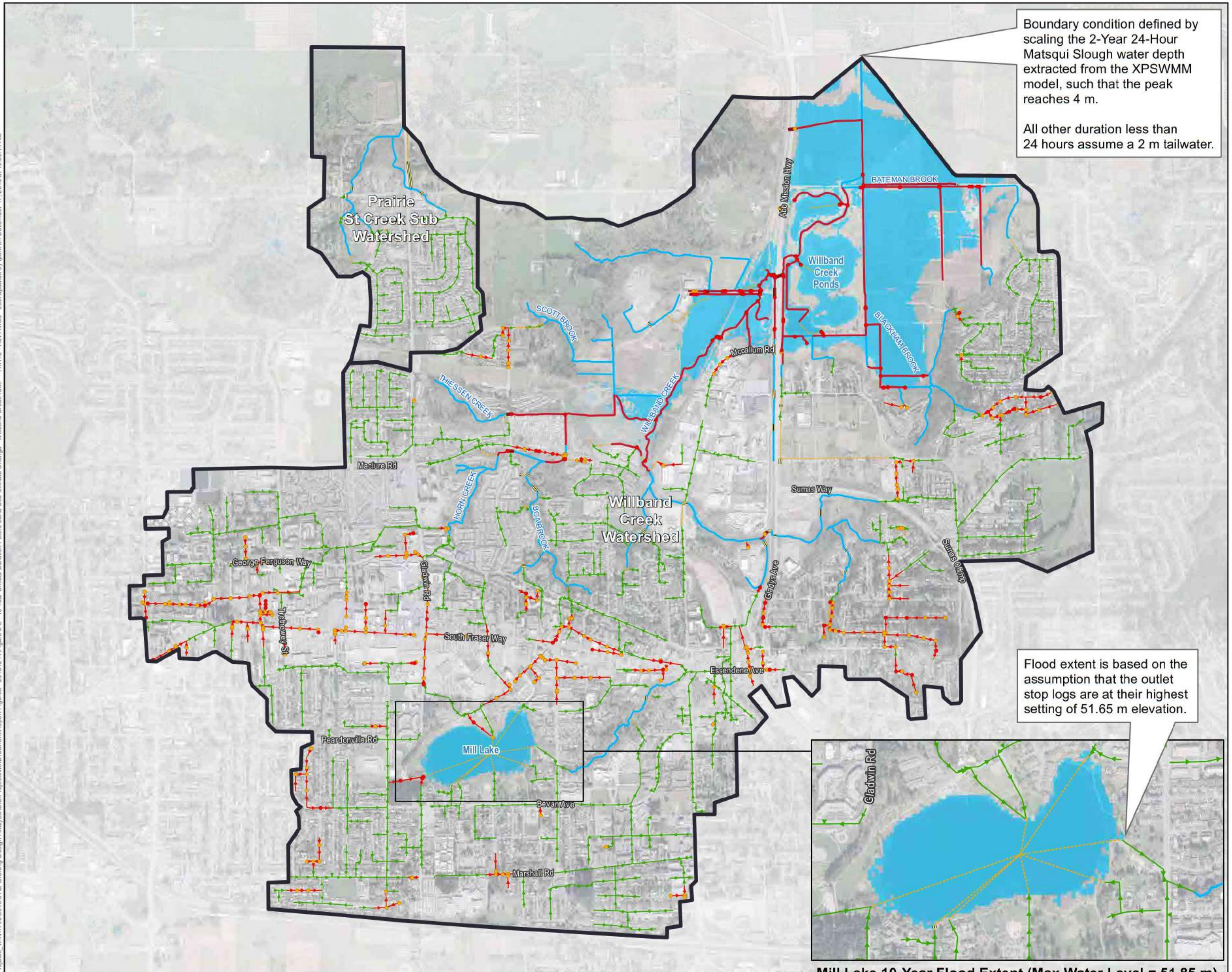
FIGURE 8.2



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

10-Year, Critical Duration System Performance (Future Land Use - Climate Change)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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Metres

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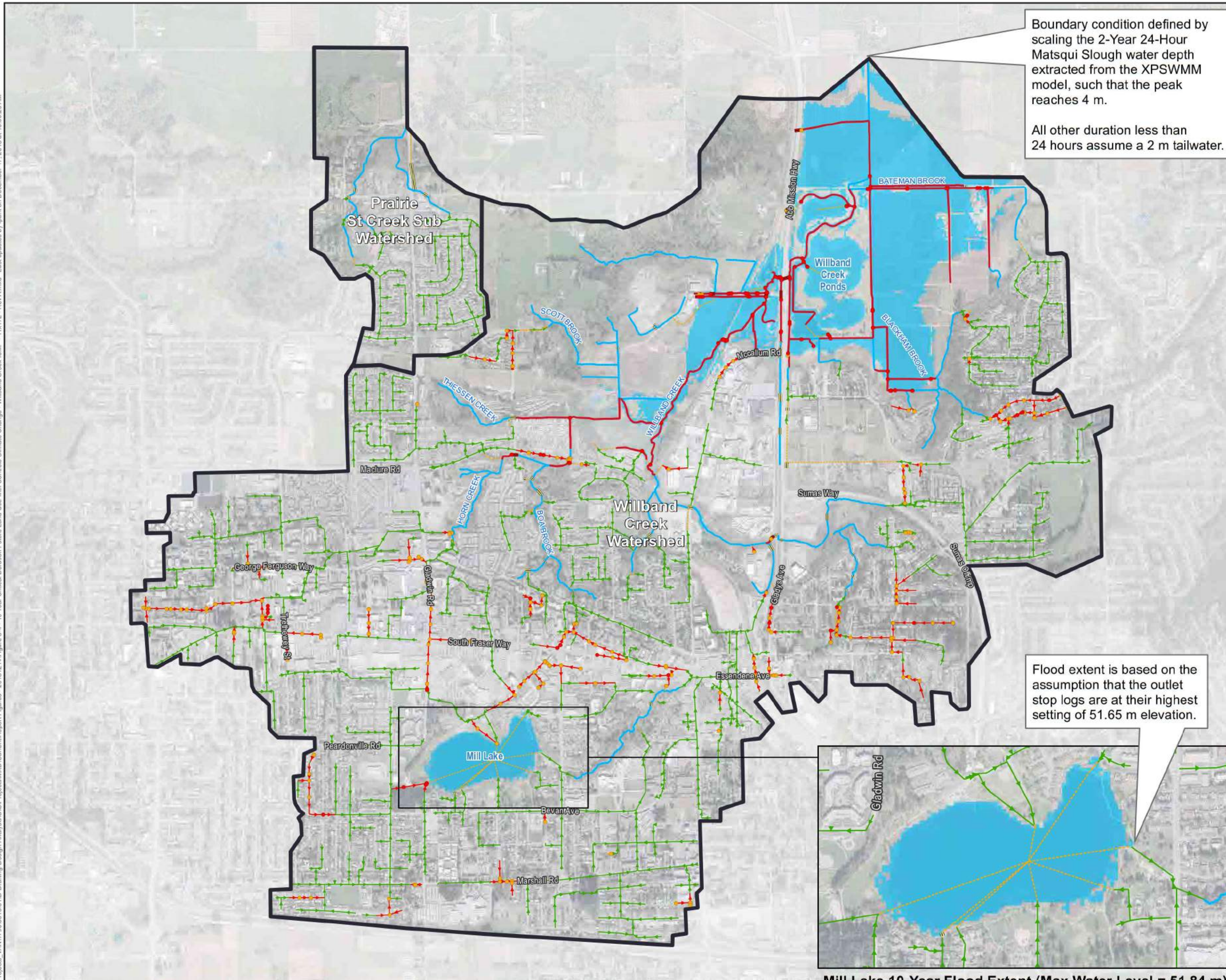
FIGURE 8.3

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8-3 - 10 Year Critical Duration Future Land Use Climate Change - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:06:14 AM



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

10-Year, Critical Duration System Performance (Future Land Use With Controls - Climate Change)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

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Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

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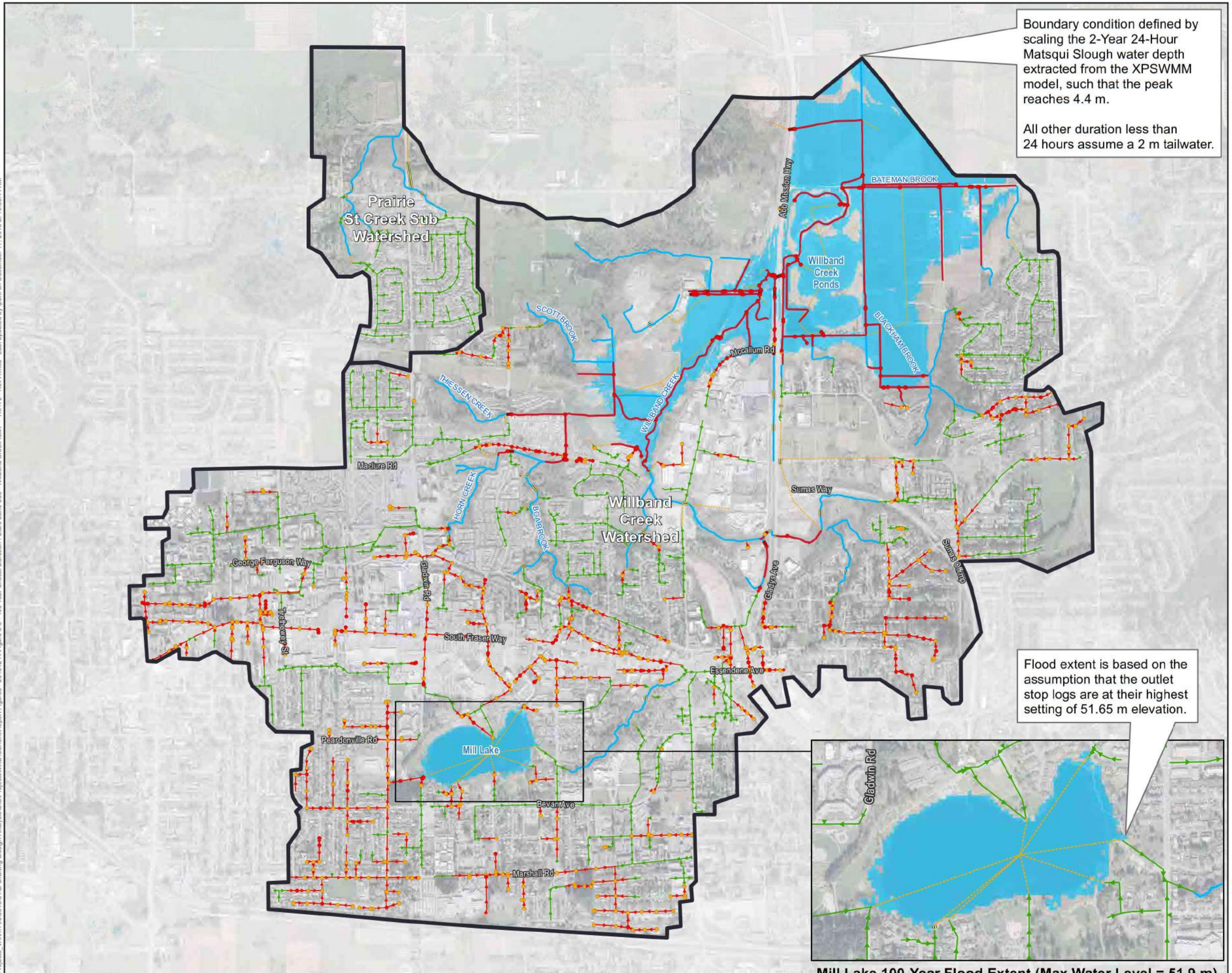
FIGURE 8.4



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Willband Creek Integrated Storm Water Management Plan

100-Year, Critical Duration System Performance (Future Land Use)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

North Vancouver, Coquitlam, Vancouver, Burnaby, Richmond, Chilliwack, Surrey, Langley, Delta, White Rock, Abbotsford

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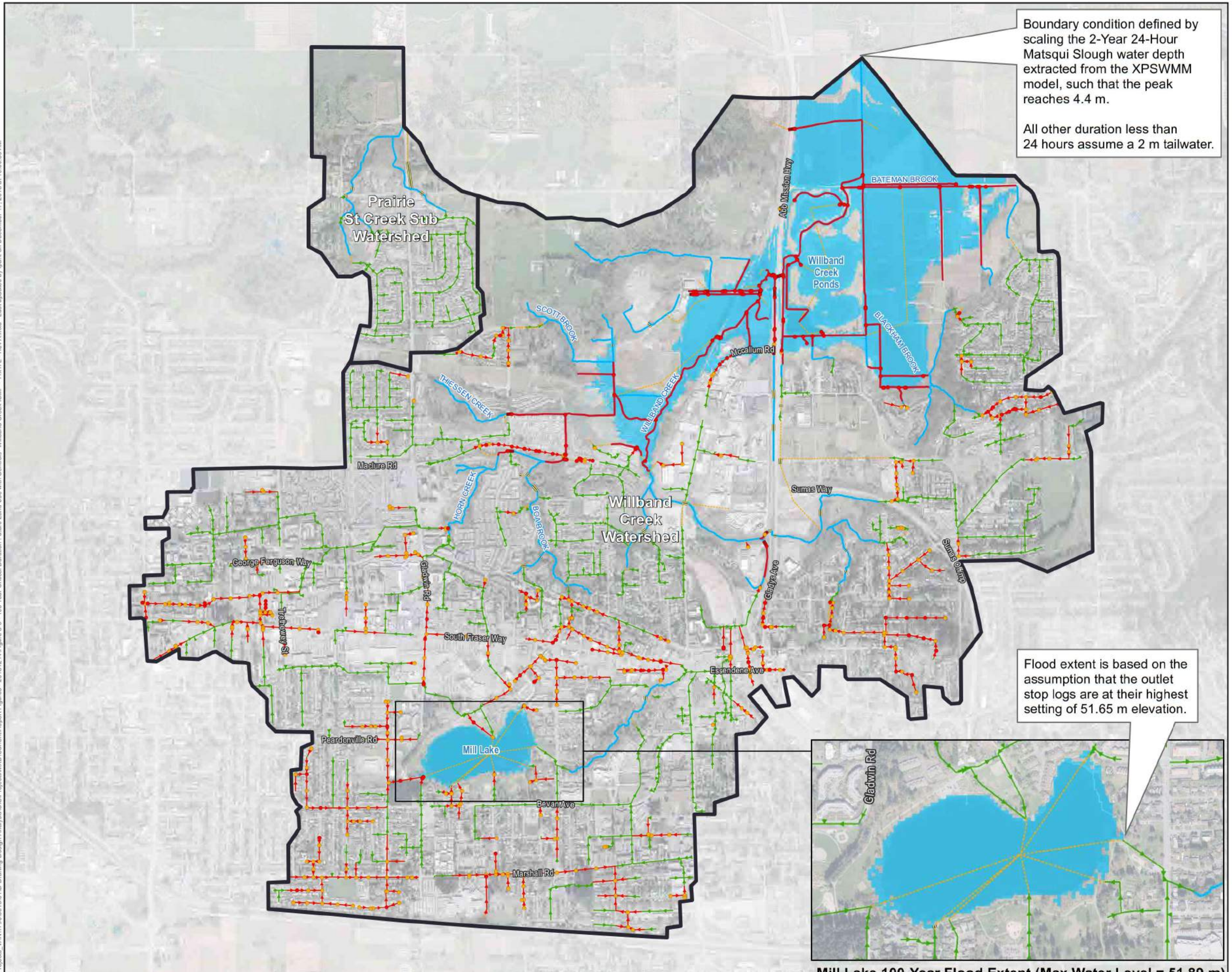
FIGURE 8.5

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8.5 - 100 Year Critical Duration Future Land Use - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:06:41 AM



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

100-Year, Critical Duration System Performance (Future Land Use With Controls)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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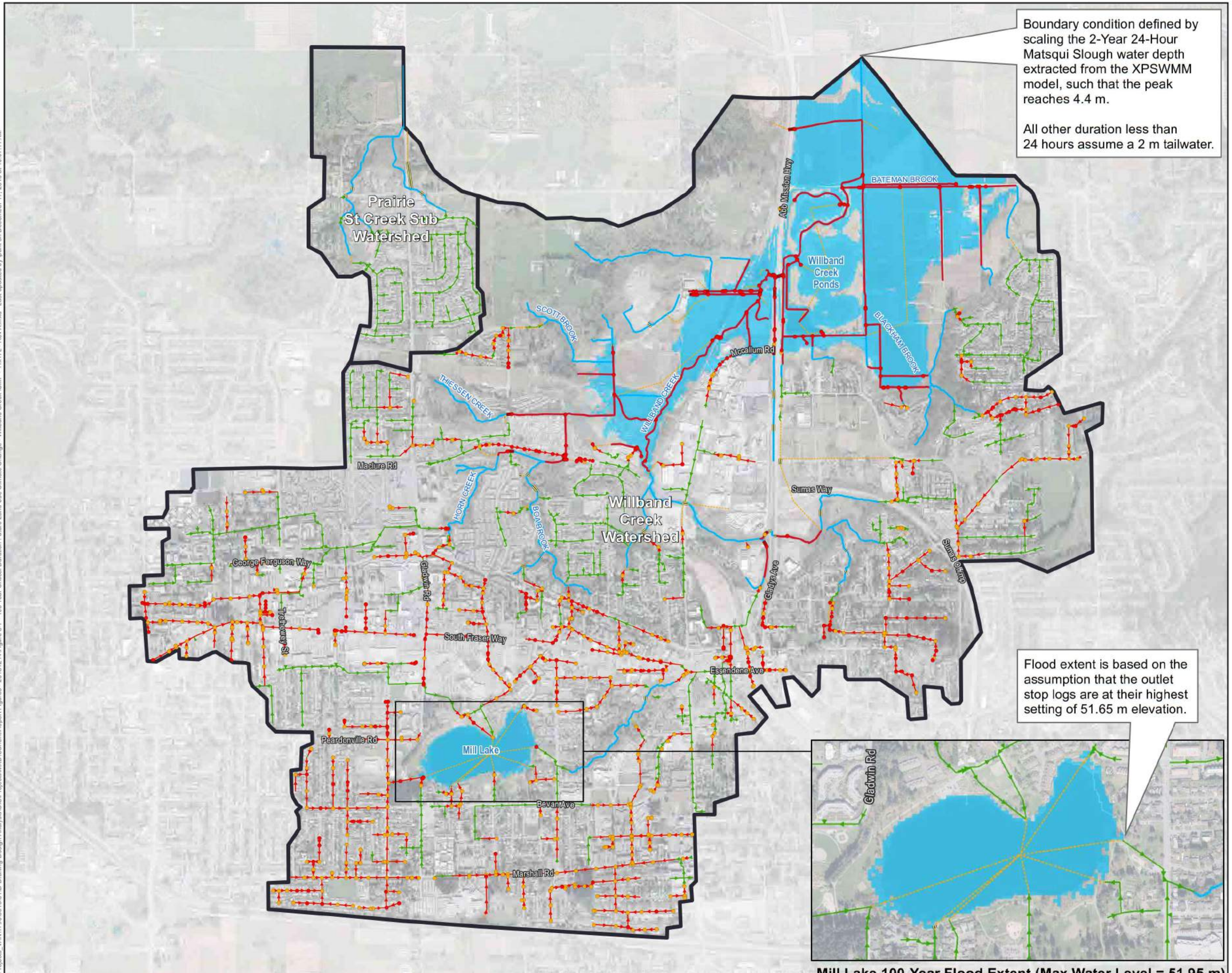
FIGURE 8.6



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Willband Creek
Integrated Storm Water
Management Plan

100-Year, Critical Duration System Performance (Future Land Use - Climate Change)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
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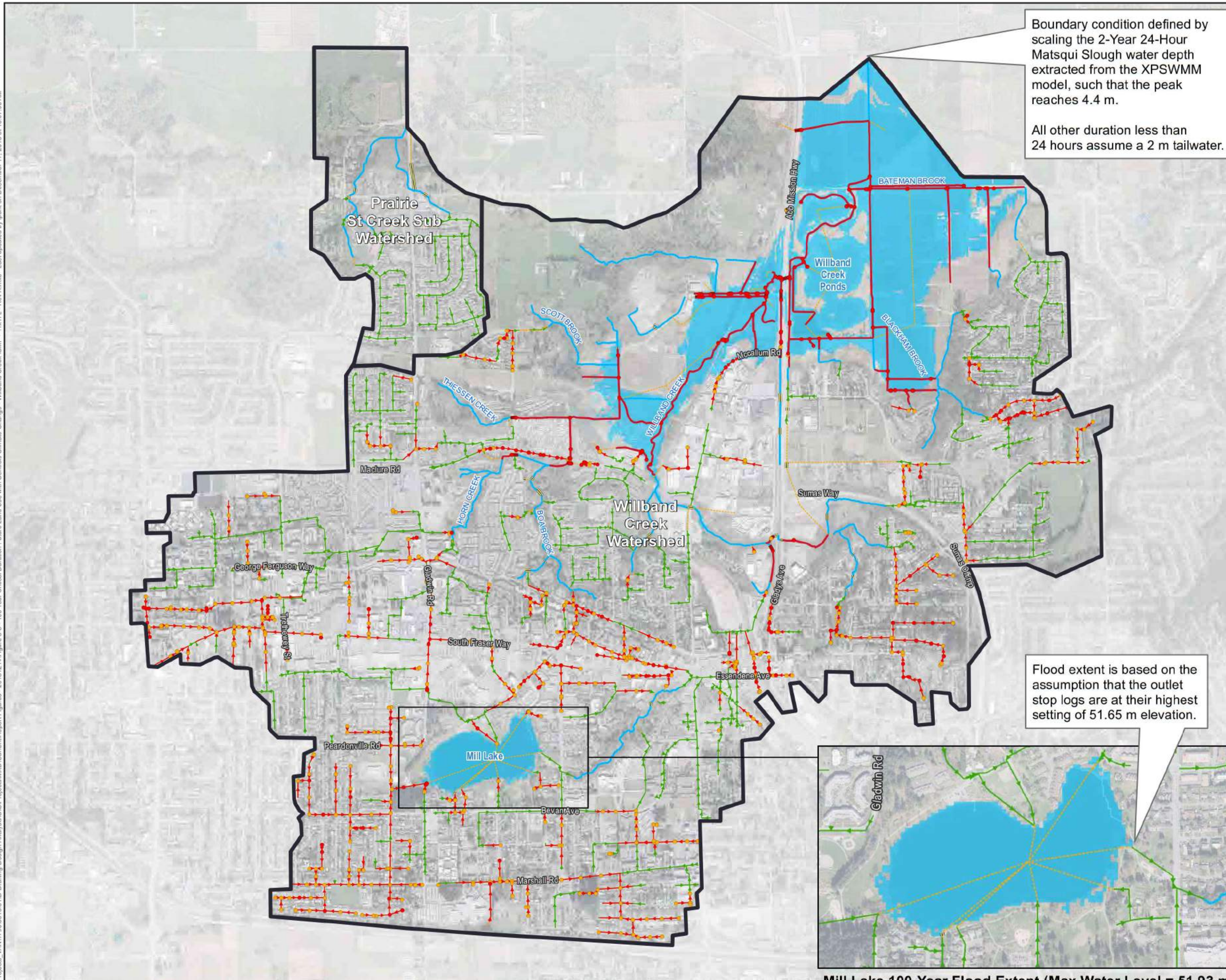
FIGURE 8.7

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8-7 - 100 Year Critical Duration Future Land Use Climate Change - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:07:11 AM



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Willband Creek Integrated Storm Water Management Plan

100-Year, Critical Duration System Performance (Future Land Use With Controls - Climate Change)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

North Vancouver, Vancouver, Burnaby, Coquitlam, Richmond, Delta, Surrey, Langley, White Rock, Abbotsford, Chilliwack

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 145 290 580 870
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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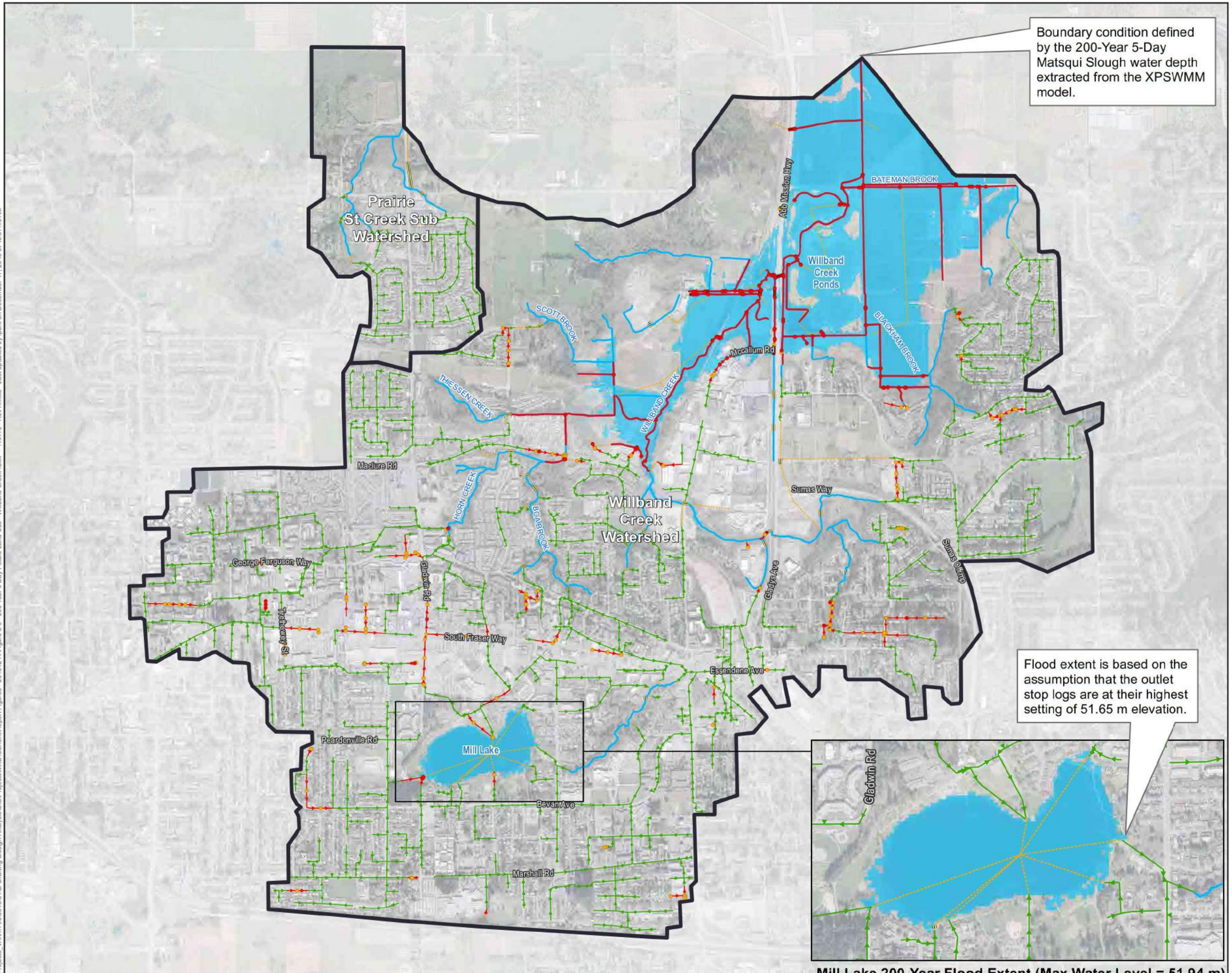
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

FIGURE 8.8

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8-8 - 100 Year Critical Duration Future Land Use with Controls Climate Change - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:07:30 AM



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Willband Creek Integrated Storm Water Management Plan

200-Year, 5-Day System Performance (Future Land Use)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

North Vancouver, Coquitlam, Vancouver, Burnaby, Richmond, Delta, Surrey, Langley, White Rock, Abbotsford, Chilliwack

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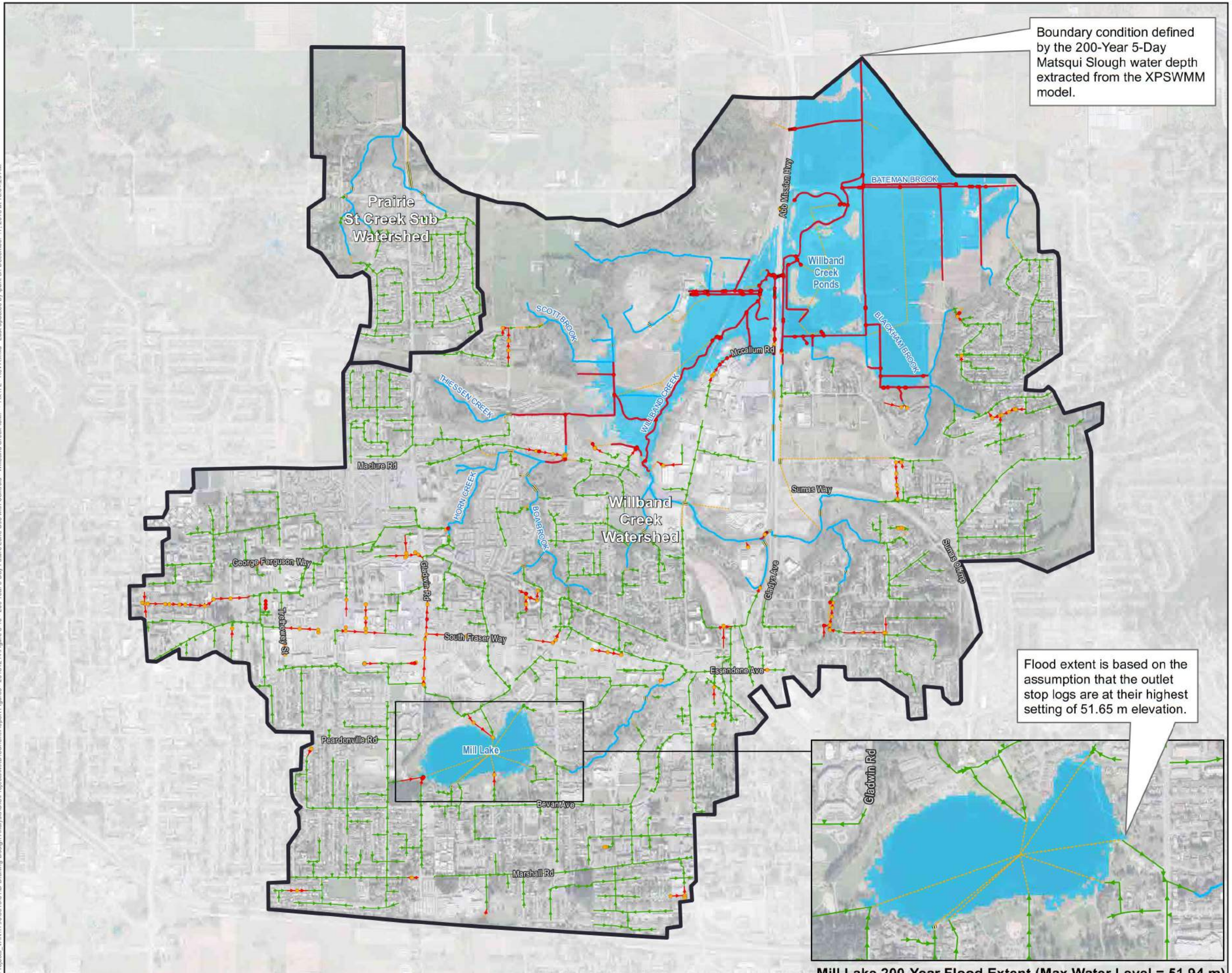
Date:	2018 / 12 / 17

FIGURE 8.9



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

200-Year, 5-Day
System Performance
(Future Land Use With Controls)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:
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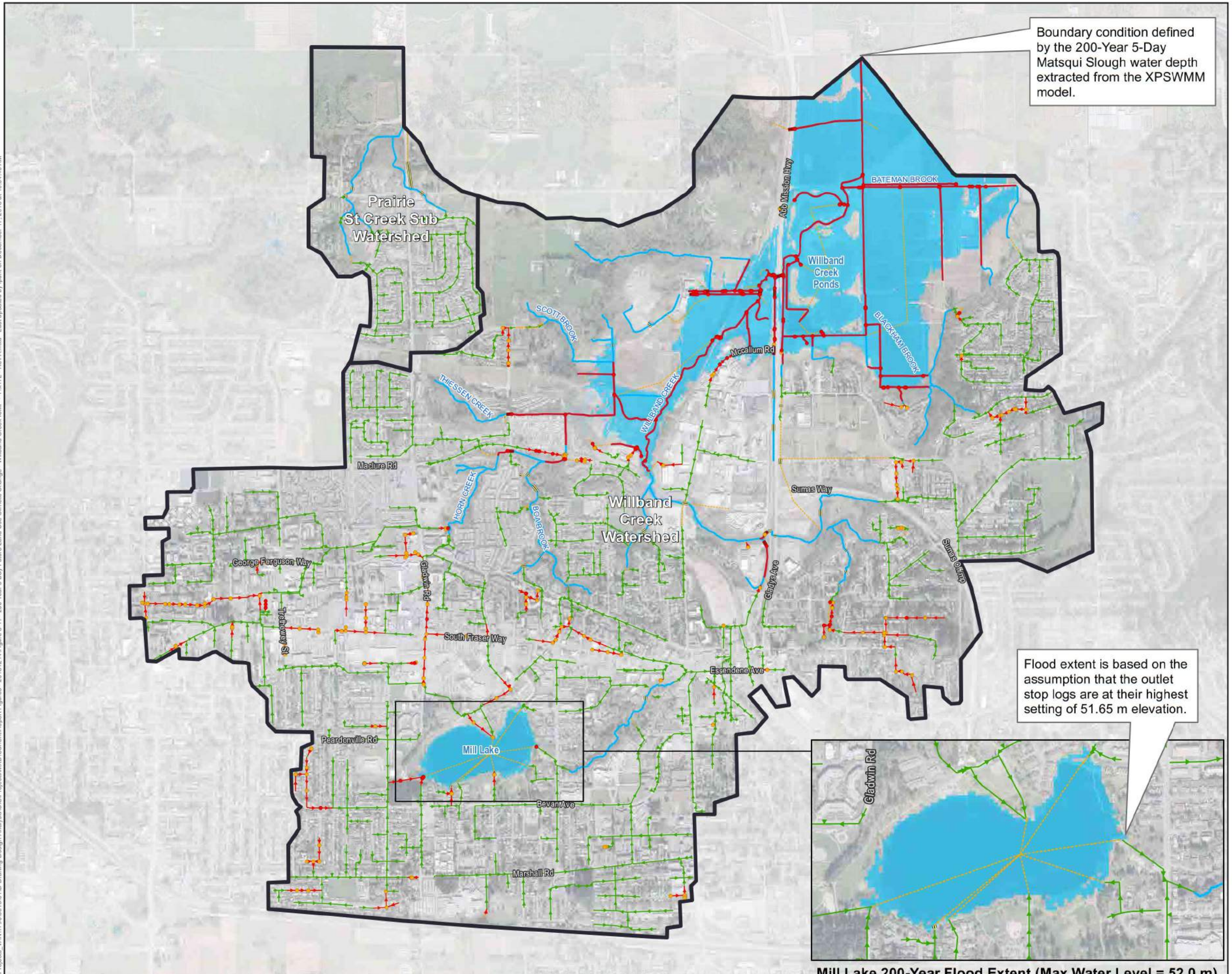
FIGURE 8.10



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

200-Year, 5-Day System Performance (Future Land Use - Climate Change)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

North Vancouver, Coquitlam, Vancouver, Burnaby, Richmond, Delta, Surrey, Langley, White Rock, Abbotsford, Chilliwack

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0 145 290 580 870
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:
Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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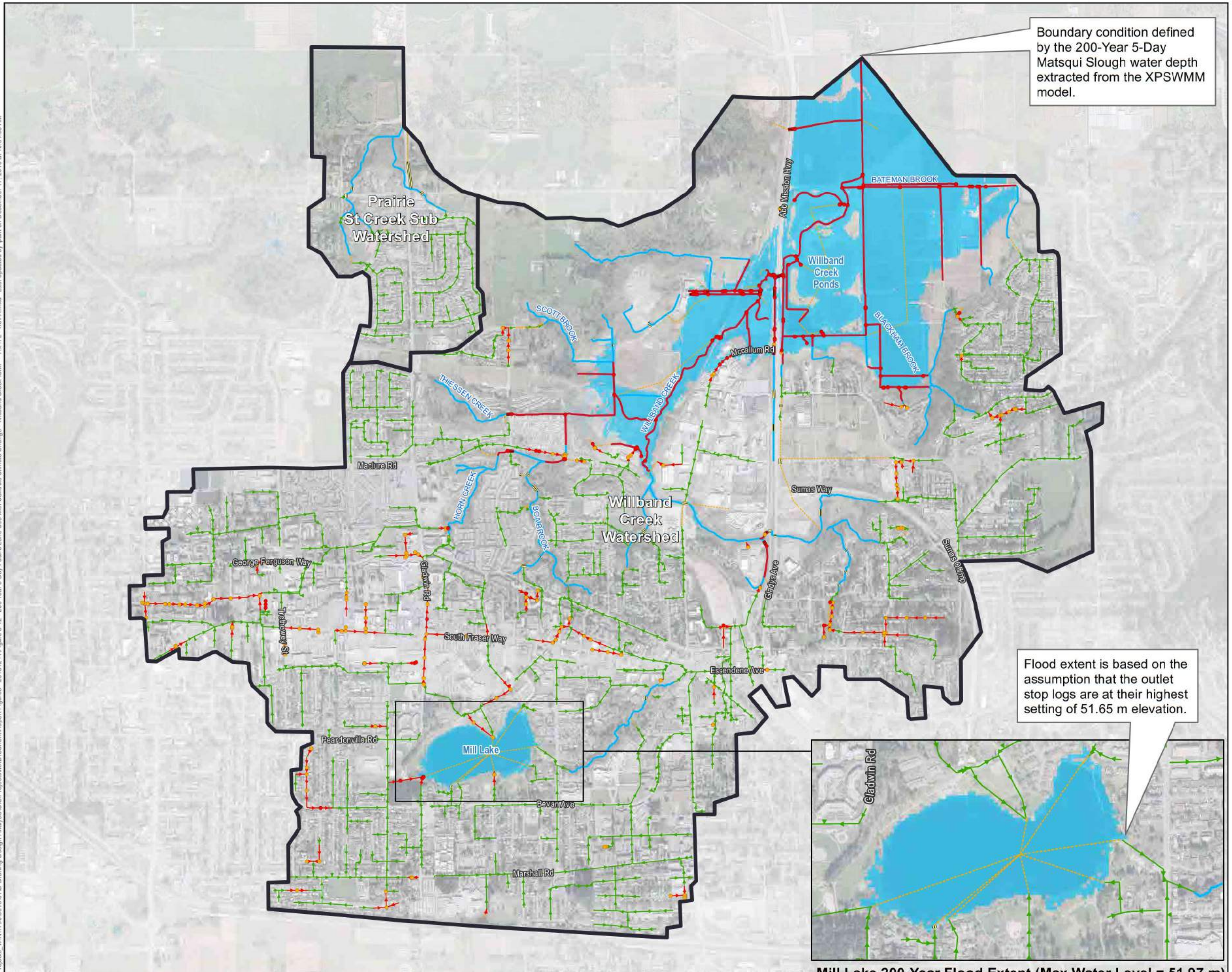
FIGURE 8.11



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

200-Year, 5-Day System Performance (Future Land Use With Controls - Climate Change)

- Willband Creek Watershed
- Potential Flood (HGL > Ground Surface)
- Potential Surcharge (HGL > Highest Crown)
- Potential Surcharge of Storm Sewer
- Potential Surcharge of Culvert
- Potential Breach of Creek
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Lowland and Mill Lake Flood Extent

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0 145 290 580 870
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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URBAN systems

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Revision:	A
Date:	2018 / 12 / 17

FIGURE 8.12

results of which are presented in **Figures 8.13** to **Figure 8.16**. When compared against Figures 6.4 to Figure 6.7 (existing condition), the following observations are made.

Storm Sewers Assessed Against Established Criteria – A very modest increase in sewer failures in the downtown area.

Culverts Assessed Against Established Criteria – Two lowland culverts are not meeting 10 Year criteria in the future condition that appeared to meet criteria in the existing condition. This may be a result of assigning the downstream boundary condition and not the culvert size directly.

Detention Ponds Assessed Against Established Criteria – No observed changes from existing conditions.

Creeks Assessed Against Established Criteria – No observed changes to the lowland systems, but one small reach in lower Horn Creek is flagged for the future conditions that did not appear for the existing condition.

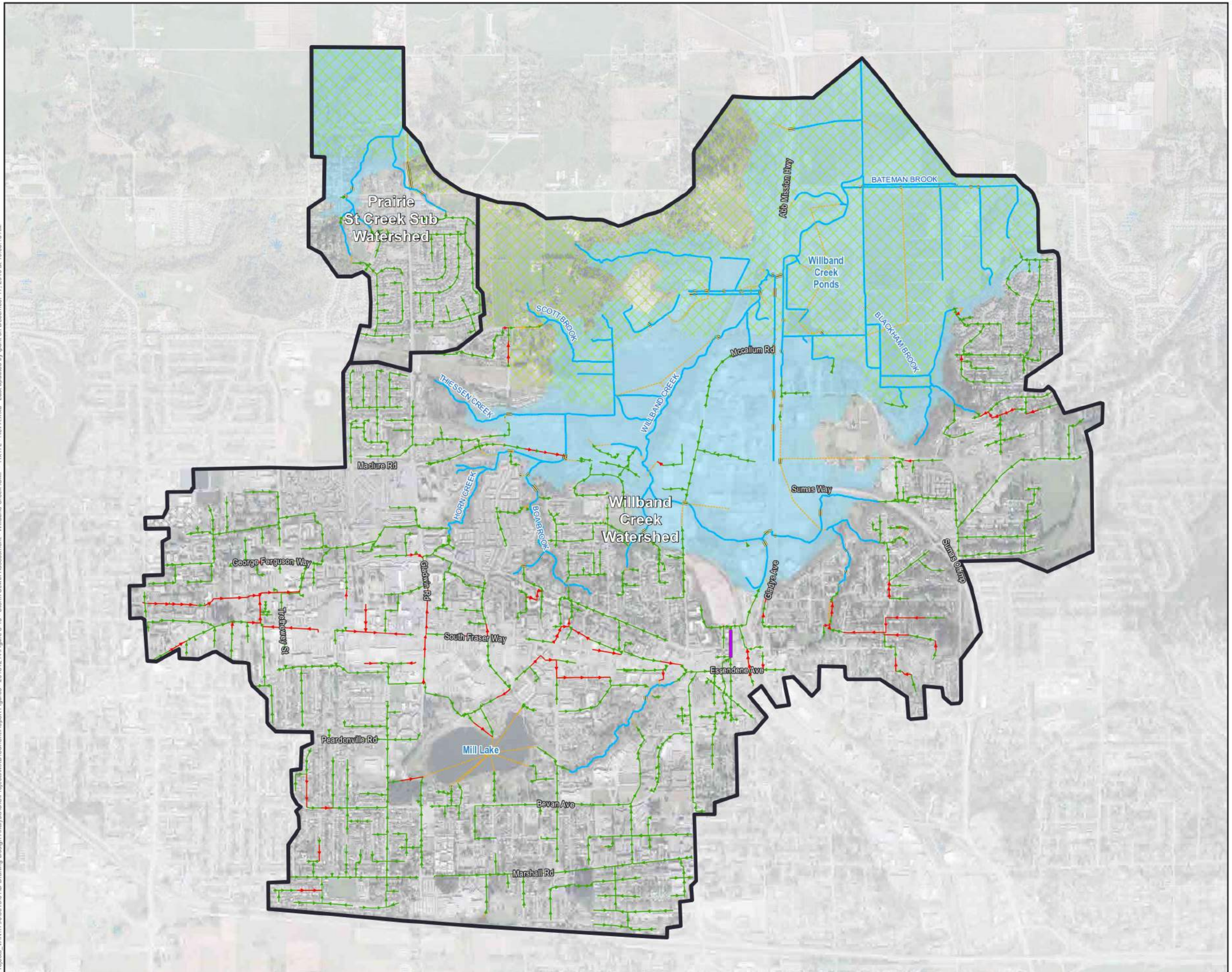
In general, the most conservative future condition scenario does not appear to have dramatic impact on the ability of infrastructure to meet established criteria.

8.5.4 Future Land Use (Controls and Climate Change)

With consideration for climate change, system performance tends to worsen where no redevelopment is occurring. But in areas that are to redevelop, the application of controls demonstrates the ability to more than compensate for the negative effects of climate change; showing in some area's performance better than the existing condition.

8.5.5 Continuous Simulation and Erosion Potential Assessment

The Stream Erosion Index (SEI) method compares results from various land use, stormwater management and climate scenarios against a baseline, often a "pre-development condition" but, in this case, the existing condition since predevelopment has not been assessed. This method has been applied to three natural channel reaches to assess the potential change in erosion risk with various future condition scenarios. The sites are numbered by their conduit ID as applied in the hydraulic model, located and highlighted blue in **Figures 8.17** to **Figure 8.19** below.



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Storm Sewer Assessed Against Established Criteria (Future Land Use - Climate Change)

No Controls

- Willband Creek Watershed
- Major Main (100-Year) Surcharge 0.3 m over Crown for > 15 min
- Minor Main (10-Year) Surcharge 0.3 m over Crown for > 5-min
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

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0 145 290 580 870
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

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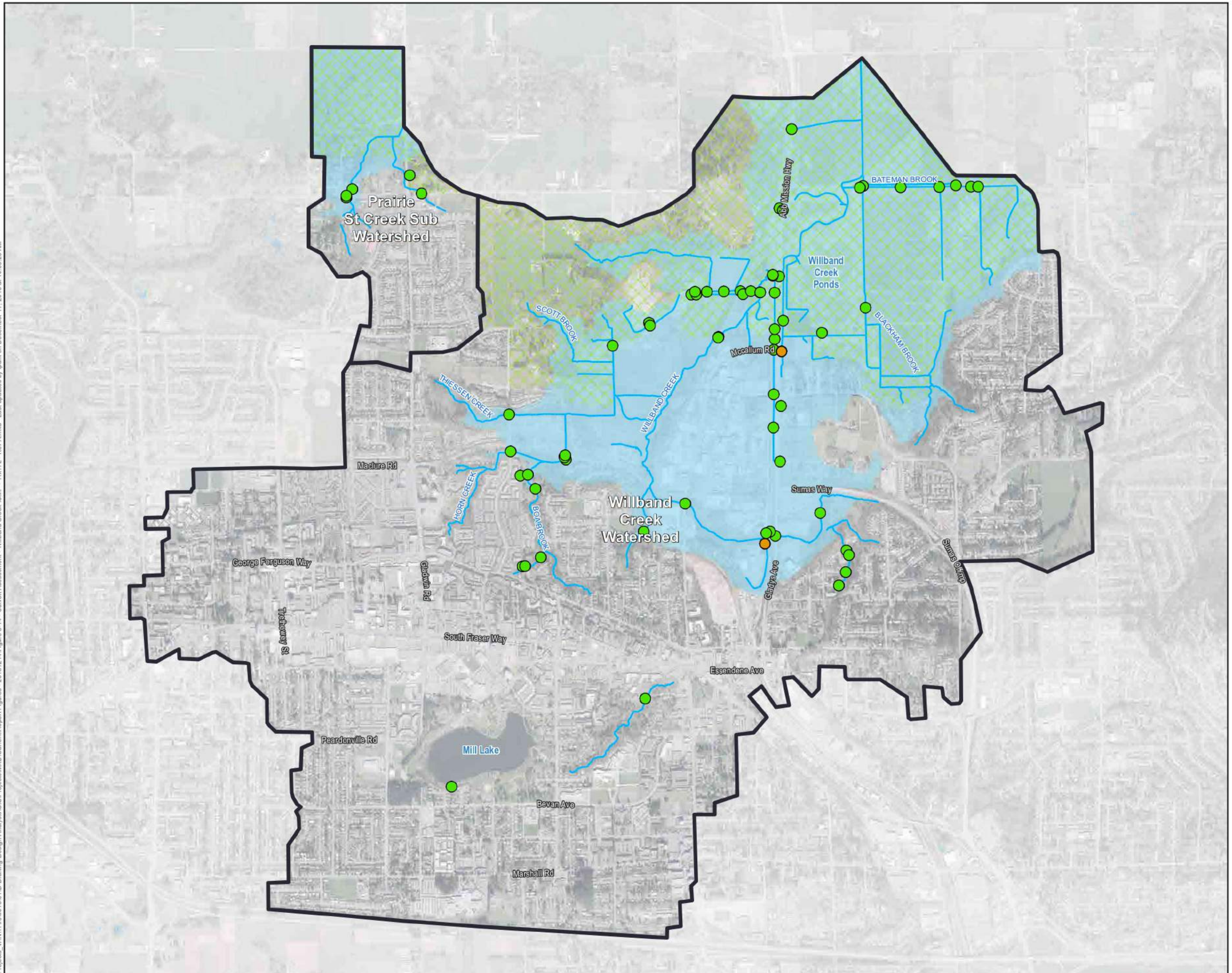
FIGURE 8.13

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\Report Figures - 20181214\Figure 8-13 - Storm Sewer Assessment - Willband Creek ISMP - 11x17L - Rev A.mxd Last updated by lpunt on December 17, 2018 at 10:05:10 AM



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Culverts Assessed Against Established Criteria (Future Land Use - Climate Change) No Controls

Willband Creek Watershed
Creek
Agricultural Land Reserve
Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

Culvert Assessment

Meets Criteria
Upland Culvert (100-Year) Surcharge > 50% of Culvert Height above the Crown
Lowland Culvert (10-Year) Surcharge > 50% of Culvert Height above the Crown

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0 145 290 580 870
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N
Scale: 1:22,000

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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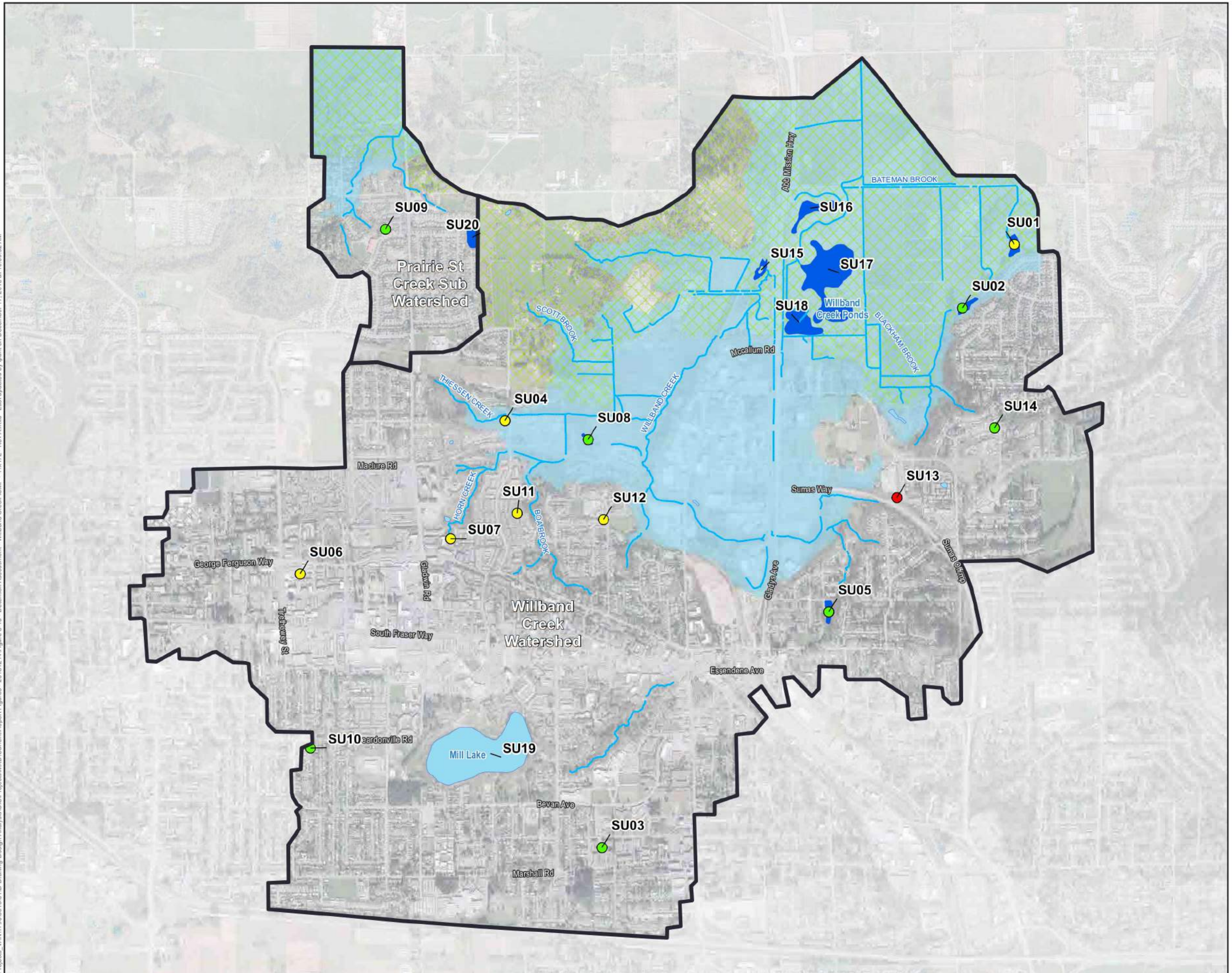
URBAN systems

FIGURE 8.14



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Detention Facilities Assessed Against Established Criteria (Future Land Use - Climate Change)

No Controls

- Willband Creek Watershed
- Detention Facility
- Lake
- Creek
- Agricultural Land Reserve
- Lowland Region (Matsqui Drainage Study Lowland Cell Boundary)

Detention Assessment

- Meets Criteria
- Outlet Modification Required to Meet Criteria
- Insufficient Storage Volume to Meet Criteria

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0 145 290 580 870
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

Data provided by the City of Abbotsford (2016), Geoadvice (2017), Thurber (2017), Dillon (2017) and Data BC (2016).

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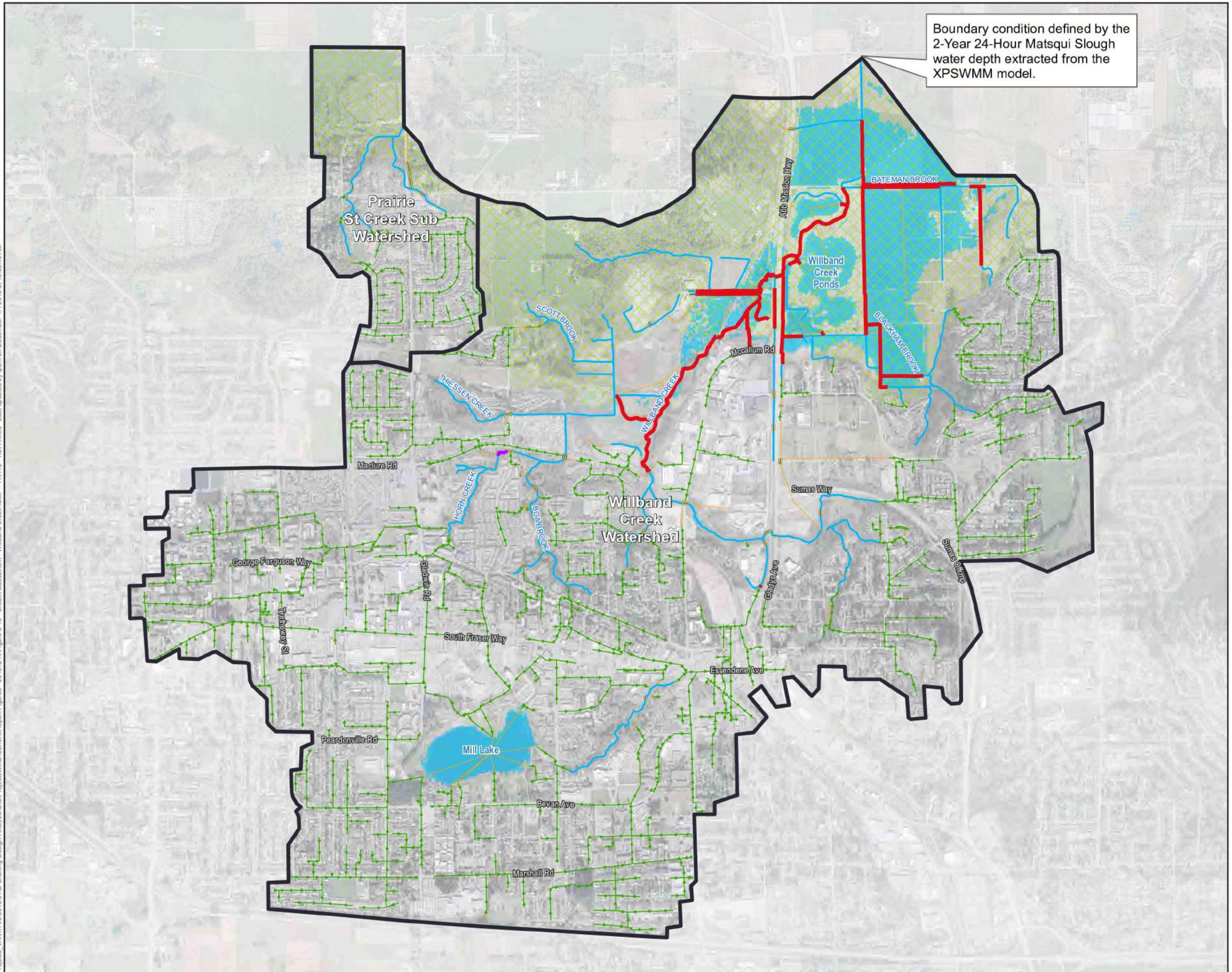
Date:	2018 / 12 / 17

URBAN systems

FIGURE 8.15



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Creeks Assessed Against Established Criteria (Future Land Use - Climate Change)

No Controls

- Willband Creek Watershed
- Conduit Added for Connectivity
- Creek
- Culvert
- Main
- Agricultural Land Reserve
- Lowland and Mill Lake Flood Extent (2-Year, 24-Hour)

Creek Assessment

- Upland Creek (200-Year, 5-Day) Potential Breach of Creek
- Lowland Creek (2-Year, 24-Hour) Potential Breach of Creek

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0 145 290 580 870
Metres

N

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000

Data Sources:

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GeoADVICE

URBAN systems

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Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

FIGURE 8.16

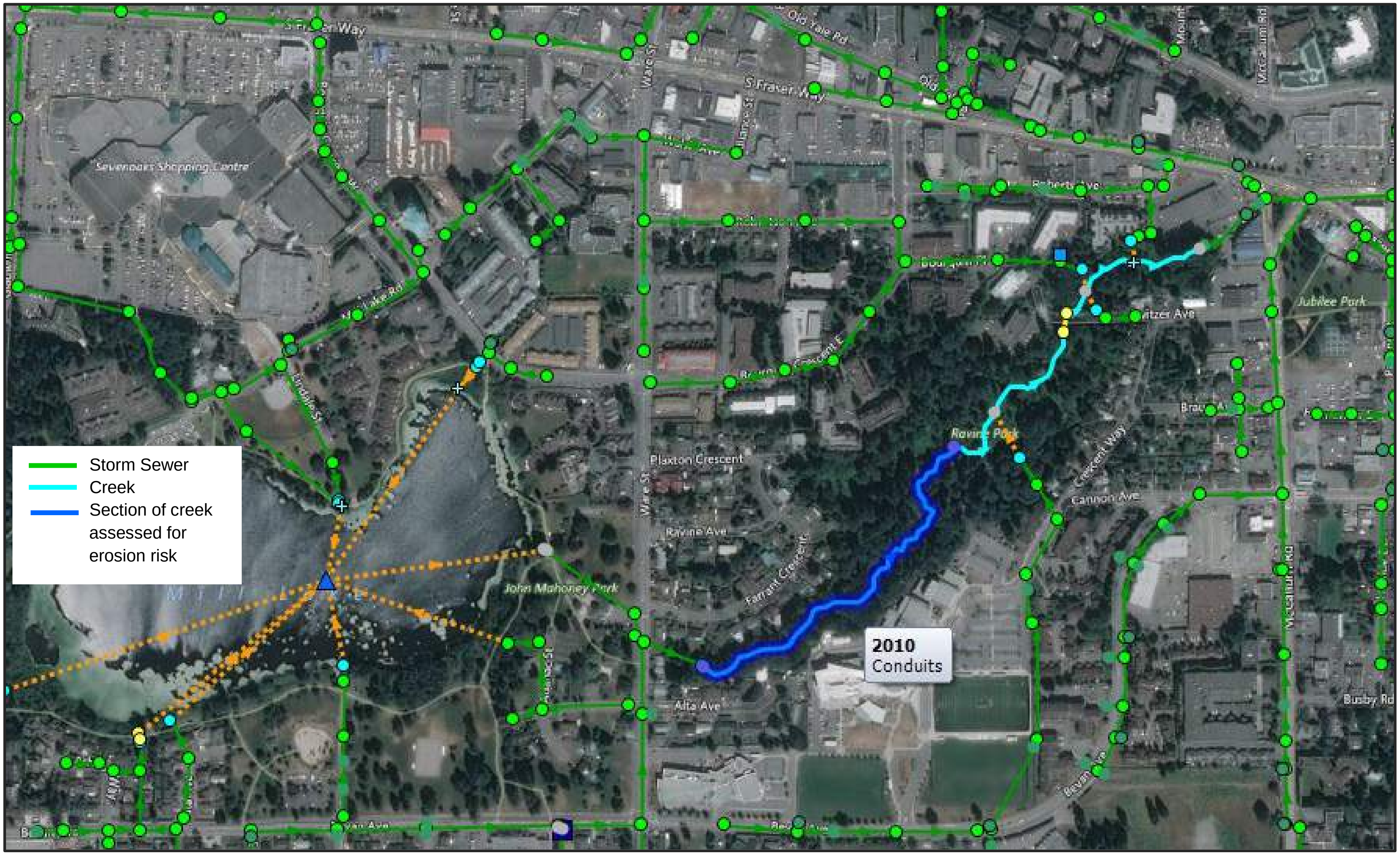

Figure 8.17 - Conduit 2010 - A section of creek (highlighted blue) immediately downstream of the storm sewer outfall from Mill Lake, and within Ravine Park.

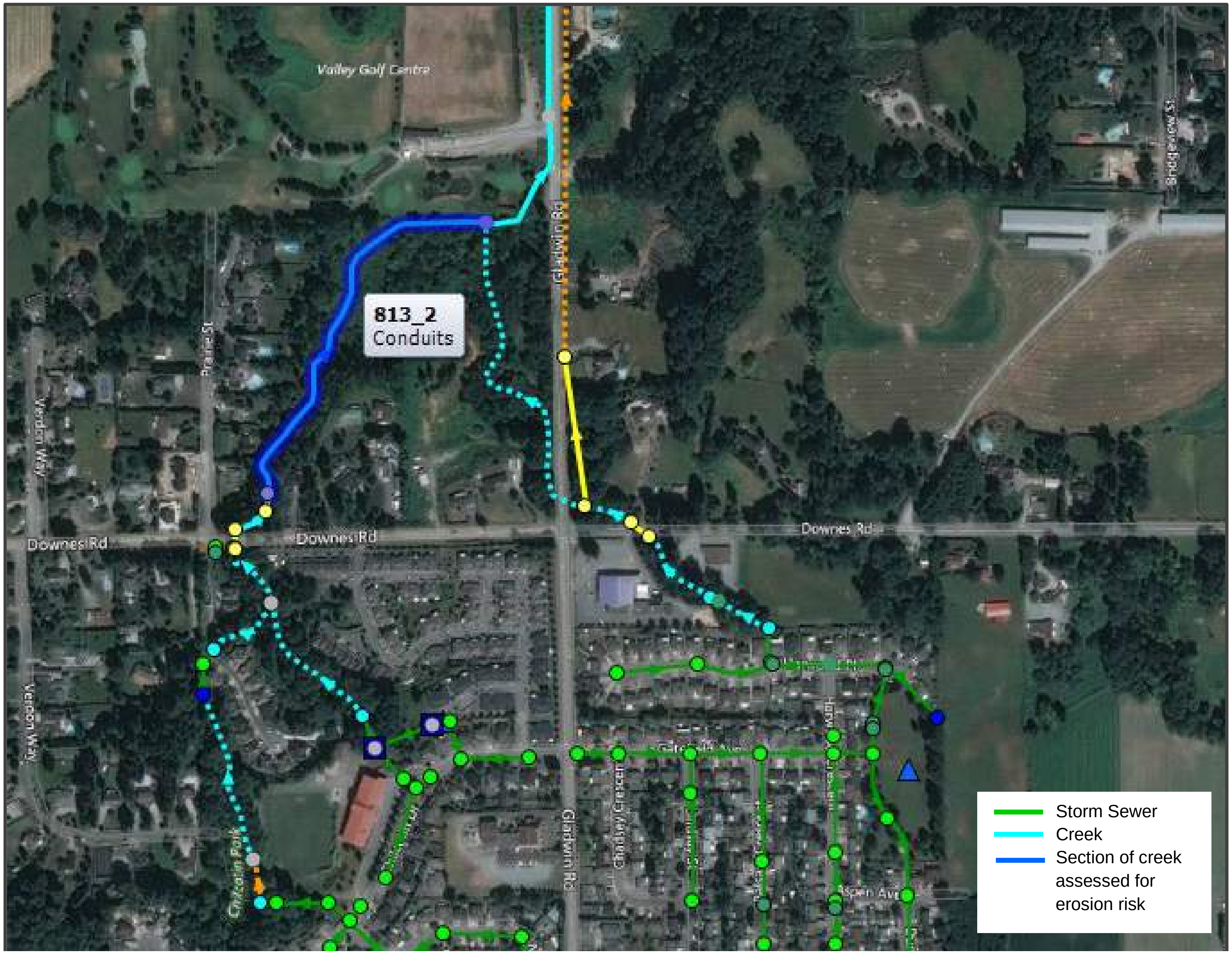

Figure 8.18 - A section of Prairie Street Creek (highlighted blue) between Downes Road and Gladwin Road

Figure 8.19 - Conduit 2635_3 - A section of Horn Creek (highlighted blue) through Horn Creek Park

Creek erosion is a function of flow over time and, more specifically, the duration flows exceed a discharge that can, or is likely to, erode a creek due to the type and size of bed materials, creek morphology, and other factors. Using continuous simulation results, this process can be calculated by comparing the flow at each time step of a hydraulic simulation to a flow estimated to be indicative of that which is channel forming. Often this "channel forming" discharge (Q_{ChlFrm}) is conceptualized as something near the 2-year return period flow but could be as low as 0.3-year to upwards of 10-year. Research has shown that a stream may experience exceedances of Q_{ChlFrm} on average 4-8 days per year, up to 24 days, therefore for this assessment a flow rate in that range has been selected through engineering judgement.

Continuous precipitation data was obtained from the City's Flowwork's database and applied for the period of 2013-2017. The selected channel-forming flows, and number of exceedances during the simulation period, are tabulated below in **Table 8.2.** A sensitivity test of these values is discussed further on in this sub-section. An assessment of potential erosion impact was then conducted for four different future condition scenarios:

- "Future" Land Use with no stormwater controls nor climate change.
- "Future with Controls" as described above, but with no climate change.
- "Future with Climate Change" but with no stormwater controls.
- "Future with Controls and Climate Change".

The flow-duration plots for each of the three sites, shown on the following pages, illustrate that the flow regimes are very similar for all tested scenarios and against the existing condition. Each site is graphed twice; first for the full range of simulation period (2013-2017), and second for the flows that are exceeded 2% of the time to show more detail.

Table 8.2 - Channel Forming Flow Estimates

Conduit	Location	Q_{ChlFrm} (m^3/s)	Number of Exceedances	Average Annual Exceedances
2010	Ravine Park	0.56	28	5.6
2635_3	Horn Creek Park	2.40	28	5.6
813_2	Prairie Street Creek	0.14	28	5.6

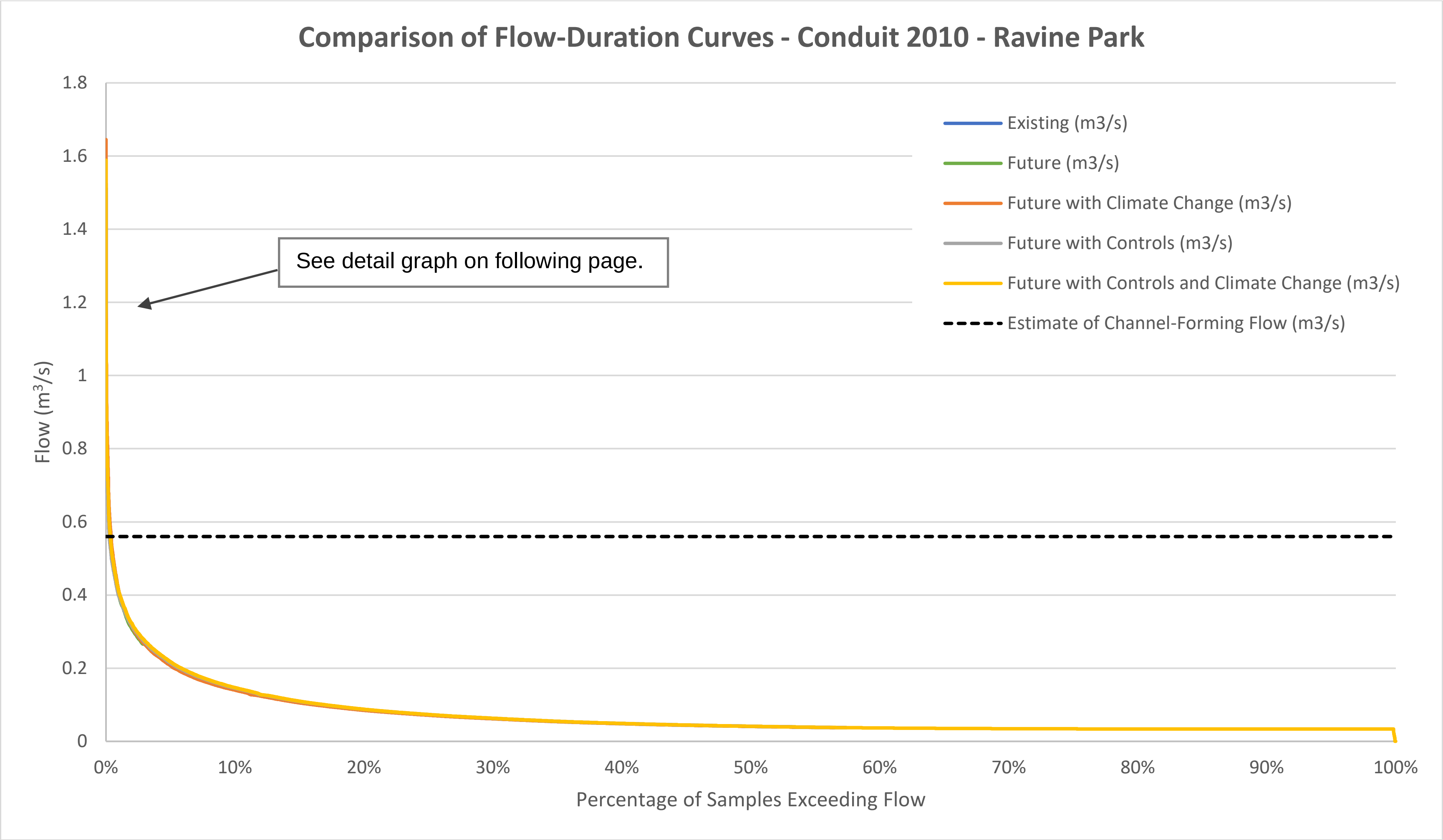

Figure 8.20 -Comparison of Flow Duration Curves for Conduit 2010 (Ravine Park)

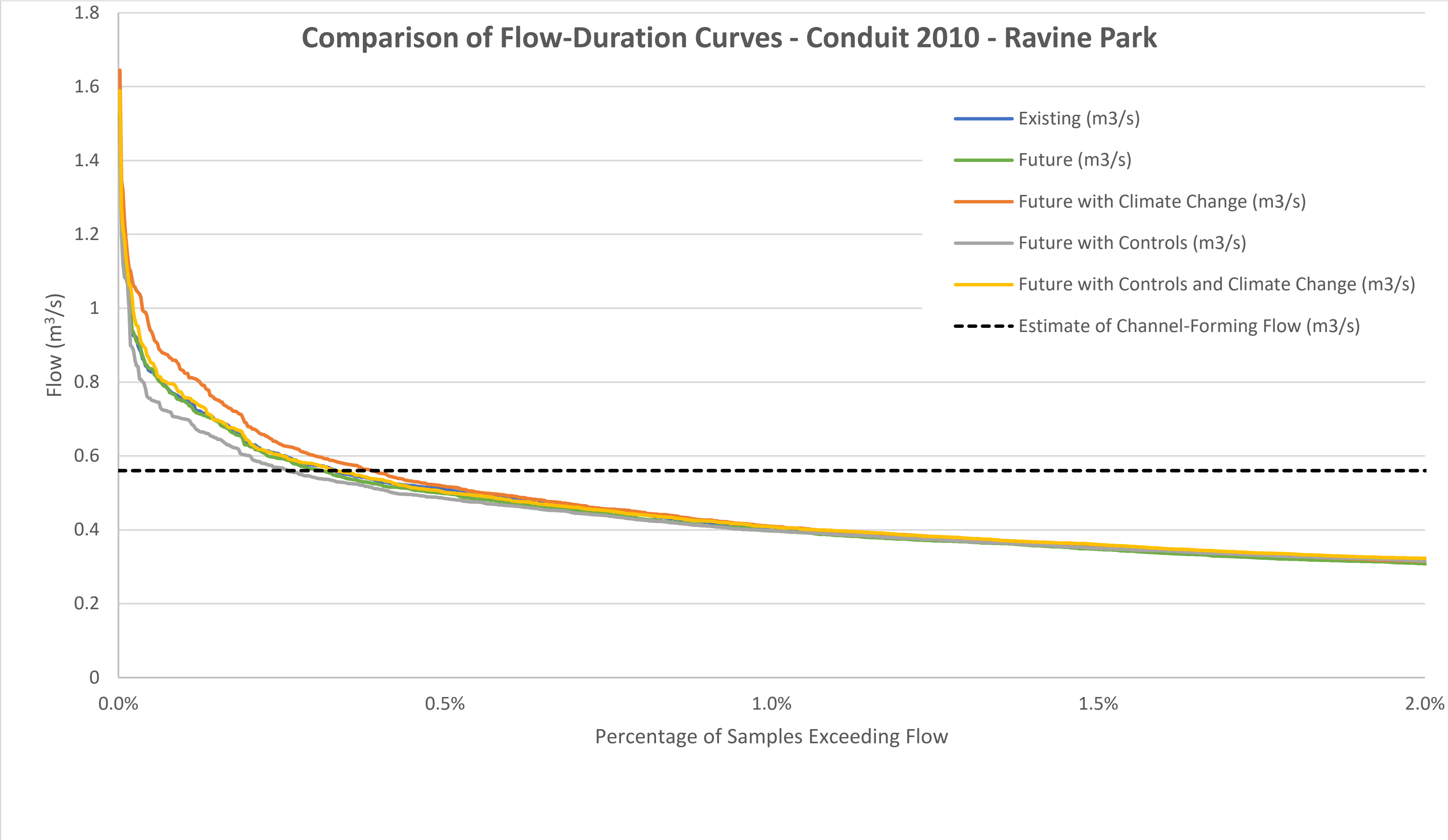

Figure 8.21 - Comparison of Flow Duration Curves for Conduit 2010 (Ravine Park) (<2%)

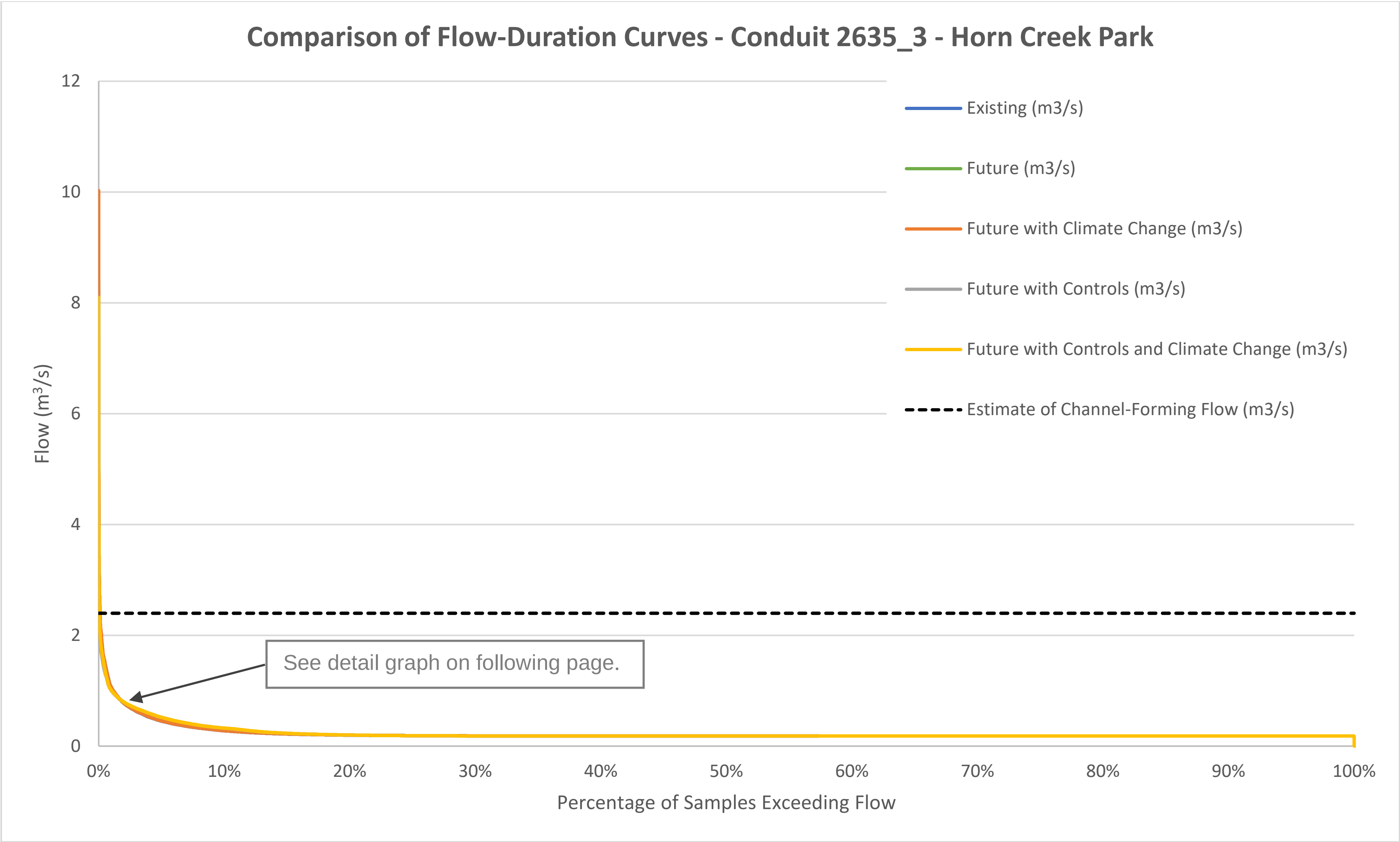

Figure 8.22 - Comparison of Flow Duration Curves for Conduit 2635_3 (Horn Creek)

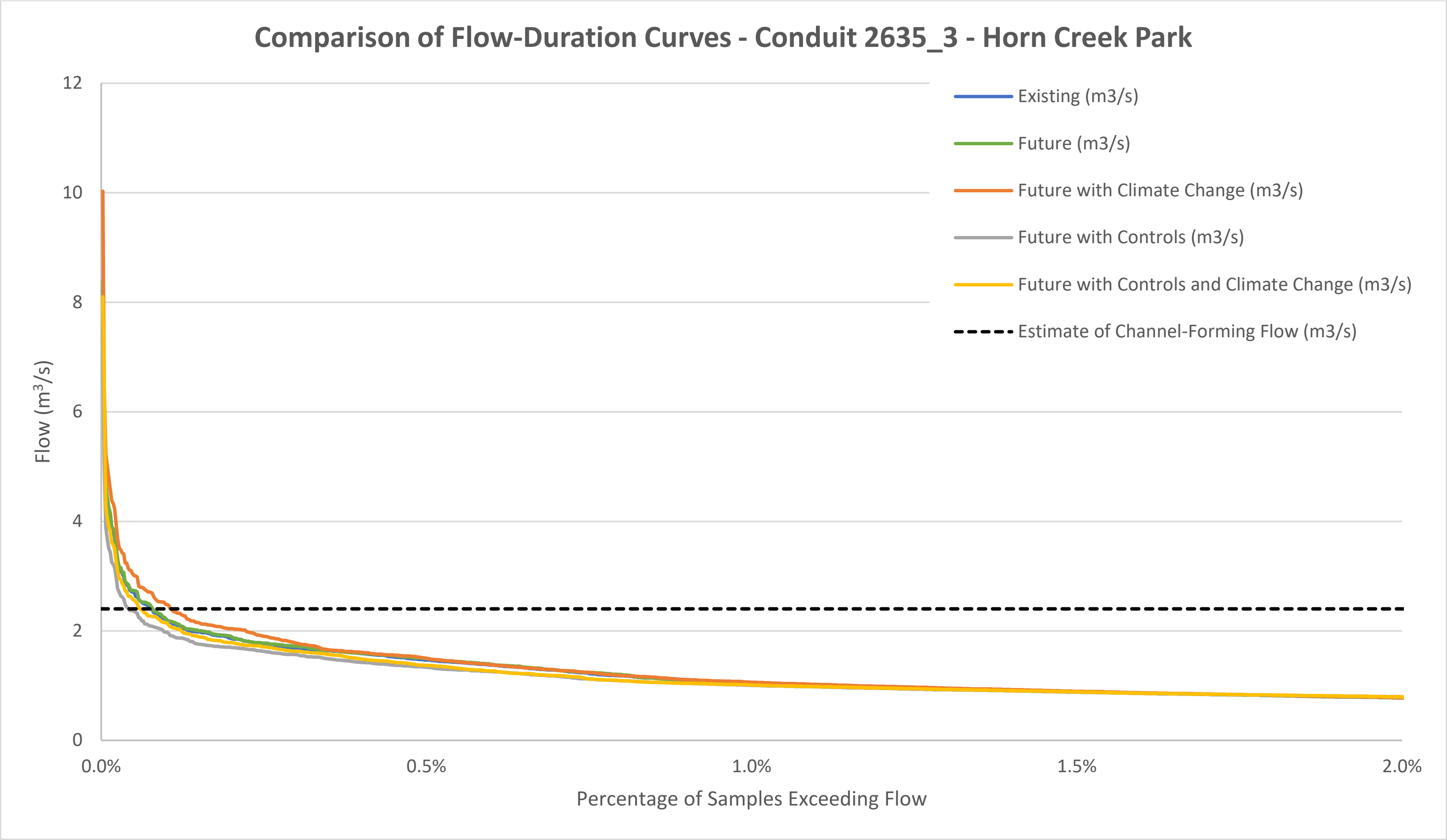

Figure 8.23 - Comparison of Flow Duration Curves for Conduit 2635_3 (Horn Creek) (<2%)

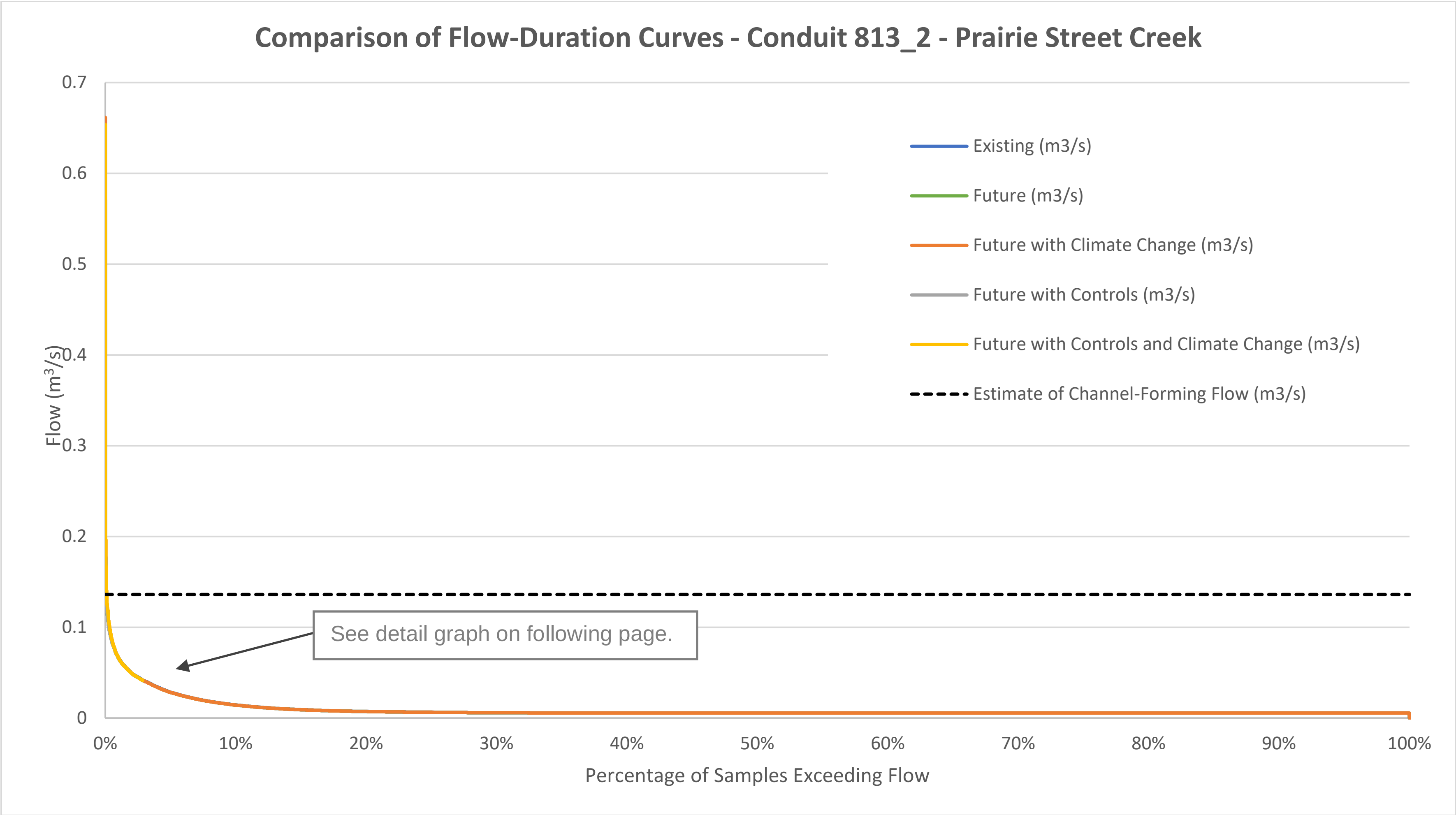

Figure 8.24 - Comparison of Flow Duration Curves for Conduit 813_2 (Prairie Street Creek)

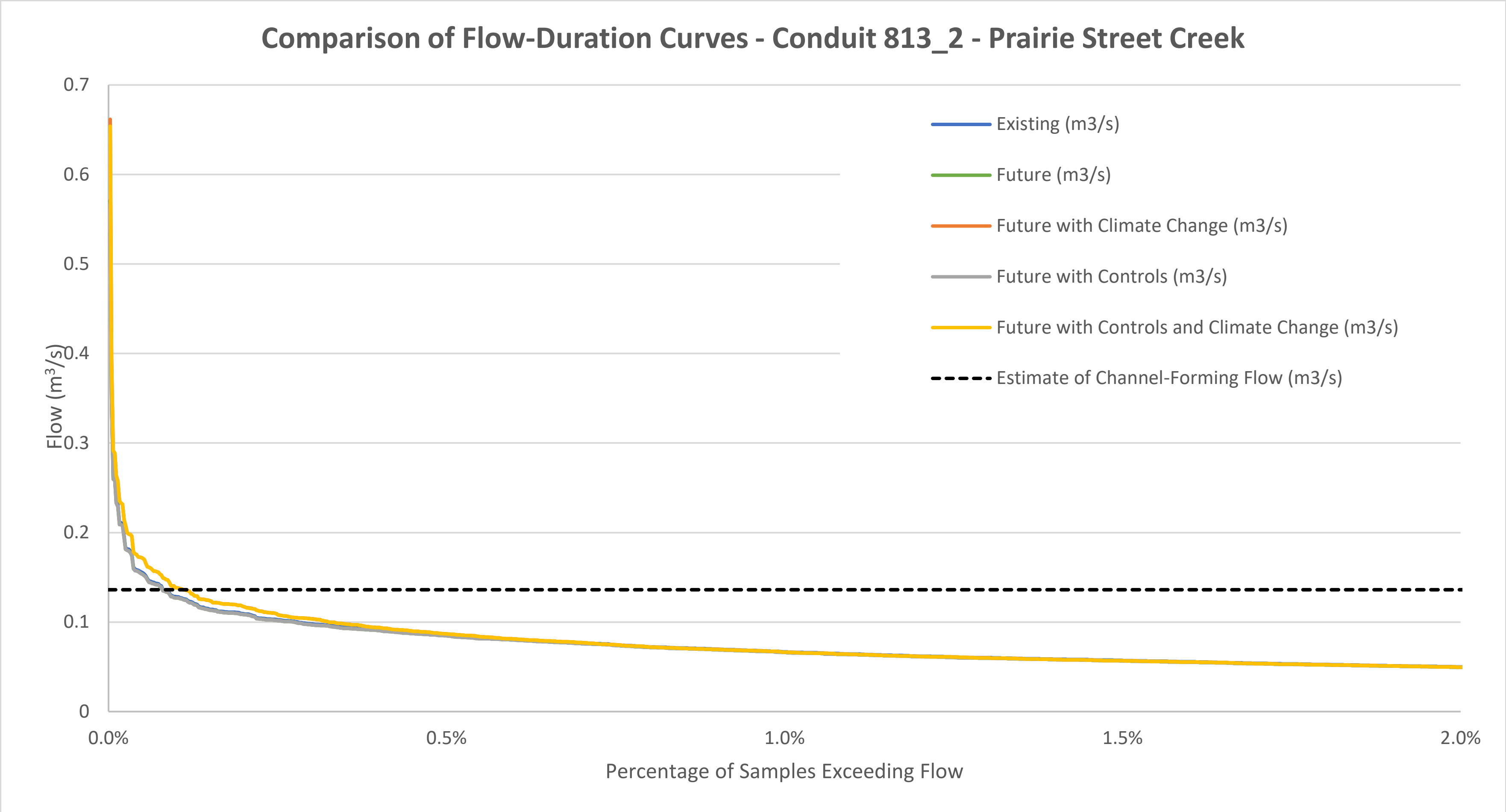

Figure 8.25 - Comparison of Flow Duration Curves for Conduit 813_2 (Prairie Street Creek) (<2%)

For the baseline condition (existing) the SEI is one (1). The SEI is the ratio of the plotted area above the channel forming Q line to that of the existing conditions. For the four scenarios assessed, SEI's at the three conduits are presented in the tables below. Because the choice of channel-forming flow is not prescriptive, the sensitivity of SEI was tested against variable Q_{ChlFrm} values; one selected 20% higher, and one selected 20% lower.

Table 8.3 - SEI Estimation

Scenario	Conduit 2010	Conduit 2635_3	Conduit 813_2
Future	0.96	1.06	0.97
Future with Climate Change	1.42	1.56	1.43
Future with Controls	0.71	0.58	0.97
Future with Controls and Climate Change	1.06	0.85	1.42

Table 8.4 - SEI Estimation with Q_{ChlFrm} 20% Higher

Scenario	Conduit 2010	Conduit 2635_3	Conduit 813_2
Future	0.98	1.06	0.98
Future with Climate Change	1.65	1.60	1.44
Future with Controls	0.64	0.59	0.97
Future with Controls and Climate Change	1.13	0.88	1.42

Table 8.5 - SEI Estimation with QChlFrm 20% Lower

Scenario	Conduit 2010	Conduit 2635_3	Conduit 813_2
Future	0.94	1.05	0.97
Future with Climate Change	1.23	1.51	1.39
Future with Controls	0.78	0.60	0.96
Future with Controls and Climate Change	1.02	0.86	1.39

As demonstrated by the tables above, the SEI is not sensitive to a change in Q_{ChlFrm} flow. The three sites are predicted to be relatively stable when measured against existing conditions. This is to say that predicted future changes are not expected to significantly change erosion risk. However, it is known that these streams are currently exhibiting erosion that should be addressed, which is discussed in subsequent sections of this study.

It appears as though climate change will potentially be a more significant driver of erosion potential than future land use, and that the 'controls' scenario is able to compensate for any increased impervious surface and bring the SEI back down below 1. However, none of the SEI's are very high, with the highest value being 1.65. It is not out of the question to find SEI's of 3 in streams that could still be classified as stable, depending on bed material(s). Although more detailed analysis could be performed to confirm or strengthen the analysis, the SEI's listed in the table do not trigger significant concern for future erosion over what may be experienced today. If the observation of erosion is considered unacceptable today, then more rigorous analysis using detailed channel geometry and bed and bank material sampling is required. As presented in Figure 5.3, a number of medium risk erosion sites, and one high risk erosion sites, were identified in the Horn Creek system.

PART 3 – MANAGEMENT STRATEGY

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9 INFRASTRUCTURE

9.1 Future Land Use - Revisited

During the conduct of this ISMP and following the analysis described in Section 8 above, the City completed Neighbourhood Plans for both the City Centre and the Historic Downtown. For those studies the City assumed full build out in accordance with the OCP. Therefore, this assumption was carried forward into the completion of this ISMP analysis. The results presented in subsequent sections represent full build out of the Neighbourhood Plan areas, whereas the "Build_35" database for redevelopment was applied everywhere else. The "Build_35" database is not a precise depiction of which properties will redevelop in the foreseeable future, but rather a depiction of anticipated redevelopment patterns and extent in the near term.

9.2 Storm Sewer Infrastructure - Revisited

The original scope of this ISMP was that only storm sewer infrastructure 300 mm in diameter or larger would be assessed for performance. But through the conduct of the Neighbourhood Plans, the City wished to assess performance of all pipes and identify future pipes on roadways that do not currently have them. For consistency, the same approach was adopted to the completion of this ISMP, therefore the results presented herein account for a greater number of storm sewers and infrastructure upgrades.

9.3 Criteria, Scenarios, and Priorities - Revisited

The criteria applied in subsequent sections remains unchanged from what was previously applied in Section 8, however system performance, upgrade requirements, and priorities have been further reviewed, and applied as follows:

9.3.1 Minimum Basement Elevations (MBE's)

Current criteria require minimum basement elevations (MBE's), or habitable floor space, to be located a minimum of 0.15 m above the major (1:100 year) hydraulic grade line. It is not current practice in the City to permit backflow preventers and pump stations, but to require gravity connections. Despite the current criteria and the fact that the existing storm sewer system was not sized for the 1:100 year event, there are some legacy buildings that have subsurface basements connected to the existing system. An inventory of these basement buildings has not been mapped by the City, and the City has also not reported any claims of flooding associated with these basement connections. Regardless, there is legitimate concern for any actions that may worsen system performance, in turn increasing the likelihood and risk of surcharging and backups into private property.

It is recommended that the City not permit additional basements (habitable floor space) below ground surface, unless one of the following three approaches are taken:

i. Upsizing, and typically deepening, the storm sewer system to accommodate gravity connections protected to the 1:100 year (major flow) level;
ii. Permit a service connection with a backflow preventer and sump-pump, along with a restrictive covenant with wording protecting the City against liability due to surcharging.
iii. Not permit a service connection, assuming foundation design can satisfy building code requirements with on-site drainage disposal (to be determined by applicant).

The above recommendations are not unique to this area but should apply to any area in the City where it is known (predicted) that the

1:100 year hydraulic grade line will be above the crown of the storm sewer system.

The cost of upsizing the storm sewer system to a 1:100 year level to accommodate gravity connections is expectedly very high. It is expected that the City would recoup upsizing costs through development cost charges (DCC's), however developers paying a DCC charge and seeking approval for basement connections would anticipatedly expect immediate service without need for added protection or limited liability to the City. Therefore, an added challenge in attempting to resize the storm sewer system for the 1:100 year event is that implementation process and risk reduction is expected to take many years. Any basement that is implemented before system improvement is complete is likely still vulnerable and will require added protection. It therefore may be unrealistic to significantly increase the level of service near term. There may be small pocket areas with sufficient grade that can be more reasonably improved in a shorter time frame, but flat topographic areas will be difficult to improve without large capital investment and expansive replacement.

9.3.2 Future Development Servicing Scenarios

Redevelopment presents an opportunity to improve storm sewer performance through successful application of on-site controls, however, it is understood that variable conditions exist and don't provide certainty to the benefits derived from them. As such, the analysis has assumed different scenarios with varying degrees of conservatism, as follows:

Scenario 1 - Future Land Use with no site controls, but with climate change[3] and existing municipal drainage systems. This scenario is used to understand the anticipated existing system performance should climate change and redevelopment proceed without controls. This is considered a "worst case" scenario.

Scenario 2 - Future Land Use with site controls applied to all lands, with climate change and existing municipal drainage systems. This scenario is used to understand the potential benefit of achieving currently defined controls on all parcels of land. This is considered a "best case" scenario.

Scenario 3 - Future Land Use with no site controls, but with storm sewer improvements to resolve performance issues to fully satisfy the City's current criteria of storm sewers sized to prevent surcharging under a 1:10 year event, or in the case of the Mill Lake Ravine trunk system, the 1:100 year event. This is a conservative, but preferred scenario for the City.

9.3.3 Key Catchment Parameters

Regardless of whether engineered infiltration systems (stormwater source controls) are successfully implemented or not, the assumption for Directly Connected Impervious Areas (DCIA) are important to the performance of the storm sewer system. Although modeling scenarios have been tested and storm sewer sizing developed on the assumption that engineered infiltration systems are not broadly applied, it remains important that impervious surfaces to the extent presented in **Table 9.1** be disconnected and routed to a pervious surface.

Through discussion with City staff, **Table 9.1** presents what is felt realistically achievable in terms of total impervious area (TIA) and the

[3] Climate change design storms are scaled up 10% from current levels.

DCIA. Please note that the DCIA represents the percent of TIA, not the percent of the total site.

Table 9.1 - Assigned Impervious Areas

Land Use	Total Impervious Area (TIA) %	Directly Connected Imp. Area (DCIA) % of TIA
Historic Downtown	100	100
Urban Centre Mixed	90	50
Urban Centre Residential	90	50
Employment	90	50
General Industrial	90	100
Industrial	90	100
City Centre Core	90	50
City Centre Residential	90	50
Secondary Commercial	90	50
Institutional	90	50
Urban 1 – Midrise	80	50
Urban 2 – Ground	80	50
Urban 3 - Infill	65	10

9.4 Potential Communal Detention Facilities to Reduce Storm Sewer Improvements

This section explores the potential of communal detention facilities on City owned land for the purpose of reducing peak flows in the storm sewer system, with the goal of reducing the need for storm sewer improvements.

9.4.1 City Centre Neighbourhood Plan Area (CCNP)

An opportunity to create a communal detention facility in the Municipal Hall civic site was evaluated for its potential to reduce surcharging in neighbouring storm sewer systems. In this case, the greatest storm sewer deficiencies exist upstream of the Municipal Hall site. Therefore, a communal pond at this location provides little benefit in reducing storm sewer surcharging. However, this site provides an opportunity for the City to implement site controls and set a positive precedence for the community. It may also serve as a local amenity and water quality facility.

9.4.2 Historic Downtown Neighbourhood Plan Area (HDNP)

An opportunity to create a communal detention facility in the vicinity the Five Corner intersection of McCallum Road, South Fraser Way, and Essendene Avenue was identified by the City. This location is upstream of deficient trunk sewers on Montrose Avenue and theoretically may have the ability to reduce surcharging, but the challenge is that the flow needing to be arrested is entering from the upstream Mill Lake Ravine Park ravine. The elevation of land at the Five Corners intersection is excessively high relative to the ravine invert, therefore, there is no realistic means to create an open storage deep enough to sufficiently arrest the flow.

Mill Lake Ravine

As an alternate, storage directly within the Mill Lake Ravine may be created by restricting flow at the transition from the ravine into the 1800 mm diameter trunk storm sewer. Using available topographic surface data (LiDAR), the storage potential of the ravine was measured as presented in **Table 9.2** below.

Table 9.2 - Mill Lake Ravine Storage

Elevation (m)	Surface area (m2)	Cumulative Volume (m3)
30	100	0
31	1,847	973
32	7,448	5,621
33	13,997	16,344
34	23,085	34,885

To prevent surcharging in the existing 1350 mm diameter pipe further downstream on Montrose Avenue during a 1:100 year event, a flow control structure would need to limit flow from the ravine to no more than 2 m^3/s. Activation would occur rarely, therefore would not interrupt the typical flow regime nor the navigability of any fish that may be present. Analysis shows that for the variety of 1:100 year events, up to 24 hours, the maximum detained volume in the ravine would be 15,000 m^3 if flows were restricted to 2 m^3/s.

Based on **Table 9.2**, the resulting maximum water surface elevation in the ravine is approximately 33 m, or a maximum depth of 3 m at the control structure. The trunk storm sewer at the inlet structure is 1.8 m in diameter, therefore depth of water above the pipe crown would be approximately 1.2 m.

Using the LiDAR topographic surface information, the extent of storage within the ravine with maximum water surface at 33 m elevation is shown in **Figure 9.1**. From a flood extent perspective this option appears viable, however before a conclusion can be reached it's recommended that regulatory agencies be consulted regarding on-line storage within the ravine, a geotechnical engineer be consulted to assess potential slope stability issues and an arborist be consulted on the potential impact to trees within the flood zone. A biologist also will need to evaluate the effects on fish and wildlife. And finally, landscape architects will need to review if there is any effect on parks tails and associated structures.

The control structure would need thoughtful consideration for debris, turbulence / erosion, and provide an emergency overflow.

Mill Lake

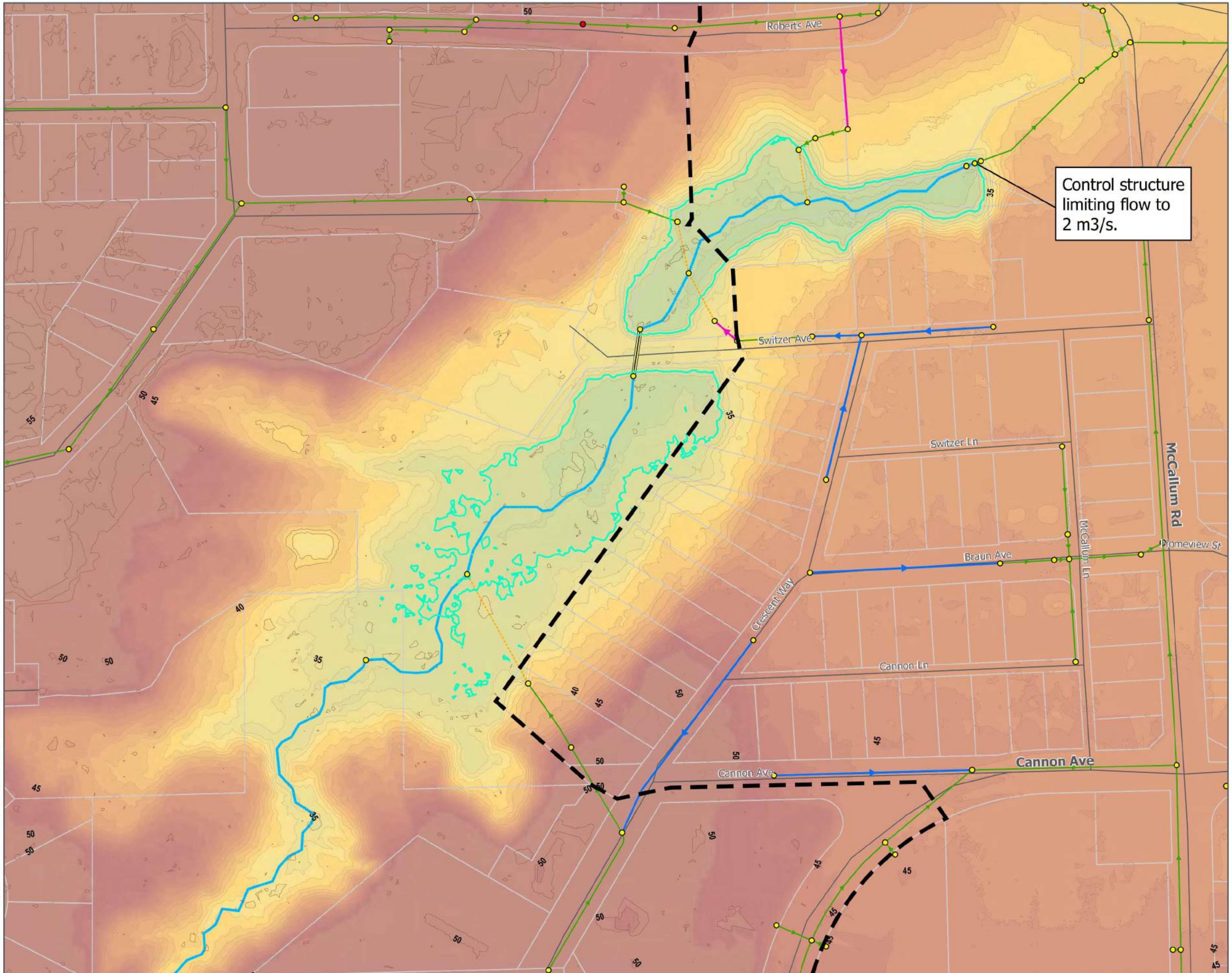
Consideration was also given to whether the Mill Lake outfall structure may be modified to reduce 1:100 year discharge in the trunk system downstream of Mill Lake Ravine, however, with significant flows entering the ravine from trunk storm sewers downstream of the Mill Lake, controlling at the lake cannot sufficiently arrest the total flow to prevent surcharge within the Historic Downtown. In addition, Mill Lake already reaches maximum capacity and the existing control structure is actively managed to prevent water backup into adjacent property. If any further restriction on lake flows were to occur, it would be necessary to significantly lower the normal water level in the lake during a winter season to create additional freeboard. And new operating protocols for the lake outfall would need to be established.

City Owned Parking Lot – West Railway Street and Essendene Avenue

The City had discussed the potential to build an infiltration or detention facility within the City owned parking lot at West Railway Street and Essendene Avenue. There are several deficient storm sewers in the area, but only those downstream of a detention facility would benefit;

presumably the existing 600 mm diameter storm sewer north of Essendene Avenue running through the parking lot to George Ferguson Way. To reduce the hydraulic grade line in the existing storm sewer, detention storage would be required at or below the elevation of the storm sewer. Assuming the City will still wish to maintain the site as a parking lot, a subsurface reservoir would be required to support traffic above. Without detention, this 130 m long storm sewer through the parking lot from Essendene Avenue to George Ferguson Way would need to be replaced to a 750 mm diameter if there are insufficient controls implemented upstream. Replacement of this pipe has a planning level capital value of $263,000. In order to prevent the existing 600 mm diameter storm sewer from surcharging, a detention storage of 180 m^3 and 1,700 m^3 would be required for the 1:10 year and 1:100 year events respectively. At roughly $1,500 per m^3, the planning level capital value of underground storage is $270,000 and $2.6M for the 1:10 year and 1:100 year events respectively. In addition, a detention vessel will have added maintenance and create a costly structure to remove if the property was to be repurposed for a building in the future. It is recommended that in this case upgrading the storm sewer through the property would be more cost effective.

However, the opportunity to create a surface-based infiltration facility to manage the runoff from the parking lot itself, and perhaps some surrounding roads or lands, is a worthwhile and recommended action. It would demonstrate the City as a leader in implementing site controls, as required by others.



Willband Creek
Integrated Storm Water Management Plan

Ravine Park Flooding

Legend

- Historic Downtown Neighbourhood Boundary
- Upgrade Main
- Proposed Main
- Existing Main
- Creek
- Culvert
- Conduit Added for Connectivity
- Contours (1 Metre)
- 33 m Contour

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

0 50 100
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:1,877 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
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Date:	2018 / 12 / 17

FIGURE 9.1

9.4.3 Historic Centre

As noted earlier, due to zoning allowances, it is very problematic to provide retention controls in the Historic Downtown (refer to the Historic Downtown Neighbourhood Plan), which covers an area of approximately 44 hectares in total when including the road right-of-ways, or 31 hectares in total of land parcels, excluding the road rights-of-ways. Criteria requires that retention and infiltration be provided for the 1:10 year 24-hour precipitation volume. For current precipitation, this is a rainfall depth of 95.5 mm. Applying an additional 10% for climate change this depth increases to 105 mm. Therefore, for the area noted the total volume of capture to satisfy the criteria ranges from 29,605 m^3 to 46,200 m^3 depending on whether or not road right-of-ways are included and what precipitation is applied. These are extensive volumes to manage and dispose of in a centralized facility. This information is provided for reference only as requested by the City. Sensitivity analysis was conducted to determine that not achieving the required controls within the Historic Downtown alone will not change the storm sewer capital program.

9.5 System Reconfiguration In Historic Downtown

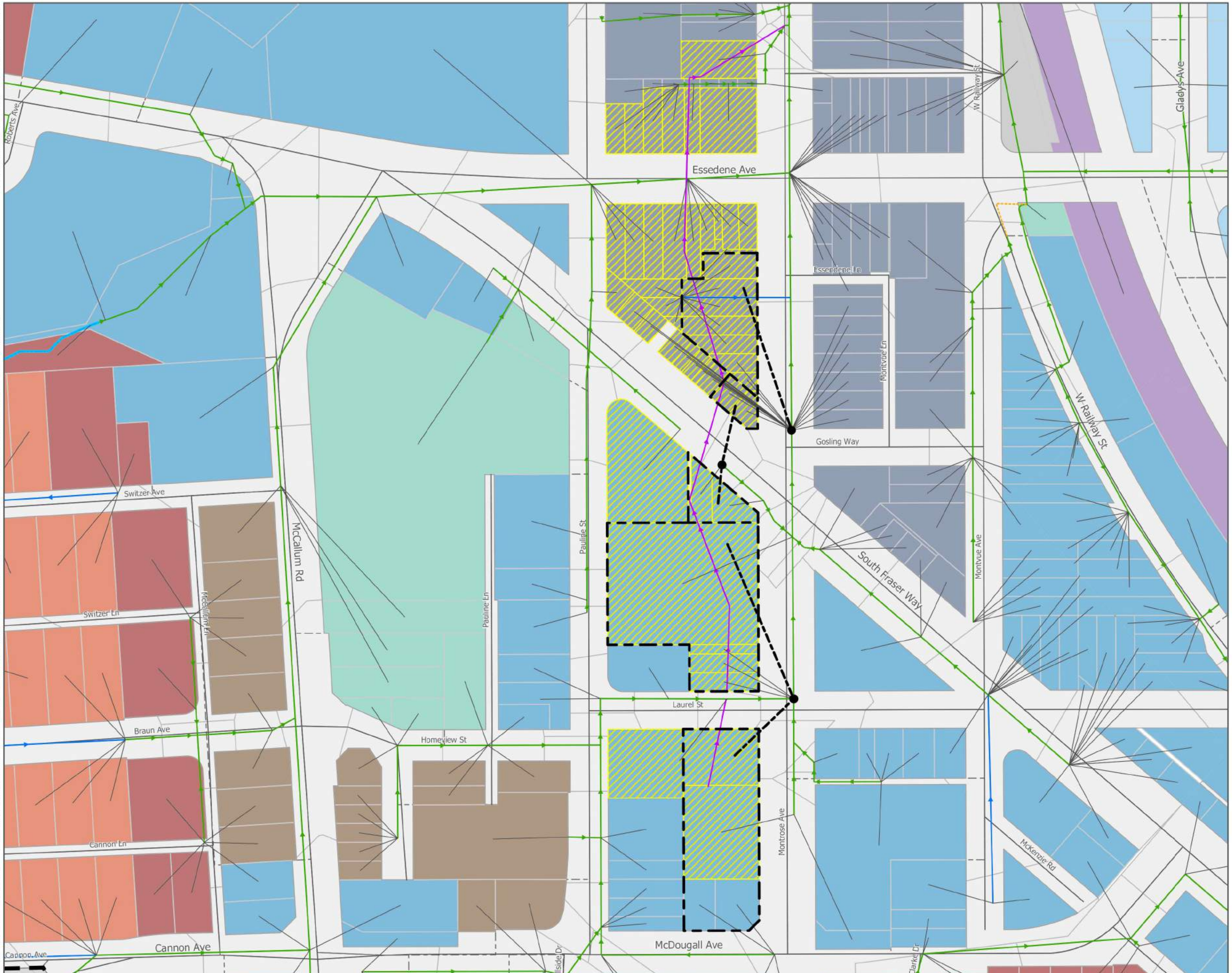
There is a segment of historic storm sewer paralleling to the west of Montrose Avenue through the Historic Centre that runs beneath historic buildings. These are believed to have been privately installed pipes by landowners to facilitate infilling of the water course and gaining more usable land for their benefit. These properties have likely connected foundation, roof, and parking area drainage to this historical pipe. Aside from the roadway crossings, the City does not have a right of way or access to these private sewers, therefore the City has intent to reroute the City infrastructure. During redevelopment owners should be required to connect to the City system. It is possible that significant groundwater exists along the alignment of the historic private pipe if in fact is was the infill of a natural creek. Decommissioning of this private pipe by landowners will require thoughtful consideration of groundwater.

The City engaged ISL Engineering separately to conduct a preliminary design investigation for this redirection of City infrastructure. A letter report titled “Montrose and South Fraser Way Storm Review Draft Report – Rev02” (ISL Engineering, March 20, 2018) was produced.

Through dialogue with the City, additional lots fronting South Fraser Way have been allocated to Montrose Avenue within this ISMP study than previously assumed by ISL, but otherwise the routing is fundamentally the same as assumed by ISL. The allocation of lot drainage to support the realignment is shown in **Figure 9.2**.

ISL Engineering, using the Rational Method, identified two pipe reaches on Montrose Avenue between Laurel Street and South Fraser Way that would surcharge under a 10-year event, and therefore ISL Engineering recommended that the storm sewer from Laurel Street to Essendene Avenue be upsized to 750 mm to prevent pipe downsizing.

The analysis as described herein (using the hydrograph method) indicates that the existing storm sewer on Montrose Avenue has sufficient capacity under the 10-year event to allow for service connection redirections and abandonment of the existing main underneath building. It is recommended that the City complete a condition assessment and monitor the observed performance of the existing Montrose Avenue storm sewer prior to reaching full conclusion on the adequacy of the existing storm sewer to accept the redirections.



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Willband Creek Integrated Storm Water Management Plan

Re-routing of Parcels to Abandon Mains Under Buildings

Legend

- Study Area
- Main Under Building (To Abandon)
- Main
- Proposed Main
- Creek
- Conduit Added for Connectivity
- Re-routed Parcel
- Sub-catchment boundary and loading point to Montrose Ave. as assumed by ISL Engineering (March 20, 2018)

Build-out Land Use

- Historic Centre
- Urban Centre Mixed
- Urban Centre Residential
- Employment
- Urban 1 - Midrise
- Urban 2 - Ground
- Secondary Commercial
- General Industrial
- Institutional
- Open Space
- Roadway Subcatchments (Allocated to Closest Node)

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 50 100
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:1,800 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

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URBAN systems

FIGURE 9.2

9.6 Upland Storage for Horn Creek and Boa Brook

Erosion potential analysis demonstrates that future development is not expected to create ***additional*** erosion risk over today's condition, however significant erosion within Horn Creek and Boa Brook has been triggered from passed development and continues to persist.

Erosion within these watercourses, and solutions, have been studied in the past, including a 2001 study prepared by Golder Associates titled "Flood and Erosion Assessment of Horn Creek / Boa Brook Downstream of Maclure Road", and a report from 2009 also by Golder Associates titled "Bank Stabilization Marshall Creek and Horn Creek Erosion Sites, Phase II and Phase III Report". The 2001 study discussed a variety of in-stream, or near stream actions such as berms, bank stabilization, armoring, bioengineering, etc. A number of bank stabilization repairs were completed between 2004 and 2011, but erosion persists at locations that have not been stabilized.

In addition to in-stream repairs, the 2009 study presented a concept for a storm water diversion pipe to potentially reduce future erosion in Horn Creek. However, the Golder study stated that *"it would not mitigate the existing bank instability issues on Horn Creek and will not reduce bank instability caused by windthrow of trees."* The study contemplated three different diversion routes, all serving a 140-hectare catchment upstream (west) of Gladwin Road, and all terminating downstream of the confluence of Horn Creek and Boa Brook adjacent to Maclure Road.

Sizing of the diversion was based on diverting 50% of the peak 1:100 year peak flow estimate of 10 m^3/s, or a diverted flow of 5 m^3/s. The Class D cost estimated for the diversion in 2009 was $4.4M for a 1.35 m diameter pipe, excluding conflicts with existing utilities, but including design and construction services. The cost is expected to be much higher today. This City has not acted on this option and has sought commentary on alternate solutions, if they exist.

The analysis conducted for this ISMP demonstrates that a reduction in flows and erosion risk can occur over time through redevelopment and the broad application of source controls. However, this process will take many years through redevelopment, yet existing erosion problems require a more immediate response.

Shy of distributed source controls or further stabilizing the creek channels, an alternative is to implement communal detention facilities to attenuate discharges to the stream. However, in this scenario the volume of water being released does not change; only the release rate. As such, there is still risk for erosion if flow rates are not reduced sufficiently.

From the erosion potential assessment presented is Section 8.5.5 - Continuous Simulation and Erosion Potential Assessment, the current "channel forming flow" for Horn Creek was estimated to be in the order of 2.4 m^3/s, which is approximately equal to the current 1:2 year peak flow. However, this current estimate is significantly higher than the historic pre-development channel forming flow that would have existing prior to development. Shy of doing comprehensive erosion threshold analysis, it is recommended that the City's discharge criteria of 5 L/s/ha be used as a reasonable planning level value as the permissible release rate to combat erosion.

While numerous small outfalls exist, this assessment has identified the three largest outfalls, as identified in **Figure 9.3** below; two on Horn Creek and one on Boa Brook.

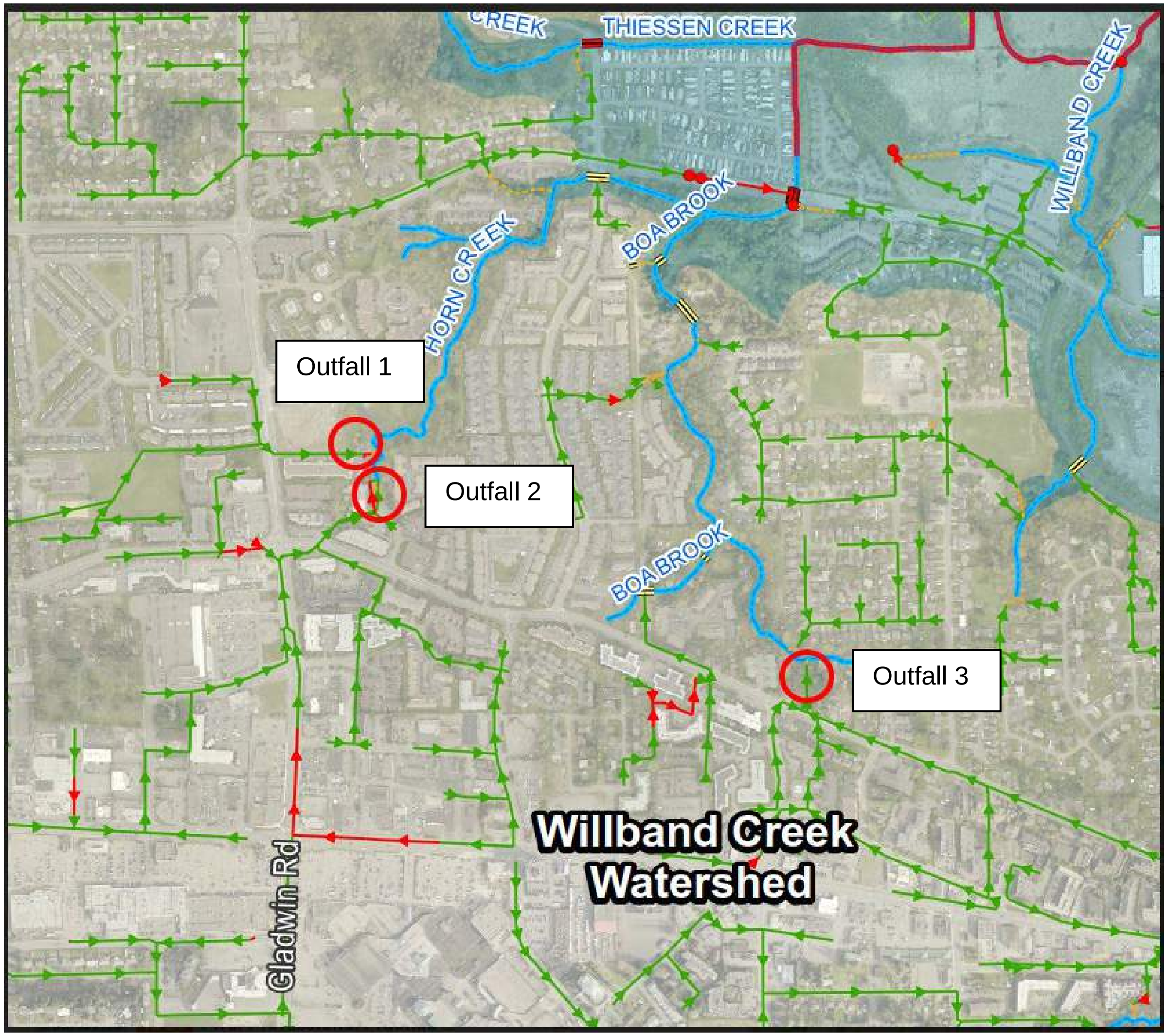


Figure 9.3 - Horn Creek and Boa Brook Primary Outfalls

Flow statistics for each of the three outfalls are provided in **Table 9.3** below:

Table 9.3 - Outfall Statistics

Outfall	Catchment Area (ha)	Permitted flow (m^3/s) at 5 L/s/ha	Existing Peak Flows (m^3/s)		
			1:2	1:10	1:100
1	148	0.74	2.7	4.2	5.8
2	50	0.25	1.5	2.6	3.5
3	20	0.10	0.6	0.9	1.2

The estimated required storage volumes at each outfall have been computed for the full range of storm events, as presented in **Tables 9.4 to 9.6** below. In all cases the volumes consider future conditions with climate change. Land base requirements are based on an assumed live storage depth of 2 meters and a land use efficient factor of 0.8 to account for such things as side slopes, access, etc. The maximum storage value for each return period is highlighted in red.

Table 9.4 - Outfall 1

Event	Live Detention Volume (m^3)	Estimated Land Requirement (m^2)
Future+CC 2yr 1hr	5,400	3,400
Future+CC 2yr 2hr	7,900	4,900
Future+CC 2yr 6hr	**10,300**	6,500
Future+CC 2yr 12hr	7,900	4,900
Future+CC 2yr 24hr	800	500
Future+CC 10yr 1hr	12,100	7,600
Future+CC 10yr 2hr	17,600	11,000
Future+CC 10yr 6hr	**23,100**	14,400
Future+CC 10yr 12hr	17,600	11,000
Future+CC 10yr 24hr	1,700	1,100
Future+CC 100yr 1hr	21,800	13,600
Future+CC 100yr 2hr	31,800	19,900
Future+CC 100yr 6hr	**41,500**	26,000
Future+CC 100yr 12hr	31,700	19,800
Future+CC 100yr 24hr	3,000	1,900

Table 9.5 - Outfall 2

Event	Detention Volume (m^3)	Estimated Land Requirement (m^2)
Future+CC 2yr 1hr	3,200	2,000
Future+CC 2yr 2hr	4,700	3,000
Future+CC 2yr 6hr	7,100	4,500
Future+CC 2yr 12hr	**7,500**	4,700
Future+CC 2yr 24hr	3,800	2,400
Future+CC 10yr 1hr	6,600	4,100
Future+CC 10yr 2hr	9,600	6,000
Future+CC 10yr 6hr	14,500	9,100
Future+CC 10yr 12hr	**15,300**	9,600
Future+CC 10yr 24hr	12,800	8,000
Future+CC 100yr 1hr	10,800	6,800
Future+CC 100yr 2hr	15,900	10,000
Future+CC 100yr 6hr	23,900	15,000
Future+CC 100yr 12hr	25,300	15,800
Future+CC 100yr 24hr	**25,700**	16,100

Table 9.6 - Outfall 3

Event	Detention Volume (m^3)	Estimated Land Requirement (m^2)
Future+CC 2yr 1hr	1,300	800
Future+CC 2yr 2hr	1,800	1,100
Future+CC 2yr 6hr	2,600	1,700
Future+CC 2yr 12hr	**2,900**	1,800
Future+CC 2yr 24hr	1,600	1,000
Future+CC 10yr 1hr	2,400	1,500
Future+CC 10yr 2hr	3,400	2,200
Future+CC 10yr 6hr	5,100	3,200
Future+CC 10yr 12hr	**5,500**	3,400
Future+CC 10yr 24hr	4,900	3,100
Future+CC 100yr 1hr	4,000	2,500
Future+CC 100yr 2hr	5,600	3,500
Future+CC 100yr 6hr	8,300	5,200
Future+CC 100yr 12hr	9,000	5,600
Future+CC 100yr 24hr	**9,300**	5,800

The largest challenge to creating communal detention will be having the necessary land in an effective location. At this time only ponds are considered, however buried tanks could also be considered, but would come at a higher construction cost.

In **Figure 9.4**, City owned properties in the general vicinity of Horn Creek and Boa Brook are highlighted and numbered. Additional privately-owned sites that are in favorable locations are also identified and numbered. However, no site has been identified that currently has a building present. Also, due to environmental impacts and expected approval difficulties, detention directly on-line of Horn Creek and Boa Brook are not yet considered.

Parameters for each site are summarized in **Table 9.7** below.

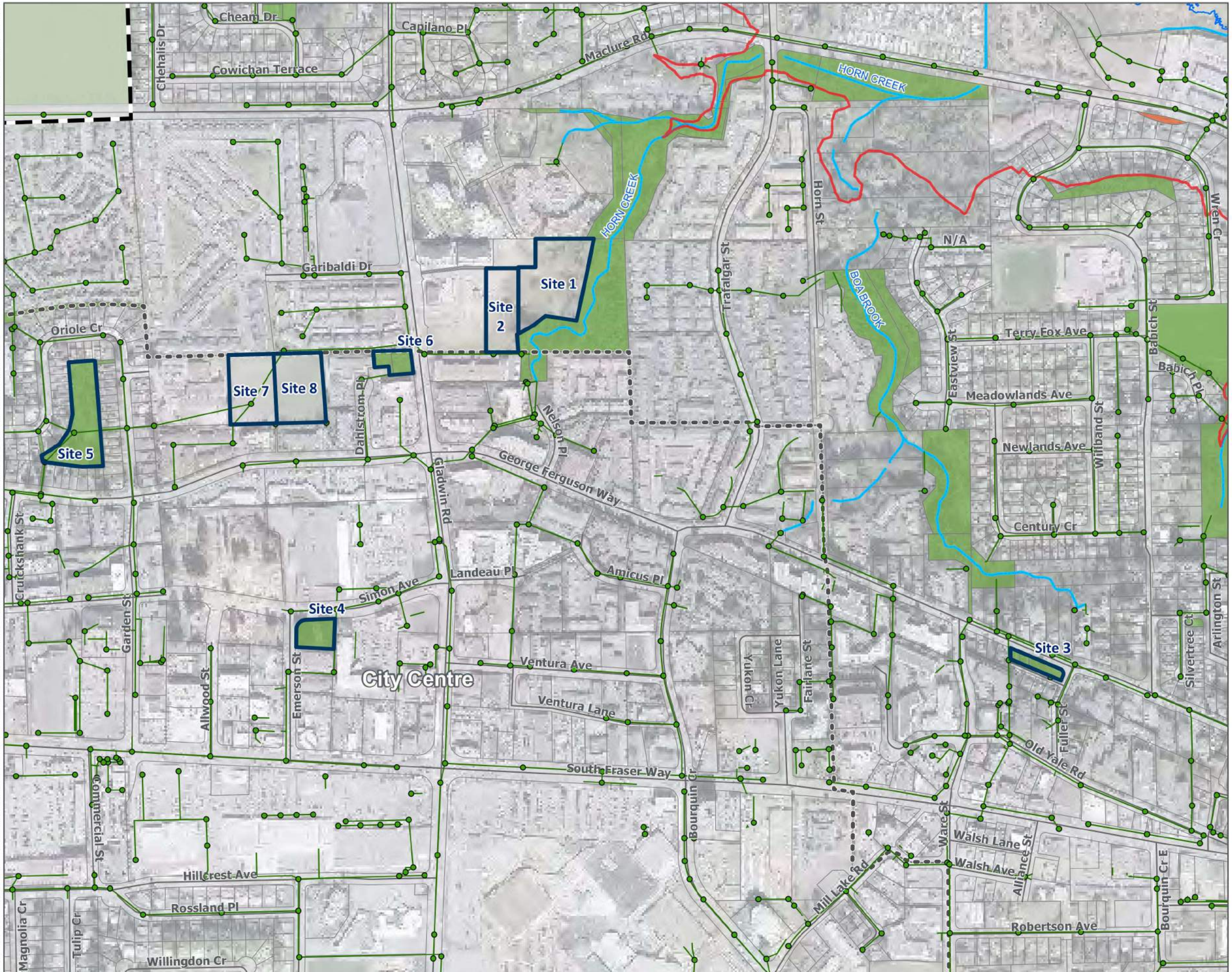
Table 9.7 - Evaluation of Candidate Communal Pond Sites

Site	Ownership	Site Area (m^2)	Outfall Served	Storage Potential (m^3)	Rough Cost (excluding land)	Approximate Service Level Offered by the Site	Relative Benefit Offered by the Site
1	Private	12,100	1	19,000	$3,135,000	1:10	High
2	Private	6,400	1	10,000	$1,650,000	1:2	Moderate
3	City	1,300	3	2,100	$346,500	<1:2	Low
4	City	2,500	2	4,000	$660,000	<1:2	Low
5	City	8,200	1	13,000	$2,145,000	>1:2	Moderate
6	City	1,800	1	2,900	$478,500	<1:2	Low
7	School Board	7,600	1	12,000	$1,980,000	>1:2	Moderate
8	School Board	7,900	1	12,600	$2,079,000	>1:2	Moderate

Storage potential is based on average depth of 2 meters and land efficiency factor of 0.8 (assuming entire site is used). Storage volumes noted are preliminary and would need further review through a preliminary design process.

Cost is based on $165 per m^3 of live storage, including 30% E&C, but excluding land. This represents a well landscaped pond facility and may be reduced if only basic landscape finishing. It also does not include resolution of conflicts with existing infrastructure.

There are multiple sites that offer significant opportunity to regulate flows to Outfall 1 (Horn Creek), which is the largest of the three outfalls and is the same catchment that would be controlled by the alternative diversion pipe previously proposed by Golder Associates. The detention ponds would provide greater benefit during more frequent,



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Willband Creek Integrated Storm Water Management Plan

Potential Pond Sites for Horn Creek and Boa Brook

Legend

- Potential Pond Sites
- Existing Manhole
- Existing Main
- Maximum Future Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Neighbourhood Plan Boundary Study Area
- Creek
- Parcel

City Land Types

- Parks (Dedicated and Undedicated)
- Road

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0 200 Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:5,683 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
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URBAN systems

FIGURE 9.4

channel forming flows, whereas the diversion was proposed to only function during rare, high flows. The diversion could be sized to also service a wider range of storm events, however, would need to be sized larger than that previously proposed by Golder Associates. If the diversion were to service Outfall 1 alone (148 ha area), a conservative design would be to size the pipe for the current 1:100 year peak flow (5.8 m^3/s) less the 0.74 m^3/s that is based on a 5 L/s/ha criteria. In round number, the diversion would be sized for 5 m^3/s, which is the same design flow proposed by Golder thereby requiring the same pipe size of 1.35 m diameter. However, the matching design flow is a coincidence only, while the operating range is significantly different based on the difference in projected peak flow between the Rational Method calculation done by Golder and the SWMM modeling conducted for this ISMP.

Given the close proximity of Outfall 1 with Outfall 2, it may be possible to service both outfalls with a single diversion, with a combined service area of 198 hectares, and a combined 1:100 year peak flow of 9.3 m^3/s (refer to Table 9.3). Staying consistent with applying the 5 L/s/ha flow as the permissible flow in the creek, the total flow remaining in the creek would be 0.99 m^3/s, leaving a remainder of 8.3 m^3/s to the diversion thereby requiring a pipe 1.5 meters in diameter if a smooth walled HDPE pipe (manning N=0.011) was selected (assuming a critical pipe grade of 1% that needs to be confirmed through design).

For Site 1 and 2, environmental approvals, land acquisition, and geotechnical stability of the steep slope on Site 1 will be significant factors that need to be explored early to evaluate the viability of these sites. For Site 7 and 8, it would be envisioned that the sports fields would need to be depressed and re-established at the bottom of surface ponds. But to be effective for the creeks these ponds need to activate frequently, which may interrupt usage of the sports fields. There may be a design concept where subsurface storage and/or an infiltration gallery is built below the fields to manage frequent rain events causing surface storage on top of the fields. This configuration, however, will increase construction cost. In combination, Sites 7 and 8 provide very significant opportunity, similarly does Site 1 and 2 in combination.

This assessment indicates that significant opportunities exist to implement communal detention ponds to address the erosion problem in at least Horn Creek. But most of the highest valued candidate sites are not owned by the City and some have environmental sensitivity. Before the viability of any site can be confirmed, preliminary engineering, property negotiations, and environmental and geotechnical stability assessment reviews are required.

Few opportunities currently exist to protect Boa Brook, unless the City acquires currently built property or seeks to implement costlier underground storage within road corridors or roadside swales, rain gardens, etc.

9.7 Lowland Storage for Willband Creek and Matsqui Prairie

The City has noted perceived changes to the frequency and extent of flooding in some portions of the Willband Creek floodplain and downstream of the Prairie Street Creek sub-catchment. However, modeling demonstrates that increased frequency of flooding should not relate to land use changes. The hypotheses for perceived increased flooding are;

1 The climate change trend of increased winter precipitation is increasing runoff volume and frequency.

2 Sedimentation and vegetation build up in watercourses is reducing the ease of water conveyance and causing the floodplain to activate more frequently.

And the predicted increase in floodplain water levels into the future are more a direct influence of climate change than re-development. The maximum water levels, whether the Willband Creek floodplain or Mill Lake, are heavily governed by downstream boundary conditions, which are dependant on the operation of the Mill Lake outfall and the performance of the Matsqui Prairie system downstream of Clayburn Road.

Dredging and removal of vegetation in existing watercourses within the floodplain will be a challenge from an environmental regulation perspective, however may be possible. Increased capacity through creation of new features, done in a manner that expands habitat, is also an option.

The City has expressed interest to install a sediment trap and increased flood storage within the lowland portion west of Highway 11. Potential candidate sites for management ponds or sediment basins are presented in **Figure 9.5**. The greatest benefit for improved flood storage will be realized by building new storage on the fringe (in the shallows) of the floodplain. But any new facility would need to avoid interactions with the landfill. While some opportunity may exist for City lands fronting Valley Road, greater hydraulic benefit will be realized if placed on property south of the landfill owned by the Fraser Valley Conservancy (Conservancy). The effective size of a facility at this location, and its cost benefit, is premature to state at this time because its performance will be governed by the long-term performance of the downstream Matsqui Prairie drainage system. During the public consultation stage of this ISMP, conversation occurred with the Conservancy who expressed concern for an urban settlement management facility being considered on their land, since their mandate is for habitat. The intent of any new facilities would be to also meet habitat objectives. It is recommended that the City reach out to the Conservancy seeking a collaborative partnership to explore designs that could meet multiple objectives.

The City has intent in 2020 to undertake a Phase II Matsqui Prairie Floodplain Study which is to look at improving lowland performance. It is therefore recommended that planning of a new management facility occur in concert with that study. The City may elect to initiate dialogue with the Conservancy early to discuss possibilities and limitations ahead of technical analysis.

9.8 Tree Canopy and Landscaping

Trees and landscaping in an urban setting have been proven to offer many hydrologic, environmental, and social benefits. The current tree canopy in the CCNP and HDNP areas is extremely low. Aside from infiltration, increasing the tree canopy and other forms of landscape will expectedly offer significant rainwater retention through evapotranspiration. In addition, trees and other forms of plants will also assist with water quality treatment. Tree canopy and minimum landscape standards for both private and public lands is strongly encouraged for beneficial rainwater management.

Infrastructure Summary of Recommendations:

1 Build a priority-based capital program for infrastructure not meeting criteria.

2 Explore candidate sites for communal ponds that may arrest erosion in Horn Creek and Boa Brook. Further evaluate these against the diversion option identified in 2009 and discussed herein.

3 Proceed with a design process for the redirection of City sewers to Montrose Avenue through the Historic Downtown to direct City flows out of private lands. Require private lands to reconnect during redevelopment.

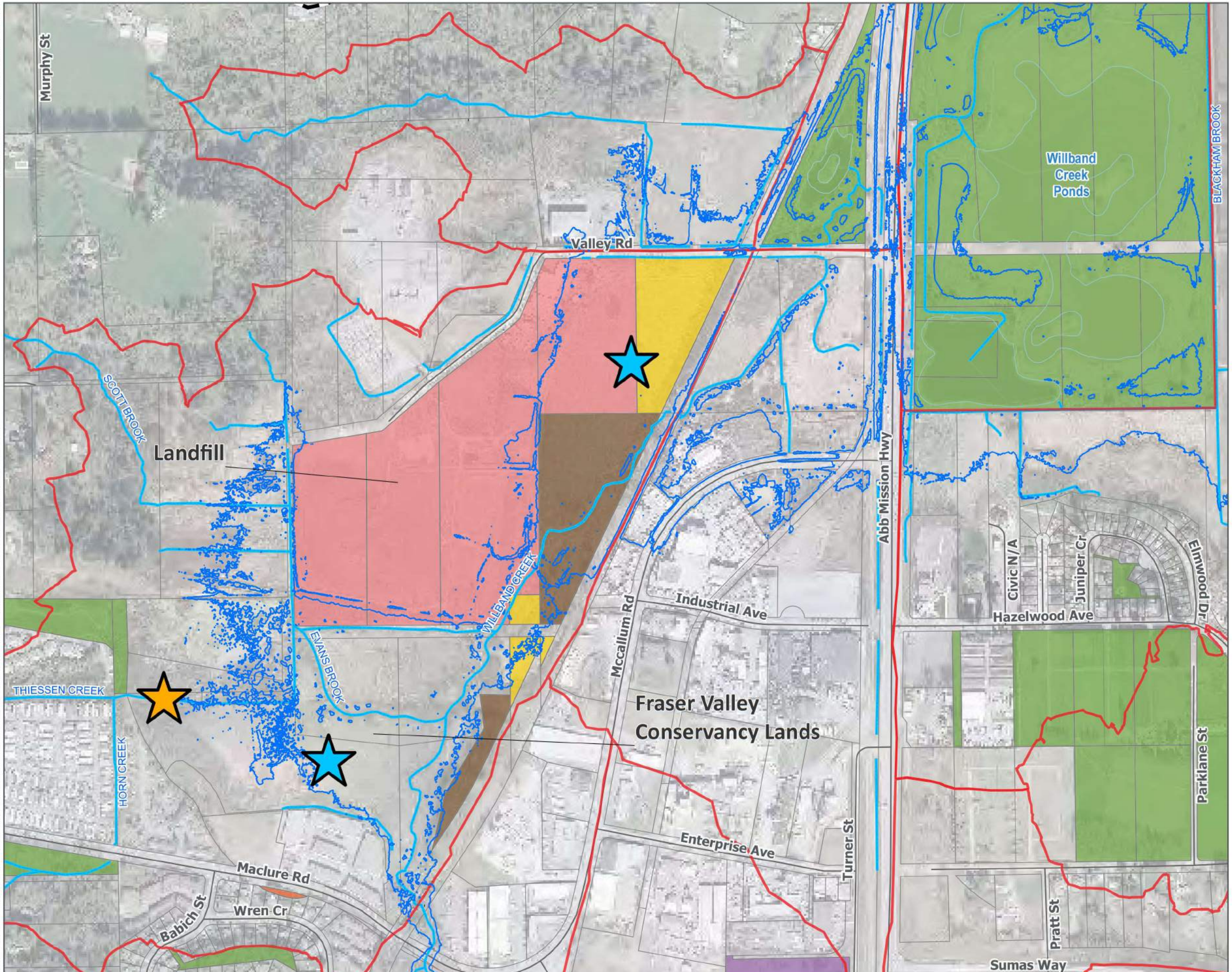
4 Conduct a condition assessment of the trunk sewer downstream of Ravine Park (high priority), then as the results dictate, conduct a study to confirm the viability and cost effectiveness of creating on-line temporary storage within Ravine Park.

5 Implement source controls at Civic sites such as the parking lot at Five Corners and the Municipal Hall site to demonstrate leadership in source controls, however these facilities will not change the performance of local storm sewer conveyance in a design event.

6 Explore a lowland detention pond in the lowlands west of Highway 11 as part of the Phase 2 Matsqui Prairie Drainage Study. Seek collaboration with the Fraser Valley Conservancy.

7 Implement stormwater source controls to the degree possible for all future developments.

8 Develop necessary programs and regulations to increase the tree canopy in the City Centre and Historic Downtown area.



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Willband Creek
Integrated Storm Water
Management Plan

Potential Lowland Basins

Legend

- Potential Storm Basin
- Potential Sediment Trap (with Property Aquisition)
- Maximum Future Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Creek

City Land Types

- General Municipal
- Parks (Dedicated and Undedicated)
- Road unconstructed
- Utility
- Vacant
- Road
- Parcel

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 200
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:6,000 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
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URBAN systems

FIGURE 9.5

10 ENVIRONMENTAL OPPORTUNITIES

There are several opportunities available to the City to improve the habitat value in the Study area. However, several constraints are associated with each of them. Discussion is provided below, with opportunity locations shown in **Figure 10.1**.

10.1 Riparian Infill

Riparian infill consists of the installation of native vegetation in areas currently lacking riparian vegetation. In particular, this consists of the Willband Creek lowlands north of Maclure Road. Native vegetation would significantly improve habitat for both aquatic and terrestrial species. However, several drawbacks are associated with this opportunity.

These include:

- Expense – the cost associated with both the initial installation and the ongoing maintenance, particularly in areas dominated by reed canary grass, can be prohibitive.
- The presence of the BC Hydro right-of-way on Lower Willband Creek precludes the installation of tree species; and
- Some landowners may be reluctant to implement an infill program if it is seen as reducing future development or redevelopment potential. The City may wish to consider financial incentives to address this concern. The City could also require some land be dedicated to riparian enhancement through their Streamside Protection and Enhancement bylaw.

10.2 Fish Access Improvement

Several culverts in the watershed (e.g., the crossing of Horn Creek at Trafalgar Street) may restrict access for fish to upstream reaches. This can be addressed through replacement with a properly sized and situated culvert that promotes access. Culverts can also be baffled to improve access. Fish ladders could also be installed to improve access to existing culverts. Weirs can also be installed to backwater culverts for improved accessibility. Constraints for these options include:

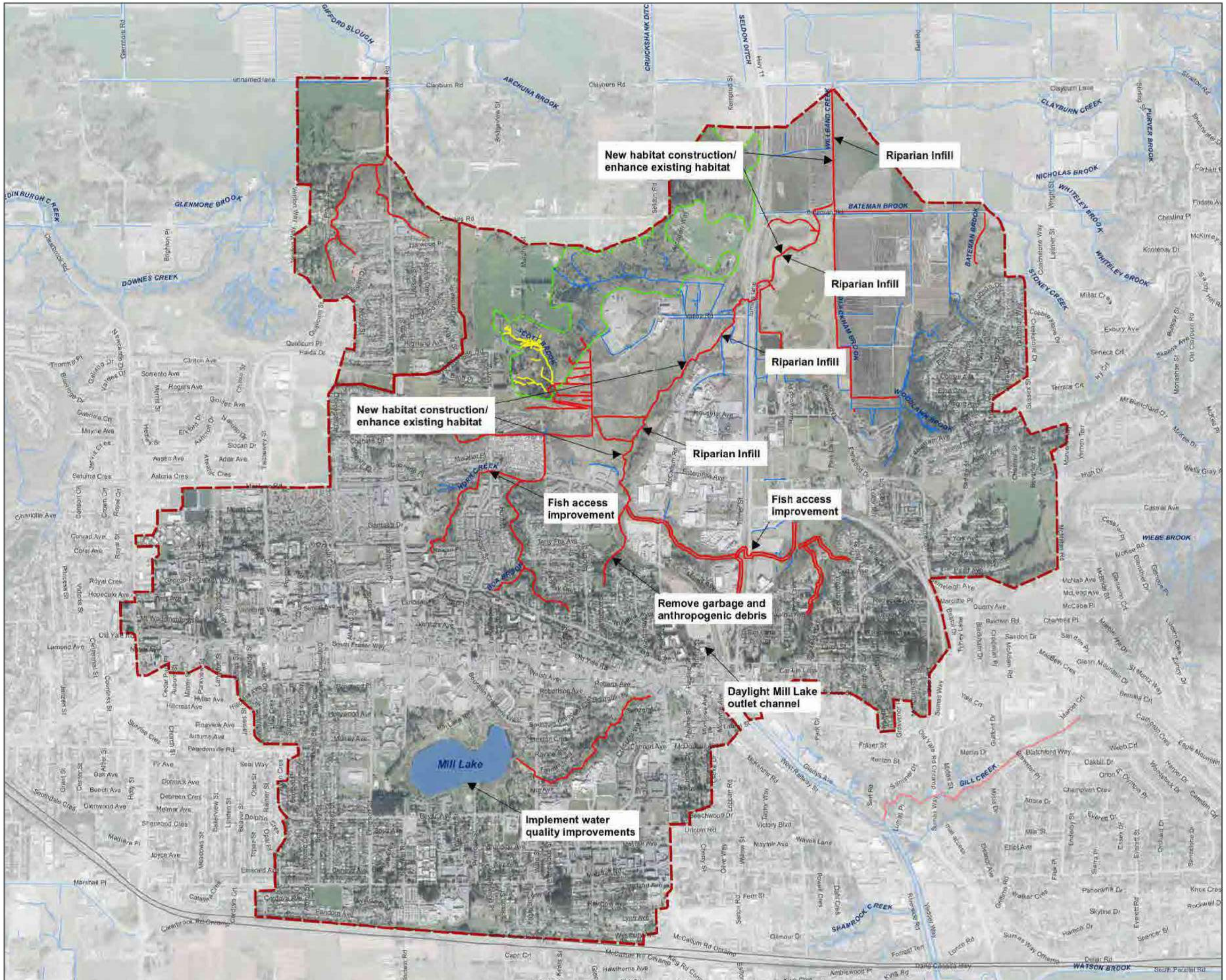
- Expense – this would be of relevance for long culverts with significant cover; and
- Baffling, ladders and weirs can restrict flow capacity. An engineering assessment would be required to determine if this would be possible.

The City would also need to consider the value of replacing or modifying culverts where barriers preclude significant fish access.

10.3 Habitat Construction

Habitat could be constructed in areas where adequate land is available, such as on Lower Willband Creek. This could include instream enhancement such as the placement of log cover structures or the creation of offline pools. Constraints include:

- Land acquisition may be required;
- Construction of new habitat can be expensive; and
- Offline pools can lead to localized increases in water temperature if not adequately buffered by riparian vegetation.



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Willband Creek Integrated Storm Water Management Plan

Environmental Opportunities

Legend

FISH CLASSIFICATION

- Class 'A' - Fish-bearing watercourses with permanent (i.e. flow for >6 months) water supply.
- Class 'A(OW)' - Lowland watercourses with permanent (i.e. flow for >6 months) water supply as a result of irrigation infrastructure. Watercourses are primarily utilized by salmonids during the overwintering period, as summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species may be present year round.
- Class 'B' - Watercourses that provide a significant source of food, nutrients and/or cool water supplies (i.e. groundwater) to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence. Permanence is unknown.
- Creeks, Streams, Channels with Unknown Classifications

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0 200 400 600 800 Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:22,000 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- Dillon (2016-18)

DILLON CONSULTING

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FIGURE 10.1

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 10-1 - Environmental Options (11x17)

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10.4 Instream Maintenance

The removal of garbage and other anthropogenic debris (e.g., the Western Tributary on Willband Creek) would serve to improve water quality. The primary constraint for this option is that it is an ongoing requirement, although it can be comparatively inexpensive.

10.5 Channel Daylighting

A significant habitat benefit could be realized through the daylighting of that portion of the Mill Lake outlet channel currently enclosed within the storm sewer system (noted on Figure 10.1). A direct benefit would be realized through the creation of approximately 900 linear metres of new channel which could be constructed with a high degree of complexity and planted with a diverse assemblage of native riparian vegetation.

An indirect benefit would be the creation of access for fish that cannot currently reach the remaining channel due to the extensive length of the storm sewer system. In addition, any remnant population(s) of fish that may remain within the outlet channel would no longer be isolated and, as a result, would be much less vulnerable to extirpation because of an environmental incident (e.g., a spill).

It should be noted that there are several significant drawbacks to this potential opportunity. Land acquisition would be required along the entire length of any sections of daylighted channel, likely at a significant expense. Municipal infrastructure would also be impacted. Finally, the cost of design and construction would be substantial. As such, daylighting may not be practical.

10.6 Water Quality Improvements – Mill Lake

There are several options that could be implemented to improve water quality within Mill Lake. For example, the installation of oil/water separators at select locations within the storm sewer system could reduce the volume of hydrocarbons reportedly discharging to the lake. Mechanized aerators and/or water circulation devices would serve to increase DO levels in the lake to the benefit of aquatic life.

However, it should be noted that increased DO may also provide a benefit for the invasive largemouth bass reported to be present.

Another benefit would be the removal of accumulated sediment and organic detritus currently reducing water depth throughout much of the lake. Deeper water would serve to buffer the increased temperature typical during the summer months and would likely increase DO levels in the water column. However, as previously indicated, metals and hydrocarbons could have accumulated in the sediment, which many indicate the material is contaminated per the Environmental Management Act.

Any material dredged from the lake would need to be sampled to determine the extent of contamination. If contamination is confirmed, disposal at a designated facility would be required at a potentially significant cost per cubic metre. In addition, the excavation of sediment could mobilize existing contamination that may be present.

10.7 Integration of Habitat Features into Stormwater Controls

As referenced in Part 2, Projections for Future Conditions report, the integration of storm water controls in response to development and climate change is expected to have a significant contribution to protecting overall health of the aquatic habitat supported within the watershed. These controls may be implemented in a decentralized manner when sites redevelop. In areas where space is limited, such as the City Centre, a centralized control facility may be considered. In either case, these control facilities can be integrated with features to improve overall watershed health.

Habitat features, and enhancements could include the following:

- Biofiltration swales to improve water quality discharging from sites. The swales could be planted with instream vegetation and riparian vegetation for a food/nutrient contribution to downstream, fish-occupied reaches.
- Detention ponds could include a wetland component. Wetlands improve water quality and provide a food/nutrient contribution to downstream, fish-occupied reaches. Wetlands are also selectively used by some wildlife species including birds (red-winged blackbird, waterfowl), mammals (muskrats, beavers) and amphibians.
- Detention ponds can be designed to allow for fish access. The ponds can be incorporated with complexing elements such as log crib structures, boulder clusters, and large woody debris.

However, detention ponds described above area more suitable for lower areas of the watershed where infiltration potential is low to medium. Where infiltration capacity it high, it may not be realist to sustain sufficient water during the summer season to accommodate aquatic species. Detention facilities in the uplands likely need to be designed as ephemeral.

Environmental Opportunities Summary of Recommendations:

1 Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road.

2 Replace or modify stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street.

3 Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation (collaboration with Fraser Valley Conservancy).

4 Removal of garbage and other anthropogenic debris from watercourses.

5 Recognized to have significant challenges, however, review the practicality of daylighting a portion of ravine downstream of Mill Lake.

6 Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged.

7 Subject to item 6 above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake.

8 Recommend “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators.

9 Apply landscaped based biofiltration site controls wherever possible.

11 GEOTECHNICAL AND SOURCE CONTROLS

11.1 Geotechnical Ravine Erosion Assessment

The scope of this ISMP did not permit for an exhaustive inspection of all watercourse segments but was limited to select reaches where issues had been reported as concern by the City. Without a series of observations or extensive research it is not possible to provide a statement on how active these erosion sites are or what the long-term fate may be. It is recommended that the City implement an annual inspection program for all watercourses. It is recommended that the inspections occur in the fall or winter when leaves have fallen, and sites are most visible.

As presented previously, 13 sites of observed channel erosion were reported by Thurber Engineering as part of this ISMP. Of the sites observed, two sites on Horn Creek were identified as "high" risk because of their proximity to infrastructure and should therefore undergo a comprehensive assessment and establishment of mitigative solutions. These sites are:

1 A pedestrian bridge and aerial pipe crossing Horn Creek (Site Horn-06) – Continued erosion will undermine the bridge abutments and pipe supports.

2 Approximately 50 m downstream of site 1 above (Site Horn 07). – Retrogressing slope will undermine the path and possibly houses. It is recommended at this site that an arborist be engaged to assess the safety of trees.

There were an additional seven (7) sites identified by Thurber as medium risk. At these sites the erosion is generally significant but does not pose a risk to adjacent infrastructure and is likely to progress somewhat more slowly. It is recommended that these sites be inspected more comprehensively, and a mitigation strategy developed. However, these sites have less urgency than the two high risk sites noted above.

The Prairie Street Creek sub-watershed was specifically added to the Willband Creek ISMP because of the City's interest in erosion concerns. Of the portions reviewed by Thurber, only a single site was identified, and as low risk. In addition, hydrologic assessment indicates that with the application of source controls, increased risk of erosion should be successfully managed. However, if no controls are implemented through future redevelopment, climate change may pose gradual increased risk over time. As noted above, it is recommended at this time that the City simply monitor the creeks on an annual basis to track changing conditions.

11.2 Infiltration Systems and Source Controls

Soil infiltration potential mapping was presented earlier. To reiterate the conditions, soils in most of the upland areas where most redevelopment is expected are characterized as rapidly to well drained. But the underlying aquifer is classified by the Province as being highly vulnerable to surface contamination. As such, while infiltration should be promoted from a hydrologic perspective, the siting and design of infiltration facilities should consider water quality.

The City's current Development Bylaw engineering and standards (Schedule F, Section 8 – Infiltration Systems) note that "Infiltration Systems in Commercial, Institutional and Multi-Family Developments are intended for runoff from roof areas only. Rooftops draining to an infiltration facility may not be used for storage of materials which may contaminate or pollute the run-off. Runoff from all other areas may be permitted to infiltrate provided groundwater protection measures and strategies are provided to the satisfaction of the engineer".

For the above noted land uses, pavement represents a significant portion of the sites and not applying infiltration measures to those areas will make them unlikely to achieve the criterial targets.

The City's current Development Bylaw engineering and standards (Schedule F, Section 8 – Infiltration Systems) further states "Rock pits/drain wells shall be used for single family infill lot Development or replacement or reconstruction of existing homes unless otherwise recommended by a geotechnical Engineer. The rock pit/drain well shall be designed by a geotechnical engineer and sized to store and infiltrate a 1:10 year rainfall event." Though not explicitly stated for rock pits/drain wells, the need for water quality treatment should also apply.

To meet the City criteria, infiltration systems may need to be coupled with temporary storage depending on the site-specific soil infiltration rate and the footprint area of the proposed infiltration system relative to the impervious area draining to it. The specific combination of infiltration surface and storage will need to be determined by the designer.

The Bylaw also provides for roadside swales, but Schedule F - Section 8 of the Bylaw notes that "*swales may be used on a **rural** highway for road drainage at the discretion of the Engineer*". The Bylaw then requires a minimum of 150 mm of topsoil lining the roadside swales. Special criteria will be needed to recognize and permit roadside swales within the urban areas.

Paved surfaces (roadways and parking lots) represent a significant source of runoff within the high density urban areas. There are positive merits to infiltration systems for these areas, however there must be an elevated attention to water quality treatment prior to infiltration. With this said, such systems should be prohibited in high pollutant risk sites such as gas stations, auto wreckers, automobile service stations or other sites involving known pollutants harmful to groundwater. This is not unique to the Willband watershed and is a common restriction in many municipalities.

It is expected that to protect a high vulnerability aquifer, runoff treatment should involve media filtration, either in the form of amended landscape growing media or with proprietary media filtration devices. Basic oil / grit separation is not considered adequate.

Within road corridors, perforated storm sewers offer some opportunity for infiltration, but these would also need to ensure sufficient treatment prior to runoff entering the sewer system. As such, roadside swales, raingardens and the like should be applied ahead of perforated storm sewers. Also, perforated sewers are intended only for low gradient systems and where the groundwater table is confirmed to be a minimum of 0.6 meters below the sewer elevation and infiltration rate appropriate.

The current Development Bylaw is relatively generic on design requirements of infiltration systems and leaves significant onus on the designer to make recommendations. It is not clear on what designs will satisfy the City.

The City has an established Storm Water Source Control Bylaw (Bylaw 2045-2011) that currently applies to CICP Lands and the Abbotsford Airport Lands and is a supplement to the Development Bylaw. Consistent with the recommendation made in the City's 2018 Master Drainage Plan update, it is recommended that this Storm Water Source Control Bylaw be adopted as a City-wide document. However, a review and potential amendments should be undertaken prior to a blanket adoption across the City. Further discussion regarding this is provided in Part 4 – Implementation.

To mitigate potential negative effects on slope stability, groundwater infiltration and recharge systems to be located within 200 m of a steep slope (i.e. greater than 25% grade) or ravine should have design input provided by a geotechnical engineer.

On a site specific basis, the recommended setback of the infiltration system from the crest of a slope should be determined by a geotechnical engineer and confirmed by a qualified professional. Local conditions, including history of instability and presence of groundwater seepage on nearby slopes should be considered. These professionals should review this report to provide regional context to their assessments.

Geotechnical and Source Controls Summary of Recommendations and Action Items:

1 Further develop a mitigation strategy for high risk erosion sites in ravines.

2 Conduct annual observation and evaluation of geotechnical stability in creek ravines.

3 Adopt the Stormwater Source Control Bylaw City-wide and not limit it to CICP and Airport Lands. A review and potential amendments are recommended prior to blanket adoption.

4 Develop criteria and standards for the application of roadside swales or other form of control in urban streets.

5 Create a Development Permit Area for the application of infiltration system in proximity to steep slopes, under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose.

12 STORM SEWER CAPITAL PROGRAM AND PRIORITIES

There are several roadways within the Plan area that do not currently have storm sewers, and many other roadways that have storm sewers smaller than the City's desired 300 mm minimum size. As desired by the City, when identifying infrastructure needs for the future storm sewers have been added to the inventory to ensure all roads have sewers, and that all sewers meet the City's desired minimum size of 300 mm. However, there are many instances where existing storm sewers smaller than 300 mm have capacity to sufficiently meet long term needs. Therefore, the priority for replacement of these is low, and itemized separately.

Storm sewer improvements have been identified to satisfy the 1:10 year criteria, with exception to the trunk storm sewer part of the Mill Lake Ravine Park system which is to satisfy the 1:100 year criteria. Similarly, culverts crossing roadways, particularly major roadways, are recommended to convey the 1:100 year flows.

Infrastructure improvements are prioritized as follows:

- **Priority 1** sewers represent those expected to surcharge even with the broad application of on-site controls, therefore should form part of the capital plan in any case.

In the case of the trunk sewer on Montrose Avenue as part of the Mill Lake Ravine Park trunk system, there are two options to consider. Each need to be explored through predesign processes. One option is to fully reconstruct the deficient section of pipe for the major (100-year) flow, which is included in **Table 12.1** below. A predesign process would assess whether full replacement is in fact required, or whether performance could be improved with only a parallel supplemental pipe.

As discussed previously, the other option is to restrict flow at the inlet to the trunk sewer to 2 m^3/s and allow temporary flooding in the Mill Lake Ravine. A predesign study should assess the potential slope stability risks and potential impact to vegetation and habitat (both aquatic and terrestrial). Construction of this option would require both Provincial and Federal environmental approvals for instream works.

An important aspect of the decision for flow control is the physical condition and life expectancy of the existing trunk storm sewer. The City has not completed a comprehensive condition assessment; therefore, its condition is unknown at this time. This is considered critical infrastructure, and structural failure of this pipe, particularly the deep portion under Essendene Avenue, could be catastrophic. **It is strongly recommended that a complete condition assessment be undertaken as soon as possible along the length from the inlet at Ravine Park to the outlet near Morey Avenue; a total length of approximately 1,000 meters.**

It is also recommended that the City process with the rerouting of City infrastructure along Montrose Avenue south of Essendene Avenue, then to notify private property owners of the reconnection strategy when redeveloping. Thoughtful consideration to how the existing pipes through private property are to be abandoned is warranted and it will require collaboration among private property owners. Abandonment will need to happen sequentially from upstream to downstream, or as a combined single initiative. How they are abandoned, if not removed, will require professional guidance from a geotechnical engineer with consideration for both risk of structural failure of the existing pipes weighed against risk of groundwater piping of soils surrounding the pipe if the pipes are infilled. And whether removed fully or abandoned in place, guidance is required to assess and accommodate groundwater movement.

- **Priority 2** sewers represent those that will not meet criteria if no site controls are applied, however could be potentially eliminated by the successful broad application of site controls. These upgrades would be included in the capital plan for a conservative approach but may be deferred and their need confirmed through further monitoring and more detailed assessment.

- **Priority 3** sewers represent those that meet criteria, but that are smaller than the City's preferred 300 mm diameter. Also considered priority 3 sewers are new mains for roads that do not currently have sewers. These are highly discretionary changes, perhaps only done when opportunity arises through road reconstruction or development, or if condition assessment indicates existing infrastructure has reached the end of its life.

Based on the above, a summary of infrastructure improvements is listed in **Table 12.1**. A detailed inventory is provided in **Appendix F**. These improvements are graphically represented in a series of plates making up **Figure 12.1**. This program is based on capacity performance only and does not involve condition or operational issues. Note that the inventory of pipes specific to the City Centre Neighbourhood Plan and Historic Downtown Neighbourhood Plan are slightly different than those presented herein because both Neighbourhood Plan boundaries are beyond the Willband Creek watershed boundary. Only upgrades contained within the Willband Creek watershed boundary are presented herein.

In all cases, pipe upgrades have been inventoried to prevent surcharge in accordance with City criteria. If some amount of surcharging can be tolerated, the extent of pipe replacement would expectedly decrease. And to re-iterate, pipe upgrades **do** include a 10% factor for climate change.

Table 12.1 - Summary of Storm Sewer and Culvert Improvements

Priority – Reason for upgrade	Minor (10-year) Criteria	Major (100-year) Criteria
Priority 1 – Performance does not meet criteria with or without the application of site controls. These upgrades include upsizing a portion of trunk sewer downstream of Mill Lake Ravine Park, on the assumption that storage in Ravine Park is not provided.	3,572 m	180 m
Priority 2 – Performance does not meet criteria if site controls are not applied extensively. These upgrades include upsizing a portion of trunk sewer downstream of Mill Lake Ravine Park, on the assumption that storage in Ravine Park is not provided.	5,026 m	152 m
Priority 3 – Meet desired minimum main size, despite adequate performance of existing main.	10,821 m	0 m
Priority 3 – Provide a main where one does not exist.	15,133 m	0 m
Total	34,552 m	332 m

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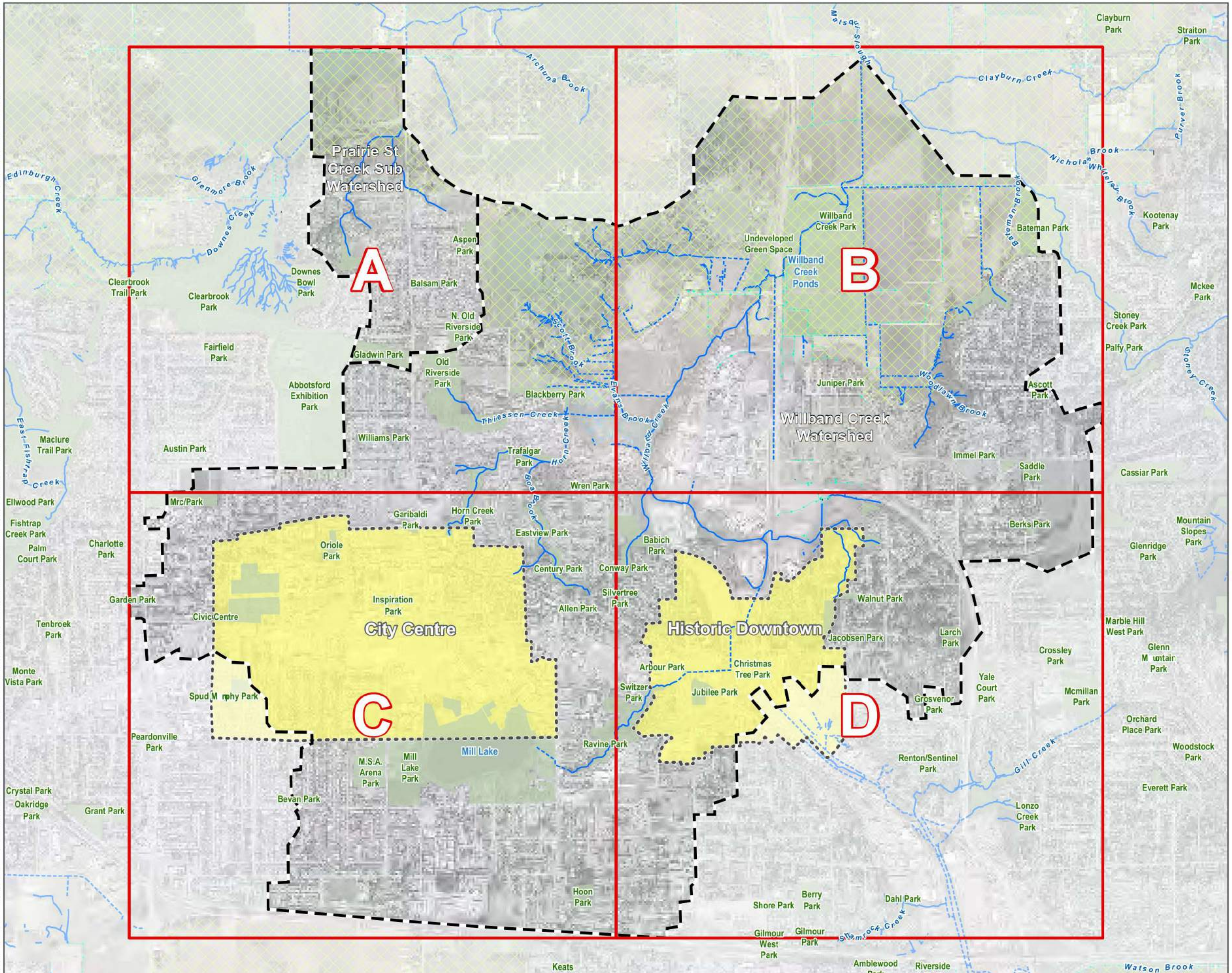
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-1 - Study Area Overview (11x17)



Willband Creek
Integrated Storm Water
Management Plan

Study Area Overview

Legend

- Map Index
- Willband Creek Watershed
- Neighbourhood Plan Area
- Agricultural Land Reserve
- Natural Watercourse
- Channelized Watercourse
- Ditch
- Park

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0 200 400 600 800
Metres

Coordinate System:
NAD 1983 UTM Zone 10N

Scale: 1:22,000
(When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
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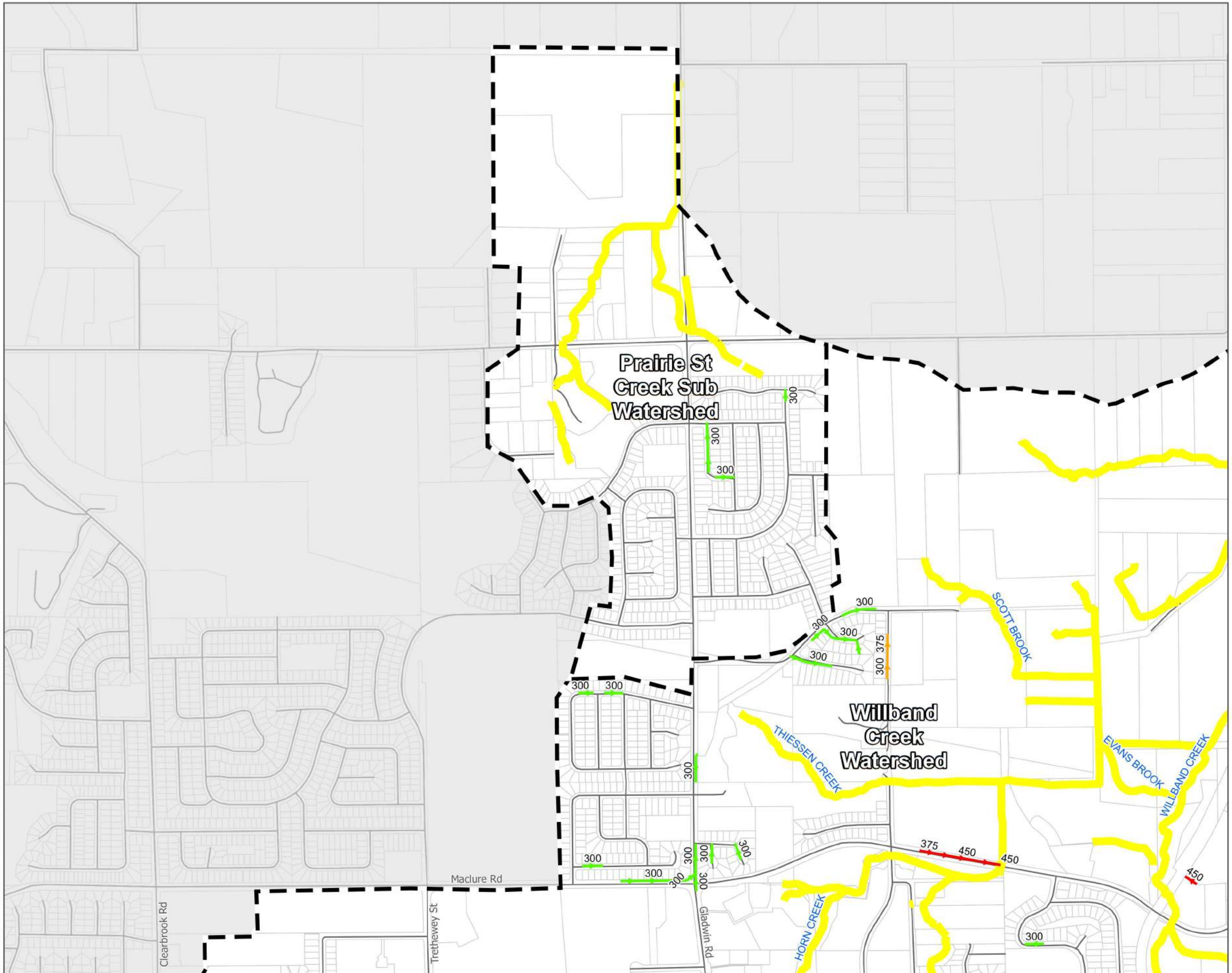
FIGURE 12.1



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Willband Creek Integrated Storm Water Management Plan

Storm Sewer Improvements

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

- Upgrade Priority 1
- Upgrade Priority 2
- Upgrade Priority 3
- New Main
- Major System

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0 200 400 600 Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

Data Sources:

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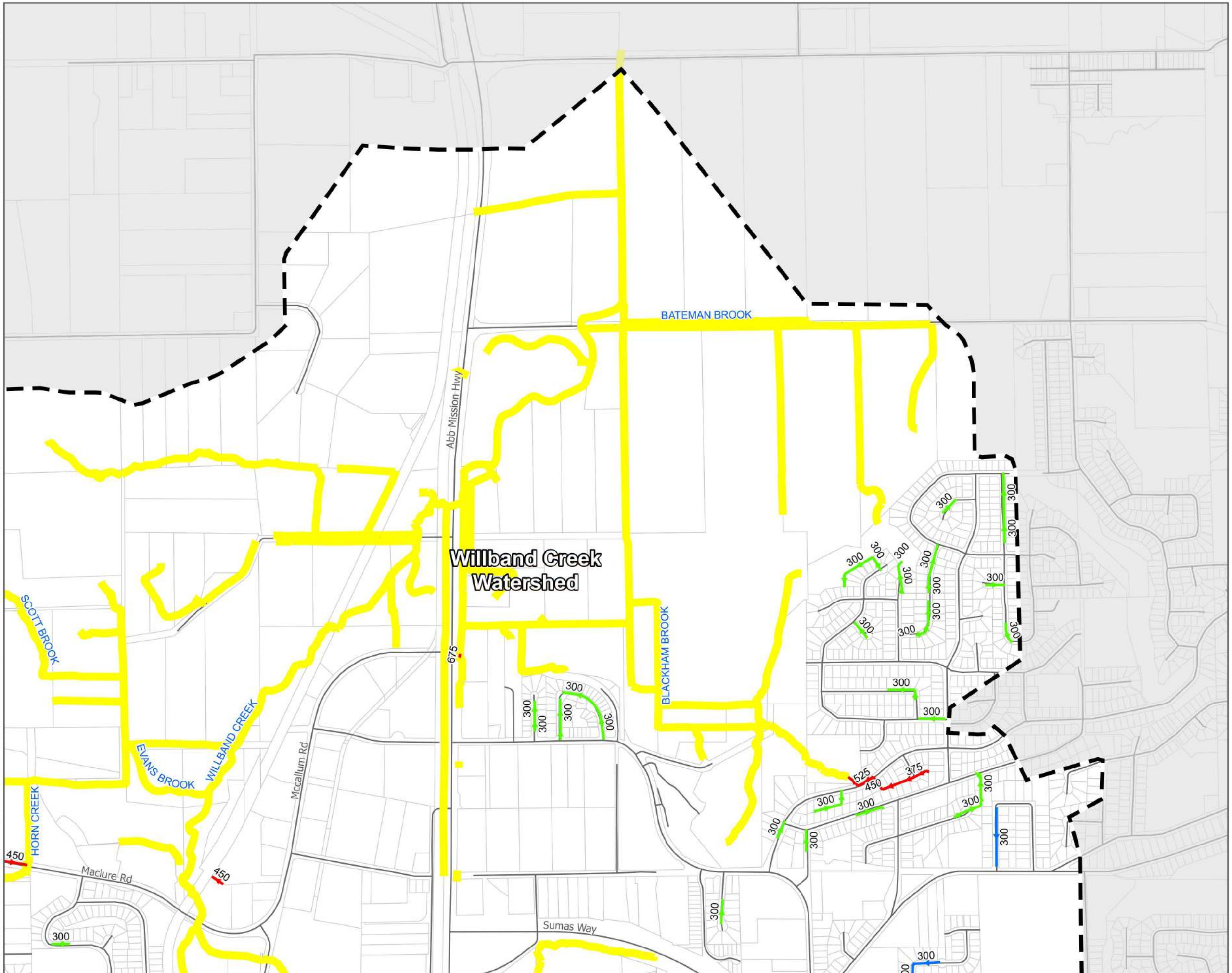
FIGURE 12.1A



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Willband Creek
Integrated Storm Water
Management Plan

Storm Sewer Improvements

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

- Upgrade Priority 1
- Upgrade Priority 2
- Upgrade Priority 3
- New Main
- Major System

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

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FIGURE 12.1B

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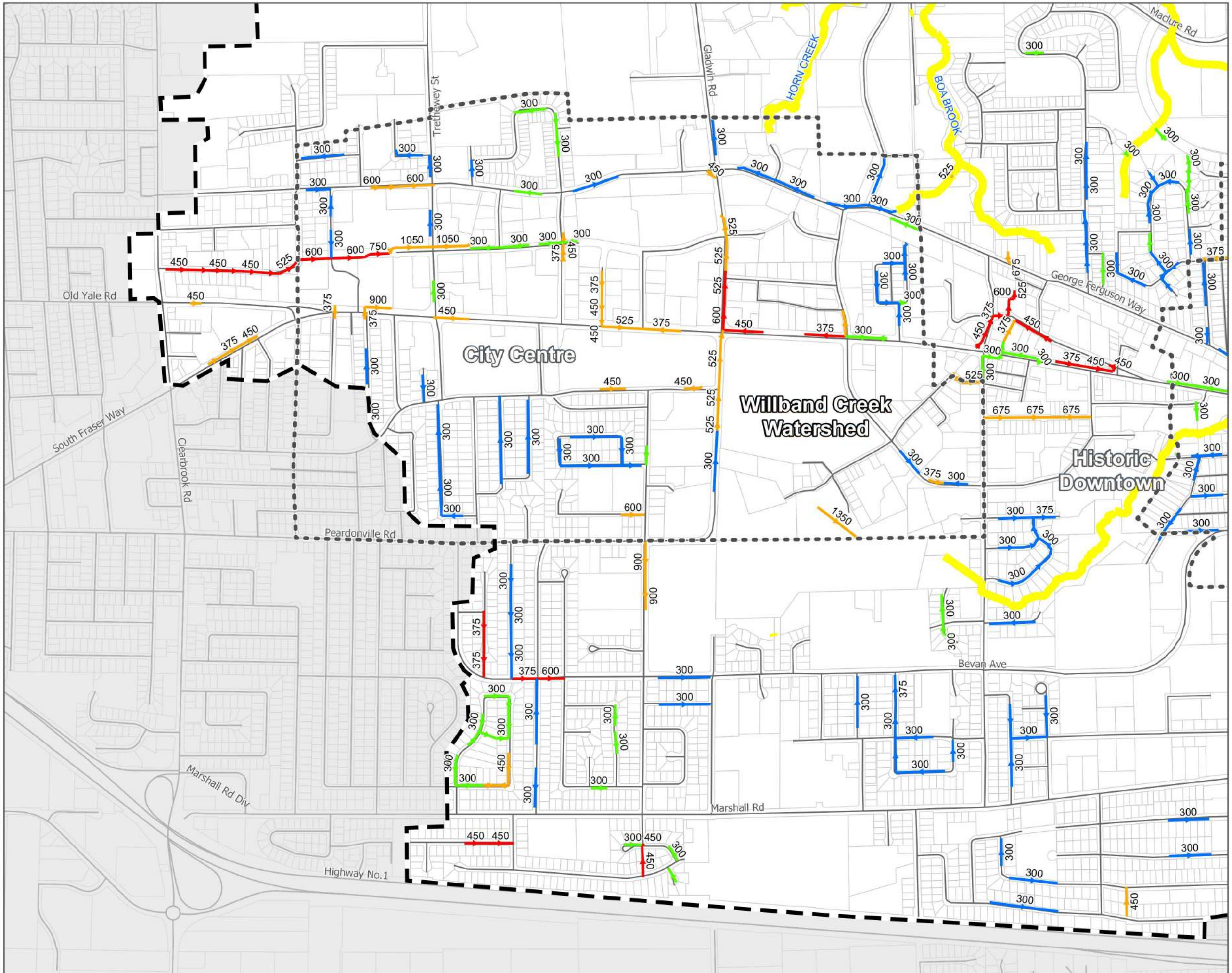
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-1 - Storm Sewer Improvements (11x17)



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

Storm Sewer Improvements

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

- Upgrade Priority 1
- Upgrade Priority 2
- Upgrade Priority 3
- New Main
- Major System

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

Data Sources:

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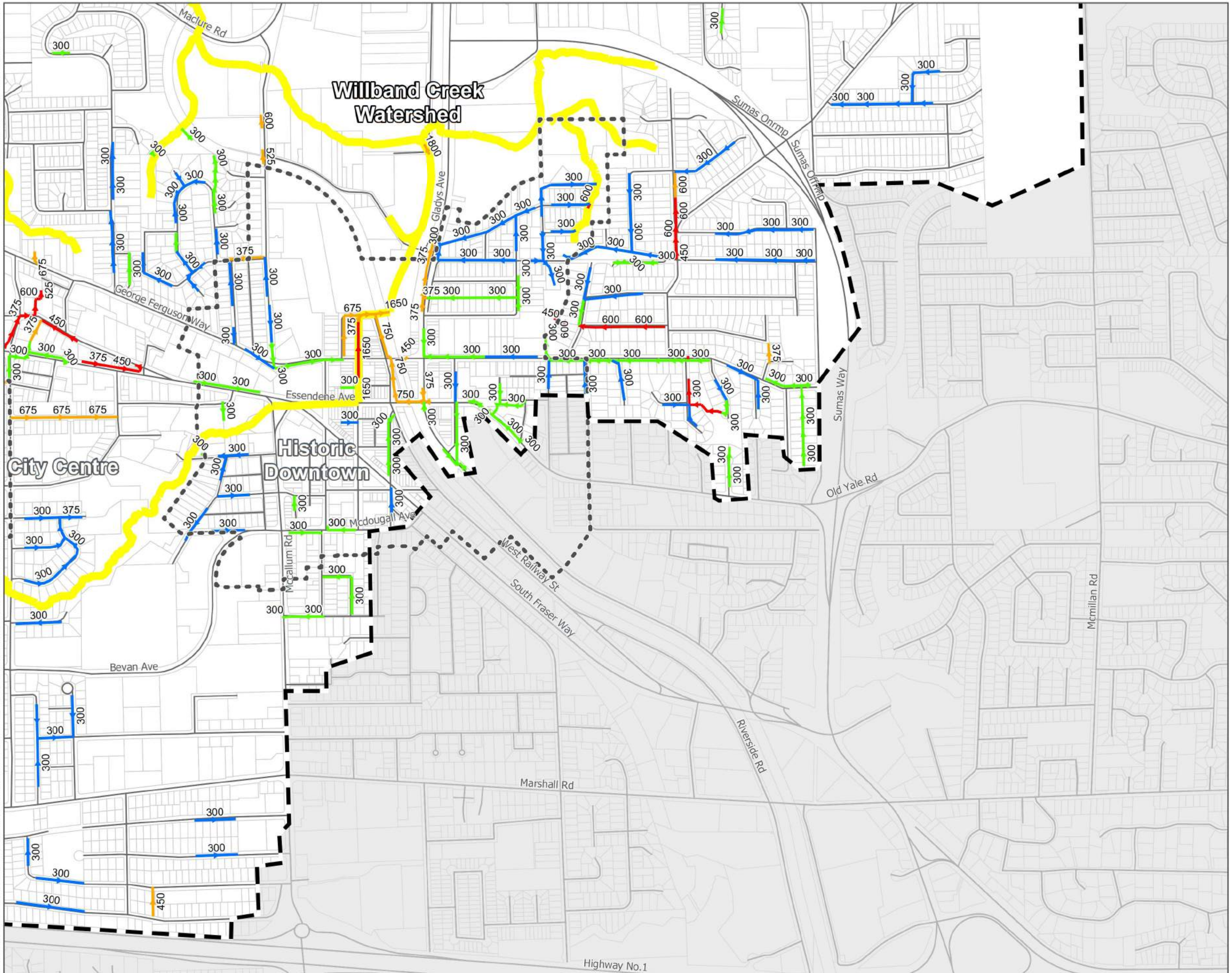
URBAN systems

FIGURE 12.1C



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Storm Sewer Improvements

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary

Upgrade Category

- Upgrade Priority 1
- Upgrade Priority 2
- Upgrade Priority 3
- New Main
- Major System

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Metres

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URBAN systems

FIGURE 12.1D

With exception to 23 meters of road crossing culverts, the remaining 100-year criteria pipe length (274 m in total) is associated with upgrade of the trunk sewer part of the Mill Lake Ravine Park system. These upgrades would be required without the application of detention within Ravine Park, but can be eliminated with storage in Ravine Park limiting its flow at 2 m^3/s.

As noted above, 8,930 m of storm sewer improvements (Priority 1 and 2) (26% of total) are deemed necessary to satisfy performance requirements assuming a conservative approach of there being no significant on-site controls being achieved. Of those, 3,752 m (10%) are deemed high priority in that performance deficiencies can not be resolved even with the application of site controls. This includes upgrade to the major 100-year trunk sewer from Mill Lake Ravine.

The remaining 25,954 m of priority 3 pipes are considered low priority and discretionary to be completed as opportunity presents itself during other capital improvement projects, redevelopment frontage improvements, or end of the life replacement of existing infrastructure.

12.1 Potential Upland Flooding and Major Flow Paths

Hydraulic performance under a 1:10 year event with identified conveyance upgrades are presented in **Figure 12.2**, while performance under a 1:100 year (major) event is presented in **Figure 12.3**. For both these sets of figures it is assumed conservatively that site controls are ***not*** successfully applied. Nodes (ie. manholes) are colour coded based on surcharging and the predicted volume of water that may flood to ground surface. As noted in the legend for **Figure 12.2 and 12.3**, flood loss volumes are presented in mega-litres (1 ML = 1,000 m^3). For both 1:10 year and 1:100 year, the clear majority of nodes (highlighted yellow) are not expected to flood or may flood less than 0.001 ML (1 m^3); all deemed very low risk. Nodes identified as potentially flooding under the 1:10 year event are associated with back-flooding from Mill Lake and detention ponds, not conveyance deficiencies, as all identified pipe upgrades are to satisfy the 1:10 year criteria, at minimum.

Conveyance improvements in the expansive lowland system have not been identified at this time because performance is significantly governed by the downstream Matsqui Prairie system which should have higher priority. Further consideration for lowland improvements is recommended through the City's Phase 2 Matsqui Prairie Drainage Study planned for 2019.

Flood loss volumes between 0.01 and 0.1 ML (10 to 100 m^3) are possibly significant, and flood volumes of 0.1 ML (100 m^3) or more are significant and warrant further investigation to assess potential impacts. Assessing the likely consequence of flooding at these locations extend beyond the scope of the ISMP and would need to be investigated as a separate initiative. For comparison and priority planning by the City, a set of **Figure 12.4** is also provided which demonstrates predicted surface flooding under the 1:100 year (major) event ***with*** successful application of site controls. By comparing the results of **Figure 12.3** and **Figure 12.4**, it can be seen that the successful application of site controls is substantial to reducing flood risk.

12.2 Detention Pond Modifications

- In **Figure 8.15** seven existing detention ponds were identified as not meeting current criteria based on the information available for this study. One of these ponds is predicted to have insufficient storage volume, and perhaps at this stage it will be unrealistic to expand it. The remaining six ponds are predicted to be under-optimized with the opportunity to improve performance through modifications to the control structure. It is recommended that these detention ponds undergo an optimization study. It would be advantageous to monitor water levels in each pond for a full winter season in advance of that study.

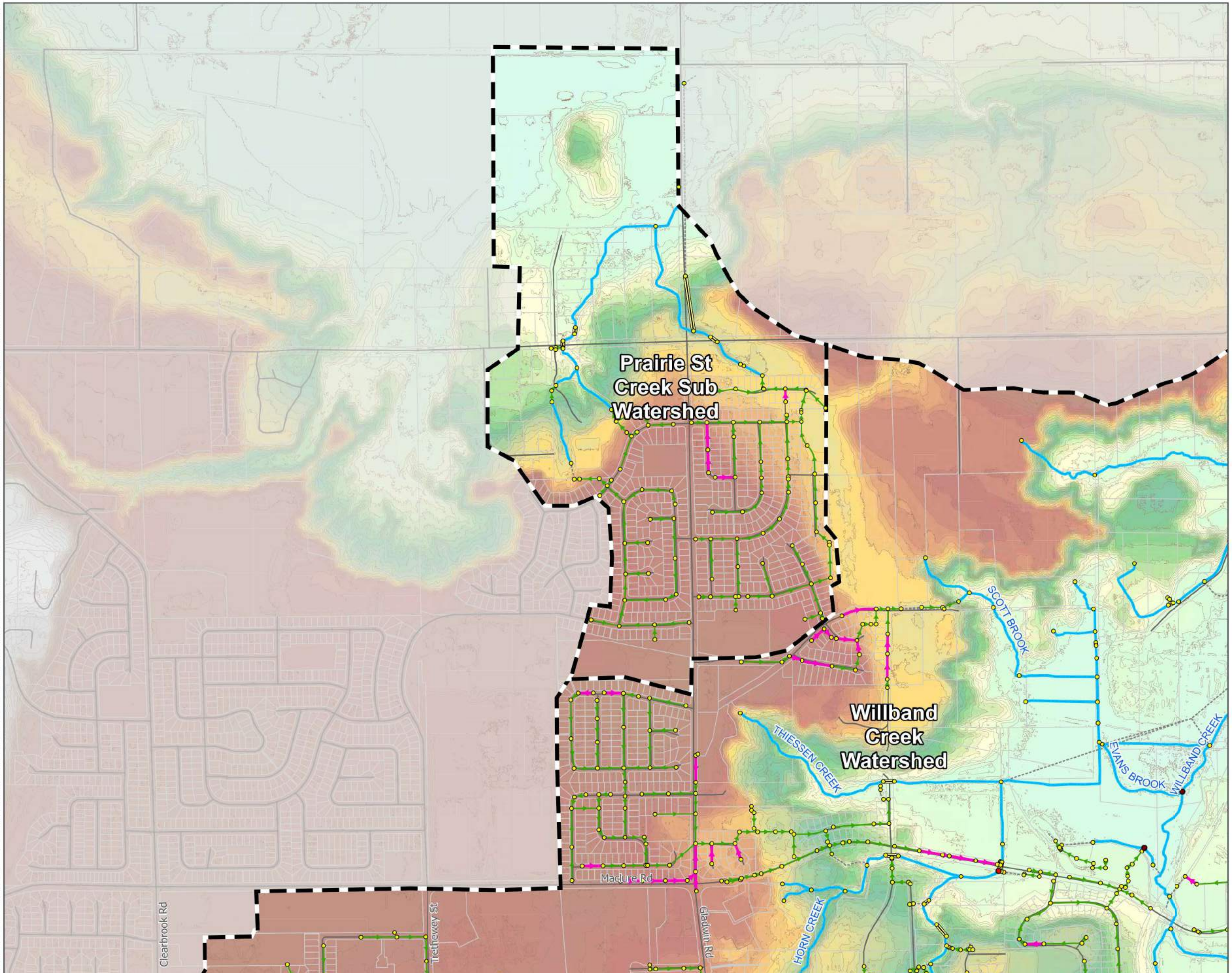
Storm Sewer Capital Program and Priorities Summary of Recommendations and Action Items

1 Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary.

2 Develop a strategy to redirect City infrastructure in Historic Downtown to Montrose Avenue and communicate service connection redirection and private sewer abandonment requirements to property owners (also flag these properties in the City data bases to ensure this requirement is not missed during any future building or development permit application).

3 Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted flood loss of 100 m^3 or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 m^3 and 100 m^3.

4 Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study.



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

**Future System Performance
(10 Year, Climate Change,
No Controls, Upgrades)**

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

North Vancouver
Vancouver
Coquitlam
Richmond
Surrey
Langley
White Rock
Abbotsford

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000
(When plotted at 11"x17")

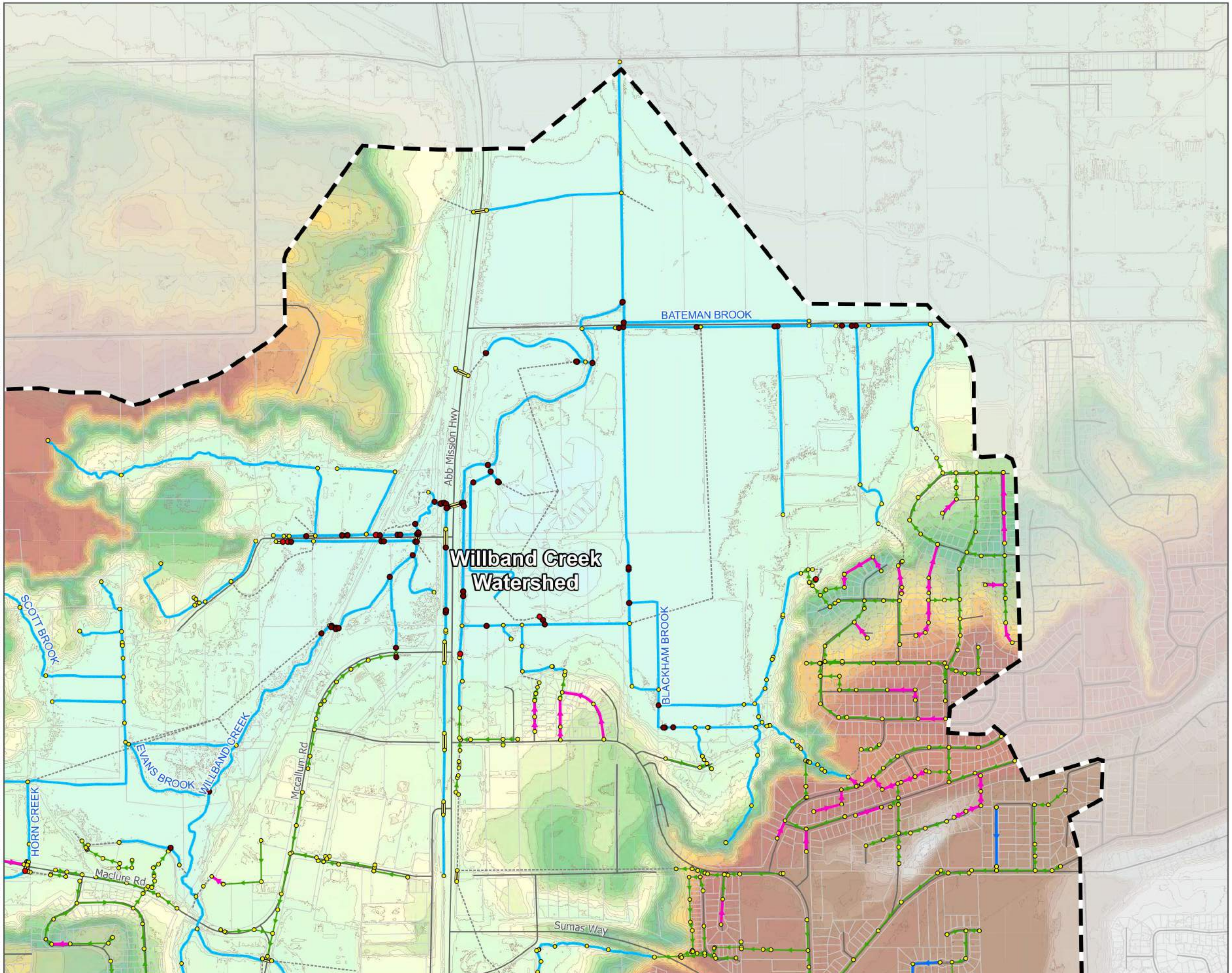
Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.2A



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Future System Performance (10 Year, Climate Change, No Controls, Upgrades)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

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Data Sources:

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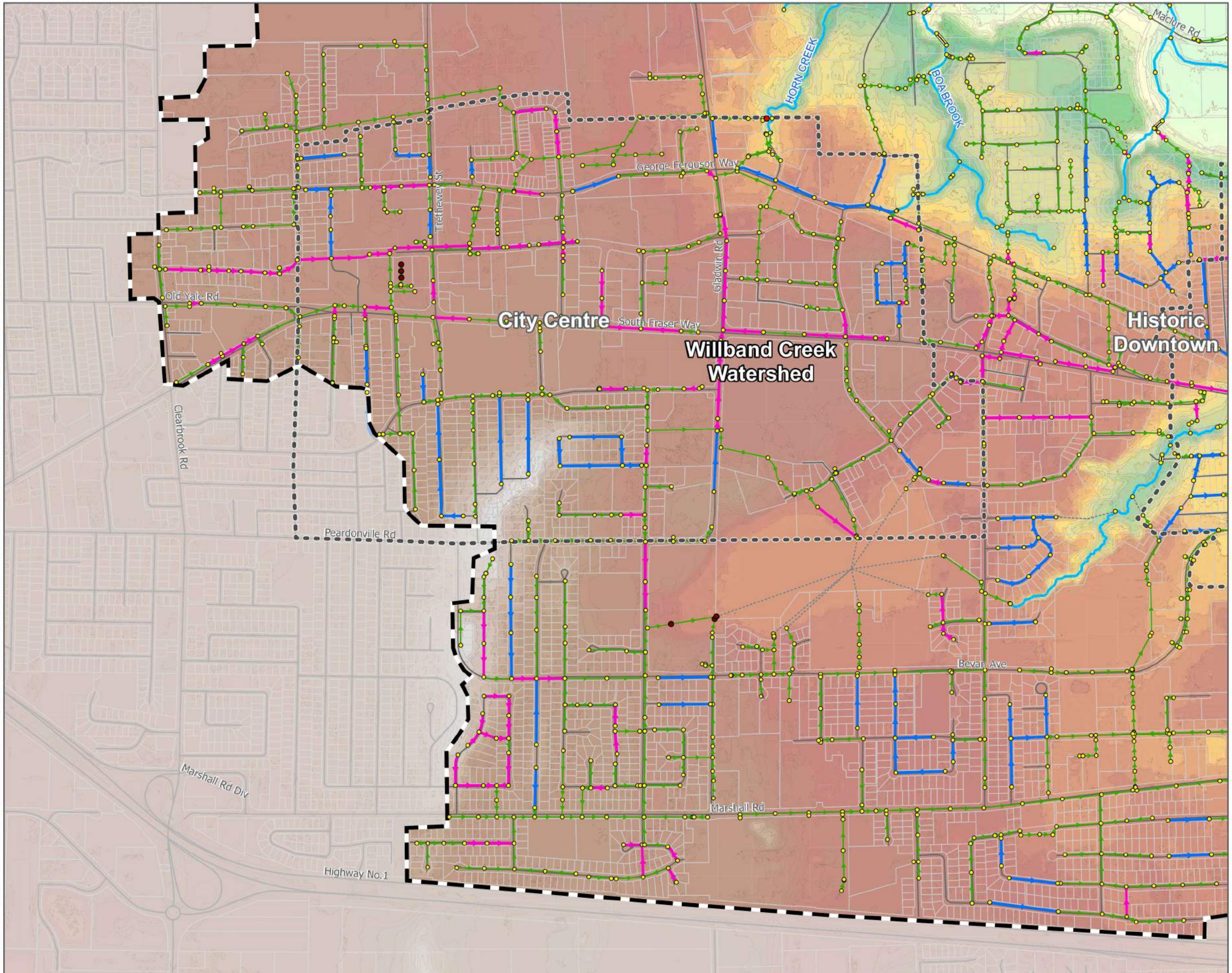
Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.2B



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Future System Performance (10 Year, Climate Change, No Controls, Upgrades)

Legend
- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)
- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

North Vancouver
Vancouver
Coquitlam
Richmond
Surrey
Langley
White Rock
Abbotsford

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

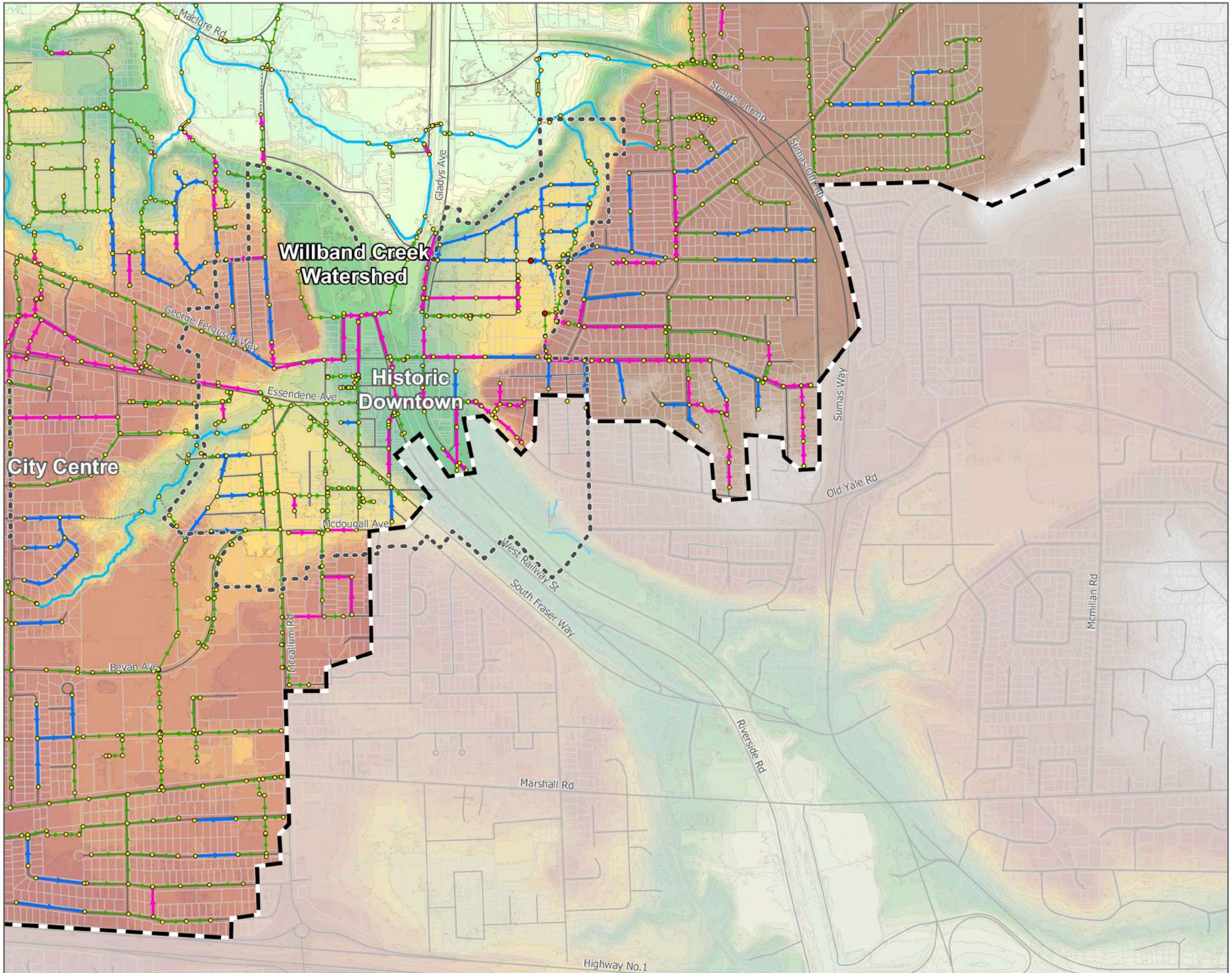
Data Sources:
- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoADVICE

Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.2C



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Willband Creek
Integrated Storm Water
Management Plan

Future System Performance (10 Year, Climate Change, No Controls, Upgrades)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

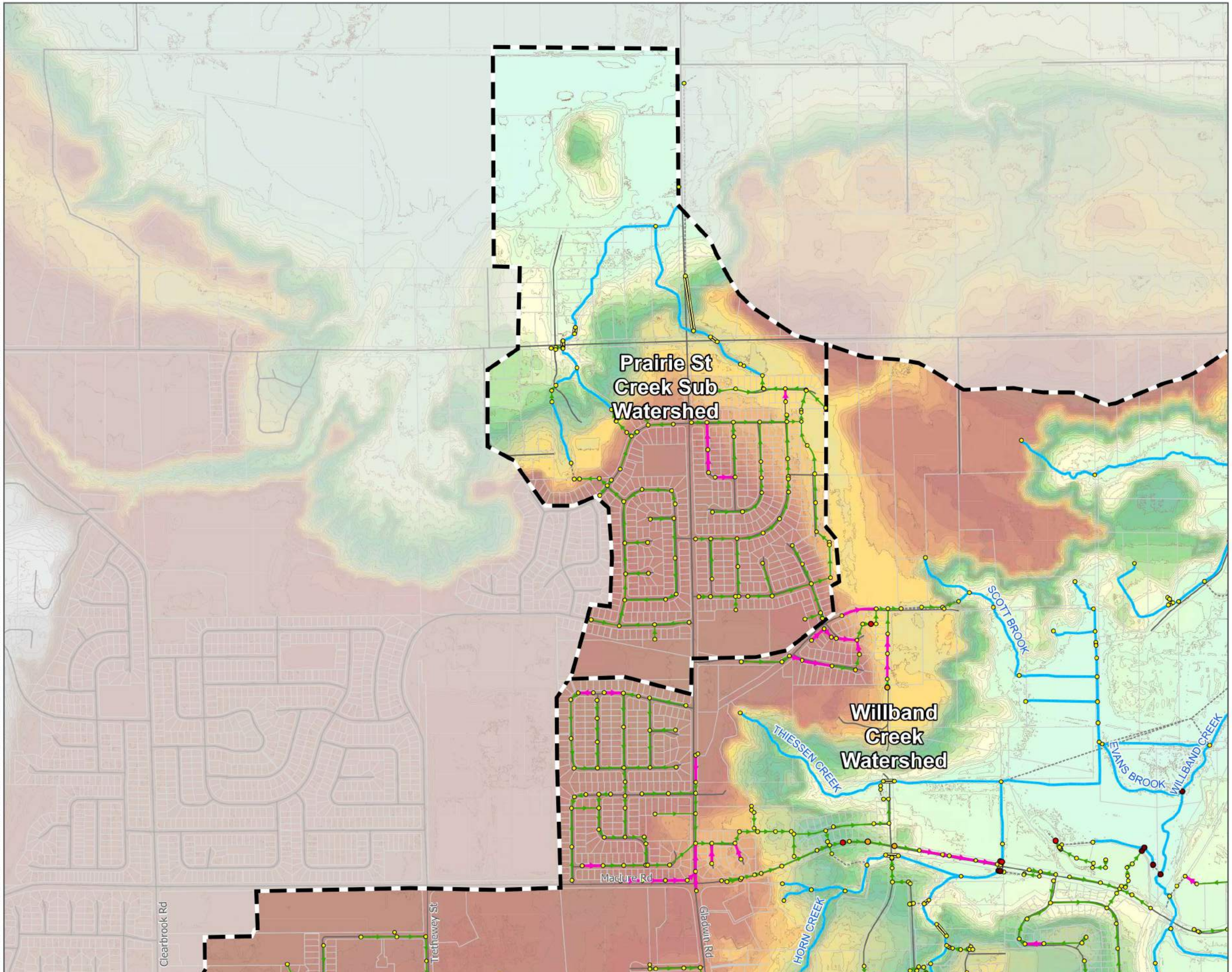
Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.2D



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

Future System Performance (100 Year, Climate Change, No Controls, Upgrades)

Legend

- Willband Creek Watershed
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoADVICE

Project #:	1790.0015.01
Author:	LP
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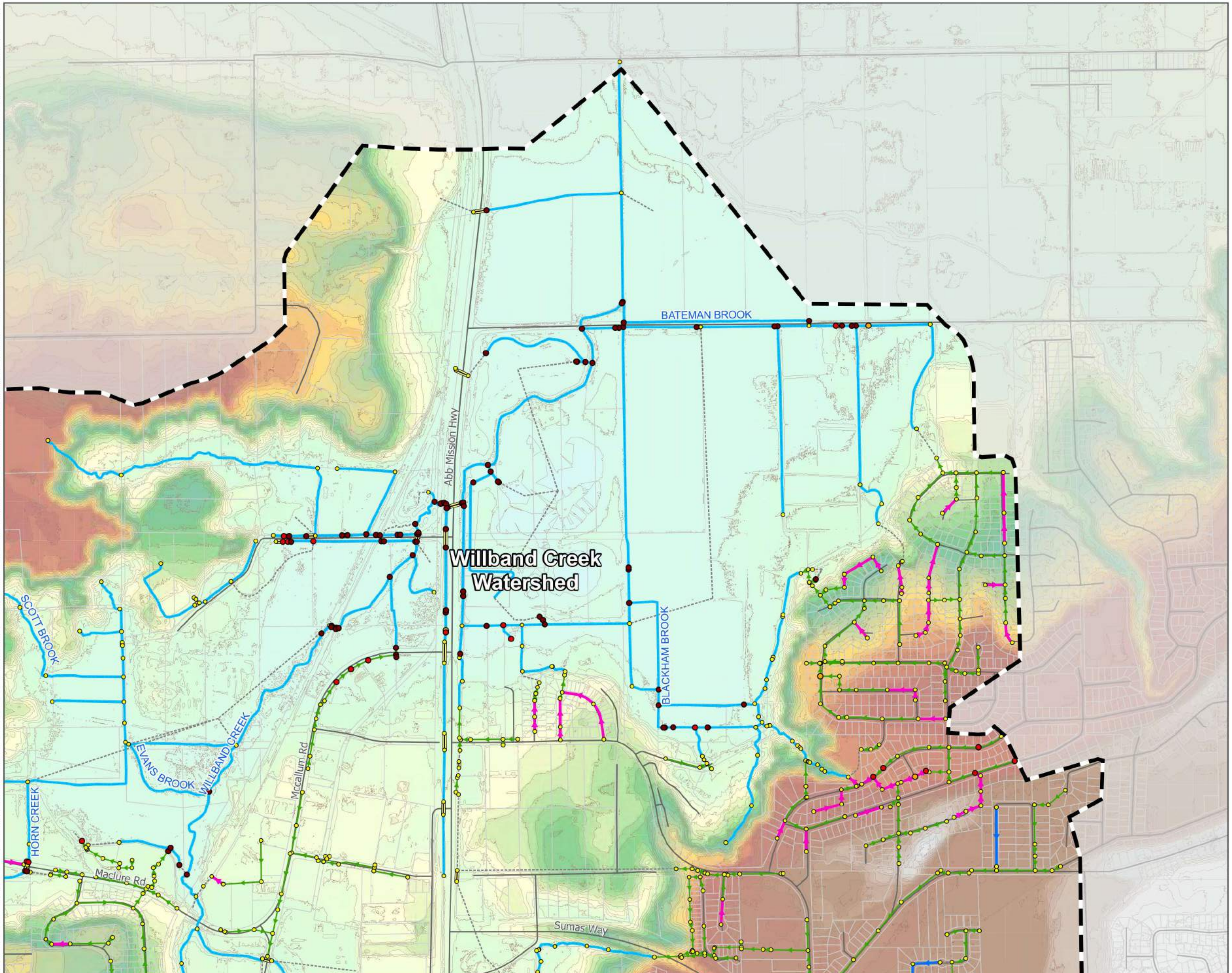
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.3A



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Future System Performance (100 Year, Climate Change, No Controls, Upgrades)

Legend

- Willband Creek Watershed
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System:
NAD 1983 UTM Zone 10N

Scale: 1:11,000
(When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
Author:	LP
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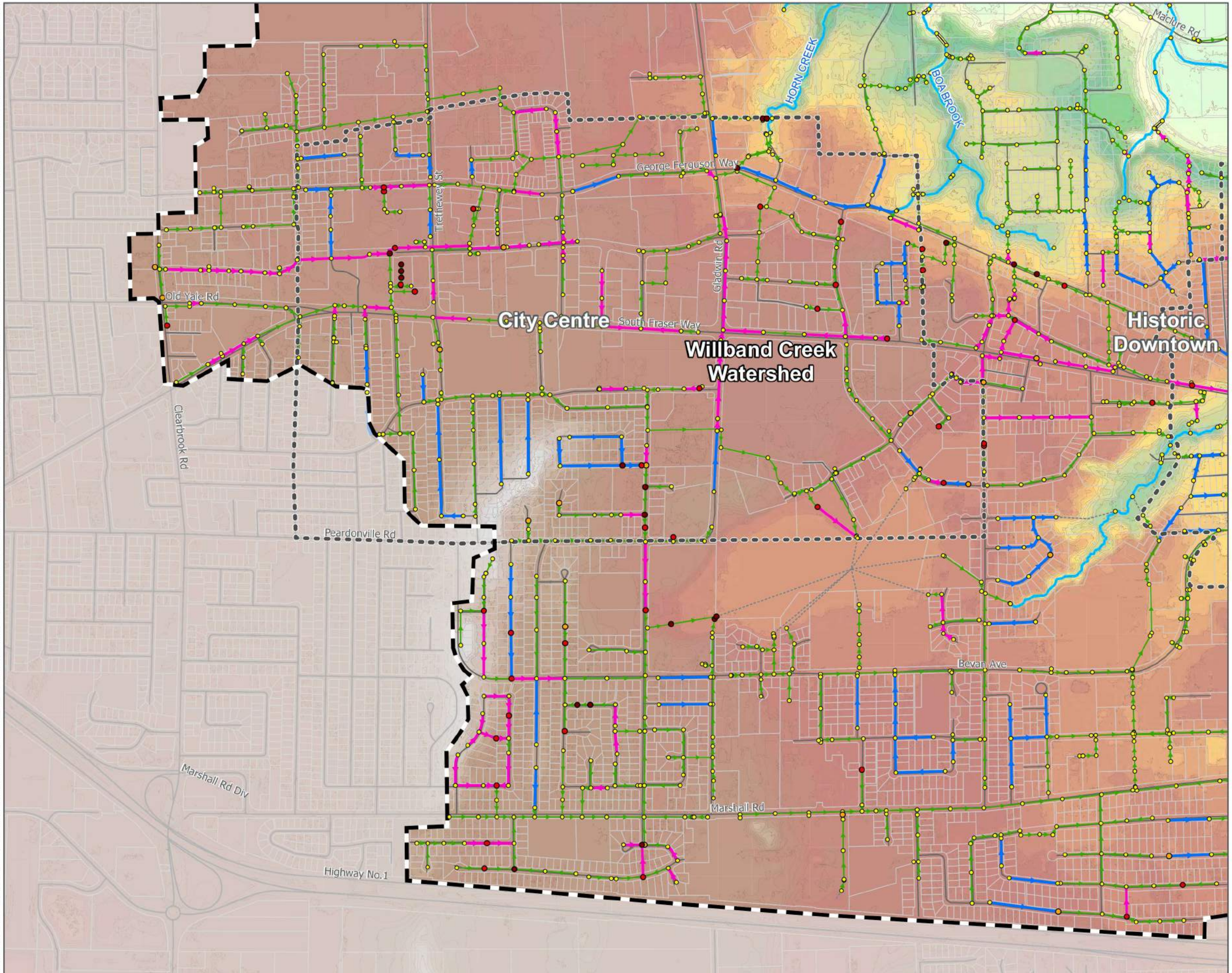
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.3B



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

Future System Performance (100 Year, Climate Change, No Controls, Upgrades)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Neighbourhood Plan Boundary Study Area
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

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URBAN systems

FIGURE 12.3C

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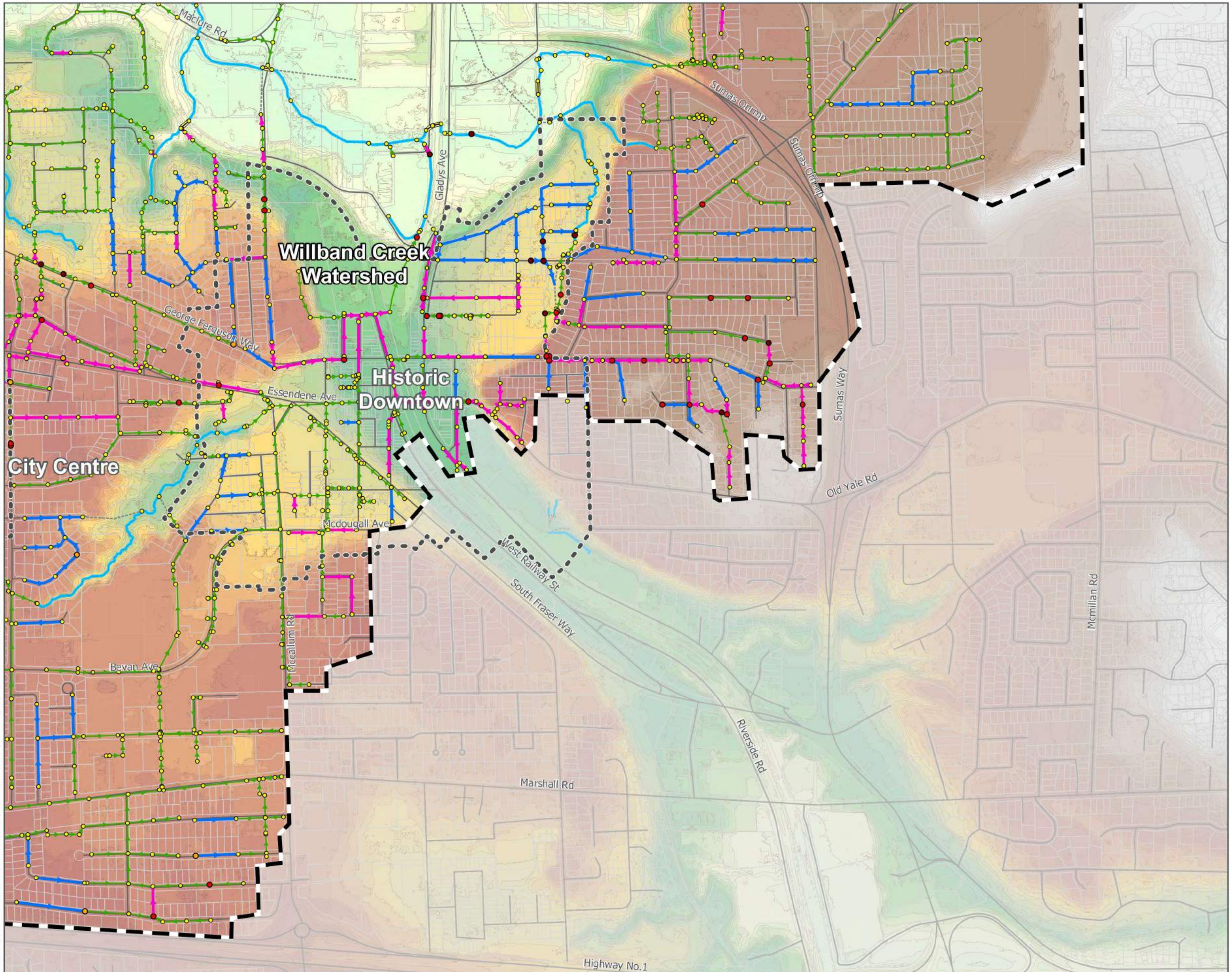
U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-3 - Future System Performance (100 Year, Climate Change, No Controls, Upgrades) (11x17)



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Willband Creek Integrated Storm Water Management Plan

Future System Performance (100 Year, Climate Change, No Controls, Upgrades)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Neighbourhood Plan Boundary Study Area
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600 Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
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Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

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FIGURE 12.3D

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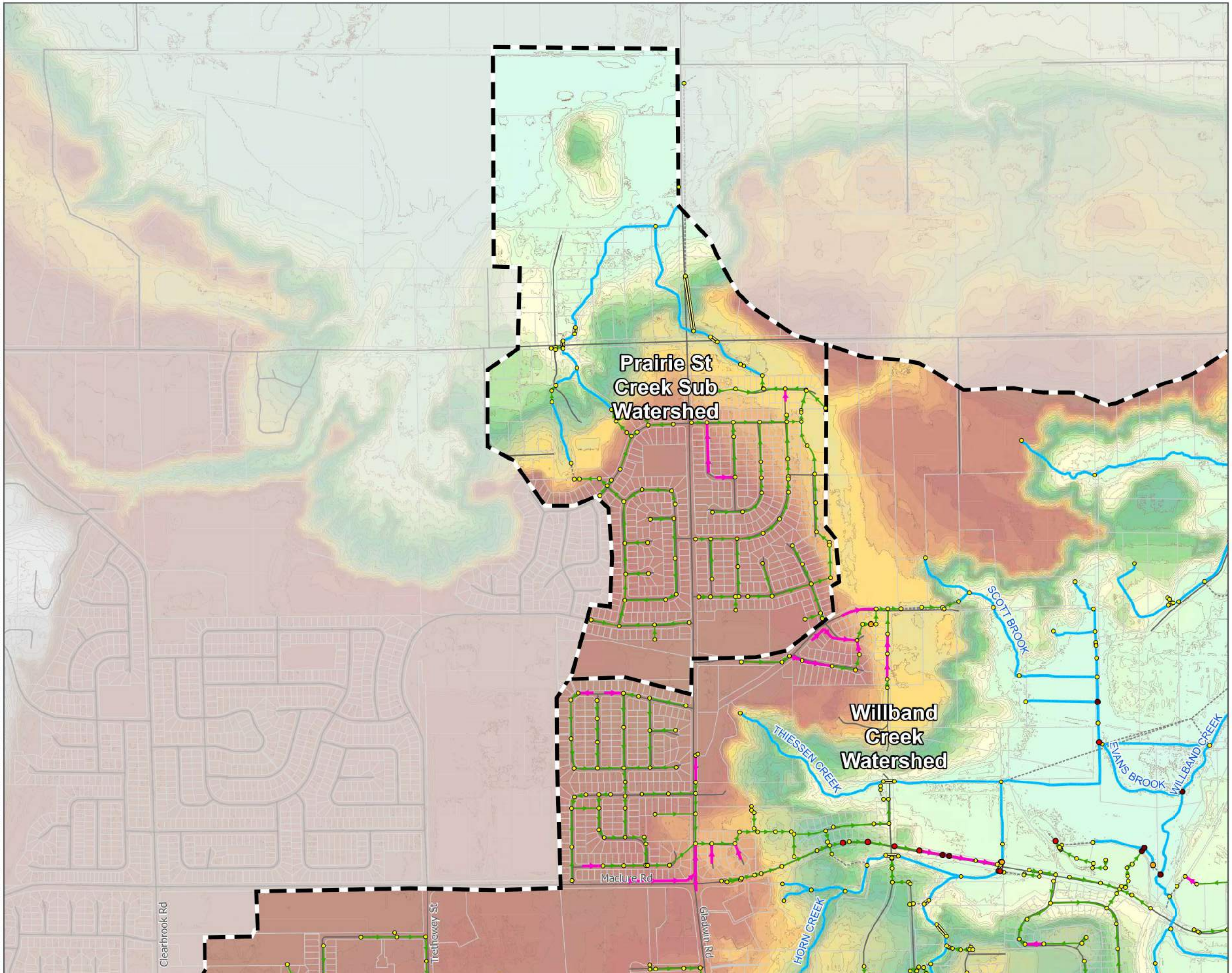

ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Future System Performance (100 Year, Climate Change, With Controls)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
Author:	LP
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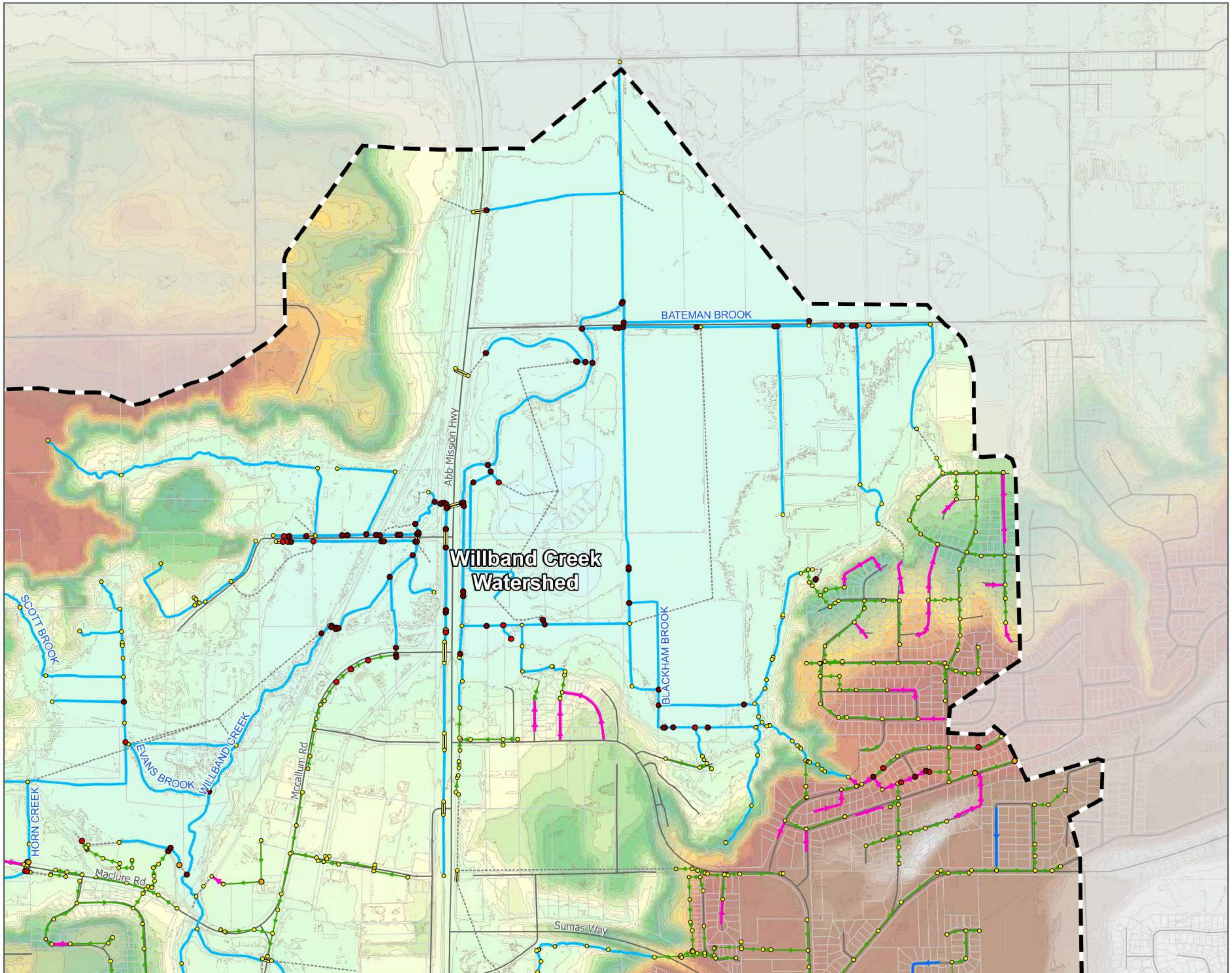
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.4A



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

Future System Performance (100 Year, Climate Change, With Controls)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System:
NAD 1983 UTM Zone 10N

Scale: 1:11,000
(When plotted at 11"x17")

Data Sources:

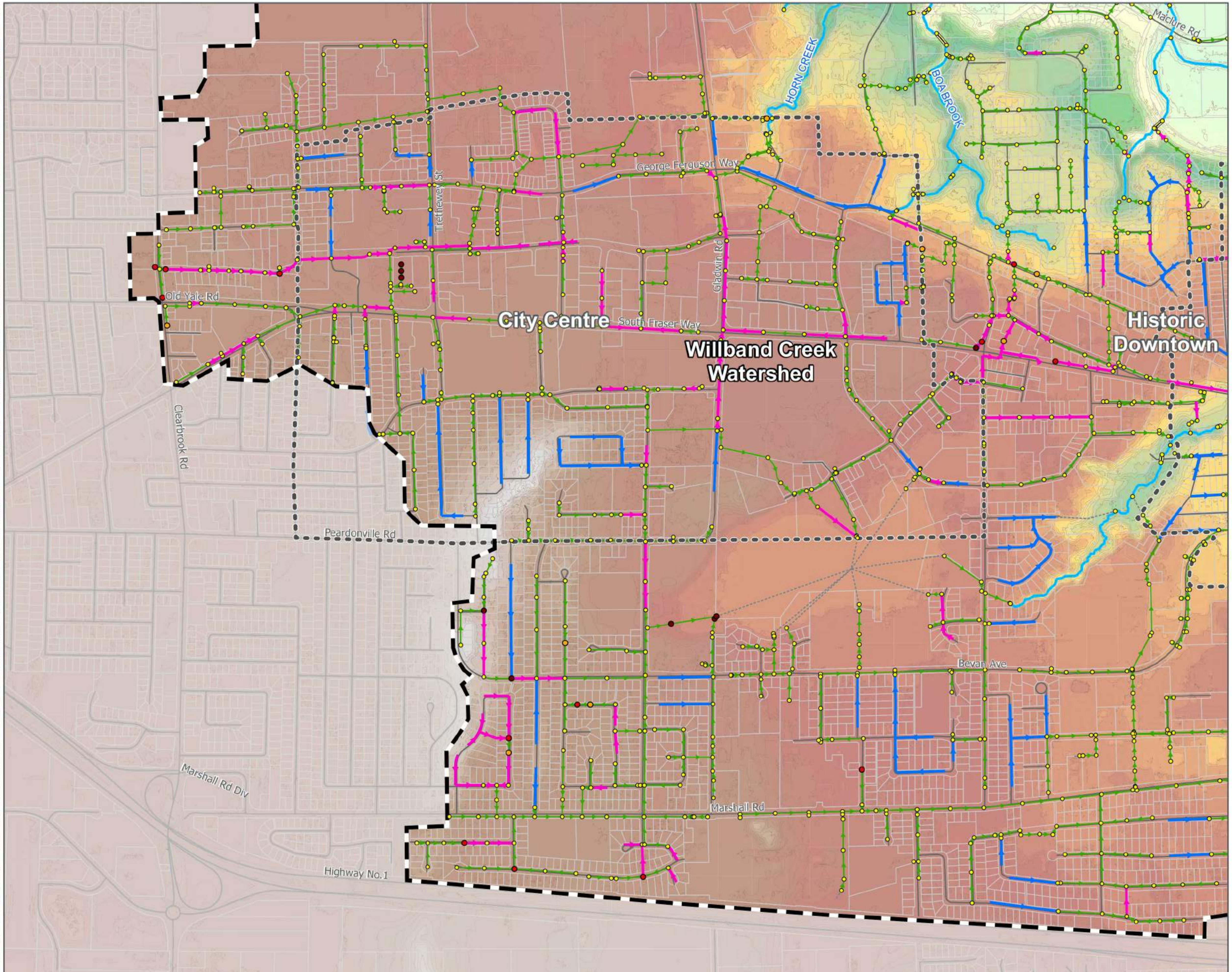
- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoADVICE

Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.4B



ABBOTSFORD

Willband Creek Integrated Storm Water Management Plan

Future System Performance (100 Year, Climate Change, With Controls)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System:
NAD 1983 UTM Zone 10N

Scale: 1:11,000
(When plotted at 11"x17")

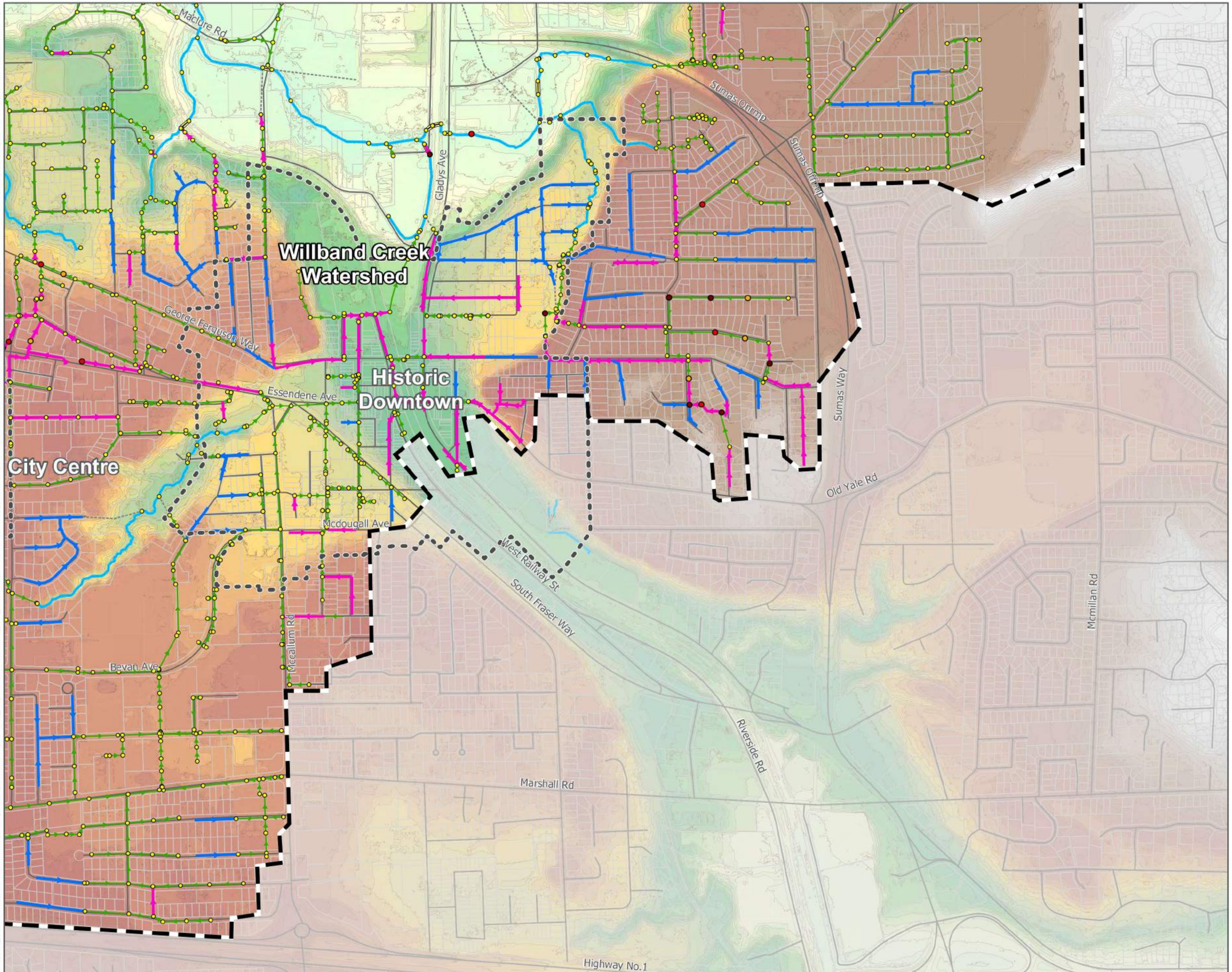
Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.4C



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Future System Performance (100 Year, Climate Change, With Controls)

Legend

- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Upgraded Main
- Proposed Main
- Existing Main
- Conduit Added for Connectivity
- Creek
- Culvert
- Contour (2 m)

Flood Loss Volumes (ML)

- ≤0.001
- ≤0.01
- ≤0.1
- >0.1

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0 200 400 600
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:11,000 (When plotted at 11"x17")

Data Sources:

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Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 12.4D

U:\Projects_VAN\1790\0015\01\D-Drafting-Design-Analysis\GIS\Projects\Pro_Projects\1790.0015.01_Part_4.aprx\Figure 12-4 - Future System Performance (100 Year, Climate Change, With Controls) (11x17)

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Last printed by lpunt on September 25, 2017 11:46 AM

13 MILL LAKE AND WILLBAND CREEK FLOODPLAIN

The City has particular interest to understand the potential change in floodplain performance as a result of changes to the upland systems and climate change. **Table 13.1** below presents a summary of the predicted maximum hydraulic grades lines within each of the modeled flood cells under various conditions. The boundary of each flood cell is depicted in **Figure 13.1.** The values for Mill Lake assume a constant position on the discharge weir and does not account for changing protocol to increase freeboard. Flooding is consistent in each flood cell across scenarios, with exception to cell 25; an apparent anomaly relative to the other cells. As shown in **Figure 13.1**, flood cell 25 is located at the transition of the uplands to the lowlands and has the main stem of Willband Creek through it. Also shown in **Figure 13.1** is the horizontal extent of projected flooding for both the existing 1:200 year condition and the maximum future condition 1:200 year condition, showing no perceptible difference between the two.

One would anticipate greater impact to the floodplain if change where a result of greenfield development (development planned for a site that is largely a green, undeveloped state), but in this case the development footprint has been previously established and proposed changes within it are not predicted to impact the floodplain performance at a macro scale. It is noted in Table 13.1, however, that when accounting for the application of site controls, the maximum water level in some cells is predicted to be minutely higher than when not considering site controls. Once again, these differences are considered within the margin of error of the analysis and the hypothesis is that the application of controls influences the timing of the runoff hydrograph peak from controlled lands to more closely coincide with the peak from the uncontrolled lands. These unvalidated differences are not considered a significant change in risk and should not dissuade the application of site controls.

Table 13.1 - Summary of Flood Cell Maximum Hydraulic Grade Lines (water surface elevation in meters geodetic)

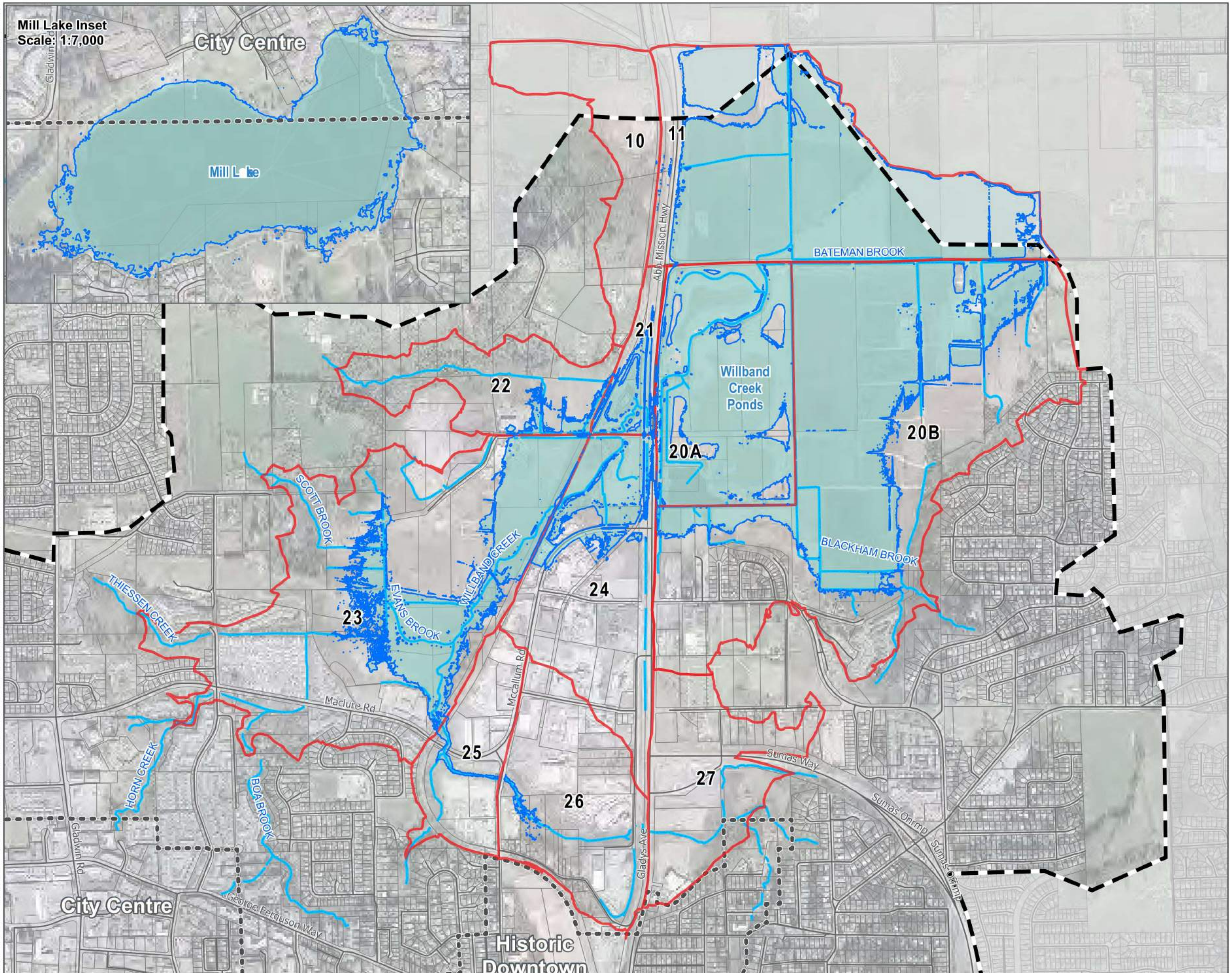
Flood Cell	1:10 year				1:100 year				1:200 year			
	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 1	Scenario 2	Scenario 3	Scenario 4
10	4.00	4.00	4.00	4.00	4.40	4.40	4.40	4.40	4.44	4.44	4.44	4.44
11	3.87	3.87	3.87	3.87	4.25	4.25	4.25	4.25	4.42	4.42	4.43	4.43
20A	4.00	4.00	4.00	4.00	4.18	4.18	4.18	4.18	4.40	4.40	4.40	4.40
20B	3.74	3.74	3.74	3.74	4.05	4.05	4.05	4.05	4.38	4.38	4.38	4.38
21	4.00	4.00	4.00	4.00	4.43	4.45	4.46	4.45	4.47	4.47	4.50	4.49
22	4.02	4.03	4.04	4.03	4.43	4.45	4.46	4.45	4.47	4.47	4.50	4.49
23	4.12	4.15	4.17	4.15	4.57	4.63	4.66	4.62	4.58	4.58	4.68	4.63
24	4.03	4.03	4.04	4.04	4.44	4.46	4.47	4.46	4.48	4.48	4.51	4.50
25	4.49	4.56	4.60	4.59	4.88	5.04	5.12	5.03	5.19	5.33	5.51	5.24
26	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75
27	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61	7.61
SU19 (Mill Lake)	51.83	51.85	51.84	51.85	51.90	51.98	51.95	51.98	51.94	51.97	51.99	52.02

Scenario 1 – Existing Condition

Scenario 2 - Future land use, no site controls, with climate change

Scenario 3 - Future land use, with site controls and climate change

Scenario 4 - Future land use, no site controls, with system upgrades and climate change



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Flood Extents (200 Year)

Legend

- Maximum Future Flood Extent (200 Year)
- Existing Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Creek

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 200
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:13,500 (When plotted at 11"x17")

Data Sources:

- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

GeoADVICE

Project #:	1790.0015.01
Author:	LP
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Status:	FINAL
Revision:	A
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URBAN systems

FIGURE 13.1

It is recommended that the City proceed with its planned Phase 2 Matsqui Prairie Drainage Study. This study is recommended before considering modifications to the existing system or creation of new pond storages in the floodplain. But for the time being, the maximum water levels provided in **Table 13.1** can be reviewed against established Flood Construction Levels (FCL's) for any new construction. The City could inventory the elevations of existing buildings and critical infrastructure within the flood plain and use them as target thresholds to test solutions during the conduct of the Phase 2 Matsqui Prairie Drainage Study.

Mill Lake and Willband Creek Floodplain Summary of Recommendations and Action Items

1 Conduct Phase 2 Matsqui Prairie Drainage Study.

2 Review water levels in **Table 13.1** against currently established Flood Construction Levels (FCL's) for new construction in the floodplain.

3 Adjust operational protocols for Mill Lake to offer greater freeboard in the winter.

14 CAPITAL COSTS

To a large extent, system performance is not sensitive to the order in which implementation occurs, therefore pipe replacement, or provision of new pipes where they do not currently exist, can be governed by other programs and redevelopment opportunities. However, investigating the structural condition of the existing Mill Lake Ravine Park trunk sewer and selecting a preferred solution to address risks associated with this system are considered high priority.

14.1 Storm Sewer Capital Costs

A complete inventory of new pipes and unit prices are provided in **Appendix F**, with a summary of costs presented in **Table 14.1** on the following page. Costs are Class D and include 50% engineering and contingencies but exclude taxes.

Table 14.1 - Summary of Storm Sewer and Culvert Costs

Priority – Reason for upgrade	Minor (10-year) Criteria	Estimated Capital Cost*	Major (100-year) Criteria	Estimated Capital Cost	Total Priority Capital Cost
Priority 1 – Performance does not meet criteria with or without the application of site controls. These upgrades include upsizing a portion of trunk sewer downstream of Ravine Park, on the assumption that storage in Ravine Park is not provided.	3,572 m	$4,616,100	180 m	$729,700	$5,345,800
Priority 2 – Performance does not meet criteria if site controls are not applied extensively. These upgrades include upsizing a portion of trunk sewer downstream of Ravine Park, on the assumption that storage in Ravine Park is not provided.	5,026 m	$7,787,500	152 m	$784,000	$8,571,500
Priority 3 – To meet desired minimum main size of 300 mm, despite the current having adequate performance.	10,821 m	$10,144,800	0 m	$ 0	$10,144,800
Priority 3 – Provide a main where one does not exist.	15,133 m	$14,207,700	0 m	$ 0	$14,207,700
Total	34,552 m	$36,756,100	332 m	$1,513,700	$38,269,800

It is worthy to re-emphasize that only the Priority 1 upgrades ($5,345,800 in total) are required regardless of site controls. Priority 2 upgrades ($8,571,500 in total) are subject to un-successful implementation of extensive site controls. The remaining Priority 3 upgrades ($24,352,500 in total) are fully discretionary.

In absence of a technical assessment for the creation of a control structure and storage within the Mill Lake Ravine Park, a recommended planning level cost for a control and storage in the ravine is $750,000, including 50% for engineering and contingencies, but excluding taxes. This also excludes modifications to the ravine itself, but it limited to the inlet structure alone. The creation of this storage would eliminate 288 m of Priority 1 and 2 storm sewer upgrades, currently valued at $1,128,641 (subject to a condition and pre-design assessment of existing pipes). The decision around which approach to take should be governed by the following steps:

1 Conduct a condition assessment of the existing trunk storm sewers,

2 Conduct a predesign assessment of the Ravine Park storage option, including geotechnical, environmental, and arborist reviews,

3 Consult with Provincial and Federal regulatory agencies before conducting predesign assessment,

4 Conduct a predesign assessment of the trunk sewer replacement option, including consideration for disruption to community and business, condition of the existing system, and need to fully replace or supplement the existing system, and

5 Update construction cost estimates of each option and conduct cost / benefit assessment.

14.2 Summary of Recommendations, Priorities and Budgets

Table 14.2 on the following pages present a summary of all recommendations. For each recommendation, a relative level of priority is assigned, along with a preliminary budget for consideration where possible. The actual budget of each item is highly subject to scope. For that reason, several recommendations have been provided a range of budget, or to be determined (TBD). It is recommended that for each item the City identify its capacity to fund each item and to conduct a scoping exercise to further define scope and budget before attempting to secure funding.

High priority items are recommended to be completed from 2019 to 2024, medium priority items from 2025 to 2030, and low priority items as funding allows.

Table 14.2 - Summary of Recommendations / Action Items and Budgetary Costs

Action	Priority	Budget Cost
LAND USE MANAGEMENT		
Explore the design of rainwater management facilities for both retention and water quality treatment in the Municipal Hall lands site and the City owned parking lot at West Railway Street and Essendene Avenue. Both facilities would serve local catchments and demonstrate the City as leaders.	Medium	$50,000 (pre-design study only)
Designate the 4 blocks of Historic Downtown between South Fraser Way to George Ferguson Way, Pauline Street to Montvue Avenue, as a special area exempting it from current stormwater site control criteria but pay cash-in-lieu for detention. However, onsite source controls are still encouraged where feasible.	High	N/A
Develop policy around service connections for subsurface floor space, both in terms of the mechanical requirements for the physical connection and statements to limit the City's liability.	High	$20,000 (excluding creation of regulatory documents)
Establish tree canopy targets and landscape standards to suit (both private and public spaces). Determine what regulatory processes would trigger implementation (eg. Building permit, re-development, capital reconstruction).	High	$30,000 (excluding creation of regulatory documents)
ENVIRONMENTAL OPPORTUNITIES		
Explore riparian planting infill program in Willband Creek lowlands north of Maclure Road.	Low	$50,000 to develop a program $100,000 to $500,000 for planting
Modify or replace stream crossing culverts to permit easier migration of fish. Notable crossing is Horn Creek at Trafalgar Street.	Low	TBD through design review

Action	Priority	Budget Cost
ENVIRONMENTAL OPPORTUNITIES Cont.		
Habitat complexing in Lower Willband Creek through creation of off-line pools, log structures, and riparian vegetation.	Low	$50,000 to develop a program Premature to offer an implementation budget, particularly if off-line pools are considered.
Removal of garbage and other anthropogenic debris from watercourses.	High	N/A
Recognized to have significant challenges, however review the practicality of daylighting a portion of ravine downstream of Mill Lake.	Low	$50,000 for investigation only
Sample sediments in Mill Lake to assess the degree of contamination and disposal costs should the lake be dredged.	Medium	$20,000
Subject to item above, decide on the (partial) dredging of the lake to increase storage, provide cooler water, and help increase DO levels. In parallel, explore mechanical aerators in Mill Lake.	Medium	TBD
Consider “end of the pipe” water quality treatment facilities for storm sewers entering Mill Lake, even if just oil / grit separators. (7 outfalls)	Medium	$1.5M to $3.0M assuming O/G, not media filltration
Apply landscaped based biofiltration site controls wherever possible.	High	N/A
GEOTECHNICAL AND SOURCE CONTROLS		
Expand Stormwater Source Control Bylaw to City-wide, and to ensure it is enforceable through the Development and Building Permit processes.	High	$50,000
Identify high risk sites (eg. auto-wreckers, service stations) which would be restricted from infiltration systems.	High	N/A

Action	Priority	Budget Cost
GEOTECHNICAL AND SOURCE CONTROLS Cont.		
Further develop an erosion mitigation strategy for Horn Creek and Boa Brook. Done in concert with the exploration of communal detention ponds discussed under "Infrastructure" below.	High	$50,000
Conduct an annual review and assessment of geotechnical stability in Horn Creek, Boa Brook and Prairie Street Creek.	High	$20,000 per year
Develop criteria and standards for the application of urban roadway Green Infrastructure. This would also include the potential application of perforated storm sewers provided water quality pre-treatment is provided.	High	$50,000
Develop a comprehensive tracking GIS database of public and private site controls.	High	TBD
Explore operating permit requirements for long term inspection and maintenance of private site controls.	Medium	$20,000
Create a Development Permit Area for the application of infiltration system in proximity to steep slopes under the guise of geotechnical hazard. It is currently envisioned this would be separate from the City's current Map 14 – Steep Slope Development Permit Area which serves a different purpose.	High	$20,000
INFRASTRUCTURE		
Video inspect trunk sewer downstream of Mill Lake Ravine Park and conduct condition assessment. It is also recommended that the City prepare a "criticality" map of the drainage system and assign operational policy on a priority basis.	**High**	$20,000
Subject to result of the above action, conduct a pre-design study to explore the potential for restricting flow at the storm sewer inlet at the downstream end of Mill Lake Ravine Park.	High	$50,000

Action	Priority	Budget Cost
INFRASTRUCTURE Cont.		
Subject to the findings of items above, decide to upgrade the trunk sewers downstream of Mill Lake Ravine Park, either through full replacement or supplemental capacity, or restrict flow at the inlet.	High	TBD
Proceed with a design process for the redirection of City sewers to Montrose Avenue through the Historic Downtown to direct City flows out of private lands. Require private lands to reconnect during redevelopment.	Low	$50,000
Notify private property owners in Historic Downtown that need to reconnect to realigned City infrastructure on Montrose Avenue and flag these properties in the City database to ensure reconnection is achieved through Building or Development permitting.	Low	N/A
Integrate Priority 1 upgrades into the City's capital plan. Integration of Priority 2 upgrades into the capital plan would be contingent on performance monitoring results (already underway by City through past recommendation) and tracking of successful application of site controls. Integration of Priority 3 upgrades is discretionary.	Priority 1 – Medium-High Priority 2 – Medium Priority 3 – Low	Priority 1 - $5,345,800 Priority 2 – $8,571,500 Priority 3 - $24,352,500
Conduct flood risk and overland flow path assessment for those areas with a history of problem or for locations identified herein as having a predicted floodloss of 100 m^3 or more. Consideration would also be given to exploring locations where flood loss volume is predicted to be between 10 m^3 and 100 m^3.	Medium	$200,000 to $500,000 depending on the level of detail
Monitor water levels in seven existing detention ponds from November to April, followed by an optimization study.	High	$100,000

Action	Priority	Budget Cost
INFRASTRUCTURE Cont.		
Monitor flows in storm sewer system to validate performance at most problematic (in theory) areas (see Figure 15.1) – based on seven sites monitored November to April. Then conduct an updated hydraulic assessment.	High	$100,000
Conduct a predesign study to further explore the potential of communal detention ponds to reduce erosion in Horn Creek and Boa Brook and compare to the diversion conceived by previous 2009 study.	High	$100,000
MILL LAKE AND WILLBAND CREEK FLOODPLAIN		
Conduct Phase 2 Matsqui Prairie floodplain assessment	High	N/A (budgeted by the City for 2020)
Initiate discussions with the Fraser Valley Conservancy regarding a floodplain storage and habitat facility west of Highway 11.	High	N/A
Review need to establish new Flood Construction Levels (FCL's) in the floodplain.	High	N/A
Adjust operational protocols for Mill Lake to offer greater freeboard in the winter.	High	N/A

14.3 Community Survey Summary

Public open house was advertised on the City web portal, newspaper and social media, and held in the afternoon of June 18, 2019 at the entrance to the Clearbrook Library. Staff were available to talk with the public and storyboards with key information were on display. Approximately 35 people took a few minutes to review the information presented and to ask questions. Generally, they were happy to see the consultation and no concerns were noted.

A second Invitational open house was advertised to local environmental groups, environmental consultants, civil consultants, first nations and government, downtown business association, and city staff. The information session was held at City Hall on June 20, 2019 with City and Urban Systems staff available to speak to storyboard displays and to answer questions. There were approximately 15 people that attended the invitational open house. Discussion centered around environmental concerns, and comments received were reviewed and incorporated into the report.

As part of identifying the publics perceptions and priorities regarding the Willband Creek watershed project, a survey was used to collect public feedback. The survey was open from April 23 to June 20, 2019 and a total of 56 surveys were completed. This is a summary of those responses.

This survey was available online and was completed on a voluntary basis.

14.3.1 Survey Participants

Survey respondents were asked to identify if they lived or worked in the study area. Of the 56 responses, 40 respondents live or work in the study area and 16 do not live or work in the study area.

14.3.2 Perceptions and Importance of the Willband Creek Watershed project

Survey participants were asked about their perception of the Willband Creek watershed project, and how important the project is for them. **Figures 14.1 through 14.4** summarize all responses. 46 of the 56 participants feel the health of the Willband Watershed is important to them and would support a moderate to significant level of community investment be used to support improvements to the watershed. As far as understanding the current overall health of the watershed, 36 participants felt optimistic about the watershed's overall health, but 16 respondents admitted they didn't know/weren't; sure.

Based on the survey responses, the top three areas of concern within the Willband Creek watershed are (1) poor water quality, (2) lack of tree canopy, and (3) invasive species in creek corridors. Each of the top three concerns received between 25 to 30 responses. The full list of concerns is shown in **Figure 14.4**.

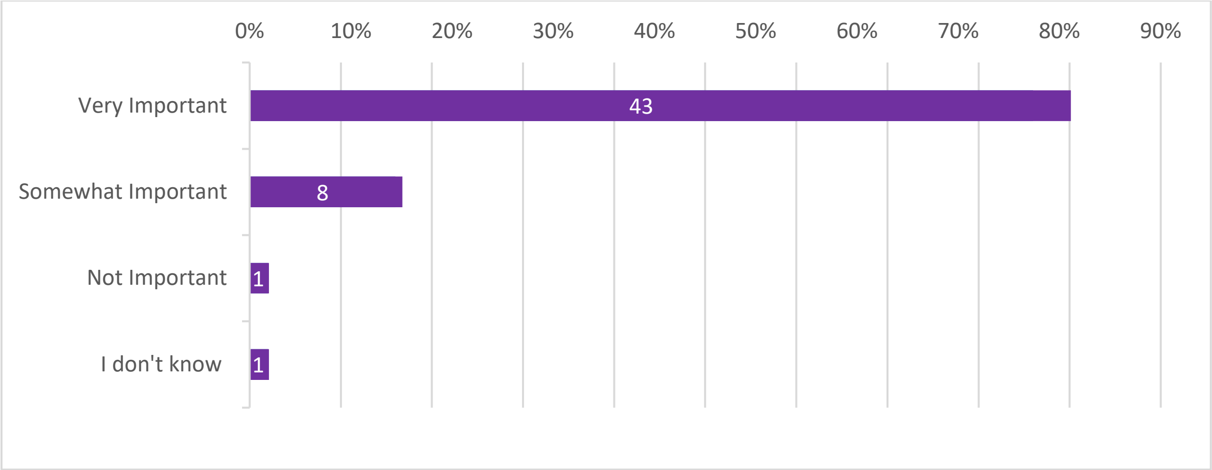

Figure 14.1 - How Important is the health of the Willband Creek watershed to you?

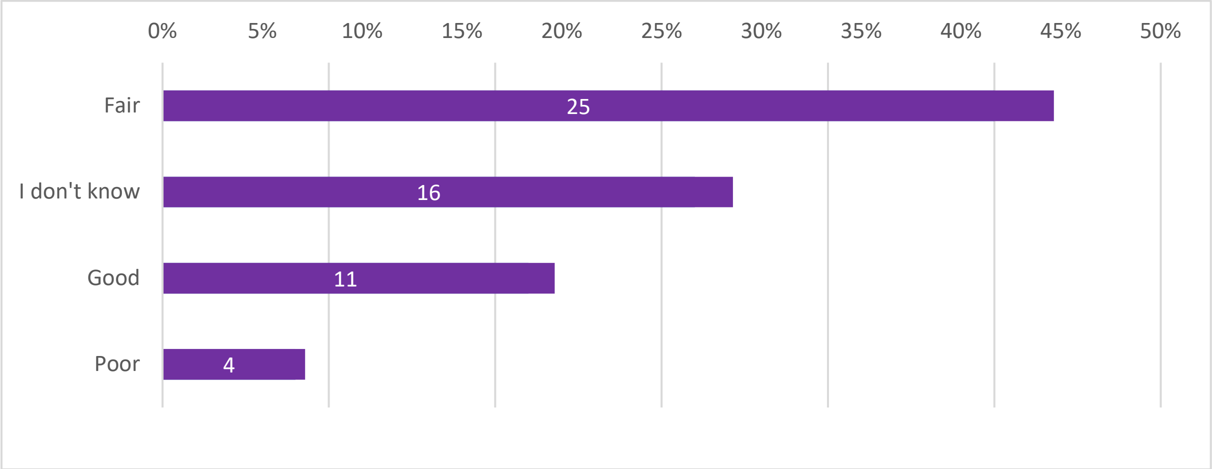

Figure 14.2 - What is your perception of the current watershed health overall in the Willband Creek watershed?

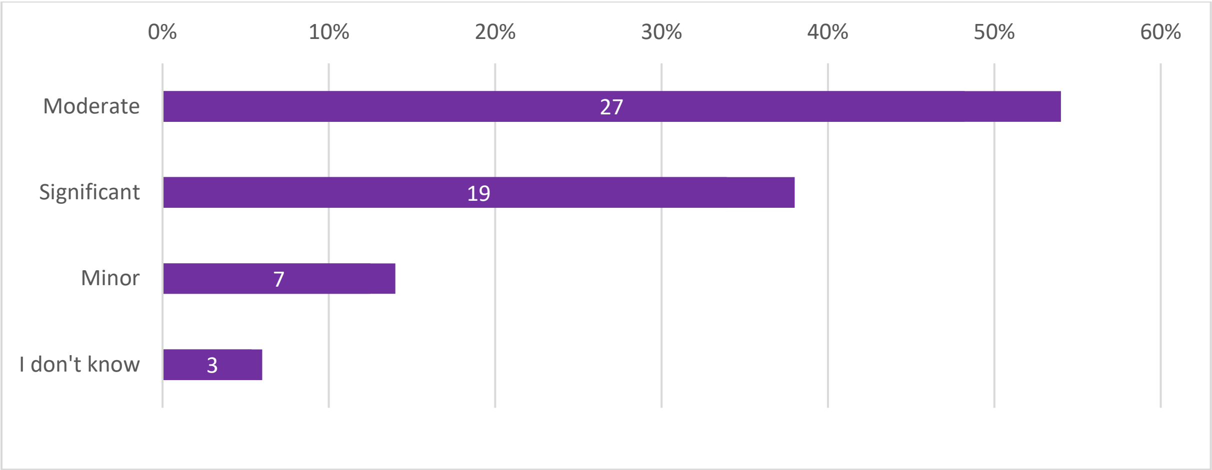

Figure 14.3 - What relative level of community investment could you support to see watershed health improve in the Willband Creek watershed?

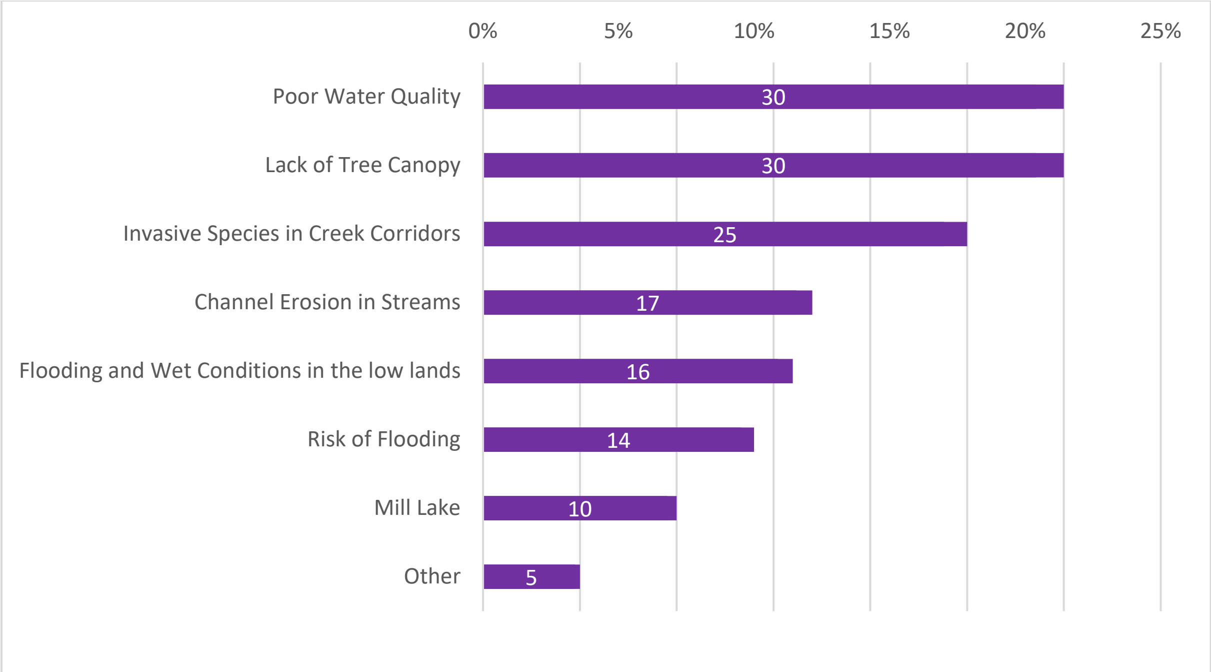

Figure 14.4 - What are the top three issues you are most concerned with in the Willband Creek watershed?

Respondents were also provided space to add any comments regarding their perceptions and importance of the Willband Creek watershed, or additional issues not listed in **Figure 14.4**. *(9 responses)*

Several respondents brought up that access via transit, trails, and automobiles was an issue.

Additional issues that were identified by respondents include:

- Animal life and habitats in the watershed (specifically fish and birds)
- Human degradation of the area including residential debris

14.3.3 Support for the Willband Creek Watershed project

In the next five questions, respondents were asked to identify their level of support for a variety of action items. The scale ranged from No Support to High Support with an additional I don't know option. **Figures 14.5 through 14.9** summarize the response data to each of the provided potential actions.

Mill Lake and Willband Creek Floodplain

As shown in **Figure 14.5**, the option to proceed with conducting a comprehensive drainage study of the downstream Matsqui Prairie drainage system and opportunities to improve water conveyance to the Fraser River received the highest support.

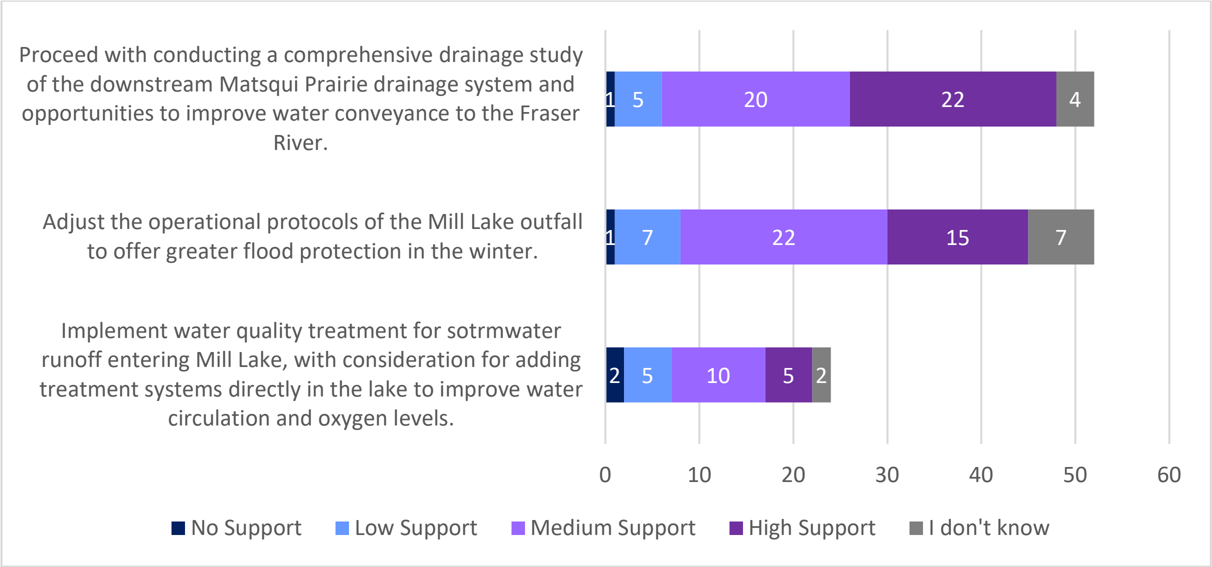

Figure 14.5 - Mill Lake and Willband Creek Floodplain

Infrastructure

In response to the proposed infrastructure actions, there was a very even spread between the two most supported options. The first option is to conduct flood risk and overland flow path assessment for areas with a history of problems or for locations identified as having the greatest chance of flooding, and the second top selected action is to monitor the performance of seven existing public stormwater detention ponds and adjust their controls as required to optimize their performance.

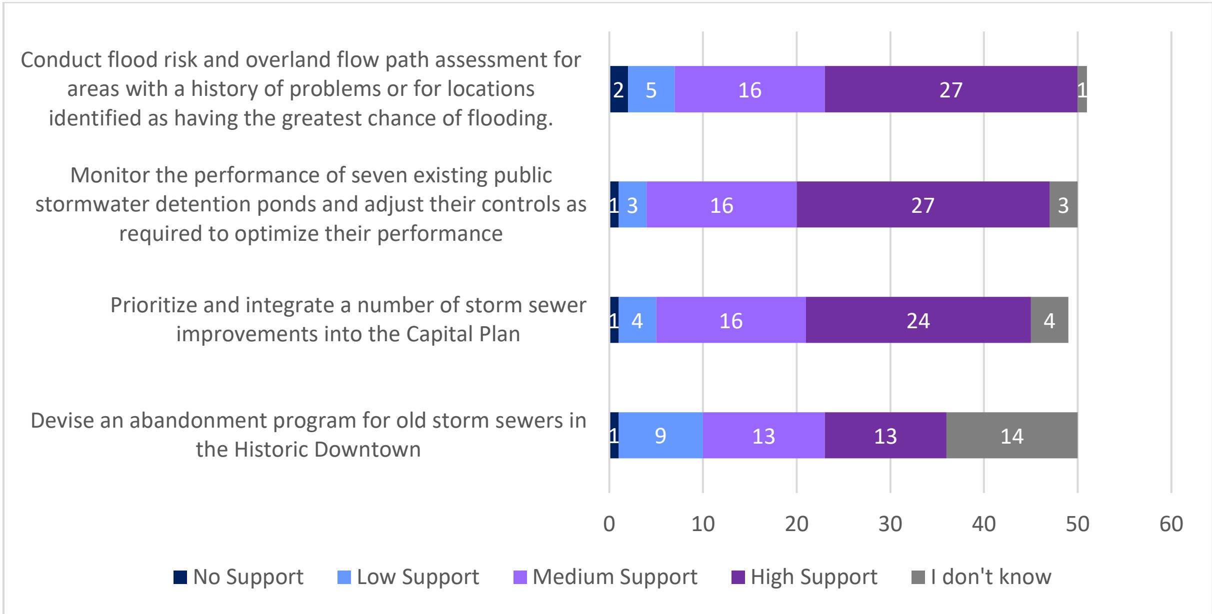

Figure 14.6 - Infrastructure

Geotechnical and Source Control

A majority of respondents highly support the City reviewing design standards for its public road corridors for consideration of increased landscape and rainwater source controls.

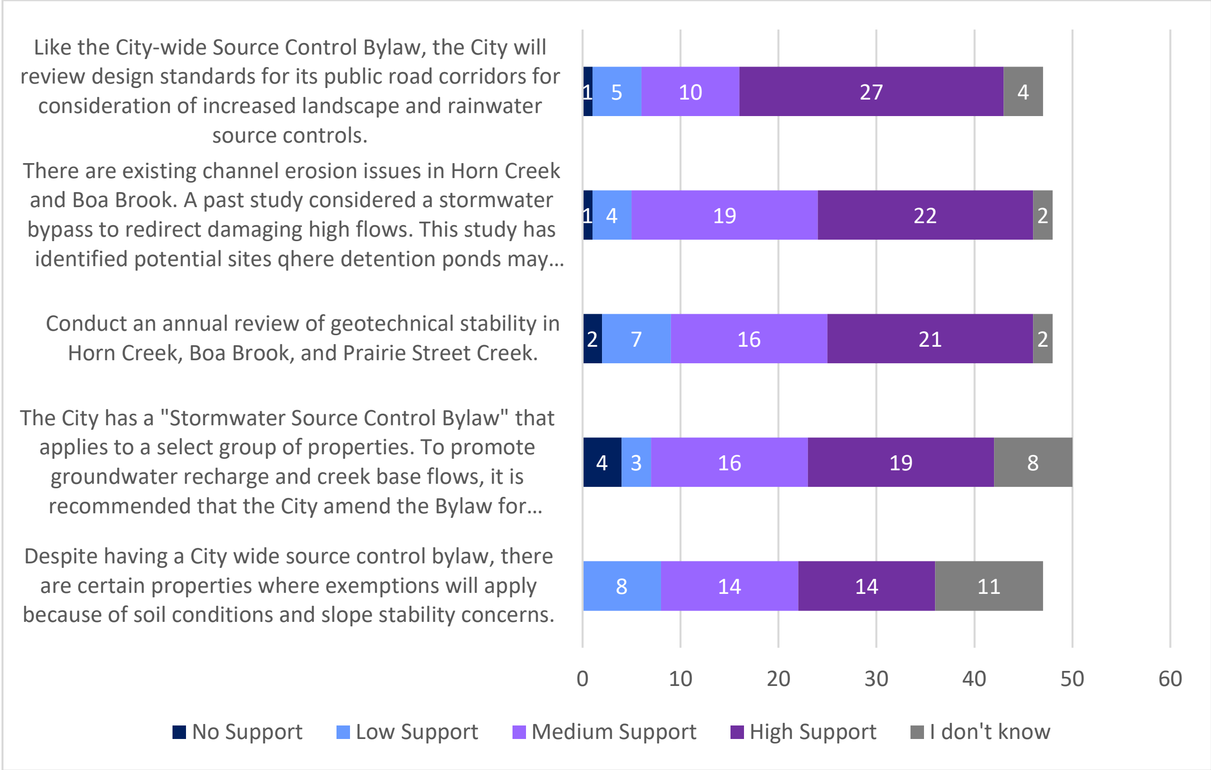

Figure 14.7 - Geotechnical and Source Controls

Environmental Opportunities

As shown in **Figure 14.8**, the majority of respondents (more than 74% for both) highly support both of the presented actions.

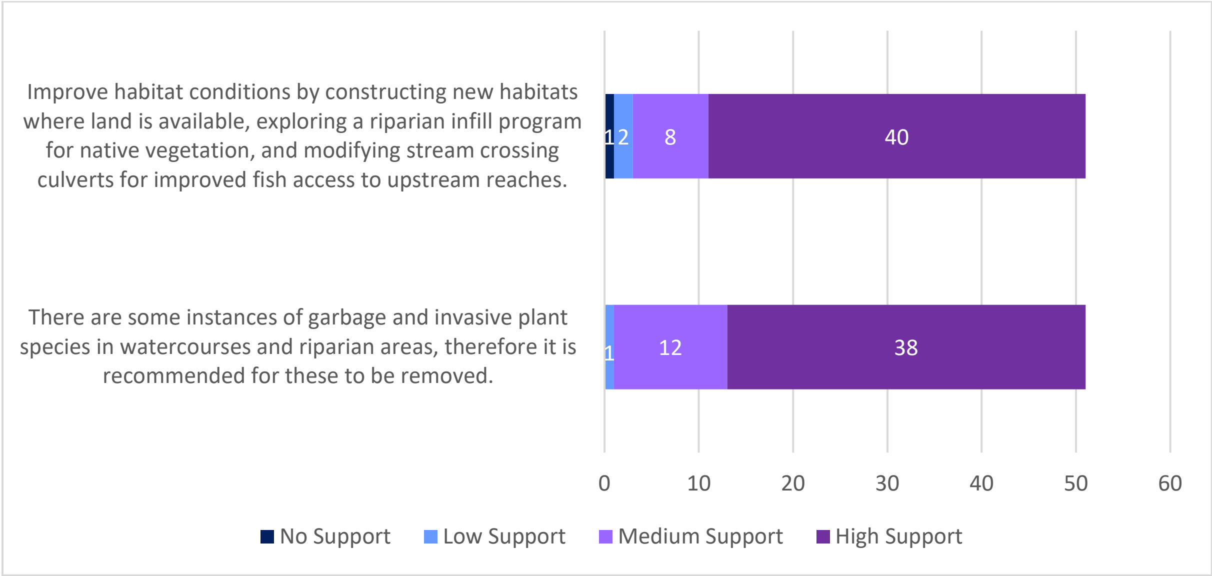

Figure 14.8 - Environmental Opportunities

Land Use Management

Of the Land Use Management actions, the more highly supported option recommends that the City establish tree canopy targets and landscape standards that suit both private and public spaces to offer hydrologic, environmental, and societal benefits. This aligns with the earlier survey question regarding the respondents' top issues most concerned within the Willband Creek watershed, where the lack of tree canopy was tied for the top concern.

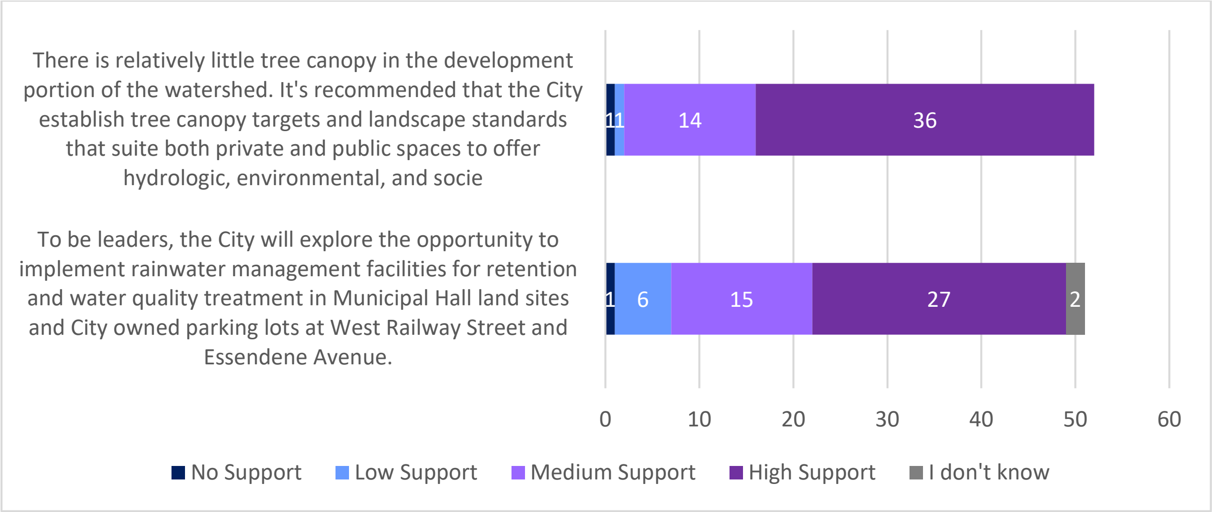

Figure 14.9 - Land Use Management

14.3.4 Final Thoughts / Suggestions

Respondents were presented with two additional open-ended questions. Themes from these responses are listed below.

Are there any other actions that the City should consider in the Integrated Stormwater Management Plan (ISMP)? *(10 responses)*

- Maintain and update existing assets and infrastructure
- Utilizing natural and environmentally conscious solutions for the watershed, and for any new developments in the area
- Maintain more natural settings for the animal life in the area
- Provide more public education regarding the watershed and what the public can do to help

Do you have any additional concerns or feedback about the Integrated Stormwater Management Plan (ISMP)? *(7 responses)*

- Concern about how agricultural runoff and increased industrial activity will affect the pollution levels in the watershed
- Need to protect and restore existing sloughs, creeks, and animal habitats
- With expansion in the Abbotsford area, the City needs to address the additional capacity required for absorbing rainfall and plan for future demand
- Need to upgrade and expand existing retention areas to accommodate higher volume

Based on the results described above, it is clear that the health of the Willband Creek watershed is important to the community and that preserving it is a priority. There is an understanding that development in the area has a negative impact on the watershed and needs to be properly addressed, especially with so much new development planning in the coming years. With the options presented in the survey, it seems that respondents are supportive of the City investing in monitoring and upgrading the infrastructure within the watershed to help with improving the health and quality of the Willband Creek watershed.

PART 4 – IMPLEMENTATION AND ADAPTIVE MANAGEMENT

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15 IMPLEMENTATION AND ADAPTIVE MANAGEMENT

15.1 Practices, Bylaws, Standards.

The City currently has clear criteria in the Development Bylaw for flow control, but the Bylaw lacks specificity in the design and application of acceptable controls and how water quality objectives will be met. This can be achieved through broader application of the separate Stormwater Source Control Bylaw, and it has been recommended both herein and the City's recently completed Plan 200K Drainage Master Drainage Plan that this Source Control Bylaw be adopted City-wide.

According to the City's recent Plan 200K Drainage Master Plan (DMP), Development Services has had some developers submit drawings for infrastructure in accordance to the Stormwater Source Control Bylaw to meet zoning requirements but did not ultimately construct the measures once zoning was approved. As stated in the DMP "the Stormwater Source Control Bylaw is a compliance bylaw but is not enforceable after the zoning without the City going to court. An enforceable bylaw must be included in the City's "Consolidated Bylaw Notice Enforcement Bylaw, 2007 Bylaw No. 1703 – 2007. This makes the Stormwater Source Control Bylaw a regulatory bylaw allowing the Bylaw Department to enforce it."

The Development Bylaw, Schedule J - Specifications and Standards for the Installation of Landscaping provides for tree planting, growing medium and structural soils that could be suitable for green infrastructure. Section 7 – Highways of Schedule F, does not specify any allowance for vegetated swales or other forms of Green Infrastructure, but Table 7.3 does note a drainage corridor of 2.25 meters in width on either side of all road classes. However, Section 4 – Drainage Systems of Schedule F, subsection 8 (k) - Swales says: "Swales may be used on a rural highway for road drainage at the discretion of the Engineer." Then subsection 8 (n) provides geometric criteria for roadside swales but says that "Roadside drainage swales……shall be used where the road drainage is minimal and can be contained safety and practically in a swale rather than a ditch." Also, it requires the swale be "designed with the roadside edge of the swale at least 2 meters from the edge of pavement."

In general, the Stormwater Source Control Bylaw provides a solid base that the City can apply more broadly across the City, but is insufficiently adopted and enforceable through the Development Bylaw. In addition, the Development Bylaw does not provide for the application of green infrastructure within road corridors, which is a shortcoming in the City leading by example, as roadways represent a significant contributor to runoff detriments.

Practices, Bylaws, and Standards Summary of Recommendations:

1 Review the Source Control Bylaw, modify as appropriate, and adopt as a City-wide document.

2 Make the Source Control Bylaw enforceable through the Development Bylaw.

3 Amend the Development Bylaw to provide clear criteria on the application of swales or other forms of Green Infrastructure within road right of ways. It is expected that developing this criterion will require collaboration between many City departments.

15.2 Integration with Other Plans

The City has recently completed a comprehensive update of its Master Plans through the Plan 200K initiative. That process resulted in several Master Plans that integrate to some degree with this Willband Creek ISMP. A synopsis of that integration is as follows:

15.2.1 Plan 200K Drainage Master Plan

The Drainage Master Plan (DMP) recognized that the Willband Creek ISMP was underway and therefore did not report significant information directly relevant to the Willband Creek watershed, however it did note the erosion issues within Horn Creek and Boa Brook, and flooding concerns around Mill Lake and in the lowlands to the north. The report also raised recommendations from past studies to address erosion in Horn Creek and Boa Brook, including site specific channel stabilization projects (several of which have since been complete by the City), and a potential stormwater bypass trunk sewer as mentioned herein Section 8 of this ISMP (not yet constructed).

As noted in Section 15.1 above, the DMP also made recommendation for the City-wide adaptation of the Stormwater Source Control Bylaw, and that the Building Permit process also adhere to it.

The capital program within the DMP did not account for any recommendations within the Willband Creek ISMP, therefore the information from this ISMP will need to be added.

Finally, the DMP also explored options for Stormwater Fees and Charges and recommended that a "feasibility study be conducted to explore and to investigate, analyze, and formulate an appropriate fee structure and ultimately develop a recommended implementation strategy for Council to decide how to proceed with the implementation phase." This aligns well with needs for the Willbank Creek watershed.

In Figures 15.1 and 15.2, cash flow requirements are presented. Figure 15.1 is the cash flow for only the recommendations associated with the Willband Creek ISMP, but excluding the priority 3 storm sewer improvements, whereas Figure 15.2 is the cash flow combining the Willband Creek recommendations with the recently completed City-wide Master Drainage Plan.

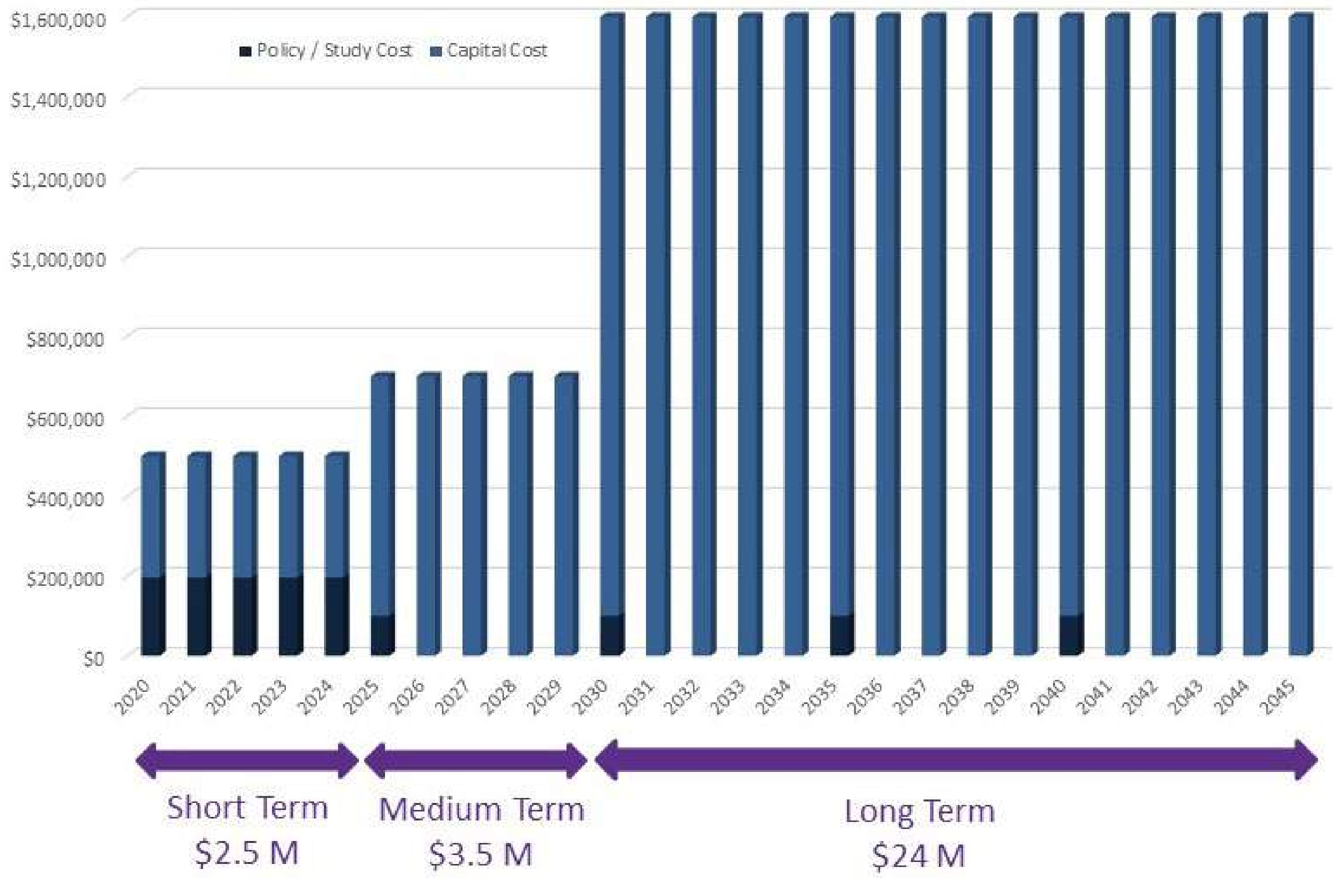


Figure 15.1 - Finance and Timeline

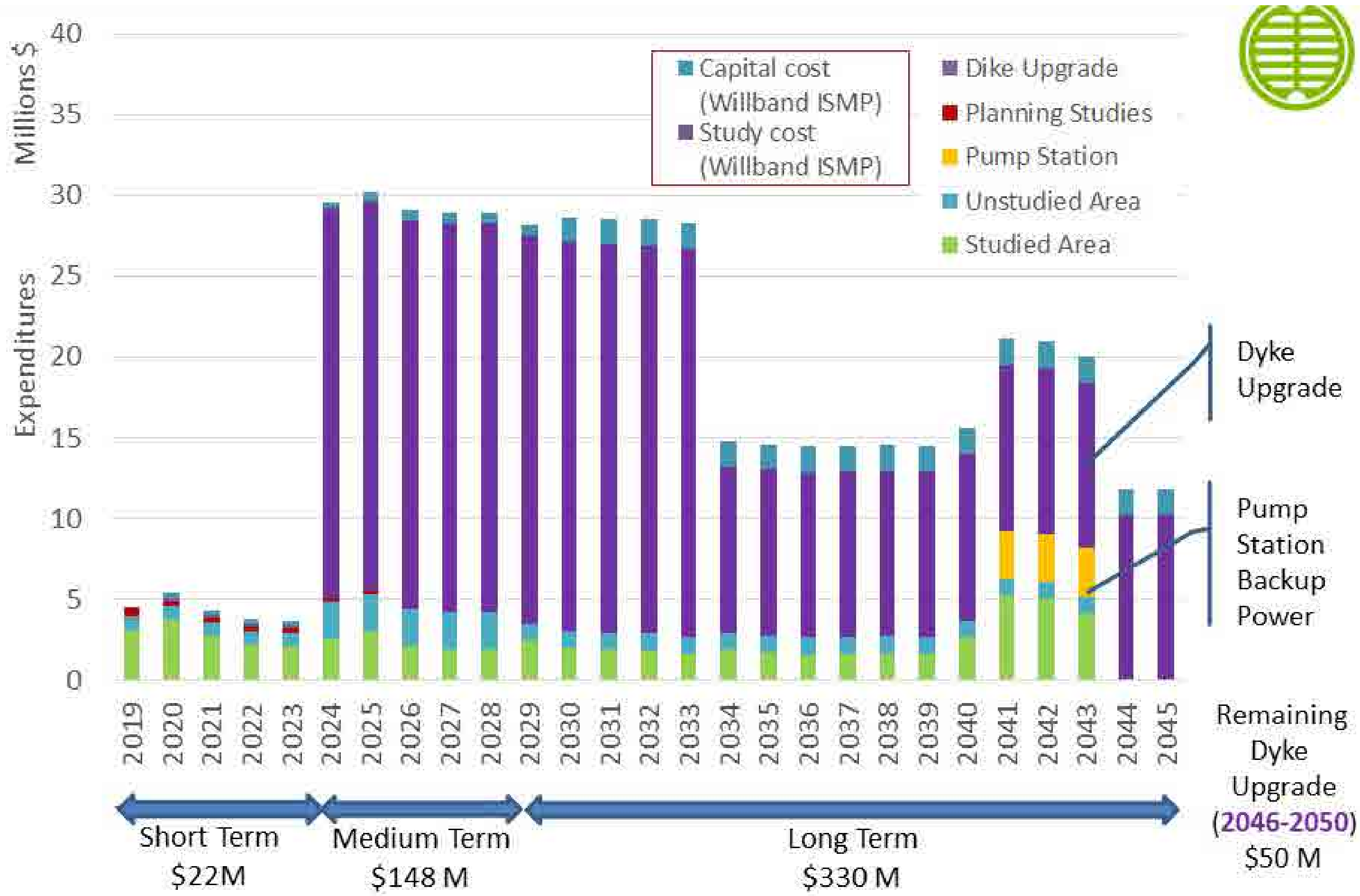


Figure 15.2 - 2018 Drainage Master Plan and Willband Creek ISMP (2019 to 2045)

15.2.2 Plan 200K Parks, Recreation and Culture Master Plan (PRCMP)

The PRCMP does not explicitly discuss stormwater management and drainage, however has significant references to tree canopy and natural assets that align well with the ISMP objectives.

Section 8.8.3 Issues and Opportunities of the PRCMP speak to "protecting natural areas", "managing natural areas", and "protecting the tree canopy". It also notes that the City does not have an Urban Forest Management strategy that could establish targets, strategies and policies for protecting existing trees and enhancing the urban forest.

Section 8.8.4 Long-Term Direction of the PRCMP makes recommendations around service delivery, policies, plans and studies, and land acquisitions. Specific recommendations that align well with the ISMP include:

- "Protect and maintain ecosystems, habitat corridors, and environmental values by embracing integrated stormwater management practices, and creating new greenways throughout the City."
- "Take efforts to increase the extent, health and diversity of the tree canopy to improve air quality, capture carbon dioxide, reduce heat island effects, support public health and quality of life, and support beauty."
- "Prepare an Urban Forest Management Strategy."

And finally, the PRCMP recognized the linkages to ISMP's stating that "It will be important to coordinate the ISMP's with the PRCMP so that any changes to the parks respects their values and opportunities to the community for recreation, leisure and nature appreciation". As discussed in Section 9 above, there are several opportunities to meet water management objectives with existing park land. Interdepartmental collaboration will be required to explore the practicality of meeting multiple objectives at these sites.

15.2.3 Plan200K Transportation Master Plan

There is relatively little alignment between the Transportation Master Plan (TMP) and this ISMP, but also no direct conflict. In general, the TMP is void of information relating to drainage or environmental protection. The only item of relevance in the TMP is support for street trees.

15.3 Operation and Maintenance

The City's mandate is to operate public infrastructure, but with current criteria there is increasing reliance on private controls. The long-term operation and maintenance (O&M) of both systems is important. Through a workshop discussion among City staff as part of the ISMP development, Operations staff expressed confidence that the current O&M of public infrastructure is sufficient and does not require adjustments. A key element of the program is active monitoring; particularly of ponds, outfalls and creeks. The City also has a routine CCTV inspection program with a 20-year cycle. This monitoring program allows the City to respond to issues in a timely manner. However, it is unclear if the City has priority ranking to its program. For instance, it is understood that the City does not currently know the condition of the trunk sewer through the Historic Downtown that takes the discharge from Mill Lake. This trunk sewer is perhaps the most critical piece of drainage infrastructure in the City upland system and should be very high priority. It is highly recommended that a condition assessment of this sewer be conducted near term. It is also recommended that the City prepare a "criticality" map of the drainage system and assign operational policy on a priority basis.

The City notes they inspect private controls on a 3 year cycle, however the City does not currently have any instrument to enforce maintenance of private stormwater management systems. The Stormwater Source Control Bylaw does have a section noting maintenance requirements, however as raised in the Plan 200K Drainage Master Plan, this bylaw currently applies to a select group of properties and is not enforceable through the Development or Building Bylaws. Adopting of this as a City-wide bylaw enforceable through the Development Permit and Building Permit would be a valuable first step. This City may wish to consider developing a more robust program for Green Infrastructure.

15.3.1 Green Infrastructure Operation and Maintenance

Green infrastructure (GI) refers to a set of stormwater management practices that collect, infiltrate, and reuse stormwater runoff as it is created when rain falls on the streets, roofs and other impervious areas found in built communities. Common examples of GI include:

- Bioretention, including bioswales, rain gardens, enhanced tree pits and green roofs and walls;
- Engineered wetlands and stormwater ponds;
- Permeable pavement; and,
- Downspout disconnection.

Learning from other jurisdictions, in particular the USA, there are various administrative tools for establishing legal responsibilities for the operation and maintenance of GI on private property. Such programs are rare in Canada. **The information below is introductory for consideration and will need to undergo a legal review to ensure any program adopted is appropriately tailored to municipal law locally.**

Administrative Tools

There are a range of administrative tools that can assist local governments in implementing GI operation and maintenance requirements. A local government can select and tailor these tools to meet requirements in a manner that fits within their existing program. Examples of administrative tools include the following:[4]

Stormwater code/manual/plan

A stormwater code/manual/plan can be used as the basis for setting inspection, operation and maintenance requirements. It can be used to define permitting and plan review processes, list required development project submittal elements, identify the party responsible for GI maintenance, define legal agreements, define the inspection process and establish enforcement measures.

With respect to incorporating private facilities into a local government stormwater maintenance program there are various option which include the following:

- Local government could inspect facilities and require that the property owner hire a qualified contractor to conduct necessary maintenance
- Local government could require facility owners to contract with a third-party inspector and provide an inspection certification letter to the local government, as well as proof that any required maintenance has been completed
- Local government could perform maintenance and charge the property owner
- Local government could assume maintenance responsibilities through a deed or easement.

[4] Herra Environmental Consultants, Inc. and Washington Stormwater Center, 2013. Guidance Document: Western Washington Low Impact Development (LID) Operation and Maintenance (O&M). Prepared for Washington State Department of Ecology Water Quality Program.

Legal agreements (such as declarations of covenant and access easements between a property owner and the local government)

Legal agreements between a private party, responsible for GI maintenance, and the local government can be recorded against a property title to help require and ensure long-term facility maintenance.

- Identify and characterize the stormwater features on site (i.e., attach as-built drawing of the lot with the location of the GI and the area served by them, design details, figures, and maintenance instructions)
- Require inspection and O&M activities and direct responsible party to local municipal code, manual, and/or project-specific O&M manual
- Identify the party responsible for retention, protection, and maintenance of GI facilities
- Describe how the responsibility for maintenance of GI facilities is transferred when property ownership changes
- Help give the local government legal access for inspection

Project-specific GI maintenance requirements

Local governments can require project specific maintenance with a requirement that O&M manuals be developed for each GI facility.

For GI on private property, a copy of each O&M manual must be retained onsite, or within reasonable access to the site, and must be transferred with the property to the new owner. If the GI facilities are distributed on individual lots, then each property owner should have an O&M manual. A log of maintenance activity, indicating actions taken, must be kept and made available for review upon request by the local government.

The project-specific maintenance requirements must be at least as stringent as those in the local maintenance standards. Because maintenance requirements and recommended procedures may evolve over time, consider allowing project proponents to include a reference to a document that can be updated periodically. The agreement can refer to the current version of the document. Some jurisdictions have online maintenance manuals that can be referenced in legal agreements, so that the most up-to-date maintenance information is available for property owners.

Financial surety measures

To ensure that GI facilities are protected and maintained after construction a local government can require a financial surety, such as a bond or an assignment of savings. If authorized by the jurisdiction's code, local governments can require that sureties are obtained by developers. This is particularly important if a jurisdiction assumes responsibility for private facility maintenance once construction has been completed. It is critical to ensure that adequate funds are available in the event of a non-compliant facility.

Record keeping and tracking process

An effective maintenance program requires the collection and tracking of GI facility maintenance information, beginning with the plan review process and continuing for the life of the facility. The following information should be included in a local government record keeping system for GI maintenance:

- Land parcel information
- As-builts or record drawings for individual lots and for public rights-of-way
- Legal agreements (e.g., covenants or easements)
- Location information (e.g., GPS data, digital maps)
- Project O&M manual
- Maintenance logs (typically included in a project O&M manual)
- Inspection forms (e.g., during construction, post-construction, ongoing annual)
- Enforcement documents

It is critical for local governments to develop effective interdepartmental recording and record management procedures to support ongoing inspections.

Inspection programs

Inspections are recommended for all GI facilities immediately post-construction. These inspections are critical to check that the facilities are installed per plan and functioning properly. Ongoing annual inspections are also recommended to ensure long-term functionality of GI facilities

Local governments could consider allowing third party inspection for GI in settings that are difficult for a local government inspector to access or if property owners do not want local government inspectors on their properties. The property owner would be required to provide the local government with inspection documentation from an approved third-party inspector, or inspections and maintenance could be arranged through a homeowner's association. This would reduce the potential liability concerns and reduce staffing needs while still allowing the jurisdiction to meet their annual inspection requirements. Local governments could consider mitigating the cost to the private property owner by crediting the inspection fee on their utility bill.

Inspectors should be trained on the function of GI facilities and proper procedures for inspection during and after construction. Inspection checklists for GI facilities are a good tool to support consistent inspection practices and can be used for record keeping. The project specific O&M document and record drawings should be reviewed before and during the inspection.

15.4 Green Infrastructure Maintenance Agreements For Private Property

In the case that local governments rely on property owners or homeowners' associations to maintain GI facilities that are on private property, maintenance agreements should be established. Before installing GI, a local government or developer should establish clear ownership of the facility and designate operation and maintenance responsibilities clearly through a written agreement[5].

The agreements tend to have language that specifies details on the following[6]:

- Party that is responsible for maintenance (private property owner or GI implementation program entity);
- Expected maintenance frequency;
- Whether or not the GI implementation agency will perform inspections of the GI project to ensure that maintenance is being performed and at what frequency the agency will inspect;
- Details on how the GI implementation agency will access the project for maintenance and/or inspections;
- Consequences if maintenance is not performed;
- Process for recording the maintenance agreement (deed record filing or easement); and,
- Permission(s) (i.e., photographing the project, etc.).

For development projects, these aspects can be incorporated into the permitting process.

[5] Environmental Protection Agency, 2012. Maintenance of Low Impact Development: Communities Are Easily Managing LID Practices. December 2012.

[6] Feehan, C., 2013. A Survey of Green Infrastructure Maintenance Programs in the United States. 2013 Hixon Fellowship Final Report. Yale School of Forestry and Environmental Studies.

15.5 Green Infrastructure Maintenance

In general, GI practices have lower long-term life cycle costs, perform better and provide additional benefits such as improved aesthetics and enhanced property values. However, no matter how well they are designed and constructed, GI will not function correctly or look attractive unless properly maintained. Maintenance activities and schedules depend on the type of facility and environmental context in which they are located. Maintenance activities could include the following[7]:

- Debris and litter removal
- Sediment removal and disposal
- Stability and erosion control
- Maintenance of mechanical components
- Vegetation maintenance
- Maintenance of the aquatic environment
- Insect control (i.e. mosquitos)
- Maintenance of other project features (i.e. fences, access roads, trails, lighting, signage, platforms)

15.6 Adaptive Management

Adaptive management is a process of monitoring, reviewing, learning, and adjusting.

15.6.1 Monitoring

Environmental health and flow monitoring are two important components of an Adaptive Management process, but the program needs to be expanded. Monitoring is broken into several categories, including physical (eg. are the desired flows and quality of water being achieved?), regulatory (eg. are the City's regulatory tools successfully guiding development?), and process (eg. are City staff properly informed and are inter-departmental processes in place to successfully direct the plan's implementation).

Physical Monitoring

Through this ISMP process, baseline water quality and health scores were stablished for Horn Creek, Boa Brook and Prairie Street Creek (refer to section 4). The Monitoring and Adaptive Management Framework developed by Metro Vancouver[8] provides a resource in developing an expanded program. As noted in that document, it is recommended that physical monitoring occur on a 5 year cycle. In the case of Horn Creek, the City has installed a semi permanent flow monitoring station and provided it provides reliable data, it is recommended the City keep this station functional long term, as it serves as a representative baseline to which future catchment changes can be measured against over time.

It is recommended that the City implement some short term (at least one winter season) monitoring within the storm sewer system and existing detention ponds as highlighted in **Figure 15.1** in order to

[7] North Carolina Environmental Quality, 2017. Stormwater Design Manual – Part A-7. Operation and Maintenance.https://files.nc.gov/ncdeq/Energy%20Mineral%20and%20Land%20Resources/Stormwater/BMP%20Manual/A-7%20%20Operation%20and%20Maintenance.pdf – Accessed December 7th, 2018.

[8]http://www.metrovancouver.org/services/liquid-waste/LiquidWastePublications/Monitoring_Adaptive_Management_Framework_for_Stormwater.pdf

validate performance. The monitoring of existing ponds will be used to confirm whether or not these ponds are performing at their optimum level, and if not, what changes should be made. The monitoring locations for the storm sewers are identified where the theoretical SWMM model indicates storm sewer capacity is inadequate for a 1:10 year flow. The chance of capturing a significant storm event (>1:2 year) within a single winter season is relatively low, but this data will allow model calibration to more confidently predict performance under a design event, in turn providing greater confidence to capital plan priorities.

It is recommended that the City implement a semi-permanent water level (not flow) gauge on Willband Creek on the upstream side of Highway 11.

It is recommended that the City require short term monitoring (one winter season) of all future stormwater source controls, private and public, to validate that their performance in accordance with design criteria.

It is recommended that the City retain a qualified geotechnical professional to inspect Horn Creek, Boa Brook and Prairie Street Creek each year for soil instabilities and risk assessment.

Finally, is recommended that water quality and benthic sampling be repeated on a 5 year cycle at the same locations as presented in Section 4.

Regulatory Monitoring

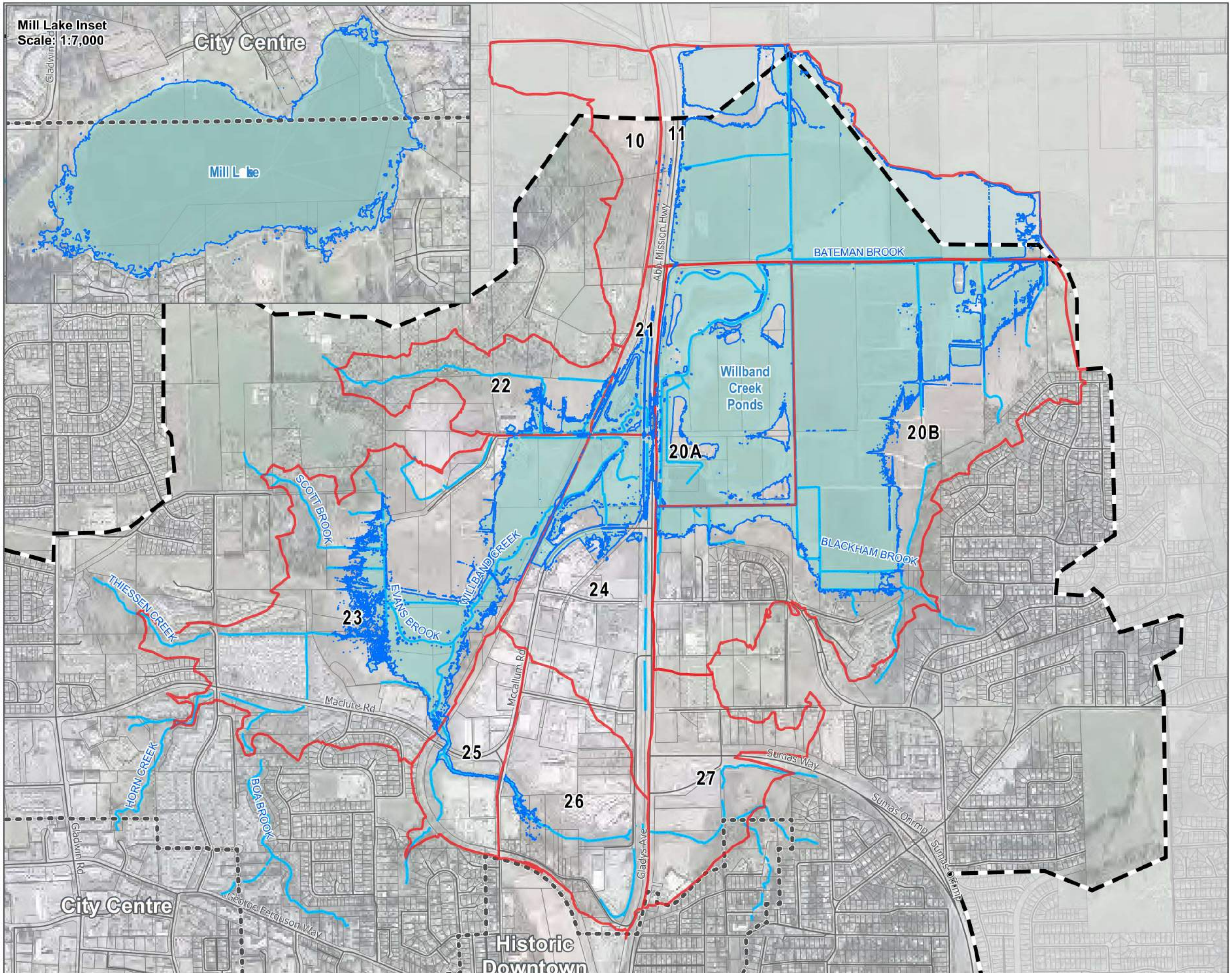
The most significant regulatory aspect to track is that source controls are being implemented in accordance with bylaws and criteria. The City's Drainage Master Plan states that because the Stormwater Source Control is not enforceable beyond Zoning, there have been instances where controls are not ultimately implemented through Development or Building. It is recommended that the City set up appropriate record systems to track that source controls are in fact being implemented through both the Development and Building Permit processes, and in accordance with the bylaws. As an extension, also track that inspection and maintenance reporting is being done.

It is anticipated that an Urban Forestry Management Strategy would include some form of regulation to guide development and private property owners. It is therefore recommended that if and when such regulation is created that tracking be implemented.

And finally, it is recommended that inspection and monitoring occur at occupancy permit that a development / building has not exceeded the permissible site coverage as permitted by the zoning bylaw, and that directly connected impervious surface does not exceed those permitted by design criteria.

Process Monitoring

The most significant aspects of process monitoring are to ensure that City inspectors are knowledgeable of design criteria and standards of the Development Bylaw and Stormwater Source Control Bylaw. An equally important process to monitor is that implementation of controls is not "slipping through the cracks" during the Development or Building Permit process. It's recommended that a "checklist" field be created in the application registry to track whether or not controls are successfully implemented.



ABBOTSFORD

Willband Creek
Integrated Storm Water
Management Plan

Flood Extents (200 Year)

Legend

- Maximum Future Flood Extent (200 Year)
- Existing Flood Extent (200 Year)
- Flood Cells
- Willband Creek Watershed
- Neighbourhood Plan Boundary
- Creek

The accuracy & completeness of information shown on this drawing is not guaranteed. It will be the responsibility of the user of the information shown on this drawing to locate & establish the precise location of all existing information whether shown or not.

0 200
Metres

Coordinate System: NAD 1983 UTM Zone 10N

Scale: 1:13,500 (When plotted at 11"x17")

Data Sources:
- City of Abbotsford (2016-18)
- GeoAdvice (2016-18)

Project #:	1790.0015.01
Author:	LP
Checked:	GS
Status:	FINAL
Revision:	A
Date:	2018 / 12 / 17

URBAN systems

FIGURE 13.1

15.6.2 Assessment

It is recommended that an audit of all above monitoring be undertaken on a 5-year cycle. Physical monitoring data would be processed for evaluation by hydrologists and environmental professionals and evaluated against all preceding data. Its recommended that the City implement a central database to record and track data for each monitoring period. The fundamental goal is to see if the hydrologic response to rainfall of the built lands is reducing, and that the water quality and watershed health is improving. This should be tracked in relationship to the changes that have occurred in the contributing catchment. As such, the number and location of development permits, building permits, and capital projects would be inventoried, and the details of their implemented source controls evaluated. The audit would first assess whether or not implementation has been successful, and then secondly assess whether or not the changes have resulted in a positive, neutral, or negative outcome to system performance, water quality, stream stability and health. It is expected that significant catchment changes will be required to result in an obvious positive outcome on the receiving watercourses. Given the anticipated influence of climate change, the assessment will need to consider the severity of precipitation that falls between audits. As such, its valuable that the City maintain permanent rain gauges and that rainfall frequency analysis be undertaken with each audit. The evaluation will be more meaningful if environmental factors can be separated from anthropogenic factors.

15.6.3 Key Performance Indicators

Cost effective, measurable, and reliable key performance indicators allow the City to determine whether or not the watershed vision is being achieved. Performance indicators need to be selected for things that can be observed and measured frequently. In the context of Willband Creek, recommended key performance indicators are:

- Reduced sediment deposits at the base of Horn Creek, Boa Brook, and Prairie Street Creek
- Stability of creek bed and banks in Horn Creek, Boa Brood, and Prairie Street Creek
- Fewer annual service complaints due to flooding
- Increase in tree canopy as measured from aerial photos
- A positive differential between the number of trees planted to the number of trees removed
- No reduction in the riparian vegetation as measured from aerial photos
- Successful implementation of source controls with all development and building permits that require them
- Improved water quality as measured in Horn Creek
- Improved benthic health as measured in Horn Creek
- Successful implementation of the Capital Program.

15.6.4 Responses

The monitoring program is important to assess the specific failure mechanism, should failure occur. Was there a poor design(s)? Has there been a significant change in weather patterns? Was there a breakdown in approval process that prevented bylaws from being enforced? Was there an infrastructure failure due to insufficient maintenance? There can be many reasons why objectives may not be met. The response(s) need to align with the cause. It is therefore premature to articulate a specific response plan at this time, but some fundamental responses may be as follows:

1 If watercourse erosion and environmental health do not stabilize, or preferably improve, the City may need to accelerate the implementation of communal management infrastructure through its capital program; either with high flow diversions or stormwater detention ponds. As determined herein this ISMP, there are relatively few opportunities for effective ponds on lands where no buildings currently exist, therefore land acquisition and building demolition may be required.

2 If development or building permits are being completed without successful source controls, the City needs to evaluate whether this was a procedural failure, or if it needs to strengthen the enforcement and penalties of the bylaws, making amendments to them accordingly.

3 If service calls occur due to structural or maintenance failure, the City needs to strengthen its Asset Management Program.

4 If maintenance of private source controls is not validated, the City should consider implementing a formal Stormwater Source Control Operating Permit program.

5 If there is increased flooding in the upland urban area not caused by structural or maintenance failure, the City may consider accelerating its pipe replacement program on a priority basis, or explore alternative mitigative measures.

6 If the funding for infrastructure change cannot keep up with demand (ie. worsening conditions) the City needs to revisit its funding stream and look to a program that provides more reliable funding.

7 If the City is not leading by example in implementing and maintaining source controls in public spaces, the City needs to evaluate its interdepartmental collaboration and priorities.

Adaptive Management Summary of Recommendations:

1 Continue to monitor flows in Horn Creek.

2 Implement a water level monitoring system in Willband Creek immediately upstream of Highway 11.

3 Educate City Staff in Building and Development departments of new requirements and create a “checklist” field in the application registry to track whether or not controls are successfully implemented.

4 Audit all monitoring data on a 5-year cycle.

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