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Project File for Schedule B Class EA:

Municipal Class Environmental Assessment for Appleby Creek Flood Mitigation between Fairview Street and New Street

A file submitted by:

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Pinedale Ave Bridge Over Appleby Creek

NOTICE OF STUDY COMPLETION

Appleby Creek Flood Mitigation
between Fairview Street and New Street

Class Environmental Assessment Study

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1 INTRODUCTION

1.1 Overview of Study and Problem Definition

Aquafor Beech Limited (Aquafor) was retained by the City of Burlington (City) to undertake a Schedule B Class Environmental Assessment of Appleby Creek, within the City of Burlington, for the extents as defined within **Figure 1.1**.

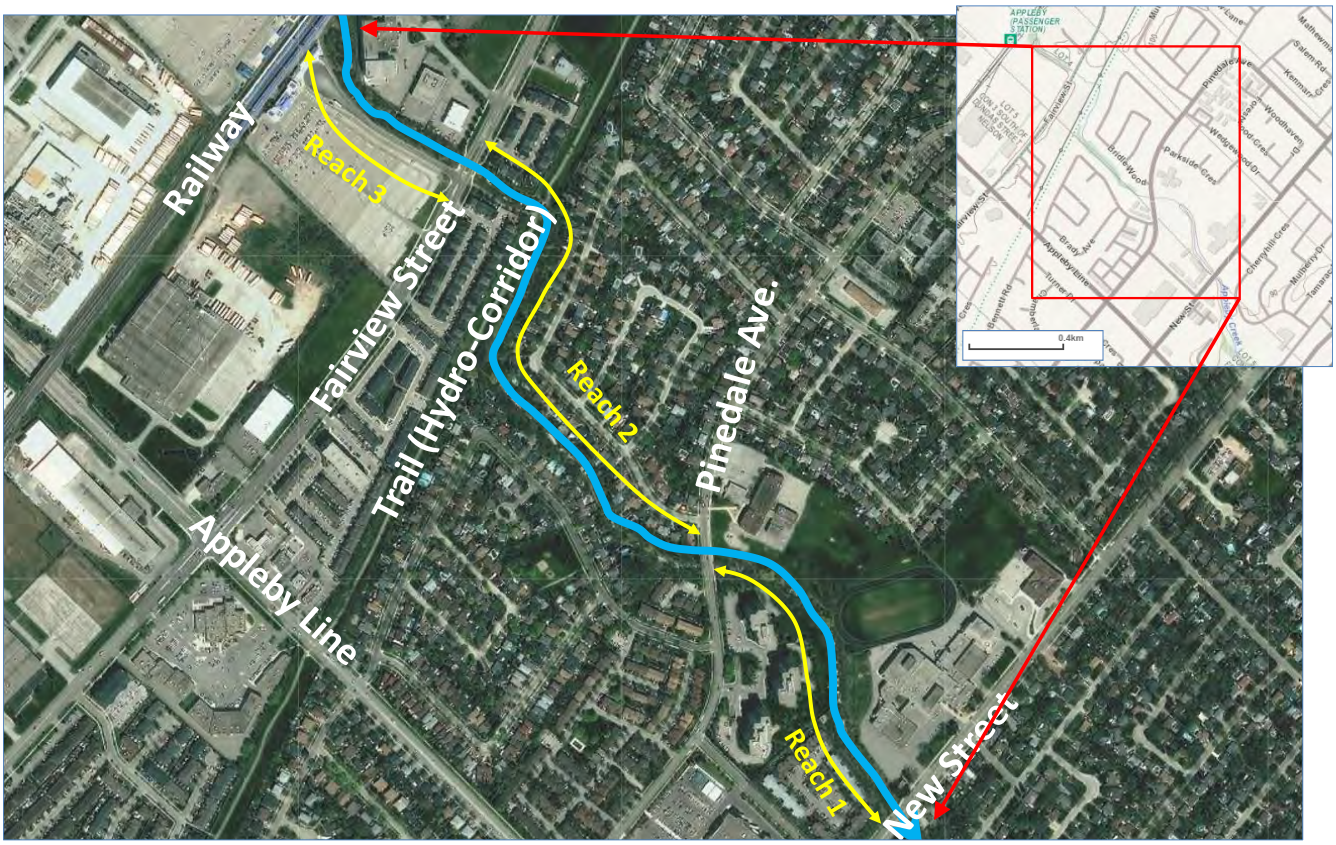


Figure 1.1: Limits of study area along Appleby Creek

The purpose of the study was to identify flood mitigation opportunities within the Appleby Creek watershed from the Canadian National (CN) Railways to New Street. The study investigated the hydraulic constraints and opportunities throughout the entire reach, with particular focus on the road crossings.

The objective of this study was to identify specific opportunities that reduce flooding risk and protect the natural heritage features and functions within the study area. Flood risks were identified and quantified as buildings within the flood limits, frequency of road inundation and hydraulic conveyance capacity of the channel and road crossing structures. As part of the environmental assessment process this study will also assess and evaluate flood mitigation

opportunities in light of mitigating biophysical, socio-cultural, built and economic environments to the Appleby Creek study area.

Previous flooding studies along Appleby Creek have identified flood risks within the study area, specifically identifying three (3) flood vulnerable areas (i.e., (1) immediately upstream of New Street, (2) the entire corridor between Pinedale Avenue and Fairview Road, and (3) immediately upstream of Fairview Road) and recommended flood mitigation opportunities including localized channel widening and widening the Pinedale Avenue culvert. Throughout this study, these risks and opportunities were included within the analysis and evaluation of alternatives.

1.2 Class Environmental Assessment Process

The Environmental Assessment Act (EAA) was proclaimed into law by the Province of Ontario in 1976 to ensure that proponents consider the environmental impacts of their proposals prior to commencement and with public transparency. The "environment" as defined by the EAA is understood broadly to include the biophysical, socio-cultural, built and economic environments and the interrelationships between them. The EAA applies primarily to public sector undertakings and extends to private sector projects where designated under regulation.

The EAA draws a distinction between "individual" and "class" environmental assessments (EA). Individual EA's are prepared for large, complex projects in which significant environmental impacts are foreseeable. A "Terms of Reference" are devised which outline the EA process, and the final EA document is submitted to the Ministry of the Environment (MOE) for approval. Alternatively, a Class EA is a streamlined approval process for a group of routine undertakings with predictable environmental impacts. Once a Class EA planning document is approved by MOE, all projects of this type are pre-approved provided that they adhere to its design. In this fashion, the Class EA process expedites approval for smaller, recurring projects.

The Municipal Class EA, which is followed here, outlines how municipal infrastructure projects are planned in accordance with the EAA. The Municipal Class EA is consistent with the EAA's five key principles for successful planning:

- Consultation with affected parties early on and throughout the process, such that the planning process is a cooperative venture;
- Consideration of a reasonable range of alternatives, both the functionally different "alternatives to" and the "alternative methods" of implementing the solution;
- Identification and consideration of the effects of each alternative on all aspects of the environment;
- Systematic evaluation of alternatives in terms of their advantages and disadvantages, to determine their net environmental effects; and

- Provisions of clear and complete documentation of the planning process followed, to allow "traceability" of decision-making with respect to the project.

The accompanying flow chart (**Figure 1.2**) illustrates the process followed in the planning and design of projects covered by the Municipal Class EA. The five phases, as illustrated, are summarized in the planning document as follows:

Phase 1: Identify the problem or deficiency.

Phase 2: Identify alternative solutions to the problem, by taking into consideration the existing environment, and establish the preferred solution taking into account public and agency review and input. At this point, identify approval requirements (e.g., OWRA, Lakes and Rivers Improvement Act, EPA) and determine the appropriate schedule for the project: proceed through the following phases for Schedule C projects.

Phase 3: Examine alternative methods of implementing the preferred solution, based upon the existing environment, public and government agency input, anticipated environmental effects and methods of minimizing negative effects and maximizing positive effects.

Phase 4: Document, in an Environmental Study Report, a summary of the rationale and the planning, design, and consultation process of the project as established throughout the above phases, and make such documentation available for scrutiny by review agencies and the public.

Phase 5: Complete contract drawings and documents, and proceed to construction and operation; monitor construction for adherence to environmental provisions and commitments. Where special conditions dictate, also monitor the operation of the completed facilities.

The extent to which the above process is followed in full depends on the project's schedule. The schedule is selected early in the process and is based on the magnitude of anticipated environmental impacts:

- **Schedule A** – Projects that typically include normal or emergency maintenance and operational activities. These projects are generally small, pose limited adverse environmental impacts, and are pre-approved without the requirement for public consultation.

- **Schedule A+ –** Similar to Schedule A, these projects are also routine and pre-approved but require public notification prior to commencement. Because these projects are pre-approved, however, there is no mechanism for appeal to MOE and public comment can only be directed to municipal council.

- **Schedule B** – Projects with greater potential for environmental impact thereby requiring notification of the public and relevant review agencies. Examples include stormwater ponds, river crossings, expansion of water or sewage plants beyond their rated capacity, and new or expanded outfalls and intakes. Schedule 'B' projects require completion of Phases 1 and 2 of the Municipal Class EA process.

- **Schedule C** – Projects that pose major environmental impacts and are therefore subject to the full scope of the Municipal Class EA planning, notification and documentation procedures. Examples include storage tanks and tunnels with disinfection, anything involving chemical treatment or expansion beyond a water or sewage plants rated capacity. Schedule 'C' projects require completion of Phases 1 through 4 of the Class EA process, before proceeding to Phase 5 implementation.

This project may be classified as a "Road Project" within the Municipal Class Environmental Assessment manual, as it involves the potential reconstruction of a road water crossing. Class EA Schedule determination for a Road Project is subject to the anticipated total cost of the project, as well as consideration to the potential environmental impacts. If the preferred alternative is to replace any structures within the study area, the new structures would have increased hydraulic capacity, and therefore the Municipal Class Environmental Assessment manual would describe these works as:

"Reconstruction of a water crossing where the reconstructed facility will not be for the same purpose, use, capacity or at the same location. (Capacity refers to either hydraulic or road capacity but does not include alterations to include or remove facilities for cycling, pedestrians or to support utilities.)" (Appendix 1, Municipal Road Project Schedules, Item 25)

The schedule classification for these works is subject to the anticipated cost of the implementation of the works, excluding the cost of acquisition of land, feasibility, engineering design, and operation of the project. For these works, if the anticipated cost of the structure replacement is greater than $2,400,000, this project would then be redefined as a Schedule C. However, if the anticipated cost of the works is less than $2,400,000, then the project is defined as a Schedule B.

This project has followed the Schedule B process, as environmental, socio-cultural, built and economic environments and the interrelationships between them are considered limited, and anticipated costs are less than the noted threshold.

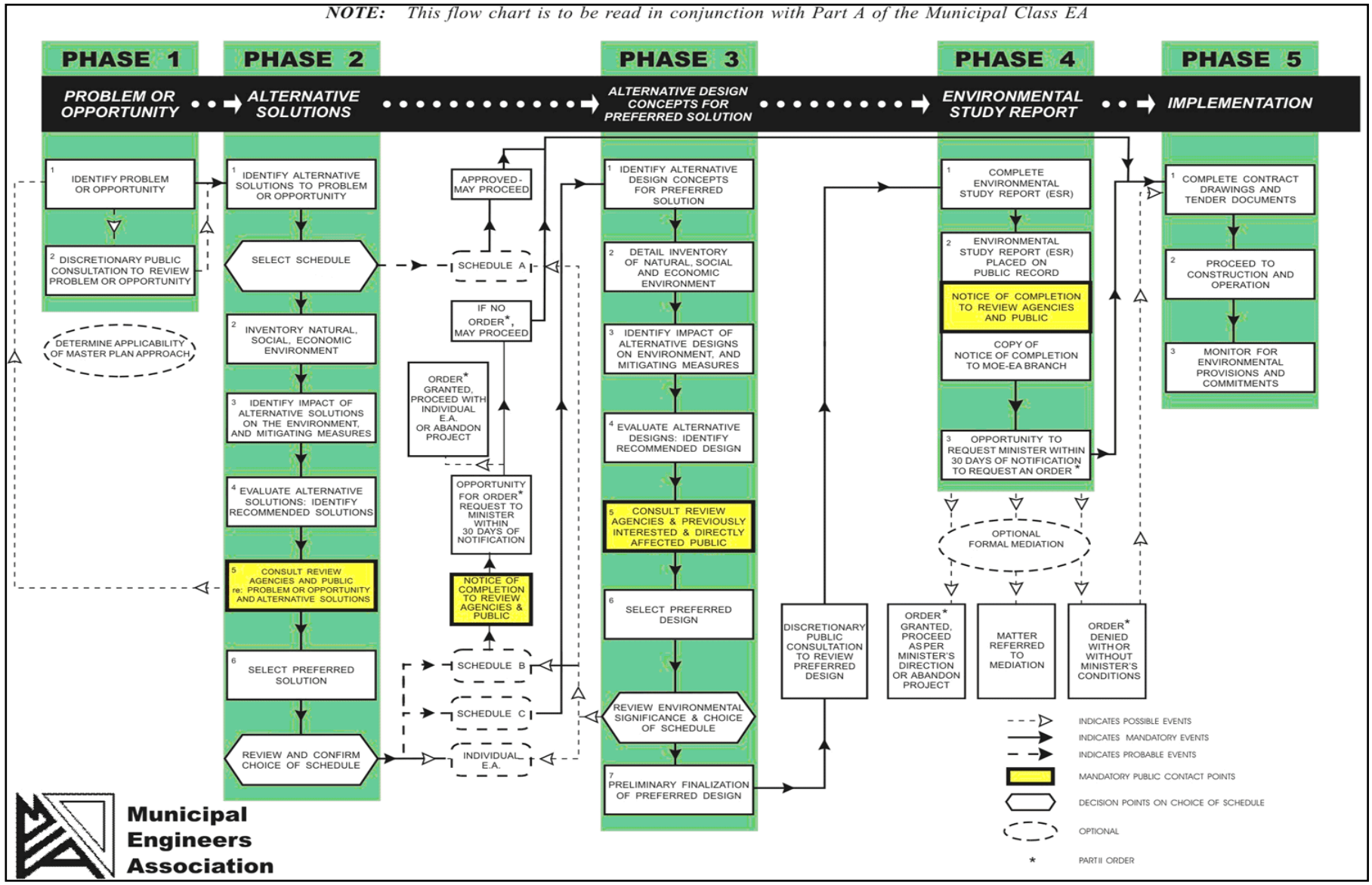


Figure 1.2: Municipal Class Environmental Assessment planning and design process.

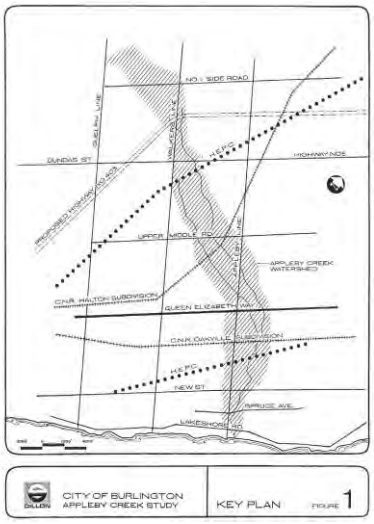
1.3 Background

Below is a summary of previous studies and reports that have been reviewed for the purposes of this study:

Appleby Creek Study (1977)
undertaken by Dillon Ltd. for the City of Burlington

This watershed study of Appleby Creek was carried out to support the development of a storm water drainage master plan of the watershed. The study identified the Appleby Creek watershed to have relatively low risks of flooding, with the main areas of concerns as the following:

- Creek corridor between Lakeshore Road and Spruce Avenue, where 5 houses on the west bank would be inundated under the major design storm;
- Restricted conveyance capacity of the culverts under the Canadian National Railway tracks and Upper Middle Road.

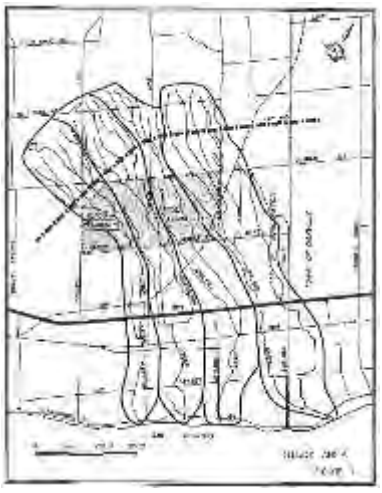


The study also investigated two mitigation methods to address the flooding issues, including controlling runoff by the provision of storage ponds and replacing/improving the structures to increase conveyance capacity. Due to the shape of the watershed (long and narrow) and localized flooding problems, the study recommended the latter method to be undertaken, which involves improving the conveyance capacity of the hydraulic structures, channel widening, and channelization.

Tuck, Shoreacres, Appleby and Sheldon Creeks Watershed Study (1985)
undertaken by the Proctor & Redfern Group for the City of Burlington

The study defined the floodplains along each of the abovementioned creeks, identified potential flooding and erosion problems, and outlined Master Drainage Plan for each watershed.

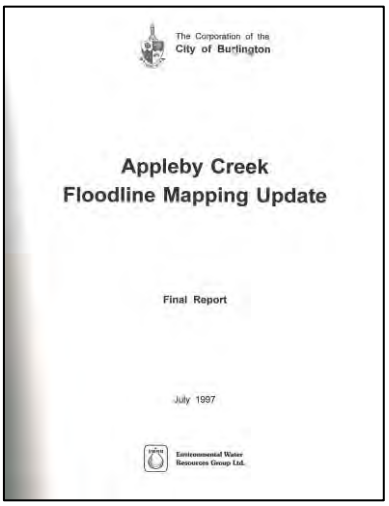
The report identified Appleby as relatively free from flood vulnerable areas. Flooding issues were mostly associated with undersized culverts.



Appleby Creek Channelization (1987)
undertaken by Dillon Ltd. for the City of Burlington

Upon reviewing the existing flooding conditions and water level calculations undertaken for the 1985 Tuck, Shoreacres, Appleby and Sheldon Creek Report, this study investigated alternative remedial measures relating to the homes located in the floodplain between Spruce Avenue and Lakeshore Road. It is suggested that downstream Appleby (Spruce to Lakeshore) should be channelized to mitigate flooding and erosion.

Appleby Creek Floodline Mapping Update (1997)
undertaken by EWRG for the City of Burlington



The purpose of the study was to update the floodline mapping along Appleby Creek. The study assessed flow conditions for the Regional, 100, 50, 25, 5, and 2-year return period events under both existing and future land use conditions.

The Regional flow for Appleby is defied in the report (as Hurricane Hazel) and it is identified that New Street Bridge, Pinedale Avenue Bridge, and Fairview Street Culverts are overland flow zones, with one (1) building in the floodplain.

The study identified the following:

- The updated Regulatory Floodplain has a total area of approximately 70 ha;
- Eleven (11) buildings in total are within the flood limit;
- New Street Bridge, Pinedale Avenue Bridge, and Fairview Street Culverts are overland flow zones, with one (1) building in the floodplain; and
- Building floodproofing is considered to be the preferred mitigation measures as it is expected to have the greatest benefit-cost ratio.

August 4th, 2014 Storm Event Burlington (2015)
undertaken by EWRG for the Conservation Halton



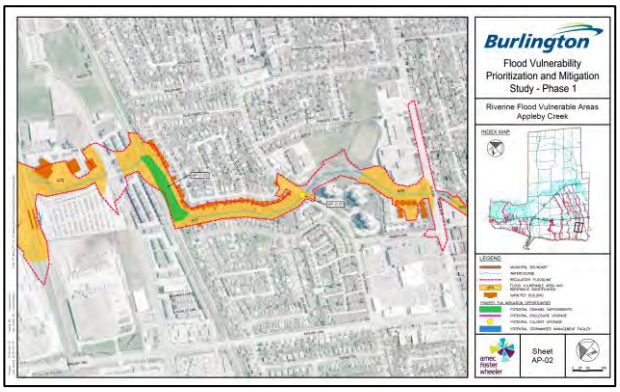
A severe, unprecedented storm hit Burlington on the afternoon and evening of August 4th, 2014. The storm generated extreme flash floods and caused significant damage to the lands and properties along Roseland, Tuck, Shoreacres and Appleby Creek. Along Appleby Creek, the estimated flow rates downstream of the QEW were roughly equal to the 50 year storm simulated flow rates (~40 m^3/s through the study area). The damages included:

- Approximately 3 watercourse crossings overtopped (none in the study area);

- Underpass flooded;
- Trails and pedestrian crossings flooded (including the Centennial Bikeway)
- Backyard flooding (throughout the corridor upstream of Pinedale Ave.); and
- Watercourse scour and erosion.

As a result, the study recommended that investigations should be conducted to determine mitigation measures to improve flood control within the areas affected the most during the August 4th event, as well as several watershed studies should also be carried out in an effort to explore opportunities to reduce storm runoff rates and volumes in general.

City Wide Flood Vulnerability, Prioritization and Mitigation Study – (2017)
undertaken by Amec Foster Wheeler for the City of Burlington



The study was undertaken in response to the August 4th, 2014 storm event and it was carried out in two (2) phases:

- *Phase 1 – City-Wide Flood Vulnerability, Prioritization and Mitigation Study*
- *Phase 2 – Priority Flood Mitigation Projects & Preliminary Design*

Appleby watershed between Fairview Street and Pinedale Avenue scored the 5th highest among the areas evaluated by the study, from a flood risk perspective. Fairview Street culvert was also given a very high priority (9th highest) as a flood vulnerable road. Channel works within the highly flood vulnerable areas and culvert upgrading at Pinedale Avenue were recommended as flood mitigation options. The study also identified additional flood vulnerable areas on Appleby Creek between New Street and Fairview Street to be further investigated.

1.4 Study Objectives

The objective of this study is to identify specific opportunities that reduce flooding risk and protect the natural heritage features and functions within the study area. Flood risks were identified and quantified as buildings within the flood limits, frequency of road inundation and hydraulic conveyance capacity of the channel and road crossing structures. As part of the environmental assessment process this study will also assess and evaluate flood mitigation opportunities in light of mitigating biophysical, socio-cultural, built and economic environments to the Appleby Creek study area.

The study is premised on recommendations from the results and recommendation from previous studies (identified in **Section 1.3**), focusing on improvements at all the road crossings.

The success of alternatives will be based on reduction of buildings and structures within the flood limits, reduction of frequency of road overtopping, increases to hydraulic conveyance capacity and limited impacts to the natural heritage within the study area.

2 PHASE I – PROBLEM AND OPPORTUNITY IDENTIFICATION

2.1 Study Area

This study investigated the area of Appleby Creek downstream of the CN Railway to upstream of New Street (**Figure 2.1**). To focus on localized problems, the study area was divided in three reaches:

- Reach 1 - New Street to Pinedale Avenue
- Reach 2 - Pinedale Avenue to Fairview Street
- Reach 3 - Fairview Street to Railway

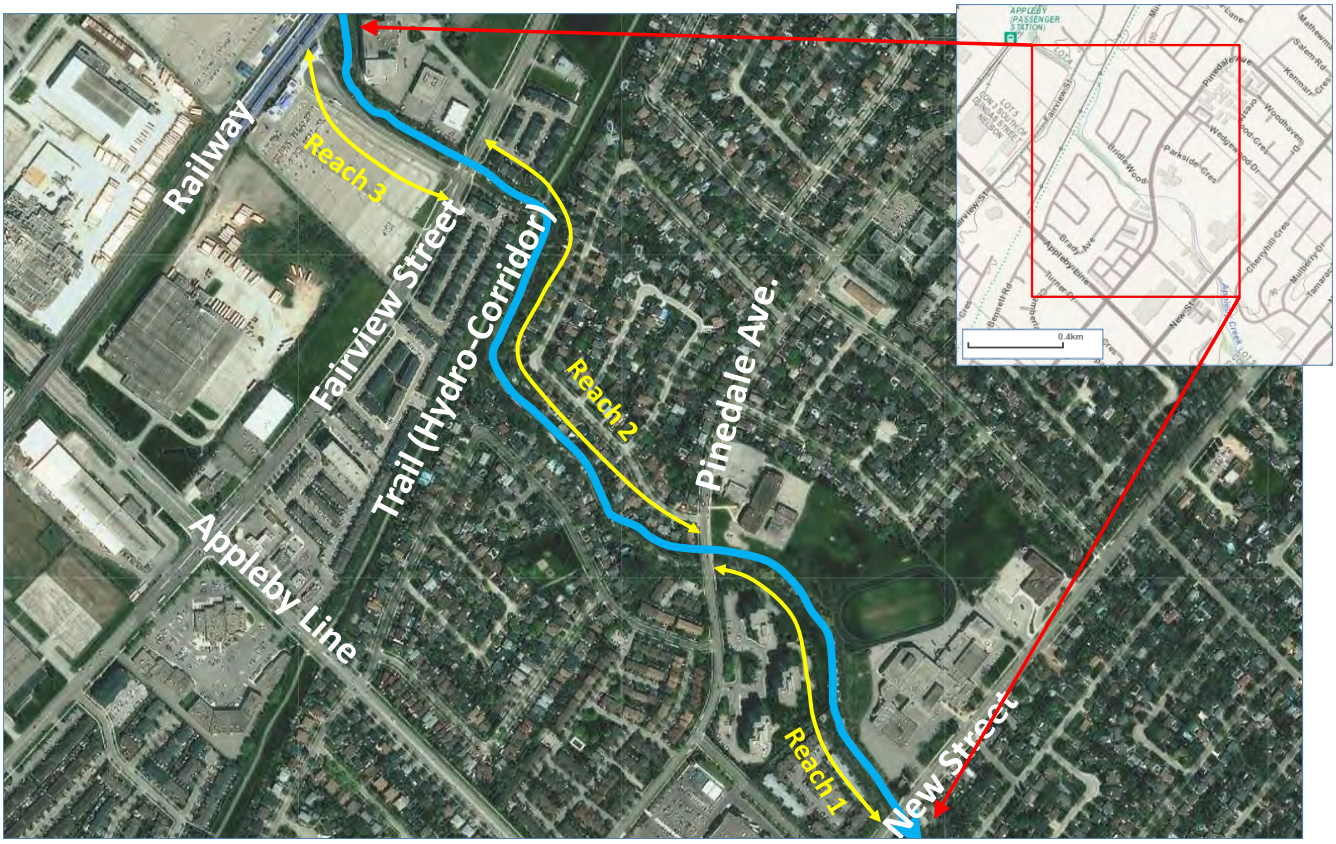


Figure 2.1: Limits of study area along Appleby Creek showing Reaches 1 - 3

Below is a description of each of identified reaches within the study area and a photo inventory is provided in **Appendix G**. Problems and mitigation opportunities are summarized at the end of this section of the report.

2.1.1 Reach 1 – New Street to Pinedale Avenue

Reach 1 of Appleby Creek extends from New Street to Pinedale Avenue, which includes approximately 500 m of the watercourse. Along the northeastern bank of the watercourse are two public schools; Robert Bateman Highschool and Frontenac Public School. There is a large grassy yard and track between the two schools. Along the southwestern bank of the watercourse is high density residential housing.

At the New Street bridge, the road is five (5) lanes (i.e., four lanes of traffic with a centre turning lane), with a sidewalk on both sides of the road. The road has a traditional curb and gutter system.

Through the reach there is a large “No Cut” zone, where the riparian corridor is not being maintained. There also appears to be some planting occurring within the floodplain terrace near the Robert Bateman Highschool.

There is a footpath along the southwestern bank that connects to Pinedale Avenue, however the trail does not connect to New Street.

The draft flood volubility study (City of Burlington, 2016) identified Reach 1 as a flood vulnerable area (FVA), FVA-AP-6, and noted that 3 buildings could be impacted be the regional flood.

2.1.2 Reach 2 – Pinedale Avenue to Fairview Rd.

Reach 2 of Appleby Creek extends from Pinedale Avenue to Fairview Road, which includes approximately 800 m of the watercourse. Upstream of Pinedale Avenue, the channel is confined to a narrow corridor between low density residential housing. Several properties have encroached into the City’s corridor, undertaking landscaping or waste dumping. There is a well-established footpath through this reach of Appleby Creek that connects Pinedale Avenue to the Centennial Bikeway upstream.

At the Pinedale Avenue bridge, the road is two (2) lanes wide, with a sidewalk on both sides of the road. The road has a traditional curb and gutter system.

The channel flows through the hydro corridor, and runs parallel to the Centennial Bikeway trail and more low-density residential housing. The Trans-Northern pipeline also runs through the hydro corridor and crosses the channel near the pedestrian bridge for the trail.

The area between the pedestrian bridge and Fairview road is also residential and the Centennial Bikeway trail runs parallel to the creek here and extends to Fairview Road, where it then connects to the Appleby GO Station parking lot.

The flood vulnerability study (Amec Foster Wheeler, 2016) identified Reach 2 as FVA-AP-7, and noted that there were 36 buildings that could be impacted by the regional flood.

2.1.3 Reach 3 – Fairview Rd. to Railway

Reach 3 of Appleby Creek extends from Fairview Road to the railway, which includes approximately 300 m of the watercourse. Along the northeastern bank of the watercourse are large commercial/industrial buildings, and the Appleby GO station and parking lot is adjacent to the southwestern bank. The Centennial Bikeway crosses Fairview Road and connects pedestrians to the GO station.

At the bridge, Fairview Road is four (4) lanes wide and has a grassy boulevard, with a sidewalk on both sides of the road. The road has a traditional curb and gutter system.

The flood volubility study (Amec Foster Wheeler, 2016) identified Reach 3 as FVA-AP-8, and noted that 4 buildings could be impacted be the regional flood.

2.2 Identification of Flood Risk Problems

Previous flooding studies along Appleby Creek have identified the limited flow conveyance at the bridges and culverts within the study area, with more than 40 buildings identified potentially impacted by the regional flood within the study area. Furthermore, recent flood events within the City of Burlington have prompted the City to continue to improve the storm water management of their creeks, including Appleby Creek.

2.3 Identification of Flood Management Opportunities

There are several opportunities to mitigate flooding along Appleby Creek through the study area. These opportunities include the following items:

- **Upgrades to road crossings** – Increasing conveyance through the culverts and bridges could reduce backwater thereby lowering upstream water surface elevations and decreasing the extent of flooding.
- **Channel widening at the cross locations** – Increasing the channel capacity through widening may also provide lower water surface elevations thus reducing building flooding. Increased hydraulic capacity of the channel will prevent the culverts from reaching maximum conveyance.
- **Floodplain enhancements and connectivity** – By providing floodplain access in areas of low risk (e.g., parks or golf courses), the flood flows and energy can be dissipated and reduce risks further downstream. Also, removing roughness from the

floodplain (e.g., dense debris) can increase conveyance and reduce harmful backwater conditions.

3 PHASE II – SITE SPECIFIC INVENTORIES

This EA addresses Phase 2 of the EA process, with site specific information intended to support the design of the preferred alternative. A summary of site-specific inventories is provided below.

3.1 Site Investigation and Topographic Survey

At the onset of the field assessments, Aquafor's fluvial specialist undertook a broad scale investigation of the entire study area. This involved walking the entire study reach and identifying erosion and flood risks and opportunities (discussed in **Sections 2.2** and **2.3**) and undertaking a broad scale survey. The broad scale survey was undertaken to accurately reflect the existing conditions of the channel and floodplain and included all road crossings and relevant storm outfalls. The survey was completed in sufficient detail for the purposes of geomorphic analysis, hydraulic modelling, and conceptual design.

The survey covered the entire study area, utilizing a differential GPS. Aquafor used this survey data to characterize the general geometry of the existing conditions for the entire study area and to supplement the existing HEC-RAS model consistent with HEC-RAS and Conservation Halton standards. Furthermore, this survey data was also used to accurately define the topographic conditions at the New Street, Pinedale Avenue, and Fairview Road. The key parameters of the survey included:

- Longitudinal profile of Appleby Creek for the entire study area, surveying the channel thalweg;
- Cross sections of Appleby Creek at representative reaches, including the low flow channel and connecting floodplain;
- Municipal infrastructure including the storm sewer headwall structure, sewer manholes and the bridge/culvert dimensions at the road crossings;

The survey data was collected using the CSRS NAD 83 projection (UTM, Zone 17) and is consistent with City's base mapping standards.

The topographic information was compiled into planforms and profiles. Focused plans and profiles of New Street, Pinedale Avenue, and Fairview Road shown in **Figures 3.1, 3.2 and 3.3**. **Table 3-1** provides summaries of the existing bridge and culvert dimensions obtained from the survey.

Table 3-1: Summary of existing conditions for all bridges within the study area

Parameter	New Street Bridge	Pinedale Avenue Bridge	Pedestrian Bridge within Hydro Corridor	Fairview Road Bridge
Structure Type:	Bridge	Bridge	Bridge	Culvert
Barrel Shape:	Beam	Arch	Beam	Box
Number of Cells:	1	1	1	2
Material:	Concrete	Concrete	Steel	Concrete
Open Bottom:	Yes	Yes	Yes	No
Height (m):	2.9	2.5	1.6	2.74
Width (m):	6.2	7.4	16	3.3 x 2
Length (m):	24	18	2.8	29
U/S Invert Elevation (m):	87.23	90.78	96.16	97.00
D/S Invert Elevation (m):	86.81	90.73	95.96	97.00
Top of Road Elevation (m):	90.51	93.5	97.78	100.08
Average Slope (%):	0.87	0.14	2.17	0

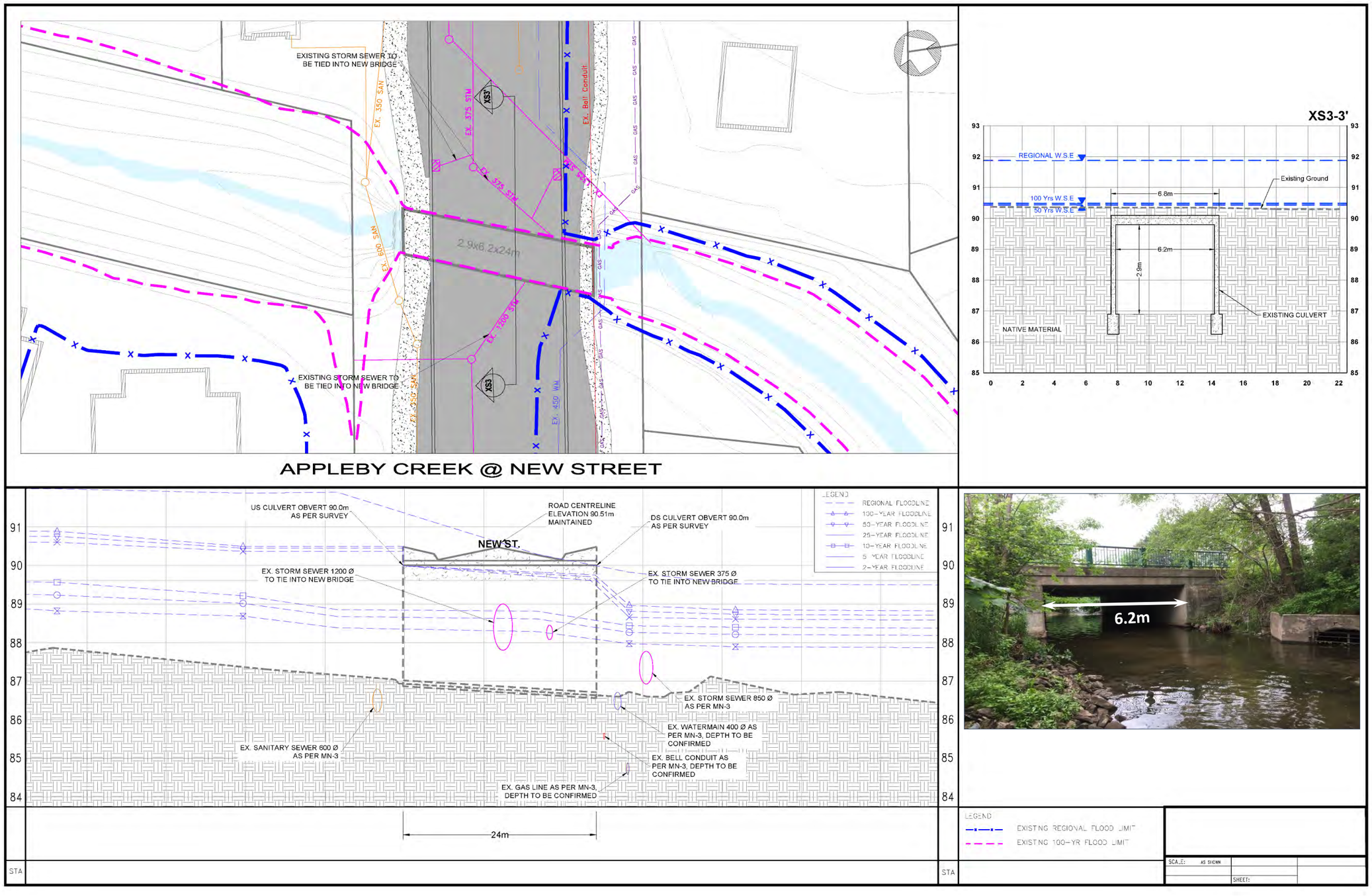


Figure 3.1: Plan and Profile of the New Street bridge

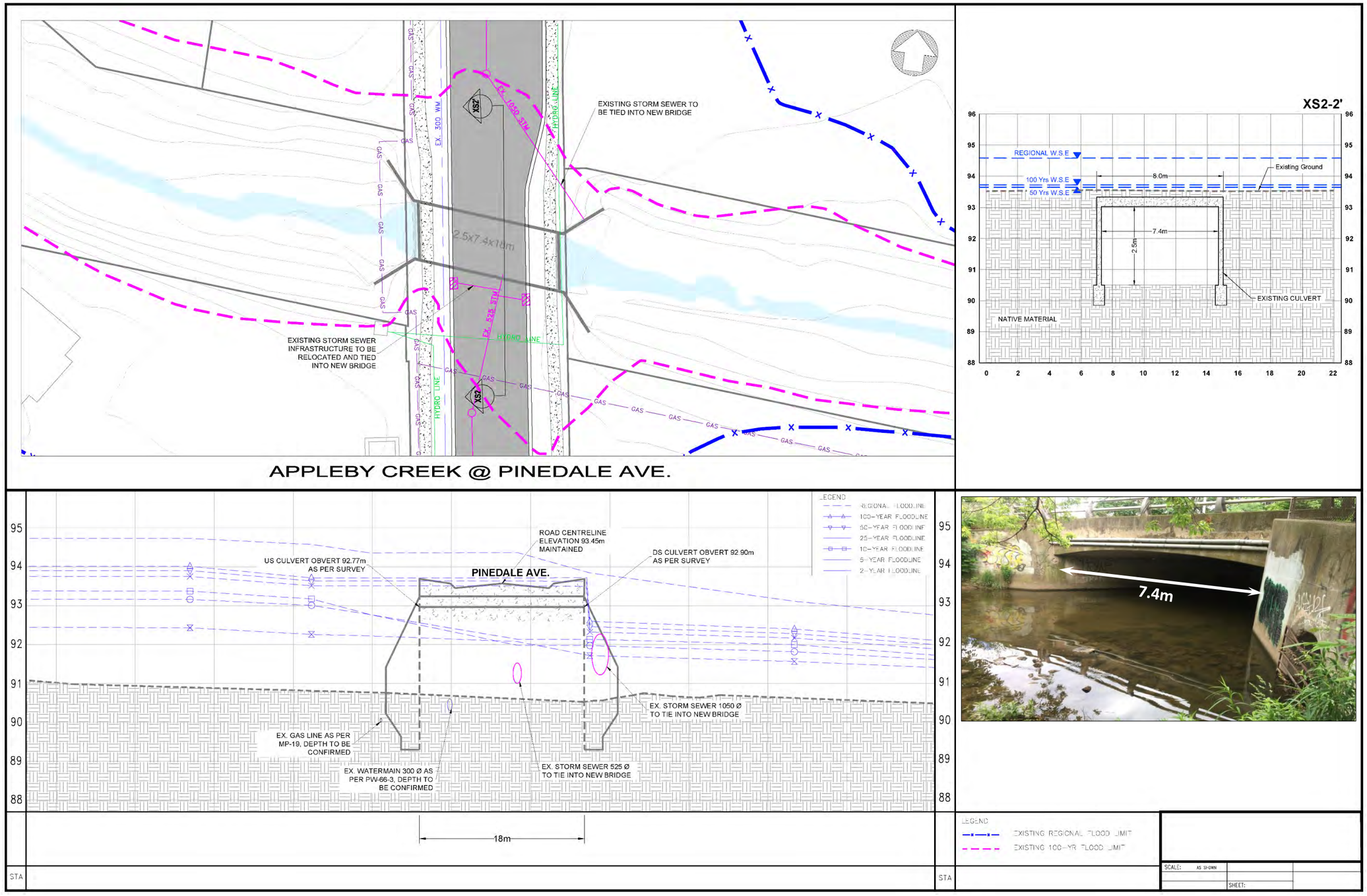


Figure 3.2: Plan and Profile of the Pinedale Avenue bridge

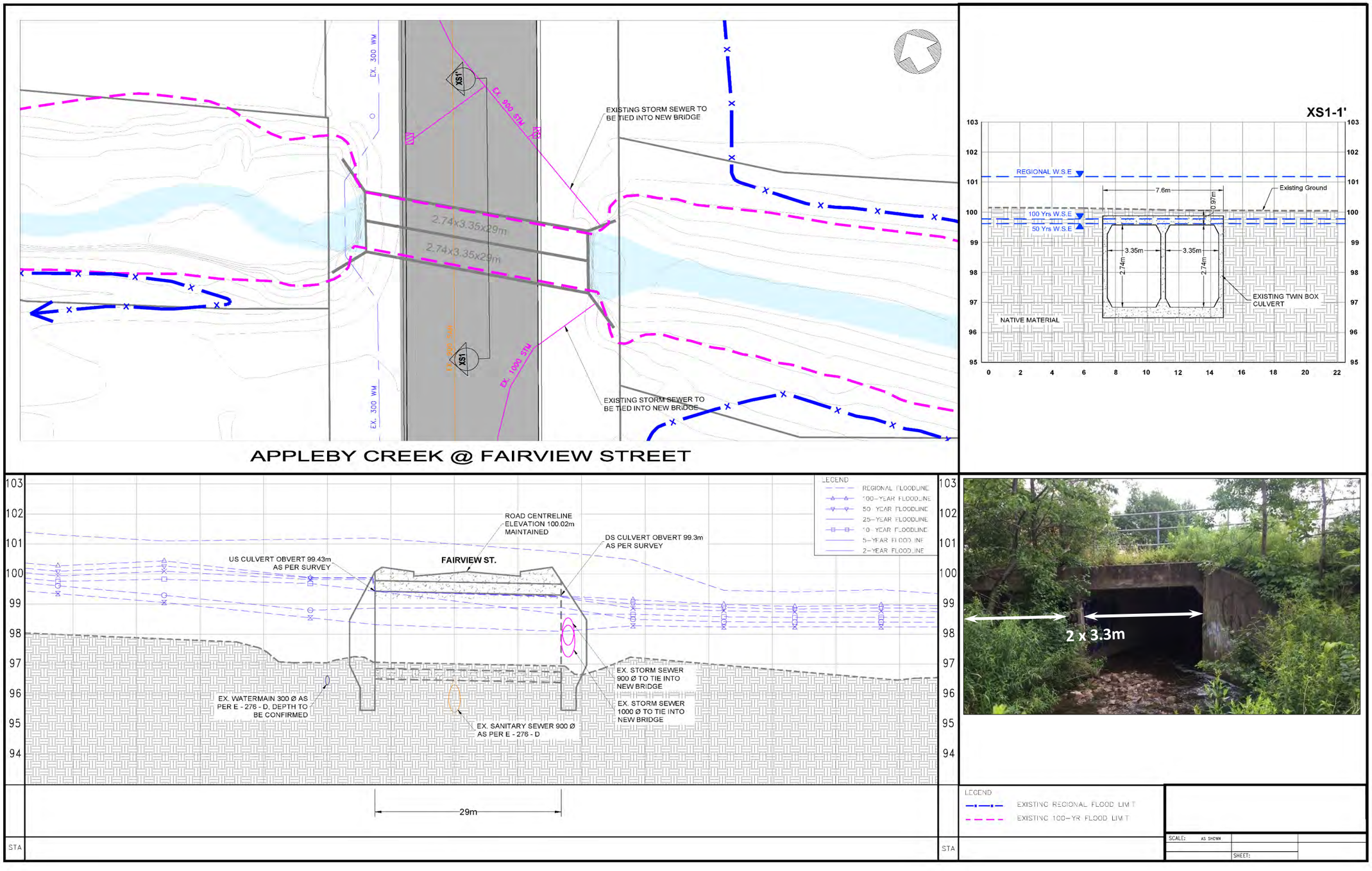


Figure 3.3: Plan and Profile of the Fairview Road bridge

3.2 Fluvial Assessment of Existing Conditions

A fluvial assessment of Appleby Creek was completed to create an understanding of the system. Aquafor undertook a broad scale field assessment, analyzed survey data and reviewed the historic conditions to develop an understanding of the existing conditions. This assessment is summarized below.

3.2.1 Overview of Drainage Area

Appleby Creek originates above the Niagara Escarpment and drains in a west to east direction. Appleby Creek is identified as being a key feature in the Regional Natural Heritage System. At Lake Ontario, Appleby Creek has a drainage area of approximately 12.1 km^2. The total watercourse length is approximately 14 km with an average longitudinal slope of 0.015 m/m. The watercourse falls through an elevation difference of approximately 200m. Approximately 65% of the watershed is developed. The Creek for the most part has been channelized.

Below are summaries of the existing fluvial conditions for each of the previously identified reaches within the study area. A photographic summary is provided in **Appendix G** for reference.

3.2.2 Reach 1 – New Street to Pinedale Avenue

Through Reach 1, Appleby Creek is an urban creek with a vegetated riparian corridor. As discussed above the river has been channelized, and has been straightened through the entire study area, which restricts the development of natural morphology. There are several long, course riffles/runs, and several short and shallow pools, which is characteristic of many channelized, urban, watercourses in southern Ontario. The low flow channel is wide and shallow, with much of the coarse bed material protruding through the water.

The channel is generally disconnected from the floodplain, as it is confined to the channelized corridor. There are small sections of the channel adjacent to the school yards that do provide some floodplain relief.

The bed material is predominantly comprised of angular rock (i.e., riprap), and sand, which is expected to be outwash from the roads. A noticeable amount of the channel bed is composed contribution materials from historic river treatment, including concrete at the New Street bridge inlet and masonry bricks and blocks. Large slugs of riprap were noted at several locations throughout the reach, and algae growth was prevalent throughout the reach.

The riparian corridor is vegetated, predominantly with grasses and shrubs, and some mature trees. The corridor is not maintained and there is a large “No Cut” zone upstream of New Street.

The riparian corridor provides shade to most of the width of the low flow channel. The riparian corridor was observed to be significantly rougher than the channel or overbanks.

Some minor bank erosion was observed, however there was no evidence of active or excessive erosion. While there was evidence of exposed tree roots, there were very few leaning trees, indicating that the channel is not experiencing active lateral erosion. There were several outfalls that appeared to be buried, which might be evidence of aggradation. Some small debris jams were noted.

3.2.3 Reach 2 – Pinedale Avenue to Fairview Road

The general channel morphology of Reach 2 is very similar to Reach 1. There is limited development of natural morphology, however there are some long riffles/runs and shallow pools. Deeper pools have developed at the outlets of the Pinedale Avenue and Fairview Road bridges, resulting from scour. The low flow channel is slightly narrower in Reach 2; however, the general form is still wide and shallow.

The channel is almost completely disconnected from the floodplain. Even through the hydro-corridor, where the grassy park could provide safe, low risk floodplain relief, the channel is still confined to the corridor and does not appear to have any significant floodplain relief.

The bed material through Reach 2 is the same as Reach 1, predominantly angular foreign stone (i.e., riprap), masonry materials and sand. Some fractured shale deposition was observed between the pedestrian bridge and Fairview Road. Also, more channel vegetation was observed through Reach 2, mainly in the form of grasses.

The riparian corridor through Reach 2 is similar to Reach 1, however there is more encroachment and some sections of the corridor have been completely manicured. The corridor still provides a significant amount of roughness, and several small debris jams were observed, which could be a result of yard waste dumping. Again, the riparian corridor was observed to be significantly rougher than the channel or overbanks.

More localized erosion was observed along the banks of the channel. At one location the erosion has migrated to the footpath that runs along the bank between the hydro corridor and Pinedale Avenue, however there is limited risk associated with the erosion. Other localized areas of erosion appeared to be associated with areas of encroachment, and lawn mowing. Failing gabions were observed between the pedestrian bridge and Fairview Road. The gabions are expected to have been placed to protect the Trans-Northern pipeline and the Centennial Bikeway trail from erosion. The gabions have rusted out at the bottoms and are slumping into the channel.

3.2.4 Reach 3 – Fairview Road to the Railway

While Reach 3 does exhibit several of the same characteristics as Reaches 1 and 2; having been straighten and confined to a narrow corridor, there are several differences. The valley corridor of Reach 3 is much steeper and deeper than both Reaches 1 and 2, and as with Reach 2, Reach 3 is completely disconnected from the floodplain.

The bed material of Reach 3 is predominantly exposed and fractured shale bedrock, and there is limited riprap or masonry material expect at locations where localized bank treatments have been placed (e.g., Fairview Road bridge inlet). The native bed material seems to have allowed for a more natural morphology to form throughout Reach 3, with an obvious riffle-pool pattern, and more meandering of the low flow channel within the valley. The low flow channel is also significantly narrower than Reaches 1 and 2, and generally has deeper flow.

The riparian corridor is completely unmaintained, and dense trees and shrubs have filled the valley. Small woody debris jams were noted throughout the reach. Tree and shrub roots were observed along the channel bed and appeared to be providing some grade control to the channel.

Erosion was observed at several locations. As noted above, the valley is very steep, and there were several locations of bank and valley erosion, some within the shale bedrock. There are several sections of gabions that are in a deteriorated state in particular at the storm sewer outlet for the Appleby GO station parking lot and the gabion weir at the inlet of the Fairview Road bridge. It is expected that the gabion weir at Fairview Road was intended to protect the 300mm watermain that crosses the channel at that location, however half of the weir has completely emptied and the other half is now creating a fish barrier.

3.3 Hydraulic Characterization

Aquafor undertook a hydraulic characterization of the existing conditions within the study area. This involved updating the HEC-RAS model and delineating floodplains for the regional and 100-year floods. The sections below explain how the model was updated and used for the flood risk analysis.

3.3.1 Existing HEC-RAS Model

Conservation Halton (CH) provided the 2006, “generic regulation model”, which was used as a base model in developing the existing conditions model. From the model provided, Aquafor updated the "ApplebyMainBranch- 2002DEM" geometry file and the "Flow data from Floodline Mapping update" flow data. The model had previously been georeferenced. The flow data was cross referenced with the flow data from the 1997 HEC-2 model received from the City of

Burlington to ensure consistency. The flow data was the same between the two models for the study area. The model was developed and run with HEC-RAS version 5.0.3.

Prior to undertaking this model update, CH provided comments and recommendations for updating this model to satisfy some of the underlying concerns. Aquafor updated the model following the provided recommendation, and submitted the model, updated floodline and a technical memo to CH for review. Aquafor received confirmation from CH that the updated model satisfied CH's requirements in February 2018 and identified that this model would be sufficient for floodline and hydraulic analysis of the proposed alternatives.

The details of the model and the modifications that were undertaken are included within the technical memo included in **Appendix A**.

3.3.2 Proposed HEC-RAS Model

Aquafor used the updated model to evaluate each of the alternatives for the three reaches within the study area. The structures and channel dimensions were adjusted to meet the requirements of the alternative. No cross sections were added for any of the proposed models, and the same flow scenario was used.

Floodlines were generated for the 100 year and Regional flood events, for each of the alternative treatments. This was done to evaluate how each of the alternative solutions impacted the flooding limits. To quantify the flooding impacts of each of the alternatives, the number of buildings that were touching or contained within the flood limits were counted.

The results of the proposed HEC-RAS model are discussed within **Chapter 4**, and a detailed summary of the model is included within **Appendix A**.

3.4 Flood Hazard Assessment

The information from the fluvial and hydraulic assessments was used to characterize the flood hazards within the study area. Flood hazards were identified using the following three categories:

1. Buildings within the floodplain;
2. Backwater conditions (i.e., limited hydraulic conveyance capacity of bridges and culverts); and
3. Frequency of road inundation

Each of the flood hazards are discussed in the subsequent sections below.

3.4.1 Buildings Impacts by Flooding

Floods can have detrimental impacts to buildings, causing risk to the land owners and potentially expensive damage. To identify how many buildings could be impacted by flooding, the 100-year and regional floodplains were delineated based on the results of the HEC-RAS model discussed in **Section 3.3.1**. The floodplains were overlain on aerial imagery and GIS data to identify which buildings that fell within the flood limits. **Figure 3.4** shows the floodplains and buildings expected to be impacted. A summary of the number of buildings within the floodplain is presented for each of the predefined reaches in **Table 3-2**.

Table 3-2: Summary of buildings within the existing floodplain for each reach

Flood Event	Number of Buildings within the floodplain			
	Reach 1	Reach 2	Reach 3	TOTAL
Regional Flood	14	14	9	37
100-Year Flood	0	0	2	2

Please note that for the purposes of the flood hazard assessment, the limits of the reaches were slightly adjusted towards the upstream side of each crossing. This was done to ensure that flood impacts associated with the road crossings (e.g., buildings along the road that were within the floodplain, backwater effect) were accounted within the reach upstream of the bridge. The exact locations of the reach breaks are shown in **Figure 3.4.**

The total number of buildings within the regional floodplain for the study area is 37. While these buildings are not to be disregarded, it is noted that there are significantly fewer buildings at risk within this area than other watercourses within Burlington. Previous studies on Tuck Creek have identified that approximately 102 buildings are within the regional floodplain downstream of the hydro corridor (City of Burlington, 2015), and approximately 143 buildings are within the regional floodplain between the hydro corridor and the Q.E.W. (City of Burlington, 2018). A recent flood study on Roseland Creek identified 35 buildings within the regional floodplain, which included the Halton Region Water Treatment Plant (City of Burlington, 2018). Therefore, the risk to buildings along this section of Appleby Creek is not as significant as other areas of Burlington.

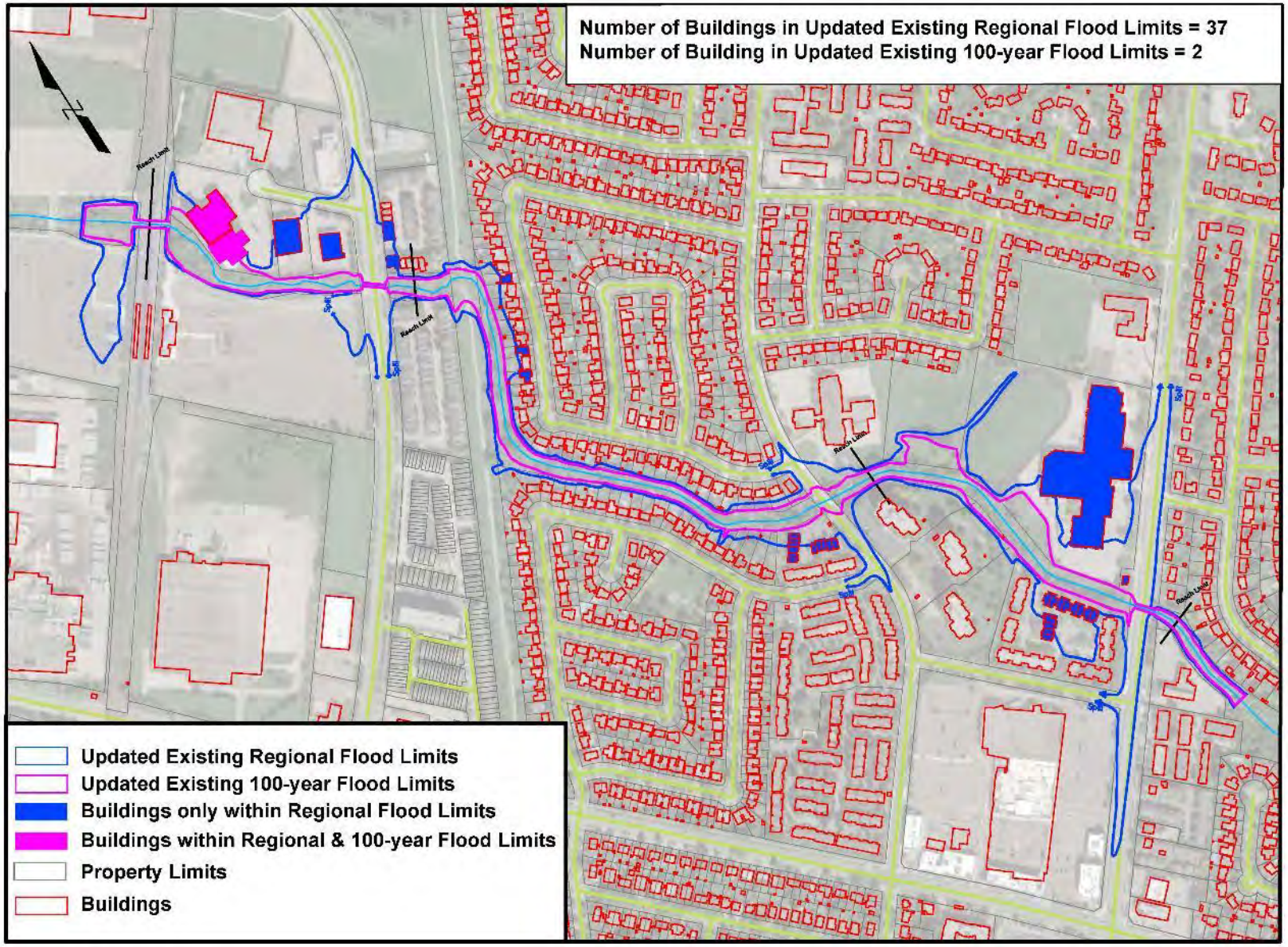


Figure 3.4. 100-year and Regional flood limits under the exiting condition

3.4.2 Hydraulic Conveyance Capacity of Bridges and Culverts

The conveyance of a bridge or culvert describes the amount of flow that expected to be passed through the culvert. For the purposes of this report the maximum hydraulic conveyance capacity is the largest design storm that can be passed through a bridge or culvert with freeboard (i.e., space between the water surface and bridge soffit). Once this flow is exceeded, significant backwatering can begin to occur, as the road embankment impounds water. If the hydraulic conveyance capacity of a bridge is low, then it is more likely that backwater conditions will occur frequently, resulting in increased water levels upstream of road crossings. A summary of the maximum hydraulic conveyance capacities for each of the bridges within the study area is presented below in **Table 3-3**.

Table 3-3: Summary of maximum hydraulic conveyance capacity for each bridge

Road Crossing	Maximum Hydraulic Conveyance Capacity	MTO Recommended Conveyance Capacity
New Street	10 year (38 m^3/s)	100 year (59 m^3/s)
Pinedale Avenue	10 year (38 m^3/s)	50 year (53 m^3/s)
Centennial Bikeway pedestrian bridge	< 2 year (21 m^3/s)	NA
Fairview Street	5 year (31 m^3/s)	100 year (59 m^3/s)

The Ministry of Transportation Ontario (MTO) provides recommended conveyance capacities for bridges and culverts within the "Highway Drainage Design Standards" (2008). The recommended conveyance is based on the road classification and river size. The recommended conveyance for each of the roads within the study is provided in **Table 3-3**.

It can be seen in **Table 3-3** that the existing conveyance capacity of the bridges is significantly less than the recommended values from MTO. Therefore, it was expected that these structures could be causing significant backwater issues. In reviewing the regional flood lines (**Figure 3.4)** it can be seen that the floodplain significantly widens at the roadways, in particular at New Street. This is caused from backwater conditions associated with the road crossings.

3.4.3 Road Inundation

Road inundation results from flows spilling over top of the roadway. This can result in roads being impassable, resulting in people being stranded or restricting access for emergency service vehicles. Through discussions with the City, impassable flow depth was estimated to be 0.3m. Frequent road inundation can also cause damage to road side utilities such as hydro or communication transformers. A summary of the inundation conditions for the road crossings is presented below in **Table 3-4**.

Table 3-4: Summary of road inundation conditions for the full range of flood flows

Flood Event	New Street		Pinedale Avenue		Fairview Road	
	Inundated? (Yes/No)	Depth of flow over road (m)	Inundated? (Yes/No)	Depth of flow over road (m)	Inundated? (Yes/No)	Depth of flow over road (m)
2 year	No	0	No	0	No	0
5 year	No	0	No	0	No	0
10 year	No	0	No	0	No	0
25 year	No	0	Yes	0.01	No	0
50 year	No	0	Yes	0.14	No	0
100 year	No	0	Yes	0.22	No	0
Regional	Yes	1.36	Yes	1.08	Yes	1.11

It can be seen in **Table 3-4** that all three roads will be inundated to an impassable level under the regional flood conditions. However, New Street and Fairview Road are not expected to be inundated during any other flood events. Pinedale Avenue is expected to be inundated for the 25, 50 and 100 year flood events also, however the maximum flow depth is expected to be approximately 0.22m, and therefore is likely still passable.

3.5 Natural Heritage

Aquafor completed series of ecological investigations to identify the existing natural conditions, assess the potential impacts and recommend mitigation measures for the preferred alternatives. Characterization of the Natural Heritage System (NHS) relied upon field surveys and review of background information sources. A summary of the field investigations completed for this study is provided below:

- Rapid vegetation community surveys;
- Botanical inventory;
- Tree Inventories;
- Phase 1 and 2 surveys for Species at Risk Bats within Treed Habitats (OMNRF, 2017);
- Breeding bird surveys;
- Snake and amphibian surveys;
- Incidental wildlife observations; and
- Aquatic habitat mapping;

A detailed summary of the assessments is included within **Appendix B**, with key findings summarized below:

- Vegetation communities within the study area are considered common and secure globally and to the province;

  - The study area is composed of one (1) Mineral Cultural Woodland (CUW1) with a Mineral Cultural Thicket (CUT1) and Mineral Cultural Meadow (CUM1) inclusions;
- Sixty-two (62) locally and provincially secure vascular plant species were identified plus an additional four (4) vascular plants identified to genus;
- Ninety-two (92) trees with diameter at breast height larger than 10cm representing nineteen (19) species were inventoried. All trees inventoried are considered secure locally, provincially, and nationally;
- Six (6) species at risk (SAR) may potentially inhabit the study area. Further studies will confirm presence. Below is a list of the potential SAR within the study area:
  - Eastern wood-pewee (Special Concern)
  - Snapping turtle (Special Concern)
  - Eastern small-footed myotis (Endangered)
  - Little brown myotis (Endangered)
  - Northern myotis (Endangered)
  - Tri-coloured bat (Endangered)
- Candidate Significant Wildlife Habitat was identified for the following species within the study area:
  - Bat Maternity Roost Colonies;
  - Eastern wood-pewee (SC, S4B); and,
  - Snapping turtle (SC, S3).
- Seventeen (17) candidate Myotis spp., and six (6) candidate Perimyotis sp. maternity roosting sites are within the study area;
- Twenty-eight (28) bird species were encountered during breeding bird surveys, of which one (1) species was confirmed with evidence of breeding;
- No anurans or snakes were identified as a result of active-hand surveys for snakes;
- Five (5) locally and provincially common wildlife species were observed incidentally during all surveys;
- The thermal classification of Appleby Creek within the study area is that of a Cool-Warm thermal regime; and,
- Fourteen (14) provincially secure fish species are within Appleby Creek in the study area: four (4) species are regionally rare and four (4) species are regionally uncommon.

3.6 Utilities Identification

Aquafor undertook a detailed review of base mapping, as-built drawings, onsite investigations and survey data to identify all the utilities surrounding the culverts. Ontario One Call was also made to further confirm the locations of some private utilities, from which locate drawings from Union Gas and Bell Canada for all three road crossings were obtained. These investigations were included as part of the EA evaluation, as relocation or replacement of utilities could be very costly or physically restrictive and could impact the preferred alternatives.

Table 3-5, Table 3-6, and Table 3-7 summarize the major utilities at each of the road crossings, and **Figures 3.1, 3.2 and 3.3** (above) show the approximate locations of the utilities.

Table 3-5: Summary of existing utilities at the New Street Bridge

Utility	Owner	Dimension (Reference drawing)
Sanitary Sewer	Halton Region	600mm (City of Burlington MN-3)
Water	Halton Region	400mm (City of Burlington MN-3)
Stormsewer & Outfall	City of Burlington	1200mm (GIS data) 375mm (GIS data) 850mm (GIS data)
Communications Line	Bell	Conduit (Bell Locate Drawings)
Sanitary Sewer	Halton Region	600mm (City of Burlington MN-3)
Gas	Union Gas	6” S CT 420kPa (Union Gas Locate Drawing)
Hydro	Hydro One	Unknown

Table 3-6: Summary of existing utilities at the Pinedale Avenue Bridge

Utility	Owner	Dimension (Reference drawing)
Gas	Union Gas	4” S C&W 420kPa (Union Gas Locate Drawing)
Water	Halton Region	300mm (City of Burlington PW-66-3)
Stormsewer & Outfall	City of Burlington	1050mm (GIS data) 525mm (GIS data)
Hydro	Hydro One	Unknown

Table 3-7: Summary of existing utilities at the Fairview Road Bridge

Utility	Owner	Dimension (Reference drawing)
Sanitary Sewer	Halton Region	900mm (City of Burlington E-276-D)
Water	Halton Region	300mm (City of Burlington E-276-D)
Stormsewer & Outfall	City of Burlington	1000mm (GIS data) 900mm (GIS data)
Gas	Union Gas	4” S YJ 1900kPa (Union Gas Locate Drawing)
Gas	Union Gas	2” PE N/A 420kPa – Pipe on bridge deck (Union Gas Locate Drawing)
Communication Line	Bell	Buried Cable (Bell Locate Drawings)
Communication Line	Bell	Conduit 9 Bell Locate Drawings)
Hydro	Hydro One	Unknown

The section of Appleby Creek along the Centennial Bikeway trail is also in close proximity to major utilities. Through this section of the study area, the Trans-Northern oil pipeline runs parallel to the trail, and crosses the Appleby Creek. The Centennial Bikeway trail runs through a hydro-corridor, therefore there are large towers along the floodplain. In reviewing the base-mapping as-built drawings and undertaking a site visit, one storm sewer outlet was confirmed and there is potential that a gas line is adjacent to the Trans-Northern pipeline.

To confirm the location and depth of the petroleum pipeline within the hydro-corridor, Aquafor contacted the Trans-Northern Pipeline via email and reply confirmed that the nominal depth of their pipeline was 1.2-1.5m and exact depth at a location should be further determined. A planform drawing of the approximate locations of the utilities along the Centennial Bikeway is shown in **Figure 3.5**. All communication records and supporting documents with utilities owners are included in **Appendix H**.

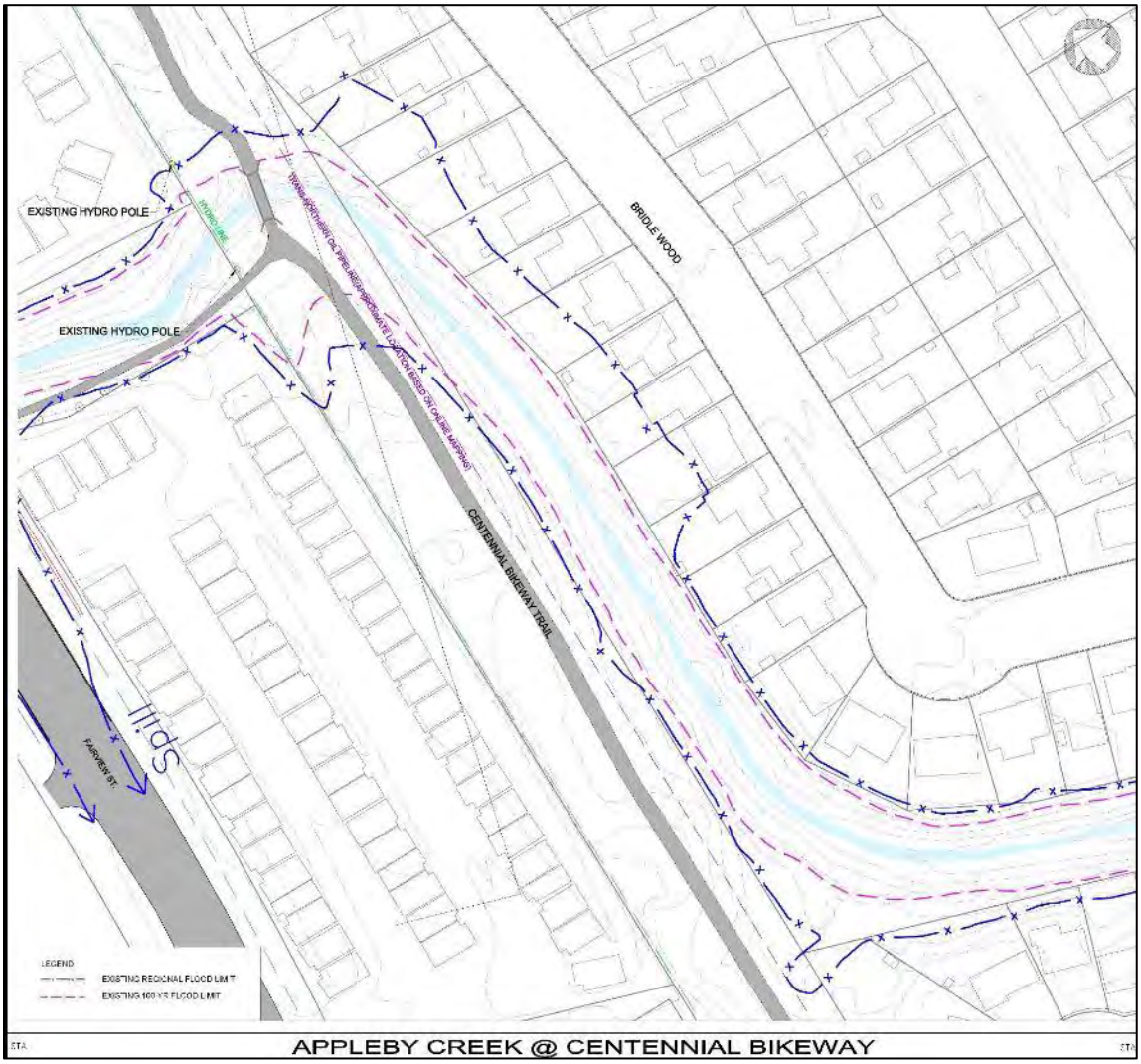


Figure 3.5: Plan of the utilities along the Centennial Bikeway adjacent to Appleby Creek

3.7 Social and Economic Conditions

3.7.1 Land Use

As noted in the Burlington Official Plan (City of Burlington, 2010), initial settlement in what is now the City of Burlington occurred along Lake Ontario and proceeded northward. Urban growth and expansion have been continuous in Burlington since the 1950s. At present, development within the Appleby Creek watershed extends approximately to the limits of Highway 407 (see **Figure 3.6**).

Between Fairview Road and New Street, the land use is dominantly low density residential, which some moderate and high-density residential land use (**Figure 3.6**). Upstream of Fairview Road the area is classified as “mixed use”, with larger commercial and industrial uses.

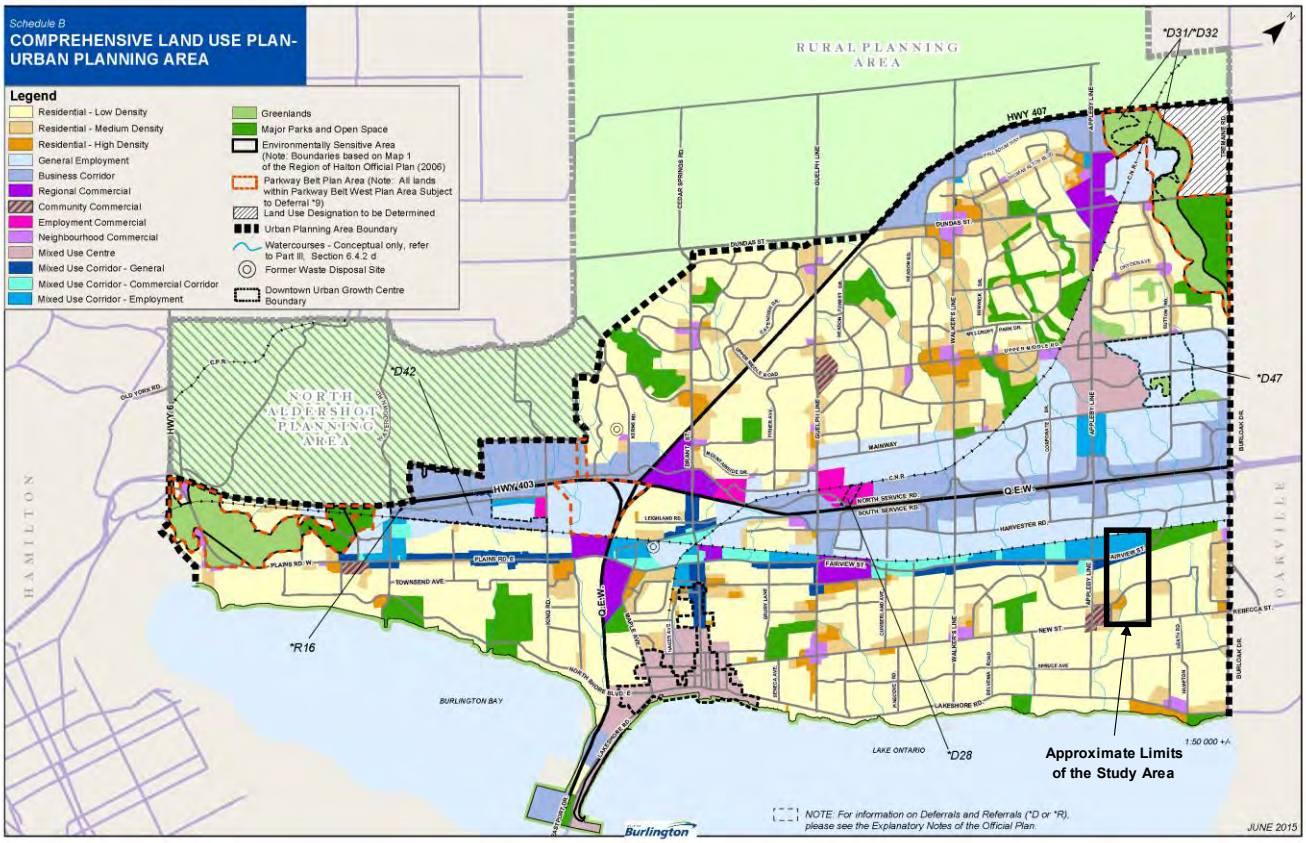


Figure 3.6: Land use within the City of Burlington (City of Burlington, 2017)

3.7.2 Transportation/Utility Corridors

Within the Appleby Creek watershed, major transportation corridors include the Queen Elizabeth Way, Highway 407, and two Canadian National Railway lines. New Street and Fairview Road are both classified as Minor Arterial roads, and Pinedale Avenue is classified as a Collector within the City of Burlington Official Plan (City of Burlington, 2010) (Figure 3.7).

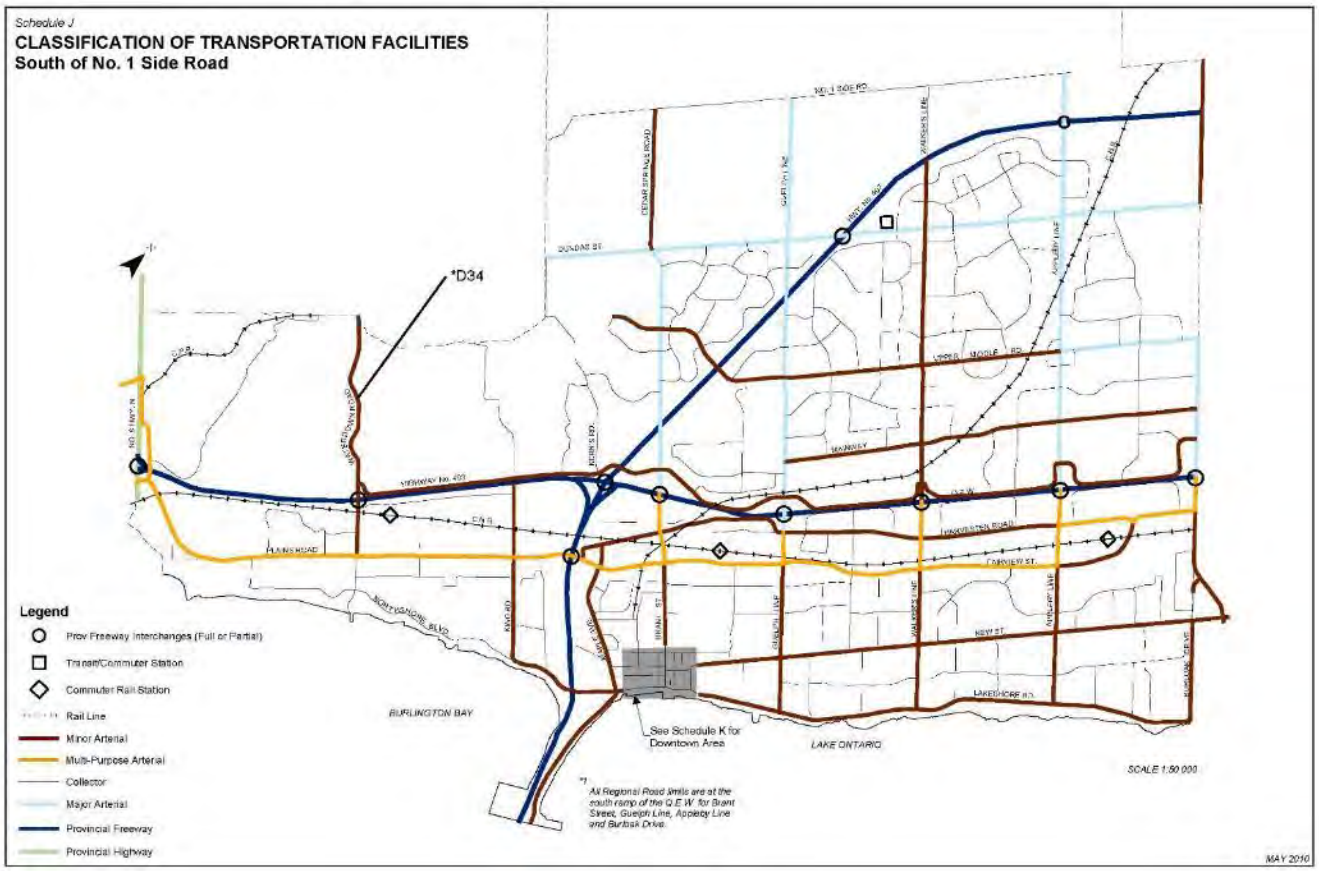


Figure 3.7: Transportation Facilities within the City of Burlington (City of Burlington, 2017)

As discussed in **Section 3.6** a hydro right-of-way traverses Appleby Creek south of Fairview Road. The Trans-Northern pipeline and Centennial Bikeway trail are also located within the hydro corridor. While there are several other utilities within the study area, there are no other major utility corridors pass through the study area.

3.7.3 Ownership

Within the study areas, Appleby Creek is contained to City owned lands, or lands with permanent easements. The corridor is very narrow (approximately 10 to 15 m wide) and leaves little room for natural channel processes. Should larger crossings be required at either location, land acquisition or easement negotiation may be required.

3.7.4 MTO - Drainage Design Standards

The MTO “Highway Drainage Design Standards” (2008) are used to define the design flow frequency for the construction of new culverts and bridges. The flow capacity of the bridge or culvert is based on the defined functional road classification (**Table 3-8**).

Table 3-8. MTO drainage design criteria as defined within B-100 Directive (2008).

Design Flow Return Period for Bridges and Culverts - Standard Road Classifications			
Functional Road Classification	**Return Period of Design Flows (Years)[123]**		**Check Flow for Scour**
	Total Span less than or equal to 6.0 m	**Total Span greater than 6.0 m**	
Freeway, Urban Arterial	50	100	130% of 100 year
Rural Arterial, Collector Road	25	50	115% of 100 year
Local Road	10	25	100% of 100-year

Note:
1. Listed design flows apply to roads under the jurisdiction of the Ministry of Transportation
2. The Fish Passage Design Flow for culverts is defined in Standard WC-12 Fish Passage Requirements Through Culverts
3. Sometimes referred to as Normal Design Flow

Given the classifications defined above and all three crossings with spans greater than 6m, both New Street and Fairview Street crossings should be designed to convey the 100-year flood, and Pinedale Avenue bridge to convey the 50-year flood. The hydraulic assessment of the existing conditions showed that New Street and Pinedale Avenue are only able to convey the 10-year flood, and Fairview Road is only able to convey the 5-year flood, suggesting conveyance capacities which do not meet the MTO directive.

4 PHASE III – EVALUATION OF ALTERNATIVE SOLUTIONS

Using the data collected to characterize the existing conditions, alternative treatment solutions were developed for each of the reaches to mitigate the flood risk hazards. Flood risks were defined for each of the alternatives which were included within the detailed evaluation, which included other physical, social, natural and economic criteria.

The development and evaluation of alternatives are described in the subsections below.

4.1 Description of Alternatives for Reach 1

Two (2) alternatives were developed to reduce flooding along the Appleby Creek corridor, which involved altering the bridge at New Street. These alternatives were evaluated against the existing conditions, taking into consideration the “do-nothing” alternative. Details of each alternative are provided below.

Please note that channel modifications were not evaluated for Reach 1. This is further discussed in **Section 4.5**.

4.1.1 Alternative 1 – Do Nothing

For the do-nothing alternative, no mitigation measures would be taken, with the exception of emergency situations. This would involve leaving the existing stream and bridges, and existing problems associated with potential of flooding will remain. The existing 100-year and regional flood limits for Reach 1 are shown in **Figure 4.1**, and the existing conditions of the New Street bridge and are shown in **Figure 4.2**. **Table 4-1** provides a summary of the existing conditions.

Table 4-1: Summary of Conditions for Reach 1, Alternative 1 - Do Nothing

Bridge Dimensions			Beam structure, 6.2m wide, 2.9m rise
Average Channel Width at Bridge			8-10 m
Maximum Hydraulic Conveyance Capacity			10-year flood
Frequency of Road Inundation			Regional flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 1 Flood Limits	Percent Decrease
Regional Flood	14	14	0%
100-Year Flood	0	0	-
*This includes the area from downstream of Pinedale Avenue to New Street			

As explained in **Section 3.4,** a flood hazard assessment was undertaken for the existing conditions which identified the number of buildings within the flood limits, road overtopping frequency and the hydraulic conveyance capacity of the road structures. This information is also presented in **Table 4-1**. Under the existing conditions for Reach 1, there are 14 buildings and units within the regional floodplain and no buildings within the 100-year storm floodplain. The updated 100-year and Regional floodlines are presented below in **Figure 4.1**. The maximum hydraulic conveyance capacity is the 10-year flood event, which is much lower than the recommended conveyance from MTO (i.e., 100-year flood). Finally, the road inundation is very infrequent, as the road is only expected to be overtopped under the regional flood conditions.

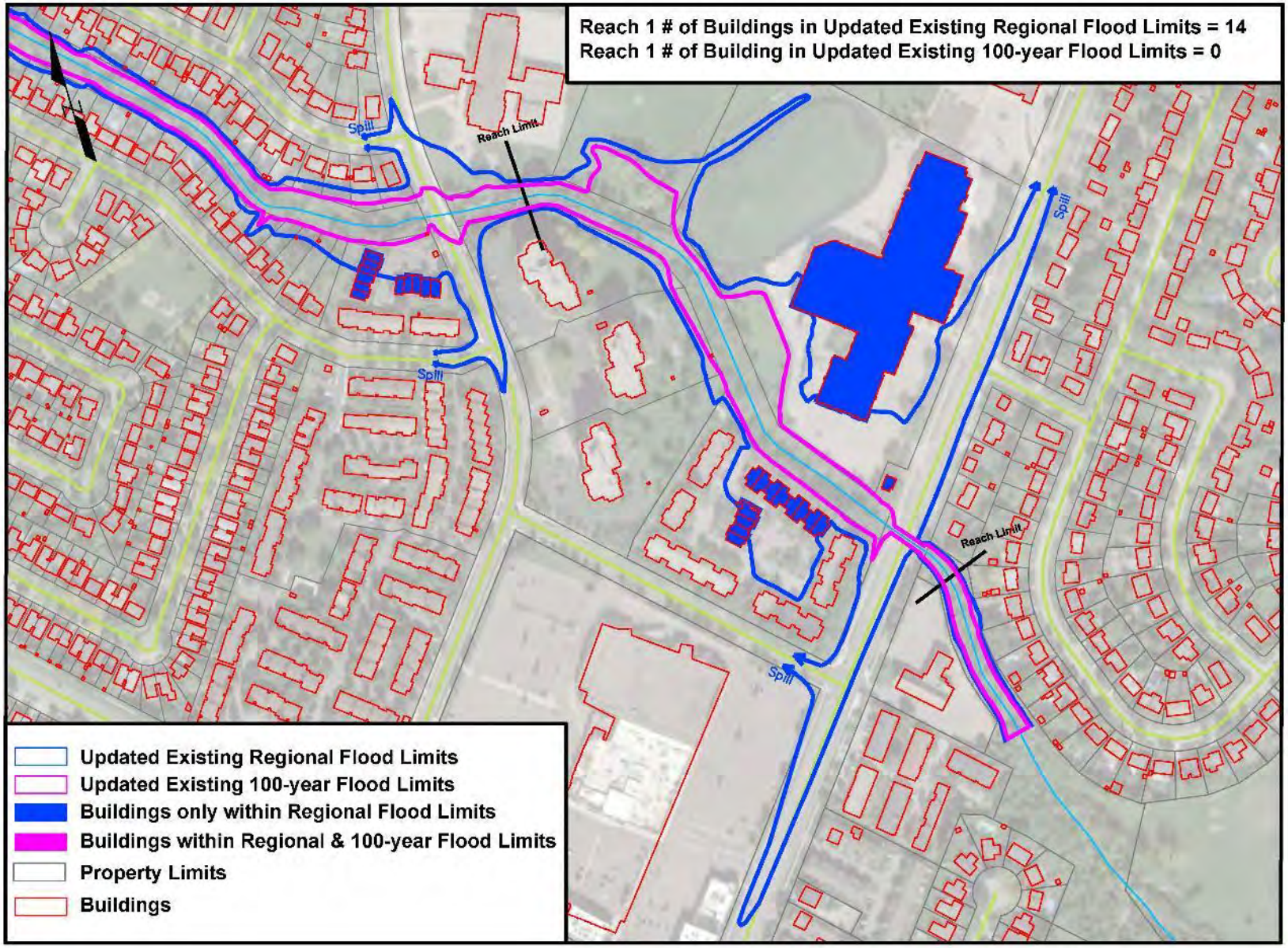


Figure 4.1: 100-year and Regional flood limits under the existing conditions

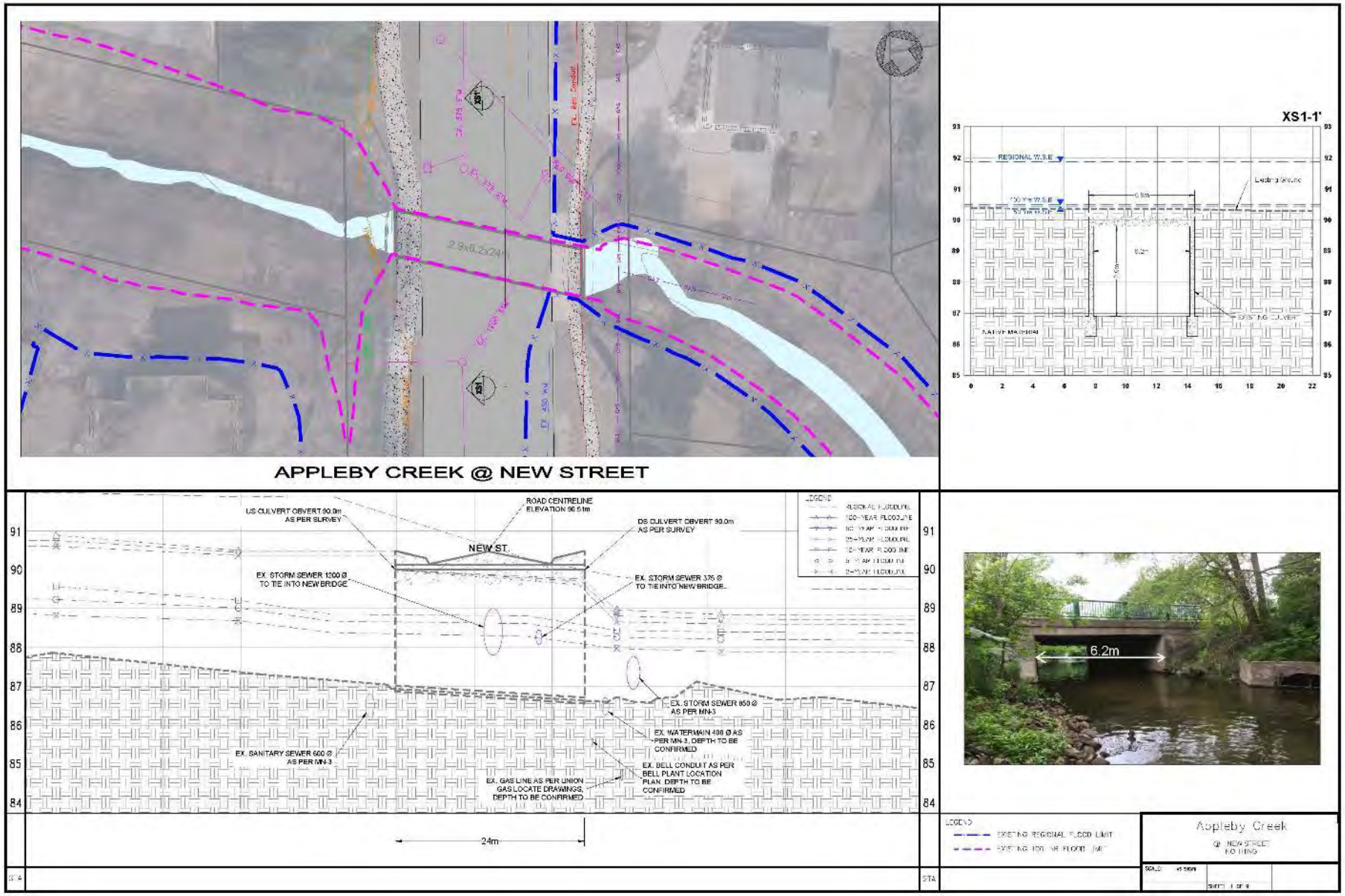


Figure 4.2: Culvert and channel dimension for Reach 1, Alternative 1 - Do Nothing

4.1.2 Alternative 2 – New Street Bridge Widening (Option 1)

This alternative investigated replacing the existing New Street bridge with a larger bridge. This would involve widening the bridge enough to ensure that the MTO recommended hydraulic conveyance is passed, and also improve terrestrial and aquatic passage. A hydraulic assessment of the bridge was undertaken, and it was determined that the minimum bridge would need to be 18m to pass the 100-year flood (which would maintain the existing road surface elevation). Minor channel works would necessary at the bridge inlet and outlet to tie the channel into the new bridge abutments. This would be undertaken using a combination of natural channel design techniques as well as engineered methods.

Flood risk hazard characterization was undertaken for all the alternatives, similar to the assessment presented in **Section 3.4**. This was done to create a quantitative and direct comparison of the flood controls for each proposed alternative. This involved updating the HEC-RAS model with the proposed bridge and channel modifications, then preparing floodplain mapping for the proposed conditions. The updated 100-year and regional floodlines are presented below in **Figure 4.3** and a summary of the results is presented in **Table 4-2**. A summary of the output from the HEC-RAS model is provided in **Table 4-3**.

Under the proposed conditions for alternative 2 for Reach 1, there will be **no buildings** within the regional and 100-year floodplains. Therefore, this alternative removes all fourteen (14) buildings/units from the existing floodplain.

As the purpose of the alternative was to provide the recommended MTO conveyance, the maximum hydraulic conveyance capacity is the 100-year flood event. This is a significant increase in conveyance capacity, and it is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1**. Minor increases in water surface elevations were observed at the downstream bounding cross section of the New Street crossing (XS1552.684), which is mostly caused by the reduced velocities and energy gradients through the larger opening as proposed within Alternative 2. However, flooding conditions downstream of New Street are not expected to be negatively impacted by the increased water levels as all flows will be contained within the creek corridor and the valley systems.

Under this alternative, road inundation is not expected to be impacted, and New Street is only expected to be overtopped under the regional flood conditions.

Table 4-2: Summary of Conditions for Reach 1, Alternative 2

Bridge Dimensions			Beam structure, 18m wide, 2.6m rise
Average Channel Width at Bridge			8-10 m
Maximum Hydraulic Conveyance Capacity			100-year flood
Frequency of Road Inundation			Regional flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 2 Flood Limits	Percent Decrease
Regional Flood	14	0	100%
100-Year Flood	0	0	-
*This includes the area from downstream of Pinedale Avenue to New Street			

Table 4-3: Summary of HEC-RAS results for Reach 1, Alternative 2

River Station	Regional Flood Flow (106 m^3/s)			100-year Flood Flow (59 m^3/s)		
	Updated Existing WSE	Alternative 2 WSE	Change	Updated Existing WSE	Alternative 2 WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
1979.323	92.44	92.44	0	91.84	91.84	0
1929.458	92.44	92.33	-0.11	91.72	91.72	0
1834.767	92.09	91.67	-0.42	91.27	91.28	0.01
1763.106	92.15	91.71	-0.44	91.07	90.97	-0.1
1714.328	92.01	91.33	-0.68	91.00	90.68	-0.32
1646.838	91.98	90.53	-1.45	90.88	89.93	-0.95
1617.242	91.98	90.6	-1.38	90.88	89.53	-1.35
1599.64	91.87	90.76	-1.11	90.49	89.52	-0.97
1552.684	89.82	90.54	0.72	88.96	89.47	0.51
1533.912	89.52	89.52	0	88.85	88.85	0
1501.136	89.49	89.49	0	88.81	88.81	0
1400	88.63	88.63	0	87.94	87.94	0

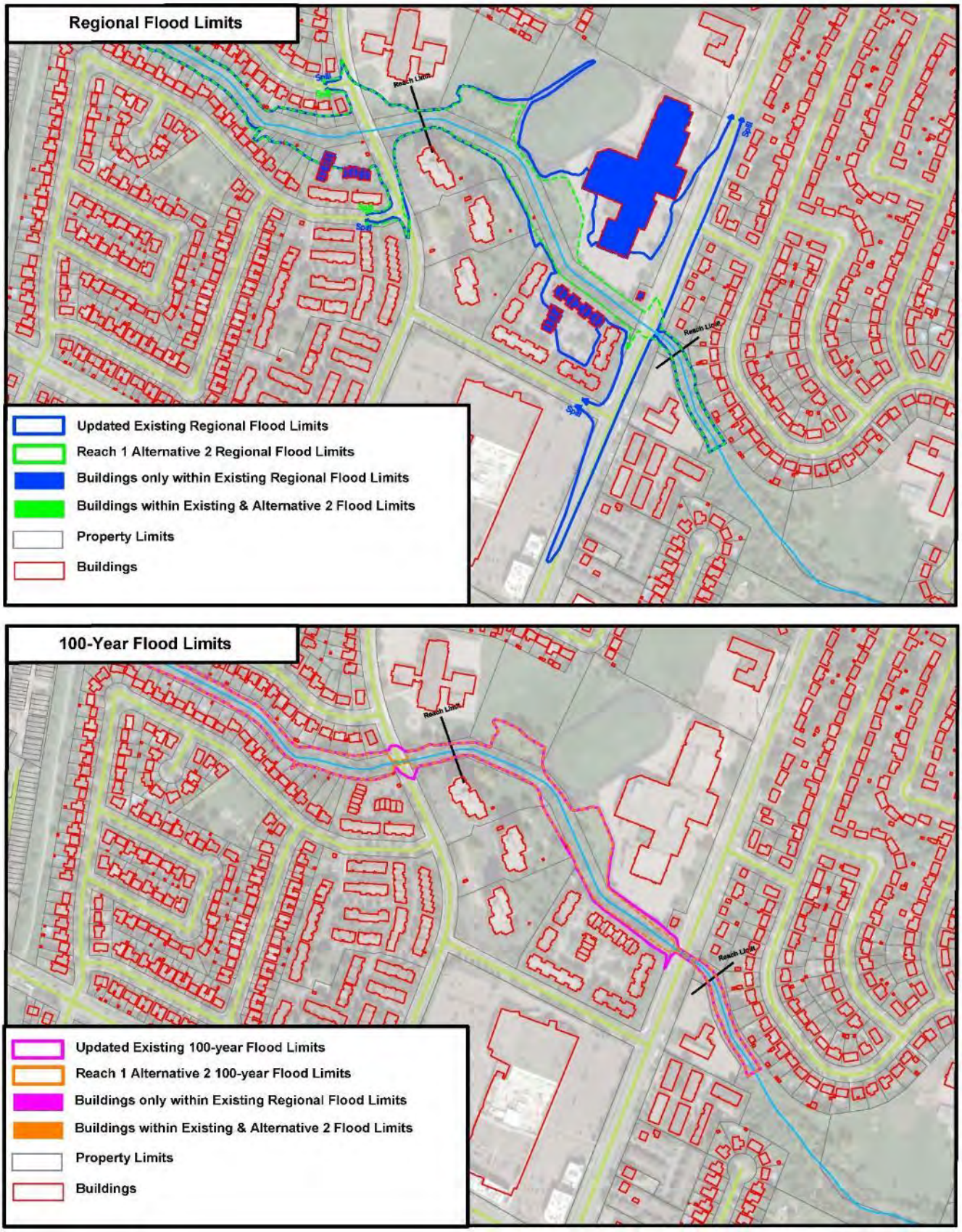


Figure 4.3: Floodline comparison for Reach 1, Alternative 2

4.1.3 Alternative 3 – New Street Bridge Widening (Option 2)

Similar to alternative 2, this alternative investigated replacing the existing New Street bridge with a larger bridge, however the intention of this alternative was to widening the bridge enough to pass the regional flood. Not only would this improve hydraulic conveyance and biological passage, there would be very limited risk to road inundation. A hydraulic assessment of the bridge was undertaken, and it was determined that the minimum bridge would need to be 40m to pass the regional flood. Localized channel works would also be necessary at the bridge inlet and outlet in order to tie the channel into the new bridge abutments.

As with alternative 2, a flood risk hazard characterization was undertaken for alternative 3. The updated 100-year and regional floodlines are presented below in **Figure 4.4** and a summary of the results is presented in **Table 4-4**. A summary of the output from the HEC-RAS model is provided in **Table 4-5**. Under the proposed conditions for alternative 3 for Reach 1, there will be no buildings within the regional and 100-year floodplains.

As the purpose of the alternative was to convey the regional flood, the maximum hydraulic conveyance capacity is obviously the regional flood. As with alternative 2, alternative 3 provides a significant increase in the conveyance capacity, and it is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1.**

Similar to Alternative 2, minor increases in water surface elevations were observed at the cross sections downstream of the New Street crossing (XS1533.912 and XS1501.136), which is mostly caused by the reduced velocities and energy gradients through the larger opening. However, flooding conditions downstream of New Street are not expected to be negatively impacted by the increased water levels as all flows will be contained within the creek corridor and the valley systems.

Under this alternative, New Street is not expected to be inundated for any floods equal to or smaller than the regional flood. Therefore, the road will be accessible, and can be used as an emergency route.

Table 4-4: Summary of Conditions for Reach 1, Alternative 3

Bridge Dimensions		Beam structure, 40m wide, 3.0m rise	
Average Channel Width at Bridge		8-10 m	
Maximum Hydraulic Conveyance Capacity		Regional flood	
Frequency of Road Inundation		N/A	
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 3 Flood Limits	Percent Decrease
Regional Flood	14	0	100%
100-Year Flood	0	0	-
*This includes the area from downstream of Pinedale Avenue to New Street			

Table 4-5: Summary of HEC-RAS results for Reach 1, Alternative 3

River Station	Regional Flood Flow (106 m^3/s)			100-year Flood Flow (59 m^3/s)		
	Updated Existing WSE	Alternative 3 WSE	Change	Updated Existing WSE	Alternative 3 WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
1979.323	92.44	92.44	0	91.84	91.84	0
1929.458	92.44	92.33	-0.11	91.72	91.72	0
1834.767	92.09	91.67	-0.42	91.27	91.28	0.01
1763.106	92.15	91.71	-0.44	91.07	90.97	-0.1
1714.328	92.01	91.33	-0.68	91.00	90.68	-0.32
1646.838	91.98	90.53	-1.45	90.88	89.93	-0.95
1617.242	91.98	90.17	-1.81	90.88	89.53	-1.35
1599.64	91.87	89.84	-2.03	90.49	88.92	-1.57
1552.684	89.82	89.83	0.01	88.96	88.91	-0.05
1533.912	89.52	89.64	0.12	88.85	88.79	-0.06
1501.136	89.49	89.61	0.12	88.81	88.76	-0.05
1400	88.63	88.63	0	87.94	87.94	0

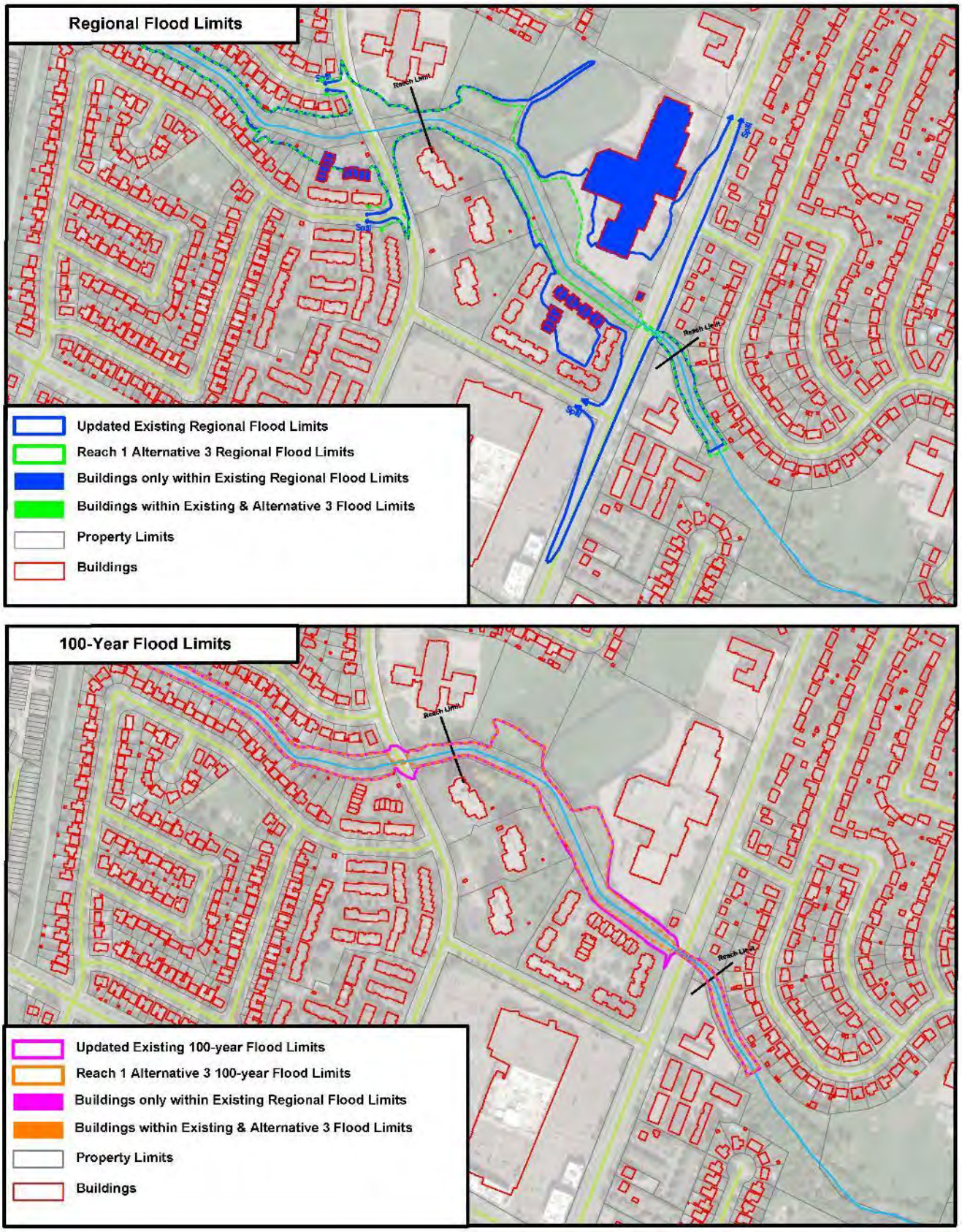


Figure 4.4: Floodline comparison for Reach 1, Alternative 3

4.2 Description of Alternatives for Reach 2

Five (5) alternatives were developed to reduce flooding along the Appleby Creek corridor, by altering the bridge at Pinedale Avenue and undertaking channel modifications through the reach. These alternatives were evaluated against the existing conditions, taking into consideration the "do-nothing" alternative. Details of each alternative are provided below.

4.2.1 Alternative 1 – Do Nothing

For the do-nothing alternative, no mitigation measures will be taken, with the exception of emergency situations. This would involve leaving the existing stream and bridges, and existing problems associated with potential of flooding will remain. The existing 100-year and regional flood limits for Reach 1 are shown in **Figure 4.5**, and the existing conditions of the Pinedale Avenue bridge and are shown in **Figure 4.6**. **Table 4-6** provides a summary of the existing conditions.

Table 4-6: Summary of Conditions for Reach 2, Alternative 1

Bridge Dimensions			Arch structure, 7.4m wide, 2.0m rise
Average Channel Width at Bridge			12-15 m
Maximum Hydraulic Conveyance Capacity			10-year flood
Frequency of Road Inundation			25-year flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 1 Flood Limits	Percent Decrease
Regional Flood	14	14	0%
100-Year Flood	0	0	-
*This includes the area from downstream of Fairview Street to Pinedale Avenue			

As explained in **Section 3.4**, a flood hazard assessment was undertaken for the existing conditions which identified the number of buildings within the flood limits, road overtopping frequency and the hydraulic conveyance capacity of the road structures. This information is also presented in **Table 4-6**. Under the existing conditions for Reach 2, there are 14 buildings and units within the regional floodplain and no buildings within the 100-year storm floodplain. The updated 100-year and Regional floodlines are presented below in **Figure 4.5**. The maximum hydraulic conveyance capacity of the Pinedale Avenue bridge is the 10-year flood event, which is much lower than the recommended conveyance from MTO (i.e., 50-year flood). Finally, the road inundation is expected to occur under the 25-year flood event, but only reach unpassable flow levels under the regional flood conditions.

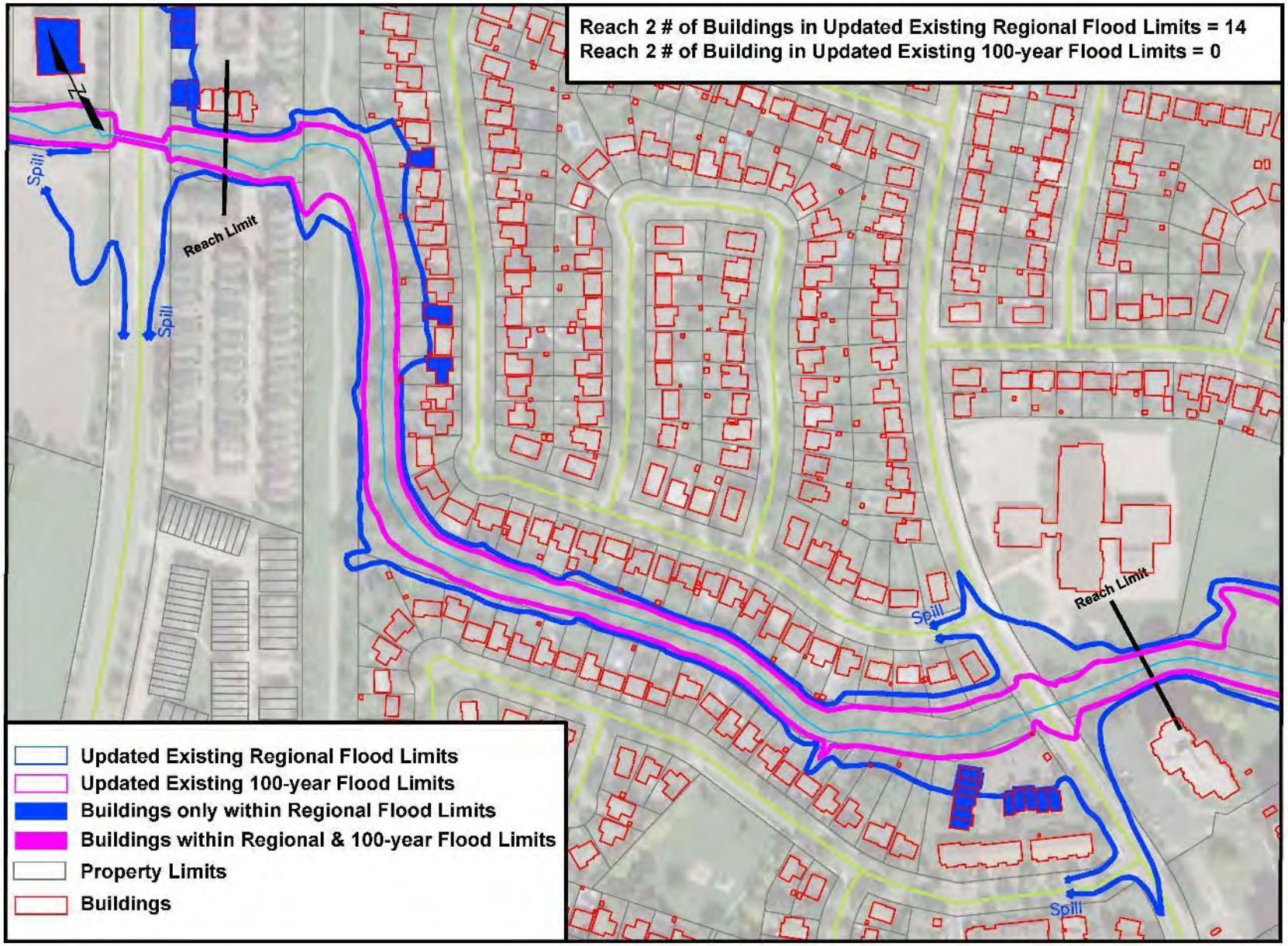


Figure 4.5: 100-year and Regional flood limits under the existing conditions

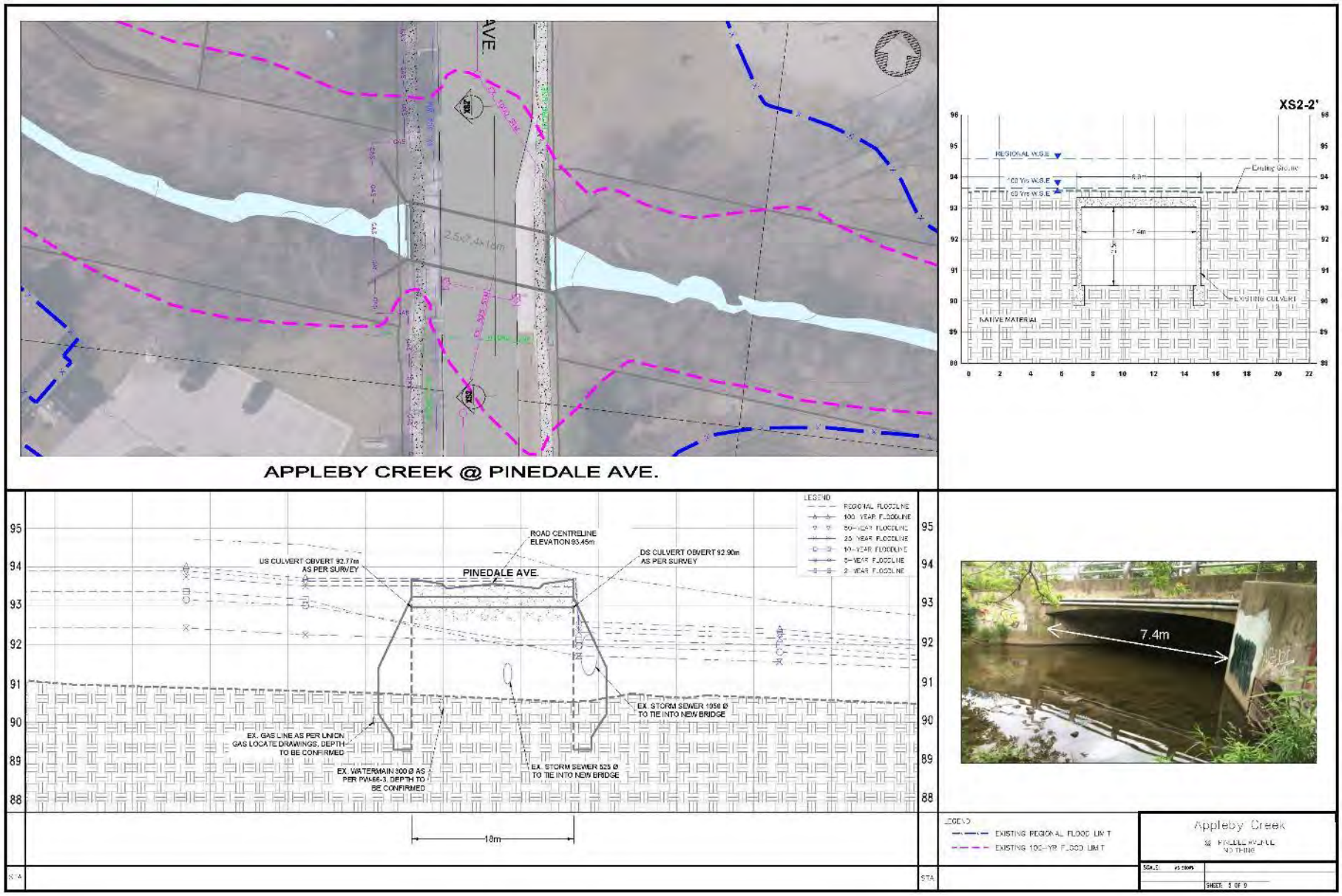


Figure 4.6: Culvert and channel dimension for Reach 2, Alternative 1

4.2.2 Alternative 2 – Pinedale Avenue Bridge Improvements (Option 1)

This alternative investigated replacing the existing Pinedale Avenue bridge with a larger bridge. This would involve widening the bridge enough to ensure that the MTO recommended hydraulic conveyance is passed, and also improve terrestrial and aquatic passage. A hydraulic assessment of the bridge was undertaken, and it was determined that the minimum bridge would need to be 18m to pass the 50-year flood while maintaining the existing road surface elevation. Minor channel works would be necessary at the bridge inlet and outlet in order to tie the channel into the new bridge abutments. This would be undertaken using a combination of natural channel design techniques as well as engineered methods.

As with the alternatives for Reach 1, a flood risk hazard characterization was undertaken for all the alternatives for Reach 2, similar to the assessment present **Section 3.4.** The updated 100-year and regional floodlines are presented below in **Figure 4.7** and a summary of the results is presented in **Table 4-7**. A summary of the output from the HEC-RAS model is provided in **Table 4-8**.

Under the proposed conditions for alternative 2 for Reach 2, it is expected that there will be three (3) buildings remaining within the regional floodplain, and no buildings within the 100-year floodplains. Therefore, this alternative removes 11 building units from the floodplain.

As the purpose of the alternative was to provide the recommended MTO conveyance, the maximum hydraulic conveyance capacity is the 50-year flood event. This is a significant increase in conveyance capacity, and it is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1.**

Under this alternative, road inundation is not expected to be impacted, and Pinedale Ave is only expected to be overtopped under the regional flood conditions.

Table 4-7: Summary of Conditions for Reach 2, Alternative 2

Bridge Dimensions			Beam structure, 18m wide, 1.9m rise
Average Channel Width at Bridge			12-15 m
Maximum Hydraulic Conveyance Capacity			50-year flood
Frequency of Road Inundation			Regional flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 2 Flood Limits	Percent Decrease
Regional Flood	14	3	79%
100-Year Flood	0	0	-
*This includes the area from downstream of Fairview Street to Pinedale Avenue			

Table 4-8: Summary of HEC-RAS results for Reach 2, Alternative 2

River Station	Regional Flood Flow (93 m^3/s)			100-year Flood Flow (54 m^3/s)		
	Updated Existing WSE	Alternative 2 WSE	Change	Updated Existing WSE	Alternative 2 WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
2798.804	99.46	99.46	0	98.99	98.99	0
2787.644	99.4	99.4	0	98.92	98.92	0
2779.95	99.49	99.49	0	98.97	98.97	0
2767.75	99.3	99.3	0	98.95	98.95	0
2754.671	99.16	99.16	0	98.63	98.63	0
2748.151	99.05	99.05	0	98.57	98.57	0
2741.901	98.84	98.84	0	98.43	98.43	0
2729.856	98.77	98.77	0	98.43	98.43	0
2720.666	98.74	98.74	0	98.3	98.3	0
2709.405	98.71	98.71	0	98.17	98.17	0
2689.134	98.65	98.65	0	97.81	97.81	0
2659.87	98.17	98.17	0	97.5	97.5	0
2644.339	97.96	97.96	0	97.37	97.37	0
2623.9	97.87	97.87	0	97.09	97.09	0
2600	97.61	97.61	0	96.9	96.9	0
2595.03	97.41	97.41	0	96.73	96.73	0
2583.38	97.29	97.29	0	96.6	96.6	0
2569.89	97.01	97.01	0	96.48	96.48	0
2543.03	96.97	96.97	0	96.34	96.34	0
2519.656	96.82	96.82	0	96.11	96.11	0
2490.54	96.77	96.77	0	96.01	96.01	0
2450.422	96.59	96.59	0	95.61	95.61	0
2406.37	96.35	96.35	0	95.47	95.47	0
2400	95.94	95.94	0	95.2	95.2	0
2357.51	95.61	95.61	0	94.81	94.81	0
2333	95.28	95.28	0	94.64	94.64	0
2300	94.89	94.91	0.02	94.27	94.32	0.05
2275.545	94.75	94.61	-0.14	94.1	93.95	-0.15
2235.326	94.79	94.5	-0.29	94.12	93.81	-0.31
2207.588	94.78	94.46	-0.32	94.1	93.76	-0.34
2153.086	94.68	93.65	-1.03	93.98	93.06	-0.92
2113.248	94.73	93.63	-1.1	94.01	92.87	-1.14
2090.014	94.73	93.59	-1.14	94.01	92.82	-1.19
2074.652	94.58	93.57	-1.01	93.72	92.81	-0.91
2039.232	93.84	92.52	-1.32	92.6	92.05	-0.55
2020.868	93.11	92.43	-0.68	92.4	91.9	-0.5

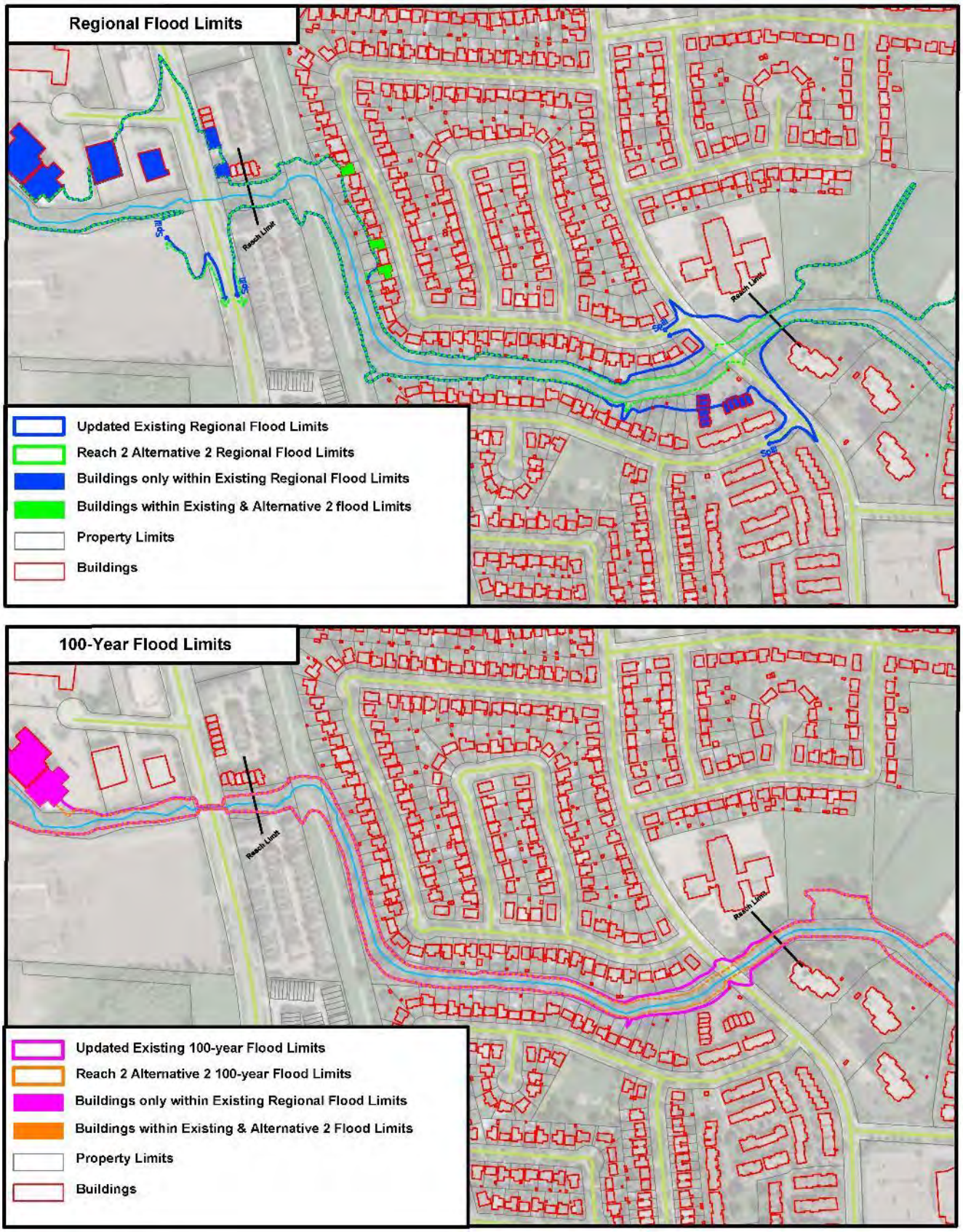


Figure 4.7: Floodline comparison for Reach 2, Alternative 2

4.2.3 Alternative 2a – Pinedale Avenue Bridge Improvements (Option 1) and Channel Works

This alternative investigated replacing the existing Pinedale Avenue bridge with a span wide enough to ensure that the MTO recommended hydraulic conveyance is passed, and undertaking channel works to provide floodplain relief. A discussion of the recommended channel modifications is presented in **Section 4.5**. As discussed above, it was determined that the minimum bridge would need to be 18m to pass the 50-year flood (which would maintain the existing road surface elevation). Minor channel works would be necessary at the bridge inlet and outlet in order to tie the channel into the new bridge abutments. This would be undertaken using a combination of natural channel design techniques as well as engineered methods.

The flood risk hazard characterization was undertaken and the updated 100-year and regional floodlines are presented below in **Figure 4.8** and a summary of the results is presented in **Table 4-9**. A summary of the output from the HEC-RAS model is provided in **Table 4-10**.

Under the proposed conditions for alternative 2a for Reach 2, it is expected that there will be only two (2) buildings within the regional floodplain, and no buildings within the 100-year floodplains. Therefore, this alternative removes 12 buildings units from the floodplain.

The maximum hydraulic conveyance capacity is the 50-year flood event. This is a significant increase in conveyance capacity, and it is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1.**

Under this alternative, road inundation is not expected to be impacted, and Pinedale Avenue is only expected to be overtopped under the regional flood conditions.

Table 4-9: Summary of Conditions for Reach 2, Alternative 2a

Bridge Dimensions			Beam structure, 18m wide, 1.9m rise
Average Channel Width at Bridge			12-15 m
Maximum Hydraulic Conveyance Capacity			50-year flood
Frequency of Road Inundation			Regional flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 2a Flood Limits	Percent Decrease
Regional Flood	14	2	86%
100-Year Flood	0	0	-
*This includes the area from downstream of Fairview Street to Pinedale Avenue			

Table 4-10: Summary of HEC-RAS results for Reach 2, Alternative 2a

River Station	Regional Flood Flow (93 m^3/s)			100-year Flood Flow (54 m^3/s)		
	Updated Existing WSE	Alternative 2a WSE	Change	Updated Existing WSE	Alternative 2a WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
2798.804	99.46	99.46	0	98.99	98.99	0
2787.644	99.4	99.4	0	98.92	98.92	0
2779.95	99.49	99.49	0	98.97	98.97	0
2767.75	99.3	99.3	0	98.95	98.95	0
2754.671	99.16	99.16	0	98.63	98.63	0
2748.151	99.05	99.05	0	98.57	98.57	0
2741.901	98.84	98.84	0	98.43	98.43	0
2729.856	98.77	98.75	-0.02	98.43	98.43	0
2720.666	98.74	98.72	-0.02	98.3	98.3	0
2709.405	98.71	98.76	0.05	98.17	97.76	-0.41
2689.134	98.65	97.42	-1.23	97.81	97.38	-0.43
2659.87	98.17	97.71	-0.46	97.5	97.34	-0.16
2644.339	97.96	97.54	-0.42	97.37	97.23	-0.14
2623.9	97.87	97.3	-0.57	97.09	97.01	-0.08
2600	97.61	97.17	-0.44	96.9	96.85	-0.05
2595.03	97.41	97.24	-0.17	96.73	96.79	0.06
2583.38	97.29	97.22	-0.07	96.6	96.77	0.17
2569.89	97.01	97.19	0.18	96.48	96.75	0.27
2543.03	96.97	97.06	0.09	96.34	96.64	0.3
2519.656	96.82	96.71	-0.11	96.11	96.33	0.22
2490.54	96.77	96.41	-0.36	96.01	96.03	0.02
2450.422	96.59	96.31	-0.28	95.61	95.5	-0.11
2406.37	96.35	96.07	-0.28	95.47	95.35	-0.12
2400	95.94	95.71	-0.23	95.2	95.07	-0.13
2357.51	95.61	95.36	-0.25	94.81	94.7	-0.11
2333	95.28	95.1	-0.18	94.64	94.53	-0.11
2300	94.89	94.84	-0.05	94.27	94.24	-0.03
2275.545	94.75	94.42	-0.33	94.1	93.86	-0.24
2235.326	94.79	94.25	-0.54	94.12	93.69	-0.43
2207.588	94.78	94.19	-0.59	94.1	93.6	-0.5
2153.086	94.68	93.53	-1.15	93.98	92.98	-1
2113.248	94.73	93.63	-1.1	94.01	92.87	-1.14
2090.014	94.73	93.59	-1.14	94.01	92.82	-1.19
2074.652	94.58	93.57	-1.01	93.72	92.81	-0.91
2039.232	93.84	92.52	-1.32	92.6	92.05	-0.55
2020.868	93.11	92.43	-0.68	92.4	91.9	-0.5

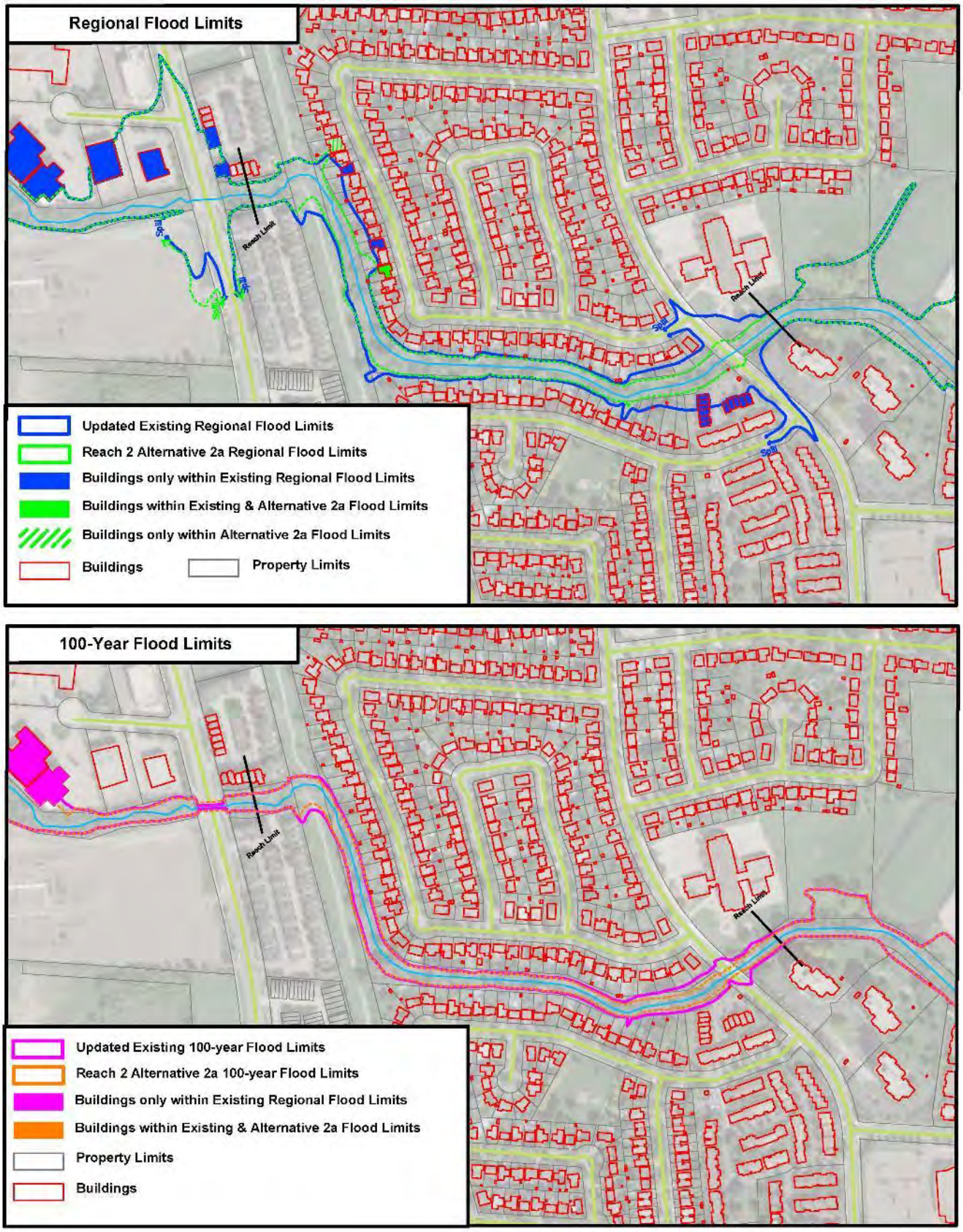


Figure 4.8: Floodline comparison for Reach 2, Alternative 2a

4.2.4 Alternative 3 – Pinedale Avenue Bridge Improvements (Option 2)

Similar to alternative 2, this alternative investigated replacing the existing Pinedale Avenue bridge with a larger span, however the intention of this alternative was to widening the bridge enough to pass the regional flood. Not only would this improve hydraulic conveyance and biological passage, there would be very limited risk to road inundation. A hydraulic assessment of the bridge was undertaken, and it was determined that the minimum bridge would need to be 30m to pass the regional flood. Similarly, localized channel works would necessary at the bridge inlet and outlet in order to tie the channel into the new bridge abutments.

The flood risk hazard characterization was undertaken and the updated 100-year and regional floodlines are presented below in **Figure 4.9** and a summary of the results is presented in **Table 4-11**. A summary of the output from the HEC-RAS model is provided in **Table 4-12**.

Under the proposed conditions for alternative 3 for Reach 2, it is expected that there will be three (3) buildings within the regional floodplain, and no buildings within the 100-year floodplains. Therefore, this alternative removes 11 buildings from the floodplain.

As the purpose of the alternative was to convey the regional flood, the maximum hydraulic conveyance capacity is obviously the regional flood. As with alternative 2, alternative 3 provides a significant increase in the conveyance capacity, and it is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1.**

Under this alternative, Pinedale Avenue is not expected to be inundated for any floods equal to or smaller than the regional flood. Therefore, the road will be accessible, and can be used as an emergency route.

Table 4-11: Summary of Conditions for Reach 2, Alternative 3

Bridge Dimensions			Beam structure, 30m wide, 2.52m rise
Average Channel Width at bridge			12-15 m
Maximum Hydraulic Conveyance Capacity			Regional flood
Frequency of Road Inundation			N/A
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 3 Flood Limits	Percent Decrease
Regional Flood	14	3	79%
100-Year Flood	0	0	-
*This includes the area from downstream of Fairview Street to Pinedale Avenue			

Table 4-12: Summary of HEC-RAS results for Reach 2, Alternative 3

River Station	Regional Flood Flow (93 m^3/s)			100-year Flood Flow (54 m^3/s)		
	Updated Existing WSE	Alternative 3 WSE	Change	Updated Existing WSE	Alternative 3 WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
2798.804	99.46	99.46	0	98.99	98.99	0
2787.644	99.4	99.4	0	98.92	98.92	0
2779.95	99.49	99.49	0	98.97	98.97	0
2767.75	99.3	99.3	0	98.95	98.95	0
2754.671	99.16	99.16	0	98.63	98.63	0
2748.151	99.05	99.05	0	98.57	98.57	0
2741.901	98.84	98.84	0	98.43	98.43	0
2729.856	98.77	98.77	0	98.43	98.43	0
2720.666	98.74	98.74	0	98.3	98.3	0
2709.405	98.71	98.71	0	98.17	98.17	0
2689.134	98.65	98.65	0	97.81	97.81	0
2659.87	98.17	98.17	0	97.5	97.5	0
2644.339	97.96	97.96	0	97.37	97.37	0
2623.9	97.87	97.87	0	97.09	97.09	0
2600	97.61	97.61	0	96.9	96.9	0
2595.03	97.41	97.41	0	96.73	96.73	0
2583.38	97.29	97.29	0	96.6	96.6	0
2569.89	97.01	97.01	0	96.48	96.48	0
2543.03	96.97	96.97	0	96.34	96.34	0
2519.656	96.82	96.82	0	96.11	96.11	0
2490.54	96.77	96.77	0	96.01	96.01	0
2450.422	96.59	96.59	0	95.61	95.61	0
2406.37	96.35	96.35	0	95.47	95.47	0
2400	95.94	95.94	0	95.2	95.2	0
2357.51	95.61	95.61	0	94.81	94.81	0
2333	95.28	95.28	0	94.64	94.64	0
2300	94.89	94.91	0.02	94.27	94.32	0.05
2275.545	94.75	94.61	-0.14	94.1	93.95	-0.15
2235.326	94.79	94.5	-0.29	94.12	93.81	-0.31
2207.588	94.78	94.46	-0.32	94.1	93.76	-0.34
2153.086	94.68	93.65	-1.03	93.98	93.06	-0.92
2113.248	94.73	93.06	-1.67	94.01	92.52	-1.49
2090.014	94.73	92.83	-1.9	94.01	92.26	-1.75
2074.652	94.58	92.97	-1.61	93.72	92.36	-1.36
2039.232	93.84	92.92	-0.92	92.6	92.3	-0.3
2020.868	93.11	92.43	-0.68	92.4	91.9	-0.5

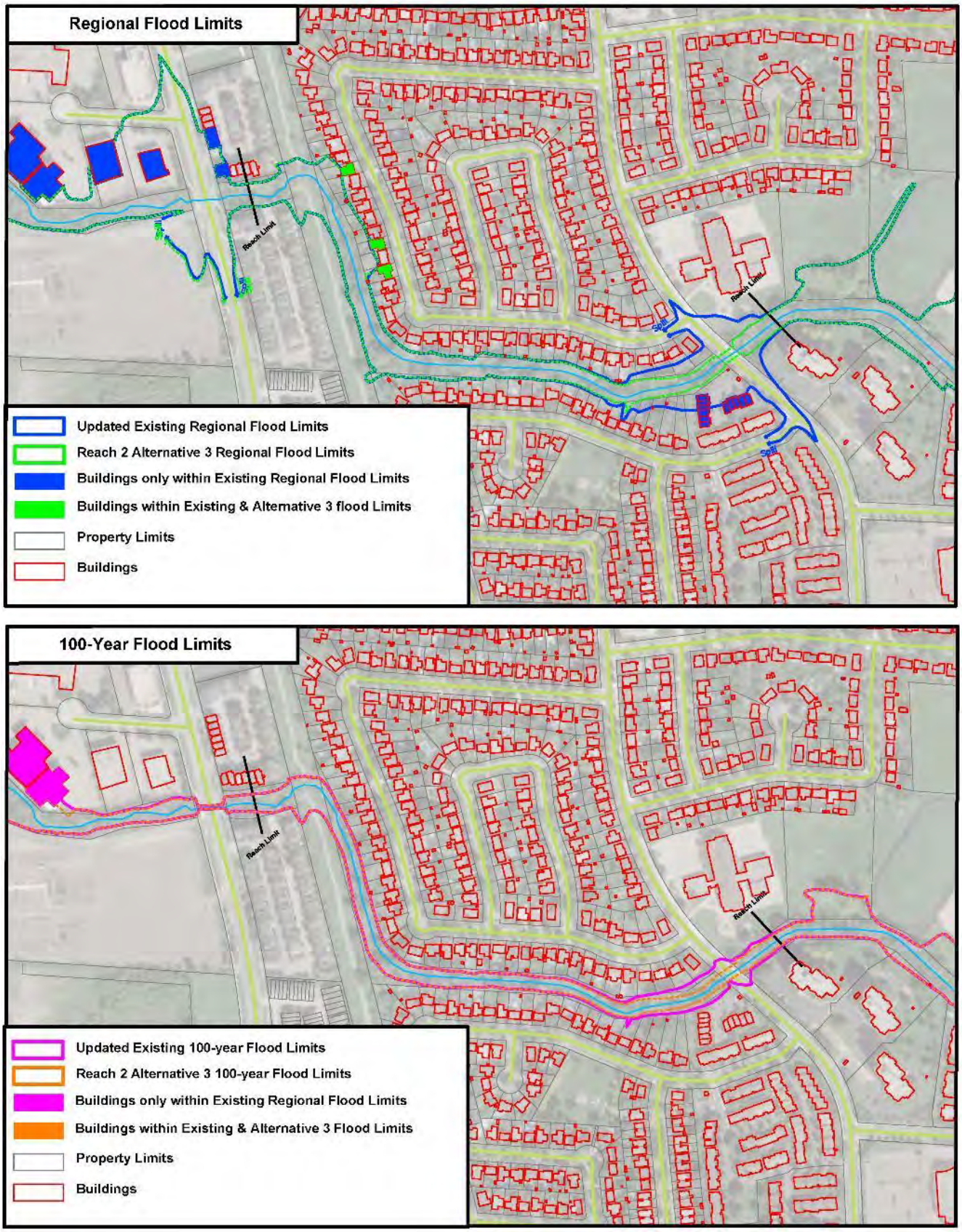


Figure 4.9: Floodline comparison for Reach 2, Alternative 3

4.2.5 Alternative 3a – Pinedale Avenue Bridge Improvements (Option 2) and Channel Works

This alternative investigated replacing the existing Pinedale Avenue bridge with a span wide enough to convey the regional flood and undertaking channel works to provide floodplain relief. A discussion of the recommended channel modifications is presented in **Section 4.5**. As discussed above, it was determined that the minimum bridge would need to be 30m to pass the regional flood. Minor channel works would be necessary at the bridge inlet and outlet in order to tie the channel into the new bridge abutments. This would be undertaken using a combination of natural channel design techniques as well as engineered methods.

The flood risk hazard characterization was undertaken and the updated 100-year and regional floodlines are presented below in **Figure 4.10** and a summary of the results is presented in **Table 4-13**. A summary of the output from the HEC-RAS model is provided in **Table 4-14**.

Under the proposed conditions for alternative 3a for Reach 2, it is expected that there will be only two (2) buildings within the regional floodplain, and no buildings within the 100-year floodplains. Therefore, this alternative removes 12 building units from the floodplain.

As the purpose of the alternative was to convey the regional flood, the maximum hydraulic conveyance capacity is obviously the regional flood. As with alternative 2, alternative 3 provides a significant increase in the conveyance capacity, and it is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1.**

Under this alternative, Pinedale Avenue is not expected to be inundated for any floods equal to or smaller than the regional flood. Therefore, the road will be accessible, and can be used as an emergency route.

Table 4-13: Summary of Conditions for Reach 2, Alternative 3a

Bridge Dimensions			Beam structure, 30m wide, 2.52m rise
Average Channel Width at Bridge			12-15 m
Maximum Hydraulic Conveyance Capacity			Regional flood
Frequency of Road Inundation			N/A
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 3 Flood Limits	Percent Decrease
Regional Flood	14	2	86%
100-Year Flood	0	0	-
*This includes the area from downstream of Fairview Street to Pinedale Avenue			

Table 4-14: Summary of HEC-RAS results for Reach 2, Alternative 3a

River Station	Regional Flood Flow (93 m^3/s)			100-year Flood Flow (54 m^3/s)		
	Updated Existing WSE	Alternative 3a WSE	Change	Updated Existing WSE	Alternative 3a WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
2798.804	99.46	99.46	0	98.99	98.99	0
2787.644	99.4	99.4	0	98.92	98.92	0
2779.95	99.49	99.49	0	98.97	98.97	0
2767.75	99.3	99.3	0	98.95	98.95	0
2754.671	99.16	99.16	0	98.63	98.63	0
2748.151	99.05	99.05	0	98.57	98.57	0
2741.901	98.84	98.84	0	98.43	98.43	0
2729.856	98.77	98.75	-0.02	98.43	98.43	0
2720.666	98.74	98.72	-0.02	98.3	98.3	0
2709.405	98.71	98.76	0.05	98.17	97.76	-0.41
2689.134	98.65	97.42	-1.23	97.81	97.38	-0.43
2659.87	98.17	97.71	-0.46	97.5	97.34	-0.16
2644.339	97.96	97.54	-0.42	97.37	97.23	-0.14
2623.9	97.87	97.3	-0.57	97.09	97.01	-0.08
2600	97.61	97.17	-0.44	96.9	96.85	-0.05
2595.03	97.41	97.24	-0.17	96.73	96.79	0.06
2583.38	97.29	97.22	-0.07	96.6	96.77	0.17
2569.89	97.01	97.19	0.18	96.48	96.75	0.27
2543.03	96.97	97.06	0.09	96.34	96.64	0.3
2519.656	96.82	96.71	-0.11	96.11	96.33	0.22
2490.54	96.77	96.41	-0.36	96.01	96.03	0.02
2450.422	96.59	96.31	-0.28	95.61	95.5	-0.11
2406.37	96.35	96.07	-0.28	95.47	95.35	-0.12
2400	95.94	95.71	-0.23	95.2	95.07	-0.13
2357.51	95.61	95.36	-0.25	94.81	94.7	-0.11
2333	95.28	95.1	-0.18	94.64	94.53	-0.11
2300	94.89	94.84	-0.05	94.27	94.24	-0.03
2275.545	94.75	94.42	-0.33	94.1	93.86	-0.24
2235.326	94.79	94.25	-0.54	94.12	93.69	-0.43
2207.588	94.78	94.19	-0.59	94.1	93.6	-0.5
2153.086	94.68	93.53	-1.15	93.98	92.98	-1
2113.248	94.73	93.06	-1.67	94.01	92.52	-1.49
2090.014	94.73	92.83	-1.9	94.01	92.26	-1.75
2074.652	94.58	92.97	-1.61	93.72	92.36	-1.36
2039.232	93.84	92.92	-0.92	92.6	92.3	-0.3
2020.868	93.11	92.43	-0.68	92.4	91.9	-0.5

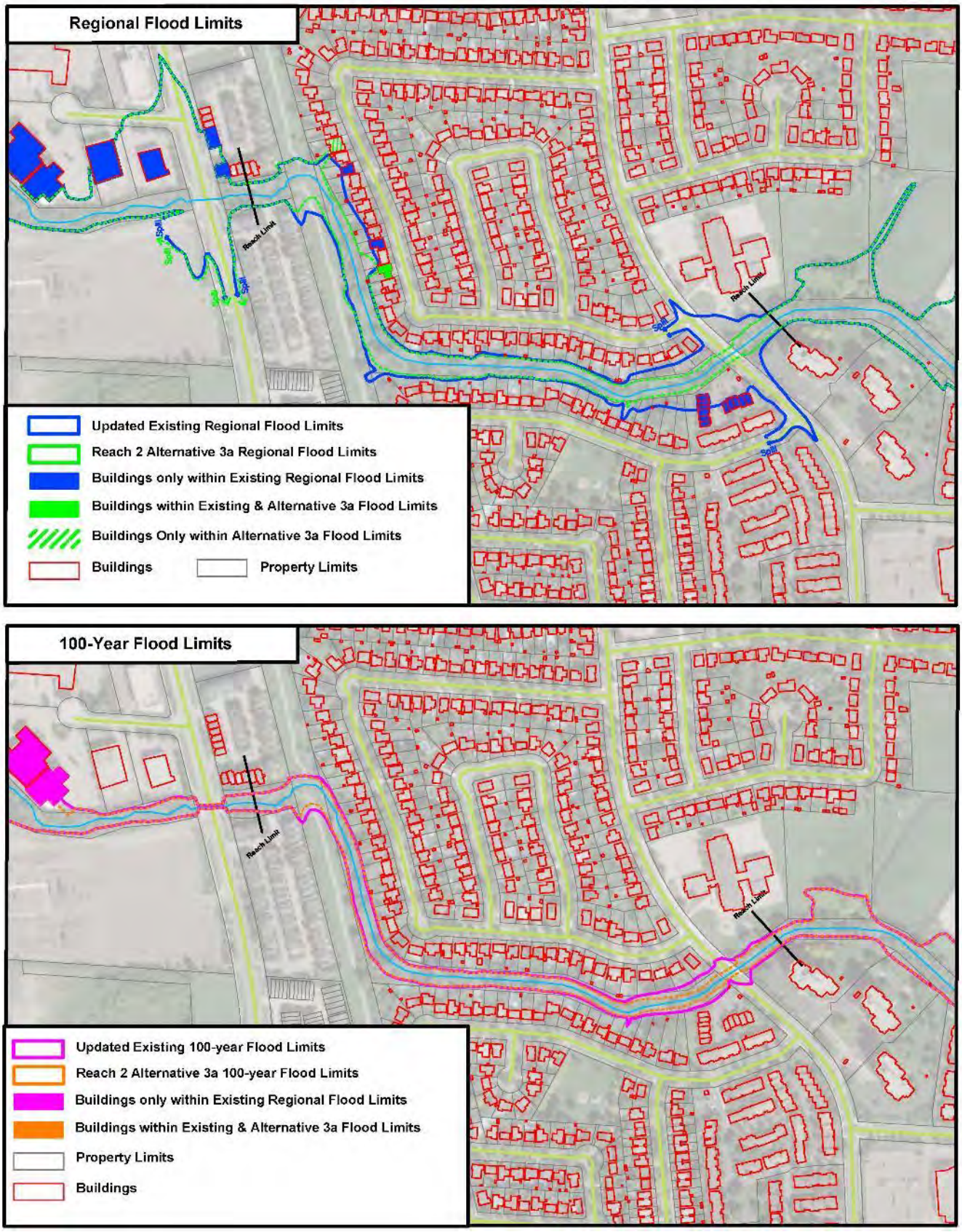


Figure 4.10: Floodline comparison for Reach 2, Alternative 3a

4.2.6 Alternative 4 – Only Channel Works

This alternative investigated only undertaking channel works through the reach to provide floodplain relief. A discussion of the recommended channel modifications is presented in **Section 4.5**. No bridge modifications would be undertaken as part of this alternative.

The flood risk hazard characterization was undertaken and the updated 100-year and regional floodlines are presented below in **Figure 4.11,** along with a summary of the results is presented in **Table 4-15**. A summary of the output from the HEC-RAS model is provided in **Table 4-16**.

Under the proposed conditions for alternative 4 for Reach 2, it is expected that there will be thirteen (13) building units within the regional floodplain, and no buildings within the 100-year floodplains. Therefore, this alternative only removes one (1) building from the floodplain.

The conveyance capacity of Pinedale Avenue is unaffected by the proposed channel modifications. Therefore, the maximum hydraulic capacity is still the 10-year flood, which is much lower than the recommended MTO capacity (i.e., 50-year flood).

The road inundation is also not improved by the proposed channel modifications and is expected to occur under the 25-year flood event, but only reach unpassable flow levels under the regional flood conditions.

Table 4-15: Summary of Conditions for Reach 2, Alternative 4

Bridge Dimensions			Arch structure, 7.4m wide, 2.0m rise
Average Channel Width at Bridge			12-15 m
Maximum Hydraulic Conveyance Capacity			10-year flood
Frequency of Road Inundation			25-year flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 4 Flood Limits	Percent Decrease
Regional Flood	14	13	7%
100-Year Flood	0	0	-
*This includes the area from downstream of Fairview Street to Pinedale Avenue			

Table 4-16: Summary of HEC-RAS results for Reach 2, Alternative 4

River Station	Regional Flood Flow (93 m^3/s)			100-year Flood Flow (54 m^3/s)		
	Updated Existing WSE	Alternative 4 WSE	Change	Updated Existing WSE	Alternative 4 WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
2798.804	99.46	99.46	0	98.99	98.99	0
2787.644	99.4	99.4	0	98.92	98.92	0
2779.95	99.49	99.49	0	98.97	98.97	0
2767.75	99.3	99.3	0	98.95	98.95	0
2754.671	99.16	99.16	0	98.63	98.63	0
2748.151	99.05	99.05	0	98.57	98.57	0
2741.901	98.84	98.84	0	98.43	98.43	0
2729.856	98.77	98.75	-0.02	98.43	98.43	0
2720.666	98.74	98.72	-0.02	98.3	98.3	0
2709.405	98.71	98.76	0.05	98.17	97.76	-0.41
2689.134	98.65	97.42	-1.23	97.81	97.38	-0.43
2659.87	98.17	97.71	-0.46	97.5	97.34	-0.16
2644.339	97.96	97.54	-0.42	97.37	97.23	-0.14
2623.9	97.87	97.3	-0.57	97.09	97.01	-0.08
2600	97.61	97.17	-0.44	96.9	96.85	-0.05
2595.03	97.41	97.24	-0.17	96.73	96.79	0.06
2583.38	97.29	97.22	-0.07	96.6	96.77	0.17
2569.89	97.01	97.19	0.18	96.48	96.75	0.27
2543.03	96.97	97.06	0.09	96.34	96.64	0.3
2519.656	96.82	96.71	-0.11	96.11	96.33	0.22
2490.54	96.77	96.41	-0.36	96.01	96.03	0.02
2450.422	96.59	96.31	-0.28	95.61	95.5	-0.11
2406.37	96.35	96.07	-0.28	95.47	95.35	-0.12
2400	95.94	95.71	-0.23	95.2	95.07	-0.13
2357.51	95.61	95.36	-0.25	94.81	94.7	-0.11
2333	95.28	95.1	-0.18	94.64	94.53	-0.11
2300	94.89	94.78	-0.11	94.27	94.24	-0.03
2275.545	94.75	94.64	-0.11	94.1	94.12	0.02
2235.326	94.79	94.62	-0.17	94.12	94.1	-0.02
2207.588	94.78	94.6	-0.18	94.1	94.08	-0.02
2153.086	94.68	94.53	-0.15	93.98	94.02	0.04
2113.248	94.73	94.53	-0.2	94.01	94.02	0.01
2090.014	94.73	94.53	-0.2	94.01	94.02	0.01
2074.652	94.58	94.16	-0.42	93.72	93.73	0.01
2039.232	93.84	93.84	0	92.6	92.6	0
2020.868	93.11	93.11	0	92.4	92.4	0

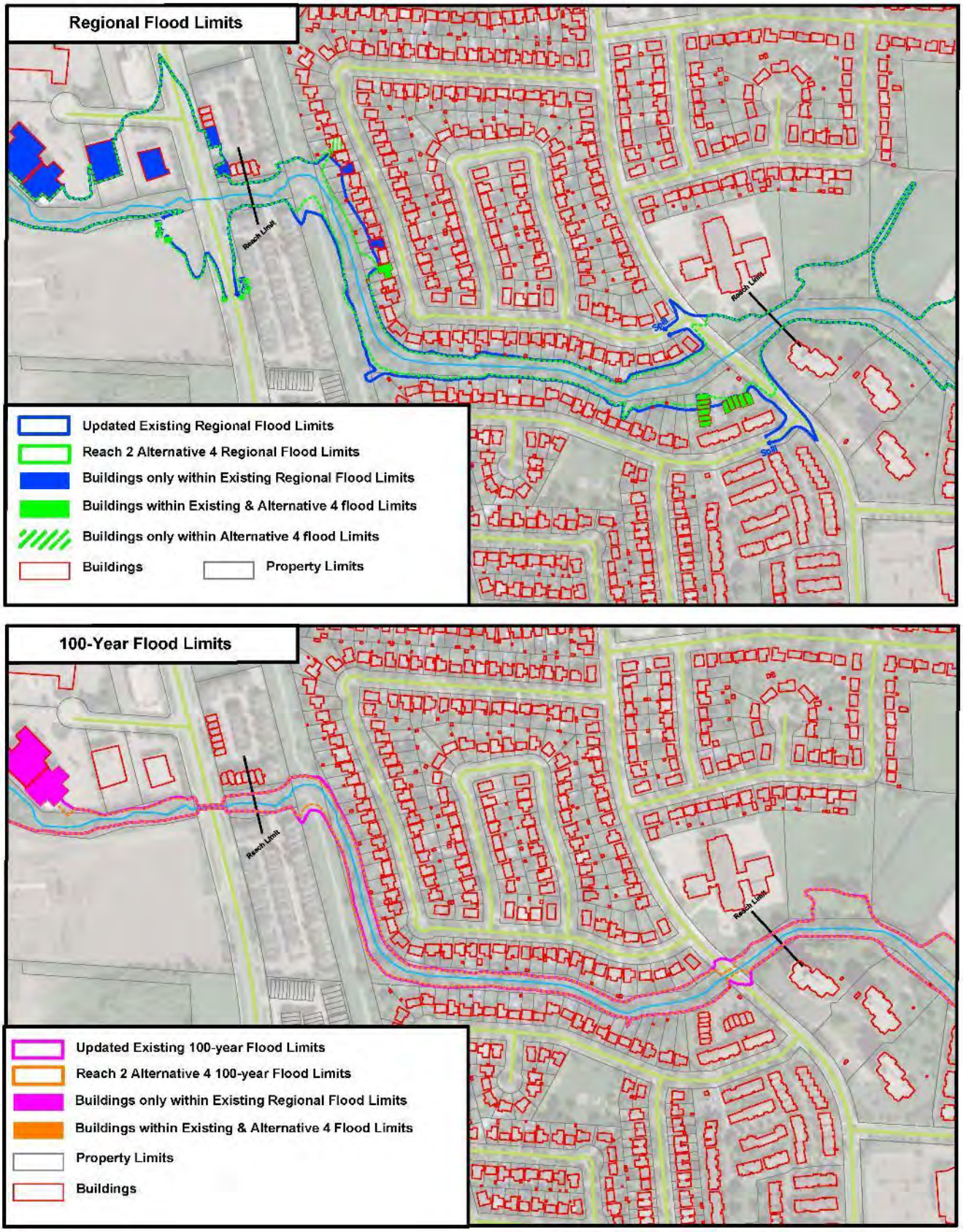


Figure 4.11: Floodline comparison for Reach 2, Alternative 4

4.3 Description of Alternatives for Reach 3

Two (2) alternatives were developed to reduce flooding along the Appleby Creek corridor, by altering the bridge at Fairview Street. These alternatives were evaluated against the existing conditions, taking into consideration the "do-nothing" alternative. Details of each alternative are provided below.

Please note that channel modifications were not evaluated for Reach 3. This is further discussed in **Section 4.5**.

4.3.1 Alternative 1 – Do Nothing

For the do-nothing alternative, no mitigation measures will be taken, with the exception of emergency situations. This would involve leaving the existing stream and bridges, and existing problems associated with potential of flooding will remain. The existing 100-year and regional flood limits for Reach 3 are shown in **Figure 4.12**, and the existing conditions of the Fairview Road bridge and are shown in **Figure 4.13**. **Table 4-17** provides a summary of the existing conditions.

Table 4-17: Summary of Conditions for Reach 3, Alternative 1

Bridge Dimensions			Double box culvert, 2 x 3.3m wide, 2.7m rise
Maximum Hydraulic Conveyance Capacity			5-year flood
Frequency of Road Inundation			Regional flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 1 Flood Limits	Percent Decrease
Regional Flood	9	9	0%
100-Year Flood	2	2	0%
*This includes the area from upstream of Go-transit Rail to Fairview Street			

As explained in **Section 3.4,** a flood hazard assessment was undertaken for the existing conditions which identified the number of buildings within the flood limits, road overtopping frequency and the hydraulic conveyance capacity of the road structures. This information is also presented in **Table 4-17**. Under the existing conditions for Reach 3, there are 9 buildings within the regional floodplain and 2 buildings within the 100-year storm floodplain. The updated 100-year and Regional floodlines are presented below in **Figure 4.12**. The maximum hydraulic conveyance capacity of the Fairview Road bridge is the 5-year flood event, which is much lower than the recommended conveyance from MTO (i.e., 100-year flood). Finally, the road inundation is very infrequent, as the road is only expected to be overtopped under the regional flood conditions.

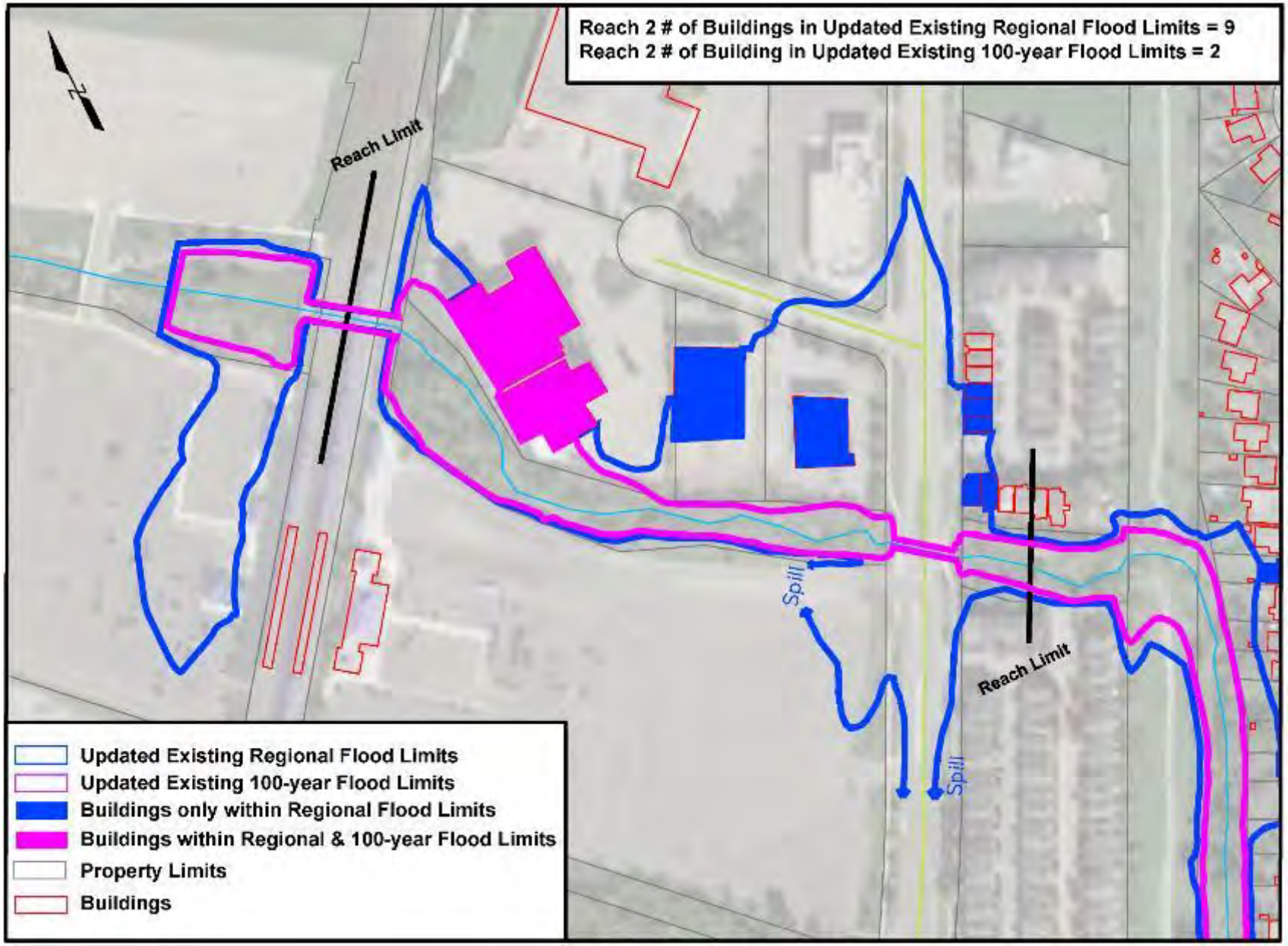


Figure 4.12: 100-year and Regional flood limits under the existing conditions

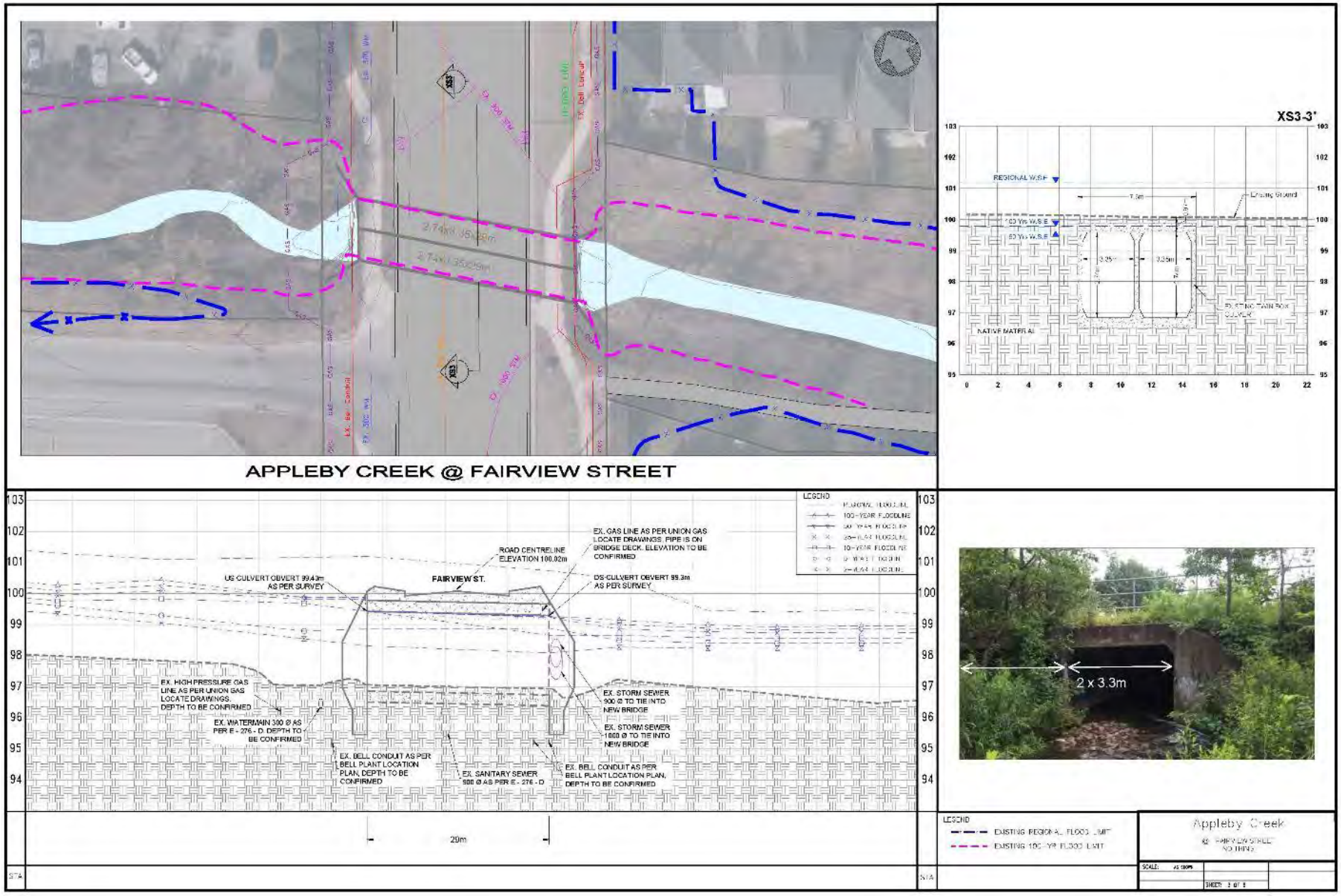


Figure 4.13: Culvert and channel dimension for Reach 3, Alternative 1

4.3.2 Alternative 2 – Fairview Road Bridge Improvements (Option 1)

This alternative investigated replacing the existing Fairview Road bridge with a larger span. This would involve widening the bridge enough to ensure that the MTO recommended hydraulic conveyance is passed, and also improve terrestrial and aquatic passage. A hydraulic assessment of the bridge was undertaken, and it was determined that the minimum bridge would need to be 17m to pass the 100-year flood (which would maintain the existing road surface elevation).

Minor channel works would necessary at the bridge inlet and outlet in order to tie the channel into the new bridge abutments. As mentioned in **Section 3.2.4**, the existing failing gabion weir creates a fish barrier upstream of Fairview Road crossing. Detailed design of the minor channel works for tying-in new bridge abutment should look into opportunities to mitigate this barrier while protecting the watermain sewer across the watercourse, including provision of low flow channel with sufficient depth, reduced vertical drops, and natural conditions in stream. This would be undertaken using a combination of natural channel design techniques as well as engineered methods. In addition, replacing the existing closed-bottom culvert with a bottomless bridge encourages potential fish passage and spawning success.

As with the alternatives for Reaches 1 and 2, a flood risk hazard characterization was undertaken for all the alternatives for Reach 3, similar to the assessment present **Section 3.4.** The updated 100-year and regional floodlines are presented below in **Figure 4.9** and a summary of the results is presented in **Table 4-18**. A summary of the output from the HEC-RAS model is provided in **Table 4-19.**

Under the proposed conditions for alternative 2 for Reach 3, it is expected that there will be four (4) buildings within the regional floodplain, and two (2) buildings within the 100-year floodplains. Therefore, this alternative removes five (5) buildings from the regional floodplain.

As the purpose of the alternative was to provide the recommended MTO conveyance, the maximum hydraulic conveyance capacity is the 100-year flood event. This is a significant increase in conveyance capacity, and it is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1.**

Under this alternative, Fairview Road is only expected to be overtopped under the regional flood conditions.

Table 4-18: Summary of Conditions for Reach 3, Alternative 2

Bridge Dimensions			Beam structure 17m wide, 2.2m rise
Maximum Hydraulic Conveyance Capacity			100-year flood
Frequency of Road Inundation			Regional flood
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 2 Flood Limits	Percent Decrease
Regional Flood	9	4	56%
100-Year Flood	2	2	0%
*This includes the area from upstream of Go-transit Rail to Fairview Street			

Table 4-19: Summary of HEC-RAS results for Reach 3, Alternative 2

River Station	Regional Flood Flow (93 m^3/s)			100-year Flood Flow (54 m^3/s)		
	Updated Existing WSE	Alternative 2 WSE	Change	Updated Existing WSE	Alternative 2 WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
3265.256	105.26	105.26	0	104.05	104.05	0
3226.566	105.29	105.29	0	104.06	104.06	0
3206.556	104.8	104.8	0	103.73	103.73	0
3146.411	103.22	103.22	0	102.64	102.64	0
3122.614	103.04	103.04	0	102.59	102.59	0
3057.861	102.46	102.46	0	101.97	101.97	0
2992.953	101.93	101.93	0	101.44	101.44	0
2967.573	101.83	101.83	0	101.17	101.2	0.03
2932.249	101.7	101.7	0	100.8	100.66	-0.14
2910.239	101.31	101.31	0	101.01	100.17	-0.84
2893.629	101.11	100.88	-0.23	101.04	99.84	-1.2
2869.761	101.18	100.53	-0.65	99.78	99.58	-0.2
2818.998	100.47	99.57	-0.9	99.15	99.12	-0.03

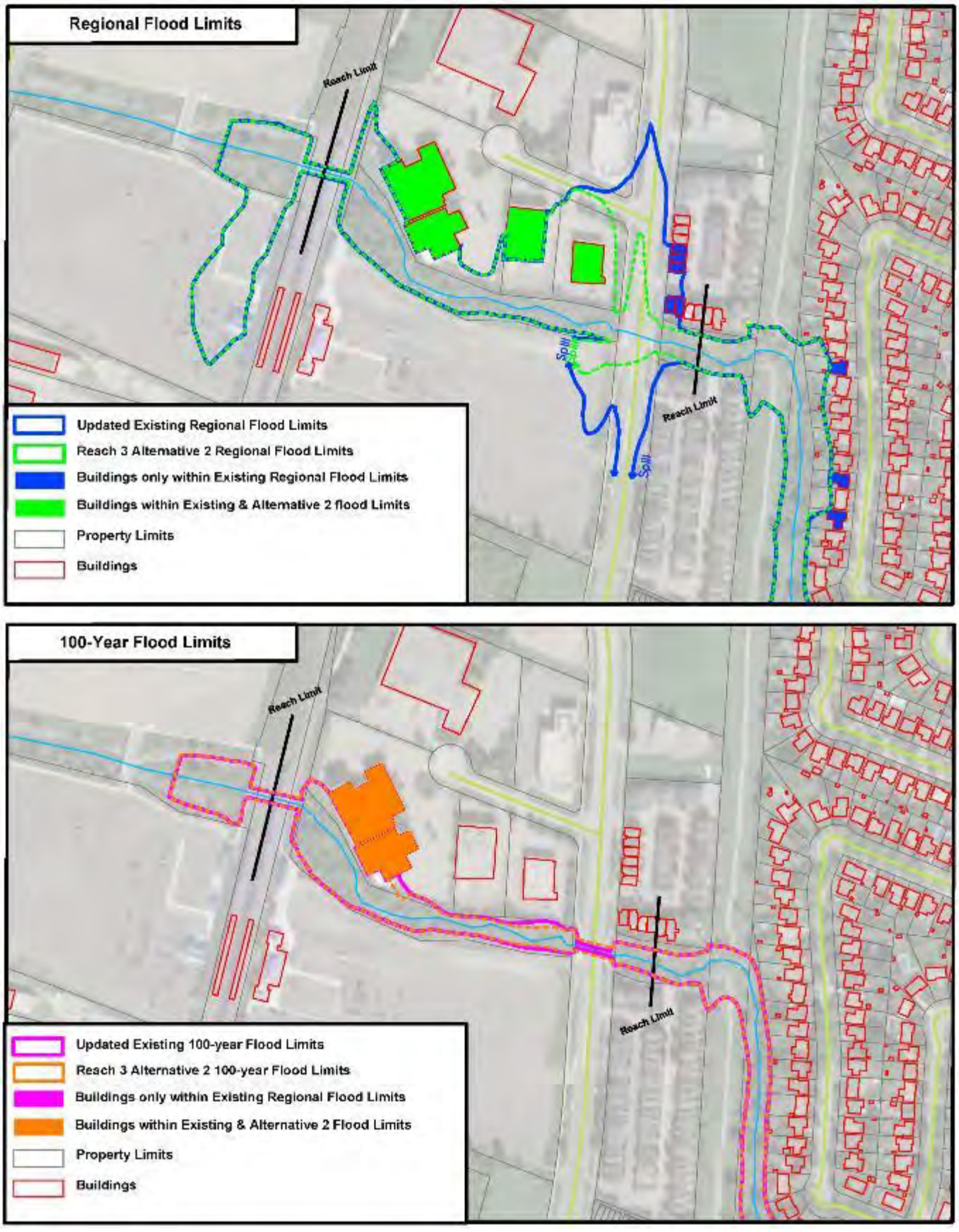


Figure 4.14: Floodline comparison for Reach 3, Alternative 2

4.3.3 Alternative 3 – Fairview Road Bridge Improvements (Option 2)

Similar to alternative 2, this alternative investigated replacing the existing Fairview Road bridge with a larger span, however the intention of this alternative was to widening the bridge enough to pass the regional flood. Not only would this improve hydraulic conveyance and biological passage, there would be very limited risk to road inundation. A hydraulic assessment of the bridge was undertaken, and it was determined that the minimum bridge would need to be 60m to pass the regional flood. Similar to alternative 2, localized channel works would be necessary at the bridge inlet and outlet in order to tie the channel into the new bridge abutments, where removal of the fish barrier upstream of the cross could be using a combination of natural channel design techniques as well as engineered methods. The replacement of the existing closed-bottom culvert with a bottomless bridge itself also encourages potential fish passage and spawning success.

As with alternative 2, a flood risk hazard characterization was undertaken for alternative 3. The updated 100-year and regional floodlines are presented below in **Figure 4.15** and a summary of the results is presented in **Table 4-20**. A summary of the output from the HEC-RAS model is provided in **Table 4-21.**

Under the proposed conditions for alternative 3 for Reach 3, there will be three (3) buildings within the regional floodplain and two (2) buildings within the 100-year floodplains. Therefore this alternative removes six (6) buildings from the floodplain.

In addition, alternative 3 provides a significant increase in the hydraulic conveyance capacity through the crossing, conveying the regional flood. It is anticipated to reduce backwater conditions that might occur during the more frequent flood events, as discussed in **Section 7.1.**

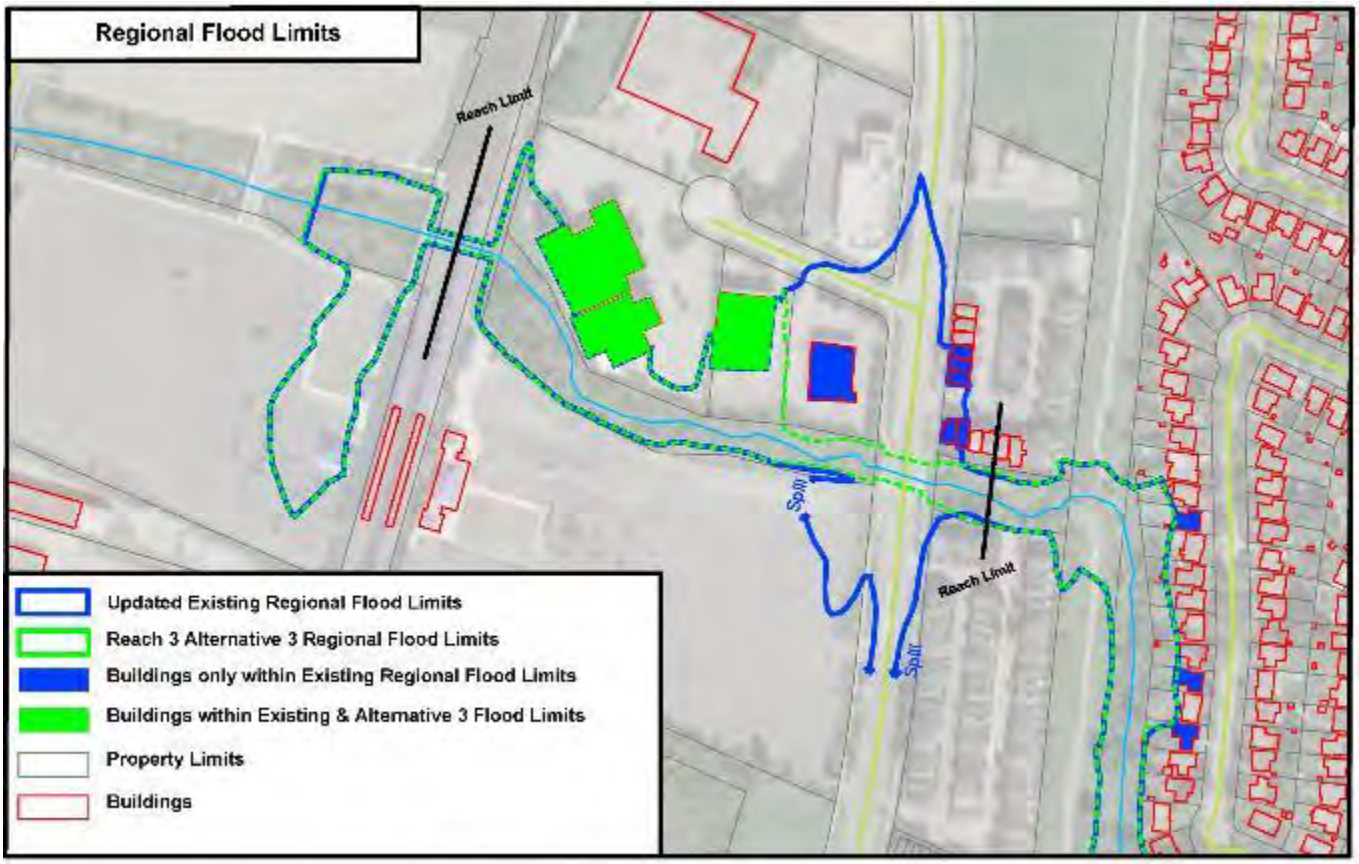
Under this alternative, Fairview Road is not expected to be inundated for any floods equal to or smaller than the regional flood. Therefore, the road will be accessible, and can be used as an emergency route.

Table 4-20: Summary of Conditions for Reach 3, Alternative 3

Bridge Dimensions			Beam structure 60m wide, 3.35m rise
Maximum Hydraulic Conveyance Capacity			Regional flood
Frequency of Road Inundation			N/A
Flood Event	Number of Buildings within the Flood Limits*		
	Updated Existing Flood Limits	Alternative 3 Flood Limits	Percent Decrease
Regional Flood	9	3	67%
100-Year Flood	2	2	0%
*This includes the area from upstream of Go-transit Rail to Fairview Street			

Table 4-21: Summary of HEC-RAS results for Reach 3, Alternative 3

River Station	Regional Flood Flow (93 m^3/s)			100-year Flood Flow (54 m^3/s)		
	Updated Existing WSE	Alternative 3 WSE	Change	Updated Existing WSE	Alternative 3 WSE	Change
	(m)	(m)	(m)	(m)	(m)	(m)
3265.256	105.26	105.26	0	104.05	104.05	0
3226.566	105.29	105.29	0	104.06	104.06	0
3206.556	104.8	104.8	0	103.73	103.73	0
3146.411	103.22	103.22	0	102.64	102.64	0
3122.614	103.04	103.04	0	102.59	102.59	0
3057.861	102.46	102.46	0	101.97	101.97	0
2992.953	101.93	101.93	0	101.44	101.44	0
2967.573	101.83	101.83	0	101.17	101.2	0.03
2932.249	101.7	101.7	0	100.8	100.66	-0.14
2910.239	101.31	100.03	-1.28	101.01	99.45	-1.56
2893.629	101.11	100.1	-1.01	101.04	99.49	-1.55
2869.761	101.18	100.1	-1.08	99.78	99.49	-0.29
2818.998	100.47	99.88	-0.59	99.15	99.27	0.12



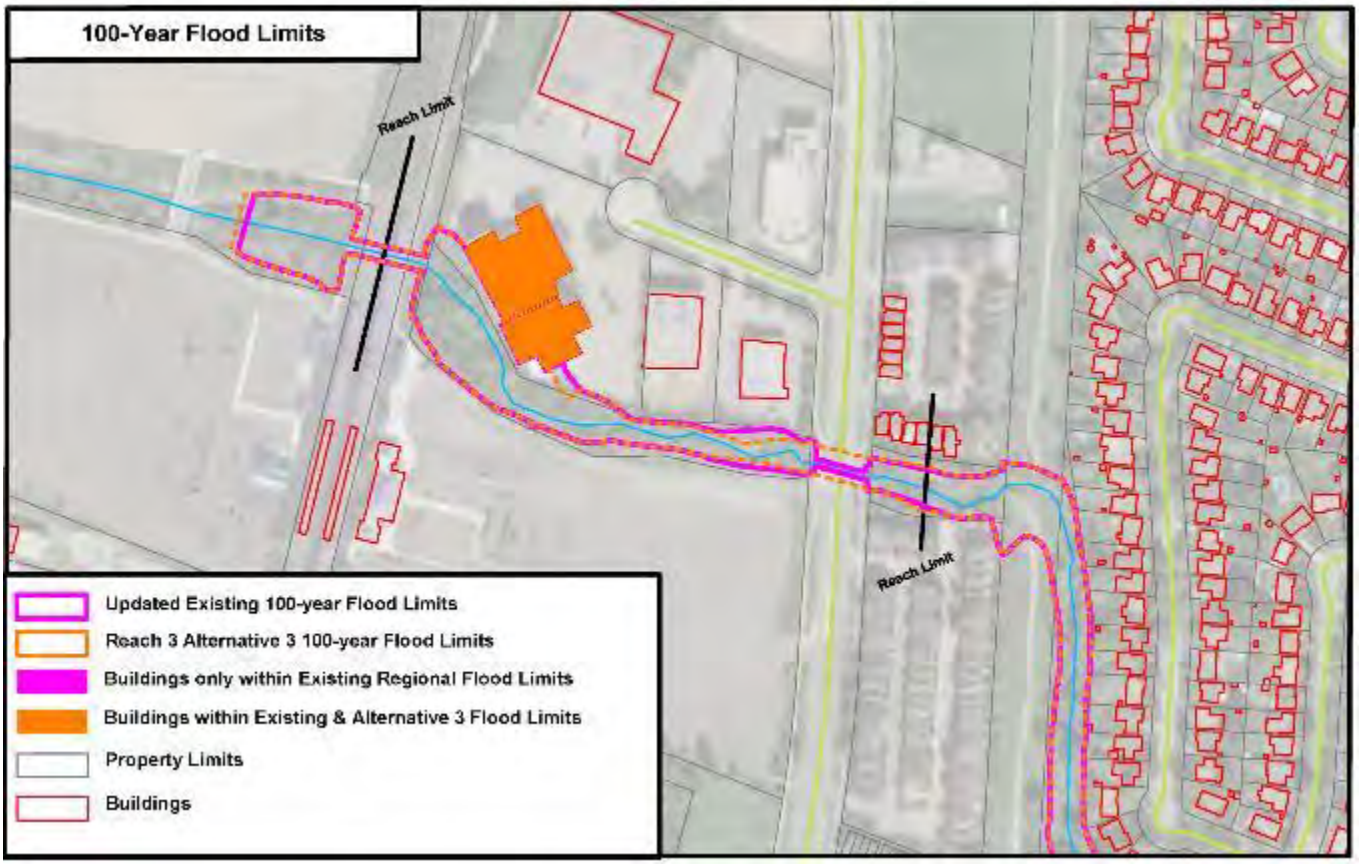


Figure 4.15: Floodline comparison for Reach 3, Alternative 3

4.4 Investigation of Low Impact Development Opportunities

A high level, qualitative assessment was undertaken to assess opportunities for using low impact development (LID) strategies to mitigate flooding within the study area. This assessment was focused on evaluating the potential for LID treatments to reduce flooding within the watershed, prior to considering this as a viable alternative.

In order to understand the potential flood mitigation opportunities, previous studies were reviewed and applied to the study area. A hydrologic assessment of Tuck Creek was completed as part of the Tuck Creek Flood Assessment, which evaluated how implementing LID treatments within the watershed would reduce flooding (City of Burlington, 2016). The study found the following key results:

- Application of LID measures to the ***entire watershed result in a notable decrease in flows for the 50- and 100-year storms***.
- Application of LID measures ***within the study area (New Street and Lake Ontario) did not result in an appreciable decrease in flows***.
- Immediate benefit of implementing LID measures within the study area would not be appreciable in terms of a reduction in flooding.
- Working to implement LID measures throughout the watershed over the long term could provide a sizeable decrease in storm flows for the 50- and 100-year events

For this study, it was assumed that if the Appleby Creek watershed was characteristically the same as the Tuck Creek watershed (i.e., similar size, land use, rainfall, etc.), the implementation of LID would likely produce similar results. Therefore, the two subwatersheds were compared, and the results are presented in **Table 4-22**.

Table 4-22: Comparison of Appleby Creek and Tuck Creek watershed characteristics

Watershed Characteristics	Appleby Creek	Tuck Creek	Percent Difference
Watershed Area (km^2)	10.99	10.57	4%
Average Annual Precipitation (mm)	839	854	2%
Percentage Urbanized	65.2	65.49	0.4%
Flows within Study Area (m^3/s)			
Regional	93	125	25.6%
100yr	54	61	11.5%
50yr	48	55	12.7%
25yr	42	48	12.5%
10yr	34	39	12.8%
5yr	28	33	15.2%
2yr	19	23	17.4%

The comparison showed that the area, average rainfall and percent urbanization between Tuck Creek and Appleby Creek are very similar, and while the flows in Tuck Creek are larger than the flows in Appleby Creek, potentially due to the stormwater ponds within Appleby Creek watershed, they are of comparable magnitude.

Therefore, it can be assumed that application of LID treatments within Appleby Creek would produce similar results to what was found for Tuck Creek, indicating that:

- There would be no immediate reduction in flooding as a result of implementing LID measures within the study area.
- Working to implement LID measures throughout the watershed over the long term could provide a sizeable decrease in storm flows for the 50- and 100-year events

Based on this assessment, implementation of LID was not considered a viable alternative for addressing the flooding risks along Appleby Creek, and therefore was not included within the evaluation. However, it is recommended that future city infrastructure projects should still consider adoption of LID measures within the Appleby Creek Watershed as they would serve to reduce peak flows within the watershed over the long term.

4.5 Investigation of Channel Modifications

Modifications to the channel were not significantly investigated as part of this EA. This was not undertaken because the flood hazard assessment (**Section 3.4**) identified that the majority of the flooding was related to the road crossing conveyance capacity and potential backwatering. Furthermore, while some debris jams observed, there were limited flood hazards resulting from limited channel conveyance. Only minor, localized erosion sites were observed (i.e., buried outfalls, bank erosion) no erosion issues posing significant risks were identified within the study area. Finally, widen and deepening channels without extensive hardening can promote erosion, resulting from disconnection from the floodplain. It would be preferable not to harden the channel as it is currently providing habitat for several fish species. Therefore, there was limited opportunity to address erosion and flood risks by undertaking channel works.

While previous studies had identified widening Appleby Creek through the hydro corridor (i.e., Reach 2) as a recommended flood mitigation opportunity (City of Burlington, 2016), this recommendation did not match the results from our analysis.

However, it was possible that providing floodplain relief in the area identified could reduce the need to widen the bridge at Pinedale Ave. Additionally, as discussed in **Sections 3.2** and **3.5** (**Appendix B**) the riparian corridor throughout Reach 2 is densely wooded with common and invasive species, and provides significant roughness for high flows. There is an opportunity to reduce the roughness and improve the form and function of the Appleby Creek.

Therefore, based on the analysis undertaken for this study and the results of the previous investigations, channel works were only considered for Reach 2. In evaluating the channel works for Reach 2, the following conditions were simulated as shown in **Figure 4.16**:

1. Floodplain widening through the hydro corridor along the Centennial Bikeway trail; and

2. Removal of dense invasive species through the riparian corridor from Pinedale Ave. to the hydro corridor, and replanting with native shrubs and grasses.



Figure 4.16: Conceptual diagram of channel works considered for Reach 2

To provide a noticeable flood relief within the corridor, the proposed cut into the floodplain is approximately 2.0m, which extends over the Trans-Northern petroleum pipeline next to the Bikeway. As mentioned in **Section 3.6**, confirmation email from Trans-Northern suggested the pipeline is typically buried 1.2m-1.5m underground, which is very likely to be exposed by the proposed cut and would require permanent relocation. Significant costs associated with the relocation of the pipeline, as well as very high level of disturbance to landowners, consultation with landowners and utilities companies are expected to incur. These considerations in turn were reflected in the ranking of alternatives, as discussed in **Section 4.7.**

4.6 Evaluation Criteria

As part of the Municipal Class Environmental Assessment Process, each alternative must be evaluated based on a set of physical, natural environment, social, cultural, and economic criteria. For this assessment technical and engineering considerations were also included. The set of criteria were developed by Aquafor and reviewed by the City of Burlington. The list of criteria and the associated scoring is presented in **Table 4-23**.

Table 4-23. Evaluation Matrix to Assess Alternatives

Evaluation Criteria		
Physical, Technical and Engineering Criteria	Potential Impact to Flood Risks	Reduction to the number of building within the flood limits
		Maximum bridge conveyance capacity (i.e., limited backwatering)
		Decrease in frequency of road overtopping
	Channel Erosion	Potential impact to channel erosion within reach
	Impact on Existing Infrastructure	Potential impact to the surrounding infrastructure (e.g., sewers, watermains, gas, roads) during and after constructions
	Lifespan of Works	Potential to increase the expected lifespan/years of works before intervention needs to be repeated
Natural, Social and Cultural Criteria	Aquatic Habitat	Potential to impact aquatic habitat conditions, including channel features and overhanging vegetation
	Terrestrial Vegetation	Potential impact to the existing mature trees and canopy cover in river corridor
	Terrestrial Habitat	Potential impact to connectivity, diversity and quantity / quality of terrestrial habitat
	Public Health and Safety	Potential impact to public health and safety includes risk to private property, parking lots, roads, footbridges and public trails
	Landowner Impacts	Potential impacts associated with the construction of facilities, particularly with respect to land uses such as residential and schools. Access / egress also needs to be considered
	Aesthetic Value	Potential for alternative to be an asset to the community by integrating facility into the surrounding community aesthetics
Economic Criteria	Capital Costs	The relative estimated costs of implementing the proposed treatment based on factors such as location, access / egress and area to dispose material
	Operations & Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area

A weighting factor was assigned to each category, which ensured that each category was valued appropriately, regardless to the number of criteria within the category. For this evaluation, the all the "Physical, Technical and Engineering Criteria" category was given the highest weighting, as this category contains the flooding criteria. The weighting factors used for this evaluation are shown in **Table 4-24**.

Table 4-24: Category weighting factors

Category	Weighting Factor	Maximum Points for Category
Physical, Technical and Engineering Criteria	0.5	50
Natural, Social and Cultural Criteria	0.25	25
Economic Criteria	0.25	25
TOTAL	**1**	**100**

For each criteria item (ie. row), a score was applied ranging from 0 to 10 (**Table 4-25**), where:

- 0 = Unfavourable, no improvement or negative impact
- 5 = Acceptable
- 10 = Favourable, most improvement or most positive impact

Table 4-25: Ranking Scheme for Criteria Evaluation of Each Alternative

No / Negative Impact	0	1	2	3	4	5	6	7	8	9	10	Ideal / Most Positive Impact

4.7 Evaluation of Alternatives

For each alternative and each study area, the criteria were evaluated, where higher scores relate to varying degrees of positive effect that an alternative, for the defined criterion, would have on the outcome. The sum of the criterion scores was determined for each alternative and the alternative with the highest score was deemed to be preferred.

A summary of scores for each of the reaches are presented in **Table 4-26, Table 4-27** and **Table 4-28.**

This ranking has been presented to the public, landowners, and relevant stakeholders, and updated based on comments as well as technical investigations.

Table 4-26. Evaluation Matrix of Alternatives for Reach 1

EVALUATION CRITERIA		Alternative 1 - Do Nothing		Alternative 2 - New Street Bridge Improvements (18m Span - 100-yr Conveyance)		Alternative 3 - New Street Bridge Improvements (30m Span - Regional Conveyance)	
		Score	Explanation	Score	Explanation	Score	Explanation
Physical, Technical and Engineering Criteria							
Potential Impact to Flood Risks	Reduction to the number of building within the flood limits	0	14 buildings within regional flood limit and 0 buildings in 100-yr flood limit	10	No buildings within regional flood or 100-yr flood limit	10	No buildings within regional flood or 100-yr flood limit
	Maximum bridge conveyance capacity (i.e., limited backwatering)	1	No increase to flood flow capacity (10-yr flood)	8	100-year floods conveyed	10	Regional floods conveyed
	Decrease in frequency of road overtopping	5	Only regional flood overtops New Street	5	Only regional flood overtops New Street	7	No analyzed flows are expected to overtop New Street
Channel Erosion	Potential impact to channel erosion within reach	5	No significant erosion issues at this time	7	Increased conveyance at bridge will decrease shear and velocity	7	Increased conveyance at bridge will decrease shear and velocity
Impact on Existing Infrastructure	Potential impact to the surrounding infrastructure (e.g., sewers, watermains, gas, roads) during and after constructions	3	Potential risk to exposure of watermain at outlet	6	Significant relocation of utilities. Watermain protected.	1	Significant relocation of utilities. Also, road and all driveways will have to be raised. Watermain protected.
Lifespan of Works	Potential to increase the expected lifespan/years of works before intervention needs to be repeated	5	Infrastructure approaching half of lifespan	10	New bridge lifespan > 50 years	10	New bridge lifespan > 50 years
Physical, Technical and Engineering Criteria Subtotal		**19**		**46**		**45**	
Weighted Score for Physical and Natural Criteria (maximum of 50 pts)		**16**		**38**		**38**	
Natural, Social and Cultural Criteria							
Aquatic Habitat	Potential to impact aquatic habitat conditions, including channel features and overhanging vegetation	2	No improvements to the degraded aquatic habitat. Culvert prevents fish passage creates an impervious in channel bed	8	Potential to increase fish passage through the culvert	8	Potential to increase fish passage through the culvert
Terrestrial Vegetation	Potential impact to the existing mature trees and canopy cover in river corridor	10	No tree removals required	7	Minimal tree removals required for culvert replacement	7	Minimal tree removals required for culvert replacement
Terrestrial Habitat	Potential impact to connectivity, diversity and quantity / quality of terrestrial habitat	5	No impact on the existing terrestrial habitat. Limited bridge span currently restricts terrestrial passage.	8	Improved terrestrial connectivity through new culvert. Limited disturbance upstream.	10	Further improved terrestrial connectivity through new culvert. Limited disturbance upstream.
Public Health and Safety	Potential impact to public health and safety includes risk to private property, parking lots, roads, footbridges and public trails	2	Continued flood risks (no risks of infrastructure failure)	6	Flood frequency reduced, & many houses removed from flood limits	9	Flood frequency further reduced, & many houses removed from flood limits
Landowner Impacts	Potential impacts associated with the construction of facilities, particularly with respect to land uses such as residential and schools. Access / egress also needs to be considered	10	No disturbance to private properties	3	High level of disruption to local residents during construction as New Street will be closed, potentially for several months.	0	High level of disruption to local residents during construction as New Street will be closed, potentially for several months. A section of New Street will need to be reconstructed and could impact driveway access.
Aesthetic Value	Potential for alternative to be an asset to the community by integrating facility into the surrounding community aesthetics	4	Aging infrastructure is not aesthetically pleasing.	8	New bridge will be aesthetically pleasing	8	New bridge will be aesthetically pleasing
Natural, Social and Cultural Criteria Subtotal		**33**		**40**		**42**	
Weighted Score for Social and Cultural Criteria (maximum of 25 pts)		**14**		**17**		**18**	
Economic Criteria							
Capital Costs	The relative estimated costs of implementing the proposed treatment based on factors such as location, access / egress and area to dispose material	10	No capital costs	5	Second highest costs associated with minor channel work and bridge replacement	0	Most significant capital costs, with minor channel work, bridge replacement and road realignment
Operations & Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	8	Minimal maintenance presently required.	8	Minimal maintenance required.	8	Minimal maintenance required.
Economic Criteria Subtotal		**18**		**13**		**8**	
Weighted Score for Economic Criteria (maximum of 25 pts)		**18**		**13**		**8**	
Total Weighted Score (maximum of 100 pts)		**48**		**68**		**63**	

Table 4-27. Evaluation Matrix of Alternatives for Reach 2

EVALUATION CRITERIA		Alternative 1 - Do Nothing		Alternative 2 - Pinedale Ave. Bridge Improvements (18m Span - 100-yr Conveyance)		Alternative 2a - Pinedale Ave. Bridge Improvements (18m Span - 100-yr Conveyance) + Channel Works		Alternative 3 - Pinedale Ave. Bridge Improvements (30m Span - Regional Conveyance)		Alternative 3a - Pinedale Ave. Bridge Improvements (30m Span - Regional Conveyance) + Channel Works		Alternative 4 - Only Channel Works	
		Score	Explanation	Score	Explanation	Score	Explanation	Score	Explanation	Score	Explanation	Score	Explanation
Physical, Technical and Engineering Criteria													
Potential Impact to Flood Risks	Reduction to the number of building within the flood limits	0	14 buildings within regional flood limit and 0 buildings in 100-yr flood limit	7	3 buildings within regional flood limit and 0 buildings in 100-yr flood limit	9	2 building within regional flood limit and 0 buildings in 100-yr flood limit	7	3 buildings within regional flood limit and 0 buildings in 100-yr flood limit	9	2 building within regional flood limit and 0 buildings in 100-yr flood limit	2	13 buildings within regional flood limit and 0 buildings in 100-yr flood limit
	Maximum bridge conveyance capacity (i.e., limited backwatering)	1	No increase to flood flow capacity (10-yr flood)	6	50-yr flood conveyed	6	50-yr flood conveyed	8	100-year and Regional floods conveyed	8	100-year and Regional floods conveyed	1	No increase to flood flow capacity (10-yr flood)
	Decrease in frequency of road overtopping	3	25-yr flood overtops Pinedale Ave.	5	Only regional flood overtops Pinedale Ave.	5	Only regional flood overtops Pinedale Ave.	7	No analyzed flows are expected to overtop Pinedale Ave.	7	No analyzed flows are expected to overtop Pinedale Ave.	3	25-yr flood overtops Pinedale Ave.
Channel Erosion	Potential impact to channel erosion within reach	5	Some minor erosional concerns, including bank erosion and buried storm outfalls	7	Increased conveyance at bridge will decrease shear and velocity	10	Minor erosional concerns addressed with channel works and increased conveyance at bridge will decrease shear and velocity	7	Increased conveyance at bridge will decrease shear and velocity	10	Minor erosional concerns addressed with channel works and increased conveyance at bridge will decrease shear and velocity	7	Minor erosional concerns addressed with channel works
Impact on Existing Infrastructure	Potential impact to the surrounding infrastructure (e.g., sewers, watermains, gas, roads) during and after constructions	10	Surrounding utilities are well protected from erosion or deterioration. No relocation required at this time.	6	Significant relocation of utilities	2	Significant relocation of utilities	4	Significant relocation of utilities. Also, road and all driveways will have to be raised.	0	Significant relocation of utilities. Also, road and all driveways will have to be raised.	3	Potential impact to asphalt trail, and gas and oil pipelines
Lifespan of Works	Potential to increase the expected lifespan/years of works before intervention needs to be repeated	5	Infrastructure approaching half of lifespan	8	New bridge lifespan > 50 years	10	New culvert lifespan > 50 years. Channel erosion works provide similar timeframe.	8	New bridge lifespan > 50 years	10	New culvert lifespan > 50 years. Channel erosion works provide similar timeframe.	7	Infrastructure approaching half of lifespan but channel erosion works lifespan > 30 years
Physical, Technical and Engineering Criteria Subtotal		**24**		**39**		**42**		**41**		**44**		**23**	
Weighted Score for Physical and Natural Criteria (maximum of 50 pts)		**20**		**33**		**35**		**34**		**37**		**19**	
Natural, Social and Cultural Criteria													
Aquatic Habitat	Potential to impact aquatic habitat conditions, including channel features and overhanging vegetation	3	No improvements to the degraded aquatic habitat. Pinedale road is not expected to be a fish barrier.	5	Potential to increase fish passage through the culvert	10	Opportunity to enhance the fish passage and aquatic habitat through the reach.	5	Potential to increase fish passage through the culvert	10	Opportunity to enhance the fish passage and aquatic habitat through the reach.	7	Opportunity to enhance the aquatic habitat through the reach.
Terrestrial Vegetation	Potential impact to the existing mature trees and canopy cover in river corridor	10	No tree removals required	7	Minimal tree removals required for culvert replacement	2	Tree removals, and reduction of tree canopy would be associated with the channel works. New native shrubs and grasses would be planted	7	Minimal tree removals required for culvert replacement	2	Tree removals, and reduction of tree canopy would be associated with the channel works. New native shrubs and grasses would be planted	2	Tree removals, and reduction of tree canopy would be associated with the channel works. New native shrubs and grasses would be planted
Terrestrial Habitat	Potential impact to connectivity, diversity and quantity / quality of terrestrial habitat	5	No impact on the existing terrestrial habitat. Limited bridge span currently restricts terrestrial passage.	8	Improved terrestrial connectivity through new culvert. Limited disturbance upstream.	3	Disturbance & removal of terrestrial habitat associated with channel works. Improved terrestrial connectivity through new culvert.	9	Further improved terrestrial connectivity through new culvert. Limited disturbance upstream.	4	Disturbance & removal of terrestrial habitat associated with channel works. Improved terrestrial connectivity through new culvert.	1	Disturbance & removal of terrestrial habitat associated with channel works. Shrubs and native grassed to be planted.

EVALUATION CRITERIA		Alternative 1 - Do Nothing		Alternative 2 - Pinedale Ave. Bridge Improvements (18m Span - 100-yr Conveyance)		Alternative 2a - Pinedale Ave. Bridge Improvements (18m Span - 100-yr Conveyance) + Channel Works		Alternative 3 - Pinedale Ave. Bridge Improvements (30m Span - Regional Conveyance)		Alternative 3a - Pinedale Ave. Bridge Improvements (30m Span - Regional Conveyance) + Channel Works		Alternative 4 - Only Channel Works	
		Score	Explanation	Score	Explanation	Score	Explanation	Score	Explanation	Score	Explanation	Score	Explanation
Public Health and Safety	Potential impact to public health and safety includes risk to private property, parking lots, roads, footbridges and public trails	2	Continued flood risks (no risks of infrastructure failure)	5	Flood frequency reduced, & many houses removed from flood limits	9	Flood frequency further reduced, & many houses removed from flood limits	5	Flood frequency reduced, & many houses removed from flood limits	9	Flood frequency further reduced, & many houses removed from flood limits	5	Continued flood risks (no risks of infrastructure failure)
Landowner Impacts	Potential impacts associated with the construction of facilities, particularly with respect to land uses such as residential and schools. Access / egress also needs to be considered	10	No disturbance to private properties	5	High level of disruption to local residents during construction as Pinedale will be closed, potentially for several months.	3	High level of disruption to local residents during construction as Pinedale will be closed, potentially for several months. Trail along creek will also need to be closed. Channel construction will be adjacent to several backyards.	1	High level of disruption to local residents during construction as Pinedale Ave. will be closed, potentially for several months. A section of Pinedale Ave. will need to be reconstructed and could impact driveway access.	0	High level of disruption to local residents during construction as Pinedale Ave. will be closed, potentially for several months. A section of Pinedale Ave. will need to be reconstructed and could impact driveway access. Trail along creek will also need to be closed. Channel construction will be adjacent to several backyards.	8	Moderate level of disturbance. Trail along creek will also need to be closed. Channel construction will be adjacent to several backyards.
Aesthetic Value	Potential for alternative to be an asset to the community by integrating facility into the surrounding community aesthetics	6	Aging infrastructure and minor erosion is not aesthetically pleasing. Vegetative riparian corridor is pleasing	8	New bridge will be aesthetically pleasing. No impact to riparian corridor.	5	Trees removal maybe aesthetically unpleasing. New bridge will be aesthetically pleasing	8	New bridge will be aesthetically pleasing. No impact to riparian corridor.	5	Trees removal maybe aesthetically unpleasing. New bridge will be aesthetically pleasing	2	Trees removal maybe aesthetically unpleasing. Aging infrastructure is not aesthetically pleasing.
Natural, Social and Cultural Criteria Subtotal		**36**		**38**		**32**		**35**		**30**		**25**	
Weighted Score for Social and Cultural Criteria (maximum of 25 pts)		**30**		**32**		**27**		**29**		**25**		**21**	
Economic Criteria													
Capital Costs	The relative estimated costs of implementing the proposed treatment based on factors such as location, access / egress and area to dispose material	10	No capital costs	6	Fourth highest costs associated with minor channel work and bridge replacement	2	Third highest costs associated with major channel work and bridge replacement	4	Second highest costs associated with minor channel work, bridge replacement and road realignment	0	Most significant capital costs, with major channel works, bridge replacement and road realignment	8	Fifth highest costs associated with channel works
Operations & Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	7	Minimal maintenance presently required.	7	Minimal maintenance presently required.	9	Removal of trees reduced debris jams and reduced maintenance.	7	Minimal maintenance presently required.	9	Removal of trees reduced debris jams and reduced maintenance.	9	Removal of trees reduced debris jams and reduced maintenance.
Economic Criteria Subtotal		**17**		**13**		**11**		**11**		**9**		**17**	
Weighted Score for Economic Criteria (maximum of 20 pts)		**17**		**13**		**11**		**11**		**9**		**17**	
Total Score		**67**		**77**		**73**		**74**		**71**		**57**	

Table 4-28. Evaluation Matrix of Alternatives for Reach 3

EVALUATION CRITERIA		Alternative 1 - Do Nothing		Alternative 2 - Fairview Street Bridge Improvements (17m Span - 100-yr Conveyance)		Alternative 3 - Fairview Street Bridge Improvements (60m Span - Regional Conveyance)	
		Score	Explanation	Score	Explanation	Score	Explanation
Physical, Technical and Engineering Criteria							
Potential Impact to Flood Risks	Reduction to the number of building within the flood limits	0	9 buildings within regional flood limit and 2 buildings in 100-yr flood limit	5	4 buildings within regional flood limit and 2 buildings in 100-yr flood limit	8	3 buildings within regional flood limit and 2 buildings in 100-yr flood limit
	Maximum bridge conveyance capacity (i.e., limited backwatering)	1	No increase to flood flow capacity (10-yr flood)	8	100-year floods conveyed	10	Regional floods conveyed
	Decrease in frequency of road overtopping	5	Only regional flood overtops New Street	5	Only regional flood overtops New Street	7	No analyzed flows are expected to overtop New Street
Channel Erosion	Potential impact to channel erosion within reach	5	No significant erosion issues at this time	7	Increased conveyance at bridge will decrease shear and velocity	7	Increased conveyance at bridge will decrease shear and velocity
Impact on Existing Infrastructure	Potential impact to the surrounding infrastructure (e.g., sewers, watermains, gas, roads) during and after constructions	10	Surrounding utilities are well protected from erosion or deterioration. No relocation required at this time.	5	Significant relocation of utilities	0	Significant relocation of utilities. Also, road and all driveways will have to be raised.
Lifespan of Works	Potential to increase the expected lifespan/years of works before intervention needs to be repeated	5	Infrastructure approaching half of lifespan	10	New bridge lifespan > 50 years	10	New bridge lifespan > 50 years
Physical, Technical and Engineering Criteria Subtotal		**26**		**40**		**42**	
Weighted Score for Physical and Natural Criteria (maximum of 50 pts)		**22**		**33**		**35**	
Natural, Social and Cultural Criteria							
Aquatic Habitat	Potential to impact aquatic habitat conditions, including channel features and overhanging vegetation	2	No improvements to the degraded aquatic habitat. Culvert prevents fish passage creates an impervious in channel bed	8	Potential to increase fish passage through bridge. Opportunities to remove fish barrier upstream of the bridge.	8	Potential to increase fish passage through the culvert. Opportunities to remove fish barrier upstream of the bridge.
Terrestrial Vegetation	Potential impact to the existing mature trees and canopy cover in river corridor	10	No tree removals required	7	Minimal tree removals required for culvert replacement	7	Minimal tree removals required for culvert replacement
Terrestrial Habitat	Potential impact to connectivity, diversity and quantity / quality of terrestrial habitat	5	No impact on the existing terrestrial habitat. Limited bridge span currently restricts terrestrial passage.	8	Improved terrestrial connectivity through new culvert. Limited disturbance upstream.	10	Further improved terrestrial connectivity through new culvert. Limited disturbance upstream.
Public Health and Safety	Potential impact to public health and safety includes risk to private property, parking lots, roads, footbridges and public trails	2	Continued flood risks (no risks of infrastructure failure)	6	Flood frequency reduced, & many houses removed from flood limits	9	Flood frequency further reduced, & many houses removed from flood limits
Landowner Impacts	Potential impacts associated with the construction of facilities, particularly with respect to land uses such as residential and schools. Access / egress also needs to be considered	10	No disturbance to private properties	3	High level of disruption to local residents during construction as Fairview Street will be closed, potentially for several months.	0	High level of disruption to local residents during construction as Fairview Street will be closed, potentially for several months. A section of Fairview Street will need to be reconstructed and could impact driveway access.
Aesthetic Value	Potential for alternative to be an asset to the community by integrating facility into the surrounding community aesthetics	4	Aging infrastructure is not aesthetically pleasing.	8	New bridge will be aesthetically pleasing	8	New bridge will be aesthetically pleasing
Natural, Social and Cultural Criteria Subtotal		**33**		**40**		**42**	
Weighted Score for Social and Cultural Criteria (maximum of 25 pts)		**14**		**17**		**18**	
Economic Criteria							
Capital Costs	The relative estimated costs of implementing the proposed treatment based on factors such as location, access / egress and area to dispose material	10	No capital costs	5	Second highest costs associated with minor channel work and bridge replacement	0	Most significant capital costs, with minor channel work, bridge replacement and road realignment
Operations & Maintenance Costs	The relative cost of operating and maintaining the facility based on factors such as location, access / egress and availability of sediment drying area	8	Minimal maintenance presently required.	8	Minimal maintenance required.	8	Minimal maintenance required.
Economic Criteria Subtotal		**18**		**13**		**8**	
Weighted Score for Economic Criteria (maximum of 25 pts)		**18**		**13**		**8**	
Total Weighted Score (maximum of 100 pts)		53		63		61	

4.8 Public and Agency Consultation

Throughout the study, an extensive public and property owners consultation program was undertaken, with a public information centre and a site walk and meetings with the Conservation Halton.

These points of contact satisfy the general criteria defined within the Municipal Class EA process for Schedule B projects where a mandatory two (2) points of contact are required.

Moreover, the following modes of public and agency interaction have been completed:

- Notice of Study Commencement;
- EA Study Information Slides (presented at the Public Information Centre); and
- Notice of Completion.

An overview of the PIC boards and a summary of the consultation program are presented below.

4.8.1 Notice of Commencement

A notice of commencement was prepared and distributed to local residents adjacent to Appleby Creek study extents, and published in the Burlington Post, and on the City of Burlington's website. The notice was first published on October 5th, 2017 and then again on October 12th, 2017.

Government review agencies as well as our First Nations stakeholders also received notification. A copy of the notice is provided in **Appendix D** and a list of the stakeholders is included in **Appendix E**.

The purpose of the notice was to notify the public that a Class EA study has been initiated, provided background on the problem definition, and contacts from the City and Aquafor in which people could engage with throughout the study.

4.8.2 Public Information Centre

The Public Information Centre (PIC) was held on April 17th, 2018 at the Appleby Ice Centre, at 1201 Appleby Line, Burlington. A series of posters were presented which outlined the following items:

- The objectives of the study and of the public information package;
- The EA process;
- The study area;
- The existing conditions at each of the reaches
- The problems and opportunities, including the existing and proposed flood limits;

- The alternatives for the study areas;
- The evaluation criteria and preliminary scoring; and
- The next steps in the process.

The PIC was attended by 15 local residents. A comment sheet was provided to the attendees to solicit input on the project and obtain input on the information presented. Several attendees completed the comment forms. A summary of the questions asked and comments received are provided below:

1) *Do you have any information on the conditions of Appleby Creek within the study area that would be useful for the study team to know? If so, please tell us what they are.*
   - Land owners provided information on previous flood conditions. Fallen trees, debris blockage, ponding, and creek bank failure have been observed by multiple land owners.

2) *Do you agree with the preliminary preferred alternatives? Why or why not?*
   - In general, responses were in support of the preliminary preferred alternative which aims to relief flooding by improving the conveyance capacities of the road crossings.

3) *Do you have any concerns about the potential impacts the preliminary preferred alternatives may have on the creek or adjacent properties?*
   - Concerns about the potential impacts the preliminary preferred alternative may have on areas downstream of the study area (south of New Street) were expressed by some of the attendees.

4) *Additional questions/comments?*
   - Questions on LID opportunities and its function of flood control were raised by one attendee.
   - Some questions and comments about the construction schedule and management, as well as loss of trees were received.

Both the public information package (slides), sign in sheet, and blank comment sheet are provided in **Appendix F**.

4.8.3 Conservation Halton Comments

Conservation Halton has been included throughout the entirety of this project as part of the technical review team, including attendance at key meetings and providing comments and feedback at interim stages throughout the project. Conservation Halton has included

engineering, planning and ecology representation as part of the technical review team. Correspondences with Conservation Halton are included in **Appendix D**.

4.8.4 Additional Input from Fairview Street & Oval Court Landowners

Branthaven Development Corporation and 5135 Fairview Holdings Inc., combined, own all of the property along the eastern limit of Appleby Creek between Fairview Street and the railway line (Reach 3), along Oval Court. Input from these landowners was obtained through a phone conversation and letter prepared by Urbantech Consulting and Jennifer Lawrence and Associates representing the two landowners respectively, which suggests the following:

There may be an opportunity, through the re-development of lands east of Appleby Creek, between Fairview Street and the railway line, as part of the Mobility Hub development, to widen the watercourse corridor to assist in containing the extent of the floodplain east of Appleby Creek to provide for additional tableland for re-development. Such options should be explored further with the adjacent landowners and approval agencies as part of future re-development.

The letter prepared by Urbantech and Jennifer Lawrence and Associates is included in **Appendix D**.

4.9 Selection of Preferred Alternative

Based on the results of the alternative evaluations and the consultation with the City, CH, and the public, the following alternatives were selected as the preferred alternatives for each reach:

Reach	Preferred Alternative
Reach 1 New St. to Pinedale Ave.	**Alternative 2** Option 1 to widen the New St. bridge (i.e., 18m span, convey 100-year flood)
Reach 2 Pinedale Ave. to Fairview Rd.	**Alternative 2** Option 1 to widen the Pinedale Ave. bridge (i.e. 18m span, convey 50-year flood)
Reach 3 Fairview Rd to Railway	**Alternative 2** Option 1 to widen the Fairview Rd. bridge (i.e., 17m span, convey 100-year flood)

The preferred alternative for each reach involves widening the existing bridges. Conveyance and backwater were noted flood risk concerns within each of the reaches, and the wider bridges will reduce this risk. Furthermore, each of these alternatives removed significant number of buildings from the floodplain.

The largest bridge span was not selected as the preferred alternative for any of the reaches. This was because the costs and feasibility of constructing the very large spans (i.e., >30m) outweighed the benefit of reduced road inundation during only the regional flood. A single geometry file comprised of the preferred alternative for each reach was prepared in the hydraulic model.

It is noted that the flood risks identified in this section of Appleby Creek are significantly less than other watercourses in Burlington, however, the conveyance at the three road crossings are restricted contributing to flooding of buildings. As it stands, the bridges have not shown significant evidence of deterioration, and are expected to be structurally stable in the near future. Recommended timing for implementing the preferred alternatives is provided in **Chapter 5**.

5 CONCEPTUAL DESIGN

Conceptual designs have been prepared for each of the preferred alternatives. Discussions and recommendations regarding staging and access, implementation timing, cost estimates, and restoration planning are provided below. Preliminary cost estimates are also provided.

5.1 Reach 1 Conceptual Design Elements

The preferred alternative for Reach 1 involves replacing the existing New Street crossing with a larger bridge. The minimum recommended span is 18m, assuming that the road surface elevation is maintained, and maximum deck thickness is 0.9m. The proposed bridge span will allow a conveyance of the 100-year flood which meets the recommended MTO conveyance standard. Minor channel works will be required at the inlet and outlet of the bridge, to ensure proper tie-in to the bridge abutment. A conceptual drawing of the preferred alternative is provided below in **Figure 5.1** and also in **Appendix C**.

5.1.1 Requirements for Utility Modification

The existing utilities at the New Street bridge have been summarized in **Section 3.6**, which included the surrounding sewers, water, gas, telecommunication lines and hydro. These utilities were assessed to determine if any impact or relocation would be necessary to accommodate the proposed bridge span. The potential disruption to the surrounding utilities is listed below. It is worth noting that review of the proposed bridge invert in comparison of the existing invert suggests that significant lowering of the channel bed is not required. In turn, the possibility of utility relocation is relatively low. However, prior to detailed design, the location and depth of the utilities identified in **Section 3.6** shall be confirmed through HydroVac services and surveys.

Temporary relocated (during construction)	Relocated/Reconnected
- Hydro	- Storm sewer outfalls (reconnected to new bridge) - Sanitary sewer (potentially relocated) - Water (potentially relocated) - Bell (potentially relocated) - Gas (potentially relocated)

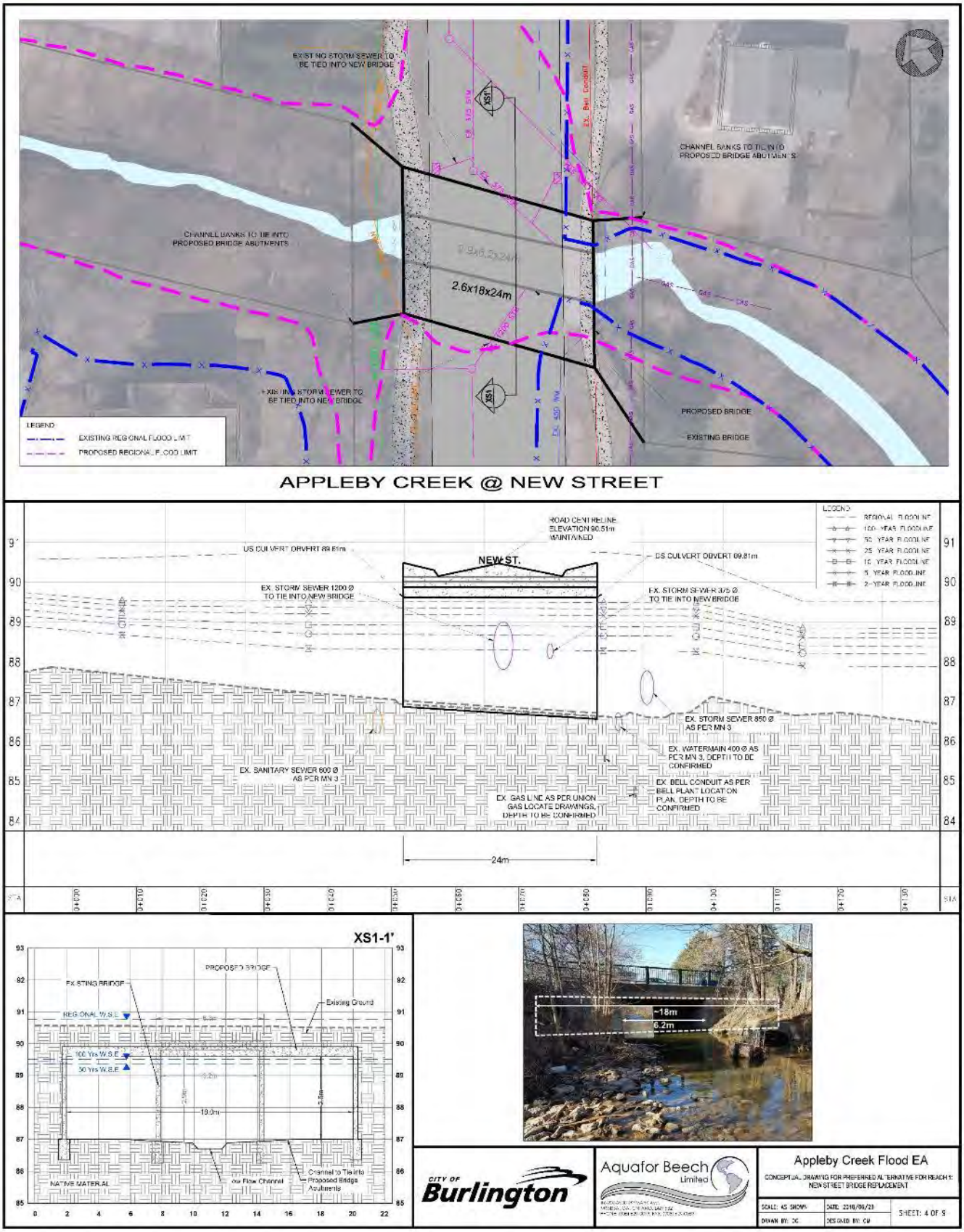


Figure 5.1: Conceptual drawing for proposed bridge widening at New St.

5.1.2 Recommended Staging, Sequencing and Access

The proposed bridge construction at New Street will disrupt the local flow of traffic, and therefore sequencing of the construction activities will be necessary to ensure that construction is completed efficiently and that the impacts to the community are minimized.

It is recommended that New Street remain partially open during the entire construction period. This can be done by first constructing the upstream side of the bridge while redirecting all traffic to the downstream lane (northern lane) and then completing the construction on the downstream side and redirecting traffic to the newly completed upstream side of the bridge. This staggered construction sequencing is recommended as New Street is a major urban arterial road and an emergence access can be maintained during construction.

The City's right-of-way and the closed roadway area can be used as storage area. If this area is not large enough there is potential for additional storage area in the southwestern corner of the Robert Bateman High School parking lot. If the additional storage area is necessary, the City will need to get permission from the school. In addition, full time traffic control will be necessary to maintain the traffic flow to a single lane on the bridge. A preliminary construction and staging plan are provided below in **Figure 5.2**.

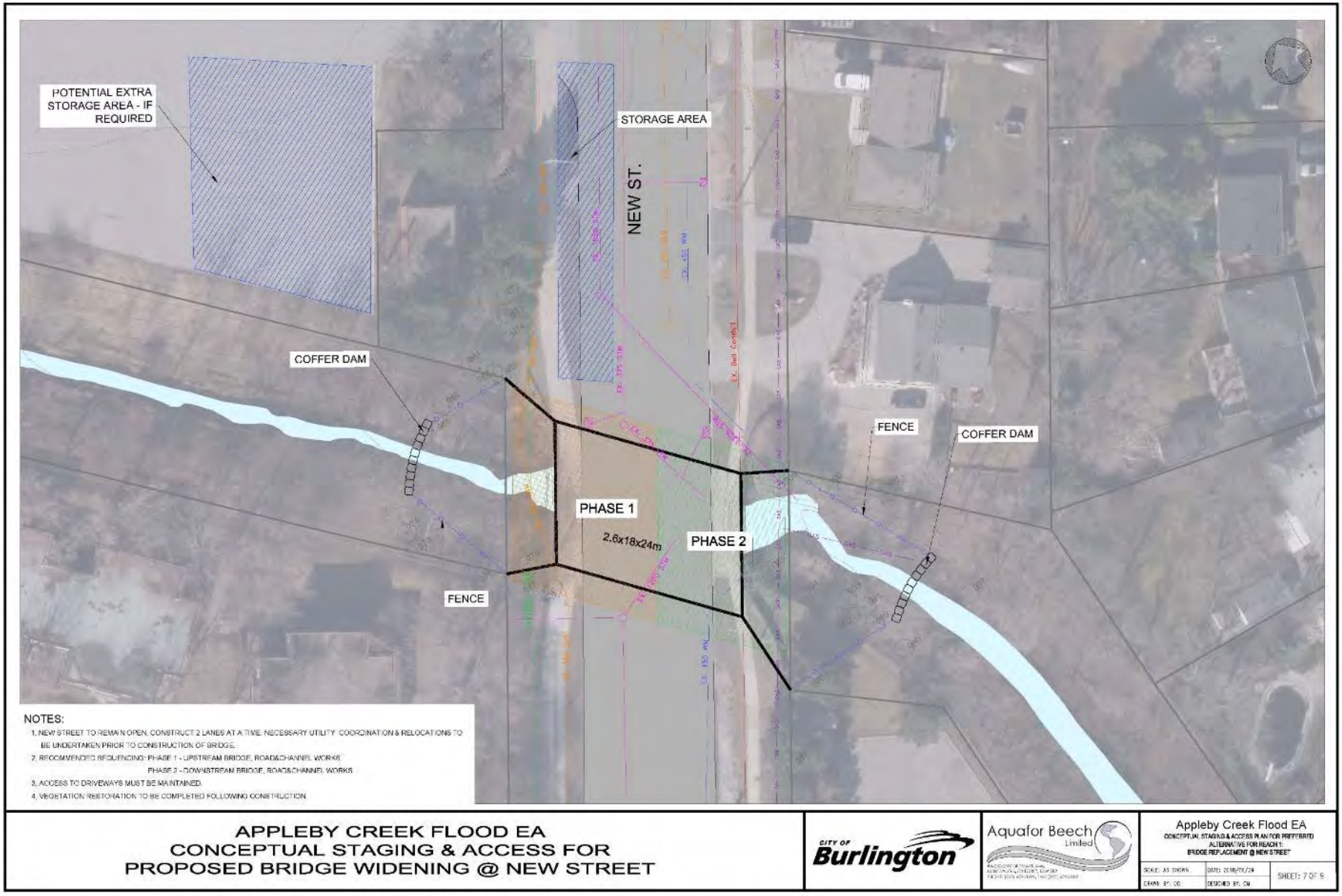


Figure 5.2: Preliminary construction, staging and sequencing plan for New Street

5.2 Reach 2 Conceptual Design Elements

The preferred alternative for Reach 2 involves upgrading the existing Pinedale Avenue crossing, with a minimum recommended span of 18m, assuming that the road surface elevation is maintained, and maximum deck thickness is 0.9m. The proposed bridge is expected to convey the 50-year flood with freeboard and the 100-year flood under pressure flow, which meets the recommended MTO conveyance design criteria. Minor channel works will be required at the inlet and outlet of the bridge, to ensure proper tie-in to the bridge abutment. Conceptual drawings of the preferred alternatives are provided below in **Figure 5.3** and also in **Appendix C**.

5.2.1 Requirements for Utility Modification

The existing utilities at the Pinedale Avenue bridge have been summarized in **Section 3.6**, which included the surrounding storm sewer, water, gas, and hydro. These utilities were assessed to determine if any impact or relocation would be necessary for the replacement of the new bridge and regrading of the floodplain. The potential disturbances to the surrounding utilities are listed below. Similar to Reach 1, significant lowering of the channel bed is also not required for the proposed bridge. In turn, there is a relatively low possibility that utility relocations would be required. However, prior to detailed design, the location and depth the utilities identified in **Section 3.6** shall be confirmed through HydroVac services and surveys.

Temporary Relocated (during construction)	Relocated/Reconnected
- Hydro	- Storm sewer outfalls (reconnected) - Gas (potentially lowered) - Water (potentially lowered)

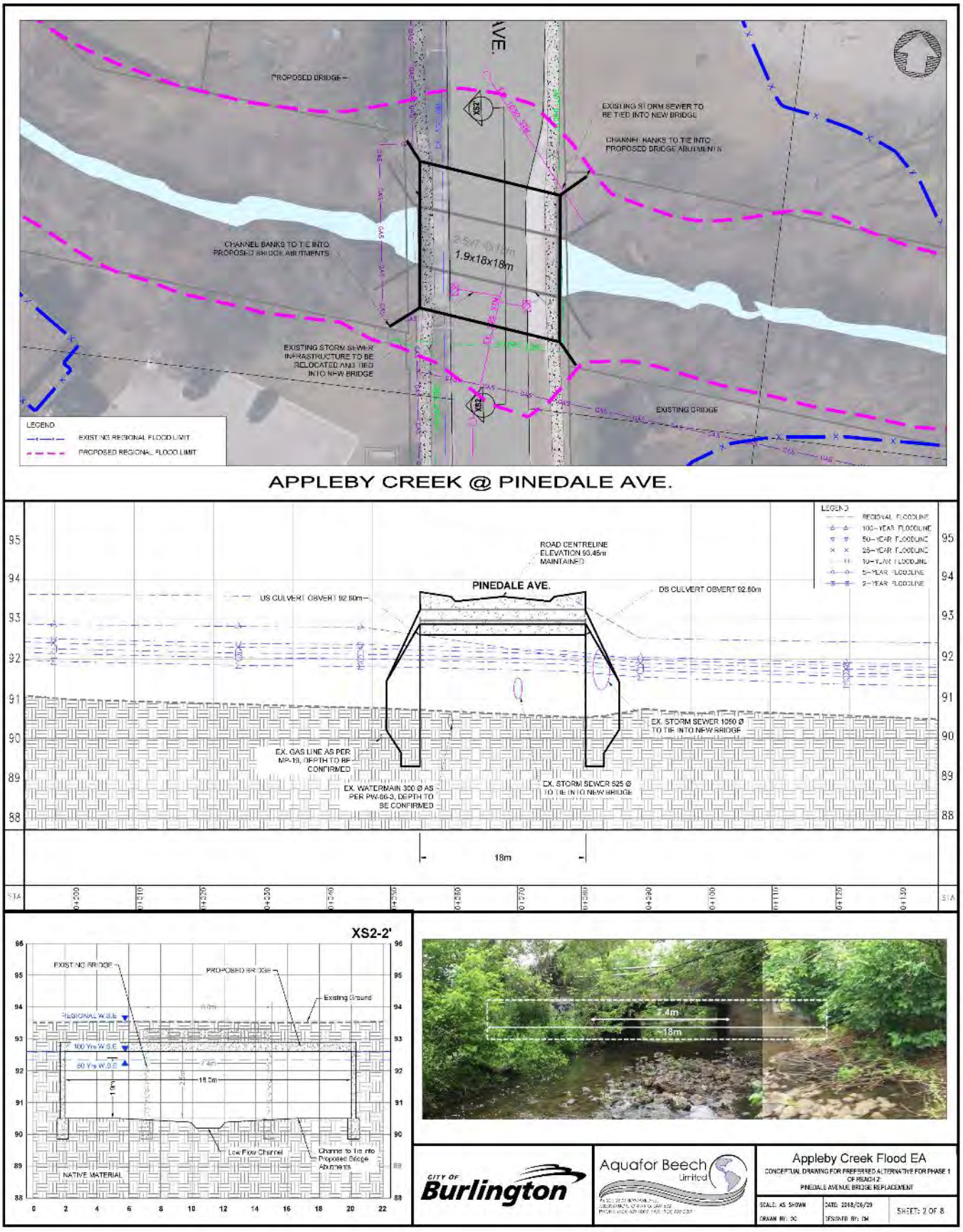


Figure 5.3: Conceptual drawing for proposed bridge widening at Pinedale Ave.

5.2.2 Recommended Staging, Sequencing and Access

The construction of Reach 2 preferred alternative is recommended to be carried out in a single phase including bridge upgrades and the associated minor channel works.

For the construction of the new bridge, a full installation approach is recommended, which requires complete closure of Pinedale Avenue. This is recommended because Pinedale Avenue is only two lanes wide at the bridge, and it is not anticipated that there will be enough space for both construction and traffic flow. A recommended detour for traffic during road closure is provided below in **Figure 5.4**, highlighting Appleby Line, New Street, and the rest of Pinedale Avenue to be used as detour routes. Due to the closure of the road, it is anticipated that the bus stops near the Pinedale bridge will need to be relocated temporarily during the construction, and the bus route may need to be temporarily modified. It is recommended that the City coordinates internally with the transportation division to find the optimal solution for the bus routing. Access to local residential houses will be maintained throughout construction. The closed roadway and a section of the Frontenac Public School are proposed to be used as storage area, however the City will need to get permission from the school to use this area. A conceptual construction and staging plan are provided below in **Figure 5.5.** Detailed construction and traffic management plan should be included in the detailed design phases.



Figure 5.4: Recommended detour route and road closures for construction of the Pinedale Avenue bridge

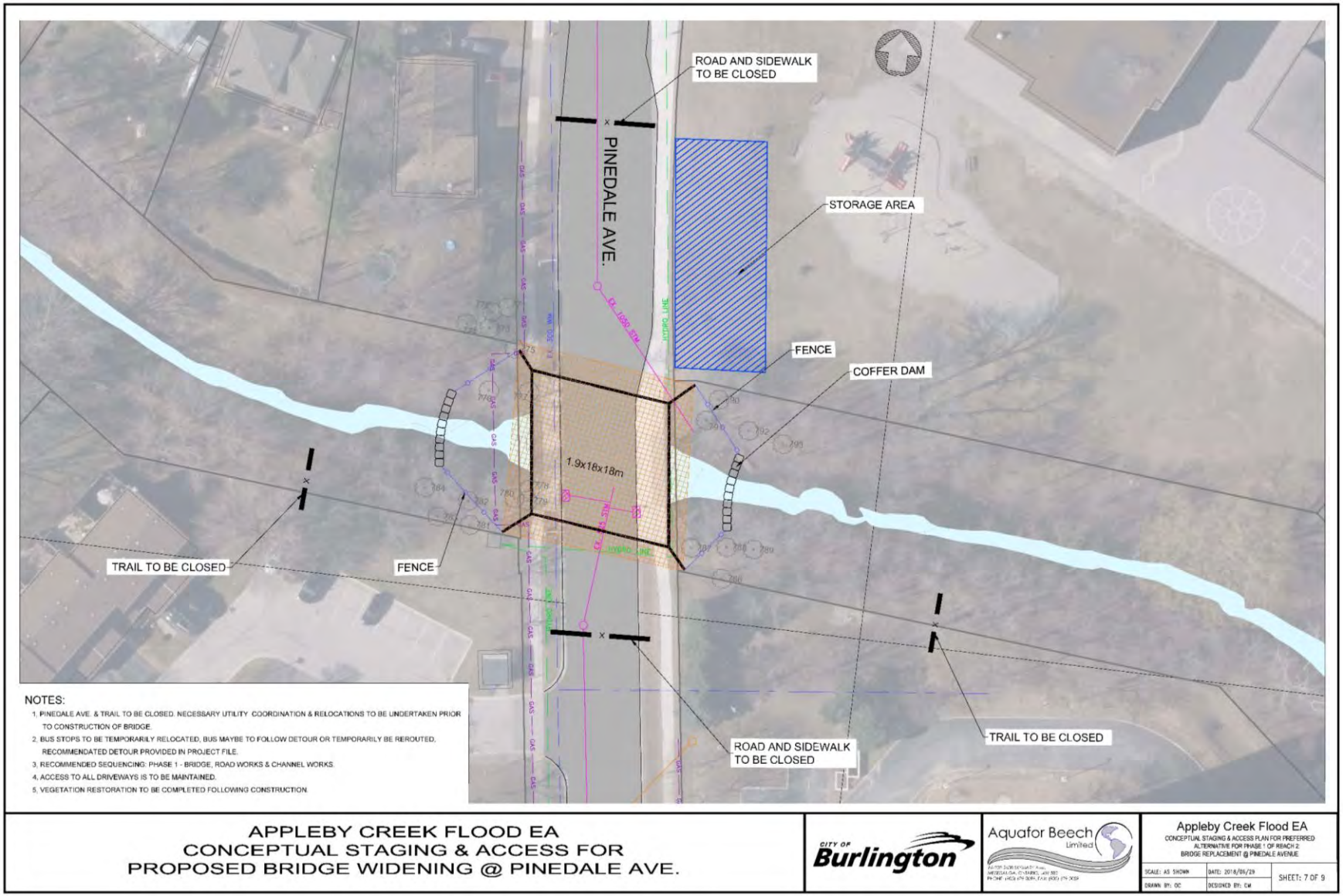


Figure 5.5: Preliminary construction, staging and sequencing plan for Pinedale Bridge

5.3 Reach 3 Conceptual Design Elements

The preferred alternative for Reach 3 involves upgrading the existing Fairview Street crossing with a wider span bridge. The minimum recommended span is 17m. The proposed bridge span will allow a conveyance of the 100-year flood with freeboard, which meets the conveyance recommendation from the MTO design criteria. Minor channel works at both ends of the bridge will be involved to ensure proper tie-in to the bridge abutment. A conceptual drawing of the preferred alternative is provided below in **Figure 5.6** and also in **Appendix C**.

In addition, as discussed in **Section 4.8.4**, options such as creek widening to further relief flooding on tablelands east side of Appleby Creek may be investigated in consultation with the private landowners on Oval Ct, should opportunities arise in the future.

5.3.1 Requirements for Utility Modification

The existing utilities at the Pinedale Avenue bridge have been summarized in **Section 3.6**, which included the surrounding sanitary and storm sewers, water, communication line and gas. These utilities were assessed to determine if any impact or relocation would be necessary for the replacement of the new bridge. The potential disturbances to the surrounding utilities are listed below. Possibility of relocation is relatively low for most of the buried utilities as significant lowering of the channel bed is not involved in the proposed design concept, except for the gas pipe identified through the bridge deck.

Temporary relocated (during construction)	Relocated/Reconnected
- Hydro	- Sanitary sewer (potentially lowered) - Storm sewer outfalls (reconnected) - Gas pipe going though bridge deck (relocated) - Gas buried (potentially lowered) - Bell (potentially lowered) - Water (potentially lowered)

As discussed above, the location and depth the utilities identified in **Section 3.6** will be confirmed through HydroVac services and survey at the detailed design stage as required.

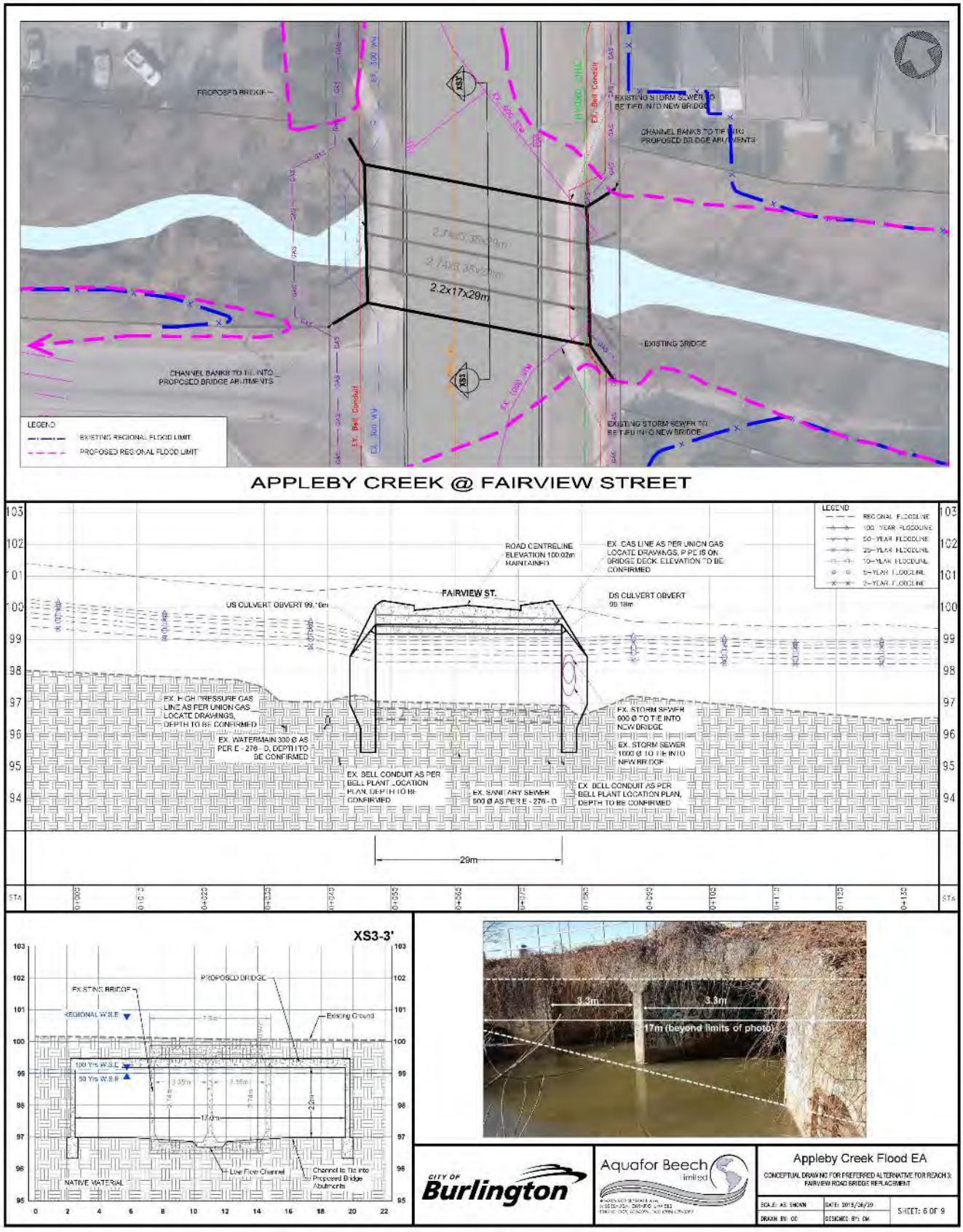


Figure 5.6: Conceptual drawing for the preferred alternative for Reach 3

5.3.2 Recommended Staging, Sequencing and Access

Similar to New Street, Fairview Road is recommended to remain partially open during the construction period. It involves first constructing the upstream side of the bridge while redirecting all traffic to the downstream lanes, and then completing the construction on the downstream side and diverting traffic to the newly constructed lanes. It is imperative that Fairview Road remain accessible not only because it serves as a major road for the local community, but the road also stops at a dead end approximately 300m past the bridge. Therefore, access over the Fairview Road bridge is necessary for the businesses and residents on the northeastern side of the bridge.

It is recommended that the City's right-of-way and the closed lanes be used as storage areas. The Centennial Bikeway trail should remain open, however the crossing at Fairview Road to the Appleby GO station parking lot will need to be temporarily relocated. In addition, full time traffic control will be necessary to maintain the traffic flow to a single lane on the bridge. A conceptual construction and staging plan are provided below in **Figure 5.7.**

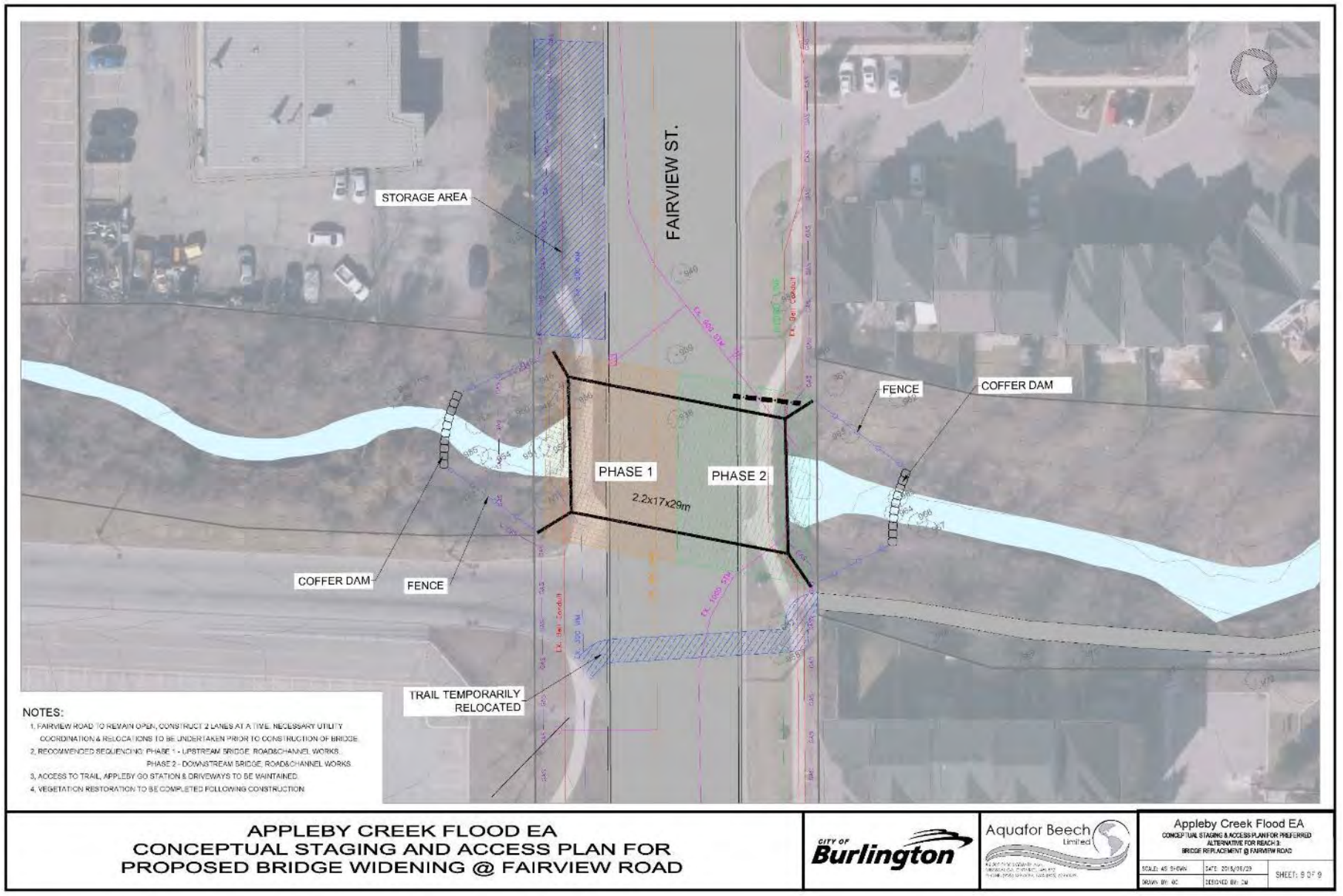


Figure 5.7: Preliminary construction, staging and sequencing plan for Fairview Street

5.4 Implementation Timing

It is noted that the flood risks identified in this section of Appleby Creek are less than other watercourses in Burlington (as discussed in **Section 3.4.1**), however flooding to adjacent properties are primarily caused by the restricted conveyance capacity of the three road crossings. Therefore, taking into context of other flood risks within the City, it is expected the implementation of these preferred alternatives might be delivered over a relatively long timeframe, should funding be restrictive.

As it stands the bridges have not shown significant evidence of deterioration and are expected to be structurally stable. It is recommended that this be confirmed with through the City's structural inspection reports. However, it is unlikely that the bridges would need to be replaced for structural reasons at this time.

Therefore, it is recommended that the City allocate funding for more urgent flood mitigations measures at this time and continue to monitor this section of Appleby Creek. Should funding become available or other capital works projects overlap and provide opportunities (e.g., road resurfacing or expansions, major utility modifications, or channel works resulting from the Appleby Creek Erosion Assessment EA), it is recommended that the City take the opportunity to implement the preferred alternatives presented here at that time.

5.5 Cost Estimate of Preferred Alternatives

Preliminary costing for the preferred alternatives has been summarized below in **Table 5-1**. Cost estimates are based on unit prices of similar projects recently completed within southern Ontario. These costs do not include ancillary fees such as contract tendering and administration, contractor mobilization, traffic control insurance, restoration, and acquiring of easements. The total approximate costs to implement the preferred solution at the New Street, Pinedale Avenue, and Fairview Street are 2.9M, 2.8M, and 2.8M respectively.

Table 5-1: Preliminary Cost Estimate of Preferred Alternatives for Each Reach.

Main Components of Construction	Reach 1	Reach 2	Reach 3
Bridge Works			
Removal	$ 250,000	$ 250,000	$ 250,000
Bridge Construction	$ 1,500,000	$ 1,500,000	$ 1,500,000
Road Construction	$ 100,000	$ 100,000	$ 100,000
Utility Relocation	$ 300,000	$ 200,000	$ 200,000
Driveway Reconnection	$ 3,600	$ 3,600	$ 3,600
Engineering & Design	$ 60,000	$ 60,000	$ 60,000
Contingency (20%)	$ 442,720	$ 422,720	$ 422,720
Subtotal	$ 2,656,320	$ 2,536,320	$ 2,536,320

Channel Works			
Hardened Channel Works	$ 150,000	$ 150,000	$ 150,000
Vegetation Restoration	$ 15,000	$ 15,000	$ 15,000
Engineering & Design	$ 60,000	$ 60,000	$ 60,000
Contingency (20%)	$ 45,000	$ 45,680	$ 45,000
Subtotal	$ 270,000	$ 270,000	$ 270,000
TOTAL	**$ 2,926,320**	**$ 2,806,320**	**$ 2,803,320**

5.6 Conceptual Vegetation Restoration Plan

A vegetative restoration plan must be developed to restore areas that have been disturbed as a result of construction. The restoration plan is to specify native species to be used to restore channel banks, the floodplain, staging areas, and the access route.

5.6.1 Tree, Shrubs and Plant Compensation and Protection

The plan must include compensation for trees removed for construction in accordance with the City of Burlington By-law 68-2013, Section 1.17 which states:

> *"Where a Public Tree(s) is to be removed and where its removal is not required due to age, health or other reasons in accordance with sound arboriculture principles, the applicant shall plant Tree(s) with the total combined diameter being equal to or greater than that of the Tree(s) to be removed. Where the total combined diameter of the Tree(s) to be planted is less than the total combined diameter of the Tree(s) removed, Council approval will be required."*

In addition to tree plantings, five (5) shrubs should be planted for every tree planted, and an herbaceous seed mix should be seeded over disturbed areas that reflect a native-species riparian corridor. All disturbed ground cover should be restored to pre-construction or better conditions with terraseeding application composed of native seed mix and a ~20% nurse crop.

Best Management Practices for trees before, during, and after construction include the following:

<u>Planning Phase</u>

- It is recommended that a Certified Arborist completes an Arborist Report and Tree Protection Plan, complete with detailed tree inventory for areas of anticipated impact.

<u>Design Phase</u>

- Arborist Report and Tree Protection Plan complete with a detailed tree inventory, identification of tree injuries and removals (including area(s) of root zone impact, the prognosis for survival, structural stability, health, and vigour) and recommendations for mitigation including additional tree protection or redesign, as necessary;
- Planned areas for construction access, staging, material storage, etc.;

- Tree protection zone (TPZ) fencing and signage, trunk protection, etc.;
- Considerations: Root and Crown pruning (raising, reduction, etc.) to avoid damage by construction equipment;
- Grade changes, slope stabilization, etc.

Construction Phase

- Site supervision by a certified arborist and communication plan;
- Installation of Urban Forestry approved tree protection measures;
- Backfill techniques and considerations; and
- Tree care during construction.

Post-Construction Aftercare

- Monitoring;
- Irrigation;
- Aeration;
- Mulching;
- Wound treatment; and
- Fertilization (not recommended for at least 1-year post-construction).

A tree protection plan should be established for trees located within the proposed construction zone of all three bridges. To aid in protecting woody plantings from damage by beaver and other rodents, woody plantings should be wrapped in plastic spiral tree guards after planting.

To avoid delays to the project, early consultation with the City of Burlington forester to discuss tree removal and replacement should be undertaken. It is noted that no Butternut or other endangered tree species were identified within the study areas, therefore no butternut health assessments are anticipated for the proposed works.

5.6.2 Recommended Areas for Replanting

Suggested areas for replanting include the riparian corridor at the bridges, areas within City's road right-of-way (in particular the areas used for construction storage), tablelands beyond creek top of slope (e.g., through the hydro corridor). Locations of plants will be determined as part of the detailed restoration plan.

5.6.3 Recommended Species

Given the linear shape of natural areas in the study area and the location of anticipated disturbance areas on the edge of woodland communities; it is recommended that trees selected for replacement should be tolerant of full to partial sun, and salt tolerant. It is highly recommended that species selection should reflect a native lowland forest community. Disturbed vegetation communities should be seeded with herbaceous species appropriate to the respective vegetation community.

To mitigate habitat loss for special concern and rare wildlife species due to construction works, it is recommended that disturbed areas be restored with native species, including potential food sources for eastern wood-pewee (e.g. seasonal berries and seeds), butterflies (e.g. host plants and nectaring plants for adults), and other migratory fauna (e.g. native fruits and seeds throughout the seasons). Host plants for target butterflies include milkweed (*Asclepias* spp.) for monarchs, asters (*Asteraceae*) for painted lady, and nettles (*Urticaceae*) for red admiral. For birds, a variety of dogwoods (*Cornus* spp.), viburnums (*Viburnum* spp.), serviceberries (*Amelanchier* spp.), oaks (*Quercus* spp.), grape (*Vitis riparia*), and staghorn sumac (*Rhus typhina*) are a few species appropriate to be planted in the study area. It is also recommended that habitat features such as woody debris, rocks, etc. are retained on the landscape to maintain ecological features and habitat functions. Barriers to fish movement should be removed to improve aquatic habitat connectivity.

5.6.4 Monitoring Plan

It is recommended that a monitoring plan be implemented which shall document the success of restoration plantings. The primary goals of the monitoring plan is to ensure that new plant material can reach the free to grow stage, and to identify potential need for adaptive management measures. The free to grow (FTG) stage is defined as the point at which 90% of woody plantings have surpassed the average height of adjacent grasses and forbs, and presumably will not be outcompeted.

Table 5-2 lists the key restoration performance measures recommended for inclusion in the monitoring plan, along with frequency and duration of monitoring activities, and adaptive management actions related to each performance measure. Each monitoring parameter is to be included in a monitoring plan which is recommended to occur in years 1, 3, and 5 post-construction, subject to monitoring results. Additional monitoring at year 10 may be required if monitoring results in years 1-5 do not provide reasonable confidence that the restoration plantings will succeed over the long term. It is recommended that a minimum of five (5) permanent vegetation monitoring plots be established for monitoring, with locations to be confirmed as part of the approvals for the restoration plan (e.g. in consultation with the City of Burlington, Region of Halton, and Conservation Halton).

Table 5-2: Monitoring, Targets, and Adaptive Management Actions for Restoration Plantings

Performance Measures	Location	Targets	Potential Outcomes	Adaptive Management Actions
Survival: Quantitative assessment of the establishment and survivorship of planted woody and herbaceous material. The survivorship of woody material should be assessed according to each size category of plan material used.	• Throughout site • Permanent monitoring plots	75% survival rate for planted material.	≥75% of planted material has survived.	• Report findings; no further action required.
			<75% of planted material has survived.	• Investigate causes of plant mortality and document findings. • Remediate causes of plant mortality. • Replace planting material as required within warranty period.
			Unbalanced survivorship among some plant types and/or species.	• Investigate causes of unbalanced survivorship and document findings. • Remediate causes of imbalance. • Provide mitigation measures such as increased rodent protection, invasive species removal, etc. • Replace planting material within warranty period.
Growth Rate: Quantitative assessment of the growth rate (e.g. last year's growth) of planted woody material. Growth rate should be assessed according to each size category of plan material used.	• Throughout site • Permanent monitoring plots	Establish and achieve varied height and cover targets to achieve structural diversity.	Structural diversity evident after 5 years.	• Report findings; no further action required.
			Unbalanced growth performance of some plant species and/or sizes. Structural diversity not evident after 5 years.	• Investigate causes of unbalanced survivorship and document findings. • Remediate causes of imbalance. • Provide mitigation measures such as increased rodent protection, invasive species removal, competition control, etc.
Free to Grow (FTG) Performance: Quantitative assessment of the percentage of woody plants that achieve FTG status.	• Throughout site • Permanent monitoring plots	FTG status achieved within 5 years after planting.	FTG status achieved within 5 years.	• Report findings; no further action required.
			FTG status not achieved within 5 years.	• Investigate possible causes of poor performance; document findings. • Remediate causes. • Provide mitigation measures such as increased rodent protection, invasive species removal, competition control, mulching, etc.

Performance Measures	Location	Targets	Potential Outcomes	Adaptive Management Actions
Invasive Species: Invasive species have the potential to outcompete planted material and negatively affect the structural diversity and ecology of the RNHS. Several invasive species, such as Garlic Mustard, Periwinkle, and European Buckthorn, have been identified on site.	• Throughout site • Permanent monitoring plots	Less than 5% of planted areas colonized by invasive species.	<5% of restored areas colonized by invasive species.	• Report findings; no further action required.
			≥5% of restored areas colonized by invasive species.	• Document, map, and photograph incident location(s); describe and map details of current extent. • Advise applicable review agencies of findings within 2 weeks of discovery. • Assess the risk of the species spreading. • Undertake invasive species removals as soon as possible. • Report observations and follow-up actions. • Monitor outcomes of control measures.
Erosion: Quantitative and qualitative measurement of erosion sites, especially near watercourse.	• Throughout site	Erosion location and severity identified and addressed.	Erosion sites and erosion severity identified.	• Document, map, and photograph incident location(s); describe details. • Remediate cause(s) of erosion. • Report observations and follow-up actions. • Advise applicable review agencies of findings within 2 weeks of discovery. • Monitor outcomes of control measures.

Performance Measures	Location	Targets	Potential Outcomes	Adaptive Management Actions
Disturbance and Encroachment: Encroachments and disturbance (e.g. dumping, unauthorized trails, vandalism, etc.) should be documented and mapped.	• Throughout site	Encroachments identified and addressed.	Encroachments within restoration areas identified.	• Document, map, and photograph incident location(s); describe details. • Identify potential negative impacts. • Report observations and follow-up actions. • Advise applicable review agencies of findings within 2 weeks of discovery. • Monitor outcomes of control measures.

5.7 Implementation Measures for Detailed Design

The following implementation measures must be taken into consideration at the detailed design stage. It is recommended that these measures be incorporated into the detailed design wherever possible.

5.7.1 Environmental Approvals and Permitting

In addition to approvals by the City's works and parks departments and potential permits under the ESA, applications will be required for permits from Conservation Halton under Ontario Regulation 162/06 (Development, Interference with Wetlands and Alterations to Shorelines and Watercourses).

Approval from the MNRF is required for a fish collection permit (fish rescue). Moreover, works must consider the Provincial Policy Statement regarding water (Policies 2.2.1 and 2.2.2) which states that "planning authorities shall protect, improve or restore the quality and quantity of water" and that "site alteration shall be restricted in or near sensitive surface water features and sensitive ground water features". To comply with the Provincial Policy Statement, channel works should be completed in the dry to protect water quality, and downstream base flows should be provided during construction to protect water quantity.

To avoid harm to breeding fishes by conducting the proposed work outside of generalized spring breeding window. The recommended construction timing window for these works is July 1st to March 31st.

To avoid harm to nesting migratory birds by conducting the proposed work outside of the generalized nesting period of April 1 to August 31. When site works must occur during the generalized nesting period, a Qualified Avian Ecologist must conduct an active nest survey immediately prior to site disturbances or alterations (e.g. tree removal). Establish temporary Nest Protection Zones for any nests at the edge of the stream corridor, which will remain in place until all fledged birds have left the vicinity or as advised by a qualified wildlife biologist. This will ensure that site alteration does not contravene the federal Migratory Convention Act (1994), which protects the nests of most breeding bird species in Ontario;

5.7.2 DFO Self-Assessment

A Self-Assessment was conducted to determine the need to apply for a Department of Fisheries and Oceans (DFO) Request for Review. The Assessment states that DFO Review is not required for Bridge Repairs only if no new fill is to be placed below the High Water Mark and that no work is to occur below the High Water Mark.

The preferred alternatives have identified replacements of the three road crossings within the study area (i.e., Fairview Road, Pinedale Avenue and New Street). At all three structures, the

bridge footings are below the High Water Mark and/or within Appleby Creek's permanent water level. Therefore, to remove and replace the structure(s), works will likely need to occur below the High-Water Mark. **Therefore, it is the opinion of Aquafor Beech Limited that DFO Review will be necessary as part of the detail design phase**.

5.7.3 Construction Staging, Erosion and Sediment Control Measures

Appropriate plans are to be included within the detailed design package, based on consultations with the City and Conservation Halton. The construction access route and staging areas are to be refined from the conceptual drawings provided within this document during the detailed design. It is recommended that this be done in consultation with the City and Conservation Halton. The detailed vegetation restoration plan is to include a plan to restore the access routes and staging areas in accordance with Conservation Halton's requirements.

Due to the sensitivity of the channel bed and underlying utilities, consideration should be given to the equipment used in the creek. Rubber-tired equipment may be required or bed protection, such as matting; specifications will be determined during the detailed design stage. Any material placed in the creek as bed protection must be removed prior to the reinstatement of flows.

5.7.4 Invasive Species Management Plan

Invasive species cause a number of negative impacts to natural areas, including, but not limited to, outcompeting native species for space and resources, thereby reducing species richness. Decreasing the amount of invasive species within the Appleby Creek corridor likely have a positive effect on the health of the NHS. Therefore, invasive species may be removed to accommodate site access and construction works, should opportunities appear.

An Invasive Species Management Plan specific to the relevant species noted within Table 5-2 shall be incorporated into the detailed design, prior to construction. The plan should consider the Best Management Practices for managing, removal, and controlling the spread of each individual invasive species, as well as the Clean Equipment Protocol. It is recommended that the plan should be continued until the planted native vegetation becomes established.

5.7.5 Tree Protection Fencing

Tree protection fencing following the specifications in Conservation Halton's Landscaping and Tree Protection Guidelines should be erected along all construction access routes and work areas. Fencing should consist of posts or t-bars with filter cloth affixed to paige wire fencing. Tree protection fencing should be located at a minimum distance of 1m from the dripline of potentially affected trees. It is likely that, due to the woodland setting specific to this project, maintaining the minimum 1m distance will not be possible in some areas. In such case, fencing should be located as far as possible from the tree.

5.7.6 Tendering, Construction Administration, and Supervision

The design consultant may be retained to provide all these services. However, it is recommended that a structural engineer, a stream restoration consultant and a landscape architect or terrestrial ecologist should provide input to the tender document, specifically the special provisions, and should provide at least part-time construction supervision (to the relevant parts of the project).

5.7.7 Post-Construction Monitoring

For stream restoration projects, Conservation Halton typically requires a commitment to post-construction monitoring for a period of a minimum of 3 to 5 years following construction as a part of the permitting agreement. Detailed as-built surveys and drawings should also be completed immediately following construction by the contractor and/or stream restoration consultant. The specific details and length of monitoring required for each restoration site may be developed by the stream restoration consultant in consultation with the City, Conservation Halton, and/or DFO during the permitting process.

6 ADDITIONAL INVESTIGATIONS REQUIRED AT THE DETAILED DESIGN PHASE

At the detailed design stage, a number of specific investigations will be required to provide a comprehensive understanding of existing conditions at the site level, which should provide the basis for detailed site design and implementation measures which build on the preliminary conceptual design elements outlined in this study report.

6.1 Detailed Hydraulic Assessment

Further refinements to the hydraulic assessment are recommended at the detailed design stage. This will include a hydraulic assessment, which will involve updating the proposed conditions to incorporate aspects of the detailed design to confirm the anticipated conveyance and flood limits. Furthermore, any outstanding comments from Conservation Halton regarding the hydraulic analysis can be addressed at this time. The assessment will also be used to confirm that no negative flooding impacts will result from the proposed works, a condition of the CH permit.

6.2 Scour Analysis

Detailed scour analysis for each new road crossing is recommended at the detailed design stage, to inform the design of bridge abutment protection from erosion and the grade of channel profile in general. The analysis can be completed in accordance with the MTO Drainage Management Manual (1997) using the results from the detailed hydraulic assessment. The estimated scour depth should be taken into consideration of the detailed design of the scour protection measures, depth of cover of buried utilities at bridge inlet and outlet, as well as the stone sizing as applicable.

6.3 Utilities Confirmation

As discussed in **Chapter 5**, there are several utilities that might be impacted by the construction of the preferred alternatives. The utility identifications that were undertaken for this EA involved reviewing GIS data, as-built drawings and preliminary locate drawings; however, still were not able to confirm the depths of a few utilities. Further investigation might be required to confirm the impact to the utilities at detailed design stages.

Relocating or realigning utilities can be spatially restrictive, timely and potentially expensive. Therefore, it is recommended that communications with utilities owners should be undertaken at early stages of detailed design, in order to get an understanding as to whether further steps (e.g., day lighting with HydroVac services) will be required.

By starting this process at the onset of the detailed design, this will allow for the utility modifications to be undertaken prior to the bridge reconstruction or to be well integrated into the construction staging.

6.4 Submission of a DFO Request for Review

Typically, a request for Review should be submitted to DFO when the project is determined through the self-assessment process that potential impacts to fish and fish habitat cannot be avoided or mitigated. Given the scope of the proposed works and nature of the existing aquatic habitat within the study area, it is recommended that a Request for Review be completed and submitted to DFO upon completion of detailed design drawings.

6.5 Submission of an Information Gathering Form

The purpose of an Information Gathering Form (IGF) is to provide relevant project information to the MNRF to inform the Ministry's determination of:

- whether any protected species or their habitats are present or adjacent to the location of the proposed activity;
- the potential effects of the proposed activity on these species and habitats;
- whether the activity is likely to contravene subsection 9(1) or 10(1) of the ESA; and,
- whether it's advisable for the proponent to apply for an overall benefit permit under clause 17(2)(c) of the ESA prior to proceeding with the activity.

As endangered bats are potentially present within the study area it is recommended that an IGF be completed and submitted to the MNRF for review once the detailed design drawings are completed.

7 POTENTIAL IMPACTS AND MITIGATION MEASURES

This section summarizes some of the potential positive and negative impacts of the preferred alternatives. Where negative impacts are identified, mitigation measures have been recommended.

7.1 Flood Risk Impacts

The preferred alternatives for each reach will reduce the number of buildings within the regional floodplain and increase the hydraulic conveyance to the MTO recommended conveyance. **Table 7-1** and **Table 7-2** summarize and compare the flood risks for the existing conditions and the preferred alternatives for each reach.

Table 7-1: Summary of buildings within the floodplain for preferred alternatives

Flood Event	Number of Buildings within the floodplain					
	Reach 1		Reach 2		Reach 3	
	Existing	Preferred Alternative	Existing	Preferred Alternative	Existing	Preferred Alternative
Regional Flood	14	0	14	3	9	4
100-Yr Flood	0	0	0	0	2	2

Table 7-2: Summary of maximum hydraulic conveyance capacity for preferred alternatives

Road Crossing	Maximum Hydraulic Conveyance Capacity		MTO Recommended Conveyance Capacity
	Existing	Preferred Alternative	
New Street	10 year (38 m^3/s)	100 year (59 m^3/s)	100 year (59 m^3/s)
Pinedale Avenue	10 year (38 m^3/s)	50 year (53 m^3/s)	50 year (53 m^3/s)
Fairview Street	5 year (31 m^3/s)	100 year (59 m^3/s)	100 year (59 m^3/s)

It is also noted that the all three roads will only be inundated under the regional flood event under the preferred alternatives.

7.2 Fluvial Geomorphology Impacts

The proposed bridges are expected to improve the local erosional and geomorphic conditions within Appleby Creek. The proposed bridges will be open bottom, so that the channel form and function can be maintained (or enhanced) through the bridge. Furthermore, the increased conveyance at the bridges is expected to locally reduce channel shear and velocity, and in turn

reduce erosion. Any local erosion at the road crossings can also be addressed as part of the bridge replacement.

The proposed alternatives are not expected to have significant impacts to the reach scale geomorphic conditions of Appleby Creek.

7.3 Hydraulic Impacts

The preferred alternatives will positively impact the flood flow hydraulics for the entire study area. At each reach, water surface elevations are expected to decrease as a result of the preferred alternatives. The preferred alternatives are not expected to have any impacts to the low flow or mean annual flow hydraulics.

As identified in **Section 6.1**, it is recommended that a detailed hydraulic analysis be undertaken as part of the detailed design to confirm the anticipated results.

7.4 Natural Heritage Impacts

Potential impacts to natural heritage features and functions as a result of the preferred alternatives were assessed within the study area. A summary of the potential negative impacts and recommended mitigation measures relating to potential negative impacts are summarized below in **Table 7-3**. A detailed discussion of these impacts can be found in **Appendix B**.

Aquafor's aquatic ecologist undertook a Self-Assessment to determine the need to apply for a Department of Fisheries and Oceans (DFO) Request for Review. As the preferred alternatives have identified replacements of the three road crossings within the study, it is the opinion of Aquafor Beech Limited that DFO Review will be necessary as part of the detail design phase. This is further discussed in **Section 5.7.2**.

7.5 Social and Economic Impacts

As discussed in the evaluation tables in **Section 4.7**, there are expected to be some negative social impacts of preferred alternatives. Lane closures are expected for both the New Street and Fairview Road bridge replacements; however, the bridges are expected to remain open for traffic. As Pinedale Avenue is only two lanes wide, it is expected that the road will have to be closed during the replacement of this bridge. This will cause some inconveniences for local residents. It is recommended that the City work with transportation department during the detailed design to establish appropriate traffic control plans, including detour routes.

There are some additional social impacts with regards to the vegetation restoration for the riparian corridor at all three crossings. This was noted within the comment responses from the

PIC. It is recommended that the City continue to communicate with the land owners in developing a detailed vegetation restoration plan.

Moreover, positive social impacts in terms of landowner education and land stewardship are expected as a result of this EA, with points of contact including the Notice of Commencement, Public Information Centre, and the Notice of Completion. The City and design consultant may continue to incorporate additional stewardship program throughout the detailed design process.

Table 7-3: Summary of recommended mitigation measures for potential natural heritage impacts

Category	Potential Negative Impact	Recommended Mitigation Measures
Vegetation Loss to Significant Woodlands	Vegetation loss will likely occur within Significant Woodlands along Appleby Creek to accommodate access and construction works.	Vegetation removed is replanted in accordance with the City of Burlington's Public Tree By-Law 68-2013 (City of Burlington, 2013). Further details are provided in the Conceptual Restoration Plans and **Appendix B**
Breeding Birds	The natural corridor of Appleby Creek is potential breeding habitat for birds. There is the potential to harm and/or disturb birds nesting in vegetation within and adjacent to disturbance areas.	Tree removals are to occur outside of the breeding bird nesting period for forest birds in Burlington (i.e., April 10th to August 12th). If site works must occur during the generalized nesting period, it is recommended that a qualified avian ecologist must conduct an active nest survey immediately prior to tree removal.
Aquatic Communities	As fish are in all reaches of Appleby Creek, there is the potential to harm fish and fish habitat during construction. Construction activities may also impact the quality of fish habitat by reducing water quality from sedimentation.	As all reaches will likely require dewatering, fish rescues should be conducted in accordance with the warm-water timing window (July 1st to March 31st) to reduce harm to aquatic species.
SAR and Species of Concern	Endangered and Threatened species known or suspected to occur within the study area. Specifically: • Tree removals may remove candidate bat maternity roosting sites; • Dewatering may temporarily limit turtle movement within the creek corridor; • There is the potential to harm and/or disturb birds nesting in vegetation within and adjacent to disturbance areas.	• Candidate bat maternity roost sites are cross referenced with proposed tree removals to determine if trees selected for removal are also candidate bat maternity roost sites. Trees should not be removed until surveys for candidate bat maternity roost sites have been completed and an IGF has been submitted to the MNRF for review; • All efforts to minimize riparian zones impacted should be exercised; • It is recommended that staging and access areas be contained to existing roads or away from the riparian corridor; and • Fish and wildlife rescues be undertaken in accordance with MNRF protocols

Category	Potential Negative Impact	Recommended Mitigation Measures
Significant Wildlife Habitat	Proposed works require vegetation removal, which is potentially suitable habitat for migratory butterflies and birds.	To mitigate the loss of potentially suitable stopover habitat for butterflies and birds, it is recommended that butterfly host plants and early and late fruiting native vegetation for birds are used in restoration plantings. See the Conceptual Restoration Plans and **Appendix B** for further details.
Linkages	Linkages are used by wildlife for many aspects of their life cycles including foraging, dispersal, nesting, etc. The Appleby Creek corridor is a link to the Lake Ontario shoreline through adjacent natural areas to the south of the study area. There are opportunities improve the form and function of the Appleby Creek corridor by removing disturbances and invasive species in the corridor.	Disturbed areas should be planted with native species, including potential food sources for eastern wood-pewee, butterflies, and other migratory fauna. It is also recommended that habitat features, such as woody debris and rocks, be retained on the landscape to maintain ecological features and habitat functions. Barriers to fish movement should be removed to improve aquatic habitat connectivity.
General Mitigation Measures	Proposed works would likely require heavy machinery working near water and adjacent to natural heritage features, in order to widen the bridges and complete minor channel works at tie-in locations.	Select Ontario Provincial Standard Specifications (including but not limited to OPSS 182, OPSS 201, OPSS 501, and OPSS 805) related to use of equipment and general environmental protection requirements for near water works shall be referred in the contract documents. To reduce disturbances within the NHS, small-sized machinery (e.g skid-steer) should be used to construct coffer dams and other necessary structures within the NHS. Furthermore, horizontal root protection measures such as wood chips should be used to reduce soil compaction within the NHS. It is recommended a detailed Tree Protection and Management Plan is completed at the detailed design stage by a Certified Arborist. Efforts should be made to reduce the amount of vegetation removed to accommodate works.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This study has been carried out under Schedule B of the Municipal Class EA process for Water and Wastewater projects, as the type of intended works have a greater potential for environmental impact thereby requiring notification of the public and relevant review agencies, and completion of Phases 1 and 2 of the Municipal Class EA process.

Subsequent phases of the process will involve detailed design, permitting, tendering, implementation and post construction monitoring.

The objective of this study was to identify specific opportunities that reduce flooding risk and protect the natural heritage features and functions along Appleby Creek between New Street and the railway. Flood risks were identified and quantified as buildings within the flood limits, frequency of road inundation and hydraulic conveyance capacity of the channel and road crossing structures.

Based on the results of the alternative evaluations and the consultation with the City, CH, and the public, the following alternatives were selected as the preferred alternatives for each reach:

Reach	Preferred Alternative
Reach 1 New St. to Pinedale Ave.	**Alternative 2** Option 1 to widen the New St. bridge (i.e., 18m span, convey 100-year flood)
Reach 2 Pinedale Ave. to Fairview Rd.	**Alternative 2** Option 1 to widen the Pinedale Ave. bridge (i.e., 18m span, convey 50-year flood)
Reach 3 Fairview Rd to Railway	**Alternative 2** Option 1 to widen the Fairview Rd. bridge (i.e., 17m span, convey 100-year flood)

The preferred alternative for each reach involves widening the existing bridges. Conveyance and backwater were noted flood risk concerns within each of the reaches, and the wider bridges will reduce this risk. Furthermore, each of these alternatives removed significant number of buildings from the floodplain.

The key conclusions and recommendations of this study are provided below:

- Flooding at New Street, Pinedale Ave, and Fairview Street within Appleby Creek corridor can be significantly reduced for the 100-year and Regional storm events. Implementation of the preferred alternatives will provide a reduction of 80% (i.e., 32 out 37 buildings) of the buildings within the regional floodplain and help relief upstream backwatering;

- It is noted that the flood risks identified in this section of Appleby Creek are significantly less than other watercourses in Burlington. Therefore, taking into context other flood risks within the City, it is expected that the implementation of these preferred alternatives could wait to be constructed, should funding be restrictive;
- Application of LID measures only within the study area is not likely to result in a notable decrease in flows, however working to implement LID measures throughout the watershed over the long term could provide a sizeable decrease in storm flows for the 50- and 100-year events;
- It is likely that some utility realignment will be required to implement the preferred alternative for all three road crossings. Furthermore, lane reductions and road closures will be necessary;
- Opportunities for terrestrial and aquatic habitat improvements exist through implementation of the preferred alternatives.

8.2 Recommendations

It is recommended that the following actions be taken:

1. That the proposed flood reduction measures be undertaken as outlined in this document;
2. That the implementation strategy outlined in this document be followed when undertaking the detailed design;
3. That the recommended additional investigations outlined in this document be undertaken prior to or during the detailed design;
4. That future implementation of LID measures within Appleby Creek watershed be undertaken as a long-term strategy when opportunity arises;
5. That tree retention be maximized to the extent possible through detailed design;
6. That a robust erosion and sedimentation control plan be prepared as part of the detail design;
7. That complete traffic management and construction staging & sequencing plans be prepared in consideration of Section 5 of this document;

9 REFERENCES

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