Township of Langley

Anderson Creek ISMP

Final Report

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Project Number:

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Date:

April 2014

Distribution List

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3	yes	Arthur Kastelein – Township of Langley
1	yes	Jeannie Lee – City of Surrey

Version Log

Version #	By	Date	Description
0	MP	March 2013	Stage 1 Draft Report Submission
1	MP	October 28, 2013	Complete ISMP Draft Report Submission
2	SB	February 13, 2014	Draft Final ISMP Report Submission
3	CO	April 25, 2014	Final ISMP Report Submission

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Executive Summary

An Integrated Stormwater Management Plan (ISMP) is a policy document that provides direction to local government and land owners to preserve and improve the overall health of a watershed while balancing and integrating the requirements of land use planning, stormwater engineering, flood and erosion protection, and environmental protection. The Township and City initiated this ISMP due to growing demand for development in the Brookswood area and in accordance with Metro Vancouver's Integrated Liquid Waste Resource Management Plan (ILWRMP).

The Anderson Creek ISMP provides guidance on how development should be managed to meet municipal commitments for watershed sustainability as well as Metro Vancouver's ILWRMP. The ILWRMP stipulates that ISMPs should encourage managing rainwater at the site level to minimize stormwater runoff and improve water quality. Guidelines for integrating appropriate stormwater source control Best Management Practices (BMPs) into community development policies to encourage low impact development are presented. As a road map for watershed health, the ISMP provides a holistic approach to protecting natural resources as development continues through a series of recommendations, strategies and standards that are sustainable provided there are resources and funds for operations and maintenance costs.

Anderson Creek is located in the southwest quadrant of the Township of Langley originating just east of 240 Street. It flows west and crosses into the City of Surrey at 196 Street and 44 Avenue before discharging into the Nicomekl River. The watershed is 3,272 Hectares (ha) in size with 850 ha of rural/urban areas, 1,853 ha of ALR, and 569 ha located within the City of Surrey. Anderson Creek has significant fish habitat and the majority of it is classified as Class A such that protection of the watercourse is critical.

The current minor drainage system in the study area consists of rock pits and infiltration trenches with a few sections of storm sewers. The major drainage system includes overland flow paths for surface runoff to Anderson Creek, several lakes (or ponds) and wetland areas, and large diameter culverts and bridges for road, driveways and pedestrian crossings of the Creek.

In the early stages of the ISMP process a series of goals and a vision was developed, with participation from Township and City staff, namely:

"Maintain and improve the health of the Creek as well as protect and enhance the current natural resources in the watershed."

The following eight goals are used to summarize the ISMP and meet the overall objectives.

Goal 1: Protect and enhance the health and natural resources of the watershed

Natural resources in the watershed include the riparian buffer zones, forested areas, watercourses, aquifers and wildlife corridors. These resources have been delineated and assessed to determine the overall health of the watershed. Highlighting and maintaining the quality and quantity of all natural resources is primary objective for this goal. Protection of resources such as re-charge water for aquifers from impending development is paramount. The Capital Works Plan detailed in this ISMP is designed to maintain and/or enhance the natural resources in the watershed through low impact development measures and implementing stormwater source control best management practices.

Goal 2: Promote participation from stakeholders for a common vision for the watershed

Two open houses were held on January 15 and 19, 2013 in conjunction with a proposed update of the Brookswood / Fernridge Community Plan. The major issues and concerns that were expressed by attendees include erosion and slope stability concerns in Anderson Creek ravine, runoff from ALR lands causing flooding in vicinity of 24/32 Avenue and

208/212 Street, aquifer recharge and water quality protection, and habitat protection and enhancement for fish/wildlife and trees.

A staff workshop was also held with Township and City representatives to collect feedback on the concerns expressed at the open houses and determine how the current system is functioning from an operations perspective. The successes and challenges that the Township and City have experienced in similar development areas in regard to stormwater source controls and tree retention were also discussed. Several other stakeholder groups were contacted for input to the ISMP which include the Township Agricultural Advisory Committee, Nicomekl Enhancement Society, and the Sunrise and Rees Lake Owners Associations.

Goal 3: Minimize risk of life and property damage due to flooding and provide strategies to attenuate peak flows

Urban development increases stormwater runoff unless it is effectively managed. Strategies to restrict post-development peak flows and volumes to current development conditions (or better) are recommended such that the frequency and magnitude of flood events and erosion are not exacerbated and reduced if possible. These strategies include implementation of stormwater source control Best Management Practices (BMPs) at the lot level and in municipal streets and rights-of-way for peak flow attenuation and volume reduction.

For analysis of the minor and major drainage system, a calibrated hydrodynamic model was developed using PCSWMM to simulate design storm events for the watershed. The model incorporates watershed characteristics for the creek, surface runoff and soil infiltration and was used to develop the drainage servicing strategy and Capital Works Plan for the area to meet Township and City design criteria and allow for development to occur.

Modifications to drainage patterns, creek sections, and vegetation on private property is noted to have increased slope instabilities and the potential for flooding. Geotechnical assessments that highlight locations where eroded banks, slope stability concerns, and fallen debris and trees are present were also reviewed in conjunction with the field assessment. The majority of these issues are in the ravine section of the Creek and it is recommended that remedial works continue to be undertaken when funds are available.

Goal 4: Prepare an inventory of watercourses, wildlife, and benthos for the watershed

Achieving this goal is necessary to determine the health and resources of the watershed to help identify what should be further protected. A number of species were identified in Anderson Creek that have an endangered status and as human activities and development continue in the watershed, long-term environmental mitigation measures must be in place to protect these species. Monitoring of benthic invertebrates (benthos) is another means of determining watershed health as the benthic species perform a variety of functions in freshwater ecosystems.

It is known that increased agricultural activities and urbanization result in poor surface and groundwater quality, riparian area removal, increased groundwater extraction and channelization of the creek. In addition, there are green spaces and wildlife corridors, including coniferous forest, that need to be protected as these are prime habitat areas.

Goal 5: Prevent pollution and maintain/improve water quality of surface flow and groundwater

The unconfined Brookswood Aquifer is vulnerable to contamination from poor water quality which is a concern particularly in municipal well capture zones. Furthermore, it is suspected that current agricultural activities, transportation corridors, and sanitary septic field disposal systems are impacting surface water and groundwater quality and quantity such that these resources should be monitored.

Particular water quality concerns include elevated nitrate levels that could be natural or could indicate the groundwater is at risk for contamination from surficial activities such as pesticide and manure application and discharges from private septic systems. Specific land uses that should not be permitted in municipal well capture zones are identified and include gas stations, auto shops, drycleaners and other chemical storage or high risk facilities. Day to day sediment buildup and contaminants from vehicles is to be treated in a stormwater source control BMP prior to infiltration or conveyance to detention ponds.

Surface water quality is also critical and treatment of runoff prior to infiltration to ground is recommended. In some areas, only roof runoff should be infiltrated unless mechanisms are in place for removal of typical road and vehicle related pollutants. Maintaining a high quality of water in the creeks, ponds and lakes is also paramount to allow for the naturally occurring flora and fauna to flourish.

Goal 6: Identify current and future agricultural, residential, commercial, and recreational land uses

Planning in the watershed is based on the Brookswood / Fernridge Community Plan, which provides a general land use and servicing framework. The current plan was being updated in conjunction with this ISMP and the update was used to define the size and location of stormwater infrastructure in the area. However, the Community Plan update is being revisited as a result of recent public input. Although the Community Plan has not been completed or adopted to date, the strategies and BMPs developed for the ISMP are applicable to any future development that may occur in the study areas. It is anticipated that future updates to the Community Plan will require a revisit of the size of proposed storm sewers and detention ponds proposed in this ISMP and the remainder of the findings and recommendations will apply as written.

Neighbourhood Plans provide specific details for smaller areas within a Community Plan boundary to guide rezoning applications considered by Council, including: specific land use, development, and environmental protection policies; green space, park, and school needs; and road, water, sewer, and storm drainage management requirements.

Locations for future land use changes in the watershed are documented in the Brookswood / Fernridge Community Plan, Township and City OCPs and the Campbell Heights Area Plan. Areas where imperviousness is likely to increase have been targeted for stormwater source controls.

Prior to any further development in the vicinity of 196A Street and 198 Street south of 34A Avenue, the Township should initiate a detailed study to investigate the groundwater table elevations and whether infiltration measures are practical for the area. The Township currently operates two drainage pump stations in this area due to elevated groundwater levels. Furthermore, enhanced infiltration should not be encouraged along the top of steep slopes as pore water pressures increase contributing to slope instability and potential failure.

Goal 7: Develop a cost effective and enforceable implementation plan

An implementation plan outlines how to achieve the strategies identified in the ISMP and includes a detailed Capital Works Plan, operations and maintenance requirements for stormwater source control BMPs, strategies for funding and enforcement, and recommended policy changes.

A major focus for the drainage servicing strategy is mandatory use of stormwater source control BMPs through introduction of a new Bylaw or enhancement of the current *Township Subdivision.* Many of these BMPs are already in use in the study area, such as rock pits, dry wells and infiltration trenches, and have proven to be a successful means for managing stormwater. Additional measures that are proposed include rain gardens, vegetated planters, porous pavers, water quality treatment systems and detention ponds. BMP's in the public realm need to be maintained, and a process to increase maintenance budgets is recommended when developments are approved.

The Capital Works Plan includes storm sewers and detention ponds which are sized based on conveyance of the 5-year and 100-year (24-hour) design storm event peak flows and volumes after infiltrating the 2-year 24-hour design storm event on-site. Portions of the proposed municipal storm sewer system are intended to be perforated PVC pipe within infiltration trenches to encourage exfiltration beyond the on-site stormwater source control BMPs.

A summary of the Capital Works Plan and preliminary phasing strategy is provided in **Table E.1**. The costs include a 30% contingency, inlet/outlet works for ponds, storm sewers and manholes, infiltration trenches (where applicable) but exclude service connections, land acquisition and ROW costs.

Table E.1 Capital Works Plan Summary

Year	Area	Description	Cost Estimate	Pond Area
1 to 5	A1	14,300m^3 Detention Pond 1 870m of conventional storm sewers 1,880m of perforated storm sewer and infiltration trenches	$ 5,754,500	1.05 ha (2.6 ac)
6 to 8	A2	6,100m^3 Detention Pond 2 460m of conventional storm sewers 1,700m of perforated storm sewer and infiltration trenches	$ 3,925,000	0.83 ha (2.0ac)
9	A3	470m of conventional storm sewers 955m of perforated storm sewer and infiltration trenches	$ 1,944,375	--
10	A4	230m of conventional storm sewers 1,075m of perforated storm sewer and infiltration trenches	$ 1,392,500	--
		Total Cost Estimate	**$ 13,016,375**	

Goal 8: Establish a monitoring and assessment strategy to ensure goals are achieved, maintained, and enforced

A key component to a successful ISMP is to develop a long-term adaptive management program that includes monitoring, operation, and maintenance strategies to verify that the vision and goals are met through the implementation plan.

Monitoring for water quality, benthic invertebrates, and erosion sites should continue to ensure current conditions are maintained (or ideally improve) and further degradation does not occur. Parameters for annual water quality analysis should include total suspended solids, nutrients (nitrogen and phosphorus), heavy metals, organics (including oil and grease), and pathogens (bacteria, coliform). Samples should be collected at the same baseline sites that were established in this ISMP. A monitoring program for checking the impacts of road salts on stream flow and groundwater should also be considered. Benthic invertebrate biodiversity index (B-IBI) sample collection along with water quality data will provide an ongoing assessment of overall watershed health. If water quality results, flow monitoring data, or erosion and slope stability worsens or show changes from the baseline conditions after implementing the ISMP recommendations then further assessment or remedial action is warranted.

Development of a public outreach program and assigning a Township ISMP coordinator will help to ensure these goals are achieved. An update to the ISMP will be warranted in the future if there are revisions to the OCP, zoning Bylaw, or Community Plan with significant changes to future land uses.

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1 Information Collection and Assessment

1.1 Introduction

The study area for this Integrated Stormwater Management Plan (ISMP) is the Anderson Creek and Unwin Watersheds, which encompasses Agricultural Land Reserve (ALR) areas, as well as rural and urban developed areas in both the Township of Langley and City of Surrey. In total, the Anderson Creek watershed is 3,272 Hectares (ha) in size with 850 ha of rural/urban areas, 1,853 ha of ALR. 569 ha are located within the City of Surrey's Unwin catchment area, of which 310 ha are ALR. Anderson Creek is located in the southwest quadrant of the Township of Surrey and crosses into the City of Surrey at 196 Street and 44 Avenue where it ultimately discharges into the Nicomekl River. The Unwin Watersheds in Surrey include smaller watercourses (including Armstrong Creek and Ross Creek) that also drain to the Nicomekl River.

1.1.1 Background

An ISMP is a document that provides direction to land owners and local government policy makers to address community land use choices and determine best options to manage these in light of the natural resources present in the area while accommodating growth by:

- Regulating redevelopment of land,
- Setting goals to control stormwater runoff,
- Protecting existing watercourses and flood plains,
- Improving water quality, riparian and fish and wildlife habitat,
- Protecting groundwater quality and quantity,
- Providing opportunities for people to interact with nature, and
- Enabling adaptive management through monitoring and modelling.

In May 2010, Metro Vancouver finalized its *Integrated Liquid Waste Resource Management Plan* (ILWRMP) for the Greater Vancouver Sewerage & Drainage District and Member Municipalities. The ILWRMP stipulates that ISMPs should encourage managing rainwater at the site level, thereby minimizing stormwater runoff and improving water quality through source controls. ISMPs are also intended to provide guidance on appropriate rainwater management practices and integrate them into community development policies.

As member municipalities, the Township of Langley and City of Surrey are committed to undertake and implement ISMPs to better protect those watersheds where development is proposed. The Township and Surrey initiated the Anderson Creek ISMP to determine how resources within the watershed should be managed and protected while balancing land development, storm water management, and the environment as part of its commitment to sustainability and Metro Vancouver's ILWRMP.

Stormwater management is intricately linked to stream health in ways that are much more subtle than a traditional "pipe and pond" analysis. As a road map for watershed health, the ISMP provides a holistic approach to protecting natural resources as development continues through a series of recommendations, strategies and standards that are sustainable with minimal operational and maintenance costs.

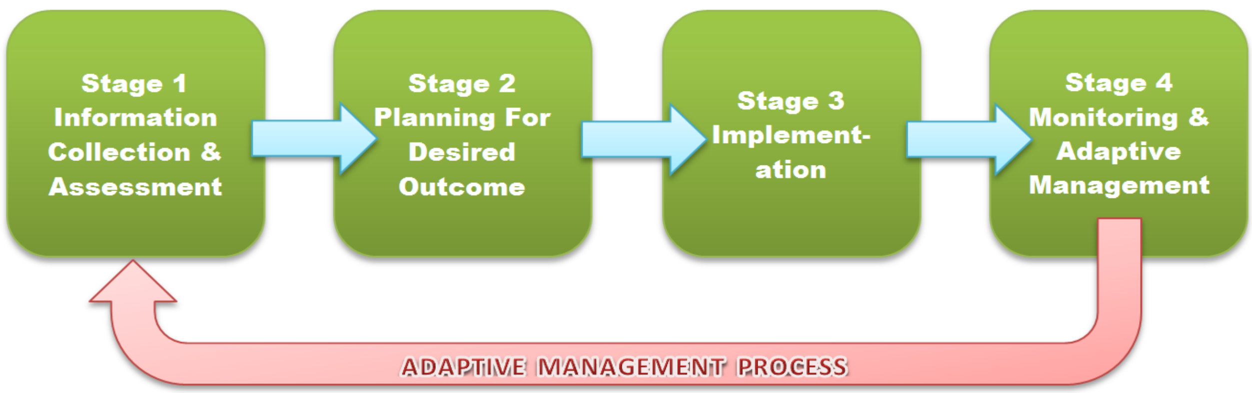
1.1.2 ISMP Process

The Anderson Creek ISMP is structured into 4 stages:

- Stage 1: Information collection and assessment;
- Stage 2: Planning for the desired outcome;
- Stage 3: Implementation; and,
- Stage 4: Monitoring and adaptive management plans.

It is important to understand that the ISMP is a long-term adaptive process. Planning for the future with a long term time horizon is challenging because of the number of variables involved and the inability to anticipate changes in personal attitudes, economic and market conditions, technology, scientific knowledge and politics. It is, therefore, critical that this ISMP be adaptable as information and conditions change.

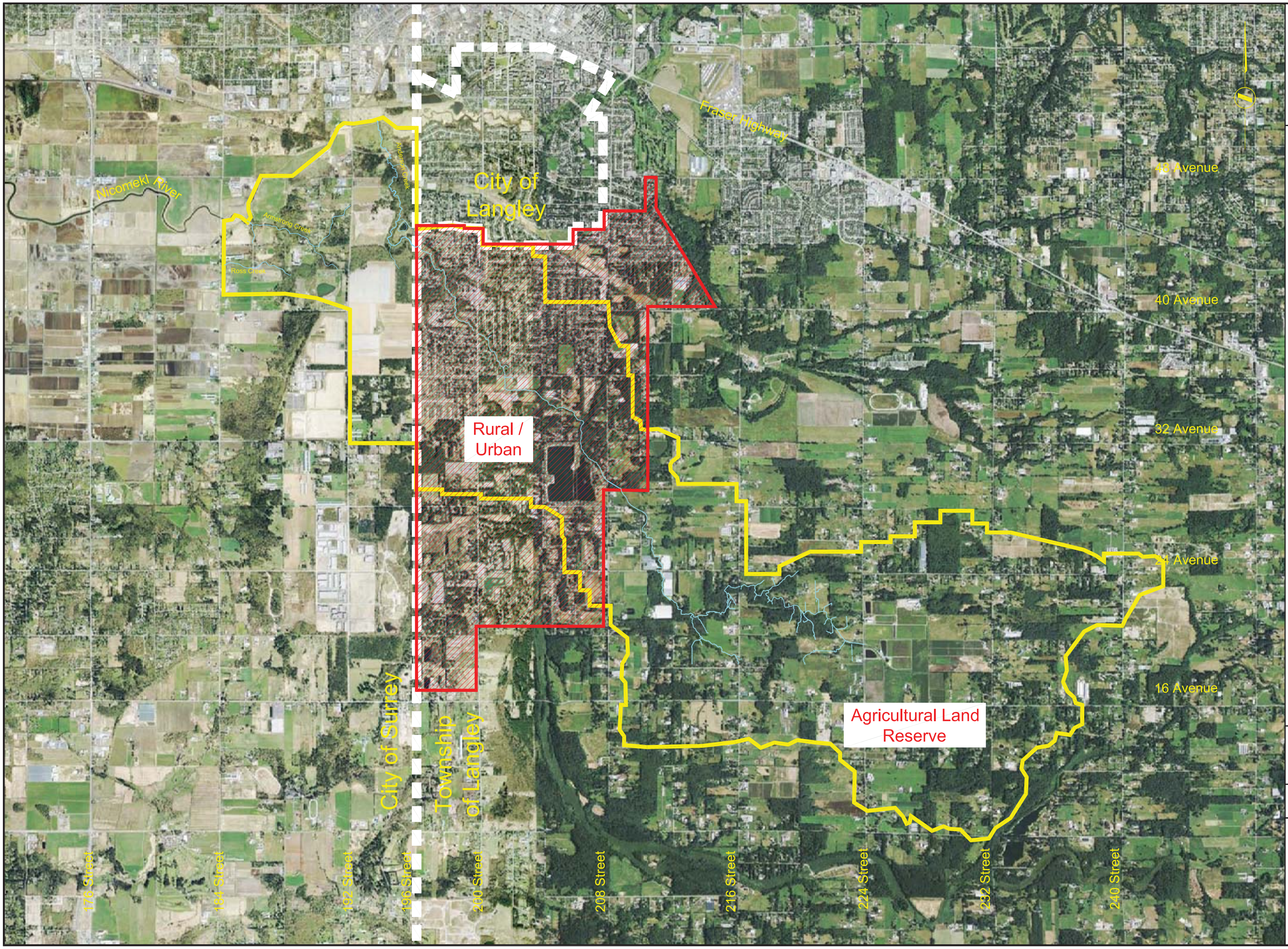
As part of the Information Collection and Assessment, the existing conditions have been documented through visual assessments, in-field measurements and tests, review of background reports, GIS database review, existing policy and Bylaw review, desktop analyses, and development of a hydrologic and hydraulic model of the existing drainage system. **Figure 1.1** shows an aerial view of the study area as well as the municipal boundaries between the Township of Langley, City of Surrey, and City of Langley.



1.1.3 Previous Studies

The Township of Langley and City of Surrey have provided background studies, GIS information, maps, and reports pertinent to the Anderson Creek and Unwin watersheds. Key issues identified that are still applicable to the current watershed condition have been incorporated and referenced in this report. In addition, discussions with Township of Langley staff and City of Surrey staff were conducted as part of the information gathering. **Section 5** contains a full list of references reviewed in preparation of this report. Several key documents that were part of the Stage 1 review include the following reports:

- Anderson Creek Master Drainage Plan Update (New East Consulting Services Ltd. 1999) – includes a comprehensive drainage study for the entire catchment area and review of proposed servicing options. An extensive open house and public consultation process was also conducted.
- Brookswood/Fernridge Community Plan (OCP Amendment Bylaw 1987 No 2475) – this OCP bylaw provides the proposed land use for the study area
- Anderson Creek Geotechnical Review (EXP Services Inc., 2012) – this study focused on terrain stability and channel morphology assessments along the creek and its tributaries between 196 and 203 Streets.
- Comprehensive Groundwater Modelling Assessment (Golder & Associates, 2005) – this report includes an assessment of the municipal well capture zones under maximum pumping conditions.



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- ISMP Study Area
- Anderson Creek
- Brookswood / Fernridge NCP

AECOM

0 1000 2000 m

Project No.	Date
60267316	October 2013

Study Area

Figure 1.1

1.2 Current Policy Framework & Criteria

The Township of Langley and City of Surrey have several policies, and criteria that mandate requirements for items such as water quality, stream setbacks, environmental protection, and peak flow attenuation. These concepts are all integral components to improving watershed health. As a policy document, an ISMP can be a powerful tool and must be read in conjunction with other municipal, provincial, and federal regulations that the Township of Langley and City of Surrey adopt. As indicated in the *Metro Vancouver 2012 Integrated Stormwater Management Plans – Lessons Learned to 2011*, it is important to understand the existing policy framework and stewardship programs already in place in order to identify opportunities and constraints as they relate to the ISMP.

With the adoption of the *Sustainability Charter*, the Township has made great efforts to provide guidance to new developments in regards to sustainable stormwater management practices. Therefore, it is important to establish what practices and policies are already in place to guide development and the public towards managing stormwater with a focus of protecting watershed health.

This section summarizes existing policies, Bylaws, design criteria, practices, and procedures currently adopted in the Township of Langley and City of Surrey that are applicable to the Anderson Creek watershed. In addition, the provincial publications related to stormwater and agricultural drainage are discussed and some of the key stakeholders are identified.

1.2.1 Township of Langley Sustainability Charter

The Township's vision for sustainability is to:

"build a legacy for future generations by leading and committing the community to a lifestyle that is socially, culturally, economically, and environmentally balanced."

The Township's Sustainability Charter outlines four main principles as part of building this legacy:

- **Leadership**: Council will provide leadership for a sustainable future;
- **Long Term Commitment**: Council will focus on enhancing the quality of life of the current generation and leaving a sustainable legacy for future generations;
- **Community Involvement**: Council believes that open, inclusive and consultative community involvement are vital to effective decision making; and,
- **Regular Reporting**: Council will implement a plan for the Sustainability Charter, as part of its annual budget process and will report the progress in achieving the sustainability goals on an annual basis.

The sustainability goals represent key aspects for the Township to achieve under this charter, which are illustrated in **Table 1.2.1**.   At project outset, the Township defined applicable goals and objectives for the ISMP to achieve in support of the Township's Sustainability Charter.   These goals are specific to the Anderson Creek ISMP, and are provided in **Table 1.2.2**.

1.2.2 City of Surrey Sustainability Charter

Surrey adopted a Sustainability Charter in 2008 which defines "Sustainability" as:

"Meeting the needs of the present generation in terms of socio-cultural systems, the economy and the environment while promoting a high quality of life but without compromising the ability of future generations to meet their own needs."

The Charter identifies three Pillars of Sustainability (Socio-cultural, Economic, and Environmental), three time frames for implementing sustainable actions and processes (immediate/short, medium, and long-term), and three spheres of influence to achieve sustainable objectives (corporate operations, municipal jurisdiction, and external organisations).

Table 1.2.1 Township of Langley Sustainability Charter Goals

Social / Cultural Goals	Economic Goals	Environmental Goals
• Celebrate our heritage • Protect our people and properties • Build corporate and community capacity • Provide and support community based leisure opportunities • ***Nurture a mindset of sustainability***	• Achieve fiscal stability and fiscal health • ***Develop livable and vibrant communities*** • Strengthen our economy • ***Invest in effective infrastructure*** • Integrate transportation into community planning	• ***Conserve and enhance our environment*** • ***Increase biodiversity and natural capital*** • ***Respect our rural character and rural heritage*** • Reduce energy consumption • Promote stewardship

Table 1.2.2 Goals and Objectives for Anderson Creek ISMP

Sustainability Charter Goal	Anderson Creek ISMP Objective
1. Nurture a mindset of sustainability	• Encourage sustainability innovation • Provide leadership for sustainability practice and innovation • Establish a monitoring and assessment strategy to ensure goals are achieved, maintained, and enforced
2. Develop livable and vibrant communities	• Focus on compact urban form and mixed use neighbourhoods in areas such as Brookswood / Fernridge • Promote participation from all stakeholders to achieve a common future vision of the watershed
3. Invest in effective infrastructure	• Manage and maintain our assets to maximize their service life • Minimize risk of life and property damages associated with flooding and provide strategies to attenuate peak flows • Develop a cost effective and enforceable implementation plan
4. Conserve and enhance our environment	• Improve stormwater quality which directly affects the health of Anderson Creek and surrounding watercourses as well as local aquifers • Prepare an inventory of watercourses and other surface water features, wildlife, and benthos • Prevent pollution and maintain/improve water quality, for surface flow and groundwater
5. Increase biodiversity and natural capital	• Protect rivers, streams, endangered species, and environmentally sensitive areas, • Protect and enhance the overall health of the watershed and its natural resources
6. Respect our rural character and rural heritage	• Preserve the agricultural land base for food production

Key themes and goals that are identified in the City of Surrey Charter and within the sphere of influence of the ISMP process include:

- Awareness and education of sustainability initiatives;
- Incorporate high quality design and beauty in the public realm and built environment;
- Protect trees, riparian areas, natural areas, and bio-diversity;
- Protect and support the agricultural land base and enhance food production;
- Create a balance between the needs of human population and the protection of terrestrial ecosystems;
- Protect groundwater and aquatic ecosystems for current and future generations; and
- Establish a built environment that is balanced with the City's role as a good steward of the environment.

Balancing the socio-cultural, environmental and economic needs and goals is part of developing an ISMP. The City's ability to achieve its vision of sustainability requires the setting of targets, and the establishment of indicators with current baseline values to monitor progress toward meeting these goals.

1.2.3 Stormwater Guidebook for BC & Beyond the Guidebook

The *Stormwater Guidebook for BC* (MWLAP 2003) provides a watercourse-level, site-specific approach to stormwater management. It introduces the concept of discharge duration; that is, the amount of time flow rates exceeds benchmark values. It was developed by an inter-governmental partnership including participants from municipalities, Ministry of Environment, and the Department of Fisheries and Oceans Canada.

As a result, a new approach for stormwater management was developed. It introduced the three-step approach of:

1) ***Retain*** smaller, frequent storm event runoff for on-site for infiltration;
2) ***Detain*** larger, infrequent storm event runoff to prevent flooding; and
3) ***Convey*** safely the released flows.

While the detain (also known as "rate control") and convey stages were already a part of the conventional approach to stormwater management, the "retain" portion was a relatively new strategy to most municipalities. This was one of the first steps in changing the perception of rain water from a liquid to be taken away to a resource that is captured and utilized on-site.

Beyond the Guidebook: Context for Rainwater Management and Green Infrastructure in British Columbia (2007) takes this idea further with more rigorous analytical techniques for examining the hydrologic impact on watercourses from development. As new research and studies develop, it is apparent that the need to control rain water volume is just as necessary as peak flow attenuation in mitigating adverse impacts on creeks.

1.2.4 Drainage Design Criteria

Township of Langley Subdivision and Development Servicing Bylaw 2011 No. 4861

The most recent version of this Bylaw was released in March 2011. Section D contains the design criteria stipulated for drainage. Under Section D3, the Township requires the following design for their major and minor conveyance systems:

- Minor Systems: 5-year storm return frequency shall be conveyed;
- Major Systems: 100-year storm return frequency shall be conveyed; and,
- Stormwater storage facilities shall limit 2-year, 5-year, and 100-year post-development peak flows to equal the corresponding pre-development peak flows.

The bylaw also provides guidelines for on-site infiltration, water quality devices, detention, minimum building elevations, and supplementary detailed design drawings for drainage infrastructure for new developments.

The criteria also specify the rain gauge to be used for the analysis which for this area of the Township is the Surrey Kwantlen Park IDF data (or intensity-duration-frequency curve). Given the patterns of rainfall distributions, the Township should consider reviewing the use of this gauge for designs in the Anderson Creek watershed. For the hydrological model assessment, the rainfall data from the Civic Centre gauge was used. Data from the High Point gauge was also used for comparison.

The bylaw also contains a provision for tree preservation and protection (Tree Protection Schedule I). This states that new developments must comply with the bylaw such that forested areas are retained where possible.

Requirements for when and what type of development application the Tree Protection Schedule applies are as follows:

- At time of submission of a development application (i.e. rezoning, subdivision & development permit);
- To all land use types (residential, commercial, industrial, institutional, and comprehensive development);
- To all new development sites not located in the Agricultural Land Reserve (ALR);
- To significant trees as defined by the Tree Protection Schedule I; and
- To environmental conservation areas identified and protected through the development process.

There are significant benefits from retaining forested areas and green spaces such as reduced impervious areas that in turn reduce stormwater runoff, potential erosion and sediment concerns, and water quality. In contrast, clearing land for agricultural uses results in increases in runoff.

Additional bylaws that have ISMP implications include:

- Streamside Protection Bylaw 2006 No. 4485;
- Soil Deposit and Removal Bylaw 2013 No. 4975; and
- Erosion and Sediment Control Bylaw 2006 No. 4381.

City of Surrey Design Criteria (May 2004)

The City of Surrey's *Design Criteria Manual* (May 2004) has similar design criteria to the Township's requirements for minor and major drainage systems:

- The 5-year event conveyed within the minor system; and,
- The 100-year event conveyed via overland flow routes, under minimum building elevations, to minimize property damage and provide a level of safety for people.

For new developments, the City requires that post-development flows must be controlled to the following criteria:

- Control the 5-Year post-development flow to 50% of the 2-Year post-development rate; or,
- Control the 5-Year post-development flow to a 5-Year pre-development flow rate.

Pre-development conditions are defined in this document as those existing in 1978. As stated in the manual, where erosion is a concern, the more stringent of the two criteria is to be met.

1.2.5 Township of Langley Water Management Plan & Water Quality Report

In November of 2009, Council endorsed the *Water Management Plan* that documents the results of a 3-year planning and public consultation strategy for managing groundwater. As stated in the document, "this plan sets out to ensure safe and sustainable groundwater for the community for generations to come".

Groundwater is a critical source of water for the Township. Across the Township about 86% of the residents rely on municipal water and approximately half of the supply is from local groundwater sources with the remainder of the water supplied from the Greater Vancouver Water District (GVWD). The remaining residents and numerous industrial and agricultural users rely on groundwater from at least 5,000 private wells. In total, groundwater supplies approximately 80% of the Township's water supply needs. Further information regarding groundwater, aquifers, and wells is provided in **Section 1.5 Hydrogeology, Soils and Erosion**.

Initiatives to reduce water use and minimise cosmetic pesticides use are also in place in the Township. The WMP recommends policies and monitoring programs to manage development near ravines and within well capture zones and aquifer vulnerable areas. It includes a recommendation that new developments maintain pre-development infiltration rates.

In 2012, the Township completed a water quality report for municipal drinking water supply wells as per the *BC Drinking Water Protection Regulation*. The 2012 report concluded that source water quality met the regulatory requirements for all health parameters, but some sources exceeded maximum acceptable limits for manganese and nitrates. The concentrations for these parameters were reduced by treatment and blending the extracted groundwater with GVWD and/or other Township well water prior to public distribution.

1.2.6 Riparian Areas and Streamside Protection

The Provincial Government passed the *Fisheries Protection Act* in July of 1997 to help ensure fish have sufficient water and habitat in the future as development continues throughout BC. Specifically, Section 12 of the Act authorizes the Province to establish policies that can be applied to various types of development as part of achieving this goal.

Subsequently, the Province passed the *Streamside Protection Regulation* (SPR) in January 2001 as a way to further define the conditions required to support the Act. In summary, the SPR evaluates existing or potential streamside vegetation conditions to determine setback requirements ranging from 15m to 30m from top of bank.

Fish habitat extends beyond just the water line. Riparian areas are considered part of fish habitat in that they provide shade to cool water temperature and are a significant source of food and nutrients for insects and fish. These areas also provide water quality benefits and peak runoff attenuation by slowing down flows, filtering runoff prior to reaching the stream and stabilizing stream banks. Riparian areas can also act as wildlife corridors, improve air-quality, reduce the urban heat-island effect, and provide aesthetic benefits. Riparian areas may include wetlands, ponds, swampy areas or other intermittent wetted areas (such as side channels and ditches) which may not have flowed throughout the entire year and are considered ephemeral. For example, conditions that are to be maintained within riparian areas may include:

- Ensuring a good coverage of organic debris such as leaves, branches, and roots;
- Providing buffer areas for stream channel migration;
- Providing vegetative and tree canopy cover for cooling water temperature;
- Stabilizing stream banks; and,
- Using vegetation as bio-filtration to remove excessive surface runoff sediments and contaminants.

The Township of Langley has enacted the *Streamside Protection Bylaw #4485* which reiterates the requirements in the SPR and also includes the Watercourse Classification Map (discussed in **Section 1.6**). **Table 1.2.3** summarizes the protection setbacks measured from top of bank. The majority of Anderson Creek is classified as a Class A – (fish bearing) stream and the required development setback from top of bank would be 30 metres. A detailed discussion for the classification and environmental conditions found within the watershed is provided in **Section 1.6 Environment**

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Table 1.2.3 Table of Streamside Protection and Enhancement Development Permit Area Widths

Watercourse Class	Colour Code	Width (m.)*,**
A	Red/Orange/Magenta	30
A (Roadside watercourse)	Red/Orange/Magenta	7.5
B (Natural watercourse)	Yellow	20
B (Constructed watercourse) **Channel width > or = 0.5m** **Channel width < 0.5m**	Yellow	15 10
B (Roadside Watercourse)	Yellow	6
C	Green	0
U (Unclassified)	Blue	To be determined***
Fraser River and Bedford Channel	n/a	30

**Measured from top of bank or edge of floodplain (as applicable).*
*** Subject to Section 3.2.15 of the Streamside Protection Bylaw #4485.*
**** In accordance with Section 3.2.15(e) of the Streamside Protection Bylaw #4485.*

1.2.7 Stakeholders

Involving stakeholders in the development of an ISMP is a key component of the study. Their local knowledge and input is valuable in determining the current conditions of the watershed and for getting feedback on proposed changes within the study area.

Nicomekl Enhancement Society (NES)

The Nicomekl Enhancement Society (NES) is a volunteer-based organization that is dedicated to protecting and preserving the Nicomekl River watershed – which includes Anderson Creek. They manage a salmon hatchery and organize public outreach events throughout the year to promote environmental and fisheries awareness across the 175 sq. km. Nicomekl watershed. The Nicomekl River and its tributaries support Coho, Chum, Chinook, Pink Salmon, Cutthroat, Steelhead, and Rainbow Trout.

NES is a "hands on" group of volunteers that operate and maintain a full-scale salmon hatchery located south of 56 Avenue at 232 Street. This includes netting spawners, taking eggs, incubation, feeding, transporting, and releasing fry at public events.

Agricultural Advisory Committee

An Agricultural Advisory Committee (AAC) is a council-appointed body that meets on a regular basis to discuss agricultural issues happening within a municipality or regional district. AACs provide a direct link to farming and ranching communities on various issues that pertain to rural and agricultural lands. Both the Township of Langley and the City of Surrey have their own representative AACs. Since approximately 75% of the Anderson Creek watershed consists of ALR, these committees are considered to be stakeholders that will have a role in shaping how the overall watershed will function.

A presentation was made to the Langley AAC on September 19, 2013. A few items that arose during the meeting include questions on what the impact of large cranberry farms would be on the watercourse, the source of elevated nitrate levels, and how post development runoff flows will be managed. There was also additional discussion on the requirement for stormwater detention at greenhouses and current flooding concerns near the 24 Avenue greenhouse operations.

Salmon Habitat Restoration Program (SHaRP)

Funded by Fisheries and Oceans Canada (DFO) Fraser Basin initiative, the City of Surrey's Salmon Habitat Restoration Program (SHaRP) is a student-based initiative promoting watershed stewardship and environmental habitat enhancement for fisheries. Established in 1996, SHaRP provides community education and increased awareness to protect streams from urban development. SHaRP activities mainly focus on education initiatives and habitat restoration work.

<u>Sunrise and Rees Lake Owners</u>

Another group of stakeholders are owners of property surrounding Sunrise and Rees Lakes. A key item for this group is preserving the quality and quantity of water in the lakes as surface and groundwater could be impacted by development.

The Township attended the Owners Annual General Meeting on October 10, 2013. At the meeting the owners expressed concerned about potential increases in lake water levels if development occurs upstream in the Lambert tributary catchment area. There was also discussion on constructing an emergency overflow outlet which should be reviewed as part of this ISMP.

1.2.8 Open Houses & Feedback

Open Houses were held on January 15 and 19, 2013 in conjunction with presentation of community workshop findings for a proposed update of the Brookswood / Fernridge Community Plan. The major issues and concerns that were expressed at the public consultation sessions include the following items:

- Erosion in Anderson ravine and slope stability concerns
- Runoff from ALR lands causing flooding in vicinity of 24/32 Avenue and 208/212 Street
- Aquifer recharge and water quality protection, and
- Habitat protection and enhancement for fish/wildlife and trees

A full summary of the comments submitted after the Open Houses are in **Appendix A**. While most of the 700 attendees were interested in the Community Plan, responses to an ISMP questionnaire submitted by 32 participants.

1.3 Land Use Planning

1.3.1 Current Land Use

The entire watershed is 3,272 ha in size which includes 1,853 ha of agricultural land reserve (ALR), 850 ha of rural/urban lands, and 569 ha of lowlands in the City of Surrey. **Figure 1.3.1** shows the zoning classifications currently in place for the Watershed, most of which has maintained its rural character.

1.3.2 Community Plan for Brookswood / Fernridge

The current community plan that was adopted in 1987 **(Figure 1.3.2)** has an area of 1,420 ha that reaches from the City of Langley border at 44 Avenue to 16 Avenue. Approximately 835 ha are within the Anderson Creek watershed. The development concept envisioned a community of 35,000 people (current population is approximately 13,000), of which 85% would be housed in single family homes and included a commercial core located around the intersection of 200 Street and 32 Avenue (as well as three smaller commercial areas) to provide local services for Brookswood / Fernridge area residents.

The objective was to create a compact, pedestrian oriented town centre surrounded by multi-family housing. The plan also included a phasing strategy for servicing which indicated that initial development would occur in the northeastern portion of the community (where Phase 1 has now been developed), followed by development in the central zone.

Since that time there have been key infrastructure improvements in the area such as the construction of sanitary sewer services along 200 Street to 0 Avenue for the High Point subdivision to the south resulting in pressure to redevelop parts of this community. In 2004, Council determined that, before any further development takes place in this neighbourhood, the Community Plan must be updated to ensure that all new development aligns with the current planning goals and objectives for the community.

The Community Plan that this ISMP is based on is shown in **Figure 1.3.3**. While it did not receive approval from Council, the strategies and BMPs developed for it are applicable to any development that occurs in the study areas.

In keeping the OCP, the Community Plan will maintain key planning objectives to accommodate projected growth whilst preserving the existing rural character of the municipality. The Community Plan must also maintain planning and development principles to support development of *Complete Communities* that support the Township's long term sustainability goals by discouraging sprawl, preserving green space and facilitating pedestrian and bike-friendly neighbourhoods. The OCP development principles require that the boundary between areas of different character is carefully planned. This includes creating greenbelts or using parkland as a buffer between urban zoned land and the ALR.

1.3.3 Campbell Heights Area

The Campbell Heights area, in Surrey, is west of the Brookswood / Fernridge area and a portion is within the Anderson Creek ISMP study area. Land use within the northern portion of the Campbell Heights area plan include industrial and office employment uses. The employment-related development seen in the Campbell Heights area suggests potential for residential support within Brookswood / Fernridge community.

There have been several servicing studies completed for the Campbell Heights area that include stormwater management plans. The proposed drainage systems have been reviewed as part of this ISMP.

1.3.4 Agricultural Areas

The Township of Langley completed an Agricultural Viability Strategy (AVS) in 2011 to enhance the viability and sustainability of the agricultural sector in the Township. This includes looking at food production, diversification opportunities, economic challenges, urbanization conflicts, environmental issues, and agricultural land competition. With approximately 78% (or 1,853 hectares) of the Anderson Creek watershed being ALR, it is important that any recommendations made as part of the ISMP be cognizant of surrounding farmlands.

The first phase of this initiative is to provide an inventory of current agricultural land use and activities to better understand farming opportunities, constraints, and policies in the Township. The 2010 Township of Langley Agricultural Profile Report by HB Lanarc provides a summary of key farm sectors and land uses currently in the Township. The 2010 HB Lanarc Report identifies the following agricultural uses present in Langley:

- Berry and vine crops;
- Greenhouse operation;
- Cultivated or fallow land;
- Housed livestock;
- Extensive livestock;
- Miscellaneous agriculture;
- Field vegetables or flowers;
- Mushroom farm;
- Forage and pasture; and
- Nursery or trees.

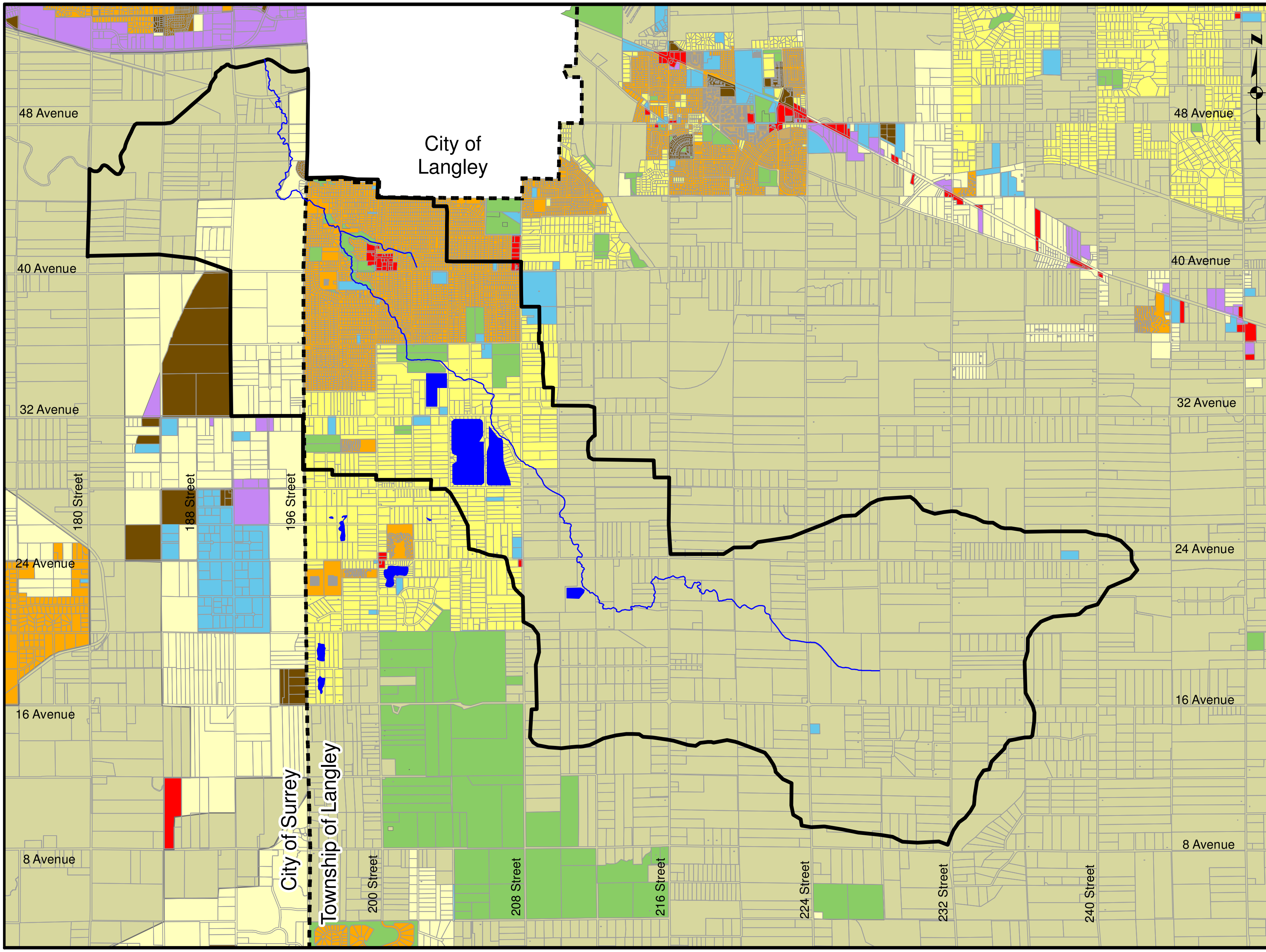
An agricultural land use inventory was completed in 2010 for the City of Surrey by the Ministry of Agriculture. The information presented in the study show that forage and pasture are the primary agricultural uses with a few parcels under berry and vegetable cultivation.

Figure 1.3.3 shows the distribution of agricultural land uses within the Anderson Creek and Unwin watersheds.

1.3.5 Planning Key Issues

Key issues related to land use planning within the Anderson Creek ISMP study area include:

- Residential development (or re-development) for areas adjacent to the Creek, its tributaries, and other surface water bodies must comply with municipal, provincial and federal environmental legislation;
- Development of the area will result in increased impervious areas that will in turn increase stormwater surface runoff causing higher peak flow rates and larger runoff volumes being discharged into Anderson Creek and surrounding water bodies if mitigation measures are not implemented;
- Increases in imperviousness may also decrease re-charge to aquifers, increase aquifer vulnerability, increase the risk of contamination of groundwater (of particular concern in municipal well capture zones), and change aquifer water levels which affects baseflows to creeks and water levels in groundwater-fed ponds and lakes;
- Environmentally sensitive areas such as wetlands, forest areas, and wildlife corridors are vulnerable to being reduced by future development; and
- Agricultural activities within the ALR may have impacts to groundwater usage and water quality.



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Anderson Creek (Main Stem)
- Watershed Boundary
- Municipal Boundary
- Existing Water Body
- Parks and Conservation Areas
- Agricultural Land Reserve

Langley Zoning

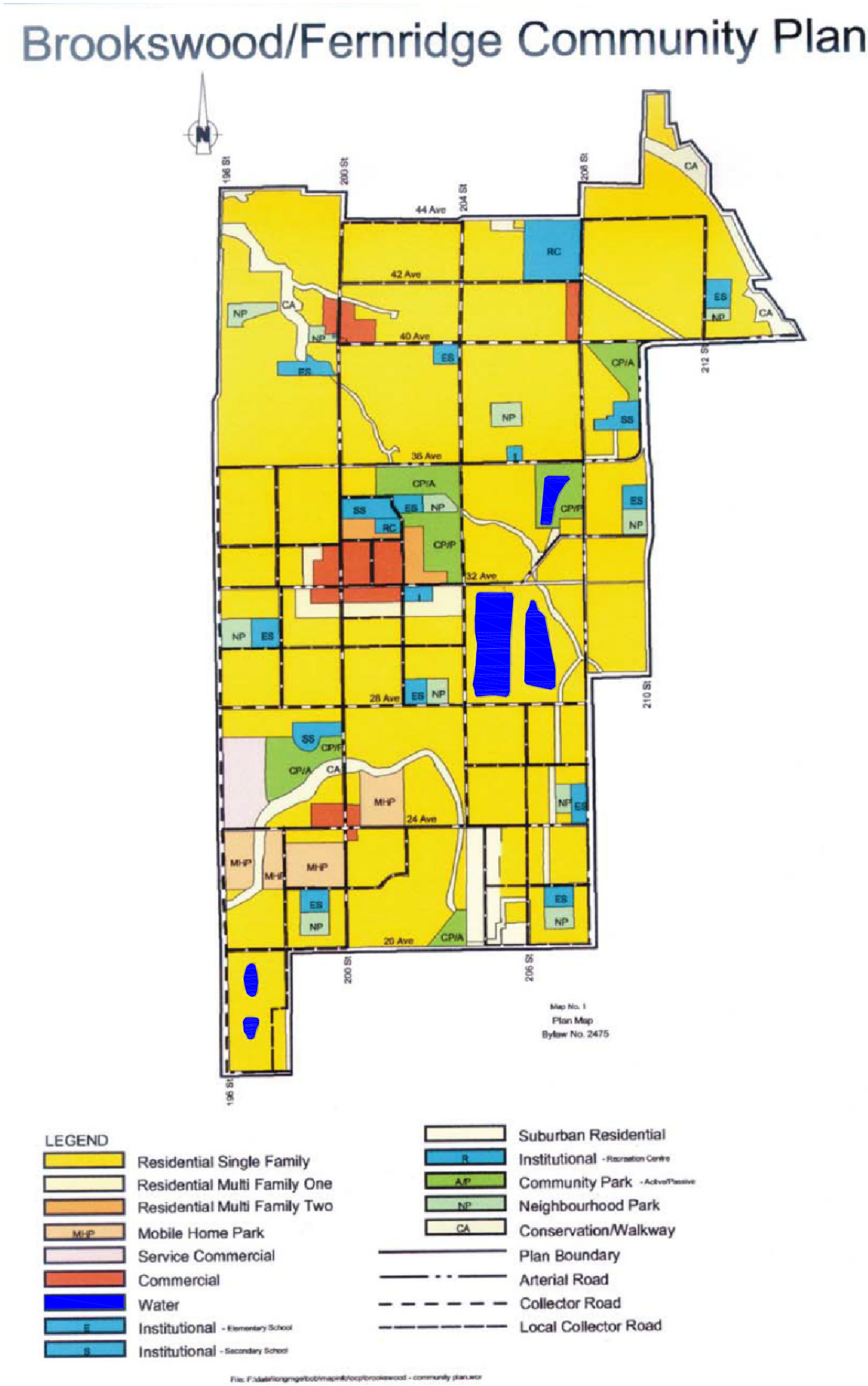
- Commercial
- Comprehensive Development
- Industrial
- Institutional
- Multiple Familty Residential
- Residential
- Rural
- Suburban Residential

0 500 1,000 2,000 Meters

Project No.	Date
60267316	October 2013

Current Zoning

Figure 1.3.1



Township of Langley / City of Surrey

Anderson Creek ISMP

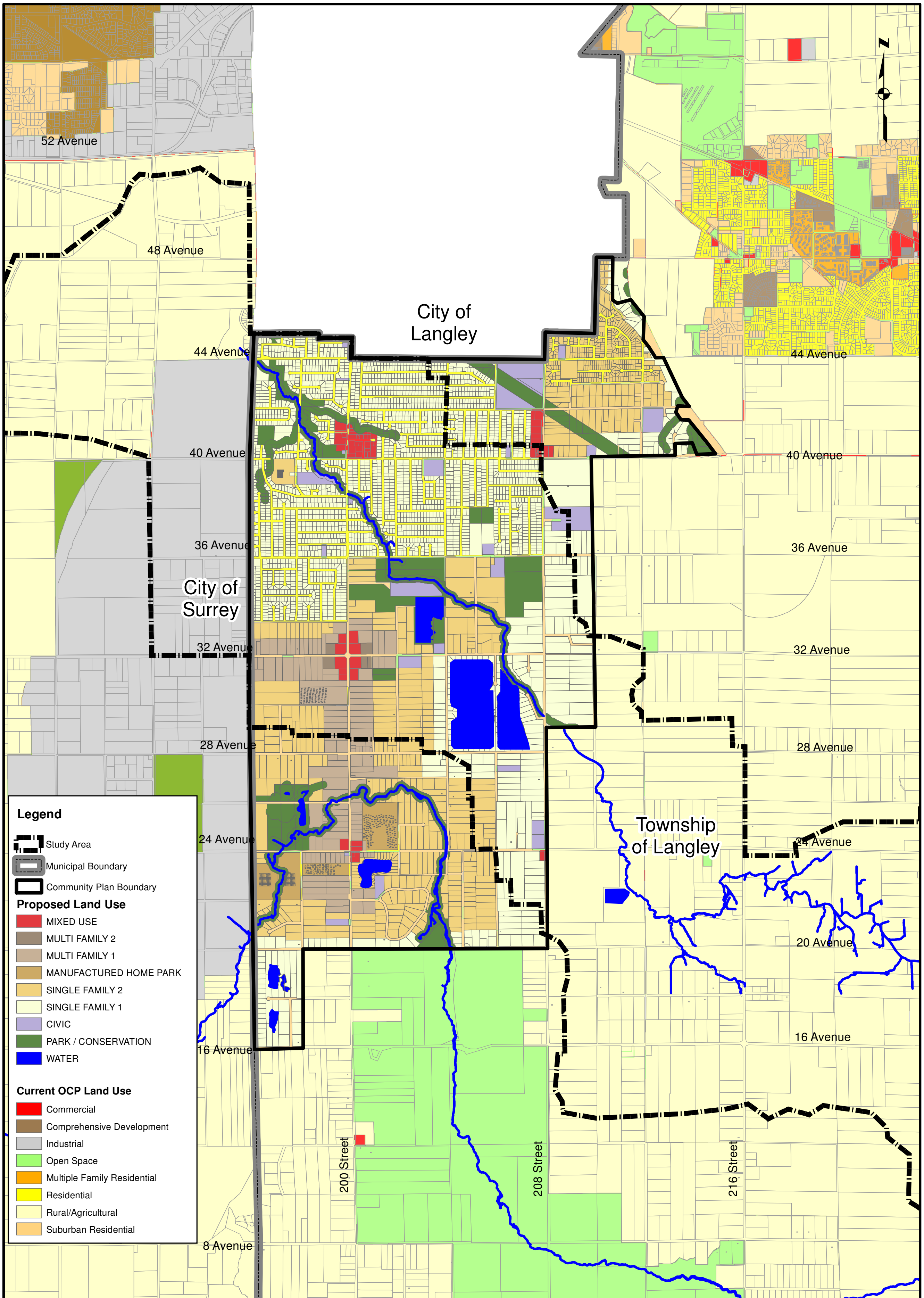
Project No. 60267316

Date October 2013

AECOM

Current Brookswood / Fernridge Community Plan (1987)

Figure 1.3.2



Anderson Creek ISMP

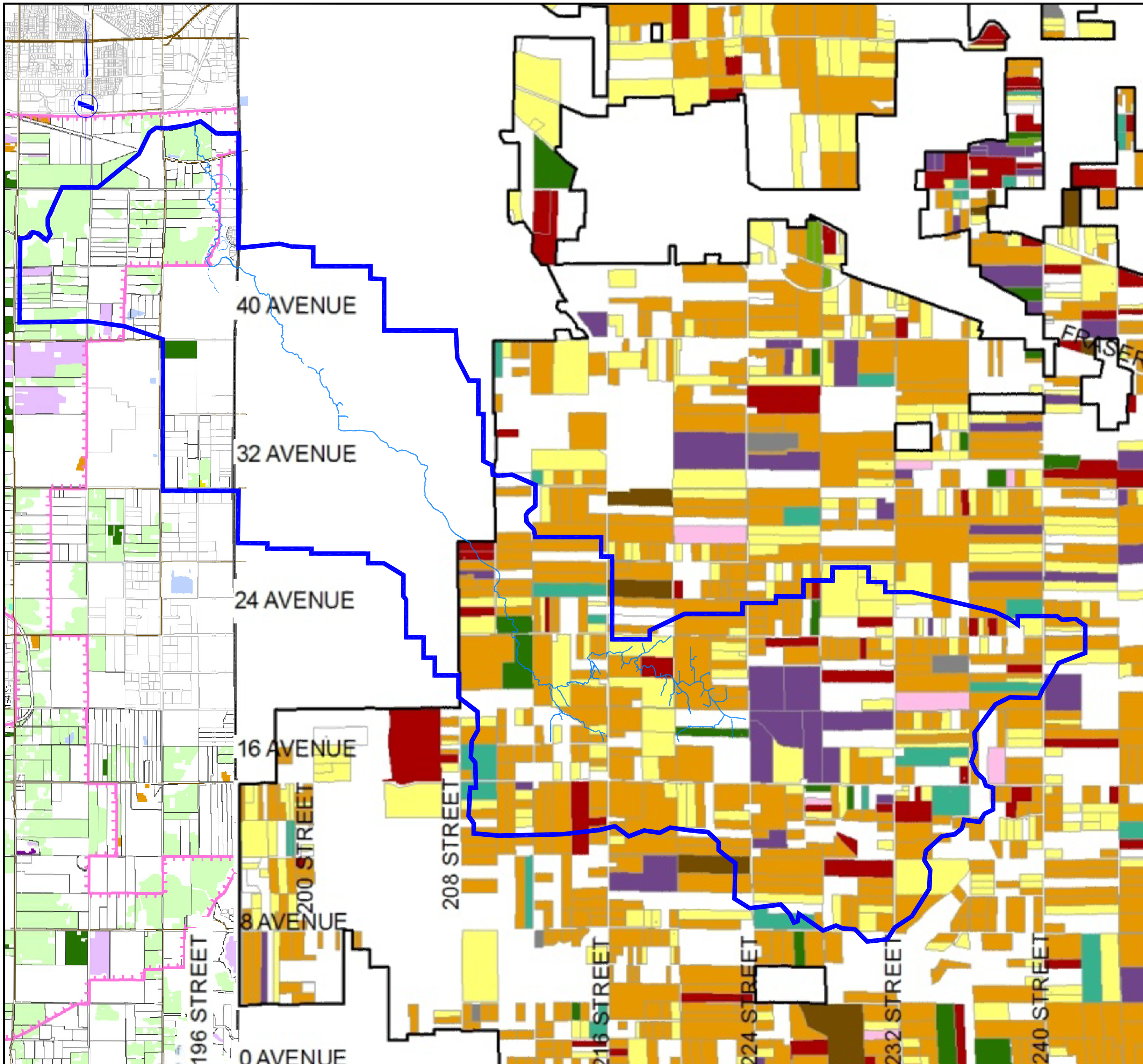
Project No.	Date
60267316	October 2013

AECOM

500 250 0 500 Meters

Disapproved Brookswood/ Fernridge Community Plan (2013)

Figure 1.3.3



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- ISMP Study Area
- Anderson Creek

Township of Langley

Agricultural Use
- Berry and vine crops
- Cultivated or fallow land
- Extensive livestock
- Field vegetables or flowers
- Greenhouse Operation
- Housed livestock
- Miscellaneous agriculture
- Mushroom farm
- Nursery or trees

City of Surrey

Cultivated Field Crops
- Forage & pasture
- Berries
- Vegetables
- Nursery & tree plantations
- Cereals
- Other
- Specialty (only 3)
- Vines
- Tree fruits
- Nut trees (only 1)

Agricultural Land Reserve
- Boundaries (2010)

Source: Township of Langley Agricultural Profile, Prepared by HB Lanarc, October 22, 2010

AECOM

Not To Scale

Project No.	Date
60267316	October 2013

Current Agricultural Land Use

Figure 1.3.4

1.4 Hydrology & Hydraulics

The following section describes the hydrological characteristics of the watershed and the hydraulic structures present within the watercourse. A summary of the topography and regional rainfall data as well as available hydrometric flow monitoring data to be incorporated into the drainage model is discussed.

1.4.1 Hydrology

Hydrology is the study of the movement, distribution, and quality of water. It involves several pathways for rainfall: back into the air through evaporation, infiltration into the soil for use by plants or contributing to local groundwater and stream flow (interflow), deep ground infiltration contributing to regional groundwater flow, or surface runoff. Understanding the hydrological characteristics specific to the Anderson Creek watershed is the first step in assessing what is needed in terms of overall watershed health, level of service to residents, and protection of life and property.

Several key aspects to the hydrological and hydraulic behaviour of the watershed were reviewed and referenced from the *1999 Master Drainage Plan Update* report by New East Consulting. The parameters that affect the hydrological characteristics of the watershed include rainfall, slope, runoff coefficient, imperviousness, infiltration rates, and soil types. These parameters are discussed in **Section 1.4.7 Hydrologic Model Parameters**.

1.4.2 Watershed Characteristics

The Anderson Creek watershed is located within the southwest portion of the Township of Langley and overlaps the Unwin catchment in the City of Surrey. From AECOM's recent experience with Anderson Creek in-stream work at 36 Avenue (replacement of a cross culvert), it was noted that there is little to no visible flow in that section of creek during dry weather periods confirming that the creek is ephemeral.

To the north of Anderson Creek is the Murray Creek watershed and to the south is the Little Campbell River watershed. The main stem of Anderson Creek is approximately 16 km in length and starts at 224 Street and 20 Avenue. However, its headwaters are split between two branches (north and south) located near 240 Street between 20 and 24 Avenues. The south branch is joined by a tributary at 228 Street which is mostly channelled. From 220 Street to 212 Street Anderson Creek flows in a deep wide ravine. At 213 Street, the creek picks up storm water discharge from Glenwood Pond, which receives water from the Lambert system that originates south of 16 Avenue.

From 208 Street, the creek traverses northwest and passes two constructed lakes: Sunrise Lake and Rees Lake. These two lakes are historical gravel pits that have since naturalized and become water bodies. Currently, there are no surface water outlets from either lake such that they do not drain to Anderson Creek. The lake water levels are regulated by groundwater levels and precipitation and are hydraulically connected to the shallow aquifer. The hydraulic conductivity present in the soils below and adjacent to the lakes is dependent on the permeability of the material and is assumed to impact the lake water levels and Anderson Creek base flows or seepage.

Further northwest, Anderson Creek enters the Brookswood and Fernridge community at 208 Street and 28 Avenue. In this area, Anderson Creek flows through mainly single family residential neighbourhoods until it reaches 200 Street at 40 Avenue where commercial and institutional developments are also present. It flows past Brookswood Pond which is similar to the two lakes in that it began as a gravel pit site then eventually naturalized over time. This pond is currently used as a recreational facility for residents in the community.

Once Anderson Creek crosses 196 Street and 44 Avenue into the City of Surrey, it enters the Unwin Catchment and eventually discharges into the Nicomekl River. The Unwin catchment is 569 hectares in size and consists mainly of industrial and agricultural land usage. This catchment also overlaps the *Campbell Heights Local Area Plan*. **Figure 1.4.1** highlights the Anderson Creek watershed.

In the City of Surrey's Unwin catchment the study area includes the Armstrong Creek Watershed that includes Armstrong Creek, O'Neil Brook, Gary Brook, and Joey Brook; which all drain in a westerly direction from 192 Street (between 48 Avenue and 42A Avenue) before eventually discharging the Nicomekl River.

The Unwin catchment also includes Ross Creek located south of 44 Avenue and drains west from 190 Street Alignment to 184 Street.

1.4.3 Topography

Figure 1.4.1 shows the topography in relation to the watershed. In general, the study area slopes northwest from 240 Street in Langley towards the Nicomekl River in Surrey. The highest elevation is located around 240 Street and 24 Avenue at 128m geodetic. The lowest elevation is within the Nicomekl River lowlands at sea level (0m geodetic). Slopes from 240 Street to Brookswood Pond range between 1 to 2%. From Brookswood Pond to the Nicomekl River slopes are flatter with an average slope of 0.5%.

The low region of the study area is within the floodplain of the Nicomekl River in Surrey. This region consists of agricultural land reserves and is very flat. East of 196 Street within the Township of Langley the physical land characteristics significantly alter into rural/urban uplands known as the Brookswood/Fernridge community.

These uplands contain low hills that are separated by wide flat valleys. There are three incised ravines in the uplands that contain Anderson Creek throughout the uplands. The ravines have an average depth of 20m with widths ranging from 40 to 100m. Proceeding eastward, the land rises to a plateau called Biggar Prairie east of 224 Street between the north and south branches. This Prairie is roughly 1,200 ha with an average slope of 1.2%.

1.4.4 Lakes and Ponds

Within the study area, there are several small ponds that are either temporary ponds or part of landscape features. Two major ponds and two lakes within the Township are of importance: Glenwood Pond, Brookswood Pond, Rees Lake, and Sunrise Lake.

Glenwood Pond is located east of 210 Street and south of 24 Avenue. Brookswood Pond, Rees Lake, and Sunrise Lake are all located within the Brookswood/Fernridge community.

Sunrise and Rees Lakes

These two lakes were initially sites for gravel extraction. Once the gravel pits were decommissioned, residential communities developed around the lakes and each property title now contains a portion of their respective lake. Rees Lake covers approximately 10 ha of surface area (20 properties) while Sunrise Lake covers approximately 23 ha (37 properties).

Currently, neither lake has an outlet nor are they hydraulically connected to a downstream surface drainage system. In terms of inlets, the upper Lambert ditch system flows into Sunrise Lake while Rees Lake does not have a formal inlet. Water levels for both lakes fluctuate according to groundwater levels and precipitation.

As noted in the *1999 Anderson Creek Master Drainage Plan* (MDP) by New East Consulting, the Township has a statutory ROW in place to use Sunrise Lake for drainage purposes. Under this agreement the Township must provide and maintain outlet works from the lake in accordance with the creation of any new inlet works.

Some of the Rees Lake properties have Restrictive Covenants allowing the Township to use the lake for storm detention purposes. Others have covenants establishing minimum building elevations and setbacks for property owners. Copies of all of these agreements are in the 1999 MDP.

Glenwood Pond

Glenwood Pond is on private property and is artificial. With approximately 1 ha of surface area, it receives flows from the lower Lambert ditch. Discharge from the pond is via an overflow weir into Anderson Creek. Currently, this pond is utilized as a private detention facility and for irrigation of greenhouse crops.

Brookswood Pond

Brookswood Pond is located on land owned by the Township at 32 Avenue and 204 Street. This pond initially started as a site to extract gravel for various road projects within Langley. As it was left undisturbed for many years, the site became naturalized into Brookswood Pond. The area surrounding this pond is utilized year-round by joggers, dog walkers, and cyclists. The pond is approximately 7 ha in size with no external flows entering the pond and no outlet from the pond. The water level in the pond is controlled by the groundwater table similar to Sunrise and Rees Lakes.

1.4.5 Hydrometric Monitoring Stations

There are two key rainfall gauges in the vicinity of the study area. The Civic Facility gauge is located to the north of the watershed while the High Point gauge is located to the south. Based on rainfall distribution maps generated by Metro Vancouver, the Anderson Creek watershed receives less rainfall than the northerly gauge but more than the southerly one. These rainfall gauges are shown on **Figure 1.4.2** along with current hydrometric and other rainfall monitoring stations in the surrounding area

Civic Facility Rain Gauge

The Civic Facility gauge (Station Name "TOLRain") is located on the Civic Facility Building at 203 Street and 65 Avenue. Data from this gauge was used for the model calibration and validation as it is the closest gauge to the study area and any model errors will be on the conservative side. Historical rain data is available from 2005 to present.

High Point Rain Gauge

The High Point rain gauge is located at 200 Street and 4th Avenue in Langley near Little Campbell River. It was installed in 2009. Rainfall recorded at this gauge is consistently lower than the Civic Facility gauge indicating that it is located in a slightly dryer region.

Anderson Creek Hydrometric Station

In March 2012, a hydrometric station was installed on Anderson Creek at 200 Street to record water levels and estimate flows. The water level data is read in conjunction with a rating curve (flow versus depth) for the creek channel to generate the approximated creek flows. Data from this site was used for the model calibration and validation of significant rainfall events recorded on January 5-12 and February 26 to March 4, 2013 and discussed further in **Section 1.4.10**.

1.4.6 Regional Hydrologic Analysis

To determine the approximate magnitude of runoff and develop unit flow rates for the Anderson Creek watershed, a regional hydrologic analysis was completed for major watersheds adjacent to our study area. Due to the creek's large catchment area (at 3,272 ha), it is important to have a clear understanding of rainfall and runoff relationships across the region and not just simply apply results obtained from one stream gauge.

The Water Survey of Canada (WSC) is the national authority responsible for the collection of standardized water resource data and information in Canada. WSC operates over 2,500 active hydrometric stations across the country and is in partnership with several provincial, municipal, and agencies. Since there is currently no permanent station located at the Anderson Creek outlet into the Nicomekl River, data from stations that are adjacent to the study area were reviewed for historical flow information. Historical flow data was reviewed from three stations that were selected based on their similarities with Anderson Creek watershed in terms of physical location, characteristics, topography, and size.

Historical maximum instantaneous peak discharge rates were obtained for every year available from WSC. Using this information, statistical analysis tools were used to determine flow rates for corresponding to specific storm return periods. A Log Pearson Type III distribution was applied to the data and the predicted unit flow rates per hectare for various return periods are shown in **Figure 1.4.3**. From this figure, an average trend line to obtain a predicted unit flow rate (L/s/ha) for each return period was established.

Brief details and locations of the three hydrometric stations are discussed below and the corresponding average flow rates for each return period are summarized in **Table 1.4.1**.

- **Station 1 Nicomekl River Station No.08MH155 (1980 to 2010):** Located on Nicomekl River at 203 Street adjacent to our study area to the north at 49°5’44”N and 122°39’36”W. The gross drainage area for this station is approximately 7,000 ha.
- **Station 2 Salmon River Station No.08MH090 (1960 to 2010):** Located on Salmon River at 72 Avenue in Langley at 49°8'1"N at 122°35'47"W that has historical flow data dating from 1960 to 2010. This station has a gross drainage area of approximately 4,900 ha.
- **Station 3 West Creek Station No.08MH098 (1960 to 2010):** Located on West Creek near Fort Langley at 49°8'36"N and 122°31'59"W that has historical flow data dating from 1960 to 2010. This station has a gross drainage area of approximately 1,140 ha.

Table 1.4.1 Predicted Peak Flow Rate

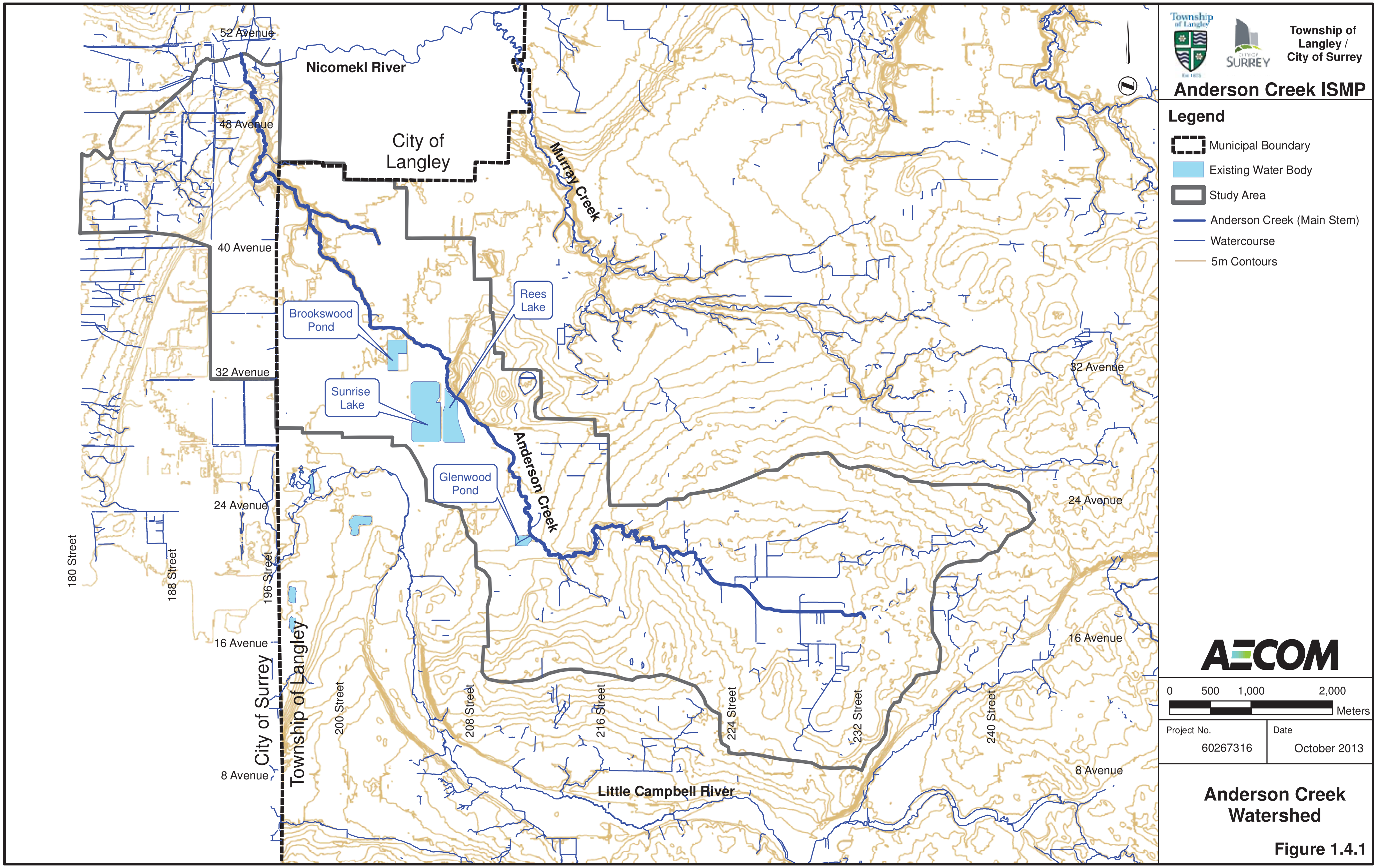
Return Period (Years)	Predicted Unit Flow Rate (L/s/ha)
200	17.7
100	16.5
50	15.3
25	14.0
10	12.2
5	10.6
2	7.9

1.4.7 Hydrologic Model Parameters

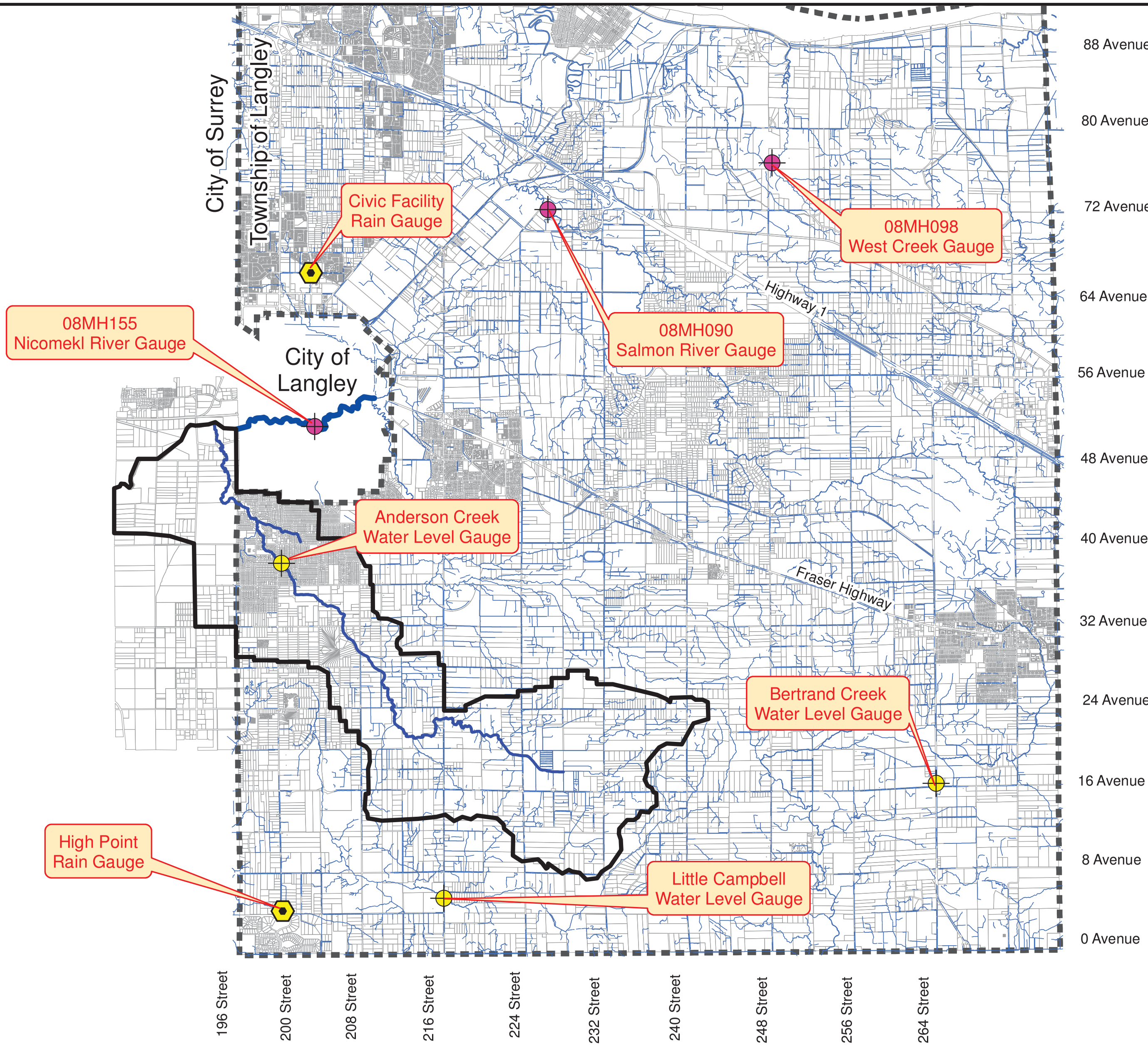
The drainage model used for the 1999 MDP was developed in OTTHYMO-89 software and the electronic files are not available. A new computer model of the Anderson Creek drainage system was developed in PCSWMM 2011. To establish the hydrologic parameters to be used in the model, the parameters used for the calibrated Little Campbell River and Salmon River hydraulic models that AECOM (formerly *EarthTech, 2007*) previously developed for the Township were reviewed. During the model calibration stage the parameters were slightly modified to better match the catchment and flow conditions for Anderson Creek. Separate sets of values were determined for the urban and rural areas as shown in **Table 1.4.2**.

Table 1.4.2 Hydrologic Parameters

Parameter	Urban	Rural
Impervious Manning’s n	0.015	0.015
Pervious Manning’s n	0.18	0.18
Impervious Depression Storage	1.0 mm	1.0 mm
Pervious Depression Storage	5.0 mm	8.0 mm
Maximum Infiltration Rate	20 mm/hr	10 mm/hr
Minimum Infiltration Rate	1.00 mm/hr	0.75 mm/hr
Decay Rate of Infiltration	0.00120 /sec	0.00120 /sec



Township of Langley / City of Surrey
Anderson Creek ISMP
Legend
Municipal Boundary
Existing Water Body
Study Area
Anderson Creek (Main Stem)
Watercourse
5m Contours
AECOM
0
500
1,000
2,000
Meters
Project No.
60267316
Date
October 2013
Anderson Creek Watershed
Figure 1.4.1
Nicomekl River
City of Langley
Murray Creek
Anderson Creek
Rees Lake
Brookswood Pond
Sunrise Lake
Glenwood Pond
Little Campbell River
City of Surrey
Township of Langley
52 Avenue
48 Avenue
40 Avenue
32 Avenue
24 Avenue
16 Avenue
8 Avenue
180 Street
188 Street
196 Street
200 Street
208 Street
216 Street
224 Street
232 Street
240 Street



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Study Area
- Anderson Creek (Main Stem)
- Nicomekl River
- Watercourse
- Municipal Boundary
- Water Survey of Canada Water Level Gauge
- Township of Langley Water Level Gauge
- Township of Langley Rain Gauge

AECOM

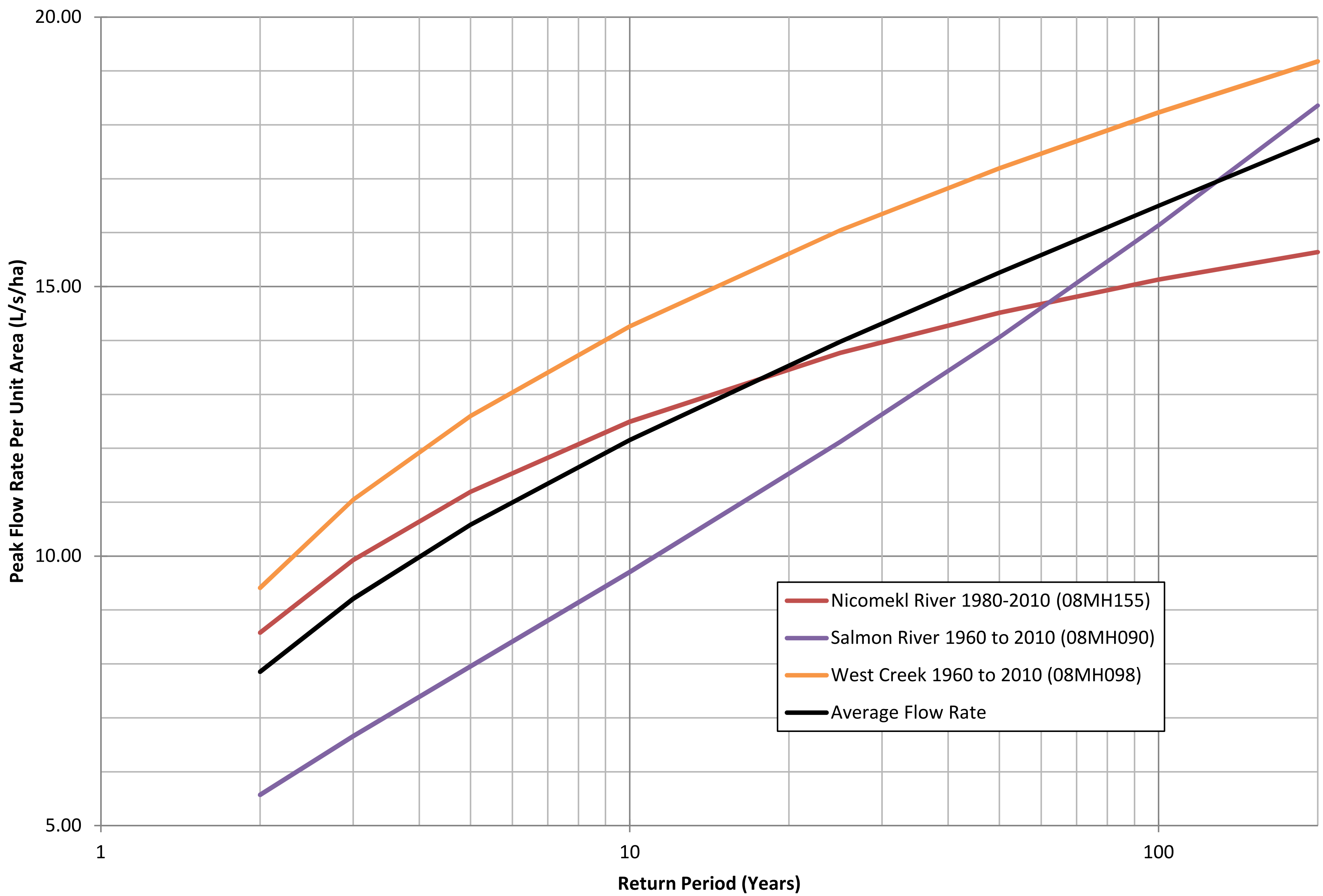
0 1,000 2,000 4,000 Meters

Project No.	Date
60267316	October 2013

Current Monitoring Stations

Figure 1.4.2

Figure 1.4.3 Predicted Peak Flow Rate



1.4.8 Current Drainage System

There are approximately 10.6 km of storm sewer pipe in the study area that discharge to Anderson Creek. Storm sewers range in diameter from 300 to 900 mm in size. Much of the existing developed area, especially the residential area north of 36 Avenue, is not serviced by storm sewers but drains to a large number of dry wells and rock pits that aid to infiltrate surface runoff. Along the main stem and tributaries of Anderson Creek there are numerous culverts and bridges at road and driveway crossings.

The Unwin catchment area that encompasses Armstrong Creek Watershed and Ross Creek includes very little storm sewer infrastructure aside from road and driveway culverts and a large diameter (1200mm) storm sewer along 184 Street that discharges in the Nicomekl River.

The focus for this analysis was on the main stem of the channel and detailed topographic survey information for ten of the major crossing locations was collected to assist with the hydraulic model development. Terra Pacific Land Surveyors completed the detailed topographic surveys of the major crossings and also picked up channel cross sections upstream and downstream of each culvert/bridge location. This information has been entered into the hydraulic model along with field data and available information from the 1999 MDP report. **Figure 1.4.4** shows the existing hydraulic structures within the watershed and these are discussed further in **Section 2.4** for the capacity review of the major culverts.

A key component of the hydrologic model development was the delineation of sub-catchment areas. These are shown in **Figure 1.4.5** and a total of 75 sub-catchments were delineated ranging from 3.3 to 116 ha in size based on existing topography and a review of previous sub-catchments identified in the 1999 MDP report. Of these 75, 57 sub-catchments drain into Anderson Creek while the remaining 14 drain into the Nicomekl River as part the Unwin Catchment area in Surrey and 4 drain to the current ponds (Sunrise, Rees and Brookswood ponds).

1.4.9 Reach by Reach Review

West of 196 Street (Surrey Side)

The lower reach of Anderson Creek and the Nicomekl tributaries in the Unwin Catchment area are located within the ALR. The Anderson mainstem channel is generally in its natural state and meanders from Colebrook road to the outlet at Nicomekl River. Upstream of Colebrook Road, Anderson Creek is surrounded by forest and becomes a ravine that continues east of 196 Street into Langley. There are several small tributaries that contribute surface flows to Anderson Creek in the ravine section.

Watercourses in the Unwin catchment are contained within the agricultural lowlands and consist of roadside ditches and forested creek channels. There are several driveway and road crossing culverts and a detailed review of the condition and capacity of these culverts has not been completed as part of this ISMP.

Between 196 Street and 36 Avenue

This reach of Anderson Creek and its tributaries is characterized as a deep forested ravine with a meandering low flow channel that experiences rapid increases in flow during heavy rainfall events. There are known locations where erosion of the creek banks is occurring and has resulted in slope stability problems. The West Branch and Crank Creek (or North Branch) tributaries have similar issues as the mainstem although these channels experience lower flow conditions due to the smaller catchment areas. There have been several terrain stability and channel morphology assessments completed for the lower section of this reach that are discussed in **Section 1.5**. Upstream of the ravine section and closer to 36 Avenue the side slopes are less steep and the creek dries up during the summer months.

Between 36 Avenue and 208 Street

Upstream of 36 Avenue the creek is an excavated channel with the overbank portions of the channel extending into the nearby playing fields at Noel Booth Park that act as a floodplain. Beyond this location there are bridge crossings with one bridge reported to cause minor backwater effects under the 100-Yr flow conditions in the 1999 Study. Further upstream the creek returns to a relatively natural state with significant vegetation on the banks which are steep and drop to an incised channel. Upstream of the 205 Street crossing, the creek widens and traverses through a rural residential area and is also reported to potentially backwater due to the 205 Street bridge.

About 60 m east of 205 Street is a private crossing, and 40 m south of 32 Avenue is a driveway bridge that is vulnerable to high flows and was reported to be submerged during the 5-Yr and 100-Yr events in the 1999 Study. Further east, the channel traverses along the toe of a steep slope to the east of Rees Lake and there are four pedestrian and driveway bridge crossings. Some were reported to be submerged during the 100-Yr event (1999 Study) and residents have also reported flooding incidences in the channel during heavy rainfall events.

Between 208 Street and 24Avenue

From 208 Street to 24 Avenue there are several pedestrian and driveway bridge crossings as the creek meanders to the southeast through a rural residential area and farmland in the ALR. The mainstem of the channel is well defined but shallow such that the surrounding fields are utilized as a floodplain area during high flow events. Backwater effects are also noted to occur due to channel restrictions. The surrounding topography rises further south reducing the floodplain area.

The 208 Street culvert and the 2450mm by 2450mm box culverts at 24 Avenue are noted to be undersized for the 100-Yr event.

Upstream of 24 Avenue

Upstream of 24 Avenue are several tributaries that feed into the mainstem of Anderson Creek. Most reaches of the mainstem and tributaries have forested riparian areas with exception of a few sections where detention ponds have been constructed for irrigation purposes or the creek is re-routed around a property.

1.4.10 Model Calibration and Validation

The model calibration and validation was completed using the flow data from the temporary water level gauge installed at 200 Street and rainfall data from the Civic Centre gauge. Hydrographs for each event are shown in **Appendix B**. and the results are summarized in **Table 1.4.3**.

As shown in **Table 1.4.3**, the model is over predicting the peak flow for the January event and under predicting the peak flow for the February event. For both events, the model is under predicting the total volume when compared with the observed flows with the February event being significantly under predicted. Further review of the observed flow and rainfall data was undertaken as discussed below which resulted in the “modified observed” data as shown in **Table 1.4.3**.

Table 1.4.3 Model Calibration Summary

	Jan 5th to 12th, 2013			Feb 26th to March 4th, 2013				
	Observed	Modeled	% Difference	Observed	Modified Observed*	Modeled	% Diff (Observed Vs Model)	% Diff (Modified Observed Vs Model)
Rain Depth (mm)	97			103				
Volume (m^3)	1,254,164	1,172,133	-6.5	1,854,005	1,720,814	1,298,393	-37.4	-24.5
Peak Flow (m^3/s)	10.88	11.95	9.8	13.23	11.28	9.53	-27.7	-15.5
Average Flow (m^3/s)	1.94	1.81	-7.2	3.30	2.66	2.31	-37.4	-12.9
Base Flow (m^3/s)	0.56	0.56	--	0.62	0.7	0.7	--	--

* Modified Observed data includes an additional correction factor due to debris buildup

Peak Flow

A review of data at other sites suggests the recorded January event peak flows and water levels should be greater than those recorded for the February event. When comparing the data recorded at the Anderson Creek water level gauge (at 200 Street) and the Civic Centre rain gauge to other hydrometric stations in the region, it was determined that the same general hydrograph shape and rainfall distribution were reported. For instance, at the Bertrand Creek gauge on 264 Street at 20 Avenue, which is about 10 km east of the Anderson gauge, has a long history of reliable data, and in the same general rainfall distribution area, the peak flows recorded for January 8 and February 28 were 11.6 m^3/s and 10.1 m^3/s, respectively.

Also at the Little Campbell River water level measurement gauge at 216 Street south of 6 Avenue, the peak river water levels were 2.0 and 1.8 m, respectively for the January and February events. Based on this assessment, it is apparent that the recorded January event peak flows and water levels should be greater than those recorded for the February event which is not the case for the Anderson Creek gauge data (observed peak flow of 10.8 m^3/s on January 9 and 13.2 m^3/s on March 1).

Upon review of the Anderson Creek stage-discharge curve and characteristics of the hydrometric station, it appears that the "observed" flow data may be reported inaccurately. There are several reasons for this that include debris build up at the water level sensor location and the fact that the water levels recorded exceed the upper limit of the stage-discharge curve.

In fact, there are known caveats on the stage-discharge curve data that include the following notes:

- Debris gets stuck between the fish baffles and causes water to back up as much as 10 cm. An estimate of the backed up water depth is removed from the recorded stage data adjusted. The net result is that the data reflects the estimate of the effective stage for use in calculating discharge (i.e. Effective Stage = Recorded Stage - Backup Estimate)
- It was also noted that model calibration could be affected by this uncertainty caused by the debris movement. Data users should be directed to the Data Notes channel in FlowWorks, which identifies dates for events at the site, including when sediment/debris is suspected to have backed water up in the culvert.

In such case, the field notes recorded on March 9, 2013 were reviewed and it was revealed that sediment and debris were expected to have impacted the recorded water levels. An offset was to be applied after the next thorough culvert cleaning and debris removal. Based on this information, a comparison of the depth and flow relationship for the February and early March event was completed. On March 1 the peak flow was estimated to be 13 m^3/s and is based on a recorded water level of 0.8 m; however, on March 2 the peak flow was estimated to be 6 m^3/s based on a water level of 0.7m, which is a significant difference in flow for a minor change in water level.

This confirms the impact of debris build up affecting the flow estimation and to account for this, an additional correction factor was applied to the raw level data for the February/March event which is presented as the "modified observed" data. This is evident in the calibration plot included in **Appendix B**.

Runoff Volume

The overall volume underestimate is attributed to potential short-term storage in porous material adjacent to the creek with the high permeability areas when the water table is elevated. In essence, this water would travel through the voids in the subsurface material during the rising limb of the storm event and then return to the creek as the water levels recede. It is possible that seepage from Sunrise and Rees Lakes are increasing the volume of water in the creek.

To more accurately model this slow release of groundwater back into the creek, one would need to integrate the PCSWMM model with a groundwater model. This could be completed as a subsequent study and would help with more accurately determining the creek baseflows.

1.4.11 Major System Capacity

The calibrated hydraulic model was used to assess the current major system infrastructure, including trunk sewers and culverts, for the 2, 5 and 100-year design storm events. The design storm distribution used was a 24hr SCS Type 1A, as per the Township's design criteria. This storm distribution produced the greatest runoff and peak flows when compared to shorter duration events.

In addition to the calibrated model, a predevelopment scenario was also developed assuming primarily forested cover throughout the watershed. Summary tables of model predicted flows for the major crossings (that were included in the topographic survey) under predevelopment and current conditions are provided in **Tables 1.4.4** and **1.4.5**. Model results for current land use with the 5-year and 100-year events applied are shown in **Figure 1.4.6** and **Figure 1.4.7** respectively. Areas where overbank storage and/or existing wetland/pond storage is present are also highlighted in the figures. Locations and volumes for the storage areas were estimated based on the GIS topographic data available provided by the Township and through field reconnaissance.

As discussed in **Section 1.4**, drainage catchments for Sunrise Lake, Rees Lake and Brookswood Pond are not hydraulically connected based on the surface flow analysis which is also highlighted in **Figures 1.4.6**.-**1.4.7** These water bodies likely contribute significant baseflow at certain times of the year to Anderson Creek given the proximity to the channel. There are also a number of large diameter drywells in the urban areas that function as sinks infiltrating significant volumes of surface water that have not been included in the hydraulic model.

Model results indicate that flooding is predicted at several creek crossings and channel locations in the reach between 205 Street and 210 Street for the 100-year event confirming anecdotal information from residents in this area. At 205 Street the peak HGL is predicted to be above ground such that flows would overtop the road, while upstream of 32 Avenue (driveway crossing) the HGL is predicted to be above the under beam of the bridge but not above ground. Further upstream, the 208 Street and 24 Avenue culvert crossings are noted as undersized for the 100-year event and the channel between these crossings is surcharged such that the overbank storage is utilized. Overbank storage in this section is also used during the 5-year and 2-year events. The culvert crossing at 216 Street is also noted as under capacity for the 100-year event but does not surcharge. **Figure 1.4.8** shows the 100-year HGL in relation to the creek channel and top of bank elevations for Anderson Creek.

The extent of flooding for the 100 year event for an area or property can be determined by applying the HGLs in Table 1.4.5 to the appropriate section of creek and projecting the HGL laterally until it meets the ground level. Township contour mapping can be used for initial estimates of the flooded areas but it should be verified by in-field survey data for any purposes requiring accurate mapping.

It should also be noted that there are several other driveway and pedestrian bridges along the reach between 36 Avenue and 24 Avenue that have not been included in the hydraulic model as they were not included in the crossing survey for budgetary purposes.

These findings are similar to those presented in the *1999 Anderson Creek Master Drainage Plan Update* in Tables 7.1 and 7.2 which list the estimated capacities for the channel reach and bridge crossings from 36 Avenue to 24 Avenue. There are some variations in the reported 5 and 100-year 24-hour peak flows but the general trends and order of magnitude for the peak flows are the same.

At this time, upgrades to existing culverts and channel cross sections are not recommended due to known erosion and slope stability issues downstream in the Anderson ravine channel sections. These types of upgrades would result in higher peak flows in the downstream sections, exacerbating those issues. Improvements upstream of 208 Street in the ALR areas are discussed in the **Section 3.3** in Enforcement Strategies and Policy Planning.

1.4.12 Current Minor System Capacity

Based on the findings from the infiltration testing and discussions with Township Operations staff, it was determined that the current system of rock pits, infiltration trenches and swales in the Brookswood area are working. They do require maintenance as localized flooding can occur as a result of clogged rock pits and perforated pipes leading to infiltration trenches. In such case, the minor drainage system was deemed adequate for the current land use scenario, which is not proposed to change.

A similar form of drainage system, but with storm sewers, exists in the Cedar Ridge area near 208 Street and 44 Avenue that was constructed in the 1990s. It consists of exfiltration sewers installed in infiltration trenches and large diameter drywells. The entire system drains towards a low point on 208 Street, where there is a large exfiltration manhole with no evidence of surcharging.

A capacity analysis of the conventional trunk sewers was completed and summarized in **Section 2.4.11**

1.4.13 Key Issues

Key issues related to hydrology and hydraulics within the Anderson ISMP study area include:

- The complex nature of the watershed characteristics (including the creek, surface runoff and soil infiltration parameters) make it a difficult one to simulate using the hydrodynamic model. Future analysis should include integrating the model with groundwater routines which are able to accurately model high rates of groundwater seepage during and after rainfall events.;
- Strategies to restrict post-development peak flows and volumes to pre-development conditions (or better) are needed such that the frequency and magnitude of flood events and erosion are not exacerbated, but reduced if possible;
- Implementation of Best Management Practices (BMPs) for control and peak flow attenuation of typical storm events will limit the impacts to the Creek and maintain aquifer recharge; and
- A drainage servicing strategy is required for the area that meets Township and City design criteria and will allow for development to occur.
- Sections of the creek do not have capacity to contain existing flows within the banks.

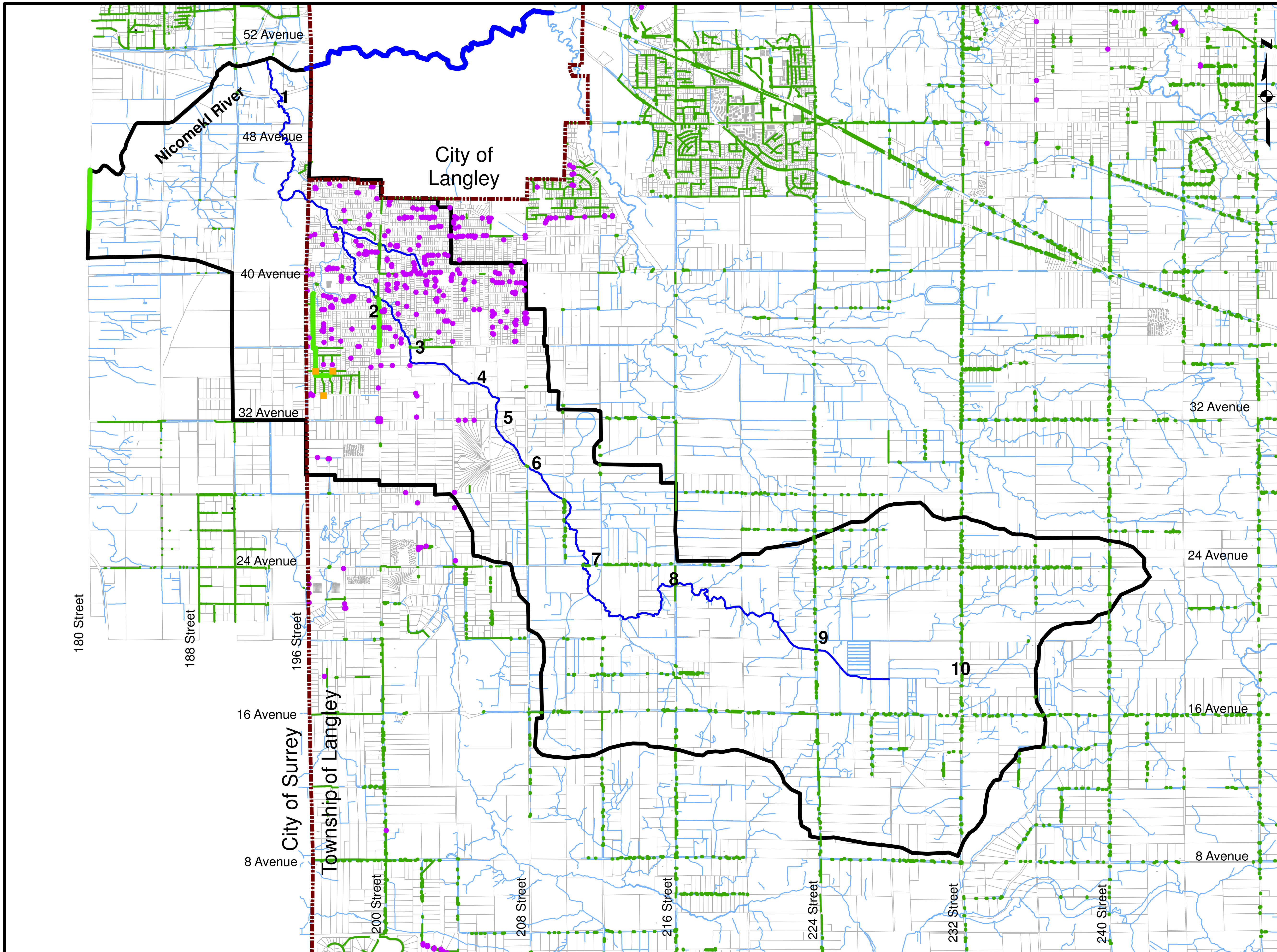
Table 1.4.4 Predevelopment Land Use Major Crossing Capacities

ID	Location on Anderson Creek	Contributing Area (ha)	u/s Inv. (m)	d/s Inv. (m)	Pipe/Bridge Dimensions (m)	Length (m)	Slope (%)	Material	1:2yr Peak Flow (m3/s)	1:5yr Peak Flow (m3/s)	1:100yr Peak Flow (m3/s)	Pipe Full Capacity (m3/s)*	1:2yr L/s/ha	1:5yr L/s/ha	1:100yr L/s/ha	1:100yr q/Q	1:100yr d/D	Ground Elev. (m)	u/s 1:100yr Max HGL	d/s 1:100 yr Max HGL
1	Crossing Colebrook Rd.	2521	1.26	1.18	10m Wide x 2.5m High	9.2	0.87	Conc.	7.2	12.86	25.72	73.8	2.9	5.1	10.2	0.35	0.87	5.02	3.90	3.90
2	Crossing 200 St.	1980	34.81	33.06	2.84 Wide x 1.77 High (x2)	61.7	2.84	Conc.	6.3	11.0	20.4	89.6	3.2	5.6	10.3	0.30	0.35	45.71	35.43	33.60
3	Crossing 36 Ave.	1859	42.67	42.56	2.2 Wide x 2.2 High (x2)	22.0	0.50	Conc.	6.0	10.6	19.2	35.6	3.2	5.7	10.3	0.72	0.66	48.10	44.13	43.98
4	Crossing 205 St.	1821	48.66	48.51	6.19m Span	7.9	1.90	--	6.0	10.4	20.8	43.7	3.3	5.7	11.4	0.48	1.00	51.63	51.45	51.41
5	Driveway Crossing South of 32 Ave	1795	50.17	50.17	10.77m Span	3.3	0.1*	--	5.9	10.3	23.0	84.5	3.3	5.7	12.8	0.28	1.00	53.29	52.65	52.61
6	Crossing 208 St.	1757	50.92	50.84	4.35m Wide x 2.44m High	21.0	0.38	CSP	5.8	10.1	20.1	16.7	3.3	5.8	11.5	1.20	1.00	54.94	53.65	53.54
7	Crossing 24 Ave.	1575	54.08	54.08	2.44m Wide x 2.48m High (x2)	15.8	0.1*	Conc.	6.1	10.1	22.2	25.6	3.9	6.4	14.1	0.96	0.84	57.28	56.18	56.16
8	Crossing 216 St.	1209	64.76	64.49	3.0 m Diameter	32.7	0.83	Steel	4.6	7.6	15.9	21.3	3.8	6.3	13.1	0.75	0.59	73.58	66.57	65.15
9	Crossing 224 St.	837	73.78	73.78	6.22m Span	6.7	0.1*	--	3.2	5.4	10.8	18.4	3.8	6.4	13.0	0.59	0.63	76.97	75.43	75.42
10	Crossing 232 St.	88	80.99	80.95	0.70m Diameter	17.8	0.22	Conc.	0.4	0.7	1.6	0.4	5.0	8.3	18.6	3.72	0.87	83.88	82.10	81.47

*Pipe Full Capacity is estimated from the cross-section and channel slope. Note Anderson Creek Channel slope between 24 Ave and 205 St is 0.2% or less

Table 1.4.5 Current Land Use Major Crossing Capacities

ID	Location on Anderson Creek	Contributing Area (ha)	u/s Inv. (m)	d/s Inv. (m)	Pipe/Bridge Dimensions (m)	Length (m)	Slope (%)	Material	1:2yr Peak Flow (m^3/s)	1:5yr Peak Flow (m^3/s)	1:100yr Peak Flow (m^3/s)	Pipe Full Capacity (m^3/s)	1:2yr L/s/ha	1:5yr L/s/ha	1:100yr L/s/ha	1:100yr q/Q	1:100yr d/D	Ground Elev (m)	u/s 1:100yr Max HGL	d/s 1:100yr Max HGL
1	Crossing Colebrook Rd.	2521	1.26	1.18	10m Wide x 2.5m High	9.2	0.87	Conc.	11.7	18.0	28.1	73.8	4.6	7.1	11.1	0.38	0.90	5.02	4.01	4.01
2	Crossing 200 St.	1980	34.81	33.06	2.84 Wide x 1.77 High (x2)	61.7	2.84	Conc.	10.3	15.3	21.3	89.6	5.2	7.7	10.8	0.31	0.36	45.71	35.44	33.64
3	Crossing 36 Ave.	1859	42.67	42.56	2.2 Wide x 2.2 High (x2)	22.0	0.50	Conc.	10.0	14.7	19.8	35.6	5.4	7.9	10.7	0.74	0.67	48.10	44.16	44.03
4	Crossing 205 St.	1821	48.66	48.51	6.19m Span	7.9	1.90	--	9.8	14.4	26.5	43.7	5.4	7.9	14.6	0.53	1.00	51.63	51.68	51.64
5	Driveway Crossing South of 32 Ave	1795	50.17	50.17	10.77m Span	3.3	0.1*	--	9.7	14.9	28.1	84.5	5.4	8.3	15.7	0.34	1.00	53.29	52.91	52.86
6	Crossing 208 St.	1757	50.92	50.84	4.35m Wide x 2.44m High	21.0	0.38	CSP	9.6	14.0	24.6	16.7	5.5	8.0	14.0	1.47	1.00	54.94	53.98	53.81
7	Crossing 24 Ave.	1575	54.08	54.08	2.44m Wide x 2.48m High (x2)	15.8	0.1*	Conc.	10.2	15.7	30.4	25.6	6.5	10.0	19.3	1.33	0.90	57.28	56.34	56.32
8	Crossing 216 St.	1209	64.76	64.49	3.0 m Diameter	32.7	0.83	Steel	7.9	11.8	21.6	21.3	6.6	9.8	17.8	1.02	0.70	73.58	66.92	65.36
9	Crossing 224 St.	837	73.78	73.78	6.22m Span	6.7	0.1*	--	5.7	8.6	14.9	18.4	6.8	10.3	17.8	0.81	0.74	76.97	75.70	75.69
10	Crossing 232 St.	88	80.99	80.95	0.70m Diameter	17.8	0.22	Conc.	0.7	1.0	2.1	0.4	7.6	11.7	24.4	4.89	0.91	83.88	82.88	81.52



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Municipal Boundary
- Flood Protection Station
- Dry Wells
- Trunk Sewers
- Storm Sewers
- Study_Area
- Anderson Creek
- Creek/Ditch
- 8 Major Culver/Bridge Crossing

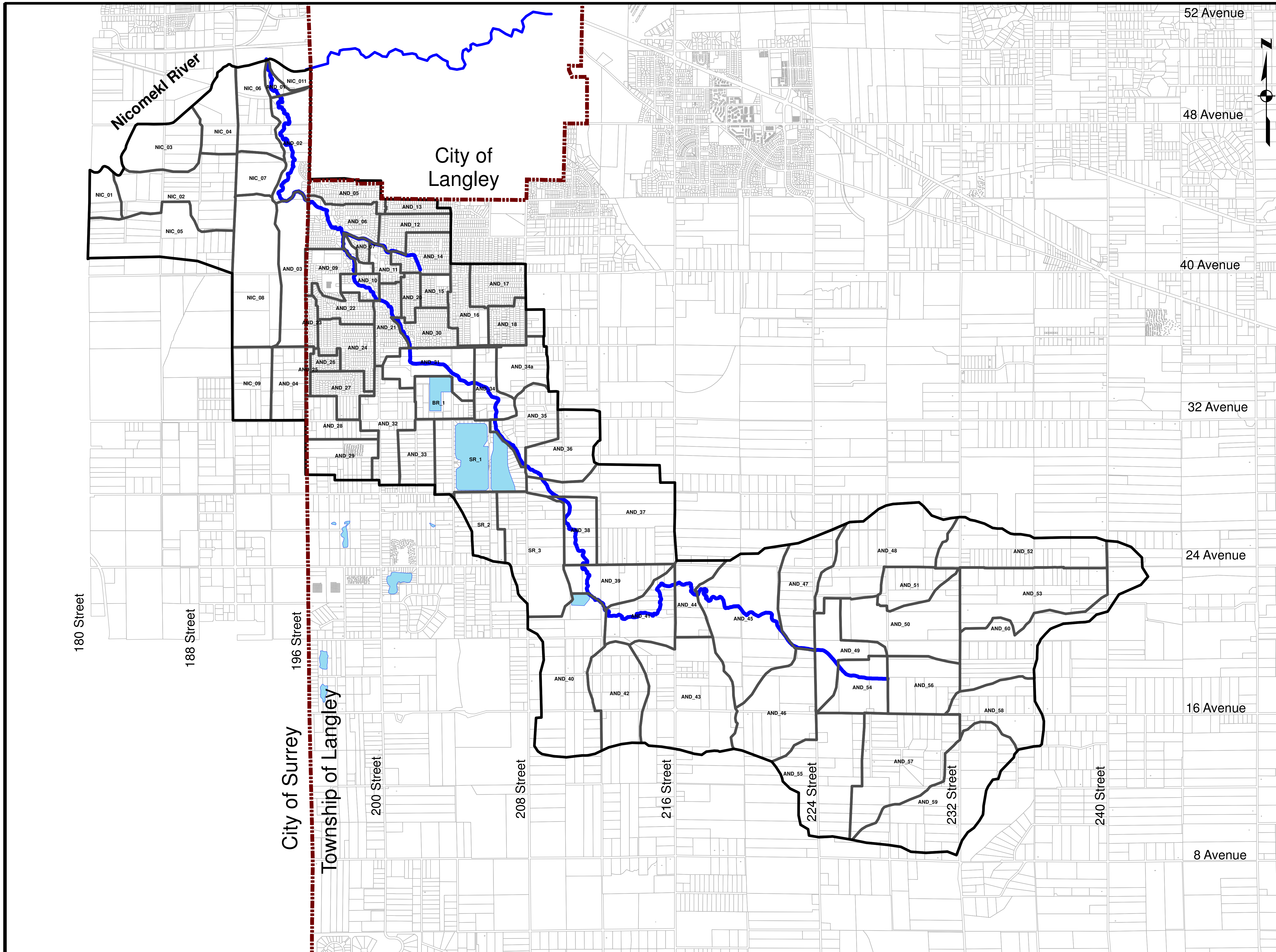
AECOM

0 500 1,000 2,000 Meters

Project No.	Date
60267316	October 2013

Current Hydraulic Structures

Figure 1.4.4



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Municipal Boundary
- Study Area
- Subcatchments with ID
- Anderson Creek
- Nicmekl River
- Existing Water Body

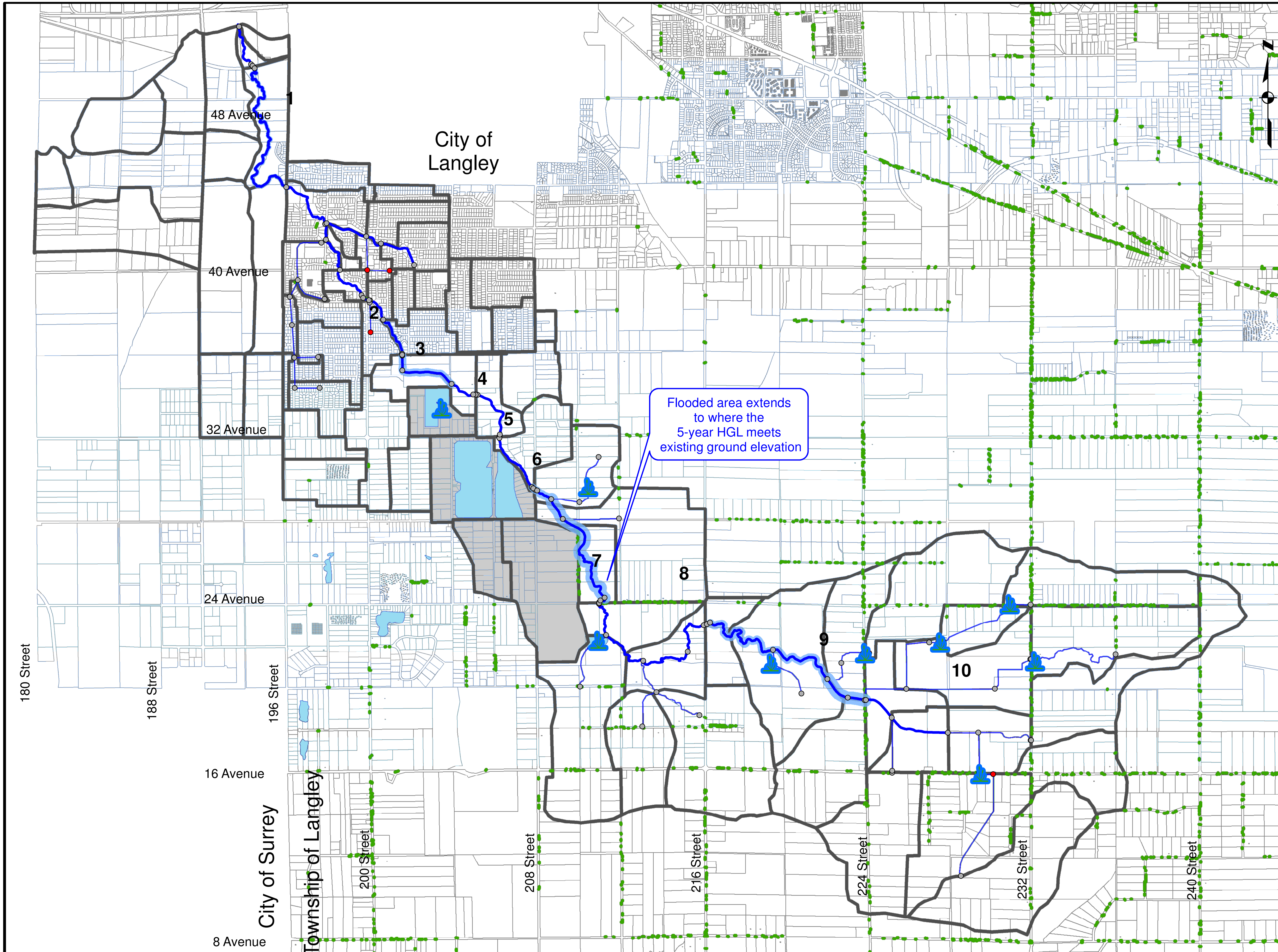
AECOM

0 500 1,000 2,000 Meters

Project No.	Date
60267316	October 2013

Sub-Catchment Areas

Figure 1.4.5



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Modelled Storage Areas
- HGL Above Ground
- Anderson Creek (Main Stem)
- Overbank Storage
- Subcatchments
- Surface Flow Not Connected
- Culverts
- Existing Water Body
- 1 Crossing ID#

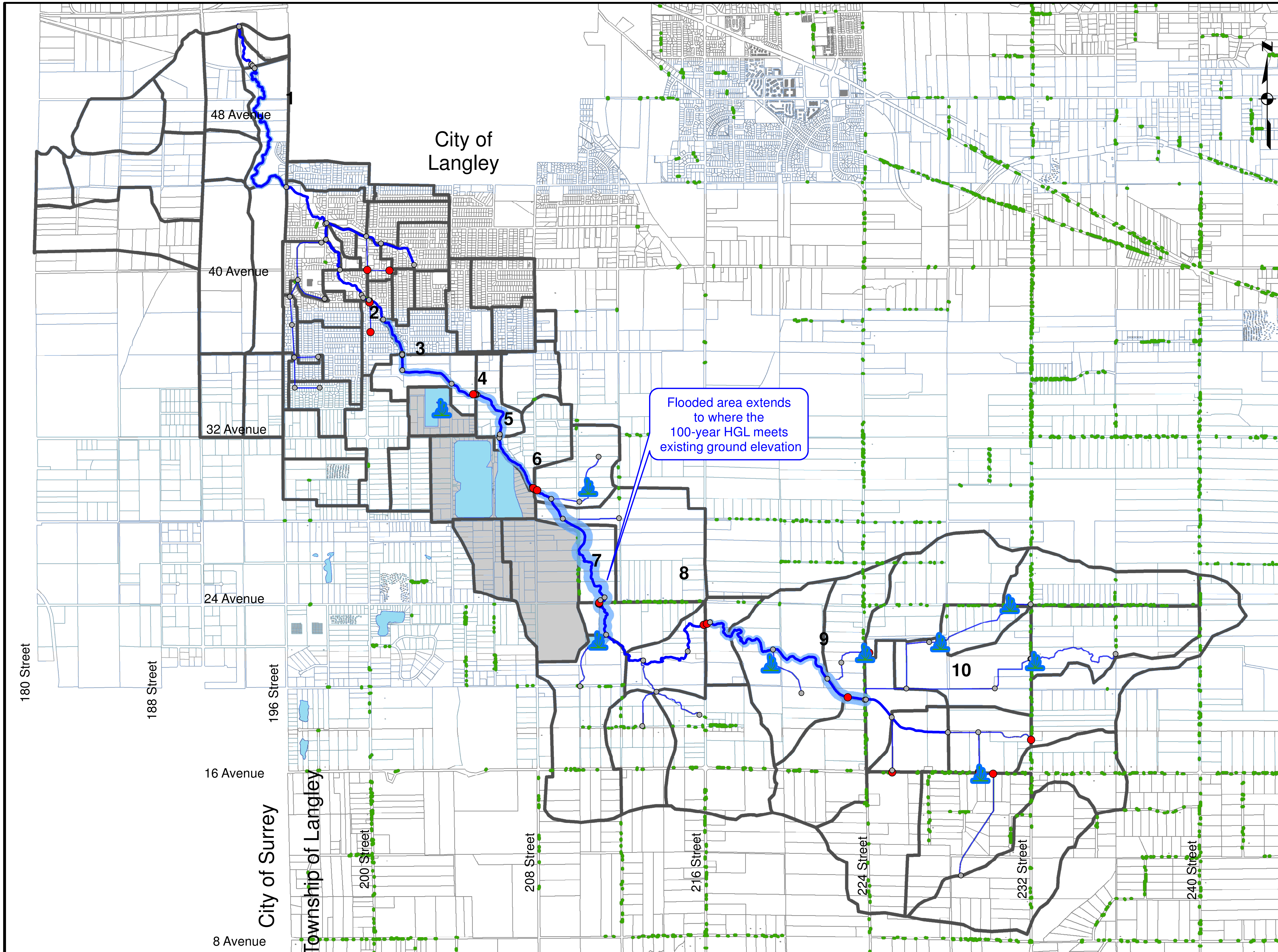
AECOM

0 500 1,000 2,000 m

Project No.	Date
60267316	October 2013

Model Results 5-yr 24hr Current Conditions

Figure 1.4.6



Township of Langley / City of Surrey

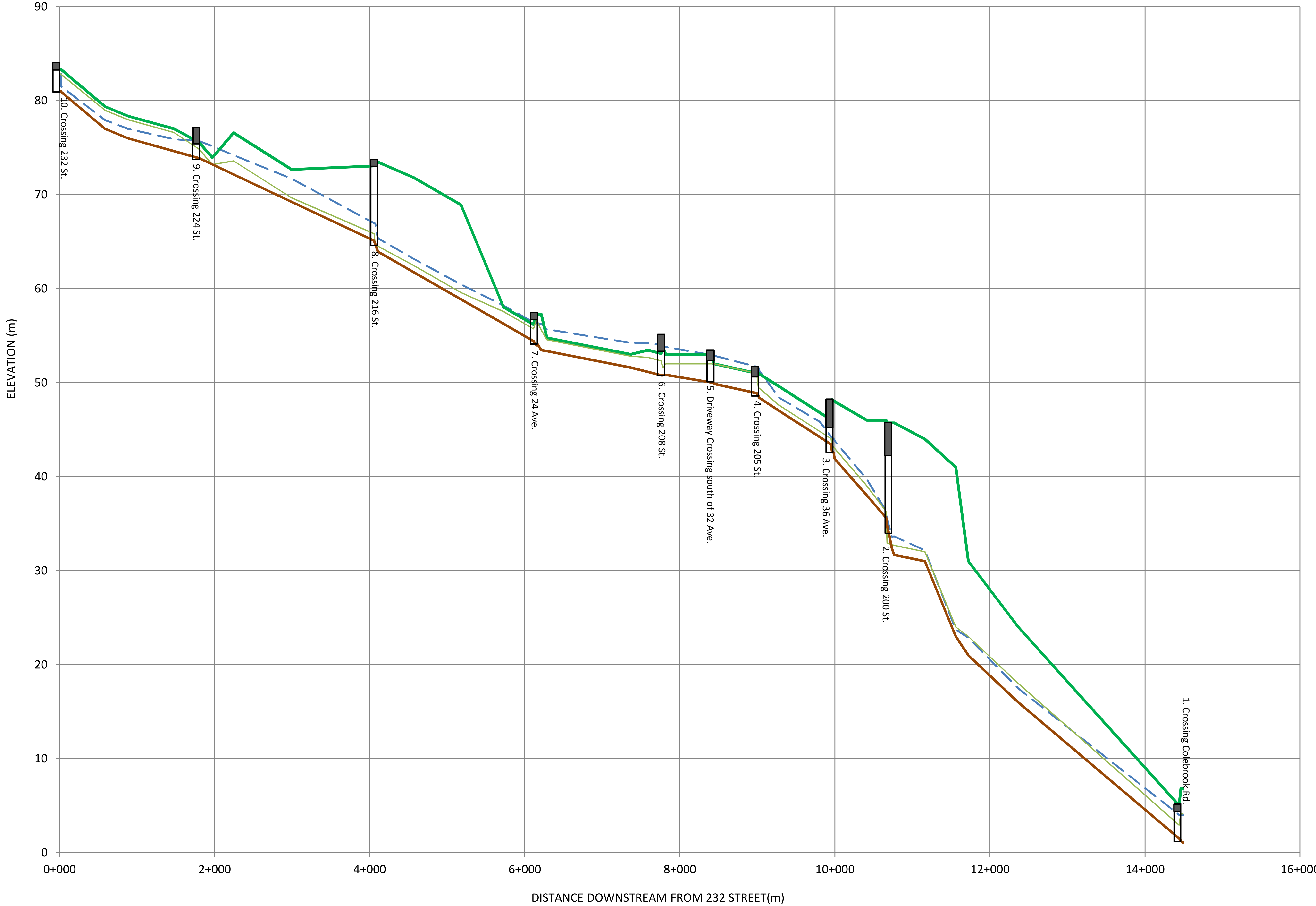
Anderson Creek ISMP

AECOM

Project No.	Date
60267316	October 2013

Model Results 100-yr 24hr Current Conditions

Figure 1.4.7



Township of Langley

City of SURREY the future lives here.

Anderson Creek ISMP

LEGEND

- Max 100-yr HGL
- Top of Bank
- Creek Channel
- Creek Bed

Surveyed Water Crossing

- Road Centre Line Elevation
- Top of Opening (Obvert)
- Invert

Scale: As Shown

Project No.	Date
60267316	October 2013

100-Yr Max HGL
Current Scenario

Figure 1.4.8

1.5 Hydrogeology, Soils, & Erosion

AECOM completed a desktop review of available information on geology, groundwater flow and potential contaminant sources in the Anderson Creek watershed. The local geology and groundwater flow system provide the framework for integrated stormwater management activities and need to be understood before enhanced infiltration options are selected. Detailed field investigations including infiltration tests at dry well locations and soil quality testing was also completed.

Anderson Creek flows to the northwest about 10 km from its headwaters in south central Langley Township before discharging to the Nicomekl River. The gradients are fairly flat in the headwater areas and increase steeply in the vicinity of 200 Street to the west just beyond the municipal boundary with Surrey then lessening again before entering the Nicomekl floodplain. In this area the creek channel is deeply incised and erosion is a concern.

1.5.1 Geology

Due to the very thick (i.e. >200m) over burden deposits in this central area of the Fraser Valley, the available bedrock mapping is poorly documented but the bedrock is likely Tertiary age sandstone, shale and conglomerate (GSC Map 1151A 1965 Roddick, J.A. and Armstrong, J.E.). Surficial geology maps show the distribution of unconsolidated geologic materials and soil in the upper 2m and provide information on the origin, age and composition of these materials. The surficial geology for the Anderson Creek watershed is provided in **Figure 1.5.1** *(GSC Map 1484A, Surficial Geology, New Westminster Armstrong, J.E. and Hicock, S.R. 1976).*

The upstream headwater portion of the creek starts in an area that is mapped as upland peat and bog deposits up to 8 m thick (SAe4) underlain by Fort Langley Formation stony clay silt 8 to 90 m thick (FLc) as shown on the figure. Near 24 Avenue Anderson Creek flows through an area of Sumas Drift, first through glacial aged ice contact sand and gravel with some lenses of stony clay marine silt, about 2 to 5 m thick (Sb) overlying the Fort Langley formation glaciomarine silts.

A little further downstream the creek passes through an area of Sumas Drift raised pro-glacial deltaic gravel and sand up to 40 m thick (Se). This is the permeable sand and gravel that forms the Brookswood unconfined aquifer. High infiltration rates are expected in this material. The available mapping shows that gravel pits have historically been developed in this area adjacent to the creek where several artificial lakes have been formed.

At the western edge of the pro-glacial Delta there is a steep slope down to the flood plain of the Nicomekl River. The floodplain along Anderson Creek is mapped as Capilano Sediments, raised beach medium to coarse sand (Cb) underlain by marine silts. There are minor bog and swamp organic and silt deposits at the mouth of the Creek (Sad).

Agricultural soil maps of the area (Luttmerding, 1981) indicate that most of the watershed is underlain by Columbia soils developed from coarse textured stratified glaciofluvial sediment deposits usually with a thin silty veneer near surface. Surface textures are typically sandy loam or gravelly sand. In the northwest corner of the watershed, there are some Coghlan soils similar to the Columbia soils but with, a cemented mineralized layer below a depth of about 0.3 m which reduces permeability and infiltration rates; however, drainage below 0.3 m is generally rapid.

1.5.2 Aquifers & Groundwater Use

There are a number of major aquifers in the Anderson Creek watershed. The major ones are the Brookswood, Hopington C, and West of Aldergrove. Aquifers within the Anderson Creek study area are shown in **Figure 1.5.2.**

The Brookswood aquifer is composed of sand and gravel deposits (shown as Sumas Drift in **Figure 1.5.1**) overlay much of the Brookswood Aquifer. This productive, unconfined sand and gravel aquifer has been used by local farms, residents, and the municipality for many decades. The BC MOE has mapped the Brookswood aquifer (MOE Aquifer No. 0041) and it is categorized as high demand, moderate production and high vulnerability to contamination. This aquifer is vulnerable to surface contamination due to the lack of a low permeability confining layer and is situated over most of the central part of the Anderson Creek watershed.

The other major aquifers are The West of Aldergrove aquifer and the Hopington C. West of Aldergrove is situated in the northeastern part of the watershed. It is categorized as moderate demand and low vulnerability to surface contamination. Hopington C is located at the northeastern tip of the watershed. It is categorized as high demand, high productivity, and high vulnerability.

A deeper confined aquifer, Langley Upland Intertill, is present in the southeastern portion of the Anderson Creek Watershed (MOE Aquifer No. 0052), but is not one of the major aquifers. It is categorized as moderate demand, moderate productivity and low vulnerability to surface contamination.

Groundwater quality in the Brookswood aquifer is generally good although slightly elevated iron and manganese concentrations can exceed aesthetic guidelines and nitrate concentrations may be elevated above predevelopment concentrations. The elevated nitrate levels could be natural or could indicate contamination from surficial activities such as pesticide and manure application, discharges from private septic systems, etc.

Brookswood Wells

Groundwater is a vital source of water to the Township for agricultural and domestic purposes. The 2012 Township of Langley Water Quality Report states that approximately 80% of water users rely on private or community wells for water. The Township withdraws water from three municipal wells in Brookswood to provide domestic water supply that is supplemented with water supplied by Metro Vancouver. The well capture zones for Brookswood Wells #7, 9, and 10 under maximum pumping conditions are shown in **Figure 1.5.3**.

There are numerous wells in the area that have an MOE well database record associated with them, but there are also many other wells that do not have a registered location. Many are no longer used because the residences are connected to the municipal water supply system. However, most of the farms and some of the residences continue to use their wells for various purposes. As such, the amount of groundwater extracted by these wells is not known, unlike the municipal wells.

The Township has conducted studies with the Ministry of Environment and the Ministry of Agriculture that show an ongoing decline of groundwater levels in some of the aquifers in the watershed. There is also concern about groundwater contamination from agricultural activities, septic systems, and poor well protection. One of the objectives of the ISMP is to develop an implementable strategy for groundwater protection and recharge. As such, the ISMP supports the Township's Water Management Plan to "ensure safe and sustainable groundwater for the community for generations to come".

1.5.3 Groundwater Recharge and Discharge

The Brookswood aquifer is primarily recharged by infiltration of rainfall and Anderson Creek. There are also natural seepage points and springs along the deeply incised ravines of Anderson Creek in the northwest portion of the watershed.

The main sand and gravel unit in the central portion of the watershed has a high capacity for infiltration. The relatively flat ground surface of the uplands, together with the permeable granular soils permits relatively high infiltration rates. During the wetter months, from November to March, precipitation recharges the underlying saturated zone and results in a rising water table. However, the *Brookswood / Fernridge Groundwater Study* (Piteau 1984) notes that during the remainder of the year, groundwater demands from irrigation, municipal and domestic wells as well as the natural groundwater discharge to Anderson Creek exceed recharge and consequently water in storage is depleted, causing a gradual lowering of the water table.

The *Brookswood Fernridge Groundwater Study (Piteau, 1984)* also provides historical information on the dry wells that form part of the stormwater management system in this part of the Township. Initial planning for the Brookswood area assumed that the relatively permeable surface sands and gravels could infiltrate all of the surface runoff from the subdivisions. As such, the drainage network in this area consists of shallow grass swales with perforated pipes and infiltration trenches, as well as drywells. Infiltration rates of up to 2 L/s per drywell (Piteau, 1984) were reported, although during wet winter weather when the groundwater table rises above the bottom of the drywells (normally about 2 m deep) infiltration rates are significantly reduced and surface flooding may occur.

There is also an area in Brookswood near 196A Street and 198 Street from 36 Avenue to 34A Avenue where local drainage is supplemented by a pumped storm sewer system that operates when the water table is elevated after prolonged periods of rainfall. This system was installed in the mid-1980s as a result of flood event that occurred in February of 1982 when elevated groundwater levels resulted in property damage. Prior to the installation of the pumped system the area was serviced by small culverts and drywells as is typical for the remainder of Brookswood. The pumped system is comprised of two pumps that automatically turn on when the groundwater level reaches a certain elevation (originally documented as 3m below ground level, Piteau 1982) and discharges to a storm sewer that runs north on 196A Street to tributary of Anderson Creek. It is critical that any future development proposed to the south of 33A Avenue complete an assessment of the groundwater levels and local geology to review whether BMPs that rely on infiltration are applicable for this area. Residents have reported high flows and erosion events downstream of the outlet when the pumps are running. This could be assessed at the same time, and perhaps the pumped flow could be directed to a future detention facility.

1.5.4 Infiltration Testing & Soil Contaminant Assessment

Infiltration testing was conducted at five selected infiltration trench locations as shown in **Appendix C**.

The work program included performing infiltration tests prior to and following maintenance measures (i.e. flushing) to assess the effectiveness of infiltration at each trench/rock pit location, and at a background test pit location.

In addition, three soil samples were collected at two of the sites: one from the lateral pipe or catch basin (surface sample), one from a test pit adjacent to the gravel filled trench (attenuation sample), and one from a second test pit located approximately two metres upslope of the sump (background sample). All the field data was then analyzed to estimate infiltration rates and the soil samples were submitted for laboratory analysis.

A summary of the conclusions is presented below with detailed descriptions of the field investigation methods and results provided in the technical memorandum in **Appendix C**.

Infiltration Testing

In general the infiltration rates appear to be relatively similar between sites and increased significantly after completion of maintenance works. Higher infiltration rates were obtained for the test pits compared to the lateral pipe configuration which indicates that sediment has likely built up surrounding the infiltration gallery over time. This highlights the need for filtering the runoff and for regular maintenance of both the sump and lateral pipes.

The relatively permeable soil conditions throughout much of the Anderson Creek watershed suggests that increasing infiltration of rainfall runoff will be effective in reducing the volume of stormwater runoff. However, filtering of sediment and other suspended solids clearly needs to be incorporated into designs. Additional methods for increased infiltration including raingardens, vegetated strips as well as enhanced infiltration trenches. Enhanced infiltration should not be encouraged along the top of steep slopes such as the incised ravines of Anderson Creek to the northwest. Infiltration increases pore water pressures in the slopes and can contribute to slope instability and failure.

Soil Contaminant Assessment

To assess the soil quality, samples from background, surface and attenuation locations at two of the sites (Sites 2 and 4) were analysed for extractable petroleum hydrocarbons (LEPH/HEPH), polycyclic aromatic hydrocarbons (PAH), total metals and toxicity characteristic leachable procedure (TCLP) metals.

Soil sample laboratory results were compared to the most stringent standard from the British Columbia Contaminated Sites Regulation (CSR) Residential Land (RL) Use Standards and the Hazardous Waste Regulation (HWR) Leachabilty Standards. The results indicate that all samples were either below the method detection limit (MDL) or below the applicable standards for the analysed parameters, except for chromium in the surface soil sample at Site 2 and arsenic in the attenuation sample at Site 4, which both marginally exceeded CSR-RL standards (see **Appendix C** for detailed analytical results). The soil land use standards for arsenic and chromium are based on exposure of humans to drinking water and given the proximity to residential lands, RL standards were applied to be conservative. Lands adjacent to roadways are typically considered commercial land use, whereby CSR Commercial Land Use (CL) standards would apply, which are less stringent for some parameters.

At both sites, the surface soil samples typically exhibited the highest concentrations of the analysed parameters, with the attenuation and background samples exhibiting similarly low or non-detectable concentrations. Concentrations of metals were generally higher in the surface soil samples, except at Site 4. TCLP metals (leachable calcium, magnesium and/or zinc) were only detected in the surface samples with the exception of the attenuation sample at Site 2, which exhibited a low concentration of leachable calcium. Additionally, hydrocarbons were only detected in the surface soil samples, and may be related to runoff from nearby paved surfaces which are considered to be a potential source of petroleum hydrocarbons and PAH's.

The metals concentrations in the attenuation sample at Site 4 were higher than both the surface and the background samples, including elevated arsenic. The difference between concentrations of metals in each of the three samples at Site 4 may be the result of a localized source or a mechanism other than stormwater runoff. If surface runoff reaching the lateral pipe caused the elevated metal concentrations, the surface sample would likely also exhibit similar or greater concentrations of metals than the attenuation sample.

Based on information collected at two sites, concentrations in the attenuation samples are similar to concentrations in the background samples and are generally lower than concentrations in the surface soil samples.

In such case, contamination of groundwater below lateral pipes and infiltration trenches is unlikely in areas under similar land and road use conditions. The impacts of elevated concentrations of metals and hydrocarbons in surface soil do not appear to extend to the lateral pipes or the adjacent soils. Traffic volume does not appear to appreciably affect the soil quality in the lateral pipes as there is little difference in concentrations of potential contaminants between sites located in residential neighbourhoods (Site 4) and sites collecting runoff from busy intersections (Site 2). Given that significant soil impacts were not observed, the impacts of infiltrating stormwater on groundwater quality are not likely significant.

Stormwater quality remains a key issue for the study area due to the unconfined Brookswood Aquifer. As shown in **Figure 1.5.2**, the Township has conducted extensive groundwater modeling studies and developed well capture zones that need to be protected. The 20-year well capture zone was selected as the target boundary to be conservative.

There are a few commercial and industrial areas within the Anderson Creek watershed that have potential to cause groundwater contamination due to fuel and chemical storage/handling. A large fuel or chemical spill on a roadway near a water supply well could result in a water quality issue in the well that is difficult and expensive to remediate. Furthermore, the majority of the area is residential or agricultural land use that is serviced with individual septic systems which can cause degradation of groundwater quality with elevated concentrations of ammonia, nitrate and/or coliforms. Similar contamination also occurs from intensive agricultural operations such as poultry farms, and on any agricultural operation with manure storage areas, especially those in areas where seasonal flooding occurs on a regular basis. Ultimately, rural or urban runoff with suspected degraded water quality should not be recharged into an unconfined aquifer near an active water supply well.

Another concern is the use of road salt as de-icers on impervious surfaces which is a preferred method for safe vehicle and pedestrian travel for many municipalities. Although its use is wide spread, the application of road salt and its impacts on the environment, stormwater runoff quality, and ground water quality have come under scrutiny. Snow melt and runoff entering open channels and water bodies which percolate to groundwater are the most common mechanisms for road salt to enter groundwater aquifers. These salts remain in solution and are not subjected to any natural removal mechanisms. Therefore, accumulations of salt content in watersheds pose risks to aquatic ecosystems, wildlife, and water quality. In light of this, Environment Canada is developing national targets to encourage ongoing implementation and to provide individual road organizations with clear targets and timelines to improve on best management practices, through a Code of Practice for Environmental Management of Road Salts.

To monitor road salt amounts entering into streams and groundwater, in situ water quality sampling and testing measures should be completed following a rain or snowmelt event after salting has been applied. Typically, parameters such as salinity and conductivity levels would be measured. Sediment and soil sampling can also be implemented, and results compared to assess the extent of road salt presence within the watershed. The Township should consider testing for road salts as described when testing for water quality.

1.5.5 Erosion and Bank Instability

The erosion of creek beds is a natural process, and the increase in development and human activities can significantly amplify the rate in which erosion occurs. Reduction of tree canopy and increasing land imperviousness (i.e. increase the runoff coefficient) will lead to a rise in stormwater peak flows, volumes and erosion. Erosion of creeks can be mitigated by maintaining good streamside ground cover, increasing vegetation and root structures, controlling peak flows, and reducing stormwater volume.
In general, there are two common forms of creek erosion which are (1) bed erosion, and (2) bank erosion.

Bed Erosion

Bed erosion (also known as bed deepening or incision) results from a variety of physical changes in the landscape over time. The removal or loss of vegetation, construction of roads and land development, all contribute to the chronic impact on bed surfaces. The main triggers for bed erosion are an increase in stormwater volume and flow.

Bed erosion appears as steps in the stream bed that progressively move upstream, leaving behind a narrow channel in the bed. This type of erosion lowers the elevation of the creek's bed deeper into the ground, causing steeper creek slopes and incisions which can lead to slope failure.

Bank Erosion

There are three processes that can occur in bank erosion either singularly or in combination with each other.

Sub-aerial erosion: This process involves the loosening of soil substrate in the creek bank, making it vulnerable to movement and displacement. This loosening of soil may be caused by activities such as frost heave, desiccation by the sun and wind, direct impact of rainfall, or human activities such as nearby vehicular or construction impacts. As water moves through the creek, it carries with it these soil particles causing them to be suspended (water cloudiness) and to be eventually deposited downstream.

Fluvial Scour: This process occurs when a force is applied to the creek bank by water flowing through the creek that exceeds the bank's resistance to this force, causing soil particles to be displaced. This force is also known as tractive force, and is directly related to a creek's water depth, slope, and hydraulic radius.

This type of erosion process also depends on the duration of the various magnitudes of flow in the stream. The methodology used to examine flow duration in each of the identified upland creeks is flow exceedance. Flow exceedance uses the continuous model to determine the amount of time that stream flows exceed a range of threshold values. Comparisons between runoff scenarios can be made to see how development will change the existing flow durations.

Mass Failure: Also known as slumping, this process can occur anywhere along a creek and often follows undercutting by scour. Usually, this type of failure happens during intense rain events and flooding where the water levels and flows within the creek rise dramatically and then suddenly drops leaving heavy saturated soils in the creak banks unsupported.

1.5.6 Erosion & Terrain Stability

Anderson Creek

In 2006, Hay and Company Inc. in conjunction with EBA Engineering Consultants Ltd. completed a study summarizing the terrain stability and channel morphology of Anderson Creek. The study focused on terrain stability and channel morphology assessments along the creek and its tributaries between 196 and 203 Streets. This study is updated every 3 years, most recently in 2012 by exp Services Inc.

The Township uses the findings to prioritize sites for bank stabilization projects on its property, and informs private property owners of any significant erosion sites on their properties, along with a recommended course of action.

The channel in the ravine valley displays signs of degradation fluvial scour as the easily erodible sandy bed and bank material is down cut also resulting in mass failure. This is evident in the numerous eroding banks and several slope failures that have resulted from undercutting at the toe of the slope. These failures contribute to large amounts of sand and gravel being deposited in the channel causing aggradation. Some material is transported downstream or onto overbank areas during peak flows which can lead to erosion in the mainstem of the channel.

Erosion and slope instability problems found in the study area include sloughing banks, slope failures, and tree-falls. The terrain assessment revealed that mass-wasting features and processes observed within the study areas appear to be the result of two primary mechanisms.

- *Toe erosion and bank over-steepening*: Slope failures at the bottom of the ravine were observed at several locations within the study area. The failures appear to be caused by a cyclic pattern of toe erosion and over-steepening (undercutting) of the banks, some of which are nearly vertical.
- *Heavy precipitation and decreased bank stability*: Slope failures near the crest of the ravine appear to be caused by periods of heavy, continuous precipitation and the associated increase in groundwater pore pressure and soil weight. Anthropogenic influences, primarily due to poor drainage practices, removal of trees and shrubs, increased loading from fill slopes, retaining walls,

and yard waste dumped over the bank may be exacerbating the problem.

Several recommendations were made in the report to address minimizing negatives impacts to future development. The following items were identified as safety setbacks along the ravines:

- All future developments should be located at least 5 m from the undisturbed natural slope crest;
- For proposed developments closer to the crest of the slope than a line extending up at 2.5H:1V from the toe of the ravine at the elevation of the creek channel, a site-specific geotechnical assessment should be carried out prior to development;
- For proposed developments set back further than the 2.5H:1V line, a site-specific geotechnical assessment of the ravine would not be required. However, property owners should complete a site topographic survey to accurately identify the ravine toe and associated 2.5H:1V setback line for their individual lot. Where toe erosion is occurring, the setback distance from the slope crest would increase to maintain the 2.5H:1V guideline.

In addition, the report recommended that owners of developments along the ravine should closely monitor their property for erosion at the toe of the ravine and record any instances of tension cracks, tree falls, slumps, slides or other potential processes that appear active along the slope or near the slope crest.

Unwin Watershed

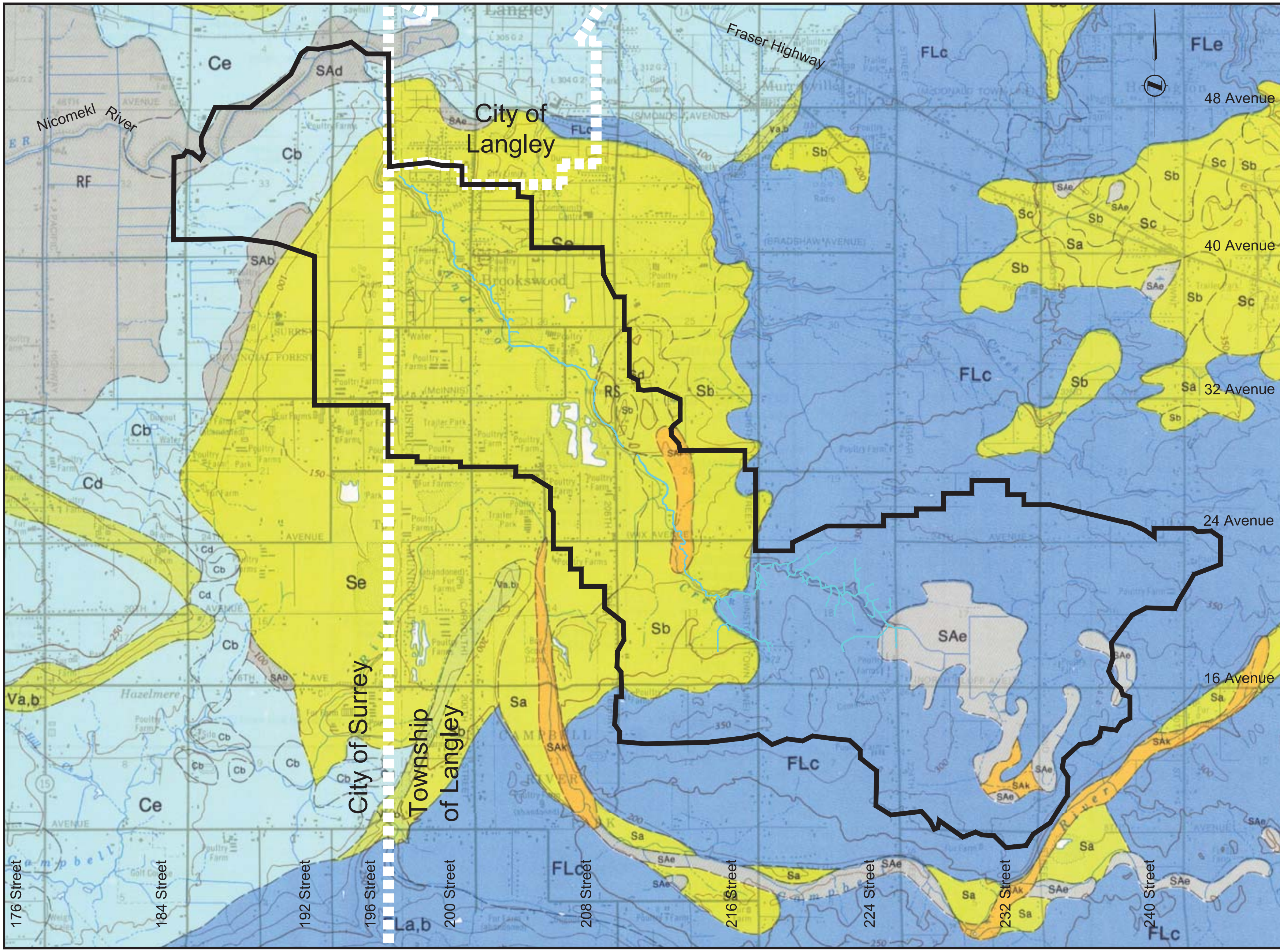
The City of Surrey also completes a ravine stability assessment program every two to four years to identify and rank instability sites based on perceived risk. The 2009 Ravine Stability Assessment report was completed by WEB Engineering and includes the section of Anderson Creek within Surrey, the Armstrong Watershed and Ross Creek.

In each of the ravine sections included the assessment there were medium and low priority erosion and debris sites present. In most cases the sites were reported in previous years and for some sites conditions have worsened while others remain unchanged. In the Armstrong Watershed there were two instances of blocked or partially blocked culverts.

1.5.7 Hydrogeological & Soil Erosion Key Issues

Key issues identified for the Anderson Creek watershed as it pertains to soil condition, groundwater, and slope stability include the following items:

- There are eroded banks and undermined slopes along the main stem, decreasing the slope stability and resulting in localized sloughing, particularly in the ravine section of the Creek.
- Anthropologic changes to drainage, creek sections, and vegetation on private property may also increase slope instabilities;
- Enhanced infiltration should not be located along the top of steep slopes as pore water pressures increase contributing to slope instability and potential failure;
- Protection for the unconfined Brookswood Aquifer from infiltration of poor quality surface water as well as over usage for domestic water supply is critical, especially in the municipal well capture zones;
- Monitoring of the groundwater quality in the Brookswood Aquifer must be maintained, particularly for elevated nitrate concentrations which can be an indicator that the groundwater is at risk for contamination from surficial activities such as pesticide and manure application, discharges from private septic systems, road salting operations, etc.
- Prior to any further development in the vicinity of 196A Street and 198 Street south of 34A Avenue, the Township or developer should initiate a detailed study to investigate the groundwater table elevations and whether infiltration measures are practical for the area; and
- Further investigation of typical infiltration rates under steady state conditions could be undertaken to determine the design rates for enhanced infiltration systems. The systems that are in place continue to work well after years/decades of existence but they are susceptible to clogging and require regular maintenance. Infiltration is a viable strategy for new development but the runoff must be clean or filtered, and an overflow pipe system is needed.



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- ISMP Study Area
- Anderson Creek
- SAb-e — Bog, Swamp, and Shallow Lake Deposits (Organics, Peat)
- SAh-k — Recent Sands (Creek Deposits)
- FLa-e — Fort Langley Formation (Glacial Deposits)
- Ca-e — Capilano Sediments (Marine Beach Sand & Silt Deposits)
- Va,b — Vashon Drift (Dense, Low-Permeability Glacial Till)
- Sa-e — Sumas Drift

AECOM

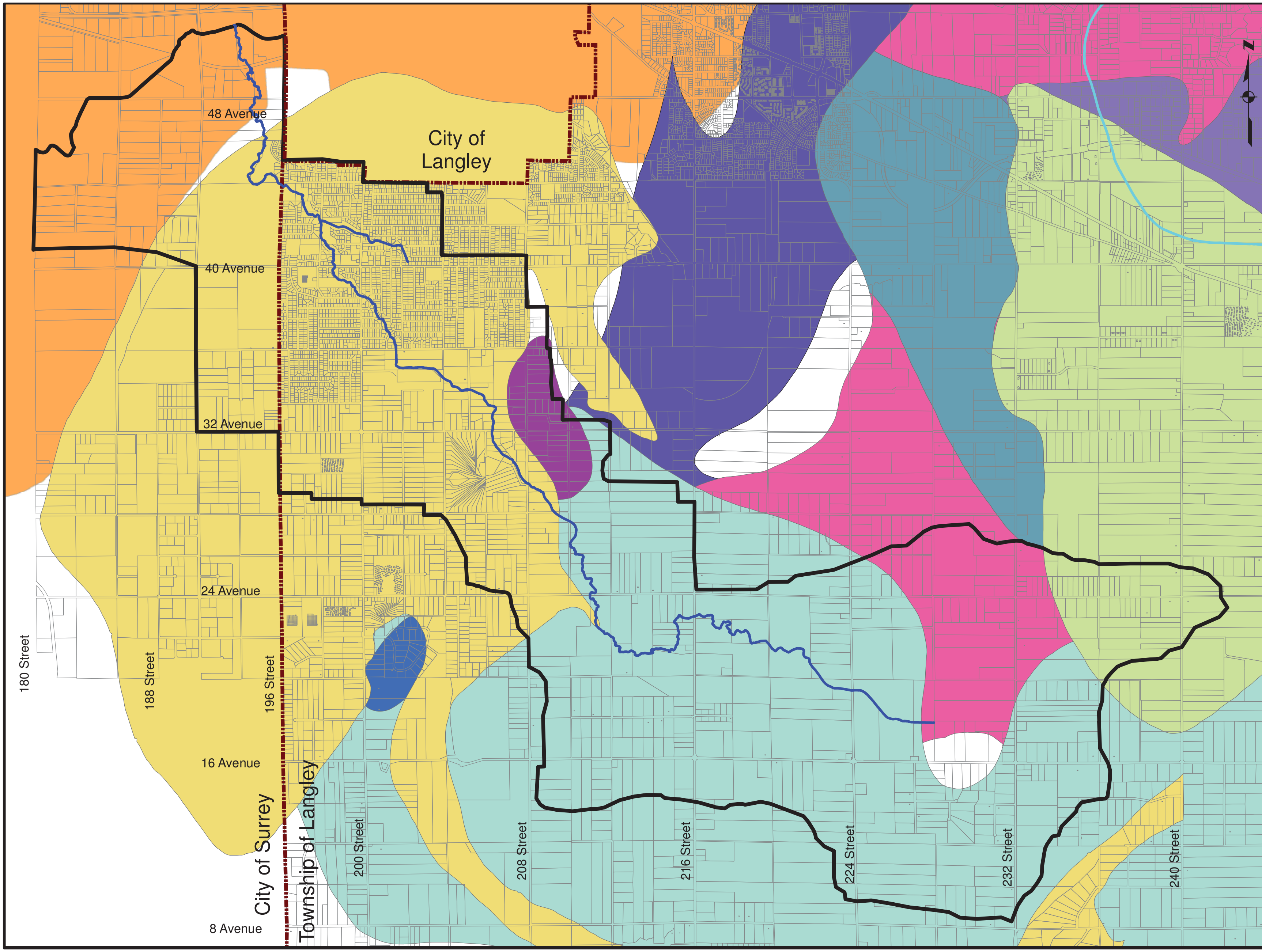
0 1000 2000 m

Project No. 60267316

Date October 2013

Surficial Geology

Figure 1.5.1



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Municipal Boundary
- Study Area
- Anderson Creek (Main Stem)
- Brookswood A
- Brookswood B
- Brookswood C
- Hopington C
- Langley Upland Intertill
- Nicomekl-Serpentine
- South of Murrayville A
- West of Aldergrove A
- West of Aldergrove B
- West of Aldergrove C

AECOM

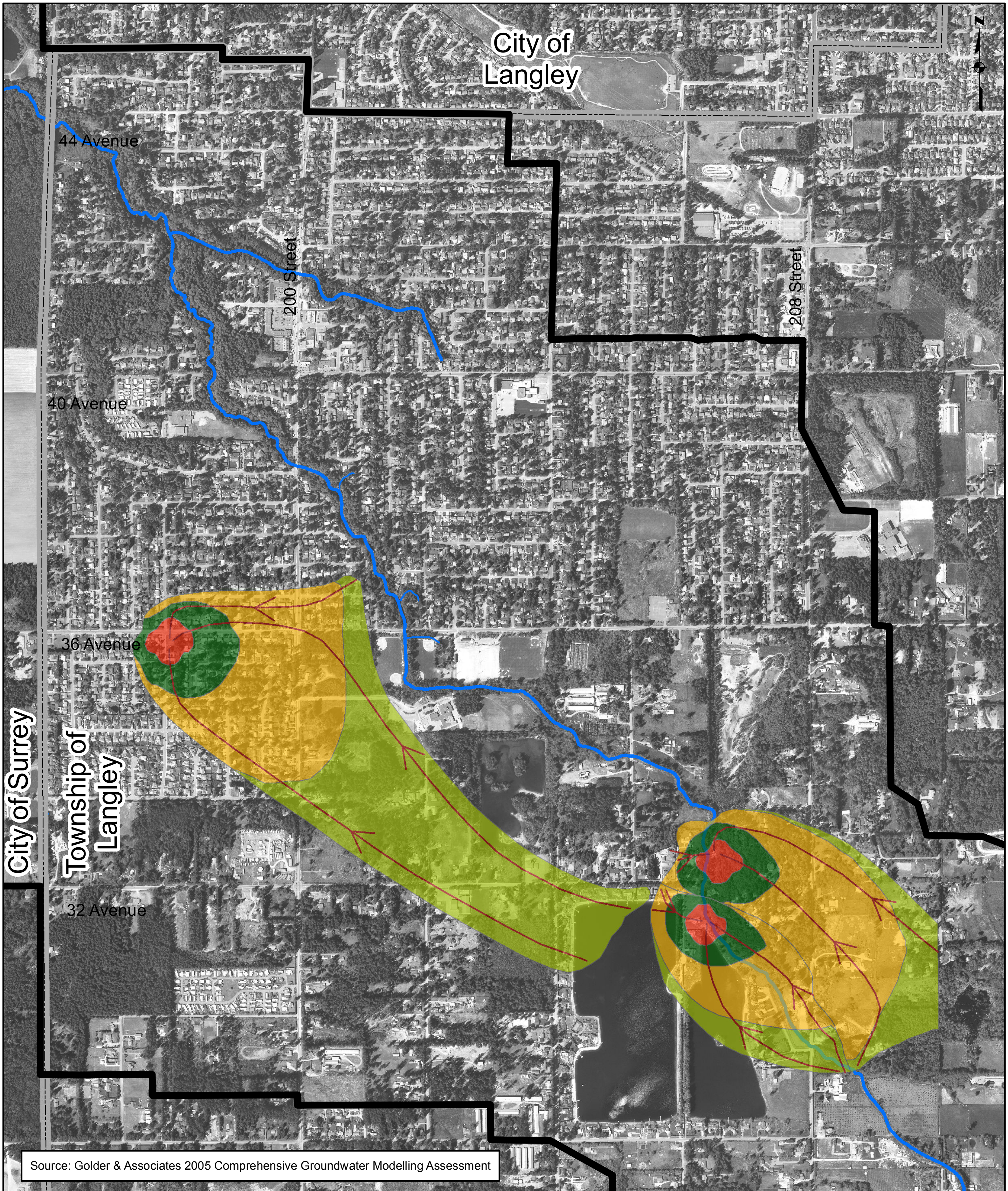
0 500 1,000 2,000 m

Project No. 60267316

Date October 2013

Anderson Creek Watershed Aquifers

Figure 1.5.2



Township of Langley / City of Surrey

Anderson Creek ISMP

Project No: 60267316

Date: October 2013

Legend

- Anderson Creek Study Area
- Capture Zone Flow Lines
- Anderson Creek

Well Capture Zone

- 60 Day
- 1 Year
- 5 Year
- 20 Year

AECOM

0 100 200 400 m

Well Capture Zones

Figure 1.5.3

1.6 Environment

The environmental component includes an inventory and assessment of current environmental conditions for terrestrial (wildlife habitats and corridors) and aquatic habitats (watercourses, wetlands) within the study area establishing a baseline. Once the baseline is established the ISMP will set out how the resources within the watershed should be managed to balance land development, stormwater management with environmental protection, preservation and enhancement. A review of current green space and stream corridors is also included in the study to provide a holistic and integrated outlook to ensure the long term health and success of the watershed.

Current and historical information and literature regarding existing environmental conditions were gathered and reviewed. This included, but was not limited to, available consultant reports, and databases such as Conservation Data Centre (CDC), Township of Langley Geosource, Fisheries Information Summary System (FISS) and Habitat Wizard.

1.6.1 Anderson Creek Classification

Anderson Creek is one of the major tributaries of the Nicomekl River, which originates in the Township of Langley and discharges into Mud Bay. The Creek flows from the Agricultural Land Reserve portion of Langley through the urban segment of the watershed northwest to Nicomekl River. According to the *1999 Lower Fraser Valley Streams Strategic Review* by Fisheries and Oceans Canada (DFO), the Nicomekl River system was classified as being endangered with a declining trend due to impacts by agriculture and urbanization resulting in poor water quality, riparian removal, channelization/dyking and increasing effective impermeable surface area.

The classification for Anderson Creek follows the Township of Langley watercourse classification system:

- **Class A**: Inhabited by fish year round or potential for year round fish presence upon reasonable means of access enhancements;
- **Class AO (Dry)**: Watercourses with intermittent water supply. May dry up in summer months, inhabited by (or potentially inhabited by) fish during over-wintering period when base flows are re-established;
- **Class AW (Wet)**: Watercourses with fish presence year round. Utilized primarily by salmonids during the over-wintering period. In general, summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species are generally present year round;
- **Class B**: Significant source of food, nutrients or cool water supplies to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence;
- **Class C**: Insignificant food/nutrient value. No documented fish presence and no reasonable potential for fish presence. These watercourses dry up soon after rainfall; and,
- **Unclassified**: Watercourses for which no detailed information exists.

The current Watercourse Classification Map (which is updated as new information becomes available)is shown in **Figure 1.6.1**. Anderson Creek is classified as primarily Class A stream along the main stem with Class AO (Dry), Class B and Class C primarily represented off the main stem. DFO's online database (Mapster, 2012) indicated that fish accessible stream length in the watershed was 32 km, inferred fish habitat was 17 km and observed fish habitat length was 15 km.

1.6.2 Fish Species

Fish species data were obtained from the BC Ministry of Environment using the Habitat Wizard application (Habitat Wizard, 2012), and the Fisheries Information Summary System (FISS) database query application (MOE, 2012). Fifteen unique fish species were listed as possibly existing in the Anderson Creek system. Additionally, reference was made to fish identified as stickleback general and coastal cutthroat trout but were left out of the overall summary species list. All fish species data for Anderson Creek are presented in

Table 1.6.1 and none are species at risk under the Species at Risk Act.

Table 1.6.1 Fish Species Recorded in Anderson Creek Watershed

Common Name	Scientific Name	BC Status	COSEWIC* Status
Black Crappie	*Pomoxis nigromaculatus*	Exotic	-
Brown Catfish	*Ameiurus nebulosus*	Exotic	-
Chinook Salmon	*Oncorhynchus tshawytscha*	Yellow	Threatened
Chum Salmon	*Oncorhynchus keta*	Yellow	-
Coho Salmon	*Oncorhynchus kisutch*	Yellow	Endangered (Interior Fraser Population)
Cutthroat Trout	*Oncorhynchus clarkii*	No Status	-
Dolly Varden	*Salvelinus malma*	Yellow	-
Kokanee	*Oncorhynchus nerka*	Yellow	-
Western Brook Lamprey	*Lampetra richa*	Yellow	-
Pink Salmon	*Oncorhynchus gorbuscha*	Yellow	-
Rainbow Trout	*Oncorhynchus mykiss*	Yellow	-
Steelhead	*Oncorhynchus mykiss*	Yellow	-
Threespine Stickleback	*Gasterosteus aculeatus*	Yellow	Special Concern

**Committee on the Status of Endangered Wildlife in Canada*

An extensive amount of fish habitat data is available as part of the Sensitive Habitat Inventory and Mapping (SHIM) Atlas for the Anderson Creek area and has been incorporated into this study.

Issues previously identified within the Anderson Creek watershed that may limit fish habitat productivity include turbidity, intermittent flows and water levels in summer, portions of stream affected by agriculture, lack of streamside cover, channel stability issues, erosion, sedimentation, and fish barriers.

1.6.3 Species at Risk

A combination of mapping programs was used to compile the list of potential species at risk. The BC Conservation Data Centre (CDC) mapping service was used to identify known locations of Red- and Blue-listed species and ecological communities in the watershed. The government of Canada's Species at Risk Registry was used to confirm species at risk for mammal, fish, birds and arthropods in the region. This list does not represent a comprehensive list of species, only sensitive species with established regional occurrence. Transient and rare species were not included in the assessment.

A summary of species at risk within the watershed are outlined in **Table 1.6.2**.

A non-sensitive occurrences search was also completed for a 5 km radius from the central point of the Anderson Creek watershed using the BC Conservation Data Centre mapping service. A total of 6 species were identified in the 5 km search area, including the following:

Vascular Plants:

- False-pimpernel (*Lindernia dubia var. Anagallidea*): BC Blue List
- California-tea (*Rupertia physodes*): BC Blue List
- Vancouver Island Beggarticks (*Bidens amplissima*): BC Blue List; SARA Schedule 1

Animal:

- American Bittern (*Botaurus lentiginosus*): BC Blue List
- Trowbridge's Shrew (*Sorex trowbridgii*): BC Blue List
- Northern Red-legged Frog (*Rana aurora*): BC Blue List; SARA Schedule 1

Table 1.6.2 Species at Risk

	Common Name	Scientific Name	BC Status	COSEWIC Status
Mammal	Mountain Beaver	*Aplodontia rufa*	-	Special Concern
	Mountain Beaver	*Aplodontia rufa rainieri*	Blue	Special Concern
	Pacific Water Shrew	*Sorex bendirii*	Red	Endangered
	Trowbridge's Shrew	*Sorex trowbridgii*	Blue	-
Amphibian	Coastal Tailed Frog	*Ascaphus truei*	Blue	Special Concern
	Northern Red-legged Frog	*Rana aurora*	Blue	Special Concern
	Western Toad	*Anaxyrus boreas*	Blue	Special Concern
Reptile	Painted Turtle – Pacific Coast Population	*Chrysemys picta,* population 1	Red	Endangered
Fisheries	Bull Trout	*Salvelinus confluentus*	Blue	Candidate
	Cutthroat Trout	*Oncorhynchus clarkia clarkii*	Blue	-
	Eulachon	*Thaleichthys pacificus*	Blue	Endangered/Threatened
	Green Sturgeon	*Acipenser medirostris*	Red	Special Concern
	Nooksack Dace	*Rhinichthys cataractae – Chehalis lineage*	Red	Endangered
	Salish sucker	*Catostomus sp. 4*	Red	Endangered
	White Sturgeon, Lower Fraser River population	*Acipenser transmontanus, pop. 4*	Red	Endangered
	Threespine Stickleback	*Gasterosteus aculeatus*	Yellow	Special Concern
Birds	American Bittern	*Botaurus lentiginosus*	Blue	-
	Bald Eagle	*Haliaeetus leucocephalus*	Yellow	Not at Risk
	Band-tailed Pigeon	*Patagioenas fasciata*	Blue	Special Concern
	Barn Owl	*Tyto alba*	Blue	Threatened
	Barn Swallow	*Hirundo rustica*	Blue	Threatened
	Black-crowned Night-heron	*Nycticorax nycticorax*	Red	-
	Black Swift	*Cypseloides niger*	Yellow	Concern
	Caspian Tern	*Hydroprogne caspia*	Blue	Not At Risk
	Common Nighthawk	*Chordeiles minor*	Yellow	Threatened
	Double-crested Cormorant	*Phalacrocorax auritus*	Blue	Not At Risk
	Great Blue Heron	*Ardea Herodias fannini*	Blue	Special Concern
	Green Heron	*Butorides virescens*	Blue	-
	Marbled Murrelet	*Brachyramphus marmoratus*	Blue	Threatened
	Northern Goshawk	*Accipiter gentilis laingi*	Red	Threatened
	Northern Harrier	*Circus cyaneus*	Yellow	Not at Risk
	Olive-sided Flycatcher	*Contopus cooperi*	Blue	Threatened
	Peregrine Falcon	*Falco peregrines anatum*	Red	Special Concern
	Purple Martin	*Progne subis*	Blue	-
	Rough-legged Hawk	*Buteo lagopus*	Blue	Not at Risk
	Sandhill Crane	*Grus canadensis*	Yellow	Not at Risk
	Short-eared Owl	*Asio flammeus*	Blue	Special Concern
	Sooty Grouse	*Dendragapus fuliginosus*	Blue	-
	Spotted Owl	*Strix occidentalis*	Red	Endangered
	Western Screech-Owl		Blue	Threatened
Insect	Autumn Meadowhawk	*Sympetrum vicinum*	Blue	-
	Johnson's Hairstreak	*Callophrys johnsoni*	Red	-

1.6.4 Environmentally Sensitive Areas

A report on wildlife and habitat in the Brookswood/Fernridge neighbourhood was produced by The Langley Environmental Partners Society in 2009. This highlighted several environmental concerns regarding development in this area. The neighbourhood contains significant tracts of 50 to 100 year old conifers that provide valuable connectivity and habitat for wildlife. It also includes the Brookswood Aquifer which is at risk of contamination and changing flow levels. Policy recommendations arising from this report include identifying and where possible, preserving wildlife habitats as part of the community and neighbourhood planning process.

Anderson Creek is divided into two separate biogeoclimatic units approximately at 32 Avenue. The portion of the watershed south of 32 Avenue belongs to the Coastal Douglas-fir moist maritime (CDFmm) subzone. This subzone includes the southwest portion of the Lower Mainland, extending across the Strait of Georgia to include much of the Gulf Islands and the southeast coast of Vancouver Island. The subzone lies in the rain shadow of Vancouver Island and Olympic Mountains, resulting in warm, dry summers and mild, wet winters in this subzone.

The portion of the watershed north of 32 Avenue belongs to the Coastal Western Hemlock very dry maritime (CWHxm) subzone. The CWHxm occurs at lower elevations along Vancouver Island and on the mainland it extends up the south side of the Fraser River as far as Chilliwack. CWHxm and CDFmm forests are dominated by Douglas-fir, accompanied by grand fir, western hemlock, western red cedar. Major understorey species include salal, dull Oregon-grape, red huckleberry, *Hylocomium splendens*, dull Oregongrape, ocean-spray, and *Kindbergia oregana*. Both subzones contain similar characteristics and boundaries between the two subzones should be considered transitional.

As part of the Township of Langley's *Evaluation of Environmentally Sensitive Areas* (ESAs), completed in 1993, ESAs were classified according to key information categories, which included:

- Geological hazard potential;
- Groundwater resources;
- Natural vegetation and wildlife habitat;
- Watercourses, fish resources and fish habitat;
- Visual assessment and cultural features; and,
- Public nominations of ESAs.

The key information categories were assembled to arrive at a final ESA designation. ESAs in the Anderson Creek watershed primarily consist of three categories, including: watercourses, aquifers and forests.

The City of Surrey's *Biodiversity Conservation Strategy* and *Ecosystem Management Study* were also reviewed to determine the ESAs highlighted in the Unwin Watershed. Areas that are identified include terrestrial hubs which are comprised of natural vegetation and wildlife habitat, and aquatic hubs surrounding watercourses and fish habitat. The Biodiversity Conservation Strategy splits the Unwin Watershed into the Serpentine Nicomekl and Campbell Heights management areas.

Conservation areas, parks, green spaces and significant natural features are important to the environmental health of a region. These areas allow such benefits as providing fish and wildlife habitat, controlling urban runoff, filtering air and absorbing carbon dioxide. There are several green space and conservation areas in the Anderson Creek watershed as shown in **Figure 1.6.2**.

Another component of watershed health is the level of stream corridor protection through maintenance of vegetated riparian corridors and is important in providing wildlife and fisheries habitat, reducing flooding risk and erosion and providing defence from non-point source pollution entering the stream. A portion of these benefits may be lost when buffers for riparian corridors are fragmented by breaks or intrusions into the corridor. Further development and fragmentation of the ESAs in the Anderson Creek watershed may have negative implications to the overall environmental health of the watershed.

1.6.5 Water Quality and B-IBI Sampling Program

A water quality and benthic invertebrate biodiversity index (B-IBI) sampling program was conducted as part of this ISMP. Detailed results from this program are included in **Appendix D** and summarized here. Four representative sampling sites along the main stem of Anderson Creek were selected based on land uses ranging from agricultural to urban, and are shown in **Figure 1.6.2**.

Sections of Anderson Creek (approximately between 24 Avenue and 36 Avenue) were dry during the sampling period. Upper watershed ditching and channelization restricted the location of water quality and benthic invertebrate sample sites. Private property access to Anderson Creek also limited sample site selection.

Water Quality

Samples were collected for water quality analysis on October 3, 2012. The results at three (AND-02, AND-03, AND-04) of the four sample sites displayed one or more exceedances above Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment (CCME 2007) and/or BC Water Quality guidelines for total aluminum, total cadmium, total copper and total iron.

Results of water quality and macroinvertebrate sampling indicates that the hydrology of the Anderson Creek watershed exhibit characteristics of an urbanized basin that contain extreme flow regimes consisting of high peak wet weather to dry weather flow ratios, a flashy storm hydrograph and low summer base flows. Flashy high flows can create issues in the watershed such as bank erosion and instability, increased sediment load in the stream and infilling. Low flows in the summer can contribute to higher water temperatures and lower dissolved oxygen levels in some reaches of the system, which can be significant impediments to fisheries resources. Bank characteristics varied at each sample site with all sites and undercut banks were present at all sample sites. Bank slopes range from slight at AND-03 to steep at all other sites. Bank stability was characterized as stable to moderately eroded.

B-IBI

Monitoring of benthic invertebrates is a means of determining watershed health as the benthic species perform a variety of functions in freshwater food webs and ecosystems. Benthic invertebrates process decomposing organic material and subsequently provide nutrients as a food source for microbial and plant growth as well as fish and birds.

Benthic invertebrate B-IBI had an overall very poor to fair stream condition rating for the Anderson Creek sampling locations. The stream condition rating for AND-04 was rated as very poor, AND-03 was rated as poor and AND-01 and AND-02 were rated as fair. Benthic invertebrate densities were highest at the AND-01 sample location and Diptera dominated the communities at all sites with exception of AND-03, where Amphipoda dominated. The AND-01 invertebrate sample site had a higher density and richness of species than all other sites.
The City of Surrey has an on-going B-IBI sampling program for Anderson Creek approximately 50m upstream of Colebrook Road (benthic site ‘AND-01’). B-IBI metric summaries provided are from spring 2006, 2007, and 2008 and are summarized in 2011 City of Surrey Benthic Invertebrate Sampling Program: Methods and Results report by Raincoast Applied Ecology. Surrey uses a different methodology and based on a reanalysis of the data the overall stream condition for the City of Surrey, Anderson Creek sample location would be categorized as Fair. These reanalysis results are consistent with the data for the furthest downstream location (AND-01) in 2012. The previous average replicate B-IBI rating in the City of Surrey report for 2011 sample results would be categorized as Very Poor. An increase of two categories occurred on the stream condition rating when pooling the results of the three replicates rather than averaging the individual B-IBI replicate ratings.

The GVRD Benthic Macroinvertebrate B-IBI Guide was used as the basis for the overall stream condition rating; however, the guide did not contain comprehensive ecological characteristic classifications for all taxa present in the samples and required a rating designation based on the professional judgement.

The difference in condition rating between the upper and lower watershed may be attributed to surrounding land use and stream habitat characteristics. Higher levels of organic carbon and nitrogen and orthophosphate levels were measured in the upper watershed, which may be attributed to the agricultural land use in the area. Differences were also noted in the substrate type between the upper and lower watersheds. Stream substrate in the upper watershed were noted as containing more clay and fines compared to the higher proportion of gravels and cobble substrate in the lower watershed. Channelization and ditching was also present in the upper watershed in comparison to the more natural channel characteristics observed in the lower watershed.

1.6.6 Overall Watershed Health

Overall the watershed condition based on benthic invertebrate sampling indicated that the lower Anderson Creek watershed condition was in fair condition and the upper watershed was in poor to very poor condition. Sample condition is based on the number of different types of invertebrates, invertebrate pollution tolerance, invertebrate feeding ecology and population attributes collected at each sample site. Water quality and habitat characteristic information is also collected at each site to provide information to support the benthic invertebrate data results. Higher levels of organics and phosphates were measured in the upper watershed and higher microbiological and nitrogen parameters were noted in the lower watershed. Results of the water and macroinvertebrate sampling indicates that the hydrology of the Anderson Creek watershed exhibit characteristics of an urbanized basin that contain extreme flow regimes.

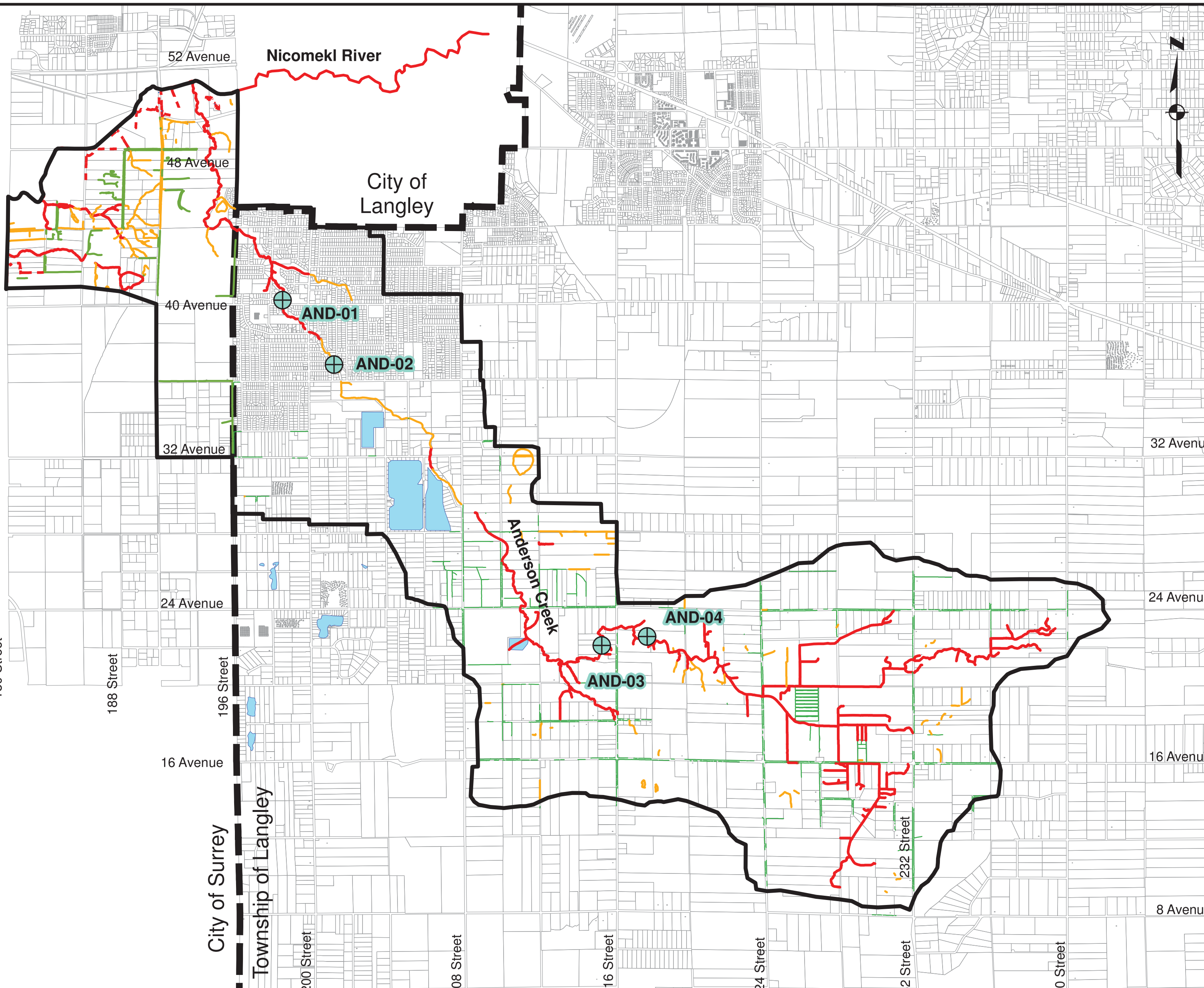
A portion of Anderson Creek was observed to be dry during the summer period. This area is located upstream and downstream of the groundwater fed manmade lakes in the central portion of the watershed. Historically this area is known to flood during the winter and heavy rainfall periods. Extreme flow regimes consisting of high peak wet weather to dry weather flow ratios, a flashy storm hydrograph and low summer base flows exist in the watershed. Flashy high flows can create issues in the watershed such as bank erosion and instability, increased sediment load in the stream and infilling. Low flows in the summer can contribute to higher water temperatures and lower dissolved oxygen levels in some reaches of the system, which can result in significant impediments to fisheries resources. Dry stream sections limit available stream habitat for fish, wildlife and invertebrate populations, which contributes to impacts to the overall health of the watershed.

A study completed for the Township of Langley in 1993 identified Environmentally Sensitive Areas (ESAs) for the region. ESAs are physical, biological and cultural features or processes that are of important value to the functioning of ecosystems. Twenty ESAs were identified as occurring in some portion of the Anderson Creek watershed. The lower portion of the Anderson Creek watershed, near the confluence to the Nicomekl River, has the greatest amount of ESAs in the watershed. Conservation areas, parks, green spaces and significant natural features are important to the environmental health of a region. These areas allow such benefits as providing fish and wildlife habitat, controlling urban runoff, filtering air and absorbing carbon dioxide. Stream Corridor Protection through maintenance of a vegetated riparian corridor is important in providing wildlife and fisheries habitat, reducing flooding risk and erosion and providing defence from non-point source pollution entering the stream. A portion of these benefits may be lost when buffers are fragmented into breaks or intrusions into the corridor. Development and fragmentation of the ESAs in the Anderson Creek watershed could have implications to the overall environmental health of the watershed.

1.6.7 Environmental Key Issues

From the environmental perspective, key issues for the Anderson Creek watershed include:

- Anderson Creek is classified as Class A (with sections of Class AO) high value for fish habitat and protection of the watercourse to support fish habitat and fish migration is a critical objective of the ISMP;
- There are a number of species identified in Anderson Creek that were rated as having an endangered status as part of the Lower Fraser Valley Streams Strategic Review (1999). As human activities and development continue within the watershed, long-term environmental mitigation measures must be in place to protect these species;
- Environmental issues that are occurring or may occur in the watershed include increased agriculture activity, urbanization, poor water quality, riparian removal, increased groundwater extraction, channelization/dyking and increasing impermeable surface area;
- As development occurs within the Anderson Creek watershed, the green spaces and corridors should remain intact and fragmentation of ESAs be restricted unless compensation measures are provided. The Brookswood/Fernridge community contains significant coniferous forest (approximately 38% of entire Township) that needs to be protected as primary habitat areas and within wildlife corridors; and
- Monitoring for water quality and benthic invertebrates indicates some areas of potential concern although insufficient testing was done for conclusive findings. Testing should be continued to ensure current conditions are maintained (or ideally improve) and further degradation does not occur.
- Overall the watershed health can be generally rated as fair given the presence of fish species such as salmonids and benthic macroinvertibrates (or taxa), good water quality, abundant riparian habitat in certain reaches as well as forest cover.



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

Water Quality and B-IBI Sampling Sites

Langley Watercourse Classification

Fish Bearing Class 'A'

Class 'A'	*Inhabited year round or has the potential for year round fish presence upon reasonable means of access enhancements.*
Class 'A(OD)'	*Watercourses with intermittent water supply. May dry up in summer months, inhabited by (or potentially inhabited by) fish during over-wintering period when base flows are re-established. (OD = Overwintering habitat, Dries up)*
Class 'A(OW)'	*Watercourses with fish presence year round. Utilized primarily by salmonids during the overwintering period. In general, summer usage is restricted by high temperatures and/or low dissolved oxygen levels. Non-salmonid species are generally present year round. (OW = Overwintering habitat, Wet all year)*

Non - Fish Bearing - Classes 'B & C'

Class 'B'	*Significant source of food, nutrient or cool water supplies to downstream fish populations. These watercourses have no documented fish presence or reasonable potential for fish presence.*
Class 'C'	*Insignificant food/nutrient value. No documented fish presence and no reasonable potential for fish presence. These watercourses dry up soon after rainfall.*
'Unclassified'	*Watercourses for which no detailed information exists*

Surrey Watercourse Classification

Class 'A'	Supports fish populations year round or have the potential to support fish populations year round
Class 'AO'	Supports fish populations generally only during winter months
Class 'B'	Do not support fish populations, provide food and nutrients to downstream fish habitats
Class 'C'	Do not support fish populations and generally only convey flows
'UN'	Unknown classification

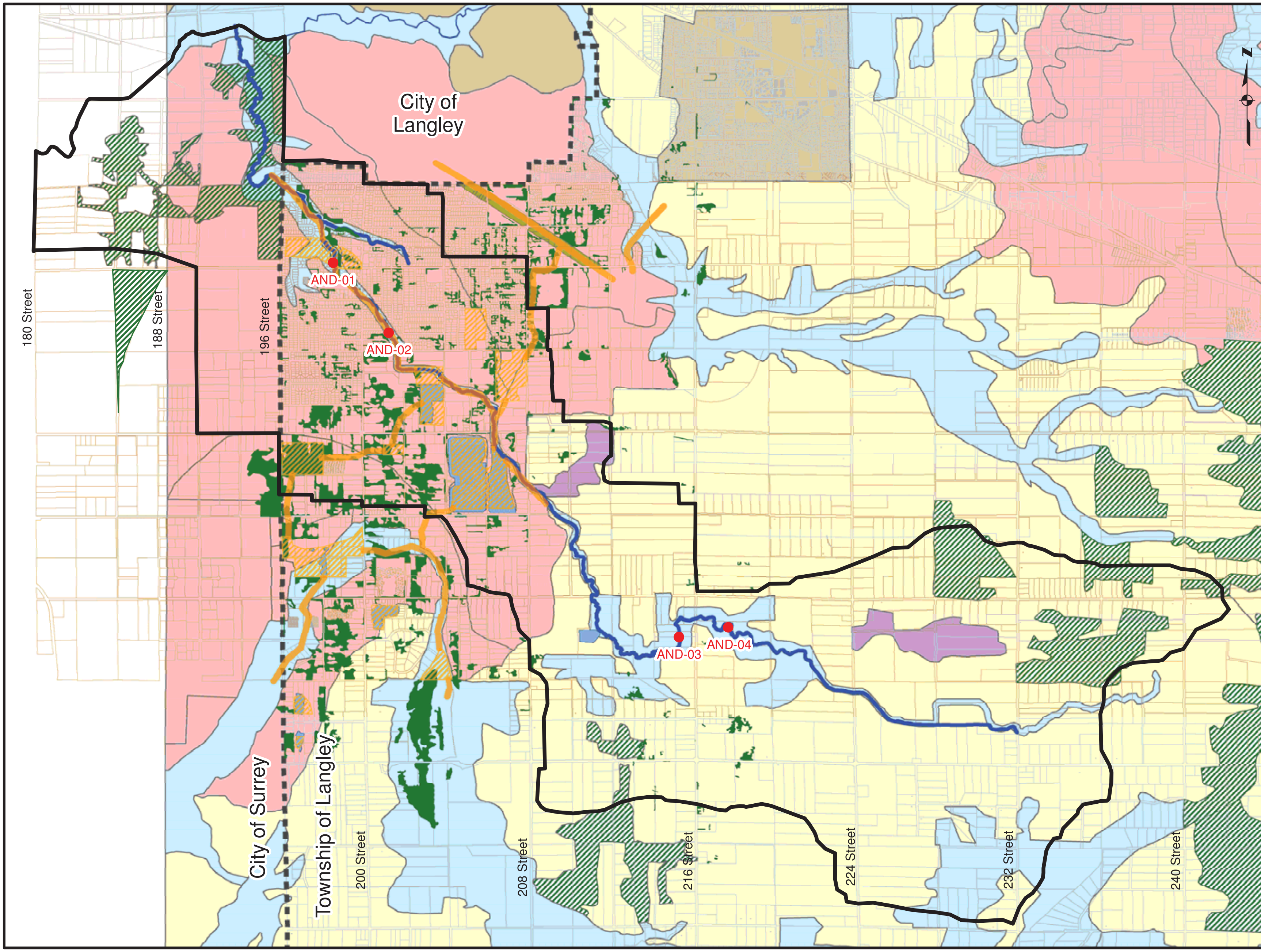
AECOM

0 500 1,000 2,000 Meters

Project No.	Date
60267316	October 2013

Watercourse Classification Map & Sample Locations

Figure 1.6.1



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Water Quality & B-IBI Sample Sites
- Study Area
- Anderson Creek
- Municipal Boundary

Environmentally Sensitive Areas

- forest
- wetland
- aquifer
- watercourse
- agriculture
- urban
- Conservation Areas
- Hydro ROW
- Wild Life Corridors
- Wildlife Patch

AECOM

0 375 750 1,500 Meters

Project No.	Date
60267316	October 2013

Environmentally Sensitive Areas & Sample Sites

Figure 1.6.2

2 Planning For the Desired Outcome

The Phase 1 consultation, open houses, policy guidelines and findings are used to define the objective for Stage 2 of the ISMP process is to determine the Ultimate Vision for the watershed over short, medium, and long-term horizons based on the findings from Stage 1. The Ultimate Vision must be a unified view of Township and City departments (Planning, Engineering, Environment, Transportation, etc.), as well as stakeholders and residents, in order to be long-standing and achievable. To help achieve this objective, a workshop was held with Township of Langley and City of Surrey to gain further insight on information collected during Stage 1, discuss how to guide low impact future developments in watershed, and complete a visioning exercise.

2.1 Summary of Langley/Surrey Workshop

The internal workshop with Township of Langley and City of Surrey staff was held on Oct.19, 2013. During the workshop the following items were discussed and have been incorporated into this ISMP where applicable.

- Current drainage systems in the area were discussed and Operations staff noted that in the Cedar Ridge area (near 208 Street and 44 Avenue) northwest of Anderson Creek watershed there is a perforated pipe sewer system that was constructed in the 1990s along 208 Street which terminates at a drywell manhole near the 4300 Block. The Township has no reported flooding complaints and there is no formal outlet pipe such that the system depends on exfiltration alone to favourable ground. This type of system is common in Brookswood and Fernridge and should be a part of the future drainage system as development occurs.
- Operations staff noted there are ongoing maintenance issues such as clogged drywells and rock pits that result in drainage problems (e.g. localized flooding, channel erosion) in the area. Designs for new development in the study area need to minimize transport of sediment and organic matter to these facilities to alleviate the risk of increased runoff. In addition, it was noted that Operations staff are already seeing problems with newly constructed rain gardens and on-lot systems (specifically for small lot developments) as residents are filling in the swales and not maintaining the rain gardens.
- This was reiterated by City of Surrey staff who have experienced similar problems and recommend that BMPs specifically for single family lot systems should be underground or require little to no maintenance. One solution that was discussed is the introduction of an annual charge to residents for the cost of maintenance, particularly for rain gardens, to allow a consistent maintenance program to be set up.
- There are known flooding problems in the vicinity of 208 Street and 210 Street along the main stem of Anderson Creek that are related to runoff from upstream catchment areas in the agricultural lands and downstream channel restrictions. During the workshop it was noted that the ISMP should also review stormwater management requirements in the ALR. One example for this is to consider the use of detention ponds to detain excess runoff from greenhouses and other large areas of

impervious surface and review building permit requirements for this.

- There was also mention of investigating how many farmers in the area participate in the Environmental Farm Plan (EFP) program initiated by the BC Agriculture Council and are using the funds for stormwater quality and quantity control measures. The EFP is a cost sharing program that encourages farmers to improve their lands in an environmentally sustainable manner through Beneficial Management Practices. There are several categories that are applicable to stormwater and groundwater management including farm runoff and stormwater control, water well management (i.e. protecting well heads or capping old wells), riparian area management, and erosion control. The projects specifically for stormwater include installation of detention ponds, diversions, and constructed wetlands.
- The need for private owners to take responsibility for maintaining watercourses on their property was discussed. Much of the Creek flows through private property and owners need to be aware that slope stabilization and erosion control is their responsibility, and requires approvals from provincial and federal agencies.
- A draft BMP options chart was presented (final version included in **Section 3**) and it was noted by Operations staff that porous asphalt is favourable but restoration and patching of the asphalt is costly as suppliers do not have the material readily available.
- Tree protection was also discussed and it was noted that trees are to be kept and protected within the study area where possible. Planning staff referenced the *Subdivision Development Bylaw Schedule I* which essentially allows for trees to be cut until a development permit is obtained. Engineering staff also noted that some residents are cutting down trees at the top of the creek/ravine banks resulting in slope instability issues. It is noted that the Township's Streamside Protection Bylaw does not apply on lands developed under streamside legislation (e.g. Streamside Protection Regulation, Fisheries Act) in place prior to adoption of the bylaw in 2006. Those land uses can continue in compliance with the streamside legislation under which they were established, but new development where a Township permit is required (e.g. building permit, subdivision, rezoning, development permit) must comply with the bylaw.

2.2 Vision for Watershed & ISMP Goals

During the internal workshop with Township of Langley and City of Surrey staff, an over-arching mission statement for the Anderson Creek ISMP was developed:

"Maintain and improve the health of the Creek as well as protect and enhance the current natural resources in the watershed."

This statement will be carried forward throughout the implementation, monitoring and adaptive management plan components of the ISMP. To further elaborate on the mission statement, eight goals were established that support the unified vision and protect, as well as improve, the overall health of the Creek and surrounding natural resources.

2.2.1 Goal 1: Protect and enhance the health and natural resources of the watershed

***Goal 1 Description*:**

Although it is not in a greenfield condition, Anderson Creek watershed is considered to be relatively undeveloped with the presence of large rural lots and farmland. Infrastructure is limited within the study area since a majority of lands rely on infiltration for stormwater management, aquifers as a source of water supply and septic systems for sanitary disposal.

As development continues there must be a conscious effort to minimize the negative impacts to groundwater, streams, and environmental areas that contribute a significant amount of value to Anderson Creek's health.

Goal 1 Opportunities/Constraints:

Environmentally valuable areas such as contiguous forests, streams, wetlands and wildlife hubs all play a critical part in determining the health of the watershed. Because of this, there is opportunity for the Township to get ahead of development and integrate development around these valuable areas. Understanding that there are current issues such as erosion and localized flooding that are occurring, it is equally important to have a plan in place that strives not to exacerbate existing problematic conditions.

Furthermore, residents within the study area heavily rely on groundwater supply for potable water. Careful consideration of development in well capture zones must be made so there are no negative impacts to this precious natural resource now and in the future.

2.2.2 Goal 2: Promote participation from stakeholders for a common vision for the watershed

Goal 2 Description:

An ISMP strives to incorporate a number of key disciplines to achieve a cohesive vision for the watershed. A fundamental objective for this ISMP is to bring together various municipal departments and stakeholders to discuss how growth and development should be managed while supporting the needs of each specific group.

Through the ISMP process, workshops and open houses have been held with residents, stakeholders, and Township of Langley and City of Surrey staff to promote unification of the long-term vision for the Anderson Creek watershed. It is imperative that communication and information be shared amongst municipalities and the public on the health status of the watershed.

Goal 2 Opportunities/Constraints:

Major issues and concerns that were expressed from stakeholders include erosion in Anderson ravine and slope stability concerns, runoff from ALR lands causing localized flooding in vicinity of 24/32 Avenue and 208/212 Street, aquifer recharge and water quality protection, and habitat protection and enhancement for fish/wildlife and trees.

Policies and infrastructure improvements detailed in this ISMP are designed to mitigate the pre-existing issues and concerns where feasible while maintaining the desire to grow and develop the community.

2.2.3 Goal 3: Minimize risk of life and property damage due to flooding and provide strategies to attenuate peak flows

Goal 3 Description:

Localized flooding, poor water conveyance, and creek erosion are known to occur in certain locations within the watershed. Although some of these issues may have existed before urban/rural development occurred, it is important that the issues are identified again now. Recommendations from this ISMP may not completely solve these chronic drainage problems but efforts can be made to try and rectify them.

Goal 3 Opportunities/Constraints:

Results from the hydraulic drainage model confirmed anecdotal information that Anderson Creek overtops the creek bank causing localized flooding between 208 Street and 212 Street. This is in part due to uncontrolled runoff coming from upstream agricultural lands (ALR) and downstream channel restrictions. Drainage guidelines for the ALR are not the same as urban areas that must follow the Township's Subdivision Development Bylaw. In such case, changes or alterations to the way drainage is managed in the ALR would involve provincial regulatory bodies beyond the Township or City's jurisdiction.

For downstream portions of the study area that are planned for future development, specific drainage facilities such as stormwater detention ponds, on-lot BMP treatments, and criteria to help attenuate peak flows and minimize potential flooding need to be implemented.

2.2.4 Goal 4: Prepare an inventory of watercourses, wildlife, and benthos for the watershed

Goal 4 Description:

An inventory for wildlife hubs and corridors, environmentally valuable areas, watercourses and fisheries will provide the Township with a baseline for comparison with future inventories as part of a long-term monitoring and assessment strategy.

Goal 4 Opportunities/Constraints:

An up-to-date inventory of sensitive species, valuable areas, and stream health is necessary in identifying opportunities for ecological rehabilitation or possible environmental enhancement within the watershed.

As part of the ISMP, water quality and B-IBI sampling was performed at three locations along the main stem of Anderson Creek (as discussed in **Section 1.6**). This provides the Township with a snap-shot of the current conditions for Anderson Creek and will help future monitoring efforts to perform a comparison of how the creek reacts to continued development. When interpreting B-IBI data, there must also be an assessment of the entire health of the stream and the overall composition of various invertebrates present. There is a need to look beyond the monitored B-IBI counts in determining the status of stream health.

For example, looking at the change in B-IBI scoring from one year to the next may only be representative of short-term effects that the stream is experiencing. It will be necessary to look at the historical nature of that stream and compare it to other streams within the watershed to obtain an accurate understanding of Anderson Creek's health condition.   Furthermore, the B-IBI assessment protocols need to be consistent from year to year and between municipalities.

2.2.5 Goal 5: Prevent pollution and maintain/improve water quality of surface flow and groundwater

Goal 5 Description:

This goal specifically aims to protect the quality and quantity of surface water that infiltrates into the ground (for recharge of the unconfined Brookswood Aquifer) or enters Anderson Creek as runoff or seepage. This is particularly critical given the large portion of the population in the watershed that relies on groundwater supply for potable water as well as a valuable environmental resource.

Goal 5 Opportunities/Constraints:

This ISMP provides a unique opportunity to get ahead of development and strategize where certain infrastructure and land forms should be placed so as to minimize any potential groundwater contamination (quality) as well as balancing infiltration rates that re-charge groundwater supply (quantity). Outlining criteria for strategically locating new development such that municipal water supply well capture zones are protected is part of what this goal is to achieve.

Existing agricultural land uses and runoff can have major impacts on surface water quality but the Township has little or no jurisdiction over agriculture and farming practices.

2.2.6 Goal 6: Identify current and future agricultural, residential, commercial, and recreational land uses

Goal 6 Description:

The current land uses and wealth of natural resources of the watershed are such that it is a highly sought after area by local residents and potential developers. As such, it is important to understand where various types of development and land forms are proposed to properly implement strategies to maintain watershed health.

Goal 6 Opportunities/Constraints:

High density or commercial areas possess opportunities for implementation of specific best management practices (BMPs) that may not necessarily be applicable for residential lots. Based on past experience and from discussions with Township and City staff, the implementation and enforcement of on-lot BMPs for single family residential lots is a challenge. It is critical that areas where drastic changes in density and land use are to occur are known in order to create an applicable implementation plan.

Also, due to the large amount of farmland located within the Anderson Creek watershed, it is critical that ALR boundaries be respected and buffer areas established.

Depending on topography, these buffer areas may provide opportunities for stormwater management facilities.

2.2.7 Goal 7: Develop a cost effective and enforceable implementation plan

Goal 7 Description:

The implementation plan supports the unified vision for the watershed and includes a number of action items that are cost effective and enforceable. The plan will be established based on a time scale that enables the Township to reasonably achieve the action items.

Action items can range from internal processes, departmental responsibilities, to the construction of mandatory stormwater infrastructure and BMPs. The implementation plan will also provide detail for a Capital Works Program for the Township to identify necessary upgrades to the existing drainage system.

Goal 7 Opportunities/Constraints:

Currently, there are only a few piped drainage systems within the watershed and the majority of developed areas manage runoff using rock pits, infiltration trenches or open-channel swales/ditches. In such case, there are opportunities to establish a formal drainage network that incorporates new infrastructure to provide an enhanced level of service as development occurs.

As mentioned in Goal 6, there are challenges associated with BMPs, primarily in single family developments. Township operations staff has noted that in some cases residents do not maintain the BMPs or alter them such that they are no longer effective. There is a need for enforcement of proper BMP maintenance by private residents or a mechanism for funding to enable Township staff to complete the required maintenance.

2.2.8 Goal 8: Establish a monitoring and assessment strategy to ensure goals are achieved, maintained, and enforced

Goal 8 Description:

For an ISMP to be long-standing, it must constantly adapt to change. This is important in order for the implementation plan to remain current and focused on its objectives. A monitoring and assessment strategy will help evaluate the progress of the implementation plan and determine where course-correction is needed. Key performance indicators (KPIs) can be established so as to quantitatively monitor how the overall health of the watershed is doing a development continues.

Goal 8 Opportunities/Constraints:

There are several methods for monitoring the overall health of the watershed. The hydrometric station installed at Anderson Creek at 200 Street (near 38 Avenue) is used to monitor water levels and estimate flow in the Creek and future data recorded at this station can be used to evaluate changes in the flow regime. A water quality and benthic invertebrate sampling program will also be recommended for comparison with baseline data.

Maintaining open communication with residents surrounding Sunrise and Rees Lakes to monitor water levels in the lakes is also recommended as development occurs in these catchment areas.

Monitoring of surface runoff and infiltration rates from individual developments is a challenge that needs to be incorporated into the overall strategy.

2.3 Potential Impacts & Protective Measures

Metro Vancouver's 2011 Regional Growth Strategy states that the Township of Langley is expected to double in population by 2041. This increase in growth is due largely to the availability of developable land and proximity to major highways that connect to surrounding major communities and amenities. Furthermore, parts of the Anderson Creek watershed area are within the Brookswood / Fernridge Community Plan area which includes significant potential for development and consequently increased impervious areas. This will result in increased stormwater surface runoff causing higher peak flow rates and larger runoff volumes that need to be managed. As impervious cover increases, groundwater re-charge rates and baseflows to creeks need to be maintained along with the quality of water being infiltrated for protection of the municipal water supply well capture zones and sensitive creek habitat areas.

ALR lands upstream of the urban development areas are unlikely to significantly change, although there is potential for alteration of crop types or farming activities such as increased construction of greenhouses (higher imperviousness) or high water use crops such as cranberries (groundwater impacts).

Downstream areas of the watershed in the City of Surrey will be impacted by development in the Campbell Heights area and any changes in the ALR to the north. Overall, both municipalities need to ensure that there is no net increase in peak flows into the Nicomekl River as a result of future development.

2.3.1 Environmental Areas to Be Protected

The Anderson Creek watershed possesses several environmental areas that must be protected for fish and wildlife habitat as discussed in **Section 1.6**. This includes riparian areas along the creek and its tributaries which are to be protected as future development occurs based on the Streamside Protection Bylaw and Provincial and Federal policies for the protection of fish and fish habitat.
Areas designated as having significant environmental sensitivity such as forests, streamside vegetation, wildlife corridors, wetlands, and natural areas are show in **Figure 1.6.2**. Specific to Anderson Creek the following shall apply:

- The banks of Anderson Creek, including the banks of the larger ravine, shall be preserved as conservation areas. Subject to conformance with Township and Provincial requirements, roads, walkways, parks, public utilities, agriculture, rural and associated uses may be located adjacent to conservation areas.
- The Streamside Protection Bylaw requires development setbacks ranging between 15 to 30 metres from a watercourse or top-of-bank of a ravine. The bylaw allows for consideration of setback variances where unique site conditions exist and the development will not have negative impacts on the streamside areas.

The health of the Anderson Creek watershed is measured in part by the integrity of its ecosystem in the midst of urban development. Therefore, long-term planning must be in place for not only accommodation of growth but also protection of forested areas and streams as habitat for sensitive fish and wildlife species. The community and neighbourhood planning studies need to consider protecting the wild life corridors on **Figure 1.6.2**.

2.3.2 Aquifer Protection

It is important that the ISMP supports the Township's Water Management Plan (WMP) that is currently in place to ensure safe and sustainable groundwater is available for future generations. The primary concerns for the water supply system are water quality protection and maintaining water levels in the aquifers. Consequently, maintaining and improving the quality of surface water infiltrated for aquifer recharge is a high priority as well as continuing to implement low flow technologies and water restrictions that are already in place across the Township.

Strategies to help recharge groundwater supplies would be to promote clean stormwater runoff entering the ground. First line measures for this may be to require new land development not adversely impact groundwater quantity and quality through proper construction of BMPs and limiting the amount of impervious surfaces. As well, locations of known point sources of pollution (e.g. gas stations) must be required to treat or dispose of their contaminated stormwater runoff away from groundwater supply and creeks. Stormwater runoff from land uses known to generate contaminants such as parking lots or major arterial roads shall be conveyed to oil/water separation devices and bioswales prior to discharge to ground or detention ponds.

There is also increasing evidence of elevated nitrate levels in groundwater due to septic systems and agricultural activities which is a concern and must be mitigated. As development occurs, no new septic systems should be installed as developers should be required to connect sanitary sewers to the Township's sewage collection system. For ALR areas, there are stormwater and source control Best Management Practices established by the Ministry of Agriculture that farmers should follow to ensure any activities that can potentially contaminate groundwater, such as nutrient management and storage, are mitigated.

These practices must be managed properly to meet Federal and Provincial guidelines for surface and groundwater quality and protection. In addition, the size of new water supply service connections could be limited to 75mm diameter for rural residential lots which will assist in restricting misuse of domestic water supply for irrigation purposes. Other methods of reducing negative impacts to groundwater include public outreach programs that aim to educate and inform residents of the importance in protecting their aquifer and encourage water conservation practices.

2.3.3 Tree Protection

The Anderson Creek watershed possesses a large number of existing trees and green spaces and, as such, it is paramount that these valuable resources be protected. Within the Township of Langley, significant trees are defined in Schedule I of the Township's Subdivision and Development Servicing Bylaw and are further described as follows:

- All trees with a trunk diameter equal to or greater than 30 cm (12 inches) measured 1.4 meters above the highest point of the natural grade of the ground measured from the base of the tree.
- The following trees over 3.0 m/10' height: Arbutus, Garry Oak, Pacific Yew, all Pine, Western Red Cedar, Douglas Fir and Grand Fir, Pacific Dogwood; Redwood and Sequoia, Maidenhair and Monkey Puzzle or other non-native trees.
- All heritage trees designated by Council or identified in the Langley Heritage Listing.
- Alders, Birch, Big Leaf Maple and Hemlock over 3.0 m/10' height in designated greenways.

The *Subdivision and Development Servicing Bylaw* includes several requirements with regards to tree protection, retention and overall tree management plans for new development sites. Although the bylaw is comprehensive with regards to tree protection during the subdivision application process, it does not protect trees in the area from pre- development cutting.

In order to preserve the existing tree cover in the Anderson Creek watershed, it is recommended that a full tree bylaw or other means of protection be introduced.

Recommended policies to support tree retention include:

- Provide incentives, such as on-site density transfers, to strategically locate future development projects to encourage protection and retention of significant stands of trees;
- Implement boulevard tree planting and greenway corridors to promote the retention/incorporation of mature trees, particularly along 200 Street, ALR landscaping buffers along 208 Street, and ensuring development of new parks promotes the retention and integration of mature and significant trees, where possible; and
- Consideration of a stand-alone Tree Protection Bylaw or other means to increase the protection for trees within Brookswood/Fernridge.

2.3.4 Erosion Protection

Erosion of creeks is mitigated by maintaining riparian ground cover, increasing vegetation and root structures, controlling peak flows, and reducing stormwater volume. Tree protection and riparian area setbacks must be maintained as development occurs and overall land imperviousness changes.

Based on the Community Plan future land use information, there are few significant changes to lands adjacent to Anderson Creek such that the riparian areas shall be maintained as they are now. The proposed stormwater management system includes extensive use of BMPs for infiltration and aquifer recharge so pre-development runoff rates will be maintained or reduced. Discharge rates from the major storm system (i.e. detention ponds) will be controlled to pre-development flow rates (2, 5 and 100-year) so peak flows and velocities in Anderson Creek will mimic greenfield conditions. Baseflows and seepage rates should also remain as per current conditions.

Erosion protection measures for specific problem areas that are already identified and recommended in the exp Services *Anderson Creek Geotechnical Review* 2012 report should continue to be undertaken as funds become available.

2.4 Drainage System Requirements for Future Land Use

For the future system capacity assessment, the draft Brookswood/Fernridge Community Plan land use was applied along with the Township and City OCP future land use information (as per **Figure 1.3.2**). The Campbell Heights Land Use Plan was also reviewed for the portions of Anderson Creek and the Unwin Catchment within the City of Surrey. It was assumed that there will be no changes to land use in the ALR areas in both the Township and Surrey.

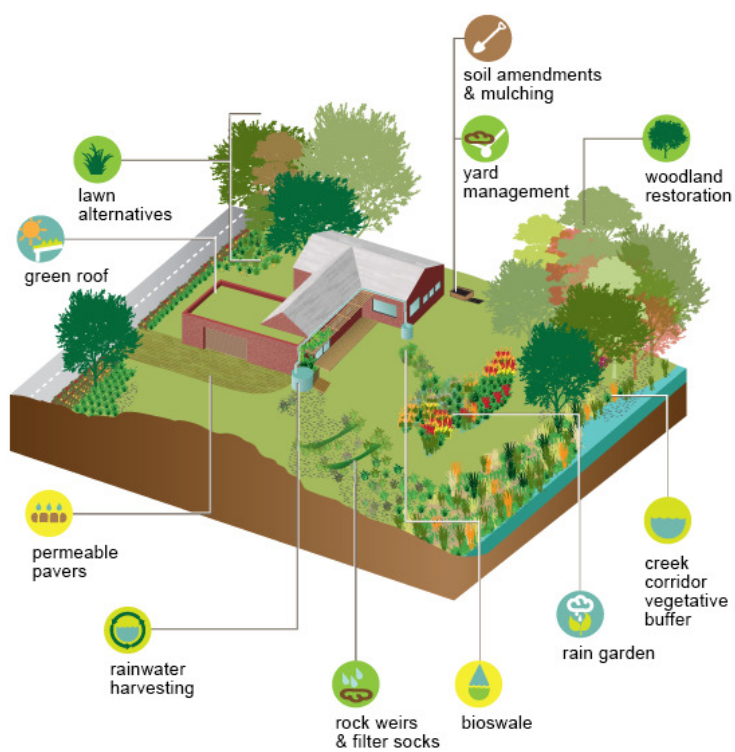
2.4.1 Proposed Stormwater BMPs

Stormwater Best Management Practices are strategies that promote and replicate natural hydrological processes to manage stormwater quantity and quality as urban development occurs. There are several BMPs that are already extensively used in the study area, particularly in the urban developed areas of Brookswood, including rock pits, infiltration trenches and swales as discussed in previous sections of this ISMP.

Stormwater BMPs are designed to manage rain where it falls and most are multi-functional in providing water quality treatment, base flow recharge, attenuating peak flows and providing interim storage capacity. Stormwater BMPs focus on three criteria that are critical to managing urban stormwater runoff:

- **Peak Discharge**: Reduce the maximum flow by slowing down runoff velocity and lengthening the duration of discharge;
- **Volume**: Reduce or delay the volume of stormwater that enters the drainage system; and,
- **Water Quality**: Improve water quality through volume reduction, filtering, and biological and chemical processes. Water quality measures can be simplified into either source reduction (reduce potential for pollution to contaminate stormwater) or treatment (pollution has already contaminated stormwater).

To evaluate the impact of various BMPs, it is important to understand the difference between total impervious area (TIA) and effective impervious area (EIA). TIA is the total amount of hard surfaces within an area that does not allow water to permeate into the soil. Impervious areas include rooftops, streets, sidewalks, and parking lot areas that are conventionally paved. EIA is the proportion of TIA which actually contributes runoff to downstream systems. If for example 25% of the water that runs off the pavement is conveyed to groundwater the EIA would be equivalent to 75% of the TIA. As such, directing stormwater runoff towards BMPs or pervious areas will help in reducing EIA and reducing the impact to downstream streams and watercourses.



BMP selection involves many factors such as physical site characteristics, treatment objectives, aesthetics, safety, maintenance requirements, and cost. Typically, there is not a single answer to the question of which BMP (or BMPs) should be selected for a site. There are usually multiple solutions ranging from stand-alone BMPs to treatment trains that combine multiple BMPs in order to achieve the objectives.

Sustainability of BMPs is based on a variety of considerations related to how the BMP will perform over time. For example, vegetation choices for BMPs determine the extent of supplemental irrigation required. Choosing native or drought-tolerant plants and seed mixes helps to minimize irrigation requirements following plant establishment. Other sustainability considerations include watershed conditions. In the area proposed for urban development, the Anderson Creek watershed contains an unconfined aquifer in which residents depend upon for water supply. Therefore, a balance between promoting stormwater infiltration to recharge groundwater while protecting the aquifer from possible contamination is critical for this area.

A number of stormwater BMPs are proposed for implementation where development is planned in the study area. These BMPs were identified based on their familiarity and function from previous applications within Township communities and surrounding municipalities. **Figure 2.4.1** illustrates locations within development areas of the watershed where specific BMPs are recommended.

2.4.2 BMP #1: Rain Gardens

Rain gardens are bio-retention systems used to capture and treat a volume of stormwater runoff. The bio-retention area is an excavated pit filled with planting soil or a sand/planting soil mix. Stormwater enters in the depression on top of the bio-retention area and percolates through the sand/soil later. Flows are then conveyed by an under-drain system connected to a storm sewer, open channel, or stream.

These BMPs work well within roadways that have parking bulges so that treatment can be provided to road runoff prior to out-letting into the storm system. They also work well in multi-family and commercial sites to treat parking lot and drive aisle runoff. However, Township and City experience with rain gardens in single family residential areas suggests they not be used unless maintenance is provided by Operations personnel, or a third party. That requires a dedicated source of funding, such as a user fee applied to properties fronting a rain garden.

Rain Garden Key Design Criteria Elements:

- Flexible in terms of size and infiltration.
- In-ground bio-retention systems.
- Ponding depths generally limited to 300mm or less for aesthetics, safety, and rapid draw down. Certain situations may allow deeper ponding depths.
- Deep rooted perennials and bushes encouraged.
- Native vegetation that is tolerant of hydrologic variability, salts and environmental stress.
- Modify soil with compost.
- Provide positive overflow.
- Maintenance is required to ensure long-term functionality.

Rain Garden Site and Design Considerations:

- Rain gardens are flexible in design and can vary in complexity according to water quality objectives and runoff volume requirements. It is important to note that bio-retention areas are not to be confused with wet ponds which permanently pond water. Bio-retention is best suited for areas with at least moderate infiltration rates (more than 2mm/hour). In extreme situations where permeability is less than 2mm/hour, special variants may apply, including under drains.
- Surface area is dependent upon storage volume requirements but should generally not exceed a maximum loading ratio of 5 sq.m. of impervious drainage area to 1 sq.m. of infiltration area
- Surface side slopes should be gradual. For most areas, maximum 3:1 side slopes are recommended, however where space is limited, 2:1 side slopes may be acceptable.
- Surface ponding depth should not exceed 150mm in most cases and should empty within 72 hours.
- Planting soil depth should generally be at least 450mm where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth may be increased, depending on plant species.
- Planting soil should be a loam soil capable of supporting a healthy vegetative cover. Soils should be amended with a composted organic material. A typical organic amended soil is combined with 20-30% organic material (compost), and 70-80% soil base (preferably topsoil). Planting soil should be approximately 4 inches deeper than the bottom of the largest root ball.
- Proper plant selection is essential for rain gardens to be effective. Typically, native plant species are best suited to the variable environmental conditions encountered.
- Locations on private property require agreements or covenants to ensure they are maintained and are not removed.

2.4.3 BMP #2: Vegetative Planters

A stormwater planter is a small, contained vegetated area that collects and treats stormwater using bio-retention. Bio-retention systems collect and filter stormwater through layers of mulch, soil and plant root systems, where pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed.

Treated stormwater is then infiltrated into the ground as groundwater (Infiltration Planter) or, if infiltration is not appropriate, discharged into a traditional stormwater drainage system (Flow-Through Planter). Stormwater planters do not require a large amount of space and can add aesthetic appeal and wildlife habitat to city streets, parking lots, and commercial and residential properties. Stormwater planters typically contain native, hydrophilic flowers, grasses, shrubs and trees.

Vegetative Planters Key Design Elements

- A form of bio-retention, but differ from rain gardens in that they are above ground systems.
- Reduces stormwater runoff volume, flow rate and controls atmospheric temperature in urban settings.
- Improves aesthetic appeal of streets.
- Provides shade to nearby buildings to reduce energy costs.

- Requires limited space.
- Flexible for use in areas of various shapes and sizes.
- Provides a cost-effective way of treating stormwater as the ratio of cost to volume of runoff treated is lower than many other stormwater best management practices.

Vegetative Planters Site and Design Considerations

- Stormwater planters are typically small scale structures and are not suitable for collection and treatment of stormwater from large impervious areas.
- Stormwater planters will need to be replaced roughly every 25 years.
- Stormwater planters should not be placed on steep slopes.
- Locations on private property require agreements or covenants to ensure they are maintained and are not removed.

2.4.4 BMP #3: Infiltration Swale

An infiltration swale is a shallow grassed channel normally constructed in linear spaces such as roads and adjacent to parking lots that can be used as a means of stormwater control and conveyance. Infiltration swales can reduce runoff velocities and provide some bio-treatment with proper vegetation and maintenance. They have been effectively used along local roads and add to the aesthetic value of a community. Typically, grass is used for the vegetation along with raised curbs and raised lawn basins for outlet control. These swales can ultimately connect to rain gardens in which more intense bio-treatment and stormwater storage can be provided.

Infiltration Swale Key Design Criteria Elements

- Swale planting is typically sodded lawn and can also include low-growing native vegetation that is water resistant and drought tolerant.
- Longitudinal slopes range from 1 to 6%.
- Side slopes range from 3:1 to 5:1.
- Bottom width of 0.6 to 1.2m. Top width between 0.8 to 2m.
- Convey the 5-year storm event with a minimum of 150mm of freeboard.
- Designed for non-erosive velocities up to the 5-year storm event.
- Design to aesthetically fit into the landscape, where possible.
- Significantly slow the rate of runoff conveyance compared to pipes.
- Refer to Township of Langley Subdivision and Development Servicing Bylaw 2011 No.4861, Drainage Supplementary Drawings, TLD 3 - Swale.

Infiltration Swale Site and Design Considerations

- Infiltration swales are sized to temporarily store and infiltrate the 6-month 24-hour storm event storm event, while providing conveyance for up to the 5-year storm with freeboard; flows for up to the 5-year storm are to be accommodated without causing erosion. Swales should maintain a maximum ponding depth of 450mm at the end point of the channel, with a 300mm average maintained throughout. Six inches of freeboard is recommended for the 5-year storm. Residence times between 5 and 9 minutes are acceptable for swales without check-dams. The maximum ponding time is 48 hours, though 24 hours is more desirable (minimum of 30 minutes). Studies have shown that the maximum amount of swale filtering occurs for water depths below 150mm. It is critical that swale vegetation not be submerged, as it could cause the vegetation to bend over with the flow. This would naturally lead to reduced roughness of the swale, higher flow velocities, and reduced contact filtering opportunities.

- Effectiveness of an infiltration swale is directly related to contributing land use, size of the drainage area, soil type, slope, drainage area imperviousness, proposed vegetation, and the swale dimensions. Use of natural low points in the topography may be suited for swale location, as are natural drainage courses although infiltration capability may also be reduced in these situations. The topography of a site should allow for the design of a swale with sufficiently mild slope and flow capacity. Swales are impractical in areas of extreme (very flat or steep) slopes. Swales are ideal along parking lot boundaries and adjacent to roads in gently sloping terrain.
- For the Anderson Creek watershed, it is recommended that infiltration swales located within boulevards drain into dry wells for the smaller, more frequent storm events. Larger storm events will be managed with an overflow system into the piped network.

2.4.5 BMP #4: Permeable Pavers

Permeable pavers are viable solutions to help reduce stormwater volume and peak flows on private property where conventional asphalt pavement is used. This type of BMP should be limited to low traffic areas such as parking lanes, driveways, and sidewalks to limit its exposure to heavy traffic loading. As such, permeable pavers are recommended to be used in walkways, parking lanes, and mews areas. They are also suitable for parking lots where the turnover averages 1 – 2 vehicles per day per stall.

<u>Permeable Pavers Key Design Elements</u>

- Almost entirely for peak rate control.
- Short duration storage.
- Minimize safety risks, potential property damage, and user inconvenience by limiting to local roads, walkways, and mews areas having lighter traffic loadings.
- Emergency overflows may be required.
- Maximum ponding depths should be assessed.
- Adequate surface slope to outlet.
- Infiltration testing is required.

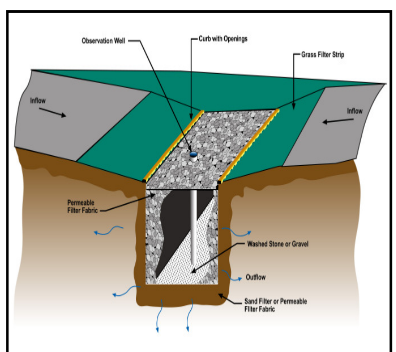
<u>Permeable Pavers Site and Design Considerations</u>

- The overall site should be evaluated for potential pervious pavement / infiltration areas early in the design process, as effective pervious pavement design requires consideration of grading.
- The bed bottom should not be compacted; however the stone sub-base should be placed in lifts and lightly rolled according to the specifications.

- During construction, the excavated bed may serve as a temporary sediment basin or trap. This will reduce overall site disturbance. The bed should be excavated to within 300mm of the final bed bottom elevation for use as a sediment trap or basin. Following construction and site stabilization, sediment should be removed and final grades established.
  - Bed bottoms should be level or nearly level. Sloping bed bottoms will lead to areas of ponding and reduced distribution.
  - All systems should be designed with an overflow system. Water within the subsurface stone bed should never rise to the level of the pavement surface.
  - While infiltration beds are typically sized to handle the increased volume from a storm, they should also be able to convey and mitigate the peak of the less-frequent, more intense storms (such as the 100-year event). Control in the beds is usually provided in the form of an outlet control structure. A modified inlet box with an internal weir and low-flow orifice is a common type of control structure. The specific design of these structures may vary, depending on factors such as rate and storage requirements, but it always should include positive overflow from the system.
  - Control of sediment is critical. Rigorous installation and maintenance of erosion and sediment control measures should be provided to prevent sediment deposition on the pavement surface or within the stone bed. Nonwoven geotextile may be folded over the edge of the pavement until the site is stabilized. The designer should consider the placement of pervious pavement to reduce the likelihood of sediment deposition. Sediment should be removed by a vacuum sweeper and should not be power-washed into the bed.
  - The underlying infiltration bed is typically 0.3 to 1.0m deep and comprised of clean, uniformly graded aggregate with approximately 40% void space. AASHTO No.3, which ranges 40-60mm in gradation, is often used. Depending on local aggregate availability, both larger and smaller size aggregate has been used. The critical requirements are that the aggregate be uniformly graded, clean washed, and contain a significant void content. The depth of the bed is a function of stormwater storage requirements, frost depth considerations, site grading, and anticipated loading. Infiltration beds are typically sized to mitigate the increased runoff volume from a 2-Year design storm.

2.4.6 BMP #5: Infiltration Trench

Infiltration trenches are typically used for on-site applications to control runoff from roof areas and other impervious surfaces. An infiltration trench allows stormwater runoff to be stored and soak into the ground and includes an outlet for discharging overflows to a storm sewer system at a controlled rate. The trenches are to be sized to suit the impervious area and infiltration rate.



INFILTRATION TRENCH

<u>Infiltration Trench Key Design Criteria Elements</u>

- Continuous perforated pipe set at a minimum slope within the stone trench.
- Limit depth to be between 1 to 2m deep.
- Trench to be wrapped in non-woven geotextile along the top, sides, and bottom.
- To be placed on un-compacted soils.
- Inspection chamber or observation well to be installed every 30m.
- Soil investigation and infiltration testing is required.

- Refer to Township of Langley Subdivision and Development Servicing Bylaw 2011 No.4861, Drainage Supplementary Drawings, TLD 12 (a), (b), (c) Infiltration facilities.

Infiltration Trench Site and Design Considerations

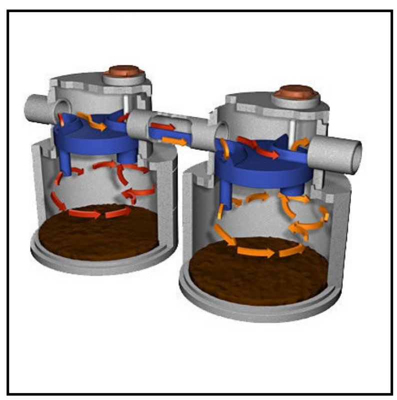
- It is desirable to maintain a 0.5m clearance above regularly occurring seasonally high water table. This reduces the likelihood that temporary groundwater mounding will affect the system, and allows sufficient distance of water movement through the soil to allow adequate pollutant removal.
- It is desired that soils underlying infiltration devices should have infiltration rates between 2 to 250 mm/hour, which in most development programs should result in reasonably sized infiltration systems. Where soil permeability is extremely low, infiltration may still be possible but the surface area required could be large, and other volume reduction methods may be warranted.
- Roadway runoff generates higher levels of suspended solids than most other urban land uses. Roadway runoff should not be discharged directly to infiltration systems without first reducing sediment loads. Infiltration BMPs are appropriate for roadway systems but must be designed in conjunction with a measure (structural or non-structural) that reduces the amount of sediment in roadway runoff prior to infiltration. There are a variety of options that will reduce sediment loads, including:
    - Vegetated systems such as grassed swales and bio-retention.
    - Structural elements such as catch basin inserts, filters, and manufactured treatment units.
    - Maintenance measures such as street sweeping and vacuuming.
    - Using some or all of these measures before discharging to an infiltration trench will minimize the accumulation of sediment that could lead to failure of an infiltration BMP. All measures for sediment reduction require regular maintenance.

2.4.7 BMP #6: Water Quality Treatment Devices

Water quality treatment devices help capture stormwater pollutants to treat urban runoff prior to discharge into infiltration devices or storm sewers. They are used in urban environments where space is limited and also may be retrofitted in existing storm systems. Water quality systems may be specified to target treatment of runoff for oils and hydrocarbons, and sand and sediment trapping.

These structures use gravity and flotation methods to remove sediments and oils and require regular maintenance to remove accumulated debris. Most devices are designed to provide a high level of total suspended solids removal for small frequent storm events that represent the majority of annual rainfall volume and pollutant load.

Water Quality Systems Key Design Criteria Elements



- Typically designed based on the total annual rainfall using historical rainfall data, total drainage area, and percent of impervious area. Small frequent storms account for a majority of annual rainfall and for a majority of the sediment loading.
- It is important to understand that storm sewers are typically designed to convey a specific flow generated by a design storm (i.e. 2, 5 and 10-Year storm events) which can be significantly higher than the annual (1-Year) event. Therefore, it is critical that these systems are integrated into the conventional storm sewer network or in combination

with other BMPs.

- Understanding the distribution of pollutant loading is important to incorporate into the sizing and design of water quality treatment devices. The devices must be able to capture pollutants present in the "first flush" rain event after a long dry spell that can be estimated using pollutant build-up/wash-off calculations.
- Devices must also provide a means for by-passing high flows without releasing or disturbing collected pollutants.

Water Quality Systems Site and Design Considerations

Water quality systems can be applied in a variety of development site situations. Because of their ability to fit within existing storm sewer networks or in-line with other BMPs, they can be installed in locations where the available land area is limited. Examples of sites in which these systems would be considered in are:

- Storm water quality retrofits for existing developments.
- Commercial parking lots.
- Automobile service stations.
- Airports and military installations.
- Vehicle loading and unloading areas.
- Areas susceptible to spills of material lighter than water (bus depots, transfer stations, etc.).
- New residential developments, re-development in the urban core.
- Pre-treatment (as part of a treatment train).

These systems are designed to accommodate the smaller, more frequent flows. These frequent flows are the most important since all storm water events contribute pollution. The frequency of the magnitude of a flow rate is dependent on the upstream drainage area and the level of imperviousness of that drainage area. If the drainage area is too large, the water quality system will be by-passed more frequently.

2.4.8 BMP #7: Detention Ponds

A detention pond is an earthen structure constructed either by a natural depression or excavation to provide temporary storage of runoff and functions hydraulically to attenuate stormwater peak flows. The pond outlet structure must be designed to control runoff to specified rates, which in the Township of Langley are the 2, 5, and 100 year pre-development flow rates. Some volume reduction may also be achieved through initial saturation into the soil and through evaporation.

Detention Pond Key Design Criteria Elements

- Size of storage and outlet structure is to be designed according to municipal design objectives to control downstream flooding, stream bank erosion, and allow for adequate freeboard.
- For water quality purposes, the pond should be designed to allow for 20% dead storage volume for sediment accumulation.
- Emergency overflows should be incorporated into the design to manage larger storm events.

- Provide trash rack, hood or other protection to prevent clogging of outlet with trash and debris.
- Vegetation should be grass or other native species.

Detention Pond Site and Design Considerations

- Detention ponds are land intensive and therefore are not suitable within ultra-urban areas.
- Suitable for residential and institutional areas, can be fitted into existing parks or open spaces.
- Not suitable for areas that contain well capture zones.
- Can be an aesthetic and recreational feature with proper plantings and surrounding trails.

2.4.9 BMP #8: Drywells or Soakaway Manholes and Rock Pits

A dry well is a subsurface storage facility that receives and temporarily stores stormwater runoff, then ultimately discharges stored runoff into the surrounding soils via infiltration. A dry well may be either a structural chamber or an excavated pit filled with aggregate. Dry wells aid to reduce the total stormwater runoff volume that would normally discharge directly into larger downstream stormwater management facilities such as a detention pond or directly to streams.

A rock pit is a subsurface rock-filled structure or dug-out pit for temporary storage of stormwater prior to infiltrating into the ground. Stormwater is channelled into the rock pit where it percolates into the ground and the rate in which it infiltrates is dependent on the soil type. These pits, sometimes called French drains, hold the water while it soaks away into the ground where it can become part of the groundwater.

Drywell and Rock Pit Key Design Criteria Elements

- Basic design requirements for a drywells and rock pits include storage volume and infiltration rate of the subgrade soils.
- Infiltrate rate of subgrade soils must be sufficient to drain the stored runoff within 72 hours and the surrounding soils must not be compacted
- Drywells require an adequately sized overflow outlet for large storm events, while rock pits should be designed to be sufficiently large enough to avoid flooding and overflow.
- At least one observation well is required for a drywell.
- Excavation of the rock pit hole or bottom of rock pit structure should be above at least 0.3m above the seasonal high water table or bedrock.
- Refer to Township of Langley *Subdivision and Development Servicing Bylaw 2011 No.4861*, Drainage Supplementary Drawings TLD 6 Rock Pit and TLD 7 Drainage Drywell.

Drywell and Rock Pit Site and Design Considerations

- Applicable only in locations where subgrade soils have medium to high infiltration rates.
- Drywells and rock pits are not suited for areas where high pollutant loading is anticipated due to potential groundwater contamination, or for areas where high sediment loads are expected during or after development.

- Specifically, drywells and rock pits should not be used in industrial or commercial areas where solvents or petroleum products are loaded, transported, stored, or applied.
- Drywells and rock pits should not be used in residential areas that would create a significant risk for basement seepage or flooding, or interfere with the operation of subsurface sewage disposal systems.
- For the Anderson Creek watershed, it is recommended that infiltration swales located within boulevards drain into dry wells for the smaller, more frequent storm events. Larger storm events will be managed with an overflow system into the piped network.
- Drywells and rock pits should not be placed within well capture zones because of the potential for groundwater contamination.

2.4.10 Storm Sewers & Detention Ponds

Soil conditions for most areas that are planned for development are known to be amenable to infiltration and the rates are assumed to be high enough to manage the 2-year event on site at the very least. In the Township's OCP, there is a requirement for developments to match current infiltration rates and in many areas of Brookswood at present there is little or no runoff during significant rain events. In such case, a rainfall depth of 64mm, representing the 2-year 24-hour rainfall depth at the Surrey Kwantlen gauge, was removed from the 5-year and 100-year design storm events for the analysis of the minor storm sewer and major detention pond systems.

This may be a conservative assumption given that developed areas in Brookswood and Cedar Ridge have drainage systems that function solely on infiltration (or exfiltration from perforated pipes and manholes) for the 5-year storm event. In addition, the drainage system for the proposed industrial area of Campbell Heights to the west of Brookswood in the City of Surrey's portion of the Anderson Creek and Unwin catchment areas will be designed as an exfiltration system for the 5-year event. However, the 2-year event was selected as there are areas where the water table is elevated and potential pockets of soils with lower infiltration rates may exist such that the redundancy and backup of an overflow storm sewer system with storage is required.

To account for the increased catchment area contributing flows to Anderson Creek the majority of the proposed storm sewer system is to be constructed with perforated pipe (within infiltration trenches) and dry well manholes to encourage exfiltration beyond the on-site BMP measures that are to be installed. Further detail should be identified at the Neighbourhood Plan level and determined during the preliminary and detailed design stages. **Figure 2.3.2** shows the layout for the proposed storm sewer network while summary information for the storm sewer diameters, peak flows, length, estimated costs and phasing are provided in **Section 3.1** in the Capital Works Plan.

For management of the 100-year major storm event and overland flows, two detention ponds are required. Overland flow routes are shown in **Figure 2.3.3**. Pond volumes were determined based on Township criteria limiting post development peak flows to pre development peak flows. Additional criteria for detention pond sizing and dimensions are provided in the *Township of Langley Subdivision and Development Servicing Bylaw 2011 No. 4861* section D9. A summary of the runoff and proposed detention pond volumes are provided in **Table 2.3.1**. Estimated catchment peak flows for the same scenarios are provided in **Table 2.3.2**

Table 2.3.1 Runoff and Proposed Detention Pond Volume

Catchment ID	Pre-Development Scenario		Current Scenario		Future Scenario - No BMPs		Future Scenario - with BMPs (2-yr Onsite Control)		Future Scenario - with BMPs and Detention Ponds	
	5-Year	100-Year	5-Year	100-Year	5-Year	100-Year	5-Year	100-Year	5-Year	100-Year
	Runoff Volume (m^3)		Runoff Volume (m^3)		Runoff Volume (m^3)		Runoff Volume (m^3)		Maximum Pond Volume Required (m^3)	
A1 (Pond#2)	19,050	48,590	46,687	102,121	36,890	67,210	3,480	31,840	1,100	6,100
A2 (Pond#1)	24,797	63,730	38,813	101,000	56,650	103,800	4,930	48,900	2,600	14,300
A3	17,694	42,340	34,184	60,625	28,030	54,190	730	23,840	--	--
A4	8,920	22,290	13,860	28,200	16,200	30,770	700	14,030	--	--
Total	**70,461**	**176,950**	**133,545**	**291,946**	**137,770**	**255,970**	**9,840**	**118,610**	**3,666**	**20,400**

As noted in **Table 2.3.1**, the two proposed ponds are denoted as Pond 1 and Pond 2. They are located in the central portions of Brookswood and designed to control overland flow from the majority of higher density development areas.

Pond 1 is to be located adjacent to Anderson Creek at Noel Booth Park and discharge to the creek. This location was selected based on the topography and to be outside (or on the fringe) of the municipal well capture zone.

For a volume of 14,300 m^3, an area of approximately 10,500m^2 is required based on a depth of 2.0m and 4H:1V side slopes. The pond will need to be isolated from the creek floodplain area such that the active storage is available for overland flows from the development area. Locating the pond in the floodplain for Anderson Creek may impact the upstream water levels; however, during the hydraulic analysis the overbank storage at this location was not significantly utilized during the 100-year peak flow simulations. In addition, there are channel and crossing restrictions upstream that have much greater impact on water levels in the area.

Pond 2 is to be located south of 33A Avenue and east of 196 Street. The pond will discharge to the existing storm sewer system to the north that ultimately discharges to a tributary of Anderson Creek. The existing storm sewer on 196a Avenue between 33A Avenue and 35A Avenue will require an upgrade to convey the proposed pond discharge. The area is known to have elevated groundwater such that the pond will need to be shallow. For a volume of 6,100 m^3, an area of approximately 8,300 m^2 is required based on a depth of 1m (due to the shallow groundwater table) and side slopes of 4H:1V.

Future development within the drainage catchment areas for Sunrise Lake will be required to manage stormwater runoff such that the discharge rates are limited to pre development rates. If required, a flow control manhole can be installed on the upstream side of the lake with an orifice limiting discharge rates to it. The design for the trunk sewer collection system in this area should include perforated pipes and manholes to encourage exfiltration and be oversized to provide additional storage. The same rationale is proposed for areas draining to the existing Brookswood Pond.

The need for an overflow from Sunrise Lake should be examined in more detail when upstream lands develop; the pipe network has been sized to accommodate flows from it.

There are several small catchment areas where development is proposed that will connect directly to Anderson Creek. These are too small for trunk storm sewer systems or ponds but it is recommended that:

- local infiltration measures and BMPs be oversized to manage the 2, 5 and 100-year peak runoff rates and volumes, with a storm sewer system for overflows.
- That infiltration measures and BMPs be provided for smaller events but detention be provided in oversize pipes with release rates set to the pre-development rates in **Table 2.3.2** for larger events.

2.4.11 Future Drainage System Assessment

A summary of the major creek crossing under the future development scenario is presented in **Table 2.3.3**. Model results upstream of 36 Avenue are identical to the current scenario, indicating that flooding is still predicted at several creek crossings and channel locations in the reach between 205 Street and 210 Street for the 100-year event. However, peak flows are reduced from 36 Avenue and onwards when compared to the current conditions scenario the 2, 5, and 100-year events. The maximum HGL has also been reduced at 36 Avenue, 200 Street, and Colebrook Road. As previously indicated, these structures are adequately sized to convey the 100-year peak flow.

The difference in peak flow between the current and future scenario is a result of the BMPs applied to Brookswood/Fernridge, which infiltrate greater amounts of storm water runoff, or detain it in ponds. This reduces the peak flow in the creek for the areas downstream of where they have been applied. While the runoff in these areas have been reduced to predevelopment rates, the flow in Anderson Creek is still greater than the predevelopment scenario. This can be expected since the BMPs have only been applied to the part of the watershed that is redeveloping. These results show that applying BMPs to future developments will have a positive impact on the downstream watershed.

An assessment of the existing trunk sewers (525mm or greater) was also completed, and summarized in **Table 2.3.4** These are conventional storm sewers designed to convey the peak 5-year flow. The capacity was calculated using Manning's equation, and the minimum pipe slope of the alignment reported in GIS. Sections of the sewer where the estimated peak flow is greater than the pipe capacity are shown in bold.

All of the trunk sewers have adequate capacity for the estimated future peak flows, with a few exceptions; the storm sewer on 196A Street south of 35A Avenue will require an upgrade to convey flow from the proposed Pond 2. The184 Street sewer in Surrey is also undersized, but is not recommended for upgrade due to its proximity to the Nicomekl River. The sewer outlet is below sea-level, which would cause the sewer to surcharge frequently, however flooding has not been reported in this area.

2.4.12 Watershed West of 196 Street

The portion of the Anderson Creek watershed in the City of Surrey will be impacted by development in the Campbell Heights area, any changes in the ALR to the north, and the remaining majority of the watershed upstream of 196 Street. A summary of the total estimated volume of Anderson Creek flow entering the City of Surrey is provided in **Table 2.3.5** during the 2, 5 and 100-year storm events. The increase in volume between the pre-development and current scenario is a result of the removal of tree cover and increases in impervious area. Peak flows in Anderson Creek have likewise increased due to these activities, which increase the risk of flooding, and amplify the erosion of the creek and its banks.

Erosion has been observed throughout Anderson Creek including the Unwin Watershed in Surrey. As reported in section 1.5.7 most of the erosion sites were identified in previous years, and site conditions have either worsened or remained the same. The erosion of creeks can be mitigated by maintaining good streamside ground cover, controlling peak flows, and reducing stormwater volume.

As shown in **Table 2.3.2 and 2.3.5** future peak flows and runoff volumes have both been reduced over current conditions by increasing infiltration and adding detention ponds. In conjunction with maintain riparian area setbacks as development occurs, these recommendations will help mitigate the effects of erosion and flooding further downstream. Other recommended BMPs such as bioswales and oil/grit separators will help to improve the water quality entering the creek from urban areas by capturing contaminates and sediments prior to infiltrating runoff.

Adopting the recommendations in this ISMP will benefit the watershed in the City of Surrey by reducing many of the harmful impacts from human activity in local and upstream tributaries.

Table 2.3.2 Catchment Runoff Estimates

Catchment ID	Area	Pre-Development Scenario				Current Scenario				Future Scenario - No BMPs				Future Scenario - with BMPs (2-yr Onsite Control)				Future Scenario - with BMPs and Detention Ponds			
		5-Year		100-Year		5-Year		100-Year		5-Year		100-Year		5-Year		100-Year		5-Year		100-Year	
		Peak Flow		Peak Flow		Peak Flow		Peak Flow		Peak Flow		Peak Flow		Peak Flow		Peak Flow		Peak Flow		Peak Flow	
	ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha	m^3/s	L/s/ha
A1 (Pond-2)	58.8	0.30	5.1	0.75	12.8	0.89	15.2	2.02	34.4	1.10	18.7	1.99	33.9	0.19	3.2	0.87	14.8	0.16	2.7	0.72	12.3
A2 (Pond-1)	91.6	0.39	4.2	0.99	10.8	0.82	8.9	2.13	23.2	1.63	17.8	3.01	32.9	0.27	2.9	1.33	14.5	0.16	1.7	0.99	10.8
A3	51.3	0.31	6.1	0.76	14.9	1.06	20.7	1.86	36.3	0.66	12.9	1.33	25.9	0.05	1.0	0.57	11.1	0.05	1.0	0.57	11.1
A4	28.3	0.15	5.3	0.36	12.7	0.41	14.5	0.83	29.3	0.50	17.6	0.95	33.5	0.06	2.1	0.40	14.1	0.06	2.1	0.40	14.1
Total to Anderson Creek	**230**	**1.15**	**5.0**	**2.86**	**12.4**	**3.18**	**13.8**	**6.84**	**29.7**	**3.89**	**16.9**	**7.28**	**31.7**	**0.57**	**2.5**	**3.17**	**13.8**	**0.43**	**0.0**	**2.68**	**0.0**

Table 2.3.3 Future Land Use Major Crossing Capacities

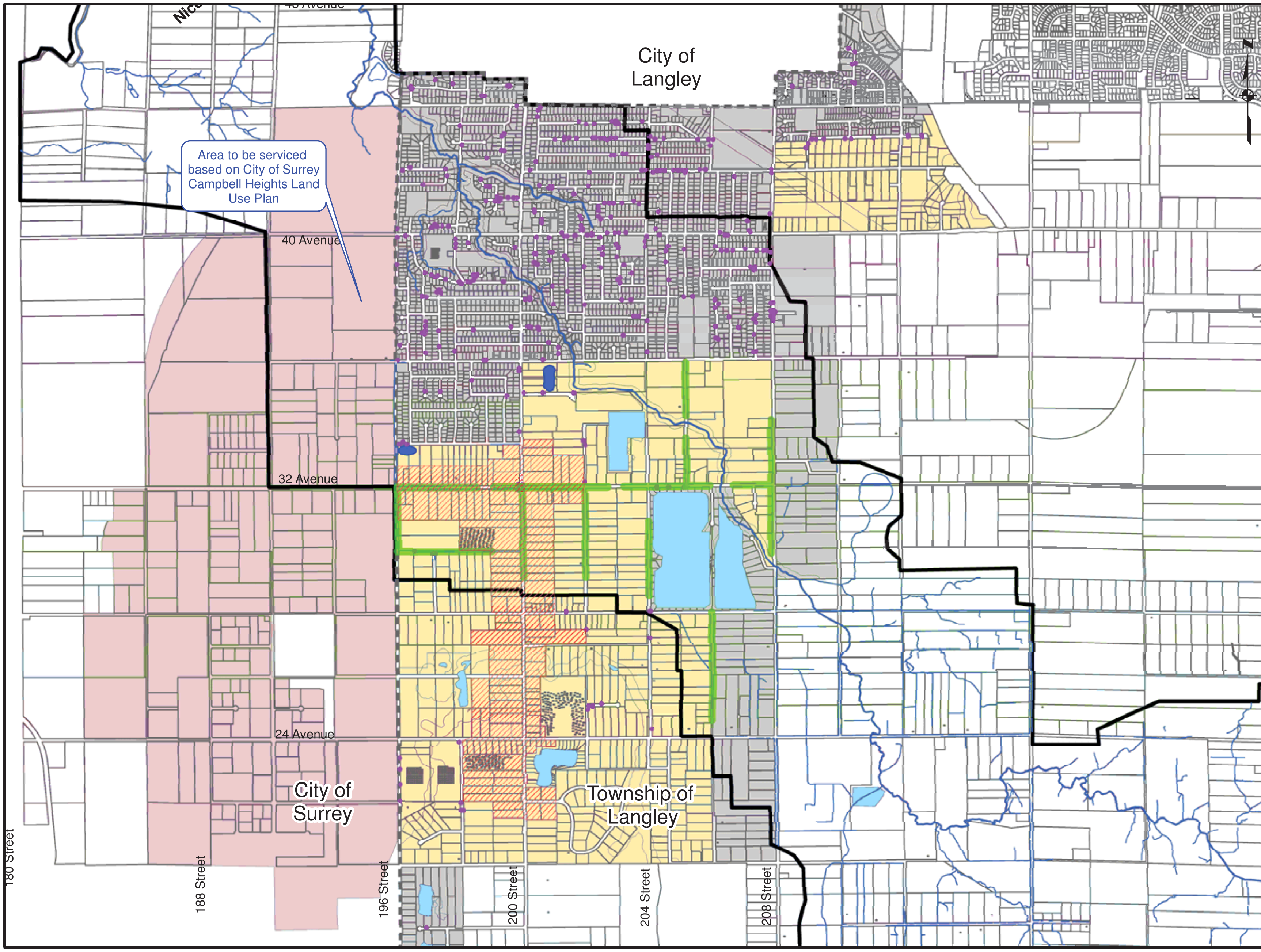
ID	Location on Anderson Creek	Contributing Area (ha)	u/s Inv. (m)	d/s Inv. (m)	Pipe/Bridge Dimensions (m)	Length (m)	Slope (%)	Material	1:2yr Peak Flow (m^3/s)	1:5yr Peak Flow (m^3/s)	1:100yr Peak Flow (m^3/s)	Pipe Full Capacity (m^3/s)	1:2yr L/s/ha	1:5yr L/s/ha	1:100 yr L/s/ha	1:100 yr q/Q	1:100 yr d/D	Ground Elev. (m)	u/s 1:100 yr Max HGL	d/s 1:100 yr Max HGL
1	Crossing Colebrook Rd.	2521	1.26	1.18	10m Wide x 2.5m High	9.2	0.87	Conc.	11.1	16.86	27.28	73.8	4.4	6.7	10.8	0.37	0.89	5.02	3.97	3.97
2	Crossing 200 St.	1980	34.81	33.06	2.84 Wide x 1.77 High (x2)	61.7	2.84	Conc.	9.9	14.6	20.5	89.6	5.0	7.4	10.4	0.30	0.35	45.71	35.43	33.61
3	Crossing 36 Ave.	1859	42.67	42.56	2.2 Wide x 2.2 High (x2)	22.0	0.50	Conc.	9.8	14.4	20.0	35.6	5.3	7.7	10.8	0.75	0.67	48.10	44.17	44.03
4	Crossing 205 St.	1821	48.66	48.51	6.19m Span	7.9	1.90	--	9.7	14.2	26.6	43.7	5.4	7.8	14.6	0.53	**1.00**	51.63	**51.68**	**51.64**
5	Driveway Crossing South of 32 Ave	1795	50.17	50.17	10.77m Span	3.3	0.1*	--	9.7	14.8	28.2	84.5	5.4	8.3	15.7	0.34	**1.00**	53.29	52.91	52.86
6	Crossing 208 St.	1757	50.92	50.84	4.35m Wide x 2.44m High	21.0	0.38	CSP	9.6	14.0	24.6	16.7	5.5	8.0	14.0	**1.47**	**1.00**	54.94	53.98	53.81
7	Crossing 24 Ave.	1575	54.08	54.08	2.44m Wide x 2.48m High (x2)	15.8	0.1*	Conc.	10.3	15.7	30.4	25.6	6.5	10.0	19.3	**1.33**	0.90	57.28	56.34	56.32
8	Crossing 216 St.	1209	64.76	64.49	3.0 m Diameter	32.7	0.83	Steel	7.9	11.8	21.6	21.3	6.6	9.8	17.8	**1.02**	0.70	73.58	66.92	65.36
9	Crossing 224 St.	837	73.78	73.78	6.22m Span	6.7	0.1*	--	5.7	8.6	14.9	18.4	6.8	10.3	17.8	0.81	0.74	76.97	75.70	75.69
10	Crossing 232 St.	88	80.99	80.95	0.70m Diameter	17.8	0.22	Conc.	0.7	1.0	2.1	0.4	7.6	11.7	24.4	4.89	0.91	83.88	82.85	81.52

Table 2.3.4 Trunk Sewer Capacity Summary

Location	Pipe Diameter (mm)	Material	Minimum Pipe Capacity (m^3/s)	Estimated 5yr Peak Flow (m^3/s)
184 Street, Surrey				
Outlet at Nicomekl River*	1200	CSP	1.03	**1.39**
North of 44 Ave	1200	CSP	3.61	1.39
Ross Ck to 44 Ave	1050	Concrete	1.87	0.67
196a Street, Langley				
196A St to Outlet	750	Concrete	1.76	1.28
196A St: 37A Ave to Outlet	900	Concrete	1.29	1.28
196A St: 36 Ave to 37A Ave	900	Concrete	1.00	0.99
196A St: 35A Ave to 36 Ave	750	Concrete	0.75	0.89
196A St: 34A Ave to 35A Ave	675	Concrete	0.35	**0.45**
34A Ave: to 196A St	600	Concrete	0.30	0.29
34A Ave	525	Concrete	0.26	0.22
200 Street, Langley				
38 Ave to Outlet	750	Concrete	0.58	0.46
37A Ave to 38 Ave	675	Concrete	0.42	0.32
36A Ave to 37A Ave	600	Concrete	0.22	0.20

Table 2.3.5 Trans-Boundary Volume Summary

24hr Storm Return Period	Total Flow Entering City of Surrey (million L)		
	Pre Development Scenario	Current Scenario	Future With BMPs Scenario
2yr	610	924	882
5yr	1018	1362	1302
100yr	2105	2248	2204



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Existing Rock Pits & Dry Wells
- Municipal Boundary
- Study Area
- No change in land use
- Future land use density to increase
- Campbell Heights Industrial Area

Potential BMPs

Note: New Rock Pits & Dry Wells to be Installed as Required

- BMP Permeable Pavers & Vegetative Planters & Rain Gardens
- BMP Infiltration Swales
- BMP Detention Pond
- BMP Infiltration Trench

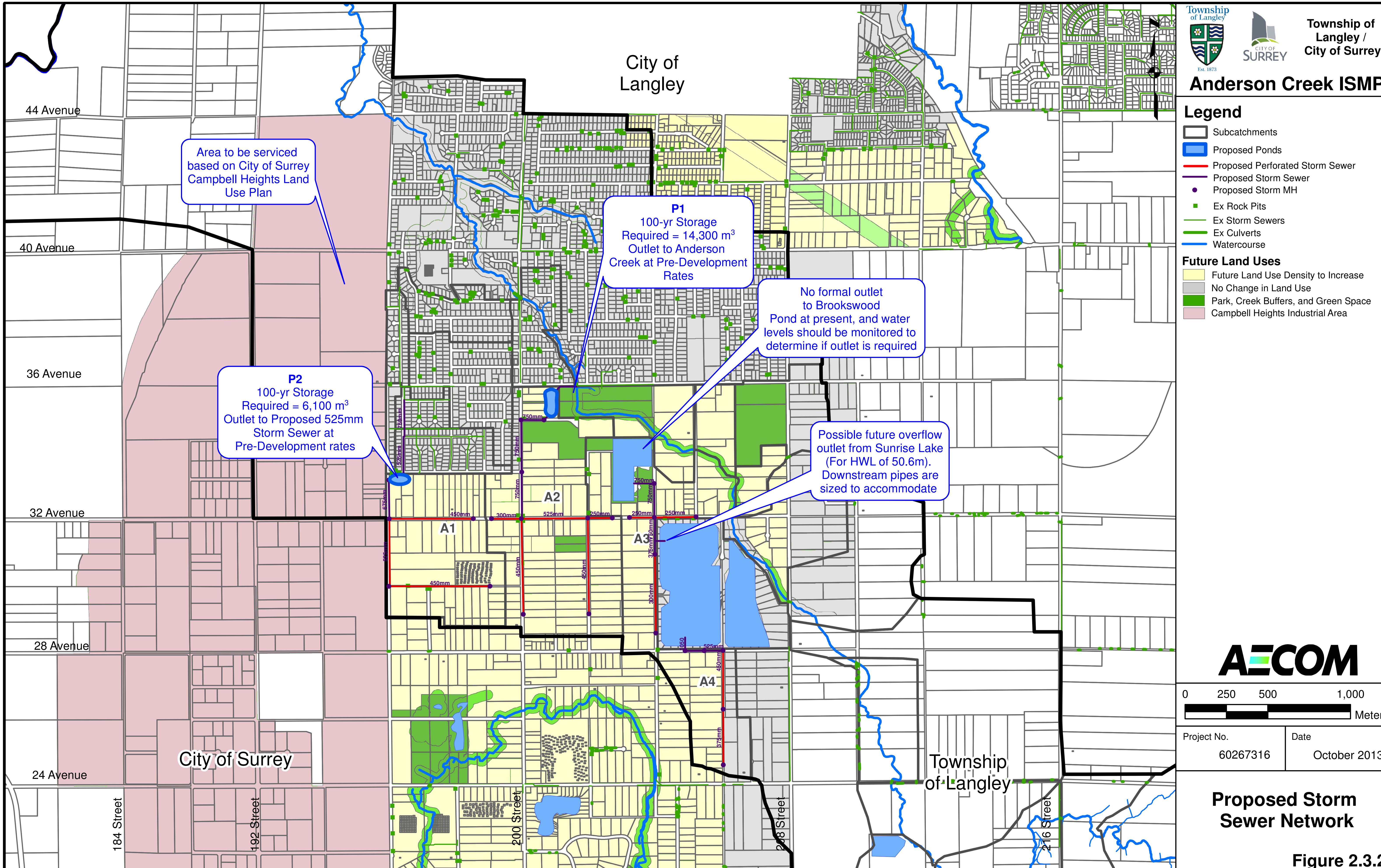
AECOM

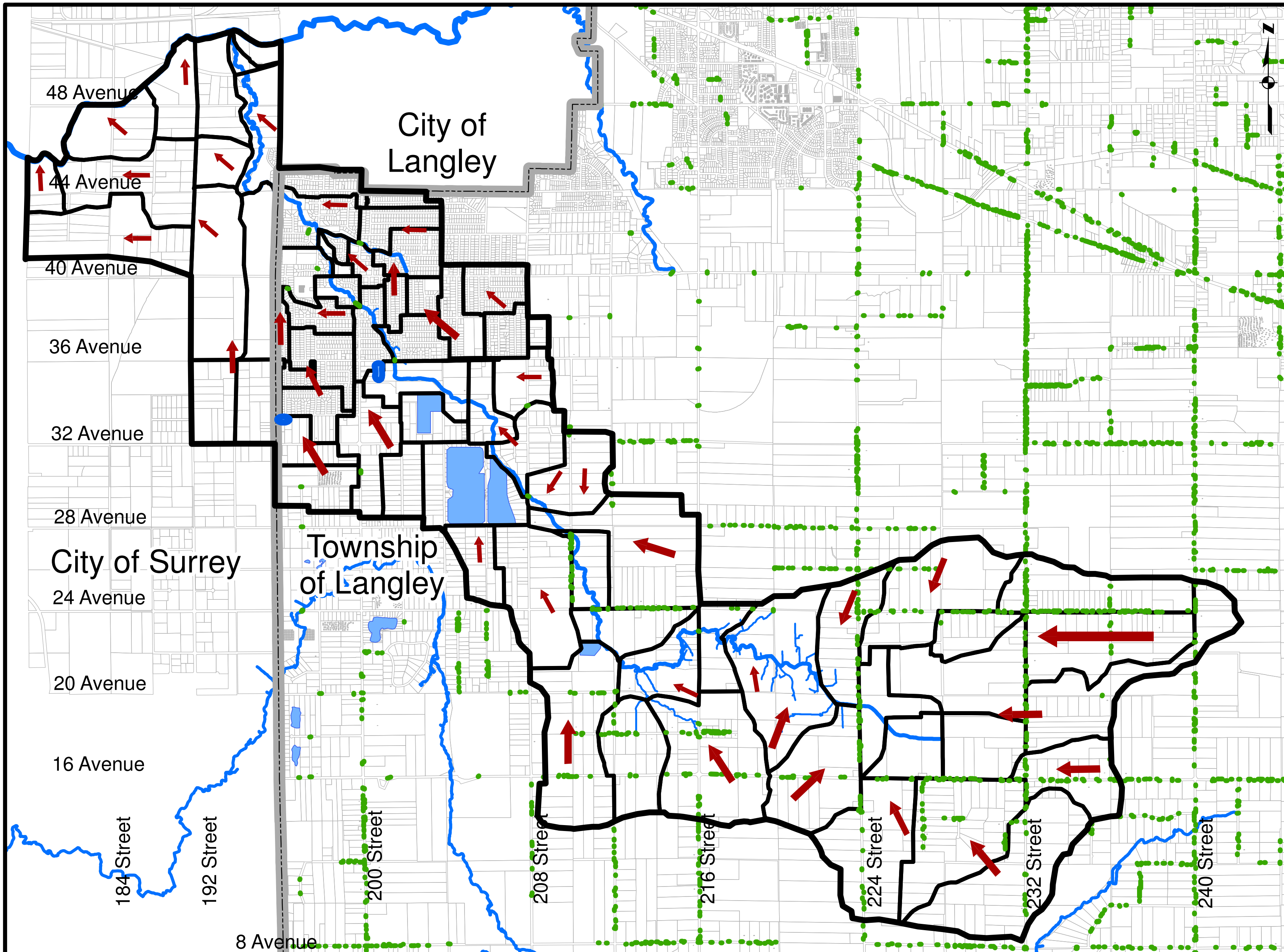
0 250 500 1,000 Meters

Project No.	Date
60267316	October 2013

Potential BMP Locations

Figure 2.3.1


City of Langley
44 Avenue
40 Avenue
36 Avenue
32 Avenue
28 Avenue
24 Avenue
184 Street
192 Street
200 Street
208 Street
216 Street
City of Surrey
Township of Langley
Area to be serviced based on City of Surrey Campbell Heights Land Use Plan
P1
100-yr Storage Required = 14,300 m³ Outlet to Anderson Creek at Pre-Development Rates
P2
100-yr Storage Required = 6,100 m³ Outlet to Proposed 525mm Storm Sewer at Pre-Development rates
No formal outlet to Brookswood Pond at present, and water levels should be monitored to determine if outlet is required
Possible future overflow outlet from Sunrise Lake (For HWL of 50.6m). Downstream pipes are sized to accommodate
A1
A2
A3
A4
750mm
450mm
300mm
525mm
250mm
375mm
Township of Langley / City of Surrey
Anderson Creek ISMP
Legend
Subcatchments
Proposed Ponds
Proposed Perforated Storm Sewer
Proposed Storm Sewer
Proposed Storm MH
Ex Rock Pits
Ex Storm Sewers
Ex Culverts
Watercourse
Future Land Uses
Future Land Use Density to Increase
No Change in Land Use
Park, Creek Buffers, and Green Space
Campbell Heights Industrial Area
AECOM
0 250 500 1,000
Meters
Project No.
60267316
Date
October 2013
Proposed Storm Sewer Network
Figure 2.3.2



Township of Langley / City of Surrey

Anderson Creek ISMP

Legend

- Municipal Boundary
- Study Area
- Drainage Subcatchments
- Existing Water Body
- Ex Culverts
- Proposed Ponds
- Anderson Creek (Main Stem)
- Overland Flow Direction

AECOM

0 400 800 1,600 Meters

Project No.	Date
60267316	October 2013

Overland Flow Routes

Figure 2.3.3

3 Implementation Plan

The Implementation Plan outlines how to achieve the strategies identified in **Section 2**. Detailed information for the Capital Works Plan, BMP operations and maintenance requirements, funding and enforcement strategies, and policy planning are provided.

3.1 Capital Works Plan and Funding Strategies

3.1.1 10-Year Phasing Plan

The Capital Works Plan includes cost estimates for all proposed storm sewer infrastructure including the detention ponds. The cost estimates have been prepared based on unit rates and lump sum amounts in our possession and are in 2013 dollars. These costs include bulk excavation and inlet/outlet works for ponds, storm sewers and manholes, infiltration trenches (where applicable), and asphalt replacement with re-use of road gravel/structural material.

The costs exclude service connections to property line, land acquisition and ROW costs. A contingency allowance of 30% for cost escalation, engineering design and construction has been included, and GST is excluded.

The proposed storm sewer network is shown in **Figure 2.4.3.** A summary of the Capital Works Plan is provided in **Table 3.1.1** while detailed information for storm sewer diameters, length and estimated costs are provided in **Table 3.1.2**.

Storm sewers and the detention ponds are sized based on conveyance of the reduced 5-year and 100-year peak flows after infiltrating the 2-year 24-hour event (or 64mm) on-site which is to be a requirement stipulated in future development permits and rezoning approvals.

Portions of the proposed municipal storm sewer system are intended to be perforated PVC pipe within infiltration trenches to encourage exfiltration beyond the on-site stormwater source control BMP measures that are to be installed. The distinction between solid and perforated storm sewers with infiltration trenches is shown in **Figure 2.4.3** and factored into the unit rates for the Capital Works Plan.

As discussed in **Section 1.4,** there are no capacity upgrades recommended for the current land use scenario. The current infrastructure is adequate for the urban and suburban land uses at present. Also, no culvert capacity upgrades are recommended for Anderson Creek as a result of the requirement that no additional flow or volume is added to the Creek due to downstream erosion and slope stability concerns.

In terms of phasing for the capital works, a preliminary timeline was established assuming that the higher density residential and commercial areas in the vicinity of 32 Avenue and 200 Street will be developed first with the remainder of the surrounding community to follow within 10 years. The infrastructure needed to service this area includes Pond 1 (36 Avenue at Anderson Creek) which should be constructed in Year 1 of development with the upstream storm sewer collection system constructed in Years 2 to 5, or as required by development.

To the west, the intent of Pond 2 (33A Avenue near 196 Street) is to service new urban single family residential areas and discharge to the existing storm sewer to the north. This pond should be constructed as part of any upstream development along with the connecting storm sewer system. This area is subject to very high groundwater levels and the effects of this on the pond and storm sewers needs to be analyzed in detail prior to development.

Infrastructure for the surrounding areas is assumed to be required later; however, the timing for development of any of these areas is subject to change based on market conditions and the land owners. Costs for an overflow outlet from Sunrise Lake have not been included, but the sewer mains along 204 Street have been sized to accommodate the additional flows.. There is currently a ROW established for an outlet from Sunrise Lake that could be installed if required when development occurs up-gradient from the lake.

The future drainage system also utilizes Brookswood Pond which does not have a formal outlet at present. Water levels would need to be monitored in the pond to determine if an outlet is required in the future due to increased flow into the pond. The area is known to have significant infiltration capacity such that no formal outlet structure has been recommended as part of this study.

System maintenance costs have not been included the Capital Works Plan and are discussed in **Section 3.2**. Land acquisition costs have not been included but the required land area is noted in **Table 3.1.1**.

Table 3.1.1 Capital Works Plan Summary

Year	Area	Description	Cost Estimate	Pond Area
1 to 5	A1	14,300m^3 Detention Pond 1 870m of conventional storm sewers 1,880m of perforated storm sewer and infiltration trenches	$ 5,754,500	1.05 ha (2.6 ac)
6 to 8	A2	6,100m^3 Detention Pond 2 460m of conventional storm sewers 1,700m of perforated storm sewer and infiltration trenches	$ 3,925,000	0.83 ha (2.0ac)
9	A3	470m of conventional storm sewers 955m of perforated storm sewer and infiltration trenches	$ 1,944,375	--
10	A4	230m of conventional storm sewers 1,075m of perforated storm sewer and infiltration trenches	$ 1,392,500	--
		Total Cost Estimate	**$ 13,016,375**	

Table 3.1.2 Detailed Capital Works Plan (per Figure 2.3.2)

Catchment Area	Description	Pond Volume (m^3) or Pipe Dia. (mm)	Length (m)	Unit Cost ($/$m^3$ for ponds or $/m for pipe)	Total Cost	Phasing Plan (Year)
A1	Pond 1	*14,300*	--	120	$ 1,716,000	1
	Storm sewer	750	870	1,500	$ 1,305,000	2 to 5
	Storm sewer in infiltration trench	300	180	1,325	$ 238,500	
		525	400	1,600	$ 640,000	
		450	1,150	1,450	$ 1,667,500	
		250	150	1,250	$ 187,500	
				Subtotal	***$ 5,754,500***	
A2	Pond 2	*6,100*	--	120	$ 732,000	6
	Storm sewer	750	200	1,500	$ 300,000	7 to 8
	Storm sewer in infiltration trench	675	260	1,300	$ 338,000	
		525	600	1,600	$ 960,000	
		450	500	1,450	$ 725,000	
		450	600	1,450	$ 870,000	
				Subtotal	***$ 3,925,000***	
A3	Storm sewer	750	470	1,500	$ 705,000	9
	Storm sewer in infiltration trench	375	80	1,375	$ 110,000	
		300	475	1,325	$ 629,375	
		250	400	1,250	$ 500,000	
				Subtotal	***$ 1,944,375***	
A4	Storm sewer	525	230	1,000	$ 230,000	10
	Storm sewer in infiltration trench	450	350	1,450	$ 507,500	
		375	340	1,375	$ 467,500	
		250	150	1,250	$ 187,500	
				Subtotal	***$ 1,392,500***	
				Total Cost Estimate	***$ 13,016,375***	

*Notes

1. Land acquisition and ROW costs not included
2. Phasing is subject to market conditions, developers and land owners
3. System maintenance cost not included
4. Cost for overflow outlet from Sunrise Lake not included
5. “Storm sewer in infiltration trench" Unit Rate includes infiltration swale on both sides of street

3.1.2 Funding Strategies

Capital works that are necessary because of condition failure of existing infrastructure or because of existing capacity constraints are generally funded by general municipal taxes or, in some jurisdictions, a dedicated stormwater utility charge. Works required as a result of development are generally funded by development through various mechanisms, the main one being Development Cost Charges.

Development Cost Charges

Development cost charges (DCCs) are collected from developers to fund the cost of providing roads, drainage, water, and sewer services for the projected growth in population. DCC rates are specified by the Township for different land uses.

An alternative would be to implement a local area service cost depending on how the area develops and the phasing of the works. However, it is rarely used as it requires the general consent of the owners of the affected properties, as costs are recovered by increased taxes on those properties phased over a specified period.

Amenity Charges

Stormwater management measures or provisions that are required for development of a particular parcel or neighbourhood area that do not meet the eligibility criteria for DCC works can be deemed as “amenities” and funded through “amenity charges”. These amenity costs can be provided as land with improvements constructed, cash plus land without improvements constructed or cash alone and are subject to special conditions determined prior to approval of the development. Specific rates would need to be determined for each stormwater management provision that is proposed for a particular neighbourhood area or specific multi-family development.

3.2 Stormwater BMP Operation & Maintenance

Municipalities, developers, and residents must understand that regular operational checks and maintenance of stormwater source control BMPs is a critical part of ensuring that they are performing well and do not become burdens. Even when BMPs are carefully designed and properly installed, they can become overgrown, clogged with debris, breed mosquitoes or other unwanted insects, generate odours, and cease to function if not properly maintained.

BMPs are more effectively maintained when they are designed to allow for easy inspection and maintenance access and take into consideration factors such as property ownership, easements, visibility, and vehicle access. Consideration should be given to how BMPs will be maintained in the future and the equipment required, as well as who is going to undertake the work. Clear and legally-binding written agreements assigning maintenance responsibilities and committing adequate municipal (or owner) funds for maintenance are also critical in developing a sustainable BMP strategy.

Table 3.2 is a decision matrix for BMPs and includes the appropriate land use applications, expected performance, operation and maintenance requirements including approximate annual costs. Cost information for stormwater source control BMP routine maintenance depends on the size and complexity of the facility and was estimated based on past projects and information from AECOM’s National Stormwater Benchmarking Initiative that included standard operating procedures and maintenance requirements for several of the BMPs.

When new developments are proposed in the Anderson Creek catchment area, the Township can use the approximate annual costs in **Table 3.2** to determine the required increase in maintenance budgets. It is recommended the Township develop a process whereby maintenance budgets for the next fiscal year are automatically increased when development is approved.

3.2.1 BMP Funding Strategies

BMPs located in the public realm are generally maintained by local government while those on private property are maintained by the owners. One exception is rain gardens, located on public streets with an expectation that property owners will maintain the ones along their street frontage. Unfortunately, in the Township and City this is not working in 10 - 20% of cases and enforcing boulevard maintenance bylaws is problematic.

Rain gardens are a highly beneficial BMP and should the municipalities wish to pursue them, consideration could be given to a reoccurring or annual maintenance charge to homeowners or strata corporations for maintenance of rain gardens in areas where they are installed. For example, if a row of single family lots are serviced with a rain garden maintained by Township, those properties would be charged a higher stormwater utility charge to pay for the maintenance. Estimated maintenance costs for rain gardens and other stormwater source control BMPs are provided in **Table 3.2**.

3.3 Enforcement Strategy and Policy Planning

3.3.1 Recommended Bylaw Modifications

Both the Township's *Subdivision and Development Servicing Bylaw 2011 No. 4861* (the Bylaw*)* and the City of Surrey's *Stormwater Drainage Bylaw (No 16610)* include sections for on-lot stormwater control measures. The Township as has detailed design drawings and criteria for on-lot measures. The focus is on swales, infiltration trenches and dry wells which are all applicable. Section D of the Bylaw includes criteria for on-site infiltration and detention for a range of development types and the facilities listed include absorbent landscapes, rain gardens and infiltration swales and trenches. Requirements for individual residential lot infiltration facilities are specified in *Schedule H Supplementary Detail Design Drawings*, which include swales and infiltration trenches, and there are detailed drawings for an exfiltration trench, rock pit and dry well. Additional detailed design drawings could be added for rain gardens, bioswale (or vegetated swale) and permeable pavers (with a sub-drain). A typical local road cross-section with BMPs could also be added in the road supplementary drawings. The road section could include detail for on-lot infiltration measures and connectivity with the municipal storm system.

Section D10.3 of the Bylaw indicates that for zones other than residential, on-site infiltration measures are to be sized to infiltrate 25mm in 24-hours. For all rural and urban areas in Anderson Creek, this ISMP stipulates that infiltration measures are to be sized for the 2-year 24-hour total rainfall, which is approximately 64mm. The Bylaw states that available stormwater management plans overrule the Bylaw which is acceptable.

Section D11 of the Bylaw for stormwater quality control could be enhanced. Reference is made to the *Sewerworks Regulation Bylaw 1998 No 3701* that includes mention of grease, oil and sand interceptors. Parking lots should be added to the list of land uses where these devices are required in the Sewerworks Regulation.

Another consideration is protection of downstream infiltration systems during site grading/house construction. There should be no discharge to the downstream system unless the runoff is filtered and clean.

Options for stormwater treatment devices such as the Filterra Stormwater Bioretention Filtration System or Imbrium Stormceptor should be included in Section D11 of the Subdivision Development Servicing Bylaw as permanent facilities.

Prior to construction of new homes and underground parkades developers should be required to assess the implications of high water tables on basements and whether water proofing is needed for parking structures.

Section D7.14 Culverts of the Bylaw should be modified to include design parameters for fish passage such as baffles and depth of flow. Introduction of baffles affects the Manning's 'n' roughness value for calculation of flow and water depth in a culvert.

The Bylaw should also include a statement enforcing trans-boundary flows such that there is no net increase in flows to Surrey. This type of statement could be inclusive for all watercourses in the Township covering inflow and outflow. Stormwater source control measures are critical in meeting this requirement.

3.3.2 Proposed Stormwater Source Control Bylaw

There is a need for a detailed Bylaw specific to lands in the Brookswood area for protection of the water quality and quantity of the unconfined aquifer as well as potential downstream erosion and slope stability impacts in Anderson Creek resulting from increased runoff.

A new Bylaw could provide specific requirements for source control by means of on-site measures to provide water quality treatment as well as discharge rate and quantity control. At present there are several water quality treatment source controls already in the *Subdivision Development Servicing Bylaw* and the list could be supplemented by adding rain gardens, vegetated planters, bioswales, and prefabricated stormwater treatment devices (such as the Filterra and Stormceptor discussed above). Infiltration trenches, dry wells and rock pits also provide a level of water quality treatment; however, for areas within the municipal well capture zones the intention is to treat surface runoff prior to infiltration. In such case, specific areas for implementation of the BMPs should be highlighted.

Pollutant sources include roads, parking lots, driveways, storage areas and loading bays. Stormwater runoff from these facilities must be treated and special precautions made for locations inside the 20-year well capture zone. Spill control plans could be required for certain high risk land uses.

A potential list of prohibited land uses for areas within the well capture zones unless stormwater management measures are approved by the Township engineering department could include:

- Meat processing facilities,
- Auto repair, sales or fuel dispensing facilities,
- Hazardous liquid storage facilities (such as dry cleaners), and
- Commercial vehicle long term parking or washing,

Stormwater rate and quantity control is required so that properties detain and infiltrate the 6-month 24-hour post-development flow and volume, and reduce the discharge rate and volume for 5-year and 100-year 24-hour events to the pre-development rate and volume. Recommended unit rates are to detain the 5-year flow to 6 L/s/ha and 100-year to 12 L/s/ha.

Additional items that could be considered for inclusion in a new Stormwater Source Control Bylaw include the following:

- Retain a professional geotechnical engineer to specify a minimum distance from an infiltration system to proposed or existing buildings foundation wall and property lines;
- Avoid other utility crossings during design of infiltration system and if crossings are unavoidable then construct an impermeable barrier such as trench dams to reduce the likelihood of conveying infiltrated water along the utility trench;
- Retain a hydrogeologist to determine the maximum groundwater table and potential mounding as a result of infiltration measures;
- Ensure there is a connection to a storm sewer for overflows and during frozen ground conditions;
- Design infiltration systems based on the saturated infiltration rate of the native soils with rates to be determined using standard percolation tests with appropriate conversion or using a double ring infiltrometer;
- Establish a maximum infiltration rate allowed for facility sizing (such as 1,000 mm/hr for known high infiltration areas); and
- Ensure that only the permeable base area of an infiltration system is included in the calculation for infiltration volume and the maximum storage time shall be 24-hours.

This new Bylaw could also address source control of runoff from properties within the ALR, although this is more of a challenge to implement given the jurisdictional issues and Provincial and Federal regulations surrounding agricultural land uses.

3.3.3 Bylaw Enforcement

For the ISMP to be successfully implemented a number of enforcement and design review activities need to occur and several of these activities are outlined below.

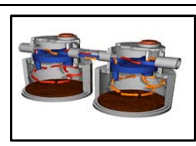
- To ensure that Class A and B streams and their riparian areas are protected all road design and building permit requirements need to be reviewed during and after construction in addition to reviews that occur at the building permit stage. Periodic reviews to ensure that streams and riparian setback areas are protected may require additional resources.
- The same applies for on-lot BMPs, as building permits need to be reviewed and the works inspected during and after construction. Plumbing inspectors may need assistance from time to time.

3.3.4 Public Education

Increasing communication, education and advocacy with the general public are required to successfully implement the source control best practices previously discussed and achieve stormwater quality and quantity management in the study area, particularly in relation to protection of the municipal water supply well capture zones. Communication, education, and advocacy play a strong supporting role in assisting technical staff in delivering the key messages to the various stakeholders. Key areas of focus include the following:

- Internal communication and education for Township staff;
- External communication and education for council, public, and other agencies;
- Development of consistent and appropriate messaging (for Council, staff, public, other agencies);
- Coordination with leadership and advocacy groups to identify stakeholders; and
- Development of a communication plan (timing, media, based on communication template, etc.).

Table 3.2 BMP Decision Matrix

BMP #	BMP TYPE	BMP IMAGE	DESCRIPTION	APPLICATIONS				PERFORMANCE			MAINTENANCE					
				Residential	Commercial	Industrial	Road/Highway	Volume Control	Peak Flow Attenuation	Water Quality	WHEN REQUIRED	TASKS	SCHEDULE	CREW SIZE (PEOPLE)	HRS PER VISIT	APPROXIMATE ANNUAL COST
1	**Rain Garden**		An excavated shallow surface depression planted with specially selected native vegetation to treat and capture runoff.	Y	Y	N	Y	Med	Med	Med/ High	Insects and/or odor problems develop.	Monitor duration of water stagnation in planters and health of plants.	On-Going (by local volunteer)			$300 / property
											There is evidence of soil eroding.	Mulch and erosion protection will need to be replenished.	Every 2 years	2	8	
											Trash, leaves, and other debris have collected on the surface. Plants wilting/dying.	Inspection of pollution buildup and vegetative condition. May require removal of pollutants and re-soiling.	Twice a year	2	4	
											Runoff is not being properly drained from the basin.	Inspection of stormwater flow and condition of inlets and outlets.	During wet periods (4 times / year)	1	2	
2	**Vegetative Planter**		A small, contained vegetated area that collects and treats stormwater using bio-retention.	N	Y	Y	N	Low	Low	High	Insects and/or odor problems develop.	Monitor duration of water stagnation in planters and health of plants.	On-Going (by local volunteer)			$225 / property
											Vegetation being to wilt or dye.	Inspection of pollution buildup and vegetative condition. May require removal of pollutants and re-soiling.	Twice a year	2	4	
											Runoff overflows planter and is not draining.	Inspection of stormwater flow and condition of inlets and outlets.	During wet periods (4 times / year)	1	1	
3	**Infiltration Swale**		Wide, shallow channels used to convey and treat stormwater. Normally grassed but can also have native vegetation. Vegetated surface reduces runoff velocity and promotes infiltration of runoff into the ground.	Y	N	N	Y	Med	High	High	Erosion to soil and profile of bioswale has changed.	Inspect and correct erosion problems, damage to vegetation, or pooling.	Annually	1	2	$210 / 500m
											Vegetation is wilting or dying, formation of rills or gullies is observed.	Reinstate vegetation on side slopes for erosion and correct formation of rills or gullies.	Annually	2	4	
											Pools of water remain stagnant 48 hours after a major storm event.	De-water and discharge to an approved location and restore to design grade.	Every 5 years or as needed	2-4	8	
											Vegetation is overgrown.	Mow and trim vegetation to ensure safety, and proper swale operation.	Twice a year	2	4	
											Garbage and sediment is collected in swales.	Remove litter and debris.	On-Going	1	1Hr / 3 months	
4	**Permeable Pavers**		Concrete grid or modular pavers that have void areas interspersed with pervious material. Provide load bearing surface for vehicles while allowing stormwater to infiltrate into the underlying soil.	Y	Y	N	Y/N	Med	Med	Med	Significant amounts of sediment have accumulated between the pavers.	Surface sweeping to be completed with a commercial vacuum sweeping unit.	Annually or as needed	1	2-4 (area dependent)	$600 / 0.25 Ha (incl. equipement rental)
											Puddling or ponding of water is visible on the surface 48 hours after a rain event.	Inspection to check surface conditions to determine if any remedial work is needed such as pothole repair, weeding, and paver replacement.	On-Going	1	4	
											Pavers are dislodging or being damaged. Surface grade is not being maintained.					
											Weeds are growing within voids.					
5	**Infiltration Trench**		Gravel-filled excavations with perforated pipes that temporarily store stormwater and allow it to drain into underlying soil. Used in linear spaces such as boulevards and where groundwater table is low.	Y	Y	N	Y	High	Med	High	Standing water is visible in the observation well for more than 48 hours after a rain event.	Catchbasins and inlets to be inspected and cleaned.	Annually	1	1	$100 / Km of trench
											Insects and/or odor problems develop.	Ensure vehicles are not driven or parked on trench.	On-going			
											There is visible damage to the trench (eg. Sinkholes).	Avoid excessive compaction from equipment and mowers	On-going			
											Trash, leaves, and other debris have collected on the surface.	Remove debris from surface to maintain proper function.	Quarterly	1-2	4	
											Runoff runs over or across the trench and not into the facility.	Repair any damages to trench.	As needed			
												Provide temporary diversions and ensure trench is protected from sediments during construction phase.	Construction Phase			
6	**Water Quality System**		Structures used to capture stormwater pollutants and treat urban runoff prior to discharge. Used in environments where space is limited and also may be retrofitted in existing storm systems.	Y	Y	Y	Y	Low	Low	Med	Excessive oil or debris is exiting the structure.	Remove sediments, trash, and trapped oil from structure and clean before onset of the dry season, after spills, and when inspection reveals oil accumulation is greater than 25mm or sediment accumulation is greater than 150mm.	Annually	1	4	$500 / vacuum truck
											Stormwater runoff is not free-flowing through the structure.					
7	**Detention Pond**		An earthen basin that provides temporary storage of runoff and functions hydraulically to attenuate stormwater peak flows and provide storage volume capacity.	Y	Y	Y	Y	High	High	High	Unwanted vegetation or invasive species begin to grow in basin. Vegetation begins dying, or vegetation becomes overgrown.	Inspect vegetation of pond to ensure healthy growth and mowing.	Annually	1	4	$2,000
											Large amounts of sediment or debris is accumulating within the basin.	Inspection of any erosion, flow channelization, bank stability, sediment/debris accumulation, and inlet/outlet issues.	Annually	2-3	4	
											Erosion or scouring around inlet and outlet structures are observed.	Pond to be drained and sediment be removed from forebay	Every 5 to 10 years	2-3	8	
											Insects and/or odor problems develop.	Pond must be inspected for proper aeration and water turnaround time.	Quarterly			
8	**Drywell / Rock Pit**		A drywell is a subsurface storage facility that receives and temporarily stores stormwater runoff, then ultimately discharges stored runoff into the surrounding soils via infiltration.	Y	N	N	Y	Med	Med	Med	Trash or debris/sediment has accumulated in drywell or rock pit.	Inspect drywell to remove any accumulated trash, debris, or sediment.	Every 5 to 10 years	2-3	4	$500 / drywell or rock pit
											Drain time of drywell exceeds 72 hours after a storm event and/or localised flooding occurs.	Monitor duration of stormwater runoff drain-down time.	As needed			

4 Monitoring and Adaptive Management

Watershed planning needs to consider horizons as far out as 25 to 50 years, which is a challenge but one that all municipalities face. Due to economic, political, climatic, technological, and social changes as well as changes in our understanding of the watershed it is imperative that the ISMP adapt accordingly to ensure the watershed vision is met over time. As such, a key component to a successful ISMP is to develop a long-term adaptive management program that includes monitoring, operation, and maintenance strategies to verify that the vision and goals set out are met through the implementation plan.

The adaptive management approach of the ISMP encourages improvement through learned experiences and performance tracking. Recently, Fisheries and Oceans Canada (formerly known as DFO) released a "*Draft Urban Stormwater Guidelines and Best Management Practices for Protection of Fish and Fish Habitat*", which describes the need for developments to implement BMPs to manage storm water through volume reduction, water quality, and detention or rate control. The recommendations identified in this report fall in line with addressing these issues and subsequently the adaptive management strategy will be to ensure that these goals are in fact being met.

4.1 Environmental Monitoring

4.1.1 Water Quality and Flow Monitoring

Monitoring Anderson Creek in terms of concentrations of pollutants and total suspended solids in addition to flow rates will be necessary in determining watershed health. There is a requirement to establish baseline conditions and compare these with post-development conditions to properly analyze the effectiveness of the implementation plan and to provide concrete evidence to Township staff and stakeholders. As such, a water quality monitoring program and continuation of the flow monitoring program are recommended as part of the adaptive management process of this ISMP.

Water quality is measured by collecting discrete samples during low summer discharges to determine base flow conditions (primarily derived from groundwater), and during larger storm events in the fall or winter months where streams discharges exceed base flow rates. Samples should be collected at least twice a year for comparison with the initial baseline samples collected during the data collection stage of this ISMP. The parameters for water quality analysis data include:

- Total suspended solids (TSS);
- Nutrients (nitrogen and phosphorus);
- Heavy metals;
- Organics (including oil and grease); and
- Pathogens (bacteria, coliform).

The existing flow meter installed at 200 Street on the main stem of Anderson Creek is a viable location to continue monitoring creek flows and water levels as development occurs.

Additional monitoring could be completed during construction of any new subdivisions or other significant developments in key locations in the watershed, such as the municipal well protection zones. For example, the Township may consider mandatory post-development water quality and discharge quantity monitoring and reporting be performed for up to three years. This post-development monitoring and reporting should ideally include the collection of data for baseline (pre-development) conditions to better determine the changes that occur.

Monitoring of the groundwater quality in the Townships aquifers must be maintained, particularly in the well capture zones which can be vulnerable to contamination. Elevated nitrate concentrations previously observed in the Brookswood Aquifer can be an indicator that the groundwater is at risk for contamination from surficial activities such as pesticide and manure application, discharges from private septic systems, road salting operations, etc.

4.1.2 Benthic Invertebrate Biodiversity Index Monitoring

It is recommended that the same four sites where water quality and B-IBI samples were collected be maintained. These sites were specifically chosen as representative of various land forms including both ALR lands and urban residential lands in Anderson Creek watershed. Site AND-02 and AND-03 also straddle the segment of Anderson Creek that dries up during summer dry seasons.

When interpreting B-IBI data, there must also be an assessment of the entire health of the stream and the overall composition of various invertebrates present. There is a need to look beyond the monitored B-IBI counts in determining the status of stream health. For example, looking at the change in B-IBI scoring from one year to the next may only be representative of short-term effects that the stream is experiencing. It will be necessary to look at the historical nature of that stream and compare it to other streams within the Township to obtain an accurate understanding of its health condition.

There should also be a consistent protocol for B-IBI assessment between the Township of Langley and City of Surrey. At the time of this ISMP in which water quality and B-IBI sampling was performed, the method of assessment was the modified Metro Vancouver approach. However, the City of Surrey has currently adopted a Washington State methodology. It is recommended that discussions with Langley and Surrey be held to determine a common approach to B-IBI scoring.

B-IBI should be done within the summer months when water levels are low. The recommended sampling frequency is once every three years and it is preferable to perform samples before and after a major development occurs.

4.2 Erosion and Ravine Stability Monitoring

There a number of erosion and slope stability sites identified along Anderson Creek. Several of these are close to existing residential properties and it is recommended that the Township and City of Surrey continue to monitor erosion conditions, slope stability, outfall locations, and riparian areas for Anderson Creek and its tributaries every two years. In addition, pre and post-development field inspections for comparison of certain key sites to determine if conditions are changing should be undertaken. Ultimately, erosion of some areas will continue to occur given the current conditions but the Township must ensure that these and future problem areas are mitigated and riparian areas are protected as development occurs.

4.3 Public Outreach and Community Incorporation

Carrying out the long-term watershed vision must be a shared responsibility. Engaging communities, schools, and politicians to participate in the ISMP process is an important step that is at times under-emphasized or overlooked. The more education and awareness that is generated about the importance of maintaining watershed health, the more likely it will be for the Township to establish funding, create capital works projects, and take a pro-active approach to future planning.

4.4 Key ISMP Coordinator

Developing a successful adaptive management plan depends largely on the continual support of Township departments and stakeholders. However, it can be at times difficult to maintain the focus of the ISMP given the substantial timeline with inevitable staff changes and daily workload demands. To facilitate this, the Township should consider creating a new position which will be responsible in moving the goals and overall vision of the Anderson Creek ISMP forward. This key ISMP coordinator will be mandated to:

- Carry out the ISMP implementation plan;
- Carry out the performance monitoring and assessment of the ISMP and make recommendations on how to adapt the ISMP for future considerations;
- Work with Township staff to implement and change recommendations identified in the ISMP where practical and applicable;
- Review and update performance targets where applicable;
- Meet with inter-jurisdictional parties to report on data results and initiatives;
- Prepare reports to Council, stakeholders, and the public on the overall health of the Anderson Creek watershed.

4.5 Review and Adapting the ISMP

As the ISMP is carried out through development, issues that arise from planning, engineering, parks, and the public specific to the ISMP should be noted and filed. These issues can range from physical limitations of space to funding shortfalls and even aesthetic grievances in which the ISMP shall be re-examined as part of the adaptive management process.

Metro Vancouver's Integrated Liquid Waste and Resource Management Plan template recommends that ISMPs be updated every 12 years. Due to the development potential in the Anderson Creek watershed, the Township may consider reviewing this ISMP more frequently to adapt to ever-growing changes in the watershed. An update to the ISMP may be warranted if:

- There is a revision to the OCP, zoning bylaw, or Community Plan is amended with significant changes to future land uses;
- Water quality and flow monitoring data show watercourses with less base flows and higher amounts of pollutants after implementing the ISMP recommendations;
- Creek erosion is worsening and there is degradation in bank stability despite implementing the ISMP recommendations; or,
- Occurrences of flooding and damage to properties have increased.

5 Recommendations

Throughout the ISMP there are several recommendations put forward and these have been summarized in this section.

Development

- Development (or re-development) of properties adjacent to Anderson Creek, its tributaries, other water bodies, wetlands, forested areas, and wildlife corridors must comply with municipal, provincial and federal legislation, guidelines, best practices and other requirements.
  Section 1.2 and 1.3.5
- Stormwater source control BMPs must be implemented to limit peak flow rates and runoff volumes discharged to Anderson Creek and surrounding water bodies to predevelopment rates. These measures must also be in place to re-charge groundwater supplies to aquifers and baseflows to creeks.
  Section 2.3
- Enhanced infiltration should not be located along the top of steep slopes as pore water pressures increase contributing to slope instability and potential failure.
  Section 1.5.4 and 1.5.7
- The Township should initiate or require the developer(s) in the vicinity of 196 St south of 33A Ave to undertake a detailed study to investigate the groundwater table elevations and whether infiltration measures are practical in the vicinity of 196A Street and 198 Street south of 34A Avenue
  Section 1.5.7
- Further investigation of typical infiltration rates under steady state conditions should be undertaken to determine the design rates for enhanced infiltration systems.
  Section 1.5.7
- Infiltration is a viable strategy for new development but the runoff must be clean or filtered, and an overflow pipe system is needed.
  Section 1.5.4 and 2.4
- Green spaces and corridors should remain intact and fragmentation of ESAs should be restricted unless compensation measures are provided.
  Section 2.3.1

Studies

- Should consider undertaking a study to assess the interconnection between groundwater and surface water with particular emphasis on the slow release of groundwater back into the creek in the vicinity of Sunrise and Rees lakes, and Brookswood pond.
  Section 1.4.4 and 1.4.10

- Continue groundwater quality monitoring in the Brookswood Aquifer, particularly for nitrate concentrations.
  Section 1.5.7 and 4.1
- Township should continue to monitor erosion conditions, slope stability, outfall locations, and riparian areas for Anderson Creek and its tributaries every two to three years.
  Section 4.2

Administration

- Township should complete culvert inspections including the headwall and wingwall every 2 to 4 years particularly for reaches in Anderson Creek that are known to surcharge.
  Section 1.4.8 to 1.4.9
- Monitoring for water quality and benthic invertebrates should be continued to ensure current conditions are maintained (or ideally improve) and further degradation does not occur. Testing for road salts entering streams and groundwater could be included in the program.
  Section 4.1
- Implement the recommended Bylaw modifications and adopt the enforcement strategies discussed in Section 3.3. Introduce a stormwater source control Bylaw specific to the Brookswood area to enhance requirements for managing storm water quantity and quality.
  Section 3.3.1 to 3.3.3
- Develop material for further public education on stormwater source control best practices, particularly in relation to protection of the municipal water supply well capture zones.
  Section 3.3.4
- Township should create an ISMP coordinator position with responsibilities of moving the goals and overall vision of the Anderson Creek ISMP forward.
  Section 4.4

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APPENDIX A
Open House Feedback

Appendix A - Open House Feedback

Date	Jan. 15, 2013 Open House	Jan. 15, 2013 Open House	Jan. 15, 2013 Open Ho	Jan. 15, 2013 Open Ho	Jan. 15, 2013 Open House	Jan. 15, 2013 Open House	Jan. 15, 2013 Open House	Jan. 15, 2013 Open House	Jan. 15, 2013 Open House
Address	20730 Reese Lake Rd	19885 37A Ave	2552 207 St	2552 207 St	20643 36 Ave	4063 - 202 St	4264 196B St	3003 208 St	3695 197A St
1. What would you like included in the ISMP?			Storm sewers.	Stormwater catchment to prevent flooding.	Re-establishing natural meander of the watercourse in areas of historic modification not yet carrying the higher density development.		Presentation of all setbacks & riparian zones. Upgrade culverts to enhance fish passage. Stabilize banks with fish-friendly measures.	Consideration and consultation with people who own property through which it flows.	No to pesticide use in the township especially for non-agricultural land. No harmful pesticides, more organic farming.
2. What areas or features of the Watershed do you like?		The wildness of the creek.			Brookswood Park; Unfortunately one side of the creek has structures located too close to the edge (in hindsight should not have been allowed).		Quite, low traffic, green space, walking/biking areas.		
3. What areas or features need to be enhanced/improved?		Perhaps the water flow in the summer could be enhanced.	Better storm water management.		Noel Booth lower field / streamside interface. Due to redirection & inappropriate "containment" of riparian buffer. More natural infiltration areas with wetland features.		Increase riparian zones where possible.	The fat that it is "dry" 3 - 4 months a year and is mostly storm drainage the other months.	
4. What watershed areas or features should be preserved or protected?	I didn't get that much out of the presentation. My main concern is to protect the groundwater. Are there proven technologies to ensure this is possible?	The chum salmon run.			Any naturally existing marsh/swamp/bog areas should not be altered or removed in any future dev't projects (to reduce capacity).		Don't allow any more commercial development within (say) 300 m of creek.	Wildlife access around creek.	
5. Other Comments					Brookswood/Fernridge is known for gravel/sand and fast infiltration rates. This is great for visible reduction of standing water following high precip events but horrible for removing contaminants or preventing micro-particulate form entering the shallow, unconfined Brookswood aquifer. Any and all active wells adding to the municipal water supply should be assessed and re-assessed for the catchment/capture zones, and activities affecting the water supply should be researched thoroughly to compile a working list of ways to prevent compromising aquifer's resource.	Crank Creek at north end of 202 St cul-de-sac. NEVER in 15 years has there been fish in the creek. In fact, it hasn't had <u>any</u> active water in it for years - only a mud puddle!		Please don't try to bring back the "holding area" dikes on my property at 3003 208 St. It wasn't a sound idea.	
protect creek health		y			y		y		
manage stormwater runoff from dev't			y	y					
protect salmon environment		y							
bank erosion							y		
protect groundwater	y				y				
trails, access, viewing areass							y		
reduce flooding				y					
other		add water in summer	Storm sewers		protect marsh/swamp/bog areas	Crank Ck classification		Wildlife access	eliminate pesticide use

Appendix A - Open House Feedback

Date	Jan. 15, 2013 Open House	Jan. 15, 2013 Telcon	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House
Address	2994 204 St	2958 - 208 St	3579 198 St	21160 18 Ave	3834 205B St	2760 210 St	20889 32B Ave	20889 32B Ave
1. What would you like included in the ISMP?	Comprehensive drainage plan which would protect & preserve the levels and quality of B/F aquifer.		Save the fish spawning grounds for salmon.	A clear understanding of the relationship of stormwater management; new development including new wells & the effect on the aquifer replenishment.		HELP from the DEVASTATING flooding on our property. We flood every time it rains all over the whole 10 acres.	* clean up of some of the areas (I see so much garbage & debris in the creek from my house). * so much garbage it breaks my heart. * protection from farm run-off.	Improved clean-up of the creek (i.e., garbage, farm/suburban runoff) -> like Rivers Day. Also preservation of buffer zones & salmon and other fish habitat
2. What areas or features of the Watershed do you like?			A salmon hatchery.	The natural beauty of the center main watercourse.		None. It is picturesque at times but it does so much damage to our property.	Fish fry from the hatchery.	Fish in the creek
3. What areas or features need to be enhanced/improved?	Green belt adjacent to creek with public access (walking trails). Erosion protection.			Culvert road crossings at times are inadequate for the seasonal peak flows. This problem will get worse with more developments.		DRAINAGE - 28th ditch needs cleaning out - Anderson Creek needs cleaning out.	* not allowing pollution/runoff from farms * allow owners of adjacent properties allowing debris clean-up.	Some areas have lots of garbage, deadfalls, etc. that prevents free running of the creek. Clean up needs to be improved.
4. What watershed areas or features should be preserved or protected?	Fish habitat green belt. Clean water flow (all year if possible).		More water retention ponds.	All areas with continuous flow.		NONE - it makes our life absolute HELL.	* the areas near the fish hatchery. * clean up of the river.	As much natural environment as possible.
5. Other Comments	I am concerned over the lack of options being presented (considered) to preserve the quality and ensure the recharge of the aquifer in the face of impending development. Next public forum should include the choices, options and technologies available.	Asked about study solutions and costs. Mentioned a previous study that was going to cost them significant amounts of money. Problem is not their fault, but comes from upstream properties - runoff needs to be managed at the source.	We need to keep the flood water full in the wetlands. Stop the development of flood water.	The Township does not have a clear mandate to take corrective action where mass fill programs are changing the water flow on private property.	I lived in Burnaby for 40 years. Moved into Brookswood in 2005. My suggestion is to use the example of Burnaby's Byrne Creek management. This creek was in very poor condition and salmon left years ago. Byrne Creek was cleaned up & is managed well with the salmon coming back.	I have 2 huge storyboards of photographs documenting the flooding in our area/property which I will give to Meghan Lee.	Please clean up the river from debris. Hire a person once a year to do this so the fish have a fighting chance.	Once this river is dead it will be very difficult to bring it back. We need to preserve it now.
protect creek health	y			y			y	y
manage stormwater runoff from dev't	y		y	y	y			
protect salmon environment			y		y		y	y
bank erosion								
protect groundwater	y			y				
trails, access, viewing areass								
reduce flooding						y		
other			allow floodplain to flood	fill permit issues			clean up debris	

Appendix A - Open House Feedback

Date	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House	Jan. 19, 2013 Open House
Address	4276 196B St	19763 40A Ave	3772 197A St	4252 196B St	3772 197A St	19821 40A Ave	
1. What would you like included in the ISMP?	Focus on the erosion effect of development in the area. Some of our homes are situated on the bank.	More greenspace along creek as development occurs.	Environmental protection.	A complete evaluation of the stability of the banks & homes built along the creek. A plan to monitor debris build-up.		Water quality & volume closely regulated. A plan for homeowners backing on creek or ravine. A plan for saving existing banks.	Deal with flooding & drainage problems along 208 and 210 Street.
2. What areas or features of the Watershed do you like?	Pleasant natural environment.	Maintain creek integrity as development occurs.	Trails/access to the water.	Environmental protection.	The creek, the lake, green space.	The natural wildlife, salmon, eagles, herons - all bird life. Public access to creek.	At the moment, none. It supports fish & birds but these benefits are obliterated by the negative affects on flooding & drainage.
3. What areas or features need to be enhanced/improved?	Rain gardens, catchment areas to take the brunt of storm water and hold temporarily until release is appropriate (gate valves?).	Runoff management.		Debris removal to ensure resident safety/property values. Erosion of land - Township land which in turn is placing private property at risk.	All of the above	Protect existing banks from further erosion. Controlled access for public i.e., salmon watching platforms, eagle viewing areas.	Improve the discharge capacity in the flatter reaches and get water moved out of the flatter areas between 24 and 32 Ave and 212 to 208 St. Also, what's happening with land use upstream of about 216 St. How is that affecting streamflow?
4. What watershed areas or features should be preserved or protected?	Measures to ensure trees and native plants in the riparian zone are not eroded.	All. The creek supports a salmon run, the creek must not be impacted as development occurs.		Fish bearing raptor corridor as well as fauna. To ensure safety of native species/wildlife.	All of it.	As natural as possible, native trees & plants re-planted. Salmon need to be protected. Water quality & volume must be closely monitored.	Anderson Cr is an important stream for fish but that is not the "last word"; this creek need serious work in the above-noted area.
5. Other Comments	Anderson Creek has areas which need to be cleaned up, i.e., tree falls blocking up water. Riprap must be installed in weak areas. A few years ago I attended a session on riparian zones on Anderson Creek (TOL) and several recommendations were made by TOL consultants regarding riprap, etc. I do not believe all were addressed at or since that time. I suggest you locate this report and incorporate into ISMP.					Bank erosion and stability is a huge problem in our neighbourhood along Anderson Creek. This plan must increase safety and security for all landowners along the watercourse. More proactive not so reactive...must be similar costs. Langley and it's residents don't utilize this resource in Brookswood. How about a plan to ease access for people to enjoy the salmon spawn & eagles with viewing areas and trails for elderly & kids.	
protect creek health		y	y	y	y	y	
manage stormwater runoff from dev't	y	y				y	
protect salmon environment		y		y		y	
bank erosion	y			y		y	
protect groundwater							
trails, access, viewing areass			y			y	
reduce flooding							y
other							

Appendix A - Open House Feedback

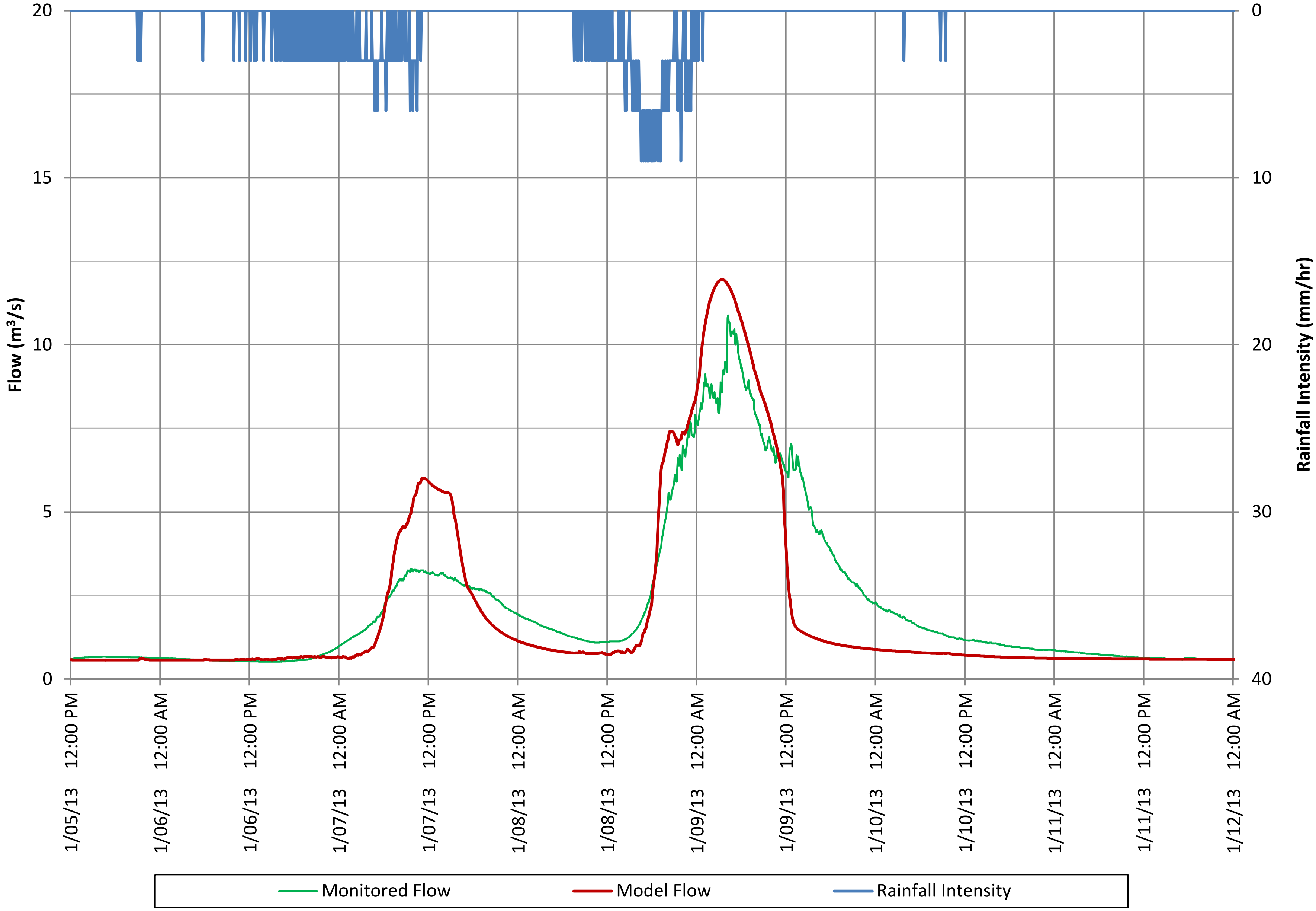
Date	Jan. 19, 2013 Open House	Received Jan. 19, 2013 (Letter)	Received Jan. 25, 2013	Received Jan. 28, 2013
Address		20643 36 Ave		20724 Rees Lake Rd
1. What would you like included in the ISMP?	Protection of tributaries, creeks, and watershed into Anderson Creek. These small streams, ditches, etc. provide water & food/nutrients, etc.		Appropriate setbacks to protect creek. Reduction of extraction of ground water to increase flow from "0" to what is was in the 1950's (use and require GVRD water be used - "no more wells")	Nicomekl Enhancement Society input/concerns. Biundary Health Unit concerns about risk of health; fish and community Fisheries and Oceans Habitat - concerns
2. What areas or features of the Watershed do you like?	Protection of the watershed . Fill permits should not be granted by the Township.			
3. What areas or features need to be enhanced/improved?	All areas of the watershed should be protected!! Without the watershed, there is no Anderson Creek.			Upstream water retention ponds Maintenance of creek; catch problems early
4. What watershed areas or features should be preserved or protected?				Nature; and individual property owners that are directly impacted by Anderson Creek ISMP
5. Other Comments		Key points related to stormwater: - glad to see stormwater planning on a watershed basis - road runoff is polluted and infiltrating it generates concerns about the aquifer - rain gardens or bioswales will not effect any protection for the integrity of the watershed if the levelling of a property with healthy stands of vegetation is permitted. - nothing is a better indicator of watershed health than the population of salmonids		All costs associated to property owners and details and information provided at all steps. Less disturbance of creeks and natural habitat.
protect creek health	y			y
manage stormwater runoff from dev't				y
protect salmon environment				
bank erosion				
protect groundwater				
trails, access, viewing areass				
reduce flooding				
other	don't issue fill permits			contact Nicomekl Enhancement; Boundary Health

Appendix A - Open House Feedback

Date	Received Jan. 28, 2013	Received Jan. 28, 2013	Received Jan. 31, 2013	Receiver Feb. 4, 2013 (email)
Address	19897 43 Ave	20798 Rees Lake Road	4088 - 198 St	19821 28 Ave
1. What would you like included in the ISMP?	The key items listed in the presentation area. What needs to be included - the missing element is how to achieve these goals.	I don't know what this quastion is asking.	When we have 2 or 3 feet of snow and seven days of rain this is no a creek it's a river. We have seen trees going by in the water and the stormwater is the cause of this and has to be addressed. When trees fall they take the banks with them.	
2. What areas or features of the Watershed do you like?	Protecting watre quality and aquifer & supporting fish and wildlife habitat.	Like the green space	We have deer, racoons, possums, coyotes, herons, eagles, owls, ducks, squirrels, fish, all creatures large and small live in this corridor and on our property. We have dozens of different birds here all year around.	
3. What areas or features need to be enhanced/improved?	Protection from development- we have already ?? enough water sheds - it is time for protection not "PAVEMENT".	Looks good to me in a natural state	You can't put another drop of water into this creek. You have to put all the storm water into reservoirs and stabilize the high banks.	
4. What watershed areas or features should be preserved or protected?	is there a reason we can't preserve and protect itall - I think this overrides development.	Ground water - Rees Lake wate levels have dropped since the greenhouses along 208 and 24th were built.	The area of Anderson Creek from 200 th to 196 has high banks and very fragile soil. You cannot put more water into this creek. We have lived on the banks of this creek for 24 years. We see the creek every day, before we purchased this house I went to the town hall to ask the Engineering Dept. (where I was directed to go) and I asked if there was anything about future plans that would change or effect this creek. I was told that nothing would be done in or around this creek because the banks were so fragile and it was a corridor for the wild animals. We made sure that we went to every meeting regarding this creek or development. We were always told that it would be impossible to put storm water in this creek because the banks were far too fragile and nay storm water would go into reservoirs or lakes in the area. No subdivision could be approved until these problems were fixed and in place. Some storm water has been put into the creek with very disastrous results. We have talked to Randy in parks, Wayne in engineering, Lakevold, Pat Anderson, Bill Linsdal, Kevin Fraser, Stephen Richardson, Steven Lan, Jamie Umpuly, Phillip Hill, Antigone, Warren, and many people hired by the township to study this problem. We were told by one person that is so serious if left unsolved it will be a disaster.	
5. Other Comments				Should not be inviting uses which have a high probability of contaminating the vulnerable (porous gravel) shallow (5 - 7 meters below the surface in areas) ground water table. Should disallow: - Agricultural uses involving the rearing of poultry and animals - Commercial greenhouses Storm runoff from impervious surfaces should be directed back to the ground to recharge the aquifer. There will be a net loss of ground water from septic systems to sanitary sewers transporting the water away however this is much better for the aquifer quality.
protect creek health	y	y		
manage stormwater runoff from dev't	y			
protect salmon environment	y			
bank erosion				
protect groundwater	y			
trails, access, viewing areass				
reduce flooding				
other	prefers no development at all			

APPENDIX B
Model Calibration Summary

Figure B-1: Anderson Creek at 200 St. - Jan 8 2013 Calibration



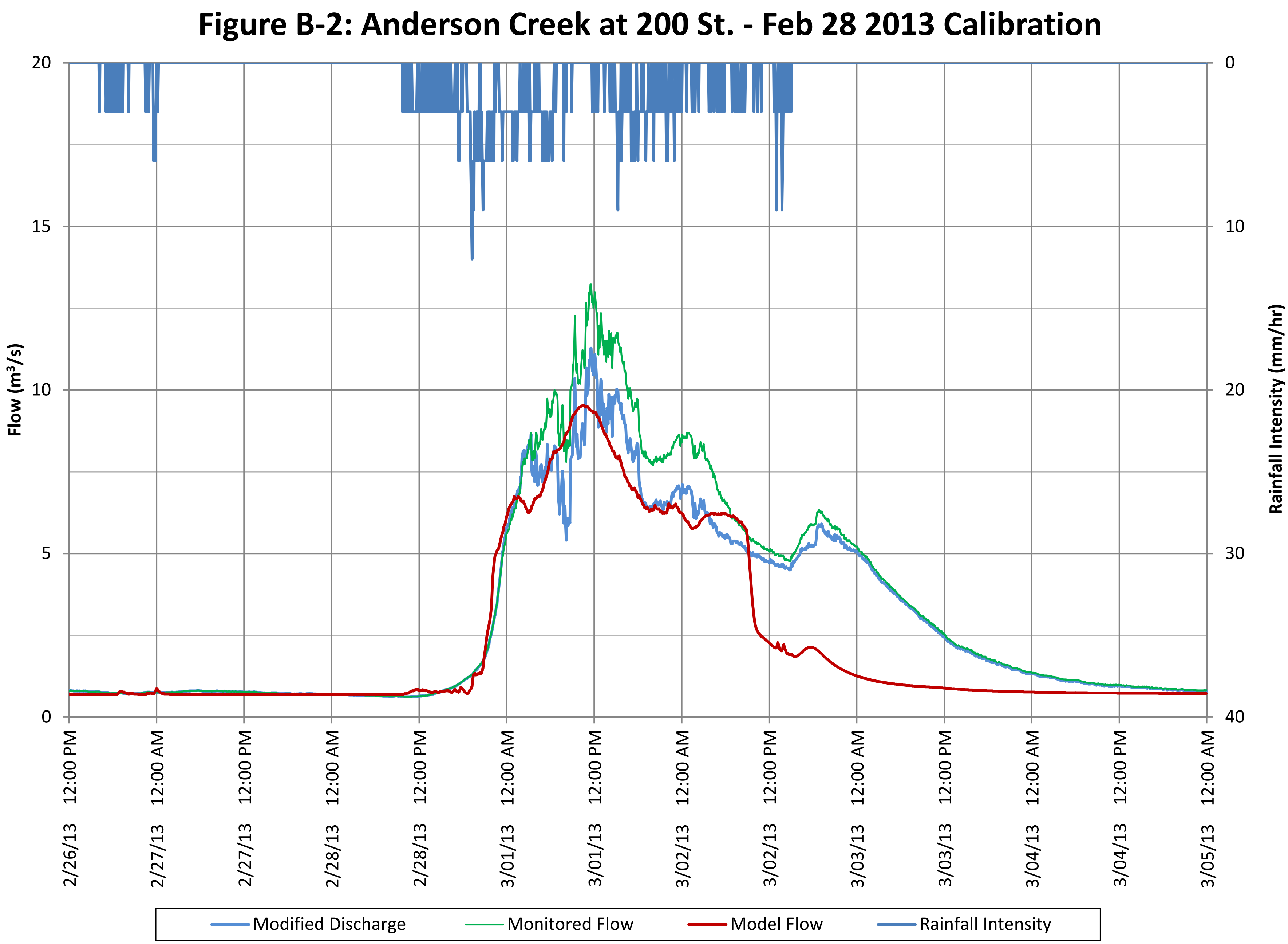
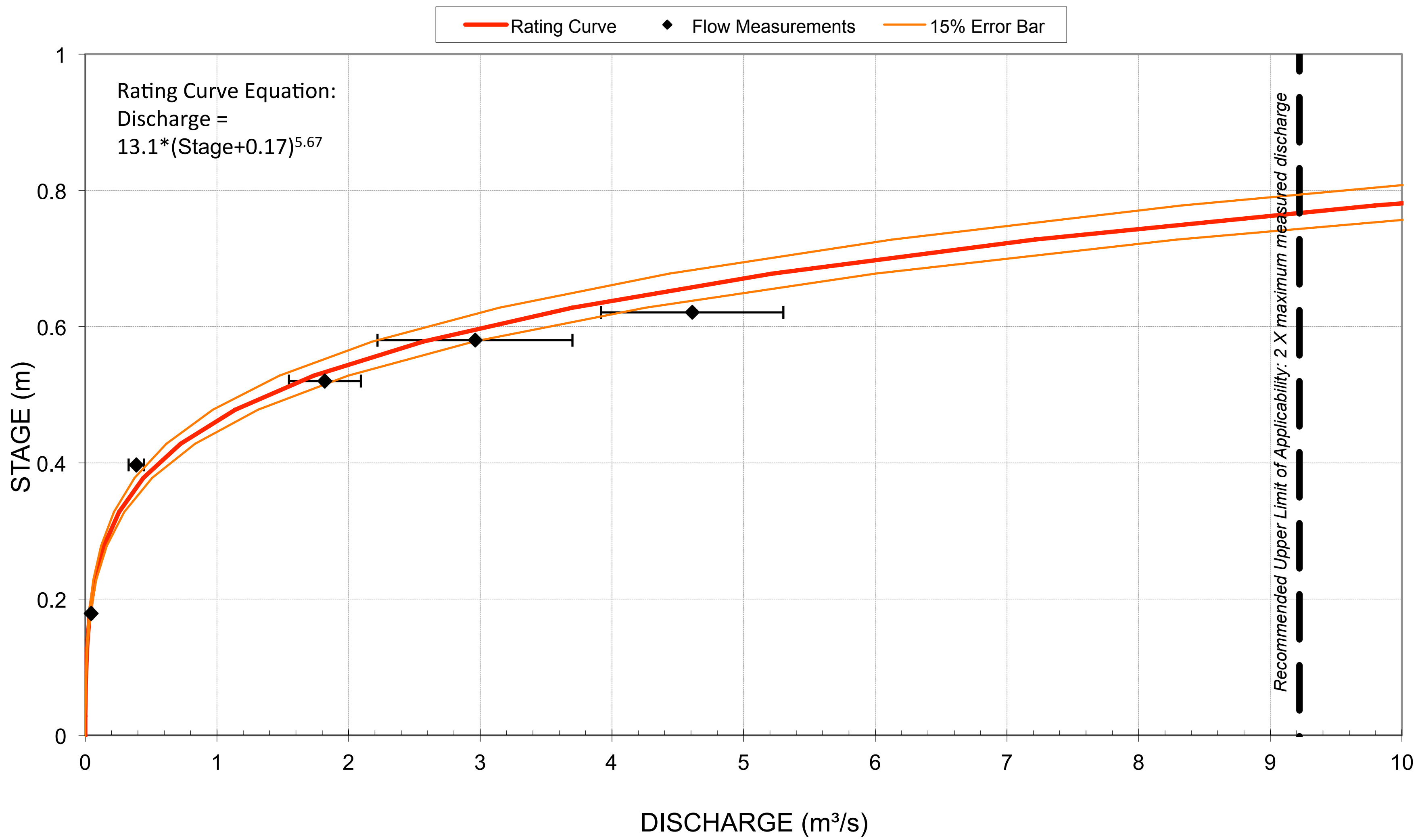


Figure B-2: Anderson Creek at 200 St. - Feb 28 2013 Calibration
Flow (m³/s)
Rainfall Intensity (mm/hr)
20
15
10
5
0
0
10
20
30
40
2/26/13 12:00 PM
2/27/13 12:00 AM
2/27/13 12:00 PM
2/28/13 12:00 AM
2/28/13 12:00 PM
3/01/13 12:00 AM
3/01/13 12:00 PM
3/02/13 12:00 AM
3/02/13 12:00 PM
3/03/13 12:00 AM
3/03/13 12:00 PM
3/04/13 12:00 AM
3/04/13 12:00 PM
3/05/13 12:00 AM
Modified Discharge
Monitored Flow
Model Flow
Rainfall Intensity

2012 Stage-Discharge
(Estimated by Method of Maximum Likelihood)
Anderson Creek



KERR WOOD LEIDAL
consulting engineers

APPENDIX C
Infiltration & Soil Testing Memorandum

AECOM
3292 Production Way, Floor 4
Burnaby, BC, Canada V5A 4R4
www.aecom.com
604 444 6400 tel
604 294 8597 fax

Memorandum

To	Stephen Bridger	Page	1
CC			
Subject	Anderson Creek Infiltration Testing and Soil Sampling		
From	Christina Hendry; Ryan Mills		
Date	July 18, 2013	60267316	

1.0 Introduction

1.1 Background

The Anderson Creek stormwater management system within the Brookswood community of Langley, BC was developed in the early 1990s to minimize property damage and control overland water flows from the 5-100 year storm events. In this area, Anderson Creek flows through mainly single family residential development until it reaches 200 Street at 40 Avenue where commercial and institutional developments are also present.

Anderson Creek flows to the northwest about 10 km from its headwaters in the south central Langley Township before discharging to the Nicomekl River. Surficial materials in the Anderson Creek area are generally proglacial deltaic sand and gravel sediments, which comprise the Brookswood Aquifer.

The stormwater management system consists of strategically placed sumps connected to perforated lateral pipes placed within a trench backfilled with crushed gravel. Filter fabric is used to separate native soils from the gravel filled trench and minimize the amount of fines entering and potentially clogging the system. The catch basins, lateral pipes and associated gravel trenches were generally located below ditches or low lying areas where surface runoff is likely to collect. After water collects within the catch basin, sediment settling occurs. Water subsequently decants into the lateral pipes and drains into the ground beneath the lateral pipe. The sumps typically have concrete bases that collect and store runoff until it can infiltrate to ground through the perforated lateral pipe. Regular maintenance is required to ensure sediment removal and long-term performance.

1.2 Initiation

As part of the ongoing Anderson Creek Integrated Stormwater Management Plan (ISMP), AECOM conducted an infiltration testing and soil sampling program on the Anderson Creek stormwater management system within the Brookswood community of Langley, BC. Details of the workplan were provided in AECOMs proposal dated April 20, 2012 and subsequently refined during discussions with Township of Langley staff. Five locations with lateral perforated stormwater collection pipes were selected for the program and included: 198A Street and 38 B Avenue (Site 1), 35 Avenue and 200

Street (Site 2), 20746 40 Avenue (Site 3), 4257 199A Street (Site 4), and 201 Street and 40 Avenue (Site 5) (hereafter referred to as the "Sites").

1.3 Scope

The scope of the program consisted of the following:

- Mobilization to the Sites;
- Daylighting two test pits at each of the Sites;
- Collecting three soil samples at each Site as follows:
  - from the lateral pipe or catch basin
  - from one test pit adjacent to the gravel filled trench
  - from a second test pit located approximately two metres upslope of the sump
- Submission of samples from two of the Sites for analysis at ALS Environmental laboratories (ALS), Burnaby, BC.
- Performing infiltration tests prior to, and following maintenance measures to assess the effectiveness of infiltration laterals and within the background test pit;
- Analysis of infiltration test data and soil sample analysis results; and
- Completion of this memorandum.

2. Field Investigation Methods

On May 14, 2013, AECOM performed infiltration testing and collected soil samples at each of the Sites identified above.

2.1 Soil and Sediment Sampling

Samples of soil were collected from three locations at each Site. Samples collected at two of the five sites were analyzed for potential contaminants that commonly occur in roadway runoff. Soil was collected from a location adjacent the lateral pipe to assess the degree to which compounds are being attenuated in adjacent soils (hereafter referred to as the "attenuation" sample) and a nearby (less than 5 m) undisturbed area upslope of the sump to assess the quality of native soils (hereafter referred to as the "background" sample). Surficial soil was also collected adjacent the top of the sump to determine the degree to which they are impacted by stormwater runoff. The lateral pipes at each of the Sites were typically free of sediment at the pipe opening or infilled with organic debris (e.g., sticks, leaves, evergreen needles, etc.), which is not considered suitable for this type of assessment and comparison to soil quality standards. Soil samples from two of the Sites were sent to ALS for analysis of hydrocarbons (extractable petroleum hydrocarbons [EPH] and polycyclic aromatic hydrocarbons [PAH]), total metals and toxicity characteristic leachable procedure (TCLP).

Soil analysis results were compared to the BC Contaminated Sites Regulation (CSR)[1] and the Hazardous Waste Regulation (HWR) Leachability Standards[2] to assess soil quality. According to the Environmental Management Act (EMA), industrial standards (IL) apply to soil within transportation right of ways. Because most zoning within the Brookswood community is residential, and in light of

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[1] *Contaminated Sites Regulation*, BC Ministry of Environment, April 1, 1997, 375/96, includes amendments up to BC Reg 97/2011.

[2] *Hazardous Waste Regulation,* BC Ministry of Environment, February 18, 1988, 63/88, includes amendments up to BC Reg 63/2009.

the potential exposure through the groundwater pathway, soil quality results were compared to CSR standards for residential use (RL).

2.1.1 Surficial Soil Samples

Surface soil was collected by hand or by shovel adjacent to sumps located at each Site after removing organic material. Each sample was collected from the top 10 cm of the soil profile and placed in laboratory prepared soil jars, which were then placed in a cooler for transport to ALS.

2.1.2 Background Samples

McRae's Environmental Services (McRae's) daylighted one test pit in a nearby undisturbed area upslope of the sump at each Site using a hydrovac. Each test pit was cleared to a depth of approximately 0.6 m to 0.8 m below ground surface (bgs). The soil samples were collected by hand from approximately 0.6 m bgs in laboratory prepared soil jars, which were then placed in a cooler for transport to ALS.

2.1.3 Attenuation Samples

McRae's Environmental Services (McRae's) daylighted one test pit adjacent the lateral pipe at each Site using a hydrovac. Each test pit was cleared to a depth of approximately 0.6 m to 0.7 m bgs to collect a sample of soil through which infiltrating stormwaters would pass to assess the influence of stormwater quality on soil quality adjacent to the trench. The soil samples were collected by hand from approximately 0.6 m bgs in laboratory prepared soil jars, which were then placed in a cooler for transport to ALS.

2.2 Infiltration Testing

Infiltration testing was performed on the background soil test pit and the lateral pipe and trench system. The lateral pipe and trench system was tested under two conditions: the existing condition of the system upon arrival at the Sites and after performing maintenance on the system which involved vacuuming sediments out of the sump and lateral perforated pipes.

Measurements of the sump dimensions (diameter and depth), the lateral pipe dimensions (distance below ground surface, diameter and length) were recorded prior to performing the infiltration tests. The lateral pipe length and trench width were assumed based on information provided by Township of Langley staff knowledge indicating that the lateral pipes ended at driveways or were 13 feet long and the trenches were usually 2 feet wide.

Infiltration testing on the existing condition of the lateral pipe and trench system was performed upon arrival at the Sites. Water from a Township of Langley water truck was supplied to the selected sumps via a fire hose. The sump was filled with water until the lateral pipe was full and the water input rate exceeded the storage capacity of the infiltration gallery, denoted by ponding above the lateral pipe opening within the sump. Once this ponding occurred, the flow rate of the water being added to the sump was reduced until a steady state ponded water level was achieved within the sump. The depth to this steady state water level was recorded, and the flow rate of the water from the fire hose was determined by repeatedly measuring the amount of time to fill a 20 L bucket. The flow meter affixed to the water truck was not suitable for measuring infiltration rates because it reported flow rates in units of litres per kilometer, without specifying the assumed velocity of the vehicle.

2.2.1 Existing Condition Infiltration Test

Infiltration testing was performed at the existing condition of the lateral pipe and trench system to determine the infiltration capacity of the system prior to maintenance measures.

The above method of infiltration testing was performed at each of the Sites, except Site 2, which had a slower infiltration rate than the other sumps. When water was added to the Site 2 sump at a similar flow rate to the other sites, the lateral pipe and trench system ponded quickly, resulting in the sump filling to ground surface. Infiltration testing at Site 2 was performed by measuring the rate at which the ponded water level decreased. This was performed by measuring the rate of water level decline between ground surface and the top of the lateral pipe.

2.2.2 Post-Maintenance Infiltration Test

Maintenance on the sump and lateral pipe was performed by McRae's following the existing condition infiltration test. Ponded water and collected sediment and debris were pumped from the sump with McRae's vacuum hose until the sump was dry. McRae's used their water lance to clear debris and sediment from the lateral pipe into the sump, and then removed this material from the sump with their vacuum hose.

After completion of maintenance activities, another infiltration test was performed on the lateral pipe and trench system to permit an assessment of the influence of regular system maintenance on system function.

The infiltration test method described above was performed at each of the Sites, except Site 3, which was installed recently and sediment had not yet accumulated in the system. As such, it did not appear to require maintenance and would likely have exhibited the same infiltration rate before and after maintenance.

The post-maintenance flow rate could not be accurately determined at Site 5 because the water pressure and volume of water emanating from the fire hose was too high and the bucket filled too rapidly, making it unfeasible to accurately measure the flow rate. Instead, the time to fill the bucket was visually estimated relative to previously measured flow rates.

2.2.3 Background Soil Infiltration Test

Infiltration testing was performed within the test pit used for background soil sampling to permit a direct assessment of the infiltration capacity of the native soil. By measuring the infiltration capacity of the native soil directly, the need to assume pipe lengths and trench width were avoided.. The infiltration test method described above was used to complete the infiltration testing in the test pits.

3. Data Interpretation

3.1 Estimated Infiltration Rates

Infiltration testing was performed at the Sites on May 14, 2013. These infiltration tests were conducted on the existing conditions of the lateral pipe and trench, the post-maintenance condition of the lateral pipe and trench and within a test pit of the background soil conditions at each of the Sites. Calculated infiltration rates are presented in Table 1.

Table 1. Results of Infiltration Testing

Site Number	Infiltration Basin Configuration					Infiltration Rate (mm/hr)		
	Basin Diameter (m)	Basin Depth (m)	Length of Lateral (m)	Lateral Diameter (m)	Assumed Width of Gravel Trench (m)	Pre-Maintenance	Post-Maintenance	Test Pit
1	0.70	1.70	3.96	0.10	0.60	2,753	1,594	14,979
2	0.70	0.62	3.96	0.15	0.60	318	1,893	4,874
3	0.60	0.90	4.60	0.15	0.60	2,609	2,609	4,753
4	0.60	0.90	3.96	0.15	0.60	176	5,047	7,601
5	0.60	0.90	4.00	0.15	0.60	1,667	7,500	5,453

The infiltration rates calculated for the existing condition ranged from 176 mm/hr to 2,753 mm/hr. Sites 2 and 4 exhibited the lowest infiltration rates (318 mm/hr and 176 mm/hr, respectively), while Sites 1 and 3 exhibited the highest infiltration rates (2,753 mm/hr and 2,609 mm/hr, respectively). These infiltration rates are considered representative of conditions prior to achieving steady state. Long-term steady state infiltration rates are expected to be lower, but would take significantly longer to achieve given the configuration of the stormwater infiltration basins and permeability of the underlying materials.

The infiltration rates calculated for the post-maintenance condition ranged from 1,594 mm/hr to 7,500 mm/hr at Sites 1 and 5, respectively. A post-maintenance infiltration test was not performed at Site 3 because the lateral pipe was recently installed and did not appear to require maintenance. Therefore, the post-maintenance infiltration rate at Site 3 is assumed to be the same as the existing condition rate.

Infiltration rates in the background soil test pits ranged from 4,753 mm/hr to 14,979 mm/hr at Sites 3 and 1, respectively. Again, these rates are not considered to be reflective of steady-state infiltration rates. A much longer testing period is required to appropriately characterize steady-state infiltration rates in the soils encountered on site.

3.2 Soil and Sediment Quality

Three soil samples were collected from each of the Sites on May 14, 2013:

1) a background sample;
2) a surficial soil sample; and
3) an attenuation sample.

Of the samples collected from each of the 5 Sites, soil samples collected from Sites 2 (200 Street and 35 Avenue) and 4 (4257 199 A Street), were analysed by ALS for EPHs, PAHs, metals and TCLP. Laboratory analytical results are presented in Table 2. The samples from these two sites were selected to determine the quality of soil adjacent to infiltration systems located near a main road with heavy traffic flow for the Brookswood community (Site 2) and on a residential road with minimal traffic (Site 4). The stormwater collection systems at these two sites have been installed for numerous years and soil is considered representative of long-term operations.

3.2.1 Site 2

The surface soil sample collected at Site 2 was dark brown organic silt with trace fine grained sand. Soil collected from the attenuation and background sample locations consisted of medium grained sand with some coarse gravel, some to trace cobbles and trace silt. The attenuation sample was brown and the background sample was reddish brown.

The surface sample collected from Site 2 exhibited concentrations that were generally below the applicable standardswith the exception of chromium, which exceeded both CSR RL and CL standards. Detectable concentrations were reported for most of the remaining metals that were analysed, HEPH and most PAHs in this surficial soil sample. TCLP metals concentrations in the surficial soil sample were below the MDL, with the exception of leachable calcium, magnesium and zinc. Of these three leachable metals that were detected, only zinc is regulated, but concentrations were well below the standard of 500 mg/L, with a concentration of 0.62 mg/L.

The attenuation and background samples collected from Site 2 reported concentrations below the CSR RL and CL standards and the HWR Leachability Standards for the analysed hydrocarbons, metals and TCLP. Both samples exhibited detectable concentrations of some metals, but concentrations were below the laboratory method detection limit (MDL) for LEPH, HEPH and PAHs. TCLP metals concentrations in the attenuation and background samples were below MDL with the exception of leachable calcium in the attenuation sample. Leachable calcium is not regulated by the Hazardous Waste Regulation.

3.2.2 Site 4

The surficial soil sample collected from Site 4 consisted of medium grained sand with trace fine and coarse gravel. This sand was orangey brown and contained organic matter including roots.

The background soil sample collected from Site 4 was medium grained sand with some cobbles, some coarse gravel and trace silt. This sand was orangey brown and contained organic matter including roots.

The attenuation soil sample collected from Site 4 consisted of brown sandy silt with trace coarse gravel. The sand was medium grained, however trace fine grained sand was also present.

The surficial soil sample collected from Site 4 exhibited concentrations below the applicable standards for all analysed parameters. LEPH/HEPH concentrations were below the MDL in the surficial soil sample. TCLP metals concentrations in the surficial soil sample were generally below

MDL with the exception of leachable calcium and magnesium. Most metals and PAH concentrations were detectable.

The attenuation sample collected from Site 4 exhibited concentrations below the applicable standards for all analysed parameters, except arsenic, which was present at a concentration that exceeded CSR RL and CL standards. Most of the other analysed metals had detectable concentrations in the attenuation sample. Concentrations of TCLP metals, LEPH/HEPH and PAH were below the MDL in the attenuation sample.

The background sample collected from Site 4 exhibited concentrations below the applicable standards for all analysed parameters. TCLP metals, LEPH/HEPH and PAHs were below the MDL in the background sample, however most metals had detectable concentrations.

3.2.3 Other Sites

Although the samples collected at Sites 1, 3 and 5 were not analysed, their physical properties are described below.

The soil collected from the attenuation and background sample locations at Site 1 consisted of brown medium grained sand with some coarse grained sand. The surface soil sample collected at Site 1 consisted of silt with some fine to medium grained sand and some fine and coarse gravel. This material was brown with rusty coloured mottling and had some organics such as grass and roots.

The soil collected from the attenuation and background sample locations at Site 3 consisted of brown fine to medium grained sand with some silt. The surface soil sample collected at Site 3 consisted of grey medium grained sand with some fine gravel and some silt.

The soil collected from the attenuation and background sample locations at Site 5 consisted of brown silt and fine to medium grained sand with some gravel. Some cobbles were present in the attenuation sample location. The surface soil sample collected from Site 5 consisted of organic silt with some fine to coarse gravel, trace cobbles and trace fine grained sand.

4. Conclusions

Based on the results of our field investigation, the following conclusions can be made:

4.1 Infiltration Rates

- Infiltration rates were difficult to determine due to the configuration of the stormwater catch basins. The high permeability of the underlying material, the depth of the water table and a relatively short testing period meant that testing conditions did not reach steady-state. A flow meter capable of accurately measuring high flows would have improved the confidence in flow estimates.

- The reported infiltration rates are considered representative of early time infiltration rates shortly after the onset of precipitation and may represent an upper bounds estimate. Steady state infiltration rates are anticipated to be much lower. As such, the infiltration rates presented in this memo should not be used as a basis for design or construction.

- Based on the results obtained from test pits, infiltration rates appear to be relatively similar between sites, with the exception of Site 1, which exhibited much higher infiltration rates. Due to site constraints, this test pit was excavated in close proximity to the infiltration gallery which was backfilled with gravel and may have biased results upward.

- With the exception of Site 1, infiltration rates increased significantly after completion of maintenance works. The moderate decrease observed at Site 1 after maintenance may be the result of approaching steady-state conditions. Infiltration rates were expected to increase after maintenance as the lateral pipes generally collect sediment and debris, which obstruct water flow. This highlights the need for, and effectiveness of, regular maintenance of both the sump and lateral pipes to ensure maximal infiltration of stormwater to the underlying aquifer and reduced surface ponding. It is our understanding that the lateral pipes are not typically flushed as part of regular maintenance activities.

- The higher infiltration rates obtained for test pits compared to the lateral pipe configuration may indicate that sediment has built up surrounding the infiltration gallery over time, despite regular maintenance. This is further supported by the presence of more variable infiltration rates for the post-maintenance condition compared to the test pit configuration. This hypothesis could be reassessed under more controlled tests involving a flow meter and much longer testing periods if information is required in key areas of the Anderson Creek drainage.

4.2 Soil Quality

- Soil from background, surface and attenuation locations at Sites 2 and 4 were analysed for LEPH/HEPH, PAH, metals, and TCLP metals. Comparison of the results with the British Columbia Contaminated Sites Regulation (CSR) Residential (RL) Land Use Standards RL and the Hazardous Waste Regulation (HWR) Leachabilty Standards suggested that all samples were either below the method detection limit (MDL) or below the applicable standards for the analysed parameters, except for chromium in the surface soil sample at Site 2 and arsenic in the attenuation sample at Site 4, which both exceeded CSR-RL standards. The marginal arsenic exceedence (17.9 mg/kg), was only slightly above the standard of 15 mg/kg. Similarly, the chromium concentration was 60.3 mg/kg and only marginally above the standard of 60 mg/kg and the reference background concentration of 58.9 mg/kg. Analytical results for soil typically vary on the order of ± 20%. The land use based standards for arsenic and chromium are based on exposure of humans to drinking water. Lands adjacent to roadways are typically considered commercial land use, whereby CSR Commercial Land Use (CL) standards would apply. These standards are less stringent for some parameters, but given the proximity to residential lands, RL standards were applied to be conservative.

- At both sites, the surface soil sample typically exhibited the highest concentrations of the analysed parameters, with the attenuation and background samples exhibiting similarly low or non-detectable concentrations. Concentrations of metals were generally higher in the surface soil samples, except at Site 4. TCLP metals (leachable calcium, magnesium and/or zinc) were only detected in the surface samples with the exception of the attenuation sample at Site 2, which exhibited a low concentration of leachable calcium. Additionally, hydrocarbons were only detected in the surface soil samples, and may be related to runoff from nearby paved surfaces which are considered to be a potential source of petroleum hydrocarbons and PAH's.

- The metals concentrations in the attenuation sample at Site 4 were higher than both the surface and the background samples, including elevated arsenic. The difference between concentrations of metals in each of the three samples at Site 4 may be the result of a localized source or a mechanism other than stormwater runoff. If surface runoff reaching the lateral pipe caused the elevated metal concentrations, the surface sample would likely also exhibit similar or greater concentrations of metals than the attenuation sample. Based on information collected at two sites, concentrations in the attenuation samples are similar to concentrations in the background samples and are generally lower than concentrations in the surface soil samples.

- Based on the above results, contamination of groundwater below lateral pipes and infiltration trenches is unlikely in areas under similar land and road use conditions. The impacts of elevated concentrations of metals and hydrocarbons in surface soil do not appear to extend to the lateral pipes or the adjacent soils. Traffic volume does not appear to appreciably affect the soil quality in the lateral pipes as there is little difference in concentrations of potential contaminants between sites located in residential neighbourhoods (Site 4) and sites collecting runoff from busy intersections (Site 2). Because soil impacts were not observed, the impacts of infiltrating stormwater on groundwater quality in the Brookswood Aquifer are not likely significant.

5.0 Recommendations

Based on the conclusions presented above, the following recommendations are offered:

- Based on feedback from contractor staff, the lateral pipes are not typically maintained as part of regular maintenance of the sumps. The sumps and lateral pipes should be maintained at regular intervals ensuring that the complete system is flushed free of debris.

- Based on the results of soil testing at two sites, the two marginal exceedances of arsenic and chromium standards are present. They are present at concentrations near reference values or may be related to a point source in native material adjacent to the infiltration gallery. Based on the data available, it does appear that special handling of soil slurry removed from lateral pipes and sumps is required.

- If steady-state infiltration rates are required to better constrain ongoing stormwater modelling, consideration should be given to excavating a large test pit to facilitate conducting double-ring infiltrometer tests for several hours. This type of testing would require a backhoe and a calibrated flow meter capable of measuring flow rates in litres per minute. To remove the uncertainty associated with as-built dimensions and construction materials, future testing should not utilize infiltration galleries if the goal is to determine infiltration rates of the geologic media.

Attachments:

Table 2.	Soil and Sediment Quality Results
Appendix A.	Infiltration Testing and Soil Sampling Site Locations
Appendix B.	Laboratory Analytical Certificates

Table 2: Soil and Sediment Quality Data

Sample ID Date Sampled	Units	SITE2-A 14-MAY-13	SITE2-B 14-MAY-13	SITE2-S 14-MAY-13	SITE4-A 14-MAY-13	SITE4-B 14-MAY-13	SITE4-S 14-MAY-13	CSR Residential Land (RL) Standards	Hazardous Waste Regulation
Physical Tests									
Moisture	%	12.6	12.8	39.6	11.5	13.7	18.0	n/a	n/a
pH	pH	6.42	6.48	5.81	5.76	5.51	5.57	n/a	n/a
Metals									
Antimony (Sb)	mg/kg	0.23	0.25	2.29	0.19	0.65	1.13	20	n/a
Arsenic (As)	mg/kg	4.40	5.12	4.05	**17.9**	11.9	12.5	15[a]	n/a
Barium (Ba)	mg/kg	26.6	30.0	48.8	61.0	47.4	54.2	400[a]	n/a
Beryllium (Be)	mg/kg	<0.20	<0.20	<0.20	0.28	0.25	0.24	4	n/a
Cadmium (Cd)	mg/kg	0.068	0.103	0.175	0.058	0.083	0.180	1.5 (pH <6.5)[a]	n/a
Chromium (Cr)	mg/kg	30.7	34.7	**60.3**	31.7	28.1	26.5	60[a]	n/a
Cobalt (Co)	mg/kg	5.77	6.46	5.91	6.66	6.12	5.64	50	n/a
Copper (Cu)	mg/kg			51.3	16.7	14.7	15.0	200 (pH 5.5 - <6.0)[a]	n/a
		15.8	12.9					1500 (pH 6.0 - <6.5)[a]	n/a
Lead (Pb)	mg/kg			85.6	2.55	3.47	34.10	100 (pH <6.0)[a]	n/a
		1.87	1.94					250 (pH 6.0 - <6.5)[a]	n/a
Mercury (Hg)	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	0.052	15[a]	n/a
Molybdenum (Mo)	mg/kg	<0.50	<0.50	2.01	0.62	0.56	0.79	10	n/a
Nickel (Ni)	mg/kg	29.0	28.6	18.5	29.1	27.0	19.5	100	n/a
Selenium (Se)	mg/kg	<0.20	<0.20	<0.20	0.24	0.21	0.20	3	n/a
Silver (Ag)	mg/kg	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10	20	n/a
Thallium (Tl)	mg/kg	<0.050	<0.050	<0.050	<0.050	0.050	0.055	n/a	n/a
Tin (Sn)	mg/kg	<2.0	<2.0	2.1	<2.0	<2.0	<2.0	50	n/a
Uranium (U)	mg/kg	0.227	0.225	0.249	0.387	0.345	0.331	16	n/a
Vanadium (V)	mg/kg	41.4	48.1	41.8	52.0	46.0	39.9	200	n/a
Zinc (Zn)	mg/kg			147	31.7	40.5	57.5	150 (pH <6.0)[a]	n/a
		28.6	30.6					1000 (pH 6.0 - <6.5)[a]	n/a
TCLP Metals									
1st Preliminary PH	pH	6.54	6.47	6.61	5.84	5.68	6.08		
2nd Preliminary PH	pH	1.16	1.16	1.18	1.17	1.17	1.20		
Final pH	pH	4.96	4.99	4.94	4.95	4.93	4.94		
Extraction Solution Initial pH	pH	4.88	4.88	4.88	4.88	4.88	4.88		
Antimony (Sb)-Leachable	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	n/a	n/a
Arsenic (As)-Leachable	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	n/a	2.5
Barium (Ba)-Leachable	mg/L	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	n/a	100
Beryllium (Be)-Leachable	mg/L	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	n/a	n/a
Boron (B)-Leachable	mg/L	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	n/a	500
Cadmium (Cd)-Leachable	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	0.5
Calcium (Ca)-Leachable	mg/L	2.3	<2.0	17.5	<2.0	<2.0	13.2	n/a	n/a
Chromium (Cr)-Leachable	mg/L	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	n/a	5
Cobalt (Co)-Leachable	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	n/a
Copper (Cu)-Leachable	mg/L	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	100
Iron (Fe)-Leachable	mg/L	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	n/a	n/a
Lead (Pb)-Leachable	mg/L	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	n/a	5
Magnesium (Mg)-Leachable	mg/L	<0.50	<0.50	1.79	<0.50	<0.50	1.32	n/a	n/a
Mercury (Hg)-Leachable	mg/L	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010	n/a	0.1
Nickel (Ni)-Leachable	mg/L	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	n/a	n/a
Selenium (Se)-Leachable	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	n/a	1
Silver (Ag)-Leachable	mg/L	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	n/a	5
Thallium (Tl)-Leachable	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	n/a	n/a
Vanadium (V)-Leachable	mg/L	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15	n/a	n/a
Zinc (Zn)-Leachable	mg/L	<0.50	<0.50	0.62	<0.50	<0.50	<0.50	n/a	500
Hydrocarbons									
EPH10-19	mg/kg	<200	<200	<200	<200	<200	<200	n/a	n/a
EPH19-32	mg/kg	<200	<200	630	<200	<200	<200	n/a	n/a
LEPH	mg/kg	<200	<200	<200	<200	<200	<200	1000	n/a
HEPH	mg/kg	<200	<200	630	<200	<200	<200	1000	n/a
Polycyclic Aromatic Hydrocarbons									
Acenaphthene	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	n/a
Acenaphthylene	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	n/a
Anthracene	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	n/a
Benz(a)anthracene	mg/kg	<0.050	<0.050	0.107	<0.050	<0.050	0.176	1	n/a
Benzo(a)pyrene	mg/kg	<0.050	<0.050	0.149	<0.050	<0.050	0.328	n/a	n/a
Benzo(b)fluoranthene	mg/kg	<0.050	<0.050	0.441	<0.050	<0.050	0.761	1	n/a
Benzo(g,h,i)perylene	mg/kg	<0.050	<0.050	0.210	<0.050	<0.050	0.306	n/a	n/a
Benzo(k)fluoranthene	mg/kg	<0.050	<0.050	0.135	<0.050	<0.050	0.256	1	n/a
Chrysene	mg/kg	<0.050	<0.050	0.224	<0.050	<0.050	0.324	n/a	n/a
Dibenz(a,h)anthracene	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	0.056	1	n/a
Fluoranthene	mg/kg	<0.050	<0.050	0.355	<0.050	<0.050	0.648	n/a	n/a
Fluorene	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	n/a
Indeno(1,2,3-c,d)pyrene	mg/kg	<0.050	<0.050	0.171	<0.050	<0.050	0.354	1	n/a
2-Methylnaphthalene	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	n/a	n/a
Naphthalene	mg/kg	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	5	n/a
Phenanthrene	mg/kg	<0.050	<0.050	0.138	<0.050	<0.050	0.241	5	n/a
Pyrene	mg/kg	<0.050	<0.050	0.336	<0.050	<0.050	0.562	10	n/a

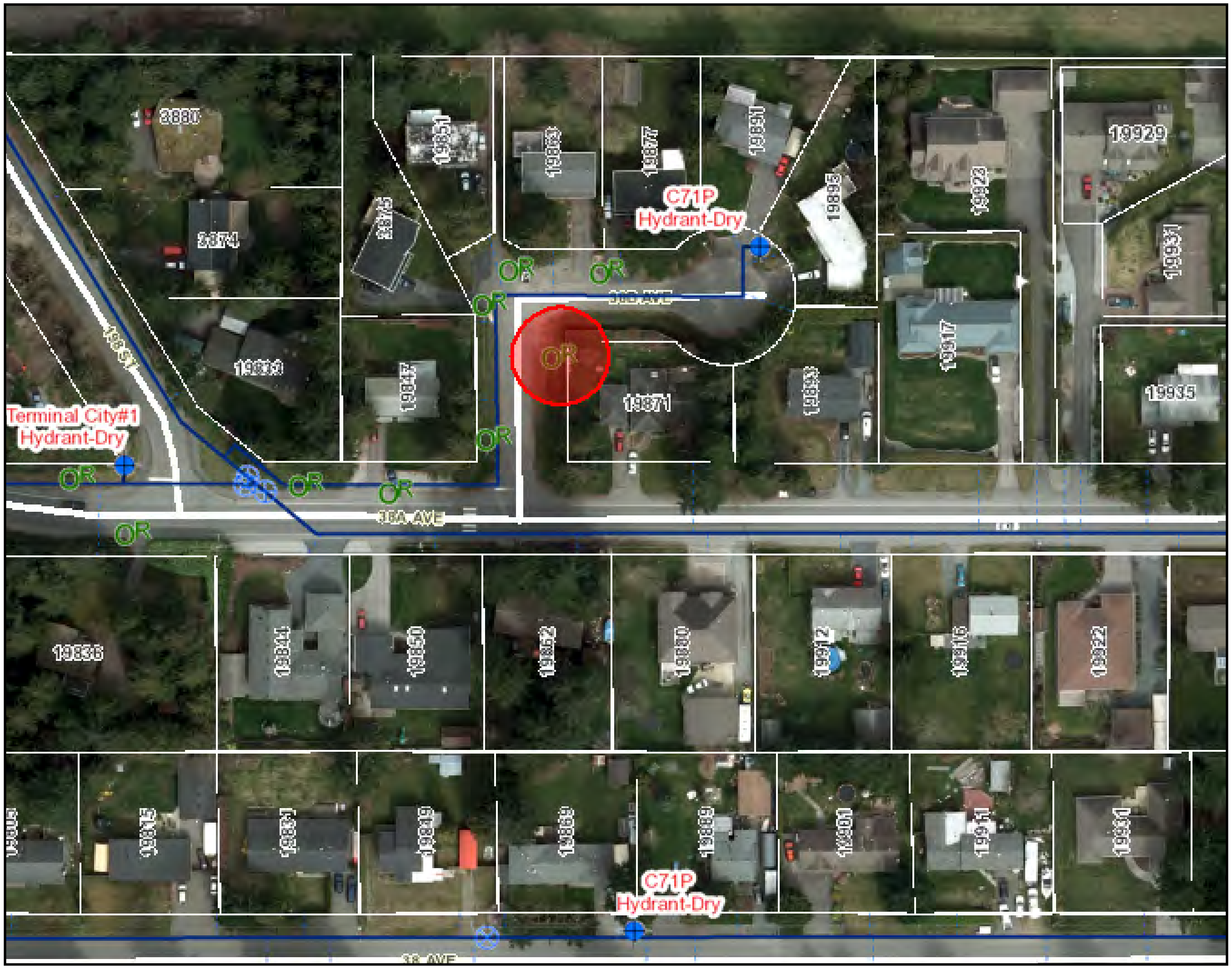
Associated ALS laboratory reports: L1301612

[a] Most stringinent standard used based on factors for either i) intake of contaminated soil, ii) groundwater used for drinking water; or iii) groundwater flow to surface water used by freshwater aquatic life

Standards

Regulation

Site 1 - 199A St and 38B Ave



Legend

Manholes

Sources

- Catch Basin
- Inlet
- Lawn Basin
- **Flow Arrows**
- **Pump Stations**

Culverts

- Box
- Arched

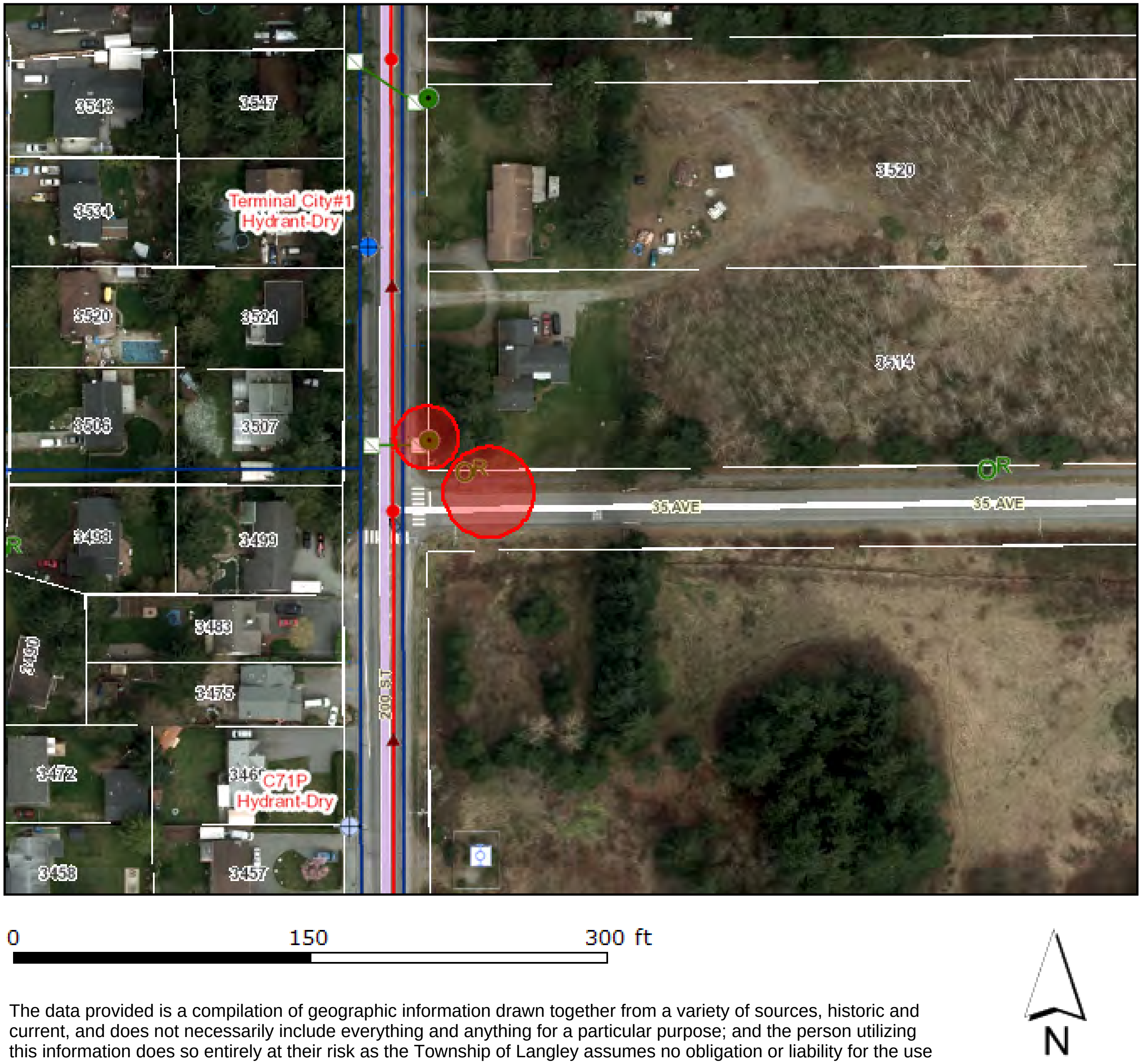
0 150 300 ft

N

The data provided is a compilation of geographic information drawn together from a variety of sources, historic and current, and does not necessarily include everything and anything for a particular purpose; and the person utilizing this information does so entirely at their risk as the Township of Langley assumes no obligation or liability for the use of this information by any person and makes no representations or promises regarding the completeness or accuracy of the information or its fitness for a particular purpose.

Map printed on: 19 April 2013 at 09:41:35

Site 2- 35Ave E of 200St



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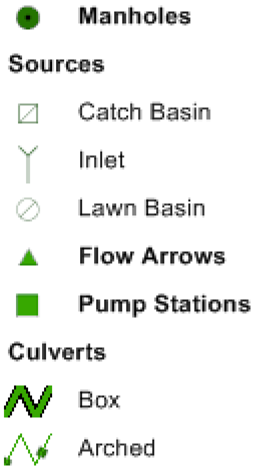

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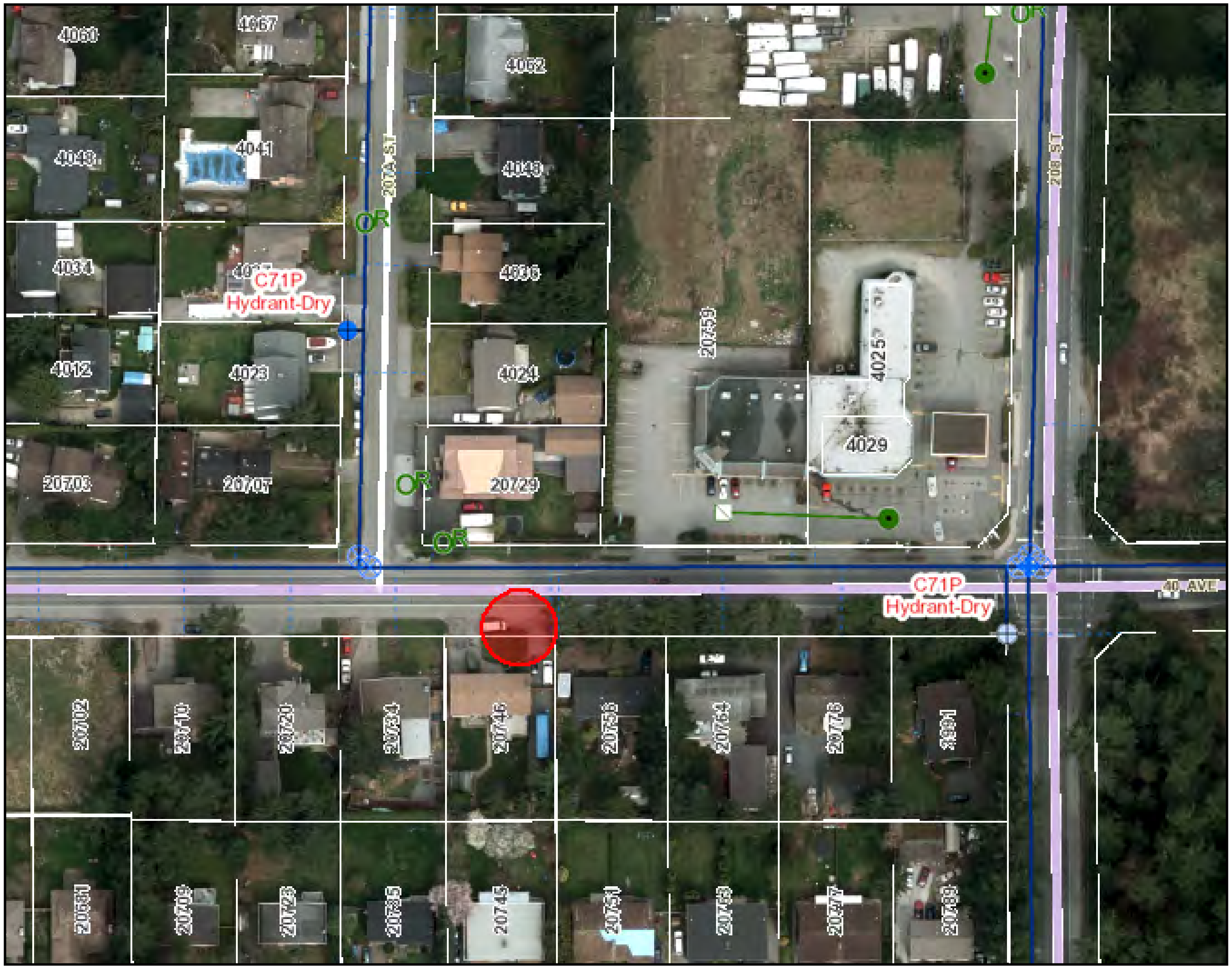
Map printed on: 19 April 2013 at 09:46:11

Site 3- 20746 40Ave



Legend

Manholes

Sources

Catch Basin

Inlet

Lawn Basin

Flow Arrows

Pump Stations

Culverts

Box

Arched

0 150 300 ft

N

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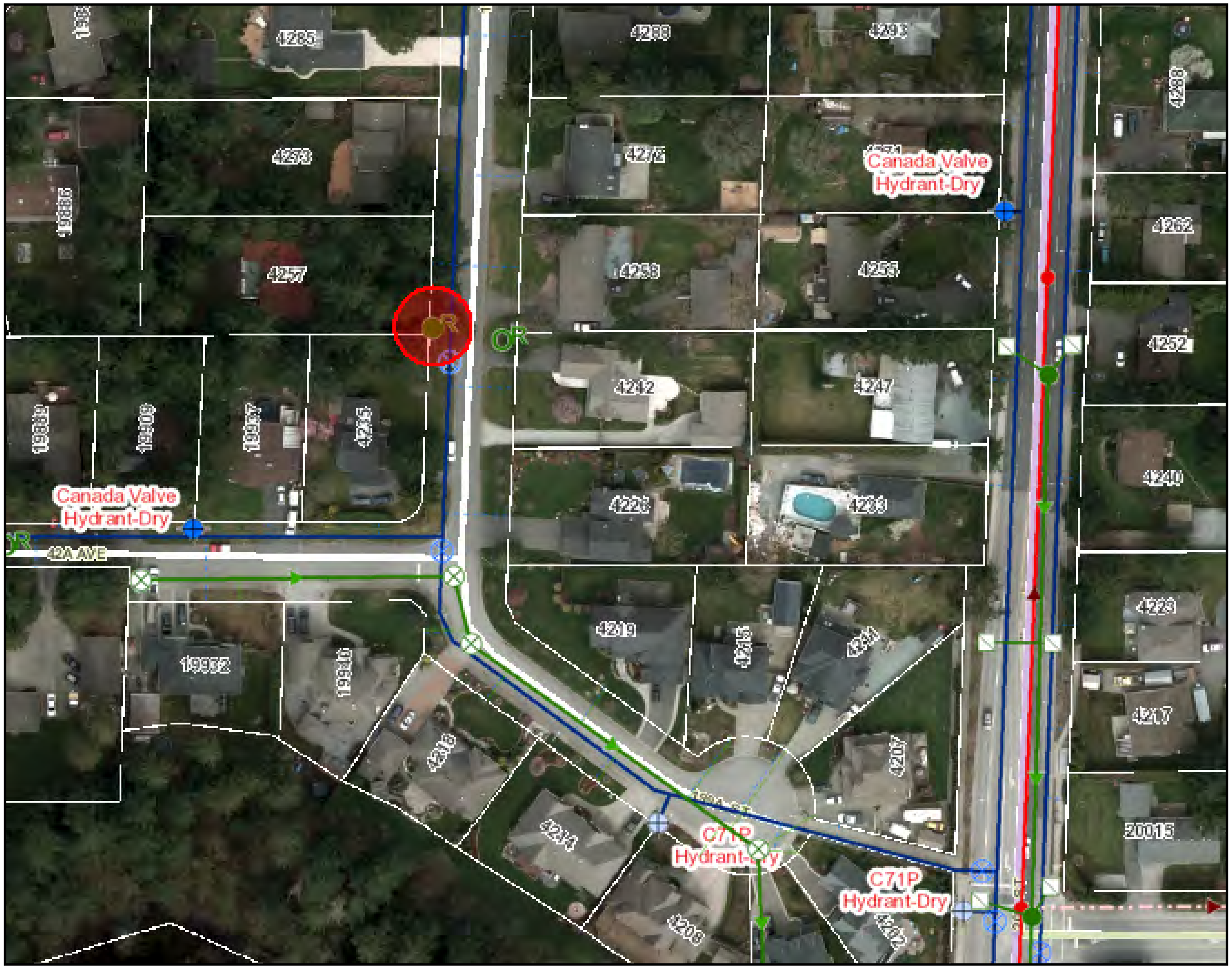
Map printed on: 19 April 2013 at 09:52:02

Site 4- 4257 199ASt



Legend

- Manholes

Sources

- Catch Basin
- Inlet
- Lawn Basin
- Flow Arrows
- Pump Stations

Culverts

- Box
- Arched

0 150 300 ft

N

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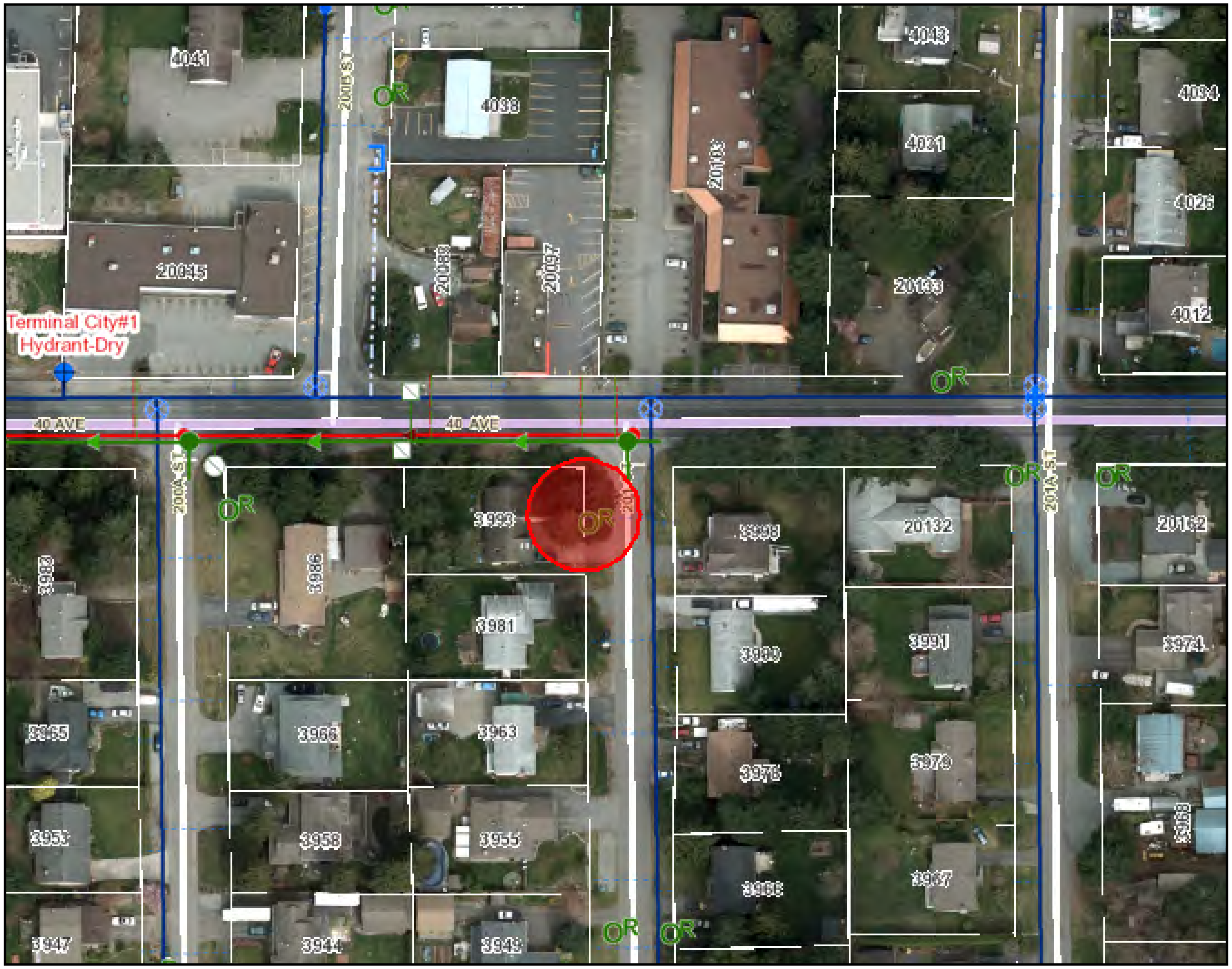
Map printed on: 19 April 2013 at 09:57:01

Site 5- 201St S of 40Ave



Legend

- Manholes

Sources

- Catch Basin
- Inlet
- Lawn Basin
- Flow Arrows
- Pump Stations

Culverts

- Box
- Arched

0 150 300 ft

N

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Map printed on: 19 April 2013 at 09:54:35

AECOM CANADA LTD.
ATTN: Ryan Mills
330 - 3292 Production Way
Burnaby BC V5A 4R4

Date Received: 14-MAY-13
Report Date: 22-MAY-13 14:52 (MT)
Version: FINAL

Client Phone: 604-444-6400

Certificate of Analysis

Lab Work Order #: L1301612

Project P.O. #: NOT SUBMITTED
Job Reference: 60267316
C of C Numbers: 10-297871, 10-297873
Legal Site Desc:

Brent Mack
Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1301612-4	L1301612-5	L1301612-6	L1301612-10	L1301612-11
	Description	soil	soil	soil	soil	soil
	Sampled Date	14-MAY-13	14-MAY-13	14-MAY-13	14-MAY-13	14-MAY-13
	Sampled Time					
	Client ID	SITE2-A	SITE2-B	SITE2-S	SITE4-A	SITE4-B
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	12.6	12.8	39.6	11.5	13.7
	pH (1:2 soil:water) (pH)	6.42	6.48	5.81	5.76	5.51
Metals	Antimony (Sb) (mg/kg)	0.23	0.25	2.29	0.19	0.65
	Arsenic (As) (mg/kg)	4.40	5.12	4.05	17.9	11.9
	Barium (Ba) (mg/kg)	26.6	30.0	48.8	61.0	47.4
	Beryllium (Be) (mg/kg)	<0.20	<0.20	<0.20	0.28	0.25
	Cadmium (Cd) (mg/kg)	0.068	0.103	0.175	0.058	0.083
	Chromium (Cr) (mg/kg)	30.7	34.7	60.3	31.7	28.1
	Cobalt (Co) (mg/kg)	5.77	6.46	5.91	6.66	6.12
	Copper (Cu) (mg/kg)	15.8	12.9	51.3	16.7	14.7
	Lead (Pb) (mg/kg)	1.87	1.94	85.6	2.55	3.47
	Mercury (Hg) (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Molybdenum (Mo) (mg/kg)	<0.50	<0.50	2.01	0.62	0.56
	Nickel (Ni) (mg/kg)	29.0	28.6	18.5	29.1	27.0
	Selenium (Se) (mg/kg)	<0.20	<0.20	<0.20	0.24	0.21
	Silver (Ag) (mg/kg)	<0.10	<0.10	<0.10	<0.10	<0.10
	Thallium (Tl) (mg/kg)	<0.050	<0.050	<0.050	<0.050	0.050
	Tin (Sn) (mg/kg)	<2.0	<2.0	2.1	<2.0	<2.0
	Uranium (U) (mg/kg)	0.227	0.225	0.249	0.387	0.345
	Vanadium (V) (mg/kg)	41.4	48.1	41.8	52.0	46.0
	Zinc (Zn) (mg/kg)	28.6	30.6	147	31.7	40.5
TCLP Metals	1st Preliminary PH (pH)	6.54	6.47	6.61	5.84	5.68
	2nd Preliminary PH (pH)	1.16	1.16	1.18	1.17	1.17
	Final pH (pH)	4.96	4.99	4.94	4.95	4.93
	Extraction Solution Initial pH (pH)	4.88	4.88	4.88	4.88	4.88
	Antimony (Sb)-Leachable (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Arsenic (As)-Leachable (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Barium (Ba)-Leachable (mg/L)	<2.5	<2.5	<2.5	<2.5	<2.5
	Beryllium (Be)-Leachable (mg/L)	<0.025	<0.025	<0.025	<0.025	<0.025
	Boron (B)-Leachable (mg/L)	<0.50	<0.50	<0.50	<0.50	<0.50
	Cadmium (Cd)-Leachable (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Calcium (Ca)-Leachable (mg/L)	2.3	<2.0	17.5	<2.0	<2.0
	Chromium (Cr)-Leachable (mg/L)	<0.25	<0.25	<0.25	<0.25	<0.25
	Cobalt (Co)-Leachable (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Copper (Cu)-Leachable (mg/L)	<0.050	<0.050	<0.050	<0.050	<0.050
	Iron (Fe)-Leachable (mg/L)	<0.15	<0.15	<0.15	<0.15	<0.15
	Lead (Pb)-Leachable (mg/L)	<0.25	<0.25	<0.25	<0.25	<0.25

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1301612-12				
	Description	soil				
	Sampled Date	14-MAY-13				
	Sampled Time					
	Client ID	SITE4-S				
Grouping	**Analyte**					
SOIL						
Physical Tests	Moisture (%)	18.0				
	pH (1:2 soil:water) (pH)	5.57				
Metals	Antimony (Sb) (mg/kg)	1.13				
	Arsenic (As) (mg/kg)	12.5				
	Barium (Ba) (mg/kg)	54.2				
	Beryllium (Be) (mg/kg)	0.24				
	Cadmium (Cd) (mg/kg)	0.180				
	Chromium (Cr) (mg/kg)	26.5				
	Cobalt (Co) (mg/kg)	5.64				
	Copper (Cu) (mg/kg)	15.0				
	Lead (Pb) (mg/kg)	34.1				
	Mercury (Hg) (mg/kg)	0.052				
	Molybdenum (Mo) (mg/kg)	0.79				
	Nickel (Ni) (mg/kg)	19.5				
	Selenium (Se) (mg/kg)	0.20				
	Silver (Ag) (mg/kg)	<0.10				
	Thallium (Tl) (mg/kg)	0.055				
	Tin (Sn) (mg/kg)	<2.0				
	Uranium (U) (mg/kg)	0.331				
	Vanadium (V) (mg/kg)	39.9				
	Zinc (Zn) (mg/kg)	57.5				
TCLP Metals	1st Preliminary PH (pH)	6.08				
	2nd Preliminary PH (pH)	1.20				
	Final pH (pH)	4.94				
	Extraction Solution Initial pH (pH)	4.88				
	Antimony (Sb)-Leachable (mg/L)	<1.0				
	Arsenic (As)-Leachable (mg/L)	<1.0				
	Barium (Ba)-Leachable (mg/L)	<2.5				
	Beryllium (Be)-Leachable (mg/L)	<0.025				
	Boron (B)-Leachable (mg/L)	<0.50				
	Cadmium (Cd)-Leachable (mg/L)	<0.050				
	Calcium (Ca)-Leachable (mg/L)	13.2				
	Chromium (Cr)-Leachable (mg/L)	<0.25				
	Cobalt (Co)-Leachable (mg/L)	<0.050				
	Copper (Cu)-Leachable (mg/L)	<0.050				
	Iron (Fe)-Leachable (mg/L)	<0.15				
	Lead (Pb)-Leachable (mg/L)	<0.25				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1301612-4	L1301612-5	L1301612-6	L1301612-10	L1301612-11
	Description	soil	soil	soil	soil	soil
	Sampled Date	14-MAY-13	14-MAY-13	14-MAY-13	14-MAY-13	14-MAY-13
	Sampled Time					
	Client ID	SITE2-A	SITE2-B	SITE2-S	SITE4-A	SITE4-B
Grouping	**Analyte**					
SOIL						
TCLP Metals	Magnesium (Mg)-Leachable (mg/L)	<0.50	<0.50	1.79	<0.50	<0.50
	Mercury (Hg)-Leachable (mg/L)	<0.0010	<0.0010	<0.0010	<0.0010	<0.0010
	Nickel (Ni)-Leachable (mg/L)	<0.25	<0.25	<0.25	<0.25	<0.25
	Selenium (Se)-Leachable (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Silver (Ag)-Leachable (mg/L)	<0.25	<0.25	<0.25	<0.25	<0.25
	Thallium (Tl)-Leachable (mg/L)	<1.0	<1.0	<1.0	<1.0	<1.0
	Vanadium (V)-Leachable (mg/L)	<0.15	<0.15	<0.15	<0.15	<0.15
	Zinc (Zn)-Leachable (mg/L)	<0.50	<0.50	0.62	<0.50	<0.50
Hydrocarbons	EPH10-19 (mg/kg)	<200	<200	<200	<200	<200
	EPH19-32 (mg/kg)	<200	<200	630	<200	<200
	LEPH (mg/kg)	<200	<200	<200	<200	<200
	HEPH (mg/kg)	<200	<200	630	<200	<200
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Acenaphthylene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Anthracene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Benz(a)anthracene (mg/kg)	<0.050	<0.050	0.107	<0.050	<0.050
	Benzo(a)pyrene (mg/kg)	<0.050	<0.050	0.149	<0.050	<0.050
	Benzo(b)fluoranthene (mg/kg)	<0.050	<0.050	0.441	<0.050	<0.050
	Benzo(g,h,i)perylene (mg/kg)	<0.050	<0.050	0.210	<0.050	<0.050
	Benzo(k)fluoranthene (mg/kg)	<0.050	<0.050	0.135	<0.050	<0.050
	Chrysene (mg/kg)	<0.050	<0.050	0.224	<0.050	<0.050
	Dibenz(a,h)anthracene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Fluoranthene (mg/kg)	<0.050	<0.050	0.355	<0.050	<0.050
	Fluorene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Indeno(1,2,3-c,d)pyrene (mg/kg)	<0.050	<0.050	0.171	<0.050	<0.050
	2-Methylnaphthalene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Naphthalene (mg/kg)	<0.050	<0.050	<0.050	<0.050	<0.050
	Phenanthrene (mg/kg)	<0.050	<0.050	0.138	<0.050	<0.050
	Pyrene (mg/kg)	<0.050	<0.050	0.336	<0.050	<0.050
	Surrogate: Acenaphthene d10 (%)	81.5	73.0	75.9	87.0	76.5
	Surrogate: Chrysene d12 (%)	107.7	106.6	88.0	111.4	100.9
	Surrogate: Naphthalene d8 (%)	84.6	71.8	75.7	89.5	76.8
	Surrogate: Phenanthrene d10 (%)	91.0	88.3	81.2	97.1	90.4

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

ALS ENVIRONMENTAL ANALYTICAL REPORT

	Sample ID	L1301612-12				
	Description	soil				
	Sampled Date	14-MAY-13				
	Sampled Time					
	Client ID	SITE4-S				
Grouping	**Analyte**					
SOIL						
TCLP Metals	Magnesium (Mg)-Leachable (mg/L)	1.32				
	Mercury (Hg)-Leachable (mg/L)	<0.0010				
	Nickel (Ni)-Leachable (mg/L)	<0.25				
	Selenium (Se)-Leachable (mg/L)	<1.0				
	Silver (Ag)-Leachable (mg/L)	<0.25				
	Thallium (Tl)-Leachable (mg/L)	<1.0				
	Vanadium (V)-Leachable (mg/L)	<0.15				
	Zinc (Zn)-Leachable (mg/L)	<0.50				
Hydrocarbons	EPH10-19 (mg/kg)	<200				
	EPH19-32 (mg/kg)	<200				
	LEPH (mg/kg)	<200				
	HEPH (mg/kg)	<200				
Polycyclic Aromatic Hydrocarbons	Acenaphthene (mg/kg)	<0.050				
	Acenaphthylene (mg/kg)	<0.050				
	Anthracene (mg/kg)	<0.050				
	Benz(a)anthracene (mg/kg)	0.176				
	Benzo(a)pyrene (mg/kg)	0.328				
	Benzo(b)fluoranthene (mg/kg)	0.761				
	Benzo(g,h,i)perylene (mg/kg)	0.306				
	Benzo(k)fluoranthene (mg/kg)	0.256				
	Chrysene (mg/kg)	0.324				
	Dibenz(a,h)anthracene (mg/kg)	0.056				
	Fluoranthene (mg/kg)	0.648				
	Fluorene (mg/kg)	<0.050				
	Indeno(1,2,3-c,d)pyrene (mg/kg)	0.354				
	2-Methylnaphthalene (mg/kg)	<0.050				
	Naphthalene (mg/kg)	<0.050				
	Phenanthrene (mg/kg)	0.241				
	Pyrene (mg/kg)	0.562				
	Surrogate: Acenaphthene d10 (%)	103.9				
	Surrogate: Chrysene d12 (%)	129.3				
	Surrogate: Naphthalene d8 (%)	102.2				
	Surrogate: Phenanthrene d10 (%)	120.3				

* Please refer to the Reference Information section for an explanation of any qualifiers detected.

Reference Information

QC Samples with Qualifiers & Comments:

QC Type Description	Parameter	Qualifier	Applies to Sample Number(s)
Matrix Spike	Calcium (Ca)-Leachable	MS-B	L1301612-10, -11, -12, -4, -5, -6
Matrix Spike	Iron (Fe)-Leachable	MS-B	L1301612-10, -11, -12, -4, -5, -6
Matrix Spike	Magnesium (Mg)-Leachable	MS-B	L1301612-10, -11, -12, -4, -5, -6
Matrix Spike	Zinc (Zn)-Leachable	MS-B	L1301612-10, -11, -12, -4, -5, -6

Qualifiers for Individual Parameters Listed:

Qualifier	Description
MS-B	Matrix Spike recovery could not be accurately calculated due to high analyte background in sample.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
EPH-TUMB-FID-VA	Soil	EPH in Solids by Tumbler and GCFID	BCMELP CSR

Extractable Hydrocarbons in Sediment/Soil
This analysis is carried out in accordance with the British Columbia Ministry of Environment, Lands and Parks (BCMELP) Analytical Method for Contaminated Sites "Extractable Petroleum Hydrocarbons in Solids by GC/FID, Version 2.1 July 1999". The procedure, based on EPA 3570, uses a rotary extraction technique to extract a subsample of the sediment/soil with a 1:1 mixture of hexane and acetone. The extract is then solvent exchanged to toluene or kept in hexane/acetone and analyzed by capillary column gas chromatography with flame ionization detection (GC/FID). EPH results include Polycyclic Aromatic Hydrocarbons (PAH) and are therefore not equivalent to Light and Heavy Extractable Petroleum Hydrocarbons (LEPH/HEPH).

Accuracy target values for Reference Materials used in this method are derived from averages of long-term method performance, as certified values do not exist for the reported parameters.

HG-200.2-CVAF-VA	Soil	Mercury in Soil by CVAFS	EPA 200.2/245.7

This analysis is carried out using procedures from CSR Analytical Method: "Strong Acid Leachable Metals (SALM) in Soil", BC Ministry of Environment, 26 June 2009, and procedures adapted from EPA Method 200.2. The sample is manually homogenized, dried at 60 degrees Celsius, sieved through a 2 mm (10 mesh) sieve (this sieve step is omitted for international soil samples), and a representative subsample of the dry material is weighed. The sample is then digested at 95 degrees Celsius for 2 hours by block digester using concentrated nitric and hydrochloric acids. Instrumental analysis is by atomic fluorescence spectrophotometry (EPA Method 245.7).

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

HG-TCLP-CVAFS-VA	Soil	Mercury by CVAFS (TCLP)	EPA 1311/245.7

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1311, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using either extraction fluid #1 (glacial acetic acid, water and sodium hydroxide) or extraction fluid #2 (glacial acetic acid), depending on the pH of the original sample. The extract is then filtered through a 0.6 to 0.8 micron glass fibre filter and analysed using atomic fluorescence spectrophotometry (EPA 245.7).

LEPH/HEPH-CALC-VA	Soil	LEPHs and HEPHs	BC MOE LABORATORY MANUAL (2005)

Light and Heavy Extractable Petroleum Hydrocarbons in Solids. These results are determined according to the British Columbia Ministry of Environment, Lands, and Parks Analytical Method for Contaminated Sites "Calculation of Light and Heavy Extractable Petroleum Hydrocarbons in Solids or Water". According to this method, LEPH and HEPH are calculated
by subtracting selected Polycyclic Aromatic Hydrocarbon results from Extractable Petroleum Hydrocarbon results. To calculate LEPH, the individual results for Naphthalene and Phenanthrene are subtracted from EPH(C10-19). To calculate HEPH, the individual results for Benz(a)anthracene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(a)pyrene, Dibenz(a,h)anthracene, Indeno(1,2,3-c,d)pyrene, and Pyrene
are subtracted from EPH(C19-32). Analysis of Extractable Petroleum Hydrocarbons adheres to all prescribed elements of the BCMELP method "Extractable Petroleum Hydrocarbons in Solids by GC/FID" (Version 2.1, July 20, 1999).

MET-200.2-CCMS-VA	Soil	Metals in Soil by CRC ICPMS	EPA 200.2/6020A

This analysis is carried out using procedures from CSR Analytical Method: "Strong Acid Leachable Metals (SALM) in Soil", BC Ministry of Environment, 26 June 2009, and procedures adapted from EPA Method 200.2. The sample is manually homogenized, dried at 60 degrees Celsius, sieved through a 2 mm (10 mesh) sieve (this sieve step is omitted for international soil samples), and a representative subsample of the dry material is weighed. The sample is then digested at 95 degrees Celsius for 2 hours by block digester using concentrated nitric and hydrochloric acids. Instrumental analysis of the digested extract is by collision cell inductively coupled plasma - mass spectrometry (modifed from EPA Method 6020A).

Method Limitation: This method is not a total digestion technique. It is a very strong acid digestion that is intended to dissolve those metals that may be environmentally available. By design, elements bound in silicate structures are not normally dissolved by this procedure as they are not usually mobile in the environment.

MET-TCLP-ICP-VA	Soil	Metals by ICPOES (TCLP)	EPA 1311/6010B

This analysis is carried out in accordance with the extraction procedure outlined in "Test Methods for Evaluating Solid Waste - Physical/Chemical Methods Volume 1C" SW-846 EPA Method 1311, published by the United States Environmental Protection Agency (EPA). In summary, the sample is extracted at a 20:1 liquid to solids ratio for 16 to 20 hours using either extraction fluid #1 (glacial acetic acid, water and sodium hydroxide) or extraction

Reference Information

fluid #2 (glacial acetic acid), depending on the pH of the original sample. The extract is then filtered through a 0.6 to 0.8 micron glass fibre filter and analysed using inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B).

MOISTURE-VA	Soil	Moisture content	ASTM D2974-00 Method A

This analysis is carried out gravimetrically by drying the sample at 105 C for a minimum of six hours.

PAH-TMB-H/A-MS-VA	Soil	PAH - Rotary Extraction (Hexane/Acetone)	EPA 3570/8270

This analysis is carried out using procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846, Methods 3545 & 8270, published by the United States Environmental Protection Agency (EPA). The procedure uses a mechanical shaking technique to extract a subsample of the sediment/soil with a 1:1 mixture of hexane and acetone. The extract is then solvent exchanged to toluene. The final extract is analysed by capillary column gas chromatography with mass spectrometric detection (GC/MS). Surrogate recoveries may not be reported in cases where interferences from the sample matrix prevent accurate quantitation. Because the two isomers cannot be readily chromatographically separated, benzo(j)fluoranthene is reported as part of the benzo(b)fluoranthene parameter.

PH-1:2-VA	Soil	pH in Soil (1:2 Soil:Water Extraction)	BC WLAP METHOD: PH, ELECTROMETRIC, SOIL

This analysis is carried out in accordance with procedures described in the pH, Electrometric in Soil and Sediment method - Section B Physical/Inorganic and Misc. Constituents, BC Environmental Laboratory Manual 2007. The procedure involves mixing the dried (at <60°C) and sieved (No. 10 / 2mm) sample with deionized/distilled water at a 1:2 ratio of sediment to water. The pH of the solution is then measured using a standard pH probe.

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

10-297871   10-297873

GLOSSARY OF REPORT TERMS

Surrogate - A compound that is similar in behaviour to target analyte(s), but that does not occur naturally in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery.
mg/kg - milligrams per kilogram based on dry weight of sample.
mg/kg wwt - milligrams per kilogram based on wet weight of sample.
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight of sample.
mg/L - milligrams per litre.
< - Less than.
D.L. - The reported Detection Limit, also known as the Limit of Reporting (LOR).
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

APPENDIX D
Environmental Memorandum

AECOM
3292 Production Way, Floor 4
Burnaby, BC, Canada V5A 4R4
www.aecom.com
604 444 6400 tel
604 294 8597 fax

To	Art Kastelein	Page	1
CC			
Subject	Anderson Creek B-IBI Summary Memo		
From			
Date	April 11, 2013	Project Number	60267316

1. Introduction

1.1 Overview

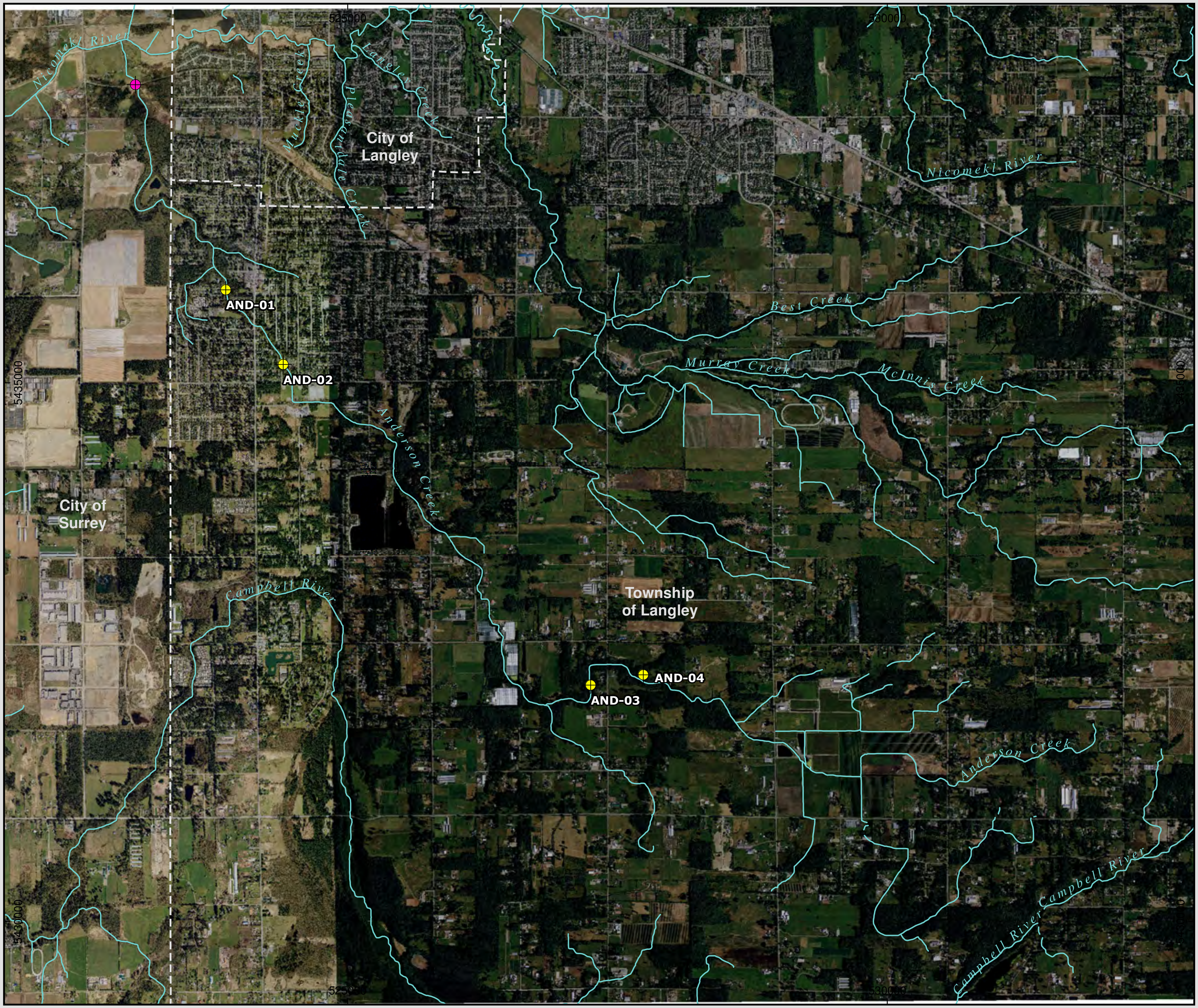
This summary memo describes the benthic studies conducted in 2012 in Anderson Creek for the Township of Langley (TOL). The purpose of this study was to establish baseline conditions, identify factors impacting environmental health and trend changes to determine the overall health of the streams. Baseline conditions were established for the TOL, which included water quality and Benthic Index of Biotic Integrity (B-IBI) monitoring in Anderson Creek. Figure 1 outlines the sample locations in Anderson Creek for the TOL sampling programs.

1.2 Study Objectives

The overall objective of the 2012 benthic study was to collect information that will be used to characterize baseline conditions in the Anderson Creek watershed. Benthic studies were modified from the guidance document issued August 2003 by the Greater Vancouver Regional District (GVRD; currently known as Metro Vancouver [MV]), GVRD Benthic Macroinvertebrate B-IBI Guide (EVS, 2003).

The specific scope of work for the 2012 benthic studies included the following:

- Establish and conduct sampling at four locations in the Anderson Creek watershed.
  - Anderson Creek: upstream of City of Surrey, Anderson Creek sample site in park zone (P-1).
  - Anderson Creek: urban, residential zoned area (R-1E).
  - Anderson Creek: rural (RU-3), agricultural land reserve area.
  - Anderson Creek: upstream rural (RU-3), agricultural land reserve area.
- Undertake B-IBI sampling at four sites during the summer dry weather.
- Conduct water quality sampling according to the following at each of the four established sampling locations, concurrently with B-IBI sampling.



Legend

- City of Surrey Sampling Site (2011)
- Township of Langley Sampling Site (2012)
- Municipal Boundary

Overview Map

Basemapping from Microsoft Bing and AECOM 2013

N
W E
S

0 500 1,000
Metres

1:50,000

NAD 1983 UTM Zone 10N

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Township of Langley
Location: Langley, BC

Anderson Creek Water Quality and B-IBI Sampling Sites 2011-2012

April 2013
Project: 60267316

AECOM

Figure 1

File Location: E:\GIS\GIS_proj\Y2013\Anderson Creek\050-GIS\02_Maps\2013-04-15-AndersonCreek\Fig1-2013-04-15-AndersonCreek.mxd   Date Revised: April 16, 2013   Prepared by: leeds   Project: 60267316

2. Methods

2.1 Dates and Locations of Aquatic Benthic Studies

Sampling for benthic invertebrates was conducted from October 3-4, 2012. Table 1 presents the coordinates of the aquatic ecology sampling locations for the TOL project. Water quality samples were conducted once on October 3, 2012 at all sample locations. Appendix D.5 shows site photos of all the locations.

Table 1. Summary of B-IBI Sampling Program Locations, 2012

Stream	Project	Sample Location	Sample Type	UTM Coordinates
Anderson Creek	Township of Langley	AND-01	Water, Benthos	10U 523867 5435863
		AND-02	Water, Benthos	10U 524401 5435171
		AND-03	Water, Benthos	10U 527249 5432197
		AND-04	Water, Benthos	10U 527739 5432292

2.2 Sample Collection & Data Analysis

2.2.1 Water Quality

All surface water samples taken were grab samples, collected in mid-stream, below the surface with the bottle mouths facing upstream. When stream depths were too shallow for sampling directly in larger sample bottles, smaller bottles were used to fill to the appropriate volumes. All bottles and sampling equipment were triple rinsed with the sample water before sample collection. Corresponding samples requiring filtration and preservation were completed in the field.

All bottles, preservatives and materials were provided by the laboratory. Samples were collected for total suspended solids (TSS) and total dissolved solids (TDS) in pre-cleaned 1 L plastic bottles. Samples for general and some inorganic parameters were collected in a 1 L plastic bottle. Samples for total metals were collected in 120 mL acid-washed plastic bottles and preserved in the field with nitric acid. Samples for nutrients were collected in 120 mL bottles. Samples for total organic carbon (TOC) were collected in 120 ml bottles and preserved in the field with sulphuric acid. Microbiological parameters were collected in sealed, sterile plastic bottles that contained the laboratory provided preservative sodium thiosulfate.

All samples were kept on ice in a cooler but not allowed to freeze and transported directly to Maxxam Analytics in Burnaby, BC. Maxxam Analytics is accredited by the Canadian Association for Environmental Analytical Laboratories. Chain of Custody forms accompanied all samples. Table 3 shows the water quality parameters that were measured and their Reported Detection Limits (RDL) provided by the laboratory.

Table 2. Water Quality Parameters and Detection Limits, 2012

Parameter	Unit	RDL	Parameter	Unit	RDL
Calculated Parameters			**Total Metals by ICPMS**		
Nitrate (N)	mg/L	0.002	Barium (Ba)	µg/L	1.0
Misc. Inorganics			Beryllium (Be)	µg/L	0.10
Acidity (pH 4.5)	mg/L	0.50	Bismuth (Bi)	µg/L	1.0
Acidity (pH 8.3)	mg/L	0.50	Boron (B)	µg/L	50
Total Hardness (CaCO3)	mg/L	0.50	Cadmium (Cd)	µg/L	0.010
Alkalinity (Total as CaCO3)	mg/L	0.5	Chromium (Cr)	µg/L	1.0
Alkalinity (PP as CaCO3)	mg/L	0.5	Cobalt (Co)	µg/L	0.50
Bicarbonate (HCO3)	mg/L	0.5	Copper (Cu)	µg/L	0.20
Carbonate (CO3)	mg/L	0.5	Iron (Fe)	µg/L	5.0
Hydroxide (OH)	mg/L	0.5	Lead (Pb)	µg/L	0.20
Anions			Lithium (Li)	µg/L	5.0
Orthophosphate (P)	mg/L	0.001	Manganese (Mn)	µg/L	1.0
Dissolved Sulphate (SO4)	mg/L	0.5	Mercury (Hg)	µg/L	0.010
Nutrients			Molybdenum (Mo)	µg/L	1.0
Ammonia (N)	mg/L	0.005	Nickel (Ni)	µg/L	1.0
Total Kjeldahl Nitrogen (Calc)	mg/L	0.02	Phosphorus (P)	µg/L	10
Nitrate plus Nitrite (N)	mg/L	0.002	Selenium (Se)	µg/L	0.1
Nitrite (N)	mg/L	0.002	Silicon (Si)	µg/L	100
Total Nitrogen (N)	mg/L	0.02	Silver (Ag)	µg/L	0.020
Total Organic Carbon (C)	mg/L	0.5	Strontium (Sr)	µg/L	1.0
Physical Properties			Thallium (Tl)	µg/L	0.050
Conductivity	µS/cm	1.0	Tin (Sn)	µg/L	5.0
pH	pH Units	-	Titanium (Ti)	µg/L	5.0
Total Suspended Solids	mg/L	1.0	Uranium (U)	µg/L	0.10
Total Dissolved Solids	mg/L	10	Vanadium (V)	µg/L	5.0
Turbidity	NTU	0.1	Zinc (Zn)	µg/L	5.0
Microbiological Parameters			Zirconium (Zr)	µg/L	0.50
Fecal Coliforms	CFU/100 ml	1	Calcium (Ca)	mg/L	0.050
E. coli	CFU/100 ml	1	Magnesium (Mg)	mg/L	0.050
Total Metals by ICPMS			Potassium (K)	mg/L	0.050
Aluminum (Al)	µg/L	3.0	Sodium (Na)	mg/L	0.050
Antimony (Sb)	µg/L	0.50	Sulphur (S)	mg/L	3.0
Arsenic (As)	µg/L	0.10			

Field measurements of pH, temperature, dissolved oxygen and specific conductivity were taken at each site using a YSI multi-metre.

2.2.2 Benthic Invertebrates

Stream benthic invertebrates were collected from each of the sample sites in Anderson Creek. The sampling procedures for Anderson Creek were modified from those established in the GVRD Benthic Macroinvertebrate B-IBI Guide (EVS, 2003). The difference in the sampling procedures included less replication than the guidelines but still enabled comparison with guidelines. Sampling replication at each site consisted of one sample in the TOL program while the MV guidelines recommend 4 replicate samples per site. However, each sample was a composite of 3 placements of the Surber sampler which is consistent with the MV guidelines. Sampling was conducted in riffle habitat along sections of stream to ensure sampling in favourable *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) habitat. EPT taxa provide an important measure of stream health so samples were only conducted within riffles. Samples were collected using a surber sampler with 250 µm mesh with substrate cleaning lasting for 5 minutes for each placement.

TOL samples were collected at the water quality sampling stations at each of the four sites. As indicated, each sample consisted of one composite sample made up of 3 riffle Surber placements. Each of the composite samples was filtered through a 250 µm screen and the sampler thoroughly washed. Washed samples were transferred to pre labeled plastic sample containers and preserved with 80% ethanol. GPS waypoints were taken at each of the locations and general area habitat recorded according to the datasheet provided in Appendix D.4.2 of the GVRD B-IBI Guide (EVS, 2003).

Stream samples of benthic invertebrates were shipped to Sandpiper Biological Consulting in Victoria, BC, for taxonomic identification to the lowest practical taxonomic level, which was to the Family or Genus level for most aquatic insects. Laboratory analysis was incompliance with protocols outlined in the GVRD B-IBI Guide (EVS, 2003).

Total density of benthic invertebrates collected by the surber sampler was calculated by total number of organisms collected from a sample per composite of three surber placements. The Surber sampler covers an area of 0.09 m^2 making the total area covered per composite sample 0.27 m^2.

2.3 QA/QC

2.3.1 Water Quality

<u>*Field QA/QC*</u>

All field equipment was maintained in good working condition and instruments were calibrated prior to use. The pH probe was calibrated prior to each field trip using prepared solutions with pH levels of 4 and 7, and the conductivity meter was checked prior to each field trip using the standard 1,413 µS/cm conductivity solution.

Water quality samples were collected by a qualified aquatic biologist. All water samples were collected using industry standard sampling protocols, however no field or trip blanks were collected as part of the TOL sampling program.

Laboratory QA/QC

Maxxam Analytics, which conducted the analyses of water samples, is a certified member of the Canadian Association of Environmental Analytical Laboratories. A quality check conducted by the lab included using a spiked sample as an estimate of accuracy of analysis, which was analyzed with the same sample batch as the Anderson Creek samples. To meet the QA/QC standard, the results from a spiked matrix must be within 80 % - 120% of the known concentration. All spiked matrix results were within QC limits. Laboratory duplicates were also run as part of the laboratory QA/QC standards, Table 3 shows the sample that was outside the duplicate criteria of 20%. The RDL was also raised due to sample interference on a laboratory duplicate for Orthophosphate. Maxxam concluded that overall the quality control results indicated that the analysis met the quality standards.

Table 3. Summary of Laboratory Duplicate Results Outside the 20% Criteria, Maxxam

Analysis Date	Laboratory Duplicate Outside of 20% Criteria	Percent Recovery
October 9, 2012	Total Phosphorus	40.1

2.3.2 Benthic Invertebrates

The laboratory responsible for identification, Sandpiper Biological Consulting, has experience in taxonomic analysis of benthic invertebrates from streams, rivers and lakes, including western Canada. Sandpiper Biological Consulting followed the QA/QC procedures as established by the GVRD Benthic Macroinvertebrate B-IBI Guide (EVS, 2003).

3. Results

3.1 Water Quality

Appendix D.4.1 provides a summary of the water quality data including mean, minimum, maximum and standard deviation for each of the sample locations. All parameters with higher concentrations than the criteria for aquatic life have been highlighted in the appendix table.

3.1.1 General Water Quality Parameters

General water quality parameters include inorganics, anions and physical properties. A complete list of all general water quality parameters with detection limits is presented in Table 2. Below is a summary of observed data trends:

- All parameters measured in Anderson Creek sampling locations reported were below CCME, and BC Water Quality Guidelines. The Guideline values for total suspended solids and turbidity are dependent on changes over background levels so comparisons between guidelines and measured values did not occur. All other general parameters with associated guideline values were below guidelines.
- Neutral to basic lab pH conditions were observed at all sites sampled, with pH measured to be slightly higher at the upper two watershed sampling sites in the agricultural land reserve area.

- Total hardness was measured to be similar at all sites except for AND-02. Total hardness ranged from 83.3-86.6 mg/L at all sites with exception of AND-02 measuring 49.9 mg/L.
- Anderson Creek systems exhibited a low sensitivity to acidic inputs, determined by the average alkalinity, calcium and total hardness. Anderson Creek mean alkalinity was measured to be 76.6 mg/L. BC Working Water Quality Guidelines outlines that waters with total alkalinity values for aquatic life greater than 20 mg/L have low sensitivity.
- Conductivity was highest in the upper watershed sample sites (479-539 μs/cm) with the lowest occurring at AND-02 (160 μs/cm). A similar result was noted for total dissolved solids, with AND-02 having the least (116 mg/L) and AND-04 having the greatest levels (404 mg/L).
- Turbidity results displayed values ranged between 0.28-2.01 NTU with the highest level measured at AND-03 and lowest at AND-01.
- Dissolved sulphate levels appeared to generally be consistent throughout the watershed sampling sites. Overall dissolved sulphate values ranged from a low of 15.7 mg/L (AND-02) to 22.6 mg/L (AND-03).
- Orthophosphate results ranged from a low of 0.0033 mg/L (AND-02) to a high of 0.35 mg/L (AND-04). A noticeable difference in the amount of orthophosphate was measured between the lower and upper watershed. Some anthropogenic sources of orthophosphate are sewage treatment effluent, agriculture, urban development and industrial effluents.

3.1.2 Nutrient

Nutrients include total organic carbon, nitrate, ammonia, total Kjeldahl nitrogen (TKN), nitrate plus nitrite, nitrite and total nitrogen. Generally, nutrient concentrations in all systems displayed variable trends. Aquatic life criteria set for ammonia to protect aquatic life are dependent on the temperature and pH of the water. A combination of lab pH values and *in situ* temperature values were used to calculate the guideline values for each of the samples. The following is a summary of observed data trends:

- Nutrient concentrations in all systems were within the water quality guidelines. Guideline values for both CCME and BC Approved Water Quality Guidelines were available for nitrate, ammonia and nitrite.
- Nitrate in the watershed displayed an increasing trend from the upper sites to the lower sites. The highest nitrate levels were observed at site AND-01 (2.46 mg/L) and the lowest at AND-04 (0.075 mg/L).
- Total nitrogen results were the highest and lowest in the lower watershed sampling sites. AND-01 measured 2.73 mg/L and AND-02 measured 0.798 mg/L.
- Ammonia concentrations were similar at all sites, with exception to a low of 0.0059 mg/L at AND-02. Ammonia levels at all other sites ranged from 0.010-0.013 mg/L.
- Total organic carbon (TOC) values were significantly greater at the upper watershed sampling sites. TOC levels at AND-01 and AND-02 were 2.46 mg/L and 3.01 mg/L respectively and AND-03 and AND-04 were 34.9 mg/L and 36.2 mg/L respectively. Typically natural waters vary between 1-30 mg/L for total organic carbon with ambient waters in British Columbia generally being less than 5 mg/L (MOE, 2001). Conditions above the general ambient conditions in British Columbia are expected in waters that are influenced by sources of naturally high organic carbon content. Natural sources of organic carbon in water include humic substances and partly degraded plant and animal material.

- TKN is a measure of the amount of organic nitrogen present. TKN levels measured displayed a similar trend as the TOC, in that levels in the upper watershed were greater than the lower watershed.

3.1.3 Microbiological Indicators

Microbiological parameters analyzed included fecal coliforms and E.coli. Fecal coliforms are common bacteria to the intestinal tracts of both human and warm-blooded animals and are an indicator of human and animal waste inputs to watercourses. Levels of fecal coliform were the highest at AND-01 sample location (600 CFU/100 mL) out of all the sample locations. Higher levels of fecal coliforms were also noted at AND-03 (210 CFU/100 mL) location. E. coli concentrations were similar in trend and concentration as those of the fecal coliform levels analyzed.

Various microbiological indicator guidelines exist for fecal and E. coli parameters with guideline values being dependent on the use of the water being sampled. The most appropriate guidelines for fecal coliform comparisons were to BC Water Quality Recreational Primary Contact guidelines and Health Canada Guidelines for Canadian Recreational Water Quality (2012). Guideline results comparisons were not included in Appendix D.4.1 for the microbiological parameters, as the guidelines require a minimum of 5 weeks of consecutive sampling and water quality sampling for this program only included a single sample. The concentration comparisons provided in this summary are for general comparative purposes only and should be applied with caution.

Health Canada guidelines for E. coli, based on recreational primary contact levels, are ≤200/100 mL for geometric mean values and ≤400 E.coli/100 mL maximum. BC Water Quality guidelines for E. coli based on recreational primary contact levels are ≤77/100 mL geometric mean. E. coli levels measured during the single sampling event were above the Health Canada recommended guidelines for recreational primary contact for a single sample at AND-01. No guidelines from Health Canada are available for fecal coliform levels. BC Water Quality guidelines for fecal coliform levels for recreational primary contact water use is ≤200/100 mL geometric mean. Only one sample was collected as part of this program so comparison to guidelines with geometric means was not possible.

3.1.4 Metals

Total metal concentrations in Anderson Creek generally trended to higher concentrations measured in the upper watershed when compared with the lower watershed sample sites. Total aluminum, cadmium, copper and iron were metals that exceed either one or both of the CCME and BC Water Quality Guidelines (chronic or acute levels) at one or more of the Anderson Creek water quality sampling locations. Tables 4 below outline the value obtained at each of the sites for the exceeded metal parameters with the most common exceedances for each of the sites. Exceeded guideline values are displayed in bold italics. Total cadmium, copper and lead guideline values are dependent on sample hardness values and vary between each sample.

Table 4. Total Metal Guideline Exceedances (µg/L) in Anderson Creek during Baseline Sampling, 2012

Sample Date	Parameter	Sample Location			
		AND-01	AND-02	AND-03	AND-04
Oct 3	Total Aluminum	3.4	4.4	**117**	99.7
Oct 3	Total Cadmium	<0.010	**0.023**	**0.043**	0.029
Oct 3	Total Copper	0.22	0.46	**2.27**	1.86
Oct 3	Total Iron	93.3	**452**	**664**	**568**

Cadmium and copper guideline value based on sample hardness; bolded values exceed guidelines

OF the four metals that exhibited higher values, all four had exceedances were at sample site AND-03 while there were no metal exceedances measured at AND-01. Sample site metal concentrations primarily exceeded CCME guidelines, with exception to total cadmium, where CCME and BC Water Guidelines values were the same.

3.2 Benthic Invertebrates

3.2.1 Benthic Invertebrate Metrics

Appendix D.4.2 displays the total number of benthic invertebrate taxa for the Anderson Creek sample sites in 2012. Figure 2 represents the total macro invertebrate densities obtained at each sample site and Figure 3 presents the macroinvertebrate species richness at each of the sample sites. Table 5 provides a summary of the percentage composition of the benthic invertebrate community at each riffle within a sampling site. *Diptera* dominated the communities at all sample sites with exception to AND-03, where *Amphipoda* dominated. *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) taxa are important in determining stream health, as they are sensitive to anthropogenic effects on a stream. Sample site AND-01 was the only site with significant presence of the EPT taxa.

Figure 2. Total Number of Benthic Invertebrates in Anderson Creek, 2012

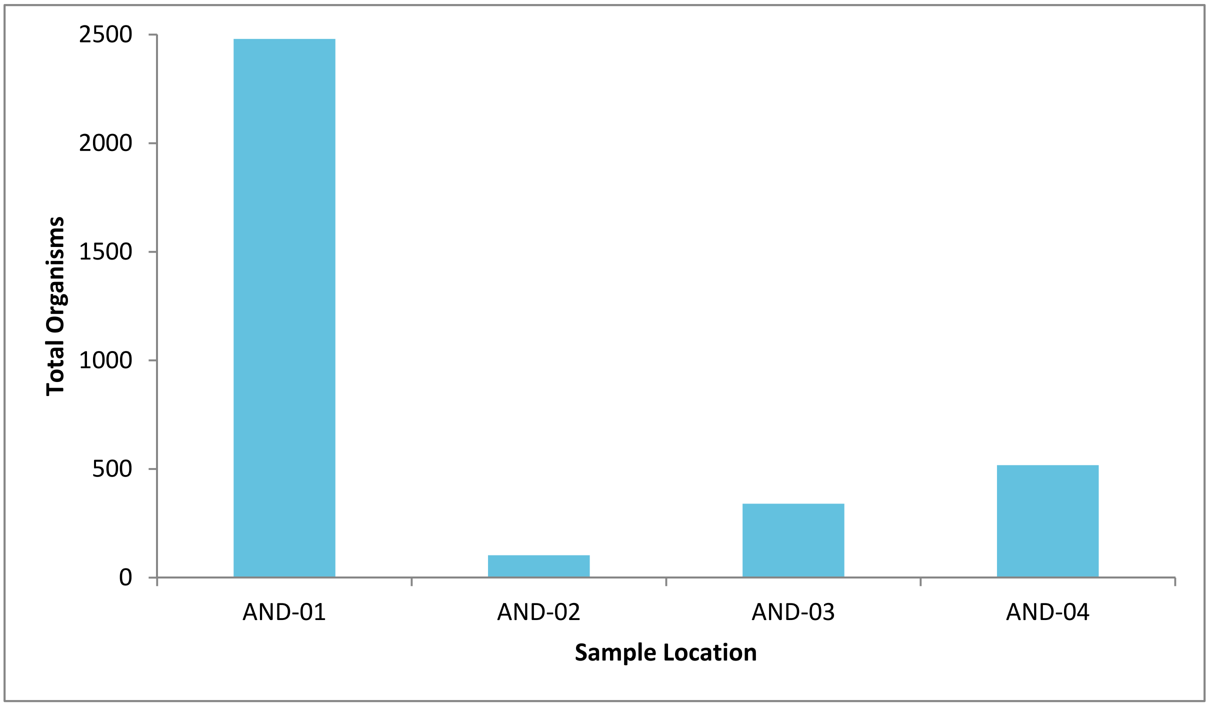

Figure 3. Species Richness of Benthic Invertebrates in Anderson Creek, 2012

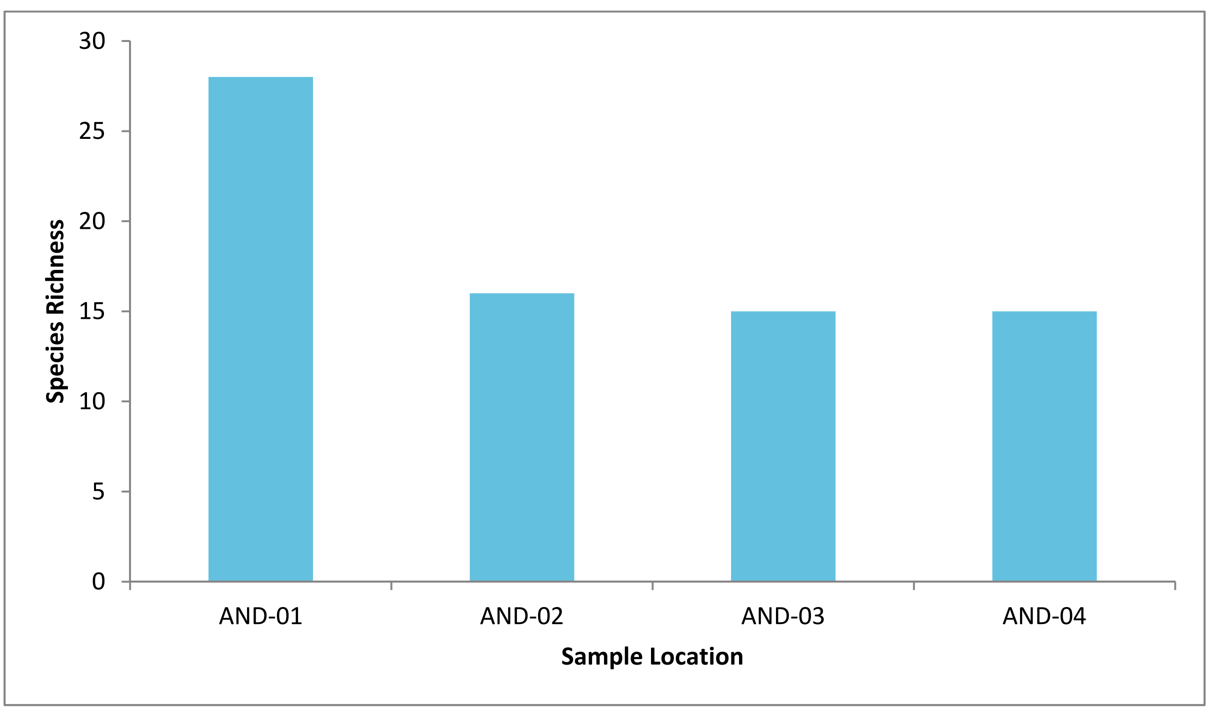

Table 5. Percentage Composition of Benthic Invertebrate Communities in Anderson Creek, 2012

Taxon	Anderson Creek			
	AND-01	AND-02	AND-03	AND-04
	Riffle 1	Riffle 1	Riffle 1	Riffle 1
Order: Ephemeroptera	11.1	4.9	1.2	0
Order: Plecoptera	14.0	2.9	0	0
Order: Trichoptera	25.2	4.9	1.2	0
Order: Diptera	**47.0**	**58.3**	32.1	**48.5**
Order: Collembola	0.3	0	0	0
Order: Trombidiformes	0.1	1.0	0	0
Order Amphipoda	0.2	12.6	**37.9**	18.3
Order: Isopoda	0	0	0	1.2
Class: Ostracoda	0	0	0.3	0.2
Subclass: Hirudinea	0.9	0	0	0
Subclass: Oligochaeta	0	0	21.2	23.6
Class: Bivalvia	0.1	0	0	0.2
Class: Gastropoda	0.2	4.9	3.8	7.3
Phylum: Platyhelminthes	0.8	0	0	0
Phylum: Nemata	0	10.7	1.8	0.8

Bolded values=dominant taxon

3.2.2 Benthic Index of Biological Integrity (B-IBI)

The below scoring system overview is derived from the GVRD Benthic Macroinvertebrate B-IBI Guide (2003). Typically a total B-IBI score consists of 4 replicate riffle results at a sampling location, which is calculated by summing ten B-IBI scores. TOL sampling methodology was modified from the GVRD guide program to included one riffle sample that contained a composite of three samples per location. The ten B-IBI scoring system consists of the following:

1. Total number of taxa
2. Number of mayfly (Ephemeroptera taxa)
3. Number of stonefly (Plecoptera) taxa
4. Number of caddisfly (Trichoptera) taxa
5. Number of long-lived taxa
6. Number of intolerant taxa
7. Tolerant individuals
8. Predator individuals
9. Number of clinger taxa
10. Dominance (top 3 taxa)

Each of the above metrics scores are assigned based on range values provided in Table 6.

Table 6. GVRD B-IBI Metric Guideline Scores Used to Determine Stream Quality

Metric	Scoring Category		
	1	3	5
Taxa Richness & Composition			
Total number of taxa	0-9	10-19	≥20
Number of mayfly (Ephemeroptera) taxa	0-2	3-5.4	≥5.5
Number of stonefly (Plecoptera) taxa	0-2	3-5.4	≥5.5
Number of caddisfly (Trichoptera) taxa	0-1	2-4.4	≥4.5
Number of long-lived taxa	0	1	≥2
Pollution Tolerance			
Number of Intolerant taxa	0	1	≥2
Tolerant individuals (%)	100-51	50-20	≤19
Feeding Ecology			
Predator individuals (%)	0-4	5-9	≥10
Population Attributes			
Number of clinger taxa	0-7	8-14	≥15
Dominance % (3 taxa)	100-76	75-51	≤50

Source: EVS, 2003

Scoring category interpretation is based on the following descriptions:

- 1: results expected in severely degraded sites
- 3: somewhat degraded sites
- 5: undisturbed sites

Total B-IBI scores obtained can be interpreted from Table 7 range values. Some range values contain gaps between each of the categories, in order to enable professional judgement to select the most appropriate category classification.

Table 7. GVRD Range B-IBI Scoring Results Interpretation Values

Metric B-IBI Score Totals	Stream Condition
46-50	Excellent
38-44	Good
28-36	Fair
18-26	Poor
10-16	Very poor

Source: EVS, 2003

Appendix D.3 provides the details of the GVRD Guideline B-IBI score rating details for the samples obtained in Anderson Creek sampling locations. Table 8 provides the summary final stream condition ratings obtained for the TOL sampling locations in Anderson Creek. Condition ratings in the Anderson Creek system were rated as very poor to fair, depending on the sampling location. Similar results for the Anderson Creek system that was previously noted in a report completed by Environment Canada from 1998-2002 when the stream system was determined to have a Possibly Stressed rating (EC, 2005). A B-IBI rating using GVRD guidelines were not calculated in the Environment Canada report and are only provided for comparative purposes.

Table 8. B-IBI Range Scores Obtained for the Township of Langley, Anderson Creek Sampling Program, 2012

Metric Scores	AND-01	AND-02	AND-03	AND-04
Metric Score	36	28	20	12
Stream Condition Rating	Fair	Fair	Poor	Very Poor

The GVRD Benthic Macroinvertebrate B-IBI Guide was used as the basis for the overall stream condition rating; however, did not contain a comprehensive ecological characteristics classification for all taxa present in the samples and required rating designation based on the professional judgement with confirmation by a trained taxonomist. Taxa with no guide designation were calculated using Washington State Department of Ecology, Sedqual Analytical Tool Development Support for the Analysis and Interpretation of Benthic Community Data (Washington Department of Ecology, 2003) and US Environmental Protection Agency (EPA), Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour, M.T., *et al*., 1999) references.

Habitat information was collected by aquatic biologists, as part of the overall B-IBI sampling protocol at each of the riffle locations where benthic invertebrates sampling was conducted. A summary table with details of each of the sample site habitat characteristics are presented in Appendix D.4.1 with individual site stream riffle data presented in Appendix D.4.2. All habitat information was collected based on conditions present in October 2012.

3.2.3 Anderson Creek Benthic Invertebrate Program – City of Surrey

Since 1999 the City of Surrey has monitored invertebrates as part of stream health monitoring and implementation of stormwater management activities. Included in the invertebrate monitoring program is a sample location in Anderson Creek along the downstream portion of the stream that traverses through the City of Surrey. The program uses a 10-metric B-IBI scoring system developed for small streams in the Puget Sound area. Guideline protocols utilized for the City of Surrey and TOL sampling programs were generally similar; however, some differences are present and required recalculation of B-IBI scores for the City of Surrey Anderson Creek sample sites in order to allow comparison between the two programs. The primary difference between the sampling programs is that three replicates are individually analyzed for the City of Surrey program, whereas three samples are composited for each of the TOL samples. For comparison, results from the 2011 City of Surrey, Anderson Creek sampling program were pooled to generate a single B-IBI score to generate a equivalent score for comparison with the TOL program. A complete list of invertebrate family/genus level data was not available for the City of Surrey monitoring programs prior to 2011 and was not included in the analysis of results. Sampling for the City of Surrey was conducted in the spring, as opposed to sampling in the summer for the TOL program, so care should be taken when comparing the two programs.

According to the GVRD B-IBI guidelines (EVS, 2003) combining samples into one composite sample for each riffle is completed to ensure that sufficient organisms are collected, particularly in streams with low invertebrate density. Reanalysis of the 2011 Anderson Creek sampling location data was completed by applying the GVRD guideline, combining the three replicate samples into one sample and reapplying B-IBI scoring. Table 9 below provides the summary of B-IBI values obtained for each replicate from the 2011 City of Surrey Benthic Invertebrate Sampling Program: Methods and Results (2012). Results of the reanalysis of the City of Surrey data by pooling of the replicate samples are provided in Table 10.

Table 9. City of Surrey Anderson Creek Sampling Results, 2011

Metric	Replicate 1		Replicate 2		Replicate 3		Mean	
	Value	Score	Value	Score	Value	Score	Value	Score
Taxa Richness	12	1	4	1	6	1	7.33	1
E Richness	2	1	2	1	1	1	1.67	1
P Richness	2	1	0	1	0	1	0.67	1
T Richness	1	1	0	1	1	1	0.33	1
Intolerant Taxa Richness	0	1	1	1	0	1	3.00	1
Clinger Richness	6	1	1	1	2	1	0.67	1
Long Life Richness	2	1	0	1	0	1	0	1
% Tolerant	0	5	0	5	0	5	4.63	5
% Predator	13.89	3	0	1	0	1	79.93	1
% Dominance (3)	63.89	3	90.91	1	85	1		3
Sample Score		**18**		**14**		**14**		
Site Score								**16**
Mean B-IBI	**15.3**							

Source: City of Surrey, 2012

Table 10. Reanalysis Results of the City of Surrey Sampling of Anderson Creek, 2011

Metric	Riffle 1	
	Value	B-IBI Score
Total number of taxa	17	3
Number of mayfly (Ephemeroptera) taxa	3	3
Number of stonefly (Plecoptera) taxa	2	1
Number of caddisfly (Trichoptera) taxa	2	3
Number of long-lived taxa	2	5
Number of intolerant taxa	5	5
Tolerant individuals (%, as a whole number)	8	5
Predator individuals (%, as a whole number)	13	5
Number of clinger taxa	10	3
Dominance (top 3 taxa; %, as a whole number)	58	3
Riffle B-IBI Score (Sum of B-IBI Scores for Each Riffle)		**36**
B-IBI Stream Condition		**Fair**

Based on the reanalysis of the data the overall stream condition for the City of Surrey, Anderson Creek sample location would be categorized as Fair. These reanalysis results are consistent with the data for the furthest TOL downstream location (AND-01) in 2012. The previous average replicate B-IBI rating in the City of Surrey report for 2011 sample results would be categorized as Very Poor. An increase of two categories occurred on the stream condition rating when pooling the results of the three replicates rather than averaging the individual B-IBI replicate ratings.

4. Summary

The information presented below is a summary of observations in the watersheds and trends from the results measured during the water quality and benthic invertebrate sampling program conducted in October 2012 for the Township of Langley, Anderson Creek ISMP, B-IBI sampling program.

- Sections of Anderson Creek were dry during the sampling period. Dry stream sections appear to occur approximately between 24th Ave and 36th Ave, which is upstream and downstream of manmade lakes (Sunrise and Rees Lakes) that are fed by groundwater. This area was historically known to flood during the winter and periods of prolonged rainfall and was the subject of a Master Drainage Plan update (1999). Dry stream sections limited water quality and invertebrate sample site selection.
- Iron oxide was noted to be present at AND-02 and increased upstream until the stream bed dried near 36th Ave.
- Upper watershed ditching and channelization restricted the location of water quality and benthic invertebrate sample sites. Private property access to Anderson Creek also limited sample site selection.
- Anderson Creek water quality results at three (AND-02, AND-03, AND-04) of the four sample sites displayed one or more exceedances above CCME and/or BC Water Quality guidelines for the following: total aluminum, total cadmium, total copper and total iron.
- Results of water quality and macroinvertebrate sampling indicates that the hydrology of the Anderson Creek watershed exhibit characteristics of an urbanized basin that contain extreme flow regimes consisting of high peak wet weather to dry weather flow ratios, a flashy storm hydrograph and low summer base flows. Flashy high flows can create issues in the watershed such as bank erosion and instability, increased sediment load in the stream and infilling. Low flows in the summer can contribute to higher water temperatures and lower dissolved oxygen levels in some reaches of the system, which can be significant impediments to fisheries resources.
- Bank characteristics varied at each sample site with all sites except AND-04 primarily consisting of soil substrate. AND-04 bank material consisted of clay and stone substrate. Undercut banks were present at all sample sites. Bank slopes range from slight at AND-03 to steep at all other sites. Bank stability was characterized as stable to moderately eroded.
- Benthic invertebrate densities were highest at the AND-01 sample location. *Diptera* dominated the communities at all sites with exception to AND-03, where *Amphipoda* dominated.
- The AND-01 invertebrate sample site had a higher density and richness of species than all other sites and the overall highest EPT richness value. Sample site AND-04 had an EPT richness of 0.
- Benthic invertebrate B-IBI had an overall very poor to fair stream condition rating for the Anderson Creek sampling locations. The stream condition rating for AND-04 was rated as very poor, AND-03 was rated as poor and AND-01 and AND-02 were rated as fair.
- The GVRD Benthic Macroinvertebrate B-IBI Guide was used as the basis for the overall stream condition rating; however, did not contain a comprehensive ecological characteristics classification for all taxa present in the samples and required rating designation based on the professional judgement. Taxa with no guide designation were calculated using Washington State Department of Ecology, Sedqual Analytical Tool Development Support For the Analysis and Interpretation of Benthic Community Data (Washington Department of Ecology, 2003)

and US Environmental Protection Agency (EPA), Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers (Barbour, M.T., *et al*., 1999) references.

5. Recommendations

The follow are final recommendations for further considerations in future benthic studies occurring within Anderson Creek.

- Water quality sampling only occurred during the one invertebrate sampling event. A more complete water quality program is recommended for future studies which should include 5 weeks of sampling within a 30 day period to allow for more comparisons with CCME and BC Water Quality guidelines. Dry and wet period sampling should also be considered.
- Further water quality sampling with additional parameters for other contaminants of concern (i.e. hydrocarbons) could be conducted to determine potential point sources for all water quality parameters that were exceeded.
- Recommend including QA/QC water quality sampling to ensure overall quality of data collection and sample analysis of the program (i.e. a field blank and a replicat sample from one site).
- Considered alternative B-IBI protocols, one alternative recommended is the Canadian Aquatic Biomonitoring Network (CABIN) Protocol (MOE 2009). The CABIN protocol is the national biomonitoring program developed by Environment Canada that provides a standardized sampling protocol and a recommended assessment approach called the Reference Condition Approach (RCA) for assessing aquatic ecosystem condition. CABIN provides the tools necessary to conduct consistent, comparable, and scientifically credible biological assessments of streams for less cost than the MV protocol.
- Benthic studies should be conducted in the Anderson Creek watersheds every 3-5 years in order to track long term trends in the area. Particular attention to B-IBI ratings and water quality guideline exceedances should be utilized as overall health monitoring indicators.

6. References

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Appendix D.1

Water Quality Data Summary

Appendix D.1- Anderson Creek Water Quality Sampling, Township of Langley 2012

RESULTS OF CHEMICAL ANALYSES OF WATER												
				Sampling Date	10/3/2012	10/3/2012	10/3/2012	10/3/2012				
	Units	RDL	CCME[a]	BC Water Guidelines	AND-01	AND-02	AND-03	AND-04	Mean	Min	Max	SD
Calculated Parameters												
Nitrate (N)	mg/L	0.002	13	32.8	2.46	0.667	0.097	0.075	0.82475	0.075	2.46	1.124081
Calculated Parameters												
Acidity (pH 4.5)	mg/L	0.50			<0.50	<0.50	<0.50	<0.50	0.5	0.5	0.5	0
Acidity (pH 8.3)	mg/L	0.50			<0.50	3.35	<0.50	<0.50	1.2125	0.5	3.35	1.425
Total Hardness (CaCO3)	mg/L	0.50			83.3	49.9	86.5	86.6	76.575	49.9	86.6	17.84925
Misc. Inorganics												
Alkalinity (Total as CaCO3)	mg/L	0.50			63.7	33.0	145	174	103.925	33	174	66.44814
Total Organic Carbon (C)	mg/L	0.50			2.46	3.01	34.9 (1)	36.2 (1)	19.1425	2.46	36.2	18.95451
Alkalinity (PP as CaCO3)	mg/L	0.50			<0.50	<0.50	<0.50	<0.50	0.5	0.5	0.5	0
Bicarbonate (HCO3)	mg/L	0.50			77.7	40.3	177	212	126.75	40.3	212	80.97763
Carbonate (CO3)	mg/L	0.50			<0.50	<0.50	<0.50	<0.50	0.5	0.5	0.5	0
Hydroxide (OH)	mg/L	0.50			<0.50	<0.50	<0.50	<0.50	0.5	0.5	0.5	0
Anions												
Orthophosphate (P)	mg/L	0.001			0.013	0.0033	0.21 (2)	0.35 (1)	0.144075	0.0033	0.35	0.167082
Dissolved Sulphate (SO4)	mg/L	0.5			16.1	15.7	22.6	18.7	18.275	15.7	22.6	3.175295
Nutrients												
Ammonia (N)	mg/L	0.005	0.34-10.3[b]	2.99-21.8[b]	0.010	0.0059	0.013	0.012	0.010225	0.0059	0.013	0.003142
Total Total Kjeldahl Nitrogen (Calc)	mg/L	0.020			0.269	0.128	1.61	1.87	0.96925	0.128	1.87	0.898139
Nitrate plus Nitrite (N)	mg/L	0.002			2.47	0.669	0.097 (1)	0.075 (1)	0.82775	0.075	2.47	1.128836
Nitrite (N)	mg/L	0.002	0.197	0.06 [q]	0.0026	0.0020	<0.020 (1)	<0.020 (1)	0.01115	0.002	0.02	0.010222
Total Nitrogen (N)	mg/L	0.020			2.73	0.798	1.71	1.95	1.797	0.798	2.73	0.795711
Physical Properties												
Conductivity	uS/cm	1			221	160	479	539	349.75	160	539	187.1744
pH	pH Units		6.5-9	6.5-9	7.94	6.89	8.12	8.25	7.8	6.89	8.25	0.619839
Physical Properties												
Total Suspended Solids	mg/L	4		Change over background [r]	<1.0	<1.0	25.4	3.4	7.7	1	25.4	11.85411
Total Dissolved Solids	mg/L	10			170	116	352	404	260.5	116	404	139.0863
Turbidity	NTU	0.1	Change over background [t]	Change over background [s]	0.28	1.61	2.01	1.47	1.3425	0.28	2.01	0.744373
Microbiological Param.												
Fecal Coliforms	CFU/100mL	1		200/100 mL [j]	600	91	210	42	235.75	42	600	252.872
E. coli	CFU/100mL	1		77/100 mL [j]	640	110	210	43	250.75	43	640	268.4193
Total Metals by ICPMS												
Total Aluminum (Al)	ug/L	3.0	100[c]	5000[z]	3.4	4.4	117	99.7	56.125	3.4	117	60.71778
Total Antimony (Sb)	ug/L	0.50		20[u]	<0.50	<0.50	<0.50	<0.50	0.5	0.5	0.5	0
Total Arsenic (As)	ug/L	0.10	5	5	0.92	0.23	2.24	3.43	1.705	0.23	3.43	1.420528
Total Barium (Ba)	ug/L	1.0		5000[u]	14.0	9.2	27.3	14.9	16.35	9.2	27.3	7.716865
Total Beryllium (Be)	ug/L	0.10		5.3[u]	<0.10	<0.10	<0.10	<0.10	0.1	0.1	0.1	0
Total Bismuth (Bi)	ug/L	1.0			<1.0	<1.0	<1.0	<1.0	1	1	1	0
Total Boron (B)	ug/L	50	29,000 (Acute); 1500 (Chronic)	1200	<50	<50	102	113	78.75	50	113	33.5

Total Cadmium (Cd)	ug/L	0.010	0.018-0.029[d]	0.018-0.029[dpu]	<0.010	0.023	0.043	0.029	0.02625	0.01	0.043	0.013696
Total Chromium (Cr)	ug/L	1.0			<1.0	<1.0	<1.0	1.3	1.075	1	1.3	0.15
Total Cobalt (Co)	ug/L	0.50		110	<0.50	<0.50	2.26	2.04	1.325	0.5	2.26	0.956852
Total Copper (Cu)	ug/L	0.20	2.0-2.9[e]	6.69-10.14 [k]	0.22	0.46	2.27	1.86	1.2025	0.22	2.27	1.014639
Total Iron (Fe)	ug/L	5.0	300	1000	93.3	452	664	568	444.325	93.3	664	249.553
Total Lead (Pb)	ug/L	0.20	1.00-2.65[f]	33.7-68.0	<0.20	<0.20	<0.20	<0.20	0.2	0.2	0.2	0
Total Lithium (Li)	ug/L	5.0		870[u]	<5.0	<5.0	<5.0	<5.0	5	5	5	0
Total Manganese (Mn)	ug/L	1.0		1090-1494[m]	80.7	83.6	145	54.4	90.925	54.4	145	38.36834
Total Mercury (Hg)	ug/L	0.010	0.026	1[y]	<0.010	<0.010	<0.010	<0.010	0.01	0.01	0.01	0
Total Molybdenum (Mo)	ug/L	1.0	73	2000	<1.0	<1.0	2.9	3.2	2.025	1	3.2	1.189888
Total Nickel (Ni)	ug/L	1.0	25.00-85.68[g]	25-65[u]	1.2	<1.0	7.7	7.4	4.325	1	7.7	3.726817
Total Phosphorus (P)	ug/L	10			17	<10	249	519	198.75	10	519	240.6552
Total Selenium (Se)	ug/L	0.10	1	2	0.11	0.13	0.25	0.15	0.16	0.11	0.25	0.062183
Total Silicon (Si)	ug/L	100			10400	8840	5910	7050	8050	5910	10400	1977.052
Total Silver (Ag)	ug/L	0.020	0.1	0.1 [n]	<0.020	<0.020	<0.020	<0.020	0.02	0.02	0.02	0
Total Strontium (Sr)	ug/L	1.0			107	90.5	118	108	105.875	90.5	118	11.38987
Total Thallium (Tl)	ug/L	0.050	0.8	0.3[u]	<0.050	<0.050	<0.050	<0.050	0.05	0.05	0.05	0
Total Tin (Sn)	ug/L	5.0			<5.0	<5.0	<5.0	<5.0	5	5	5	0
Total Titanium (Ti)	ug/L	5.0		2000[uw]	<5.0	<5.0	<5.0	<5.0	5	5	5	0
Total Uranium (U)	ug/L	0.10	33 (Acute), 15 (Chronic)	300[u]	<0.10	<0.10	0.11	0.14	0.1125	0.1	0.14	0.01893
Total Vanadium (V)	ug/L	5.0		6[u]	<5.0	<5.0	<5.0	<5.0	5	5	5	0
Total Zinc (Zn)	ug/L	5.0	30	33 [o]	<5.0	<5.0	11.3	7.3	7.15	5	11.3	2.971532
Total Zirconium (Zr)	ug/L	0.50			<0.50	<0.50	0.55	0.64	0.5475	0.5	0.64	0.066018
Total Calcium (Ca)	mg/L	0.050			22.8	12.8	21.0	20.8	19.35	12.8	22.8	4.458326
Total Magnesium (Mg)	mg/L	0.050			6.44	4.37	8.28	8.43	6.88	4.37	8.43	1.902297
Total Potassium (K)	mg/L	0.050		373-432[ux]	1.50	0.941	10.1	12.8	6.33525	0.941	12.8	6.012318
Total Sodium (Na)	mg/L	0.050			9.03	9.48	69.0	78.6	41.5275	9.03	78.6	37.47105
Total Sulphur (S)	mg/L	3.0			5.5	6.3	8.6	8.7	7.275	5.5	8.7	1.621471

a) Canadian water quality guidelines for the protection of aquatic life, Council of Ministers of the Environment, 2007. http://www.ccme.ca/publications/ceqg_rcqe.html

b)Exceedance based on Temperature and pH.; CCME guidelines converted to mg/L total ammonia-N by multiplying value x 0.8224.

c) 5 ug/L at ph<6.5; 100 ug/L at pH ≥6.5.

d) calculated as 10 exp $^{(0.86*[Log(Hardness)] -3.2)}$ *; expressed using total hardness of samples*

e) calculated as $e^{0.8545[ln(hardness)]-1.465}$ *x 0.2 ug/L; expressed using total hardness of samples*

f) calculated as $e^{1.273[ln(hardness)]-4.705 ug/L}$ *; expressed using total hardness of samples*

g) calculated as $e^{0.76[ln(hardness)]+1.06 ug/L}$ *; with a minimum of 25 ug/L regardness of water hardness; expressed using total hardness of samples*

h)0.4 mg/L at hardness 10mg/L; calculate -51.73 +92.57 log10 (hardness) x 0.01; expressed as total hardness of samples

i)100 mg/L unless aquatic moss present then 50 mg/L

j) based on the recreation - primary contact value (geometric mean); geometric mean requires 5 samples collected in a 30-day period

k)calculated as 0.094 (hardness) +2; expressed using total hardness of samples

l)3 ug/L at hardness is ≤ 8 mg/L; e(1.273 1n hardness)-1.460) at hardness > 8 mg/L; expressed using total hardness of samples

m) Instantaneous maximum calculated from 0.01102(hardness) + 0.54; expressed using total hardness of samples

n)0.1 ug/L at hardness ≤ 100mg/L; 3 ug/L at hardness >100mg/L

o)33 ug/L at hardness of ≤90 mg/L (Acute); and 33+0.75(hardness mg/L-90) for hardness that exceeds 90 mg/L

p) 0.01 at hardness 30 mg/L; 0.02 ug/L at hardness 60 mg/L; 0.03 ug/L at hardness 90 mg/L; 0.04 at hardness 120 mg/L; 0.05 ug/L at hardness 150 mg/L; 0.06 at hardness 210 mg/L. BC Working water quality criteria

q) 0.06 mg/L maximum when chloride values are less than 2 mg/L; 0.12 mg/L maximum when chloride values between 2-4 mg/L

r) Change from background of 25 mg/L at any one time for a duration of 24 h in all waters during clear flows or in clear waters; Change from background of 5 mg/L at any one time for a duration of 30 d in all waters during clear flows or in clear waters; Change from background of 10 mg/L at any time when background is 25 - 100 mg/L during high flows or in turbid waters; Change from background of 10% when background is >100 mg/L at any time during high flows or in turbid waters

s) Change from background of 8 NTU at any one time for a duration of 24 h in all waters during clear flows or in clear waters; Change from background of 2 NTU at any one time for a duration of 30 d in all waters during clear flows or in clear waters;
Change from background of 5 NTU at any time when background is 8 - 50 NTU during high flows or in turbid water; Change from background of 10% when background is >50 NTU at any time during high flows or in turbid waters

t) Clear flow: Maximum increase of 8 NTUs from background levels for a short-term exposure (e.g., 24-h period). Maximum average increase of 2 NTUs from background levels for a longer term exposure (e.g., 30-d period);
High flow or turbid waters: Maximum increase of 8 NTUs from background levels at any one time when background levels are between 8 and 80 NTUs. Should not increase more than 10% of background levels when background is > 80 NTUs

u) A compendium of working water quality guidelines for British Columbia, 2006. http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html

v) 25, maximum at hardness of 0 to 60 mg/L as CaCO3; 65, maximum at hardness of 60 to 120 mg/L as CaCO3; 110, maximum at hardness of 120 to 180 mg/L as CaCO3; 150, maximum at hardness greater than 180 mg/L as CaCO3

w) 2000 ug/L, median threshold level: Scenedesmus; 4600 ug/L, median threshold level : Daphnia

x) As KCl, threshold for Daphnia magna immobilization

y) Guidelines for drinking water, primary-contact recreation and food processing industry

z) Guideline for wildlife, livestock and irrigation water supply

"<"	*Less than detection limit.*
0.125	*Value exceeds CCME guideline.*
0.125	*Value exceeds BC WQ guidelines*
0.125	*Value exceeds both CCME and BC WQ guidelines*

RDL = Reportable Detection Limit.

EDL = Estimated Detection Limit.

(1) RDL raised due to sample matrix interference.

(2) Sample was originally analysed within hold time. Data quality required investigation. Re-analysis was completed past recommended hold time.

Appendix D.2

Benthic Invertebrate Data

Appendix D.2 - Township of Langley Benthic Invertebrate Sampling Data, 2012

	AECOM	LANGLEY (2012)					
		Subsampling		1/2 fines			
	Family	**Genus/ species**	**Stage**	**AND-01**	**AND-02**	**AND-03**	**AND-04**
Ephemeroptera							
	Unid J or Damaged		N	30			
	Baetidae	Unid J	N	181	5	4	
	Caenidae	Unid J	N	20			
	Heptageniidae	Unid J or Damaged	N	6			
	Leptophlebiidae	Unid J/D	N	39			
Plecoptera							
	Unid J or Damaged			40			
	Chloroperlidae	Unid J or Damaged	N	71			
	Chloroperlidae	Sweltsa sp group	N	37			
	Nemouridae	Unid J or Damaged	N	197			
	Nemouridae	Zapada sp	N		1		
	Perlodidae	Unid J or Damaged	N	2	2		
Trichoptera							
	Unid J or Damaged		N	11	1		
	Glossosomatidae	Glossosoma sp	N		3	3	
	Hydropsychidae	Hydropsyche sp	N	586			
	Hydropsychidae	Parapsyche sp	N	2			
	Phryganeidae	Ptilostomis sp				1	
	Rhyaciphilidae	Rhyacophila brunnea or vao	N	21			
	Rhyacophilidae	Rhyacophila vepulsa	N		1		
	Rhyacophilidae	Rhyacophila verrula	N	5			
Diptera			P	2		4	7
Diptera	Unid J or Damaged				1		
	Ceratopogonidae	Bezzia or Palpomyia sp	L	3	1	9	1
	Chironomidae Adult		A	2			
	Chironomidae Pupa		P	41	1	1	22
	Chironomidae	Unid J or Damaged	L	29	3	16	9
	Chironomidae	**Chironomini**	L		2	5	3
	Chironomidae	Dicrotendipes sp	L				1
	Chironomidae	Polypedilum (Polypedilum) sp	L		4		1
	Chironomidae	**Tanytarsini**					
	Chironomidae	Micropsectra sp	L	41	1	20	6
	Chironomidae	Rheotanytarsus sp	L				56
	Chironomidae	**Orthocladiinae**	L	53	5		30
	Chironomidae	Brillia sp	L		24	5	1
	Chironomidae	Cricotopus/Orthocladius sp	L	22		5	15
	Chironomidae	Diplocladius sp	L	1	8		
	Chironomidae	Eukiefferiella sp	L	38	1	13	6
	Chironomidae	**Tanypodinae**	L			1	26
	Chironomidae	Thienemannimyia sp	L			15	59
	Empididae	Unid J	L				1
	Empididae		P				1
	Empididae	Chelifera/Metachela sp	L	4			
	Empididae	Clinocera sp	L		1		
	Empididae	Neoplasta sp	L			2	3
	Simuliidae	Unid	P	280	1		
	Simuliidae	Simulium sp	L	510	3	4	1
	Simuliidae	Simulium sp	P	72		6	2
	Tipulidae Unid J L		L	3			
	Tipulidae	Dicranota sp	L	61	3	3	
	Tipulidae	Hexatoma sp	L	1			
	Tipulidae	Limnophila sp	L	1	1		
	Tipulidae	Tipula sp	L	2			
Collembola							
	Unid J			8			

Appendix D.2 - Township of Langley Benthic Invertebrate Sampling Data, 2012

	AECOM	LANGLEY (2012)					
		Subsampling		1/2 fines			
	Family	**Genus/ species**	**Stage**	**AND-01**	**AND-02**	**AND-03**	**AND-04**
Hydracarina				2			
	Sperchontidae	Sperchon sp			1		
Amphipoda							
	Unid J			2		2	
	Gammaridae	Gammarus lacustris		4	13	129	95
Isopoda							
	Asellidae	Caeridotea sp					6
Ostracoda							
	Candonidae	Candona sp				1	1
Hirudinea							
	Piscicolidae	Piscicola sp		23			
Oligochaeta							
	Lumbricidae	Unid J/D					19
	Tubificidae					72	103
Bivalva		Unid/J					1
	Pisidiinae	Pisidium sp		2			
Gastropoda	Unid J					7	3
	Ancylidae	Ferrissia fragilis				1	3
	Lymnaeidae	Unid J/D					3
	Physidae	Unid J/D					1
	Physidae	Physella gyrina			4	1	8
	Planorbidae	Unid J/D		4			20
	Planorbidae	Gyraulus sp			1	4	
Platyhelminthes							
	Planariidae	Polycelis coronata		20			
Nematoda				1	11	6	4

Legend

A=adult
Unid J = Unidentified Juvenille
Unid = Unidentified
L=Larva
N=Nymph
P=pupa
terr=terrestrial

Appendix D.3

B-IBI Rating Summary

Appendix D.3 - Township of Langley, B-IBI Rating Summary, 2012

Site ID	AND-01		AND-02		AND-03		AND-04	
Device	Surber		Surber		Surber		Surber	
Collection Date	4-Oct-12		3-Oct-12		3-Oct-12		3-Oct-12	
METRIC	**Value**	**B-IBI Score**	**Value**	**B-IBI Score**	**Value**	**B-IBI Score**	**Value**	**B-IBI Score**
Total number of taxa	28	5	16	3	15	3	15	3
Number of mayfly (Ephemeroptera) Taxa	4	3	1	1	1	1	0	1
Number of stonefly (Plecoptera) taxa	3	3	2	1	0	1	0	1
Number of caddisfly (Trichoptera) Taxa	4	3	2	3	2	3	0	1
Number of long-lived taxa	2	5	1	3	0	1	0	1
Number of intolerant taxa	12	5	6	5	3	5	0	1
Tolerant individuals (%, as a whole number)	26	3	27	3	62	1	51	1
Predator individuals (%, as a whole number)	6	3	17	5	6	3	2	1
Number of clinger taxa	10	3	7	1	3	1	1	1
Dominance (top 3 taxa) (%, as a whole number)	55	3	68	3	82	1	84	1
Riffle B-IBI score (SUM of B-IBI score)		**36**		**28**		**20**		**12**
Stream Condition		**Fair**		**Fair**		**Poor**		**Very Poor**

B-IBI Scores
1=Results expected in severely degraded sites
3=Somewhat degraded sites
5=Undisturbed sites

Appendix D.4.1

Habitat Characteristics

Appendix D.4.1: Habitat Characteristics of AND-01, AND-02, AND-03, AND-04

Sites	AND-01		AND-02		AND-03		AND-04	
General Stream Characterization								
Channelized (Y or N)	Y		Y		Y		Y	
Aquatic biota present	Fish, macrophyte		Moss, iron oxide, periphyton, fish, macrobenthos		Periphyton, fish, macrobenthos		Moss, fish, macrobenthos, iron oxide	
Riparian zone and Land Use Characteristics	**Left Bank ***	**Right Bank***	**Left Bank***	**Right Bank ***	**Left Bank***	**Right Bank ***	**Left Bank***	**Right Bank ***
Human Disturbances								
Dike / riprap	1	1	1	1	1	1	1	1
Buildings	3	1	4	3	4	4	4	4
Pavement	4	1	4	4	1	1	1	1
Road / railway	4	1	4	4	4	1	1	1
Pipes (inlet or outlet)	1	1	1	1	1	1	1	1
Landfill / garbage dump	1	1	1	1	1	1	1	1
Urban park / maintained lawn	1	3	3	2	1	2	4	4
Row crops / agriculture	1	1	1	1	4	4	4	4
Pasture / rangeland	1	1	1	1	4	4	4	4
Logging operations	1	1	1	1	1	1	1	1
Vegetation								
Riparian vegetation	Grass, herbs, shrubs, deciduous/coniferous trees	Grass, herbs, shrubs, deciduous/coniferous trees	Herbs, shrubs, deciduous/coniferous trees	Grass, herbs, shrubs, deciduous/coniferous trees	Grass, herbs, shrubs, deciduous/coniferous trees	Grass, herbs, shrubs, deciduous/coniferous trees	Herbs, shrubs, deciduous/coniferous trees	Grass, herbs, shrubs, deciduous/coniferous trees
% Riparian cover	>75	>75	75	75	75	75	>75	>75
Bank characteristics								
Stability (stable, slightly eroded, moderately eroded, severely eroded	Stable	Moderately Eroded	Slightly Eroded	Slightly Eroded	Stable	Stable	Slight	Moderately Eroded
Bank slope (slight, moderate, steep, other)	Steep	Steep	Moderate-Steep	Moderate-Steep	Moderate	Slight	Moderate	Steep
Undercutting (present, absent)	Present	Present	Present	Present	Present	Present	Present	Present
Material (clay, rock, soil, mud, stones)	Soil	Soil	Soil/Stone	Soil/Stone	Soil	Soil/Clay	Clay/Stone	Clay/Stone

*Looking downstream

1=not present, 2 = on the bank, 3 = within 10 m, 4 = >10 m

AECOM

Appendix D.4.2

Riffle Characteristics

Appendix D.4.2: Riffle Data of AND-01, AND-02, AND-03, AND-04, Anderson Creek, 2012

Location	Riffle	% Embeddedness	Boulder (>250 to 4000 mm)	Cobble (>64 to 250 mm)	Gravel (>2 to 64 mm)	Sand (0.06 to 2 mm)	Clay	Wood	Average Water Depth (cm)	Wetted Channel Width (m)	Bankfull Channel Width (m)	Comments
AND-01	**Riffle 1**	0-25	0	0	75	25	0	25	11.7	6.4	26.9	Brookswood park adjacent, stream in ravine, left bank residential properties, invasive ivy on left bank, trail system throughout area, bank stabilization measures present
AND-02	**Riffle 1**	0-25	20	75	5	0	0	5	11.0	4.5	6.4	Stream channel dries upstream near 36th Ave, channel restoration and crossing improvements occurring at 36th Ave, iron oxide present, residential properties on top of both banks, residential structures located near stream, invasive plant growth on right bank
AND-03	**Riffle 1**	25-50	0	25	60	15	0	25	35	5.6	13.8	Large agricultural properties surrounding area, anthropogenic structures along and surrounding stream section, water tanic
AND-04	**Riffle 1**	0-25	0	10	5	20	85	15	4.7	1.1	5.2	Evidence of erosion in area, fence structures across stream, frogs observed in sample area

Appendix D.5

Photographs

Photograph 1. ↑
Looking downstream from AND-01 sampling location with bank reinforcement structure in background (October 3, 2012).

Photograph 2. ↑
Looking upstream towards the AND-01 sampling site (October 3, 2012).

Photograph 3. ↑
Upstream of the AND-01 sample site looking at bank erosion (October 4, 2012).

Photograph 4. ↑
Looking upstream at the AND-02 sample location (October 3, 2012).

Photograph 5. ↑
Looking downstream at the AND-02 sample location (October 3, 2012).

Photograph 6. ↑
Looking at the right bank adjacent to AND-02 sample site with invasive plant coverage (October 3, 2012).

Photograph 7. ↑
Downstream of AND-02 sample location, looking at bank erosion along the left bank (October 3, 2012).

Photograph 8. ↑
Looking downstream from AND-03 sample location (October 3, 2012).

Photograph 9. ↑
Looking upstream at the AND-03 sample location (October 3, 2012).

Photograph 10. ↑
Looking upstream from AND-03 sample location from a footbridge across the stream, towards bank armouring along left bank (October 3, 2012).

Photograph 11. ↑
Looking upstream at the AND-04 sample location (October 3, 2012).

Photograph 12. ↑
Looking downstream from AND-04 sample location (October 3, 2012).

Photograph 13. ↑
Downstream of the AND-04 sample location, looking at a fence across the stream (October 3, 2012).

Photograph 14. ↑
Downstream of the AND-04 sample location at erosion along the stream bank (October 3, 2012).

Photograph 15. ↑
Looking downstream towards Colebrook Road near the City of Surrey Anderson Creek sample location (October 4, 2012).

Photograph 16. ↑
Looking downstream from the Colebrook Road bridge at Anderson Creek, near the City of Surrey sampling location (October 4, 2012).

Photograph 17. ↑
Looking downstream towards 36th Avenue at section of dry stream channel adjacent to Noel Booth Park (October 4, 2012).

Photograph 18. ↑
Looking downstream from 36th Avenue at new instream works along Anderson Creek (October 4, 2012).

Photograph 19. ↑
Looking downstream at a dry section of Anderson Creek at the north end of 201th Street (October 4, 2012).

Photograph 20. ↑
Looking southwest along the bank of Sunrise Lake (September 15, 2012).

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The attached Report (the “Report”) has been prepared by AECOM Canada Ltd. (“Consultant”) for the benefit of the client (“Client”) in accordance with the agreement between Consultant and Client, including the scope of work detailed therein (the “Agreement”).

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- represents Consultant’s professional judgement in light of the Limitations and industry standards for the preparation of similar reports
- may be based on information provided to Consultant which has not been independently verified
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- was prepared for the specific purposes described in the Report and the Agreement
- in the case of subsurface, environmental or geotechnical conditions, may be based on limited testing and on the assumption that such conditions are uniform and not variable either geographically or over time

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