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Falcon Creek
Erosion Control Study
(CNR to Willowbrook Road)

City of Burlington
Regional Municipality of Halton

September 2024

Prepared By:

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In association with:
North-South Environmental, Water's Edge, AMICK, and Soil Engineers

Prepared For:

The Corporation of the City of Burlington

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VALDOR WATER RESOURCES

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EROSION CONTROL STUDY (FALCON CREEK)

Introduction

Valdor Engineering Inc. was retained by the City of Burlington to complete an erosion control study for an approximately 275 m reach of Falcon Creek between the Canadian National Railroad (CNR) and Willowbrook Road, including background investigations (topographic, geotechnical, ecological, archaeological and geomorphic) and to prepare numerous mitigation alternatives, as well as conceptual and detailed designs for the preferred solution. The main objectives of the erosion control study are to assess the current erosion status and to identify a preferred set of alternatives to stabilize the existing creek erosion, including bank sections that have fallen into the creek which has resulted in creek instability and ongoing erosion that poses a threat to public infrastructure within the Willowbrook Road ROW.

The study is being completed as per the EA Process as a Schedule B project, in accordance with the Municipal Class Environmental Assessment process, which is an approved process under the *Environmental Assessment Act* (2015). The Public Information Centre (PIC) was held virtually on Wednesday, 08 March 2023. This study fulfills Phase 1 and Phase 2 of the Municipal Class Environmental Process.

Problem Identification

The subject reach of the existing watercourse (Falcon Creek) between the CNR and Willowbrook Road has four key locations that are in poor condition due to existing erosion. Two of these areas adjacent Willowbrook Road pose a threat to the road structure itself and potentially the infrastructure/services associated with the road and within the road ROW (*e.g.* hydro, safety railings, etc.).

Identification of Alternative Solutions to the Problem

A list of five initial erosion mitigation options was prepared for Erosion Sites #1 and #2 including: (1) do nothing (existing conditions); (2) vegetated slope (3:1 to 4:1); (3) vegetated sub-angular riverstone slope (2:1) or vegetated earth-anchoring system (*e.g.* Terrafirm) at 2:1 slope; (4) vegetated slope stabilization system (*e.g.* Terra Slope 45); and, (5) implement monitoring program. Six initial erosion control options were prepared for Erosion Sites #3 and #4 including: (1) do nothing (existing conditions); (2) vegetated slope (3:1 to 4:1); (3) vegetated earth-anchoring system (*e.g.* Terrafirm) at 2:1 slope with geogrid and turf reinforcement mat and bank stabilization system (*e.g.* Scourlok) at 0.125:1 slope with earth anchors; (4) vegetated slope stabilization system (*e.g.* Terra Slope 45); (5) partial height armourstone retaining wall; and, (6) full height armourstone retaining wall.

Inventory of the Natural, Social, and Economic Environment

Investigations were completed to evaluate the existing conditions regarding the natural, social and economic environment within the study area. The study area consist of primarily residential dwellings including some commercial / industrial usage that contributes to the local economy. The fluvial geomorphology investigations confirmed that four significant erosion sites are present along Falcon Creek within the study area and that two of these sites are threatening public infrastructure along Willowbrook Road. Two of the identified erosion sites do not pose an imminent threat to private infrastructure based on preliminary investigations. Hydraulic investigations confirmed the subject reach of Falcon Creek is impacted by a significant floodplain with multiple spills. The geotechnical investigations revealed that the steep eroded slopes within

the subject site are likely the result of shallow translational slope failure. Loss of support for the slopes was caused by toe erosion at the edge of the creek. Existing tree roots have slowed the rate of erosion of the slopes, although undercutting has exposed roots and caused trees to lean towards the slope in some cases. The natural heritage investigations revealed that the following natural heritage features are present within the study area: fish and fish habitat; species at risk; significant wildlife habitat; and, migratory bird nesting habitat. The following natural heritage features were confirmed not present: significant woodland; significant valleyland; life science area of natural and scientific interest (ANSI); natural heritage system; savannah, tallgrass prairie, alvar; and, provincially significant wetlands or other wetlands. Archaeological investigations (Stage 1 and Stage 2 Property Assessment) were completed for the study area and no archaeological resources were encountered.

Identification of Impacts of Solutions on the Environment and Mitigating Measures

There are no significant negative impacts anticipated from an environmental, social or economic perspective as a result of the proposed erosion mitigation design. Changes to vegetation on the site will be minimized and new and compensation plantings will be of native varieties. Efforts will be made to preserve existing vegetation and to further intensify plantings along the tops of existing slopes in re-graded areas where possible and within the creek block owned by the City. The erosion mitigation design alternatives will have beneficial impacts regarding downstream water quality which has positive economic implications. Public safety will also be improved as a result of discouraging access to the steep slopes by planting thorny shrubs and re-grading of slopes. As such, it is anticipated that the proposed alternatives will have an overall positive social and economic benefit on the community.

Evaluation of Alternatives and Identification of the Recommended Solution

Five to six initial erosion mitigation options were evaluated for each erosion site with consideration given to various economic, social and environmental factors using a decision matrix and the preferred option was determined.

Consultation with Review Agencies and Public

A public meeting was held on 08 March 2023 to present and discuss the erosion mitigation alternatives and to solicit feedback and comments from the public and review agencies. Meetings were also held directly with the City, Conservation Halton, Six Nations of the Grand River, Mississaugas of the Credit First Nation, and area residents.

Selection of the Preferred Solution and Preliminary Construction Cost Estimate

Based on the evaluation of options, the preferred set of alternatives includes: Option #5 (implement monitoring program to track and assess erosion risk) at Erosion Site #1; Option #5 (implement monitoring program to track and assess erosion risk) at Erosion Site #2; Option #3 (install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1) at Erosion Site #3; and, Option #3 (install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1) at Erosion Site #4. To address public safety concerns, thorny shrubs will be installed along the top of bank in the vicinity of Erosion Sites #3 and #4 along with safety railings. To address signs of failure noted regarding the Willowbrook Road storm sewer inlet headwall and wingwalls as part of the stormsewer outfall and culvert assesssments, the existing headwall and wingwalls will be replaced using armourstone. The preferred erosion mitigation strategy provides a cost-effective and compact erosion control solution that avoids disturbance to existing private properties while maintaining a naturalized channel. Based on the preparation of a set of conceptual / preliminary design drawings, the estimated preliminary construction cost for the preferred set of alternatives is approximately $1,105,458.00 (incl. 20% contingency and excl. HST).

Implementation Strategy for the Preferred Option

An implementation strategy was provided to assist with the next stages in the process to complete the construction of the proposed creek erosion mitigation strategy. The next steps will involve preparing a Notice of Completion, allowing for a 30-day review period, preparing the detailed design for the preferred alternatives, completing an additional bat acoustic survey in June 2024 or June 2025 depending on the anticipated construction timing, obtaining necessary construction permits, preparing tender documents, meeting with local stakeholders to notify them of the final design for construction, reviewing bids and award the construction contract to the successful bidder and constructing the proposed erosion mitigation strategy.

Summary and Recommendations

It is recommended that the City continue with the necessary steps required to implement the preferred set of erosion mitigation alternatives, as it will protect against future erosion and potential damages to public infrastructure and provide an overall net benefit.

1.0 INTRODUCTION

Valdor Engineering Inc. was retained by the City of Burlington to complete an erosion control study for an approximately 275 m reach of Falcon Creek between the Canadian National Railroad (CNR) and Willowbrook Road, including background investigations (topographic, geotechnical, ecological, archaeological and geomorphic) and to prepare a number of mitigation alternatives, as well as conceptual and detailed designs for the preferred option. The Consultant Team assembled by Valdor for this assignment included the following firms:

- Valdor Engineering – Lead consultant, water resources and municipal engineers;
- North-South Environmental – Ecologists;
- Water's Edge – Fluvial geomorphologists;
- Soil Engineers – Geotechnical engineers; and,
- Amick – Archaeologists.

The main objectives of the erosion control study are to develop an approach that will facilitate improvements to currently eroded areas, protecting the watercourse from further erosion.

1.1 Site Area and Location

The study area is located in the City of Burlington, and includes the portion of Falcon Creek between the CNR and Willowbrook Road that runs through privately and publicly owned lands. A study area location plan is provided in **Figure 1.1**. Falcon Creek continues downstream of the study area to the eventual outlet of the creek into Lake Ontario.

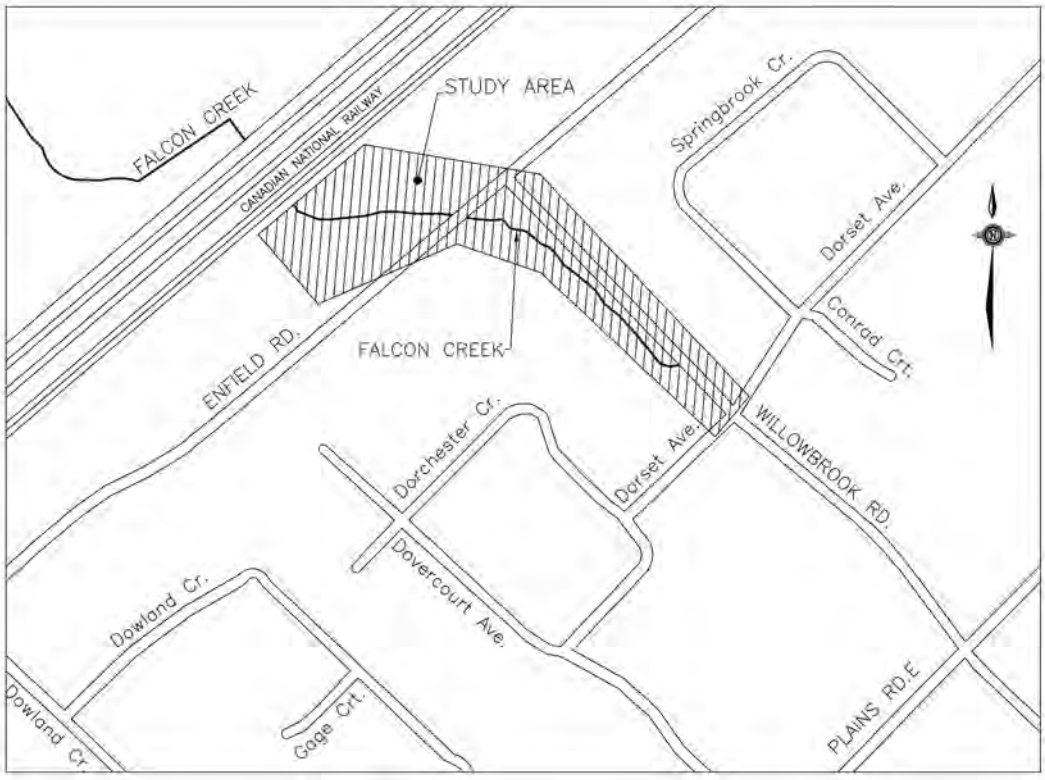


Figure 1.1: Study Area Location Plan

1.2 Problem Identification and Purpose of Study

The City of Burlington is undertaking the preparation of erosion control and detailed design for a section of Falcon Creek extending from the CN Railroad to Willowbrook Road following the Municipal Class Environmental Assessment (EA).

As reported in the *City of Burlington 2020 Creeks Inventory and Erosion Assessment* report, sections of this reach have been significantly eroded and remediation measures are required as private properties and public infrastructure are at risk. The City retained Valdor Engineering to complete the *Falcon Creek Hydrology and Hydraulics Study* (Dec 2012) and additional investigations on Falcon Creek were completed as part of the Aldershot Go Major Transit Station Area (MTSA) Study.

The length of the study area is approximately 275 meters within City easements on private property and the public road allowance along Willowbrook Road. Falcon Creek outlets to Hamilton Harbour and Lake Ontario and includes a drainage area of approximately 380 ha. Land uses within the watershed consist of rural and residential/industrial developed areas and includes the Burlington Golf and Country Club near the downstream limit of the watershed at North Shore Boulevard.

The project purpose is to complete an erosion control study to identify a preferred set of alternatives to stabilize the existing creek erosion, including bank sections that have fallen into the creek which has resulted in creek instability and ongoing erosion. The project includes the completion of the erosion control study and proposed design while following the Class EA process. This includes the completion of surveys and field investigations to analyze available alternatives and present the preferred solution for detailed design and construction, while considering hydraulic impacts and revising existing modelling. Detailed design and construction supervision will also be included as a part of the project, pending successful completion of the preceding project components.

1.3 Study Scope

The scope of this project is limited to the following components:

- Background review of available relevant studies and reports provided by the City;
- Field inspections and topographical survey of the for the subject reach of Falcon Creek;
- Completion of geotechnical investigation for subject reach of Falcon Creek;
- Completion of a geomorphological assessment of the subject reach of Falcon Creek;
- Completion of a natural environment assessment for the subject reach of Falcon Creek;
- Completion of an archaeological assessment for the subject reach of Falcon Creek;
- Preparation of several design options and the selection of a preferred option based on a decision matrix analysis and meetings with the City, CH and the Public;
- Preparation of a conceptual design and cost estimate for the preferred option;
- Preparation of detailed design, cost estimate and construction contract documents for the preferred option; and
- Providing construction inspection services, a monitoring program and as-constructed drawings for the preferred option.

1.4 Municipal Class Environmental Assessment

The study is being completed as per the EA Process as a Schedule B project, in accordance with the Municipal Class Environmental Assessment process, which is an approved process under the *Environmental Assessment Act* (2015). The Public Information Centre (PIC) was held virtually on Wednesday, 08 March 2023. This study fulfills Phase 1 and Phase 2 of the Municipal Class Environmental Process.

Based on discussions at the PIC and comments received, the Public is generally supportive of the proposed efforts by the City to mitigate erosion along the subject reach of Falcon Creek. Miscellaneous documentation including notices, comments from the Public, indication of how comments were addressed, and presentation materials provided at the PIC will be included in the Project File as per Municipal Class EA process requirements. Key PIC documents and a copy of the comments received are provided in **Appendix C**.

1.5 Previously Completed Available Studies and Information

A review of the following studies and key design drawings provided by the City and CH was completed in preparing the report for the Tuck Creek Erosion Control Study:

- Aquafor Beech Ltd., *City of Burlington 2020 Creeks Inventory and Erosion Assessment*, 26 May 2021.
- Valdor Engineering, *Falcon Creek Hydrology and Hydraulic Study*, December 2012.
- Hydraulic models for the study area provided by the City and CH.
- Miscellaneous plans and available design and as-constructed drawings, air photos and satellite images, and topographic mapping for the study area provided by the City of Burlington and Conservation Halton.

2.0 SITE INVESTIGATIONS AND EVALUATION OF EXISTING CONDITIONS

2.1 Additional Completed Site Investigations

A number of additional background investigations were completed as part of the erosion control study and referred to in the review and evaluation of various mitigation options. These investigations included a topographic survey, a geotechnical study, a natural environment assessment, archaeological study, a geomorphological study and general field inspections. Copies of the various additional reports are provided in **Appendix A**. A summary of the results and recommendations of the reports are provided in the following sections.

2.1.1 Topographic Survey

A topographic survey was completed by Water's Edge for the subject reach of Falcon Creek, which was used along with available bare earth LiDAR data sets to generate elevation contours for the creek area. The base map prepared including contours is provided in Drawing **DWG-3.1** in **Section 3.0**.

2.1.2 Geotechnical Studies

A geotechnical investigation of the Falcon Creek erosion sites was performed by Soil Engineers Ltd. to evaluate the subsoil and groundwater conditions in the vicinity of potential design and construction works associated with potential mitigation regarding the creek erosion sites. The field work, consisting of eight (8) boreholes extending to depths ranging from 3.7 to 6.7 m below grade, was completed between 05 and 07 December 2022. The locations of the boreholes are illustrated on Drawing Nos. 1 and 2 in the *Geotechnical Assessment for Erosion Control Study and Rehabilitation, Enfield Road and Willowbrook Road, City of Burlington* (Soil Engineers, 19 January 2023) included in **Appendix A**. Based on the investigation completed, it was determined that the steep eroded slopes within the subject site are likely the result of shallow translational slope failure. Loss of support for the slopes was caused by toe erosion at the edge of the creek. Existing tree roots have slowed the rate of erosion of the slopes, although undercutting has exposed roots and caused trees to lean towards the slope in some cases.

The boreholes completed determined that beneath a layer of earth fill extending to the depths from 1.9 to 3.5 m, the site is underlain by a silty clay till with localized sand deposit in some borehole locations. Upon completion of the field work, groundwater was recorded at depths from 3.5 to 6.6 m below grade. Due to the proximity of Falcon Creek, groundwater can be expected at the level of the creek bottom during the wet season. During the dry season, the groundwater can be lower than the creek bottom, as observed during our field investigation. The groundwater is subject to seasonal fluctuations of the water level in the creek.

In addition, a soils chemical analysis was conducted in conjunction with the geotechnical investigation to determine the environmental quality of the soils at the site and to meet the applicable Ministry of the Environment, Conservation and Parks (MECP) Standards. A copy of the report entitled *Soils Characterization, Erosion Control Study and Rehabilitation, Falcon Creek, City of Burlington* (Soils Engineers, 14 February 2023) is provided in **Appendix A**.

Representative soil samples were collected from 6 of the 8 boreholes to determine the environmental quality of the samples collected. The samples were sent to AGAT Laboratories, accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA), for chemical

analysis of Metals and Inorganics (M&I), Polycyclic Aromatic Hydrocarbons (PAHs) and Petroleum Hydrocarbons (PHCs) parameters.

A review of the results of the soil samples indicates that, the tested parameters at the tested locations meet the Table 2.1 ICC ESQS Standards. The results of the analysis for the field duplicate sample (DUP S1) yielded concentration of Barium of 248 µg/g which exceeds the Table 1 Standards value of 220 µg/g. The original sample (BH1/3) yielded concentration of Barium of 206 µg/g which meets the Table 1 Standards. Based on the findings, the concentration of Barium may be an isolated concentration within the sample collected at BH1. The overall concentration of Barium meets Table 2.1 RPI Standards.

2.1.3 Natural Environment Study

Field investigations were completed by North-South Environmental (NSE) to characterize the terrestrial, aquatic and wildlife resources and to provide an assessment of the ecological features and functions within the study area. A copy of the natural environment report entitled *Natural Heritage Existing Conditions and Constraints Analysis Report, Falcon Creek Erosion Control Project* (NSE, May 2024) is provided in **Appendix A**.

Specifically, the ecological investigations included an aquatic habitat assessment, fish community assessment, ecological land classification (ELC), botanical inventory, and wildlife assessment. Ecological field investigations were conducted by NSE staff between 08 June 2022 and 07 December 2022. In addition, screening was completed for species at risk, significant wildlife habitat and significant woodland.

Aquatic Habitat Assessment

An aquatic habitat assessment was completed on 07 July 2022, for the stretch of Falcon Creek within the study area. This assessment included observations of fish, substrates, instream-cover, wetted and bankfull width, water and bankfull depth, and in-stream (as applicable) and riparian / bank vegetation. Through the assessment specific consideration was given to identify existing constraints and opportunities to improve fish habitat and fish passage. Upstream of Enfield Road, there was no instream vegetation. Dominant riparian vegetation consisted of Crack Willow (*Salix fragilis*) and Black Walnut (*Juglans nigra*) which provides approximately 40% overhanging vegetation shade cover within the upstream reach. Fish barriers within the upstream reach included downed woody debris and the closed-bottom culverts at low flow. Downstream of Enfield Road, there was no instream vegetation. Dominant riparian vegetation consisted of primarily Black Walnut (*Juglans nigra*) and Crack Willow (*Salix fragilis*) which provides approximately 30% overhanging vegetation shade cover within the downstream reach. Fish barriers within the downstream reach included downed woody debris, rock debris, and the closed-bottom culverts leading under Enfield Rd, and a closed-bottom culvert and culvert grate leading under Willowbrook Road.

Fish Community

The downstream (‘Reach 1’) and upstream (‘Reach 2’) reaches of Falcon Creek within the study area were surveyed on 07 July 7 2022 by two ecologists with Class 2 Backpack Electrofishing certification to assess fish community composition and aquatic habitat characteristics including the thermal regime. During NSE aquatic habitat assessment, two species were recorded residing in the study area. These species were Western Blacknose Dace and Creek Chub. Land Information Ontario (LIO) and fisheries information provided by Conservation Halton were reviewed, however, no species were identified within the specific study area but were present in

Falcon Creek. No known Species at Risk (SPA) fish species occur within the study area or Falcon Creek.

Ecological Land Classification (ELC)

Vegetation communities in the study area were assessed using the Ecological Land Classification (ELC) system for Southern Ontario (Lee et al, 1998) by a qualified practitioner. Vegetation community mapping is shown in Figure 4 of the natural heritage report provided in **Appendix A**. One vegetation community type (two units) and one anthropogenic area was identified within the study area including "Fresh-Moist Willow Lowland Deciduous Forest" (FOD7-3), and "Manicured", respectively. Ash trees appear to have been one of the dominant trees in this community until recently. The dead standing ash trees appear to have succumbed to damage from the non-native Emerald Ash Borer.

Botanical Inventory

A single-season flora inventory was conducted by a qualified vegetation ecologist. The locations of any Species at Risk, provincially rare species, or regionally rare species were recorded. Incidental vegetation records were also recorded during other field surveys. Of the plant species documented:

- 31 (58%) are native, and 22 (42%) species are non-native.
- No Species at Risk (SAR) were recorded.
- No species are provincially rare.
- Two (2) species are regionally uncommon in Halton Region: Canada Garlic (*Allium canadense var. canadense*), Eastern Red Cedar (*Juniperus virginiana var. virginiana*)

Wildlife

Breeding bird surveys were conducted by a qualified avian ecologist using the OBBA survey protocol (OBBA 2001). Two visits were conducted in Spring/Summer of 2022, separated by at least 14 days. A total of 25 species of birds were noted during breeding bird surveys and incidentally during other field surveys. Four Barn Swallow (*Hirundo rustica*) and two Chimney Swift (*Chaetura pelagica*), both Species at Risk, were observed foraging along the creek north of Enfield Road.

Bat screening assessments were completed by a qualified ecologist from NSE. Two visits were conducted on 10 June and 13 June 2022. The survey was a screening-level assessment to determine potential presence of bat species in the area. Of the bat passes recorded, there were three different bat species:

- Big Brown Bat (*Eptesicus fuscus*)
- Eastern Red Bat (*Lasiurus borealis*)
- Hoary Bat (*Lasiurus cinereus*)

All three bat species are considered of secure status in Ontario, and none are listed under the provincial Endangered Species Act.

A tree bat habitat assessment was completed by a qualified ecologist from NSE on 07 December 2022. Thirty-three trees in the area of possible impact have potential to provide suitable bat habitat. This indicates habitat potential and does not confirm whether roosting is present or absent.

Six additional wildlife species were recorded within the study area. Species observed include five mammals and one insect species: Eastern Grey Squirrel (*Sciurus caroliniensis*), Eastern Chipmunk (*Tamias striatus*), Green Frog (*Lithobates clamitans*), Red Squirrel (*Tamiasciurus hudsonicus*), Raccoon (*Procyon lotor*), and Ebony Jewelwing (*Calopteryx maculate*). None of these species is Species at Risk or provincially rare.

Species at Risk / Significant Wildlife Habitat / Significant Woodland

A list of Species at Risk (SAR) which could potentially occur in the area was compiled based on the background review. The presence or potential presence of Significant Wildlife Habitat (SWH) in the study area was assessed using the SWH Criteria Schedules for Ecoregion 7E (OMNRF, 2015). The two treed units along Falcon Creek within the study area (one located north of Enfield Road, and the other south of Enfield Road) are believed to meet the stand density threshold to be considered 'woodland' though field measurements were not undertaken to confirm this. However, as both units are less than 0.5 ha in size they do not meet criteria to be considered 'significant woodland'.

Summary of Natural Heritage Constraints

Based on the background review, existing conditions, and policy review and assessment completed by NSE, a summary of ecological constraints is provided in **Table 2.1**.

Table 2.1: Summary of Natural Heritage Constraints

Constraint	Assessment
Fish and Fish Habitat	**Present.** Falcon Creek is fish habitat. Depending on the alternative selected, there may be potential for impact to fish and fish habitat. A DFO Request for Review may be required once the design alternative has been selected.
Species at Risk	**Present** (Barn Swallow and Chimney Swift). Additional SAR may be present.
Significant Wildlife Habitat	**Present** One type of confirmed SWH is present: Habitat for Special Concern and Rare Wildlife Species. There are six types of candidate (i.e., 'potential') SWH: Bat Maternity Colonies, Turtle Wintering Areas, Reptile Hibernacula, Migratory Butterfly Stopover Areas, and Turtle Nesting Areas.
Significant Woodland	None present.
Significant Valleyland	None present.
Life Science Area of Natural and Scientific Interest (ANSI)	None present.
Natural Heritage System	None present.
Savannah, Tallgrass Prairie, Alvar	None present.
Provincially Significant Wetlands or Other Wetlands	None present.
Migratory Bird Nesting Habitat	**Present** The study area supports migratory birds that could be disturbed during erosion control works.
Conservation Halton Regulated Area	**Present** The study area is within Conservation Halton's regulated limit. A permit from Conservation Halton is required.
Conservation Halton Hazard Lands	**Present** Conservation Halton has hazard lands mapped within the study area (floodplain hazard, stable top of slope hazard, and meander belt hazard). A permit from Conservation Halton is required.

2.1.4 Geomorphological Study

A fluvial geomorphology assessment was completed by Water's Edge (WE) for the 275 m long subject reach of Falcon Creek. A copy of the geomorphological report entitled *Falcon Creek Fluvial Geomorphological Assessment and Channel Design, Burlington, Ontario* (Water's Edge, 12 April 2024) is included in **Appendix A**.

The purpose of this study was to determine geomorphic stream conditions and a general review of erosion and bankfull flows. Site inspections and a geomorphic survey of Falcon Creek were completed by WE staff on 16, 17, and 26 May 2022 followed by a Creek walk on 29 June 2022. Falcon Creek is a 3rd order stream that flows through the Escarpment and Sand Plains physiographic regions and drains into Lake Ontario. To carry out the fluvial geomorphic and erosion assessment, a geomorphic survey of approximately 275 m of the stream reach in the area of interest was carried out. The sediment substrate in the riffles of the studied reach was dominated by gravels and cobbles. As such, the study reach was determined to show characteristics of a Rosgen C3/C4 channel. The field investigations indicate that the bankfull discharge is approximately 5.16 m^3/s. Bank erosion is occurring within the reach. The channel has been classified as 'In Adjustment' and 'Fair' conditions for river stability.

Erosion Site #1

Erosion Site #1 is a steep left bank and is having bank failure of non-cohesive bank material. Though the bank has lots of gravel, the angle of the bank combined with the silty sand is at risk for erosion due to the flow resulting in stress greater than the critical shear stress of the bank material. There is also undercutting at the bank. This is the outside bank of a curve and would have the highest velocities in the channel. The right bank opposite ES#1 is a point bar, with deposition taking place. Across from point bars creating a vortex flow which can lead to the undercutting of the bank due to the geometry of the cross section. The banks are almost vertical at points which is at risk of continued degradation over time. The rate of erosion is not high.

Erosion Site #2

Erosion Site #2 is across from ES #1. The top of bank has been eroding causing fences and trees to lean into the river. Judging by the slope of the bank there has been slump/rotational failure in the bank and or possible frost heave associated with it. The bank appears to be less course material than the RB so it would react differently to the flows. The private infrastructure is not at current risk, but it is unsightly. Though there is deposition at this site, it is not enough to make up for the erosion. Compared to a 2015 photo, the site has not been altered significantly. As a result, annual erosion rates are seen to be low.

Erosion Site #3

Erosion Site #3 is along Willowbrook Road. This is a cut bank on a corner of the creek. As it is the outside bank it will have the highest velocities of the cross section. The bank is unnaturally steep and is close to public infrastructure (Willowbrook Road). The toe of the slope has been completely eroded away. There is minimal vegetation to stabilize the bank. The bank material appears to be silty clay which has the potential to slump. There are exposed tree roots indicating erosion.

Erosion Site #4

Erosion Site #4 is also along Willowbrook Road. The left bank is the site of erosion and is a steep bank. The section appears to have been straightened. The opposite side of the river has a gradual slope into the floodplain of private landowners. The site of erosion has public infrastructure at risk. The toe of the right bank has been undercut. Roots are exposed and there is almost no

vegetation to armor the bank. The channel is wider and deeper than other spots showing that the river is being entrenched and widened. Compared to a 2015 photo, the top of bank has been eroded further. Based on the 2015 photo there are trees that have recently fallen over. In 2022, the roots have been exposed further. This site has the highest priority due to the high rate of erosion and proximity to Willowbrook Road.

2.1.5 Archaeological Assessment

A Stage 1 and Stage 2 archaeological assessment was completed by AMICK Consultants Limited for the 275 m long subject reach of Falcon Creek. The purpose of the assessment was to identify sites, to assess the cultural heritage value or interest of identified archaeological sites, and to recommend the most appropriate strategies for those archaeological sites where mitigation of impacts is necessary. Stage 1 (Background Study and Property Inspection) includes a review of the geography, land use and historical information for the study area and is often supplemented with a property inspection. Stage 2 (Property Assessment) consists of a survey of the property that includes strategies employed, depending on the nature of the property (*e.g.* walking a ploughed field, test-pitting, etc.). As a result of the Stage 1 and Stage 2 Property Assessment of the study area completed by AMICK, no archaeological resources were encountered and the following recommendations were provided:

- No further archaeological assessment of the study area is warranted.
- The Provincial interest in archaeological resources with respect to the proposed undertaking has been addressed.
- The proposed undertaking is clear of any archaeological concern.

A copy of the archaeological assessment is provided in **Appendix A**.

2.1.6 Economic and Social Environment

Based on observations during field investigations, the existing environment within the study area is described as follows:

- There is some economic activity based on the commercial and industrial businesses; and,
- Economic growth is limited.

The existing social environment within the study area is described as follows:

- The current land use consists of primarily of residential lands with a small amount of commercial / industrial lands;
- Some persons are employed within the study area;
- Residential and employment densities have been relatively constant for many years; and,
- Development expansion is restricted by the current floodplain and railroad corridor.

2.1.7 General Field Inspections

Based on observations during field surveys and creek walks, four key erosion sites were identified within the subject reach where existing banks are in poor condition. There were some additional areas where minor erosion is occurring but not presenting any immediate issues. Some minor debris piles were also noted within the subject reach consisting of fallen trees, branches, leaves, and other debris that has accumulated over time. The four erosion sites identified were named Erosion Sites #1, #2, #3 and #4, and the approximate location of each is shown on Drawing **DWG 3.1** in **Section 3**.

A shed in disrepair and fallen wooden fencing was observed within the lot associated with 417 Enfield Road near Erosion Site #2 and piles of leaves, branches, and other yard waste were found apparently dumped on the bank slopes within the city-owned creek block adjacent 420 Enfield Road. In addition, raised gardens have been planted within the city-owned creek block adjacent 420 Enfield Road. The bank slope at Erosion Site #1 is steep but not as high as at Erosion Sites #3 and #4. The bank slope at Erosion Site #2 is relatively mild. Several trees along the top of slope at Erosion Site #3 and Erosion Site #4 also have roots that are exposed, as the soil supporting the trees has partially eroded away. Photos of the creek at Erosion Sites #1, #2, #3, and #4 are provided in **Photos 2.1**, **2.2**, **2.3** and **2.4**, respectively.

2.2 Hydrotechnical Review

A HEC-RAS hydraulic model was obtained from Conservation Halton for Falcon Creek. The hydraulic model section geometry was updated by Valdor based on the topographic survey and the available bare-earth LiDAR data sets. Additional cross sections were added to better define the locations of the identified erosion sites and where erosion mitigation works may be implemented. In addition, culvert details were updated based on field observations and measurements, as required. The existing hydraulic model will be updated at the detailed design stage based on the preferred erosion mitigation options to confirm that there is no increase in water surface elevations for the Regulatory storm (*i.e.* existing flooding conditions will not be impacted). Flows for the existing CH HEC-RAS model are summarized in **Table 2.2**, below. Based on a preliminary review of the existing CH model, 8 of the existing model cross-sections (2016.332 through 1737.330) fall within the subject reach. To prepare for the hydraulic analysis for the preferred alternative to be completed at detailed design, 7 additional cross-sections were added as required to better define the proposed changes to the creek. The hydraulic analysis is discussed further in **Section 4.1.1**.

Table 2.2: Summary of HEC-RAS Peak Flows through the Subject Site

Section	HEC-RAS Model Peak Flows (m^3/s)			
	2-year	5-year	100-year	Regional
1983.3 to 1779.8	3.03	7.46	20.57	25.35

Note: The current CVC HEC-RAS model includes the 100-yr and Regional flows only. The 2-yr and 5-yr peak flows were obtained from the *Falcon Creek Hydrology and Hydraulic Study* (Valdor, December 2012).

Photo 2.1: Erosion Site #1 – Falcon Creek Upstream of Enfield Road

Photo 2.2: Erosion Site #2 – Falcon Creek Upstream of Enfield Road

Photo 2.3: Erosion Site #3 – Falcon Creek Adjacent Willowbrook Road

Photo 2.4: Erosion Site #4 – Falcon Creek Adjacent Willowbrook Road

2.3 Review of Existing Services and Infrastructure in the Study Area

The subject reach of Falcon Creek receives drainage from the upstream watercourse through an existing 1.8 m diameter CSP culvert at the CNR line. Flow is conveyed through a second 1.5 m diameter concrete culvert under Enfield Road. The downstream end of the subject reach flows through an inlet grate to a 1.5 m diameter concrete pipe that is connected to a large MH on Willowbrook Road and then flows south through a 90 inch diameter stormsewer along Willowbrook Road. There are two outfall pipes that convey flow to the creek located within the subject reach, including a CSP outfall pipe which conveys drainage from 419 Enfield Road and a concrete outfall pipe located adjacent 417 Enfield Road that conveys drainage from the Enfield Road ditch via a CB.

A review of the existing services and infrastructure was completed based on visual observations during field work and referring to the as-constructed plan and profile drawings available from the City. A copy of the plan and profile drawings for Enfield Road (**Figure A.2**) and Willowbrook Road (**Figure A.3**) is provided in **Appendix A**. *Please note that, prior to construction, the Contractor shall complete a final review of available drawings and secure locates within the study area.* Based on our visual field observations and review of the available plan and profile drawings from the City, the following key services/infrastructure items were identified for consideration in completing the detailed design and construction of the proposed erosion mitigation works:

Reach Between CNR and Enfield Road

- 1.8 m diameter CSP culvert including headwall under the CNR.
- Wooden and chainlink fencing through private property along either side of the watercourse.
- 2 inch gasmain NW of Enfield Road.
- 15 inch sanitary sewer including MH's along Enfield Road.
- 8 inch watermain along Enfield Road.
- Hydro poles including wires along NE side of watercourse.
- Hydro poles including power lines, transformers, telephone, signage and street lighting along the NW side of Enfield Road.
- CSP outfall pipe located adjacent 419 Enfield Road.
- Concrete outfall pipe located adjacent 417 Enfield Road.
- 1.5 m diameter concrete culvert under Enfield Road including headwall and wingwall.

Reach Between Enfield Road and Willowbrook Road

- Hydro poles including power lines, telephone, signage and street lighting along the SW side of Willowbrook Road.
- Signage along Willowbrook Road.
- 15 inch sanitary sewer including MH's along Willowbrook Road.
- Guard rails along the SW side of Willowbrook Road.
- Stone HW and wingwalls and grate located at the inlet to the Willowbrook Road stormsewer.

- Wooden retaining wall adjacent 423 Dorset Avenue.
- 1.5 m diameter concrete inlet pipe and 15 feet by 12 feet box MH and 90 inch diameter stormsewer starting north of Dorset Avenue.

2.3.1 Stormsewer Outfall and Culvert Assessments

In completing the review of existing services and infrastructure, preliminary visual assessments were also conducted on 05 May 2022 regarding the condition of stormsewer outfalls and culverts within the study area. Photos of the two culverts, two stormswer outfalls and the inlet to the Willowbrook stormsewer within the study area are provided in **Photos D.1** through **D.9** in **Appendix D**. The results of the preliminary visual assessment are summarized as follows:

1. CNR Culvert – Photos of the CNR culvert are provided in **Photos D.1** and **D.2**. Based on our visual assessment, the CNR culvert appears to be in good condition.
2. Stormsewer Outfall Adjacent 419 Enfield Road – A photo of the CSP stormsewer outfall located adjacent 419 Enfield Road is provided in **Photo D.3**. Based on our visual assessment, the stormsewer outfall appears to be in good condition with only slight deformation.
3. Stormsewer Outfall Adjacent 417 Enfield Road – A photo of the concrete stormsewer outfall located adjacent 417 Enfield Road is provided in **Photo D.4**. Based on our visual assessment, the stormsewer outfall appears to be in good condition with only slight pipe cracking visible.
4. Enfield Road Culvert – Photos of the Enfield Road culvert are provided in **Photos D.5**, **D.6** and **D.7**. Based on our visual assessment, the Enfield Road culvert appears to be in good condition. It is noted that localized erosion is present on the east side of the upstream face where drainage from the Enfield Road ditch is conveyed to the creek. The area is lined with a quantity of rip rap and broken concrete but further investigations and the implementation of end treatment may be warranted to ensure the erosion does not worsen. Should repairs be deemed necessary, the City may consider the implementation of repairs through separate capital project funding within the Roads, Parks and Forestry Division.
5. Inlet to Willowbrook Road Stormsewer – Photos of the inlet to the Willowbrook stormsewer are provided in **Photos D.8** and **D.9**. Based on our visual assessment, the stormsewer inlet pipe appears to be in good condition. Portions of the stone headwall and south wingwall, however, are showing visible signs of deterioration (*i.e.* cracks and missing stones). As such, further investigations and mitigation works may be warranted to ensure the condition of the headwall and south wingwall does not worsen.

2.4 Identification of Key Issues

Several key issues were identified that are considered a part of this erosion mitigation study. These include the importance of mitigating existing erosion to protect infrastructure located on private and public property and to limit sediment released into the watercourse. Public safety is also a key concern at all erosion sites, as banks are generally steep and up to a few meters in height.

Erosion within the creek is both a naturally occurring phenomenon as well as the result of anthropogenic induced changes in the watershed characteristics (*i.e.* increase in development and impervious surfaces) over time that have lead to an overall increase in erosive forces acting on the watercourse bed and banks. The erosion that occurs within the study area at the key identified

erosion sites is predominantly the result of undercutting of the toe of the slope which then leads to shallow translational slope failure whereby the upper slope collapses leaving a steep failure surface devoid of vegetation that is vulnerable to further weathering and erosion from localized surface flow / runoff.

There are a total of four (4) significant erosion sites within the subject reach that were identified for potential mitigation works. These sites are discussed further in **Section 3.1**. Consideration must be given to the long term effectiveness of any proposed erosion control measures, while minimizing the initial cost and long-term maintenance requirements for the City. The proposed design should also attempt to maintain a naturalized channel to the extent possible. Channel capacity must be maintained to prevent an increase in upstream flooding due to the proposed erosion mitigation measures. Impacts to existing vegetation should be minimized; in particular trees identified as a being significant by NSE. The proposed works should minimize disturbance to local residents. During construction works, any existing services must also be protected or relocated as required.

2.5 Consideration of Impacts to the Natural, Social and Economic Environment

The proposed erosion mitigation design will have impacts (positive and negative) on the natural, social and economic environments. The natural environment is potentially affected by the erosion control works through: removal of existing vegetation and wildlife in and near the subject creek, the addition of vegetation as a part of the proposed works and the altering of the creek itself (which potentially impacts the downstream watercourse and receiving body of water). The social environment could be affected through increases or decreases in aesthetic value of the creek due to erosion control works, the ability to have access to the creek where safe to do so, the safety of the creek due to the steepness of erosion sites and through impacts to residents as a result of construction such as: noise, visual disruption, or loss of part of their property. The economic environment could be affected through: the protection or pushing back of property boundaries as a result of the design approach taken, the performing of functions such as reducing the amount of sediment entering the watercourse (which may have economic benefits) and the protection of infrastructure near the subject site. Additional discussion about the anthropogenic causes of erosion and how the proposed design will minimize them is included in **Section 3.4**.

3.0 MITIGATION OPTIONS

3.1 Key Areas Identified for Possible Mitigation

There are four (4) key locations identified within the subject site where erosion has occurred and where mitigation may be required. These locations are shown on Drawing **DWG 3.1** and include two sites located north of Enfield Road (Erosion Site #1 and Erosion Site #2) and two sites located south of Enfield Road along the west side of Willowbrook Road (Erosion Site #3 and Erosion Site #4). Erosion Site #1 is located on private property associated with 419 and 423 Enfield Road and Erosion Site #2 is located on private property associated with 415 and 417 Enfield Road. Although the City maintains an easement along the reach of Falcon Creek north of Enfield Road to the railroad, the area is confined, and access is challenging. Bank erosion associated with Erosion Sites #1 and #2 appears to be progressing slowly and, although there are buildings and structures nearby, these buildings and structures do not appear to be in imminent danger. Erosion Site #3 located on the west side of Willowbrook Road within the road ROW and south of Enfield Road is the one erosion site along this reach of Falcon Creek identified in the City of Burlington's *2020 Creeks Inventory and Erosion Assessment* (ABL, May 2021) and is considered the primary site of concern. The creek at this location is severely eroded with steep banks situated in close proximity to Willowbrook Road and poses a threat to both the road and associated infrastructure and services. Erosion site #4 is also located on the west side of Willowbrook Road within the road ROW and within the south part of the study area and north of Dorset Avenue. The erosion at this site consists of steep banks, although not as steep as Erosion Site #3, that extends for approximately 40 m parallel to the road. Similar to Erosion Site #3, the erosion has migrated close to Willowbrook Road and also poses a threat to both the road and associated infrastructure and services.

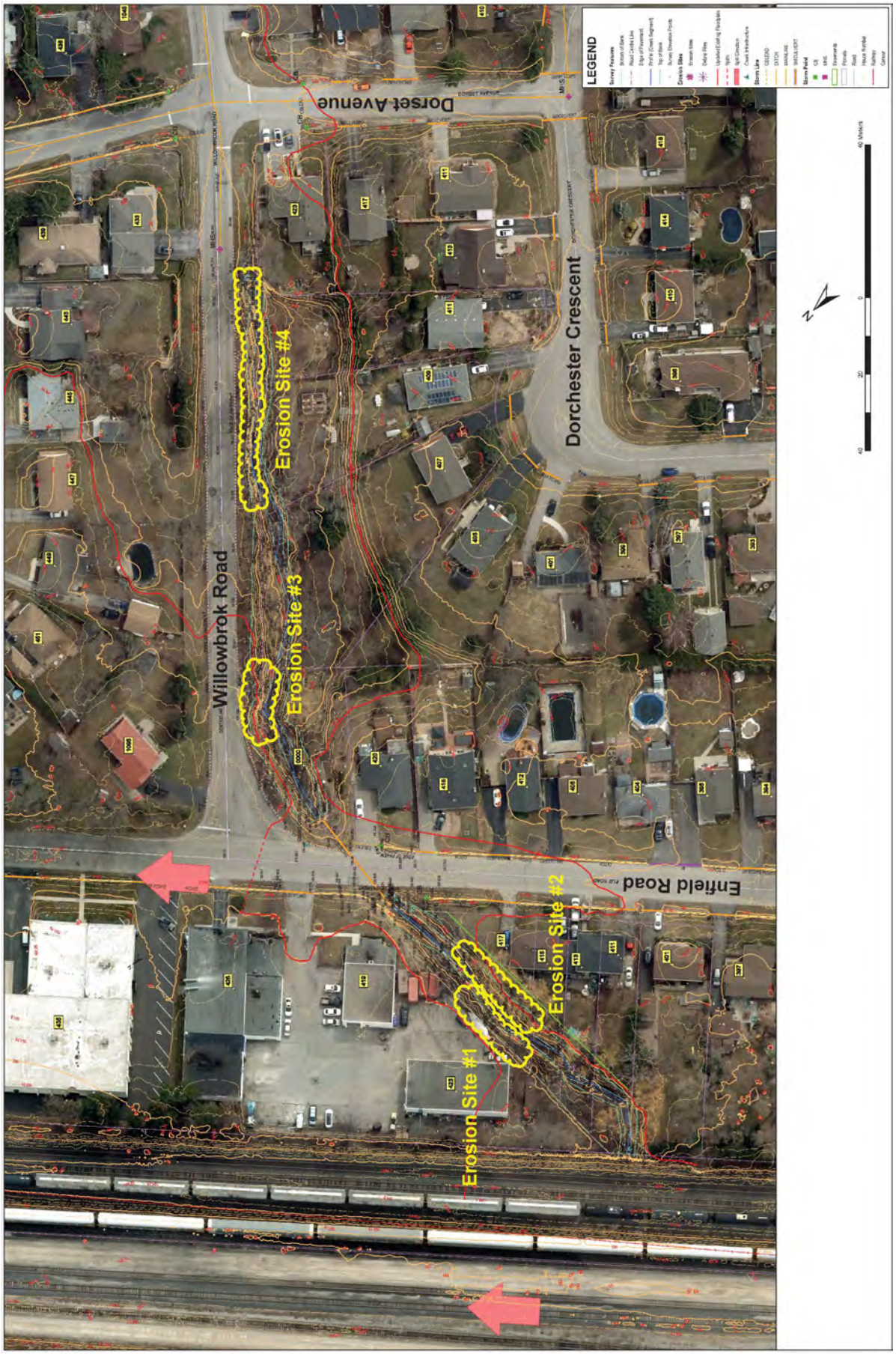
3.2 List of Mitigation Options

To complete an evaluation of alternatives for the proposed erosion mitigation of Falcon Creek, a number of potential options were analyzed. The list of options consists of several different scenarios for each erosion site that were designed to address the existing erosion within the subject reach of Falcon Creek. At Erosion Sites #1 and #2, a total of five options were considered, while six options were evaluated for Erosion Sites #3 and #4. A summary of the advantages and disadvantages of each of these options is provided in **Table 3.1**, **Table 3.2**, **Table 3.3** and **Table 3.4**. The alternatives are labeled Option 1 through Option 5/6 for each erosion site and this section provides a brief description of each alternative.

3.2.1 Erosion Site #1

Option 1 (Site #1) – Do Nothing (Existing Conditions)

Maintain the *status quo* (*i.e.* no erosion mitigation or other improvements). Without the erosion mitigation works, the subject reach will continue to erode, although at a slow rate based on preliminary field observations. Additional sediment will continue to be released at a slow rate to the downstream watercourse and lake due to continued bank erosion including potential impacts to aquatic and terrestrial habitat. Erosion Site #1 lies within private property not owned by the City, although the City does maintain access rights associated with an existing municipal easement. Since the site is located on private property that is fenced on either side, there are no obvious or specific safety concerns for the public or private landowners resulting from the existing erosion. Due to the confined nature of this site, it is not readily accessible for construction and there is a concern that more damage than good may result



DWG 3.1: Location of Identified Erosion Sites

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from any proposed mitigation works. There is some uncertainty, however, whether the rate of erosion could accelerate with time and present a concern for the adjacent buildings and structures in the future. This option could lead to future erosion control measures in this area being more costly to complete should mitigation be deemed necessary in the future. This option will prevent any disruption of the existing natural flora and fauna and potential damages to private property on-site due to construction. A figure showing the do nothing option (existing conditions) is included in **Figure 3.1** and a summary of the advantages and disadvantages is provided in **Table 3.1**.

Option 2 (Site #1) – Vegetated Slope (3:1 to 4:1)

Existing erosion at Erosion Site #1 could be addressed by filling and/or cutting the existing top of bank to a maximum final grade of 3:1 (H:V) with possible realignment of the watercourse. The proposed slope would be seeded/planted with low-light tolerant vegetation, and existing trees removed in the process would be replaced at the top of the slope. This option would provide a much more stable slope, while the realignment of the watercourse would prevent further erosion of the bank due to flow during frequent events including reduced downstream impacts to aquatic and terrestrial habitat. Channel realignment would provide long-term erosion control improvements with moderate maintenance costs. The disadvantages of this solution are that re-grading the existing bank would not be possible by fill alone (due to loss in floodplain storage) and additional cut within the floodplain and channel realignment would require the removal and replacement of existing trees including possible impacts to bat habitat. In addition, the use of fill on the east bank could result in a shift of the potential long term stable slope to the west. A significant issue with this approach is the further encroachment of the watercourse required within private property on the west side of the watercourse that would be located outside the existing municipal easement. A conceptual design layout for Option 2 is included in **Figure 3.2** and a summary of the advantages and disadvantages is provided in **Table 3.1**.

Option 3 (Site #1) – Vegetated Sub-Angular Riverstone Slope (2:1) or Vegetated Earth-Anchoring System at 2:1 Slope

This option employs riverstone toe protection to stabilize the base of the existing slope and either vegetated sub-angular riverstone or an earth anchoring system (Terrafirm or equivalent) and bioengineering to stabilize the top of the slope at 2:1 (H:V). This option involves cutting back the slope from the existing top of bank to a maximum final grade of 2:1 (H:V) with the stone toe protection installed up to the 2-year flood elevation. This option would allow the existing channel to be left as-is, while the east bank slope would be cut back to the west of the existing fence. The proposed slope would be seeded/planted with low-light tolerant vegetation, and existing trees removed in the process would be replaced at the top of the slope. This option would provide a stable slope that is highly naturalized and is a long term solution for erosion control including reduced downstream impacts to aquatic and terrestrial habitat. There would be less disturbance within private property than with a 3:1 cut/fill solution (Option 3) and there would be no increase in floodplain storage (assuming cut). Disadvantages of this solution are that cutting back the existing slope would require the removal and replacement of some existing trees including possible impacts to bat habitat and may result in shifting the long term stable slope to the east. Disadvantages of the riverstone toe protection and earth anchoring system include the relatively higher costs to build and maintain. A conceptual design layout for Option 3 is included in **Figure 3.3** and a summary of the advantages and disadvantages is provided in **Table 3.1**.

Option 4 (Site #1) – Vegetated Slope Stabilization System (1:1)

This option involves lining the existing eroded bank with stone toe protection up to the 2-year flood level to prevent further erosion of the bank. The remainder of the slope would be lined with a slope stabilization system (TerraSlope45 or equivalent) at a maximum slope of 1:1. The

Table 3.1: Summary of Erosion Mitigation Options – Erosion Site #1

Mitigation Option	Description	Advantages	Disadvantages
1	Do Nothing (Existing Conditions) – No mitigation work to be completed	• Cost savings (if erosion risk is low and if mitigation is not required) • No tree removal required or possible impacts to bat habitat • No disruptions/impacts during construction including disturbance to fish and other aquatic species	• Erosion issues may become worse, including sedimentation downstream including impacts to aquatic/terrestrial habitat • Ultimate repair costs will be higher (if mitigation is required) • Potential liability issues (private property) (if erosion risk is high)
2	Vegetated slope (3:1 to 4:1) with riverstone toe protection to the 2-yr water surface elevation with or without channel realignment and cut or fill to achieve the requisite slope	• Very naturalized long-term solution • Low-moderate maintenance costs • No reduction in floodplain storage (if slope is achieved by cut) • May improve natural channel sinuosity (with channel realignment) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Potential reduction in floodplain storage (if slope is achieved by fill) and channel realignment will be required • Tree removal required including possible impacts to bat habitat • Significant addition/removal of material required • Potential to shift long term stable slope west • Disturbance to private infrastructure (e.g. parking area, fencing) may occur (if slope is achieved by cut and maybe also with fill) • Construction required outside municipal easement • Unnecessary cost (if erosion risk is low and if mitigation is not required) • Temporary disturbance to fish and other aquatic species during construction
3	Vegetated sub-angular riverstone slope (2:1) or vegetated earth-anchoring system (e.g. Terrafirm) at 2:1 slope with geogrid and turf reinforcement mat and including riverstone toe protection to the 2-yr water surface elevation with or without channel realignment and cut or fill to achieve the requisite slope	• No reduction in floodplain storage (if slope is achieved by cut) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat • Tree removal requirements may be reduced compared to Options 2 or 4	• Potential long term maintenance costs • Potential to shift long term stable slope to east • Potential reduction in floodplain storage (if slope is achieved by fill) and not feasible without channel realignment • Unnecessary cost (if erosion risk is low and if mitigation is not required) • Tree removal required including possible impacts to bat habitat • Temporary disturbance to fish and other aquatic species during construction
4	Vegetated slope stabilization system (e.g. Terra Slope 45) with geogrid and erosion mat at 1:1 slope and including riverstone toe protection to the 2-yr water surface elevation	• No reduction in floodplain storage • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Significant excavation and engineered fill required • High construction cost • Tree removal required including possible impacts to bat habitat but less than Option 2 • Unnecessary cost (if erosion risk is low and if mitigation is not required) • Temporary disturbance to fish and other aquatic species during construction
5	Implement monitoring program (e.g. using erosion pins) to track and assess erosion risk and the requirement for mitigation	• Cost savings (if erosion risk is low and if mitigation is not required) • Provides more certainty whether mitigation is required • May avoid disruptions/impacts during construction including disturbance to fish and other aquatic species • Minimal natural heritage impacts (assuming construction is avoided)	• Ultimate repair costs will be higher (if mitigation is required) at a later time • Existing erosion may continue (although at a slow rate) that may result in degradation of terrestrial and aquatic habitats

benefits of this alternative are that tree removal would only need to occur within the slope and excavation area, there would be minimal reduction in floodplain storage and it is a more naturalized solution than using other options such as retaining walls. Disadvantages include the requirement for significant back-excavation and the installation of engineered fill, and a relatively high construction cost. Some trees on the slope within private property would also need to be removed including possible impacts to bat habitat, and there would be relatively high long term maintenance costs with this solution. A conceptual design layout for Option 4 is included in **Figure 3.4** and a summary of the advantages and disadvantages is provided in **Table 3.1**.

Option 5 (Site #1) – Implement Monitoring Program

Option 5 consists of the implementation of an erosion monitoring program to monitor and further quantify the rate of erosion over time. This approach is often preferred for sites where the impacts of erosion on buildings or other structures is not identified as an immediate concern, however, further data collection is warranted to better assess the rate of erosion and to ensure that it does not become a concern. Advantages of this approach include avoiding possible impacts to bat habitat and the disturbance to fish and other aquatic species during construction. Implementing this approach avoids the unnecessary expenditure of municipal funds and provides more certainty whether any mitigation works are, in fact, required. Should it be identified through monitoring that erosion is becoming a concern to buildings or other structure, the ultimate mitigation costs may be higher if the construction of mitigation works is completed at a later time. A conceptual design layout for Option 5 is included in **Figure 3.5** and a summary of the advantages and disadvantages is provided in **Table 3.1**.

3.2.2 Erosion Site #2

Option 1 (Site #2) – Do Nothing (Existing Conditions)

Maintain the *status quo* (*i.e.* no erosion mitigation or other improvements). Without the erosion mitigation works, the subject reach will continue to erode, although at a slow rate based on preliminary field observations. Additional sediment will continue to be released at a slow rate to the downstream watercourse and lake due to continued bank erosion including potential impacts to aquatic and terrestrial habitat. Erosion Site #2 lies within private property not owned by the City, although the City does maintain access rights associated with an existing municipal easement. Since the site is located on private property that is fenced on either side, there are no obvious or specific safety concerns for the public or private landowners resulting from the existing erosion. Due to the confined nature of this site, it is not readily accessible for construction and there is a concern that more damage than good may result from any proposed mitigation works. There is some uncertainty, however, whether the rate of erosion could accelerate with time and present a concern for the adjacent buildings and structures in the future. This option could lead to future erosion control measures in this area being more costly to complete should mitigation be deemed necessary in the future. This option will prevent any disruption of the existing natural flora and fauna and potential damages to private property on-site due to construction. A figure showing the do nothing option (existing conditions) is included in **Figure 3.6** and a summary of the advantages and disadvantages is provided in **Table 3.2**.

Option 2 (Site #2) – Vegetated Slope (3:1 to 4:1)

Existing erosion at Erosion Site #2 could be addressed by filling and/or cutting the existing top of bank to a maximum final grade of 3:1 (H:V) with possible realignment of the channel. The proposed slope would be seeded/planted with low-light tolerant vegetation, and existing trees removed in the process would be replaced at the top of the slope. This option would provide a much more stable slope, while the realignment of the channel would prevent further erosion of the bank due to flow during frequent events including reduced downstream impacts to aquatic and

Table 3.2: Summary of Erosion Mitigation Options – Erosion Site #2

Mitigation Option	Description	Advantages	Disadvantages
1	Do Nothing (Existing Conditions) – No mitigation work to be completed	• Cost savings (if erosion risk is low and if mitigation is not required) • No tree removal required or possible impacts to bat habitat • No disruptions/impacts during construction including disturbance to fish and other aquatic species	• Erosion issues may become worse including sedimentation downstream including impacts to aquatic/terrestrial habitat • Ultimate repair costs will be higher (if mitigation is required) • Potential liability issues (private property) (if erosion risk is high)
2	Vegetated slope (3:1 to 4:1) with riverstone toe protection to the 2-yr water surface elevation with or without channel realignment and cut or fill to achieve the requisite slope	• Very naturalized long-term solution • Low-moderate maintenance costs • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat • May improve natural channel sinuosity (with channel realignment)	• Potential reduction in floodplain storage (if cut/fill balance cannot be achieved within floodplain) • Unnecessary cost (if erosion risk is low and if mitigation is not required) • Tree removal required including possible impacts to bat habitat • Temporary disturbance to fish and other aquatic species during construction
3	Vegetated sub-angular riverstone slope (2:1) or vegetated earth-anchoring system (e.g. Terraform) at 2:1 slope with geogrid and turf reinforcement mat and including riverstone toe protection to the 2-yr water surface elevation with or without channel realignment and cut or fill to achieve the requisite slope	• No reduction in floodplain storage (if slope is achieved by cut) • Tree removal may be avoided if slope achieved with fill • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Potential long term maintenance costs • Potential reduction in floodplain storage (if slope is achieved by fill) and may not be feasible without channel realignment • Disturbance to private infrastructure (e.g. fencing) (if slope achieved by cut) • Unnecessary cost (if erosion risk is low and if mitigation is not required) • Tree removal required including possible impacts to bat habitat if slope achieved by cut • Temporary disturbance to fish and other aquatic species during construction
4	Vegetated slope stabilization system (e.g. Terra Slope 45) with geogrid and erosion mat at 1:1 slope and including riverstone toe protection to the 2-yr water surface elevation	• No reduction in floodplain storage • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Significant excavation and engineered fill required • High construction cost • Disturbance to private infrastructure may occur (e.g. fencing) • Tree removal required including possible impacts to bat habitat • Unnecessary cost (if erosion risk is low and if mitigation is not required) • Temporary disturbance to fish and other aquatic species during construction
5	Implement monitoring program (e.g. using erosion pins) to track and assess erosion risk and the requirement for mitigation	• Cost savings (if erosion risk is low and if mitigation is not required) • Provides more certainty whether mitigation is required • May avoid disruptions/impacts during construction including disturbance to fish and other aquatic species • Minimal natural heritage impacts (assuming construction is avoided)	• Ultimate repair costs will be higher (if mitigation is required) at a later time • Existing erosion may continue (although at a slow rate) that may result in degradation of terrestrial and aquatic habitats

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terrestrial habitat. Channel realignment would provide long-term erosion control improvements with low maintenance costs. The disadvantages of this solution are that re-grading the existing bank would not be possible by fill alone (due to loss in floodplain storage) and additional cut within the floodplain and channel realignment would require the removal and replacement of existing trees including possible impacts to bat habitat. A significant issue with this approach is the further encroachment of the watercourse required within private property on the west side of the watercourse. A conceptual design layout for Option 2 is included in **Figure 3.7** and a summary of the advantages and disadvantages is provided in **Table 3.2**.

Option 3 (Site #2) – Vegetated Sub-Angular Riverstone Slope (2:1) or Vegetated Earth-Anchoring System at 2:1 Slope

This option employs riverstone toe protection to stabilize the base of the existing slope and either vegetated sub-angular riverstone or an earth anchoring system (Terrafirm or equivalent) and bioengineering to stabilize the top of the slope at 2:1 (H:V). This option involves cutting back the slope from the existing top of bank to a maximum final grade of 2:1 (H:V) with the stone toe protection installed up to the 2-year flood elevation. This option would allow the existing channel to be left as-is, while the west bank slope would be cut back ensuring no loss in floodplain storage. A fence would likely be provided along the top of slope for public safety. The proposed slope would be seeded/planted with low-light tolerant vegetation, and existing trees removed in the process would be replaced at the top of the slope. This option would provide a stable slope that is highly naturalized and is a long-term solution for erosion control including reduced downstream impacts to aquatic and terrestrial habitat. A significant issue with this approach is the further encroachment of the watercourse required within private property on the west side of the watercourse. Disadvantages of this solution are that cutting back the existing slope would require the removal and replacement of some existing trees including possible impacts to bat habitat. Disadvantages of the riverstone toe protection and earth anchoring system include the relatively higher costs to build and maintain. A conceptual design layout for Option 3 is included in **Figure 3.8** and a summary of the advantages and disadvantages is provided in **Table 3.2**.

Option 4 (Site #2) – Vegetated Slope Stabilization System (1:1)

This option involves lining the existing eroded bank with stone toe protection up to the 2-year flood level to prevent further erosion of the bank . The remainder of the slope would be lined with a slope stabilization system (TerraSlope45 or equivalent) at a maximum slope of 1:1. A fence would likely be provided along the top of slope for public safety. The benefits of this alternative are that tree removal would only need to occur within the slope and excavation area, there would be minimal reduction in floodplain storage and it is a more naturalized solution than using other options such as retaining walls. Disadvantages include the requirement for significant back-excavation and the installation of engineered fill, and a relatively high construction cost. Some trees on the slope within private property would also need to be removed including possible impacts to bat habitat, and there would be relatively high long term maintenance costs with this solution. A significant issue with this approach is the further encroachment of the watercourse required within private property on the west side of the watercourse. A conceptual design layout for Option 4 is included in **Figure 3.9** and a summary of the advantages and disadvantages is provided in **Table 3.2**.

Option 5 (Site #2) – Implement Monitoring Program

Option 5 consists of the implementation of an erosion monitoring program to monitor and further quantify the rate of erosion over time. This approach is often preferred for sites where the impacts of erosion on buildings or other structures is not identified as an immediate concern, however, further data collection is warranted to better assess the rate of erosion and to ensure that it does not become a concern. Advantages of this approach include avoiding possible impacts to

bat habitat and the disturbance to fish and other aquatic species during construction. Implementing this approach avoids the unnecessary expenditure of municipal funds and provides more certainty whether any mitigation works are, in fact, required. Should it be identified through monitoring that erosion is becoming a concern to buildings or other structure, the ultimate mitigation costs may be higher if the construction of mitigation works is completed at a later time. A conceptual design layout for Option 5 is included in **Figure 3.10** and a summary of the advantages and disadvantages is provided in **Table 3.2**.

3.2.3 Erosion Site #3

Option 1 (Site #3) – Do Nothing (Existing Conditions)

Maintain the *status quo* (*i.e.* no erosion mitigation or other improvements). Without the implementation of erosion mitigation works, the subject reach will continue to erode and additional sediment will continue to be released to the downstream watercourse and lake including potential impacts to aquatic and terrestrial habitat. Erosion Site #3 lies mostly within the Willowbrook Road ROW and the City also owns a parcel of land opposite the erosion site on the west side of the creek. Although the do nothing alternative would provide short term cost savings and preclude the removal of any trees, the ultimate repair costs will only increase and public infrastructure (*i.e.* Willowbrook Road and utilities/services) will continue to be at high risk of potential damages. A figure showing the do nothing option (existing conditions) is included in **Figure 3.11** and a summary of the advantages and disadvantages is provided in **Table 3.3**.

Option 2 (Site #3) – Vegetated Slope (3:1 to 4:1)

Existing erosion at Erosion Site #3 could be addressed by filling the existing top of bank to a maximum final grade of 3:1 (H:V) with realignment of the channel. Cutting at this location to achieve a 3:1 slope is not possible without encroaching within Willowbrook Road. The proposed slope would be seeded/planted with low-light tolerant vegetation, and existing trees removed in the process would be replaced at the top of the slope. This option would provide a much more stable slope, while the realignment of the channel would prevent further erosion of the bank due to flow during frequent events including reduced downstream impacts to aquatic and terrestrial habitat. Channel realignment would provide long-term erosion control improvements with moderate maintenance costs and may provide an opportunity to improve the natural channel sinuosity. The disadvantages of this solution are that re-grading the existing bank with fill would reduce the existing floodplain storage and additional cut within the floodplain and channel realignment would require the removal and replacement of existing trees including possible impacts to bat habitat. Also, the addition of fill could shift the long term stable slope to the west. Since the property to the west of the Willowbrook Road ROW at this location is owned by the City, channel realignment and filling to the west would not encroach on private property. A conceptual design layout for Option 2 is included in **Figure 3.12** and a summary of the advantages and disadvantages is provided in **Table 3.3**.

Option 3 (Site #3) – Vegetated Earth-Anchoring System at 2:1 Slope and Bank Stabilization System at 0.125:1 Slope

This option employs a bank stabilization system (Scourlok or equivalent) to stabilize the base of the existing slope at 0.125:1 (H:V) and an earth anchoring system (Terrafirm or equivalent) with plantings to stabilize the top of the slope at 2:1 (H:V). A fence would be provided along the top of slope for public safety. This option involves cutting the slope from the existing top of bank to install the Scourlok units installed up to the 2-year flood elevation (or higher). The compact footprint that can be achieved with this design will avoid encroachment within Willowbrook Road and will avoid the need for channel realignment and will provide long-term erosion control improvements. The Scourlok units include a layer of topsoil on the front face that will be planted

with native vegetation species to achieve a more naturalized solution than armourstone (Options 5 or 6). The Terrafirm and Scourlok units are secured using earth anchors that minimizes the requirement for extensive back excavation. Tree removal will be required including possible impacts to bat habitat but less extensive than with Option 6. The compact footprint of this design avoids the potential shift in long term stable slope to the west and will achieve a net gain in floodplain storage. The disadvantages of this solution are that long term maintenance costs may be higher than Option 2. A conceptual design layout for Option 3 is included in **Figure 3.13** and a summary of the advantages and disadvantages is provided in **Table 3.3**.

Option 4 (Site #3) – Vegetated Slope Stabilization System (1:1)

This option involves cutting and lining the existing eroded bank with stone toe protection up to the 2-year flood level to prevent further erosion of the bank including reduced downstream impacts to aquatic and terrestrial habitat. The remainder of the slope would be cut and lined with a slope stabilization system (TerraSlope45 or equivalent) at a maximum slope of 1:1. A fence would likely be provided along the top of slope for public safety. The benefits of this alternative are the minimal reduction (or possible increase) in floodplain storage and it is a more naturalized solution than using other options such as retaining walls. Also, tree removal to the west of the watercourse would be avoided including possible impacts to bat habitat. Disadvantages include the requirement for significant back-excavation and the installation of engineered fill, and relatively high construction and maintenance costs. An advantage of this approach is the minimal encroachment to the west of the Willowbrook Road ROW, however, this is not a significant constraint since the City owns the property to the west. A conceptual design layout for Option 4 is included in **Figure 3.14** and a summary of the advantages and disadvantages is provided in **Table 3.3**.

Option 5 (Site #3) – Partial Height Armourstone Retaining Wall

This option is similar to Option 4, with armourstone blocks used to stabilize the base of the existing slope instead of riverstone. The top portion of the slope would be stabilized using vegetated sub-angular riverstone at a slope of 2:1, an earth anchoring system at a slope of 2:1 (Terrafirm or equivalent) with bioengineering or a slope stabilization system at a slope of 1:1 (TerraSlope45 or equivalent). A fence would likely be provided along the top of the retaining wall or top of slope for public safety. This option would require less armourstone and a shorter wall height than Option 6 and would involve very little disturbance to municipal infrastructure with no reduction in floodplain storage. Disadvantages of the armourstone wall and earth anchoring system or slope stabilization system include relatively high construction and maintenance costs. Also, tree removal is required including possible impacts to bat habitat. Although it is more natural than Option 6, armourstone is not a naturalized solution and may not be well supported by Conservation Halton. Significant excavation is required but less than Option 6. A conceptual design layout for Option 5 is included in **Figure 3.15** and a summary of the advantages and disadvantages is provided in **Table 3.3**.

Option 6 (Site #3) – Full Height Armourstone Retaining Wall

This option is similar to Option 5, with armourstone blocks extending the full height of the slope and without the need for further stabilization of the upper banks. The primary advantages of this option include the minimal amount of encroachment required within the watercourse and the robust level of protection provided regarding erosion. A fence would be provided along the top of the retaining wall for public safety. This option would require more armourstone and a higher wall height than Option 5 and would involve minimal disturbance to municipal infrastructure (although more than for Option 5) with no reduction in floodplain storage. Disadvantages of the armourstone wall include high construction and maintenance costs. Also, tree removal is required including possible impacts to bat habitat. In addition, armourstone is not a naturalized solution

Table 3.3: Summary of Erosion Mitigation Options – Erosion Site #3

Mitigation Option	Description	Advantages	Disadvantages
1	Do Nothing (Existing Conditions) – No mitigation work to be completed	• Short term cost savings • No tree removal required or possible impacts to bat habitat (although trees may fall over due to erosion) • No disruptions/impacts during construction including disturbance to fish and other aquatic species	• Erosion issues will become worse including sedimentation downstream and including loss of trees and aquatic/terrestrial habitat due to erosion • Ultimate repair costs will be higher • High risk of damages to public infrastructure
2	Vegetated slope (3:1 to 4:1) with riverstone toe protection to the 2-yr water surface elevation with or without channel realignment and cut or fill to achieve the requisite slope	• Very naturalized long-term solution • Low-moderate maintenance costs • No reduction in floodplain storage (if slope is achieved by cut) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat • May improve natural channel sinuosity (with channel realignment)	• Potential reduction in floodplain storage (if slope is achieved by fill) and channel realignment is required • Trees will require removal including possible impacts to bat habitat and replacement on slope and at location of realigned channel • Potential to shift long term stable slope to west • Disturbance to public infrastructure (e.g. Willowbrook Rd) will occur (if slope is achieved by cut) • Temporary disturbance to fish and other aquatic species during construction
3	Vegetated earth-anchoring system (e.g. Terrafirm) at 2:1 slope with geogrid and turf reinforcement mat and bank stabilization system (e.g. Scourlok) at 0.125:1 slope with earth anchors with cut to achieve the requisite slope	• Tree removal requirements may be reduced including possible impacts to bat habitat compared to Options 4,5 or 6 • Channel realignment may be avoided • Disturbance to public infrastructure (e.g. Willowbrook Rd) will be minimized/avoided • Avoids potential shift in long term stable slope to the west (compared with fill options) • No reduction in floodplain storage • Provides more naturalized solution than armourstone (Options 5 or 6) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Potential long term maintenance costs • Tree removal including possible impacts to bat habitat required including possible impacts to bat habitat (but less than Options 4, 5 or 6) • Temporary disturbance to fish and other aquatic species during construction
4	Vegetated slope stabilization system (e.g. Terra Slope 45) with geogrid and erosion mat at 1:1 slope and including riverstone toe protection to the 2-yr water surface elevation	• No reduction in floodplain storage • Tree removal requirements may be reduced including possible impacts to bat habitat compared to Option 2 • No channel realignment required • Provides more naturalized solution than armourstone (Options 5 or 6) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Significant excavation and engineered fill required • Potential disturbance to public infrastructure (e.g. Willowbrook Rd) • High construction cost • Tree removal required including possible impacts to bat habitat • Temporary disturbance to fish and other aquatic species during construction
5	Partial height armourstone retaining wall for bottom portion of the slope including riverstone toe protection with the top portion of the slope either with vegetated sub-angular riverstone (2:1 slope) or vegetated earth anchoring system (e.g. Terrafirm) at 2:1 slope with geogrid and turf reinforcement mat or vegetated slope stabilization system (e.g. Terra Slope 45) with geogrid and erosion mat at 1:1 slope	• Less armourstone required than Mitigation Option 6 • No reduction in floodplain storage • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat • Disturbance to public infrastructure (e.g. Willowbrook Rd) may be avoided/minimized	• Less 'hard' armouring than Option 6 but still not well supported by Conservation Authority or First Nations (not naturalized) • Costly to build and maintain • Tree removal required including possible impacts to bat habitat • Significant excavation required but less than for Option 6 • Temporary disturbance to fish and other aquatic species during construction
6	Full height armourstone retaining wall with riverstone toe protection	• No reduction in floodplain storage • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Not well supported by Conservation Authority or First Nations (not naturalized) • Costly to build and maintain • Tree removal required including possible impacts to bat habitat • May not be feasible without disturbance to public infrastructure (e.g. Willowbrook Rd) • Significant excavation required • Temporary disturbance to fish and other aquatic species during construction

and is not well supported by Conservation Halton. Significant excavation is required but less than Option 6. A conceptual design layout for Option 3 is included in **Figure 3.16** and a summary of the advantages and disadvantages is provided in **Table 3.3**.

3.2.4 Erosion Site #4

Option 1 (Site #4) – Do Nothing (Existing Conditions)

Maintain the *status quo* (*i.e.* no erosion mitigation or other improvements). Without the implementation of erosion mitigation works, the subject reach will continue to erode and additional sediment will continue to be released to the downstream watercourse and lake including potential impacts to aquatic and terrestrial habitat. Erosion Site #4 lies within the Willowbrook Road ROW, however, the site lies immediately adjacent private property located to the west and the existing low flow channel straddles the demarcation line between City and private property along this reach of the watercourse. Although the do nothing alternative would provide short term cost savings and preclude the removal of any trees, the ultimate repair costs will only increase and public infrastructure (*i.e.* Willowbrook Road and utilities/services) will continue to be at high risk of potential damages. A figure showing the do nothing option (existing conditions) is included in **Figure 3.17** and a summary of the advantages and disadvantages is provided in **Table 3.4**.

Option 2 (Site #4) – Vegetated Slope (3:1 to 4:1)

Existing erosion at Erosion Site #4 could be addressed by filling the existing top of bank to a maximum final grade of 3:1 (H:V) with realignment of the channel. Cutting at this location to achieve a 3:1 slope is not possible without encroaching within Willowbrook Road. The proposed slope would be seeded/planted with low-light tolerant vegetation, and existing trees removed in the process would be replaced at the top of the slope including possible impacts to bat habitat. This option would provide a much more stable slope, while the realignment of the channel would prevent further erosion of the bank due to flow during frequent events including reduced downstream impacts to aquatic and terrestrial habitat. Channel realignment would provide long-term erosion control improvements with moderate maintenance costs and may provide an opportunity to improve the natural channel sinuosity. The disadvantages of this solution are that re-grading the existing bank with fill would reduce the existing floodplain storage and additional cut within the floodplain and channel realignment would require the removal and replacement of existing trees. Also, the addition of fill could shift the long term stable slope to the west. A significant constraint to filling at this location is the fact that a portion of the watercourse along the west side of this reach is located outside of the Willowbrook Road ROW on private property and with no existing municipal easement. A conceptual design layout for Option 2 is included in **Figure 3.18** and a summary of the advantages and disadvantages is provided in **Table 3.4**.

Option 3 (Site #4) – Vegetated Earth-Anchoring System at 2:1 Slope and Bank Stabilization System at 0.125:1 Slope

This option employs a bank stabilization system (Scourlok or equivalent) to stabilize the base of the existing slope at 0.125:1 (H:V) and an earth anchoring system (Terrafirm or equivalent) with plantings to stabilize the top of the slope at 2:1 (H:V). A fence would be provided along the top of slope for public safety. This option involves cutting the slope from the existing top of bank to install the Scourlok units installed up to the 2-year flood elevation (or higher). The compact footprint that can be achieved with this design will avoid encroachment within Willowbrook Road and also private property outside the road R.O.W. and will provide long-term erosion control improvements. The Scourlok units include a layer of topsoil on the front face that will be planted with native vegetation species to achieve a more naturalized solution than armourstone (Options 5 or 6). The Terrafirm and Scourlok units are secured using earth anchors that

minimizes the requirement for extensive back excavation. Tree removal will be required (although many are non-native species) including possible impacts to bat habitat but less extensive than with Option 6. The compact footprint of this design avoids the potential shift in long term stable slope to the west and will achieve a net gain in floodplain storage. The disadvantages of this solution are that long term maintenance costs may be higher than Option 2.

A conceptual design layout for Option 3 is included in **Figure 3.19** and a summary of the advantages and disadvantages is provided in **Table 3.4**.

Option 4 (Site #4) – Vegetated Slope Stabilization System (1:1)

This option involves cutting and lining the existing eroded bank with stone toe protection up to the 2-year flood level to prevent further erosion of the bank including reduced downstream impacts to aquatic and terrestrial habitat. The remainder of the slope would be cut and lined with a slope stabilization system (TerraSlope45 or equivalent) at a maximum slope of 1:1. A fence would likely be provided along the top of slope for public safety. The benefits of this alternative are the minimal reduction (or possible increase) in floodplain storage and it is a more naturalized solution than using other options such as retaining walls. Tree removal to the east of the creek would be required (although many are non-native species) including possible impacts to bat habitat, however, tree removal to the west of the watercourse would be avoided. Disadvantages include the requirement for significant back-excavation and the installation of engineered fill, and relatively high construction and maintenance costs. It is possible this option may encroach within Willowbrook Road should significant back excavation be required. A significant advantage of this approach is it would avoid any encroachment within private property to the west of the Willowbrook Road ROW. A conceptual design layout for Option 4 is included in **Figure 3.20** and a summary of the advantages and disadvantages is provided in **Table 3.4**.

Option 5 (Site #4) – Partial Height Armourstone Retaining Wall

This option is similar to Option 4, with armourstone blocks used to stabilize the base of the existing slope instead of riverstone. The top portion of the slope would be stabilized using vegetated sub-angular riverstone at a slope of 2:1, an earth anchoring system at a slope of 2:1 (Terrafirm or equivalent) with bioengineering or a slope stabilization system at a slope of 1:1 (TerraSlope45 or equivalent). A fence would likely be provided along the top of the retaining wall or top of slope for public safety. This option would require less armourstone and a shorter wall height than Option 6 and would involve very little disturbance to municipal infrastructure with no reduction in floodplain storage. Disadvantages of the armourstone wall and earth anchoring system or slope stabilization system include relatively high construction and maintenance costs. Although it is more natural than Option 6, armourstone is not a naturalized solution and may not be well supported by Conservation Halton. Significant excavation is required but less than Option 6. Also, tree removal is required (although many are non-native species) including possible impacts to bat habitat. This option should avoid construction on private property. A conceptual design layout for Option 5 is included in **Figure 3.21** and a summary of the advantages and disadvantages is provided in **Table 3.4**.

Option 6 (Site #4) – Full Height Armourstone Retaining Wall

This option is similar to Option 5, with armourstone blocks extending the full height of the slope and without the need for further stabilization of the upper banks. The primary advantages of this option include the minimal amount of encroachment required within the watercourse and the robust level of protection provided regarding erosion. A fence would be provided along the top of the retaining wall for public safety. This option would require more armourstone and a higher wall height than Option 5 and would involve minimal disturbance to municipal infrastructure (although more than for Option 5) with no reduction in floodplain storage. Disadvantages of the

Table 3.4: Summary of Erosion Mitigation Options – Erosion Site #4

Mitigation Option	Description	Advantages	Disadvantages
1	Do Nothing (Existing Conditions) – No mitigation work to be completed	• Short term cost savings • No tree removal required or possible impacts to bat habitat (although trees may fall over due to erosion) • No disruptions/impacts during construction including disturbance to fish and other aquatic species	• Erosion issues will become worse including sedimentation downstream and including loss of trees and aquatic/terrestrial habitat due to erosion • Ultimate repair costs will be higher • High risk of damages to public infrastructure
2	Vegetated slope (3:1 to 4:1) with riverstone toe protection to the 2-yr water surface elevation with or without channel realignment and cut or fill to achieve the requisite slope	• Very naturalized long-term solution • Low-moderate maintenance costs • No reduction in floodplain storage (if slope achieved by cut) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Potential reduction in floodplain storage (if slope is achieved by fill) • Trees will require removal including possible impacts to bat habitat and replacement on slope and at location of realigned channel (although many are non-native species) • Disturbance to public infrastructure (e.g. Willowbrook Rd) will occur (if slope is achieved by cut) • Works will encroach on private property (if slope achieved by fill) and channel realignment will be required • Temporary disturbance to fish and other aquatic species during construction
3	Vegetated earth-anchoring system (e.g. Terrafirm) at 2:1 slope with geogrid and turf reinforcement mat and bank stabilization system (e.g. Scourlok) at 0.125:1 slope with earth anchors with cut to achieve the requisite slope	• Tree removal requirements may be reduced including possible impacts to bat habitat compared to Option 6 • Channel realignment may be avoided • Disturbance to public infrastructure (e.g. Willowbrook Rd) will be minimized/avoided with flexibility to reduce footprint in 'tight' areas by stacking Scourlok units • Avoids potential shift in long term stable slope to the west (compared with fill options) • Provides increase in floodplain storage • Provides more naturalized solution than armourstone (Options 5 or 6) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat • Avoids works encroaching on private property	• Potential long term maintenance costs • Tree removal required including possible impacts to bat habitat (but less than Option 6) (although many are non-native species) • Temporary disturbance to fish and other aquatic species during construction
4	Vegetated slope stabilization system (e.g. Terra Slope 45) with geogrid and erosion mat at 1:1 slope and including riverstone toe protection to the 2-yr water surface elevation	• No reduction in floodplain storage • Provides more naturalized solution than armourstone (Options 5 or 6) • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat • May avoid works encroaching on private property	• Significant excavation and engineered fill required • High construction cost • Disturbance to public infrastructure (e.g. Willowbrook Rd) may occur at some locations • Tree removal required including possible impacts to bat habitat (although many are non-native species) • Temporary disturbance to fish and other aquatic species during construction
5	Partial height armourstone retaining wall for bottom portion of the slope including riverstone toe protection with the top portion of the slope either with vegetated sub-angular riverstone (2:1 slope) or vegetated earth anchoring system (e.g. Terrafirm) at 2:1 slope with geogrid and turf reinforcement mat or vegetated slope stabilization system (e.g. Terra Slope 45) with geogrid and erosion mat at 1:1 slope	• Less armourstone required than option 6 • Possible increase in floodplain storage • May avoid works encroaching on private property • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Less 'hard' armouring than Option 6 but still not well supported by Conservation Authority or First Nations (not naturalized) • Costly to build and maintain • Significant excavation required but less than Option 6 • Tree removal required including possible impacts to bat habitat (although many are non-native species) • Disturbance to public infrastructure (e.g. Willowbrook Rd) may occur at some locations • Temporary disturbance to fish and other aquatic species during construction
6	Full height armourstone retaining wall with riverstone toe protection	• No reduction in floodplain storage • May avoid works encroaching on private property • Will improve bank stabilization and reduce sedimentation downstream including impacts to aquatic/terrestrial habitat	• Not well supported by Conservation Authority or First Nations (not naturalized) • Costly to build and maintain • Potential to shift long term stable slope to east (to be checked at detailed design) • Significant excavation required • Tree removal required including possible impacts to bat habitat (although many are non-native species) • Disturbance to public infrastructure (e.g. Willowbrook Rd) may occur at some locations • Temporary disturbance to fish and other aquatic species during construction

armourstone wall include high construction and maintenance costs. In addition, armourstone is not a naturalized solution and is not well supported by Conservation Halton. Also, tree removal is required (although many are non-native species) including possible impacts to bat habitat. Significant excavation is required. This option should avoid construction on private property. A conceptual design layout for Option 6 is included in **Figure 3.22** and a summary of the advantages and disadvantages is provided in **Table 3.4**.

3.3 Evaluation of Mitigation Options

3.3.1 Evaluation Criteria

The evaluation criteria selected for ranking the various options are based on an established evaluation procedure used by Conservation Halton for similar projects following the Municipal Class EA Process. The evaluation criteria relate to the natural, social and economic environments that are key considerations required to successfully navigate the EA process. Accordingly, the evaluation criteria were chosen to include the following:

- *Physical / Natural Environment Criteria*
    - mitigation of existing erosion risks;
    - impacts to aquatic habitat;
    - impacts to terrestrial habitat;
- *Technical and Engineering Criteria*
    - technical feasibility;
    - road safety;
    - control of flooding;
- *Social / Cultural Environment Criteria*
    - parks and recreation;
    - community disruption;
    - archaeological impacts;
- *Economic Environment Criteria*
    - construction costs; and,
    - maintenance costs.

Further details pertaining to the selected evaluation criteria are provided in Section 3.3.3.

3.3.2 Preliminary Cost Estimate for Scoring Purposes

In order to score the options in terms of total estimated cost, a preliminary relative cost estimate was prepared for each of the proposed options. A summary of the total relative estimated costs for scoring the options regarding construction and maintenance costs is provided in **Tables 3.5** and **3.6**, respectively.

Table 3.5: Total Preliminary Estimated Construction Costs (Relative) for Mitigation Options – for Scoring Purposes Only

Option	Preliminary Estimated Construction Cost			
	Erosion Site #1	Erosion Site #2	Erosion Site #3	Erosion Site #4
Option 1 (Do Nothing)	Low	Low	Low	Low
Option 2	Moderate	Moderate	Moderate-High	Moderate
Option 3	Moderate to Moderate-High	Moderate to Moderate-High	Moderate to Moderate-High	Moderate to Moderate-High
Option 4	High	High	High	High
Option 5	Low to Low-Moderate	Low to Low-Moderate	Moderate-High	Moderate-High
Option 6	-	-	High	High

The preliminary construction cost estimate (for scoring purposes only) does *not* include costs associated with any additional land acquisition (if required) or the relocation of underground services (if required).

Table 3.6: Total Preliminary Estimated Maintenance Costs (Relative) for Mitigation Options – for Scoring Purposes Only

Option	Preliminary Estimated Maintenance Cost			
	Erosion Site #1	Erosion Site #2	Erosion Site #3	Erosion Site #4
Option 1 (Do Nothing)	Low	Low	Low	Low
Option 2	Low-Moderate	Low-Moderate	Low-Moderate	Low-Moderate
Option 3	Moderate to Moderate-High	Moderate to Moderate-High	Moderate to Moderate-High	Moderate to Moderate-High
Option 4	Moderate-High	Moderate-High	Moderate-High	Moderate-High
Option 5	Low to Low-Moderate	Low to Low-Moderate	Moderate to Moderate-High	Moderate to Moderate-High
Option 6	-	-	Moderate	Moderate

3.3.3 Evaluation Procedure

The procedure developed by Conservation Halton was used to evaluate the various erosion mitigation options for each of the four identified erosion sites. Based on this procedure, a maximum score is assigned to each of the identified selection criteria. In addition, the maximum score for mitigation of erosion risk, impacts to aquatic environment and impacts to terrestrial

environment is further adjusted based on the existing condition of each site regarding the specific criteria. In this way, the maximum score is weighted more heavily for sites where the erosion risk is significant and where the existing aquatic and terrestrial habitat quality is high. The maximum score for each selection criterion was assigned as follows:

- Mitigation of Existing Erosion Risks (varies from 5.0 to 20.0);
- Impacts to Aquatic Habitat (varies from 0.0 to 10.0);
- Impacts to Terrestrial Habitat (varies from 0.0 to 10.0);
- Technical Feasibility – Project Complexity (2.5) and Infrastructure Impacts (5.0);
- Road Safety (2.5);
- Control of Flooding (5.0);
- Parks and Recreation (5.0);
- Community Disruption – Project Compatibility (5.0) and Disruption (5.0);
- Archaeological Impacts (5.0);
- Construction Costs (20.0); and,
- Maintenance Costs (5.0).

In order to calculate the preferred option, the total score for each option for each identified erosion site was calculated. Based on the evaluation procedure, the option with the highest total weighted score for each identified erosion site was determined to be the preferred alternative. Further details regarding the scoring procedure for the identified evaluation criteria are provided below.

Mitigation of Existing Erosion Risks

Where existing erosion risks are substantial, close to the maximum score of 20 may be achievable. Where erosion risks are lower, maximum scores are not achievable. Higher risk is generally defined as pending slope failure, potential loss of structures, potential impacts to critical infrastructure, etc. Lower risk is defined as minor bed/bank erosion toward a naturalized area or non-active use (*e.g.* vacant land), etc. Scoring is calculated based on the assigned degree of mitigation (cells shaded in green) multiplied by the adjusted maximum score divided by 10. Low risk is assigned a maximum score of 5, medium risk is assigned a maximum score of 10 and high risk is assigned a maximum score of 20.

Impacts to Aquatic Habitat

Where existing aquatic habitat is of higher quality, the maximum score of 10 is not achievable and it is also possible to achieve a negative score where harm is expected. Where the existing channel is degraded, full of rubbish/debris, has barriers to fish passage etc., the maximum score of 10 may be achievable. The adjusted maximum score is determined as follows:

- Existing Aquatic Habitat Quality is High – Maximum Score = 0
- Existing Aquatic Habitat Quality is Moderate – Maximum Score = 5
- Existing Aquatic Habitat Quality is Low – Maximum Score = 10

The degree of improvement/mitigation or impact (negative score) is scored in the evaluation table (cells shaded in green). Greater improvements to fish and aquatic habitat score higher.

Improvements may be with respect to restoration of bed materials/substrates, riparian plantings, reduced turbidity, improved passage/connectivity. Scoring also considers potential construction impacts (relative to existing conditions) where disruption is expected to result from construction. Where on-going degradation is expected under the do-nothing option this is typically considered a negative impact (negative score). If improvements are expected the score is positive and represents the potential for improvement relative to existing habitat quality and if harm is expected the specified negative value is used. Scoring is calculated based on the assigned degree of mitigation (cells shaded in green) multiplied by the adjusted maximum score divided by 10. If a negative degree of mitigation is assigned, however, that value is used instead for the scoring.

Impacts to Terrestrial Habitat

Where existing terrestrial habitat is of higher quality, the maximum score of 10 is not achievable and it is also possible to achieve a negative score where harm is expected. Where there is rubbish/debris and minimal/low quality riparian vegetation, etc., the maximum score of 10 may be achievable. The adjusted maximum score is determined as follows:

- Existing Terrestrial Habitat Quality is High – Maximum Score = 0
- Existing Terrestrial Habitat Quality is Moderate – Maximum Score = 5
- Existing Terrestrial Habitat Quality is Low – Maximum Score = 10

The degree of improvement/mitigation or impact (negative score) is scored in the evaluation table (cells shaded in green). Greater improvements to terrestrial habitat score higher such as increased buffers, increased planting density, inclusion of key features (*e.g.* raptor poles), etc. Scoring also considers potential construction impacts relative to existing conditions and including any loss of habitat for interim periods. Where on-going degradation is expected under the do-nothing option this is typically considered a negative impact (negative score). If improvements are expected the score is positive and represents the potential for improvement relative to existing habitat quality and if harm is expected the specified negative value is used. Scoring is calculated based on the assigned degree of mitigation (cells shaded in green) multiplied by the adjusted maximum score divided by 10. If a negative degree of mitigation is assigned, however, that value is used instead for the scoring.

Technical Feasibility

Options that result in lower project complexity considering permitting/coordination requirements with community members and stakeholders, etc. score higher than those options that result in higher project complexity. Similarly, options that result in fewer or less significant impacts to existing infrastructure (*e.g.* sewers, watermains, gas, roads) score higher than those options that result in greater impacts to existing infrastructure.

Road Safety

Options that result in greater proximity of the top of bank to the edge of pavement, road shoulder, guard rail scores lower as the road safety risk is considered greater.

Control of Flooding

Options that enable a greater reduction in flood risk to public and/or private lands for longer time score higher than options that increase or decrease only slightly the flood risk.

Parks and Recreation

Options that provide opportunities for increased safety or utility of trails and/or outdoor recreational facilities (*e.g.* improvements to parkland, trails, etc.) are assigned a higher score than those options that do not provide such opportunities.

Community Disruption

Options are assigned a score based on the compatibility of the proposed works with adjacent properties. For example, the removal or addition of features which reduces the utility for neighbouring lands results in a lower score. As an example, removal of mature vegetation adjacent residential properties results in a low score. Less disruption to the surrounding community and residents scores higher (*e.g.* consideration of traffic/road closures, access impacts to shops, etc.)

Archaeological Impacts

Options that result in less disturbance of areas with archaeological potential and cultural heritage resources are assigned a higher score than those options that result in greater disturbance.

Construction Costs

Options that incur a higher total net present value regarding construction costs of the proposed works, obtaining permits, etc. are assigned a lower score than options that incur a lower cost. Relative construction costs for each option for the identified erosion sites is provided in **Table 3.5**.

Maintenance Costs

Options with a lower total present value cost for maintaining proposed works throughout their anticipated design life are assigned a higher score than options with a high cost. Relative maintenance costs for each option for the identified erosion sites is provided in **Table 3.6**.

3.3.4 Results of the Evaluation

Summaries of the evaluation and scoring procedure results for each erosion site are provided in **Table 3.7**, **Table 3.8**, **Table 3.9** and **Table 3.10**. Based on this approach, the following preferred erosion mitigation alternatives were determined:

- Erosion Site #1 – (Option #5): Implement monitoring program (*e.g.* using erosion pins) to track and assess erosion risk and the requirement for erosion mitigation.
- Erosion Site #2 – (Option #5): Implement monitoring program (*e.g.* using erosion pins) to track and assess erosion risk and the requirement for erosion mitigation.
- Erosion Site #3 – (Option #3): Install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1 slope seeded and/or planted with native species vegetation to provide a durable and naturalized solution to protect Willowbrook Road from the current erosion risk.
- Erosion Site #4 – (Option #3): Install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1 slope seeded and/or planted with native species vegetation to provide a durable and naturalized solution to protect Willowbrook Road from the current erosion risk.

Table 3.7: Summary of Evaluation of Erosion Mitigation Options – Erosion Site #1

TABLE 3.7: SITE #1 - EVALUATION CRITERIA Falcon Creek Erosion Control Study		Maximum Score	Adjusted Maximum Score	Option 1 Do Nothing	Option 2 Vegetated Slope (3:1 to 4:1)	Option 3 Vegetated Sub-Angular Rivestone Slope (2:1) or Vegetated Earth-Anchoring System	Option 4 Vegetated Slope Stabilization System (1:1 Slope)	Option 5 Implement Monitoring Program
				SCORE				
Physical / Natural Environment Criteria								
Mitigation of Existing Erosion Risks	Where existing erosion risks are substantial, close to the maximum score may be achievable. Where erosion risks are lower, maximum scores are not achievable. **Higher Risk**: Pending slope failure, potential loss of structures, potential impacts to critical infrastructure, etc. **Lower Risk**: Minor bed/bank erosion toward a naturalized area or non active use (vacant land), etc. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10.	20.0	5.0	0.0	4.0	4.0	4.0	3.5
		10.0		0.0	8.0	8.0	8.0	7.0
Impacts to Aquatic and/or Terrestrial Habitat	Where existing aquatic habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score where harm is expected. Where the existing channel is degraded, full of rubbish/debris, has barriers to fish passage etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to fish and aquatic habitat would score higher. Improvements may be with respect to restoration of bed materials/substrates, riparian plantings, reduced turbidity, improved passage/connectivity. Scoring should also consider potential construction impacts (relative to existing conditions) where disruption is expected to result from construction. Where on-going degradation is expected under the do-nothing this could be considered a negative impact (negative score). Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	8.0	8.0	8.0	7.0
		10.0		-2.0	8.0	8.0	8.0	7.0
	Where existing terrestrial habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score when harm is expected. Where there's rubbish/debris or minimal/low quality riparian vegetation, etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to terrestrial habitat score higher, including increased buffers, increased planting density, inclusion of key features (e.g., raptor poles), etc. Scoring should also consider potential construction impact relative to existing conditions as well as consider the loss of habitat for interim periods. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	4.0	6.0	7.0	6.0
		10.0		-2.0	4.0	6.0	7.0	6.0
	Physical / Natural Environment Criteria Subtotal	**40.0**		**-4.0**	**14.0**	**18.0**	**19.0**	**16.5**
Technical and Engineering Criteria								
Technical Feasibility	Less complexity of the Project: Consider permitting/coordination requirements with community members and stakeholders, etc.	2.5		2.5	1.0	2.0	1.5	2.0
	Less impacts to existing infrastructure (e.g., sewers, watermains, gas, roads)	5.0		5.0	2.0	4.0	4.0	4.0
Road Safety	Closer proximity of top of bank to edge of pavement, road shoulder, guard rail scores lower	2.5		2.5	2.5	2.5	2.5	2.5
Control of Flooding	Greater reduction of flooding risks to public and/or private lands for longer time scores higher	5.0		2.0	4.0	4.0	4.0	3.0
	Technical and Engineering Criteria Subtotal	**15.0**		**12.0**	**9.5**	**12.5**	**12.0**	**11.5**
Social / Cultural Environment Criteria								
Parks and Recreation	Opportunities which increase safety or utility of trails and/or outdoor recreational facilities would score higher (e.g., improvements to parkland, trails, etc.)	5.0		2.0	3.0	3.0	3.0	3.0
Community Disruption	Compatibility of proposed works with adjacent properties (i.e. removal or addition of features which reduces utility for neighbouring lands scores lower). As an example, removal of mature vegetation adjacent residential properties would score lower.	5.0		4.0	2.0	3.0	4.0	4.0
	Less disruption to the surrounding community and residents scores higher (e.g., consideration of traffic/road closures, access impacts to shops, etc.)	5.0		4.0	2.0	2.0	2.0	3.0
Archaeological Impacts	Less disturbance of areas with archaeological potential and cultural heritage resources scores higher	5.0		4.0	3.0	4.0	4.0	4.0
	Social / Cultural Environment Criteria Subtotal	**20.0**		**14.0**	**10.0**	**12.0**	**13.0**	**14.0**
Economic Environment Criteria								
Construction and Maintenance Costs	Total net present value cost(s) of constructing the proposed works, obtaining permits, etc. This should also be considerate of anticipated life cycle costs expected to replace the structure over a set design life (e.g., 100 years). Higher costs score lower.	20.0		20.0	12.0	10.0	4.0	18.0
	Total present value cost for maintaining proposed works throughout their anticipated design life. Higher costs score lower.	5.0		5.0	4.0	2.5	2.0	4.5
	Economic Criteria Subtotal	**25.0**		**25.0**	**16.0**	**12.5**	**6.0**	**22.5**
Total		100.0		47.0	49.5	55.0	50.0	64.5

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Table 3.8: Summary of Evaluation of Erosion Mitigation Options – Erosion Site #2

TABLE 3.8: SITE #2 - EVALUATION CRITERIA Falcon Creek Erosion Control Study		Maximum Score	Adjusted Maximum Score	Option 1 Do Nothing	Option 2 Vegetated Slope (3:1 to 4:1)	Option 3 Vegetated Sub-Angular Rivestone Slope (2:1) or Vegetated Earth-Anchoring System	Option 4 Vegetated Slope Stabilization System (1:1 Slope)	Option 5 Implement Monitoring Program
				SCORE				
Physical / Natural Environment Criteria								
Mitigation of Existing Erosion Risks	Where existing erosion risks are substantial, close to the maximum score may be achievable. Where erosion risks are lower, maximum scores are not achievable. **Higher Risk**: Pending slope failure, potential loss of structures, potential impacts to critical infrastructure, etc. **Lower Risk**: Minor bed/bank erosion toward a naturalized area or non active use (vacant land), etc. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10.	20.0	5.0	0.0	4.0	4.0	4.0	3.5
		10.0		0.0	8.0	8.0	8.0	7.0
Impacts to Aquatic and/or Terrestrial Habitat	Where existing aquatic habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score where harm is expected. Where the existing channel is degraded, full of rubbish/debris, has barriers to fish passage etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to fish and aquatic habitat would score higher. Improvements may be with respect to restoration of bed materials/substrates, riparian plantings, reduced turbidity, improved passage/connectivity. Scoring should also consider potential construction impacts (relative to existing conditions) where disruption is expected to result from construction. Where on-going degradation is expected under the do-nothing this could be considered a negative impact (negative score). Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	8.0	8.0	8.0	7.0
		10.0		-2.0	8.0	8.0	8.0	7.0
	Where existing terrestrial habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score when harm is expected. Where there's rubbish/debris or minimal/low quality riparian vegetation, etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to terrestrial habitat score higher, including increased buffers, increased planting density, inclusion of key features (e.g., raptor poles), etc. Scoring should also consider potential construction impact relative to existing conditions as well as consider the loss of habitat for interim periods. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	4.0	6.0	7.0	6.0
		10.0		-2.0	4.0	8.0	7.0	6.0
	Physical / Natural Environment Criteria Subtotal	**40.0**		**-4.0**	**14.0**	**18.0**	**19.0**	**16.5**
Technical and Engineering Criteria								
Technical Feasibility	Less complexity of the Project. Consider permitting/coordination requirements with community members and stakeholders, etc.	2.5		2.5	1.0	2.0	1.5	2.0
	Less impacts to existing infrastructure (e.g., sewers, watermains, gas, roads)	5.0		5.0	2.0	4.0	4.0	4.0
Road Safety	Closer proximity of top of bank to edge of pavement, road shoulder, guard rail scores lower	2.5		2.5	2.5	2.5	2.5	2.5
Control of Flooding	Greater reduction of flooding risks to public and/or private lands for longer time scores higher	5.0		2.0	4.0	4.0	4.0	3.0
	Technical and Engineering Criteria Subtotal	**15.0**		**12.0**	**9.5**	**12.5**	**12.0**	**11.5**
Social / Cultural Environment Criteria								
Parks and Recreation	Opportunities which increase safety or utility of trails and/or outdoor recreational facilities would score higher (e.g., improvements to parkland, trails, etc.)	5.0		2.0	3.0	3.0	3.0	3.0
Community Disruption	Compatibility of proposed works with adjacent properties (i.e. removal or addition of features which reduces utility for neighbouring lands scores lower). As an example, removal of mature vegetation adjacent residential properties would score lower.	5.0		4.0	2.0	3.0	4.0	4.0
	Less disruption to the surrounding community and residents scores higher (e.g., consideration of traffic/road closures, access impacts to shops, etc.)	5.0		4.0	2.0	2.0	2.0	3.0
Archaeological Impacts	Less disturbance of areas with archaeological potential and cultural heritage resources scores higher	5.0		4.0	3.0	4.0	4.0	4.0
	Social / Cultural Environment Criteria Subtotal	**20.0**		**14.0**	**10.0**	**12.0**	**13.0**	**14.0**
Economic Environment Criteria								
Construction and Maintenance Costs	Total net present value cost(s) of constructing the proposed works, obtaining permits, etc. This should also be considerate of anticipated life cycle costs expected to replace the structure over a set design life (e.g., 100 years). Higher costs score lower.	20.0		20.0	12.0	10.0	4.0	18.0
	Total present value cost for maintaining proposed works throughout their anticipated design life. Higher costs score lower.	5.0		5.0	4.0	2.5	2.0	4.5
	Economic Criteria Subtotal	**25.0**		**25.0**	**16.0**	**12.5**	**6.0**	**22.5**
Total		100.0		47.0	45.5	55.0	50.0	64.5

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Table 3.9: Summary of Evaluation of Erosion Mitigation Options – Erosion Site #3

TABLE 3.9: SITE #3 - EVALUATION CRITERIA Falcon Creek Erosion Control Study		Maximum Score	Adjusted Maximum Score	Option 1 Do Nothing	Option 2 Vegetated Slope (3:1 to 4:1)	Option 3 Vegetated Earth-Anchoring (2:1) and Bank Stabilization (0.125:1) System	Option 4 Vegetated Slope Stabilization System (1:1 Slope)	Option 5 Partial Height Armourstone Retaining Wall	Option 6 Full Height Armourstone Retaining Wall
				SCORE					
Physical / Natural Environment Criteria									
Mitigation of Existing Erosion Risks	Where existing erosion risks are substantial, close to the maximum score may be achievable. Where erosion risks are lower, maximum scores are not achievable. **Higher Risk**: Pending slope failure, potential loss of structures, potential impacts to critical infrastructure, etc. **Lower Risk**: Minor bed/bank erosion toward a naturalized area or non active use (vacant land), etc. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10.	20.0	20.0	0.0	16.0	17.0	16.0	18.0	20.0
		10.0		0.0	8.0	8.5	8.0	9.0	10.0
Impacts to Aquatic and/or Terrestrial Habitat	Where existing aquatic habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score where harm is expected. Where the existing channel is degraded, full of rubbish/debris, has barriers to fish passage etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to fish and aquatic habitat would score higher. Improvements may be with respect to restoration of bed materials/substrates, riparian plantings, reduced turbidity, improved passage/connectivity. Scoring should also consider potential construction impacts (relative to existing conditions) where disruption is expected to result from construction. Where on-going degradation is expected under the do-nothing this could be considered a negative impact (negative score). Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	8.0	7.0	7.0	4.0	3.0
		10.0		-2.0	8.0	7.0	7.0	4.0	3.0
	Where existing terrestrial habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score when harm is expected. Where there's rubbish/debris or minimal/low quality riparian vegetation, etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to terrestrial habitat score higher, including increased buffers, increased planting density, inclusion of key features (e.g., raptor poles), etc. Scoring should also consider potential construction impact relative to existing conditions as well as consider the loss of habitat for interim periods. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	4.0	7.0	7.0	3.0	2.0
		10.0		-2.0	4.0	7.0	7.0	3.0	2.0
	Physical / Natural Environment Criteria Subtotal	40.0		-4.0	28.0	31.0	30.0	25.0	25.0
Technical and Engineering Criteria									
Technical Feasibility	Less complexity of the Project: Consider permitting/coordination requirements with community members and stakeholders, etc.	2.5		2.5	1.0	2.0	1.5	1.5	1.0
	Less impacts to existing infrastructure (e.g., sewers, watermains, gas, roads)	5.0		5.0	5.0	4.0	2.0	3.5	1.5
Road Safety	Closer proximity of top of bank to edge of pavement, road shoulder, guard rail scores lower	2.5		0.0	2.5	2.0	2.0	2.0	2.5
Control of Flooding	Greater reduction of flooding risks to public and/or private lands for longer time scores higher	5.0		2.0	1.0	4.5	4.5	4.5	5.0
	Technical and Engineering Criteria Subtotal	15.0		9.5	9.5	12.5	10.0	11.5	10.0
Social / Cultural Environment Criteria									
Parks and Recreation	Opportunities which increase safety or utility of trails and/or outdoor recreational facilities would score higher (e.g., improvements to parkland, trails, etc.)	5.0		2.0	3.0	3.0	3.0	3.0	3.0
Community Disruption	Compatibility of proposed works with adjacent properties (i.e. removal or addition of features which reduces utility for neighbouring lands scores lower). As an example, removal of mature vegetation adjacent residential properties would score lower.	5.0		4.0	2.0	4.0	4.0	3.0	3.0
	Less disruption to the surrounding community and residents scores higher (e.g., consideration of traffic/road closures, access impacts to shops, etc.)	5.0		4.0	3.0	3.0	2.5	2.0	1.0
Archaeological Impacts	Less disturbance of areas with archaeological potential and cultural heritage resources scores higher	5.0		4.0	3.0	4.0	2.5	3.0	2.0
	Social / Cultural Environment Criteria Subtotal	20.0		14.0	11.0	14.0	12.0	11.0	9.0
Economic Environment Criteria									
Construction and Maintenance Costs	Total net present value cost(s) of constructing the proposed works, obtaining permits, etc. This should also be considerate of anticipated life cycle costs expected to replace the structure over a set design life (e.g., 100 years). Higher costs score lower.	20.0		20.0	8.0	10.0	4.0	8.0	4.0
	Total present value cost for maintaining proposed works throughout their anticipated design life. Higher costs score lower.	5.0		5.0	4.0	2.5	2.0	2.5	3.0
	Economic Criteria Subtotal	25.0		25.0	12.0	12.5	6.0	10.5	7.0
Total		100.0		44.5	60.5	70.0	58.0	58.0	51.0

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Table 3.10: Summary of Evaluation of Erosion Mitigation Options – Erosion Site

TABLE 3.10: SITE #4 - EVALUATION CRITERIA Falcon Creek Erosion Control Study		Maximum Score	Adjusted Maximum Score	Option 1 Do Nothing	Option 2 Vegetated Slope (3:1 to 4:1)	Option 3 Vegetated Earth-Anchoring (2:1) and Bank Stabilization (0.125:1) System	Option 4 Vegetated Slope Stabilization System (1:1 Slope)	Option 5 Partial Height Armourstone Retaining Wall	Option 6 Full Height Armourstone Retaining Wall
				SCORE					
Physical / Natural Environment Criteria									
Mitigation of Existing Erosion Risks	Where existing erosion risks are substantial, close to the maximum score may be achievable. Where erosion risks are lower, maximum scores are not achievable. **Higher Risk**: Pending slope failure, potential loss of structures, potential impacts to critical infrastructure, etc. **Lower Risk**: Minor bed/bank erosion toward a naturalized area or non active use (vacant land), etc. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10.	20.0	20.0	0.0	16.0	17.0	16.0	18.0	20.0
		10.0		0.0	8.0	8.5	8.0	9.0	10.0
Impacts to Aquatic and/or Terrestrial Habitat	Where existing aquatic habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score where harm is expected. Where the existing channel is degraded, full of rubbish/debris, has barriers to fish passage etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to fish and aquatic habitat would score higher. Improvements may be with respect to restoration of bed materials/substrates, riparian plantings, reduced turbidity, improved passage/connectivity. Scoring should also consider potential construction impacts (relative to existing conditions) where disruption is expected to result from construction. Where on-going degradation is expected under the do-nothing this could be considered a negative impact (negative score). Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	6.0	7.0	7.0	4.0	3.0
		10.0		-2.0	6.0	7.0	7.0	4.0	3.0
	Where existing terrestrial habitat is of higher quality, maximum scores are not achievable and it is also possible to achieve a negative score when harm is expected. Where there's rubbish/debris or minimal/low quality riparian vegetation, etc., maximum scores may be achievable. The degree of improvement/mitigation or impact (negative score) is scored in the green box. Greater improvements to terrestrial habitat score higher, including increased buffers, increased planting density, inclusion of key features (e.g., raptor poles), etc. Scoring should also consider potential construction impact relative to existing conditions as well as consider the loss of habitat for interim periods. Scoring is calculated based on the assigned degree of mitigation (green box) multiplied by the adjusted maximum score divided by 10. However, if a negative degree of mitigation is assigned that value is used instead for the scoring.	10.0	10.0	-2.0	4.0	7.0	7.0	3.0	2.0
		10.0		-2.0	4.0	7.0	7.0	3.0	2.0
	Physical / Natural Environment Criteria Subtotal	40.0		-4.0	26.0	31.0	30.0	25.0	25.0
Technical and Engineering Criteria									
Technical Feasibility	Less complexity of the Project: Consider permitting/coordination requirements with community members and stakeholders, etc.	2.5		2.5	1.0	2.0	1.5	1.5	1.0
	Less impacts to existing infrastructure (e.g., sewers, watermains, gas, roads)	5.0		5.0	0.5	4.0	2.0	3.5	1.5
Road Safety	Closer proximity of top of bank to edge of pavement, road shoulder, guard rail scores lower.	2.5		0.0	0.0	2.0	2.0	2.0	2.5
Control of Flooding	Greater reduction of flooding risks to public and/or private lands for longer time scores higher.	5.0		2.0	1.0	4.5	4.5	4.5	5.0
	Technical and Engineering Criteria Subtotal	15.0		9.5	2.5	12.5	10.0	11.5	10.0
Social / Cultural Environment Criteria									
Parks and Recreation	Opportunities which increase safety or utility of trails and/or outdoor recreational facilities would score higher (e.g., improvements to parkland, trails, etc.)	5.0		2.0	3.0	3.0	3.0	3.0	3.0
Community Disruption	Compatibility of proposed works with adjacent properties (i.e. removal or addition of features which reduces utility for neighbouring lands scores lower). As an example, removal of mature vegetation adjacent residential properties would score lower.	5.0		4.0	1.0	4.0	4.0	3.0	3.0
	Less disruption to the surrounding community and residents scores higher (e.g., consideration of traffic/road closures, access impacts to shops, etc.)	5.0		4.0	1.0	3.0	2.5	2.0	1.0
Archaeological Impacts	Less disturbance of areas with archaeological potential and cultural heritage resources scores higher.	5.0		4.0	2.0	4.0	2.5	3.0	2.0
	Social / Cultural Environment Criteria Subtotal	20.0		14.0	7.0	14.0	12.0	11.0	9.0
Economic Environment Criteria									
Construction and Maintenance Costs	Total net present value cost(s) of constructing the proposed works, obtaining permits, etc. This should also be considerate of anticipated life cycle costs expected to replace the structure over a set design life (e.g., 100 years). Higher costs score lower.	20.0		20.0	12.0	10.0	4.0	8.0	4.0
	Total present value cost for maintaining proposed works throughout their anticipated design life. Higher costs score lower.	5.0		5.0	4.0	2.5	2.0	2.5	3.0
	Economic Criteria Subtotal	25.0		25.0	16.0	12.5	6.0	10.5	7.0
Total		100.0		44.5	51.5	70.0	58.0	58.0	51.0

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The advantages of the preferred alternatives include the following:

- The existing erosion along Falcon Creek will be mitigated with the erosion control strategy at the identified mitigation sites. The design will maintain the naturalized state of the creek as much as possible. Erosion control measures will consist of re-grading and bioengineering rather than with hard armouring where possible.

- The proposed erosion mitigation strategy will only address erosion that poses an immediate risk to adjacent private and public infrastructure, minimizing construction impacts and costs. Public safety will also be addressed where possible.

- All construction works will be completed on land currently owned by the City, without the need to impact or negotiate with adjacent landowners regarding the purchase of additional property.

3.4 Impacts of the Preferred Mitigation Options on the Environment

The impacts of the preferred creek erosion control option on the natural, social and economic environments are anticipated to be generally positive. The proposed solutions at each of the four identified erosion sites will reduce the amount of sediment released into Falcon Creek due to erosion, which will be beneficial to the stream and receiving bodies of water. This will reduce the TSS loading (including any adsorbed contaminants) of the downstream watercourse, improving water quality in the creek and Lake Ontario. The proposed alternatives also entail planting more native species of trees and shrubs near the watercourse. This will further stabilize the banks, reducing the amount of sediment being released into the creek, improving water quality and providing additional shading to the creek, which will reduce the thermal impacts on the watercourse. Infiltration and evapotranspiration will also be promoted with the addition of more vegetation cover. The erosion control measures will also protect the existing creek banks, vegetation, property boundaries, and other infrastructure.

While erosion is a naturally occurring phenomenon, it is often exacerbated by anthropogenic factors such as development over time within upstream catchments and local activities in urban watercourses such as the subject reach of Falcon Creek. Contributing factors to erosion may include increases in impervious surfaces in the upstream drainage area, the dumping of debris onto the banks of the creek and the trampling of vegetation near the creek. While historical development was constructed to a different design standard, modern urban design criteria regarding stormwater management has evolved and improved in recent decades to include the mitigation of erosion. The proposed erosion mitigation works will avoid potential damages to Willowbrook Road and associated infrastructure within the road ROW that could otherwise result in negative economic impacts.

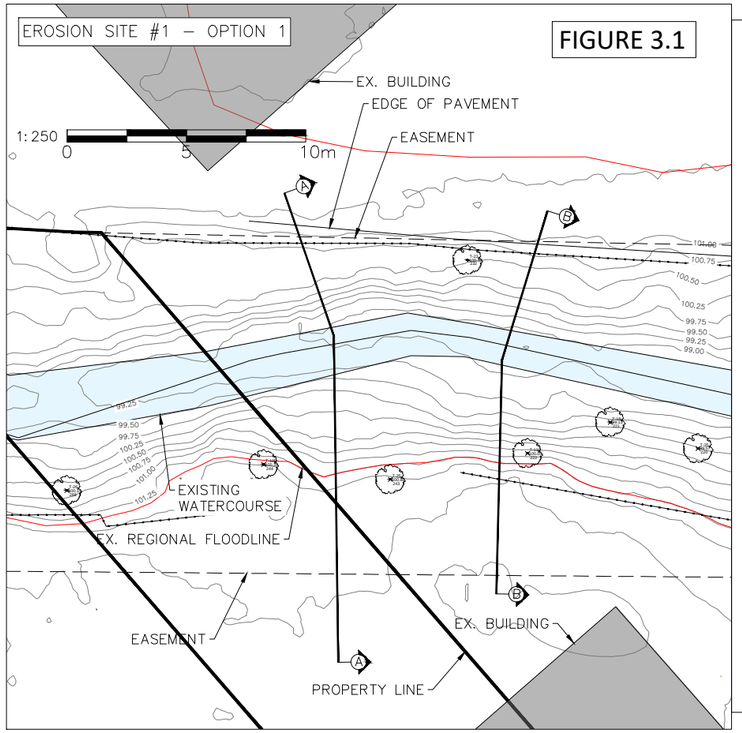
Regarding local activities that may also exacerbate creek erosion, the overall proposed erosion mitigation strategy aims to address these issues by suggesting the City educate property owners and frequent users of this space about the impacts of dumping yard waste and debris within the creek and valley and the importance of maintaining a healthy undergrowth to stabilize soils along the watercourse. In addition, such an education program could inform residents about different LID measures that could be installed within residential lots to promote infiltration, reduce impervious surfaces and improve vegetation cover, all of which would reduce runoff to the creek that may further contribute to bank erosion. The public could be educated about these approaches

through information mailed to residents near and adjacent the subject site. This material could also include any incentives that the City may choose to offer that would encourage residents to install LID practices or other technologies.

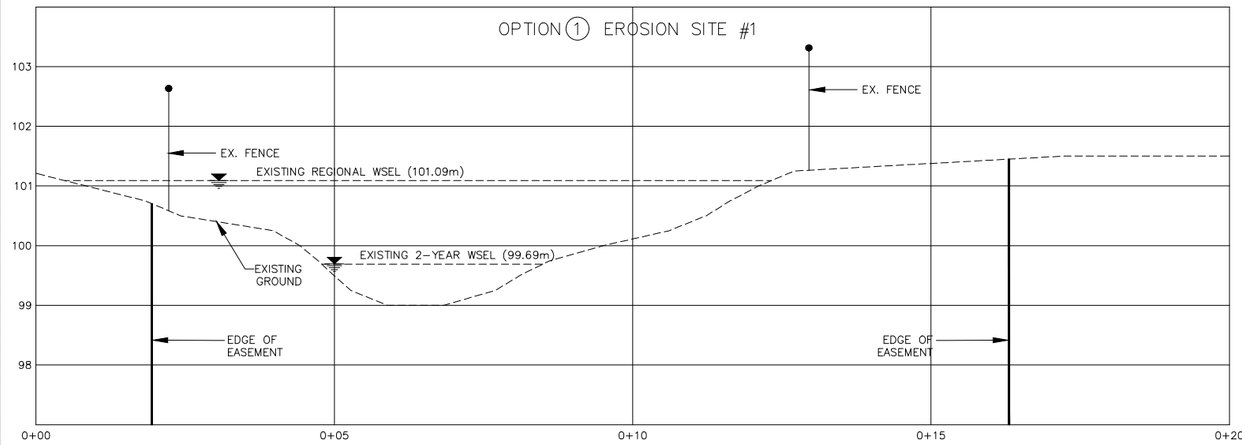
Construction activities may cause temporary increases in sediments entering Falcon Creek although erosion and sediment control measures, including by-pass pumping to enable working in the dry, will be implemented to minimize this. Some of the vegetation along the edges of the creek will have to be removed to facilitate the implementation of the proposed erosion mitigation options; however, efforts will be made to provide increased planting densities within the replanted areas following construction. Trees determined to be significant by NSE will be preserved and incorporated into the design if possible. Construction timing will be limited to certain times of the year as per recommendations by NSE to ensure minimal impacts to terrestrial, aquatic and wildlife and habitat. Construction equipment may cause some minor inconvenience to local residents due to noise and dust and possible lane restrictions; however, this will be of a temporary nature only.

EROSION SITE #1 – OPTION 1

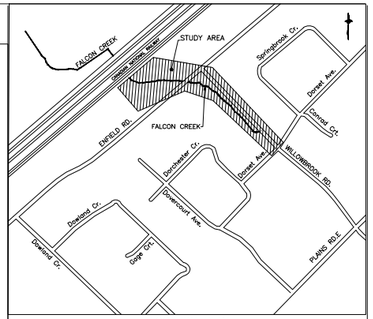
FIGURE 3.1



OPTION 1
DO NOTHING



SECTION A–A
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



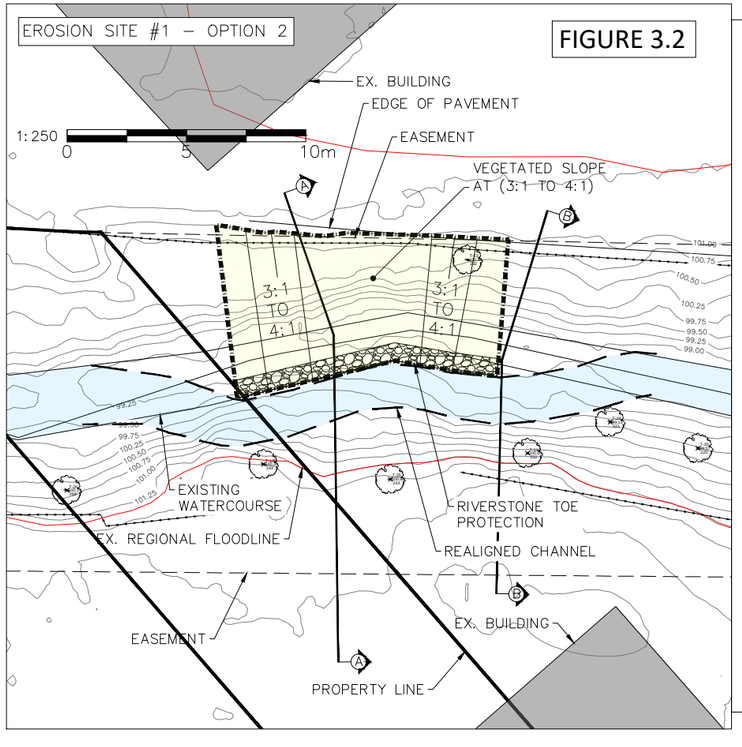
LOCATION PLAN
N.T.S.

LEGEND

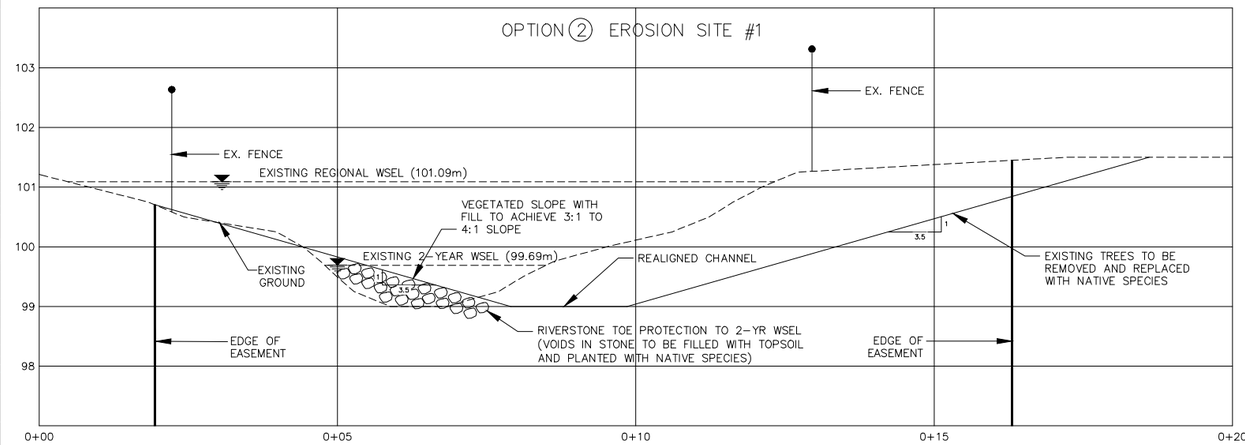
- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

EROSION SITE #1 – OPTION 2

FIGURE 3.2



OPTION 2
VEGETATED SLOPE (3:1 TO 4:1) USING FILL WITH RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL WITH CHANNEL ALIGNMENT (CUT NOT POSSIBLE WITHIN CITY'S EASEMENT)



SECTION A–A
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

CONSULTANT:

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www.valdor-engineering.com

CLIENT: CITY OF BURLINGTON

PROJECT: FALCON CREEK EROSION CONTROL

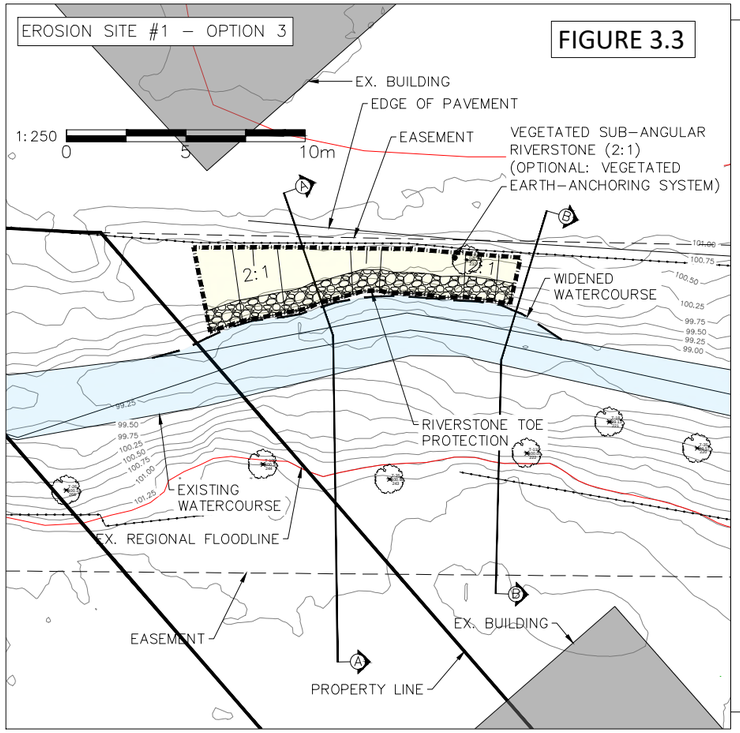
EROSION SITE #1

EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

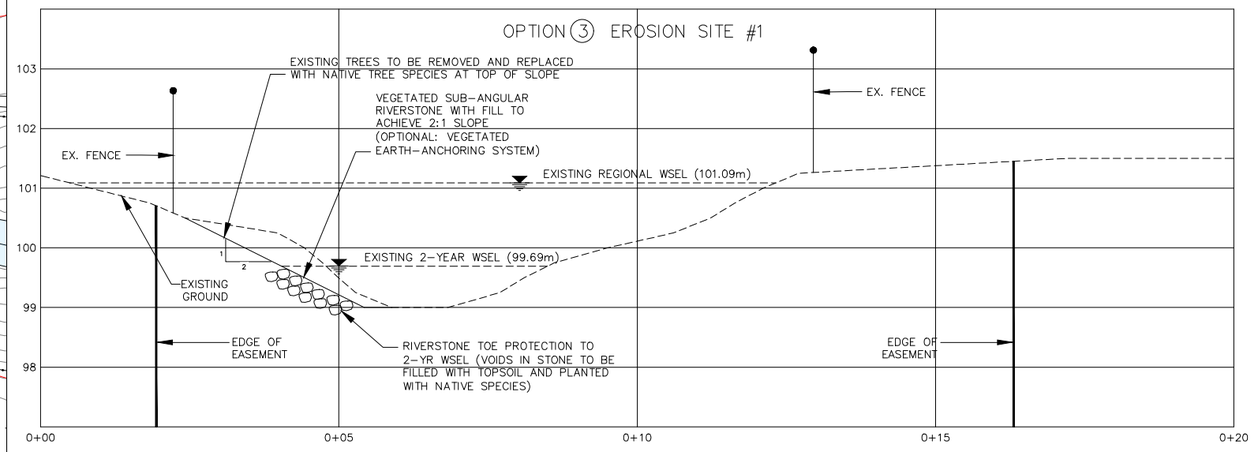
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.1 FIGURE 3.2

EROSION SITE #1 – OPTION 3

FIGURE 3.3



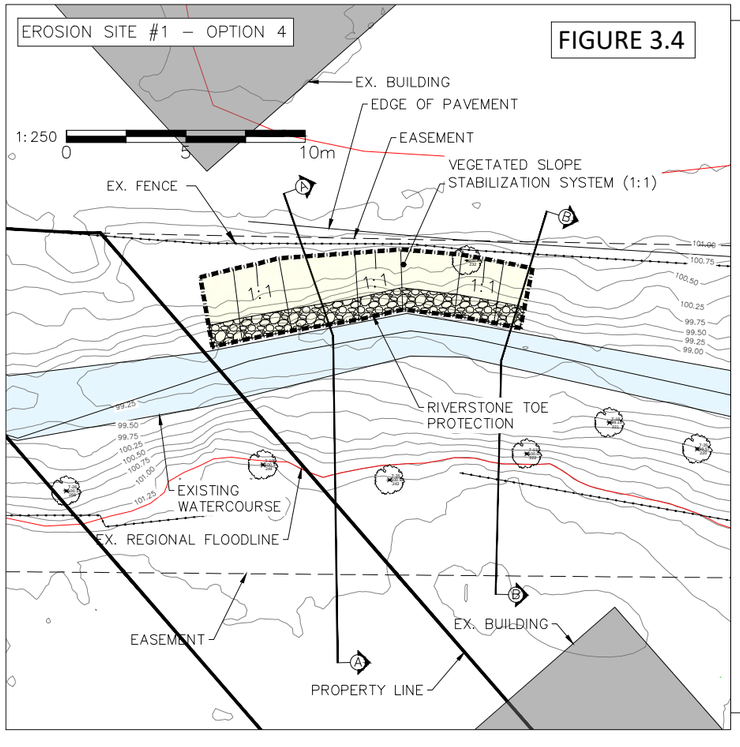
OPTION 3
VEGETATED SUB–ANGULAR RIVERSTONE SLOPE (2:1) OR VEGETATED EARTH–ANCHORING SYSTEM AT 2:1 SLOPE USING CUT (FILL NOT FEASIBLE WITHOUT WATERCOURSE REALIGNMENT)



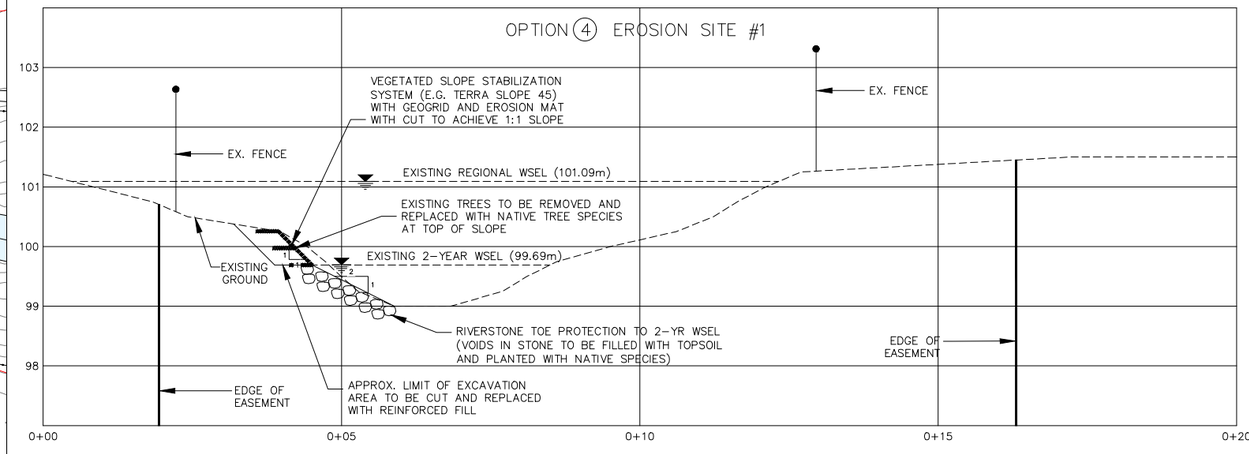
SECTION A–A
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

EROSION SITE #1 – OPTION 4

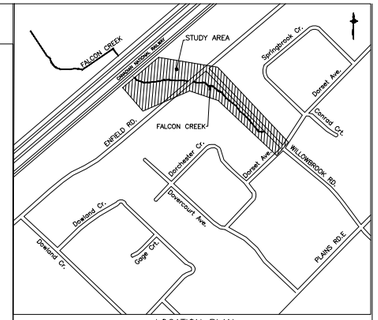
FIGURE 3.4



OPTION 4
VEGETATED SLOPE STABILIZATION SYSTEM (E.G. TERRA SLOPE 45) WITH GEOGRID AND EROSION MAT AT 1:1 SLOPE INCLUDING RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL



SECTION A–A
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS

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EROSION SITE #1

EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

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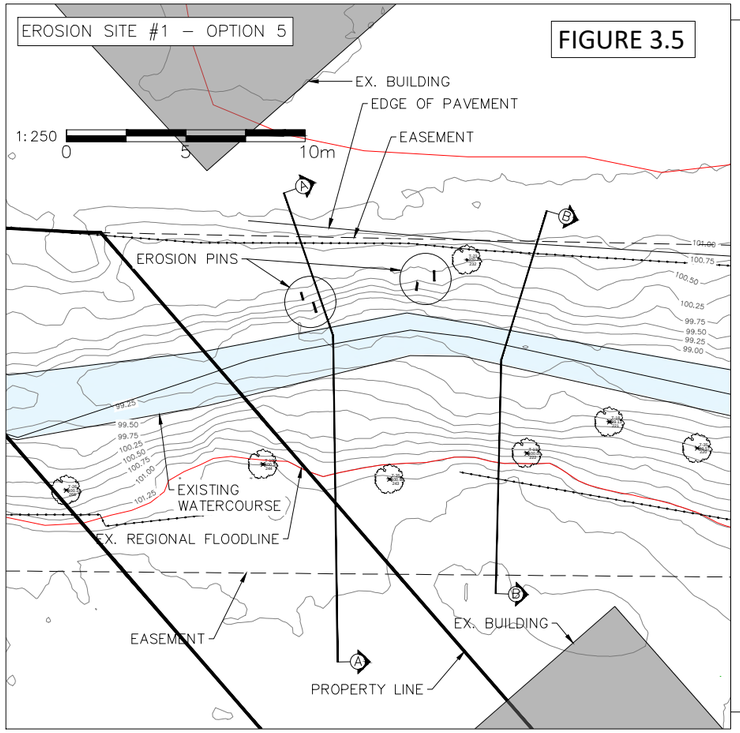
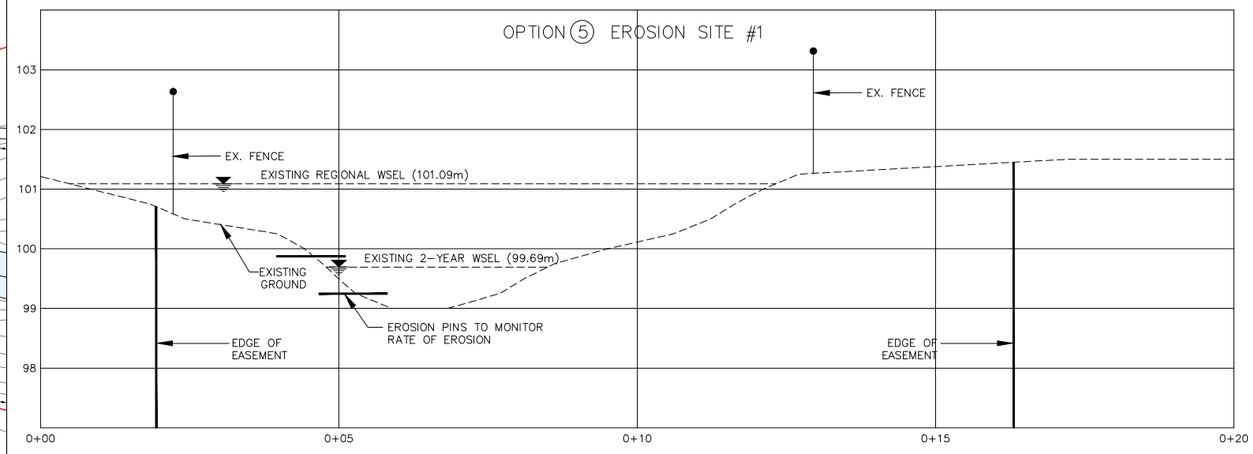
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.3 FIGURE 3.4

EROSION SITE #1 – OPTION 5

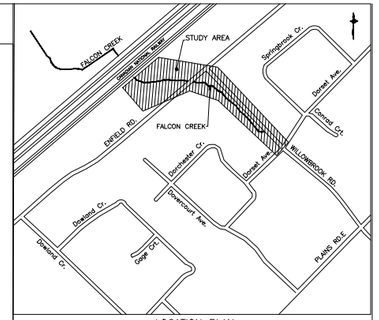
FIGURE 3.5



OPTION 5
IMPLEMENT MONITORING PROGRAM USING EROSION PINS



SECTION A–A
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS		
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CLIENT:
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PROJECT:
FALCON CREEK
EROSION CONTROL

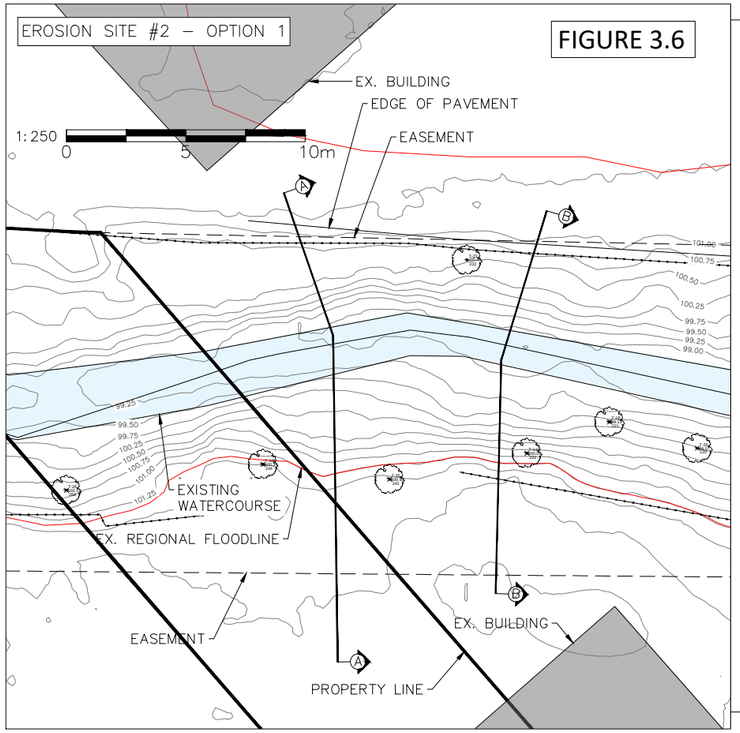
EROSION SITE #1

EROSION MITIGATION OPTIONS
CONCEPTUAL PLAN

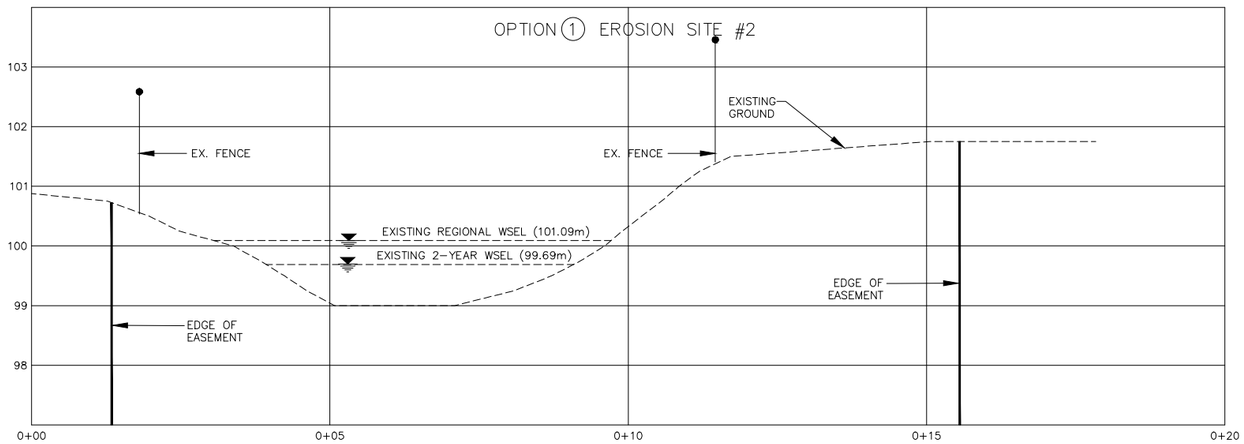
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.5

EROSION SITE #2 – OPTION 1

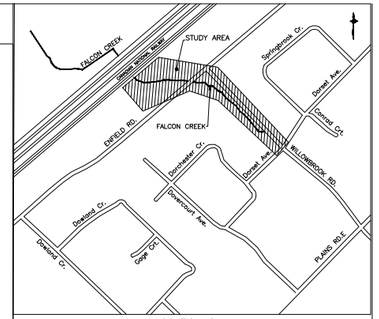
FIGURE 3.6



OPTION 1
DO NOTHING



SECTION B–B
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



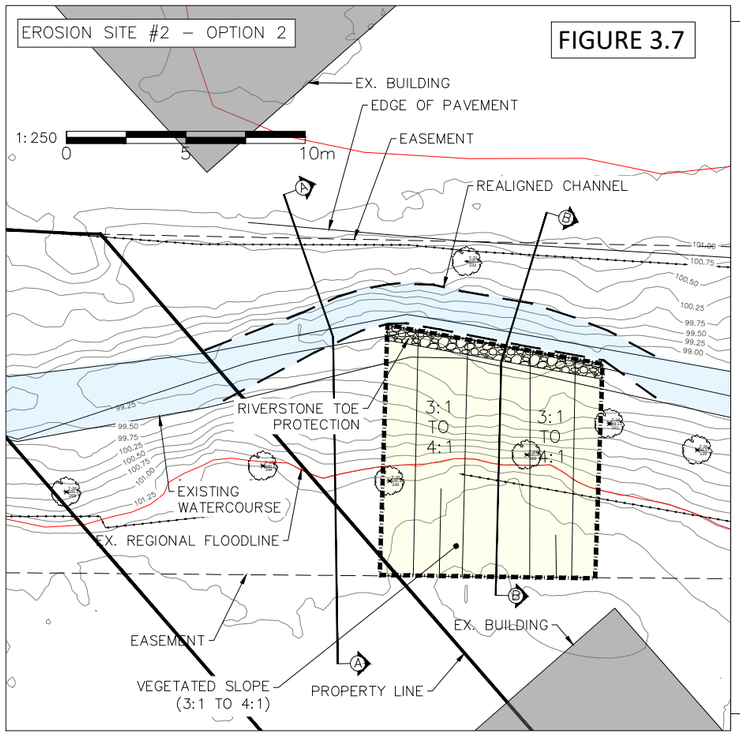
LOCATION PLAN
N.T.S.

LEGEND

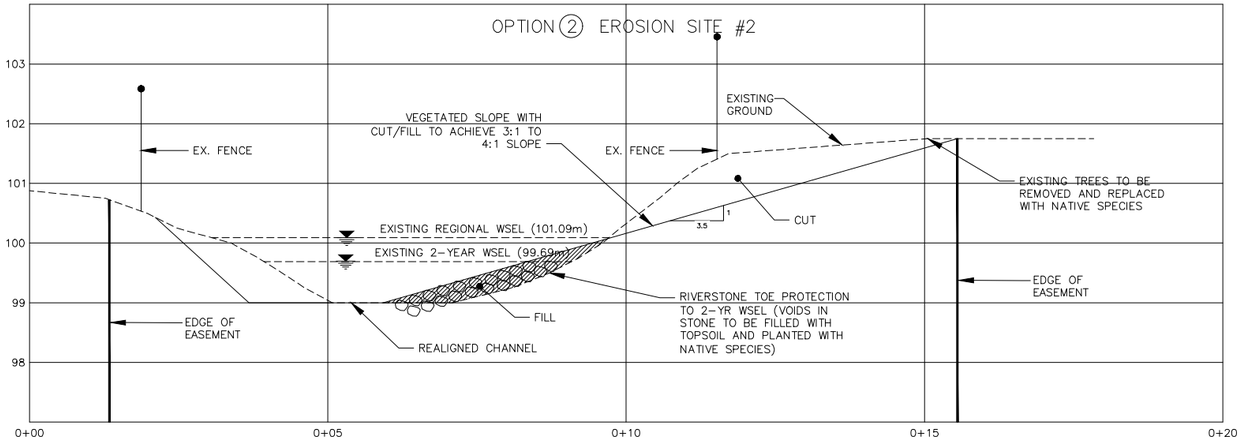
- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

EROSION SITE #2 – OPTION 2

FIGURE 3.7



OPTION 2
VEGETATED SLOPE (3:1 TO 4:1) USING CUT/FILL WITH RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL WITH CHANNEL ALIGNMENT



SECTION B–B
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

REVISIONS

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CLIENT: CITY OF BURLINGTON

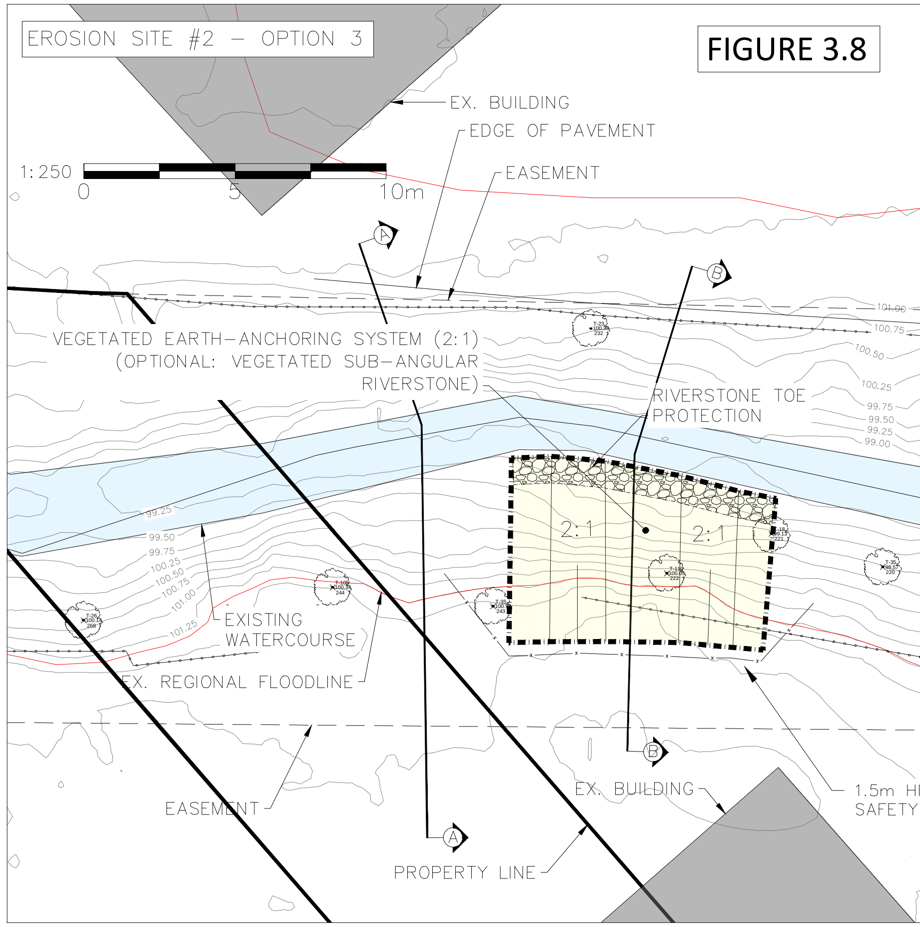
PROJECT: FALCON CREEK EROSION CONTROL

EROSION SITE #2

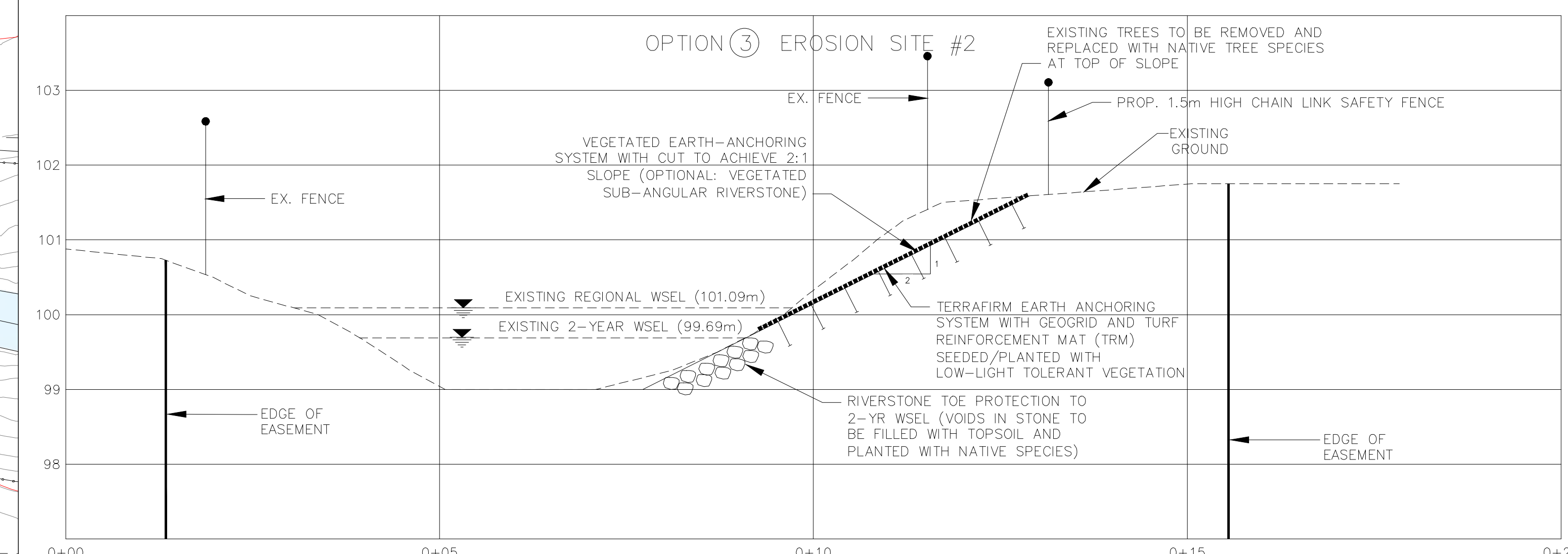
EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.6 FIGURE 3.7

FIGURE 3.8

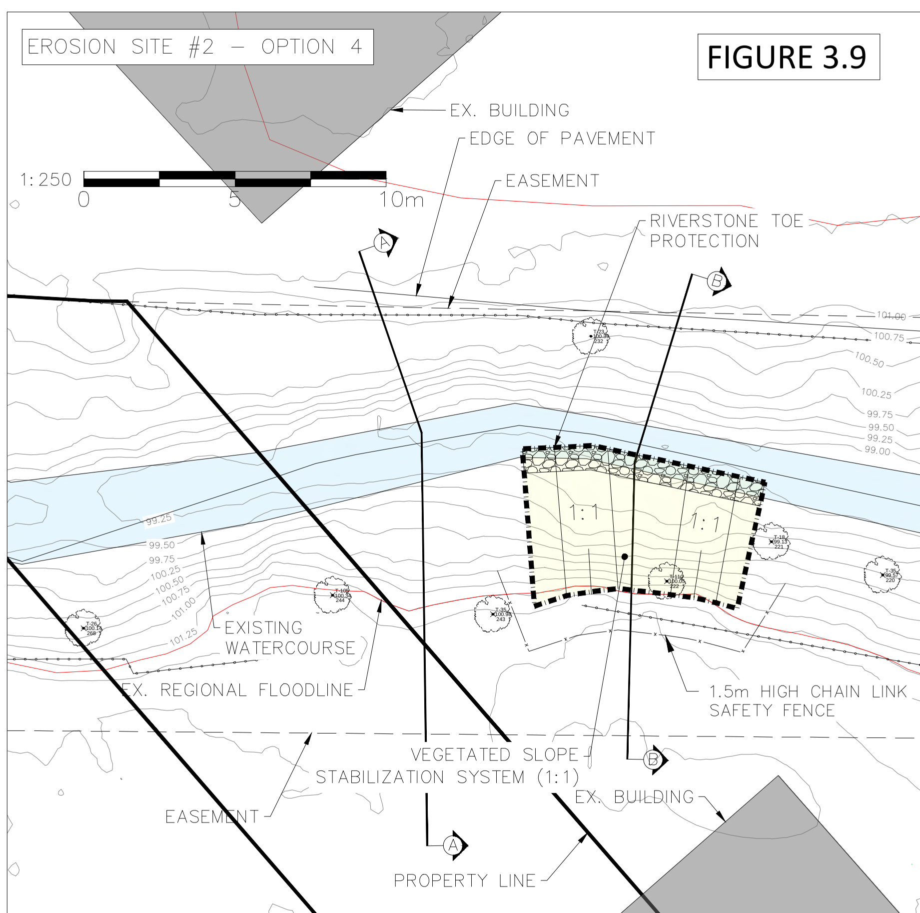


OPTION 3
VEGETATED EARTH–ANCHORING SYSTEM AT 2:1 SLOPE USING CUT (FILL NOT FEASIBLE WITHOUT WATER COURSE REALIGNMENT) OR VEGETATED SUB–ANGULAR RIVERSTONE SLOPE (2:1)

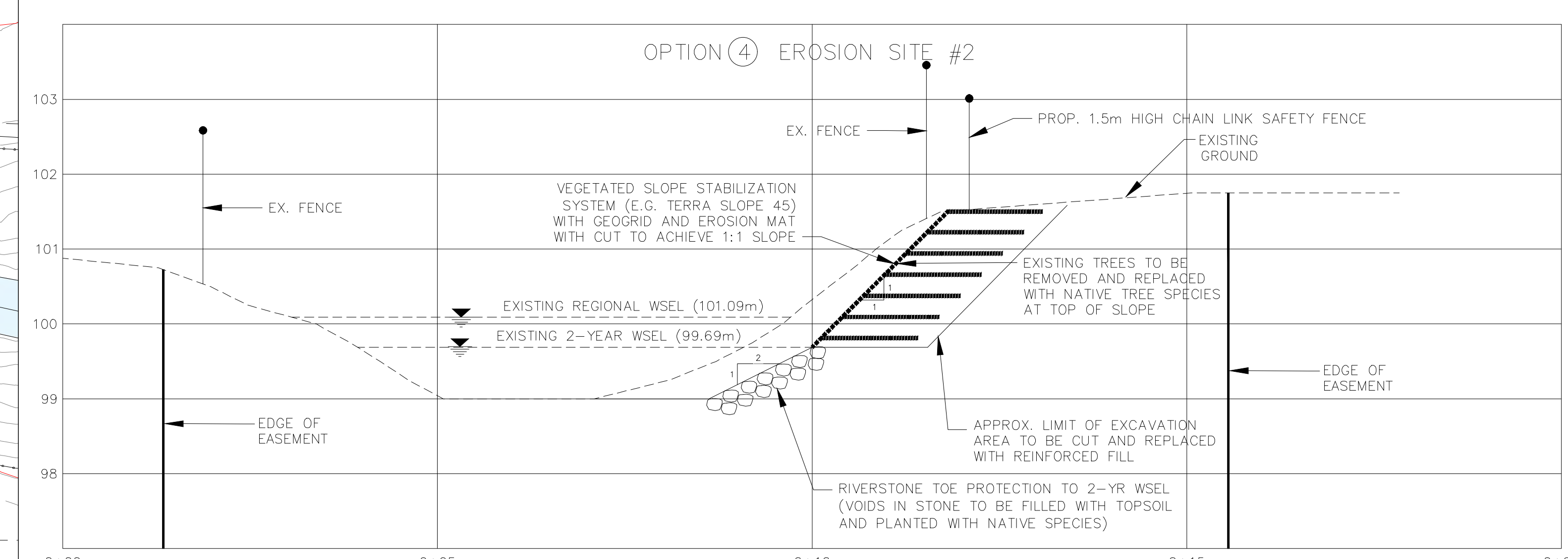


SECTION B–B
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

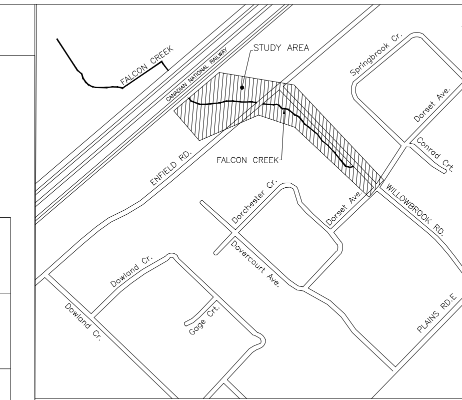
FIGURE 3.9



OPTION 4
VEGETATED SLOPE STABILIZATION SYSTEM (E.G. TERRA SLOPE 45) WITH GEOGRID AND EROSION MAT AT 1:1 SLOPE INCLUDING RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL



SECTION B–B
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

CONSULTANT:

VALDOR ENGINEERING INC.
Consulting Engineers - Project Managers

CLIENT: CITY OF BURLINGTON

PROJECT: FALCON CREEK EROSION CONTROL

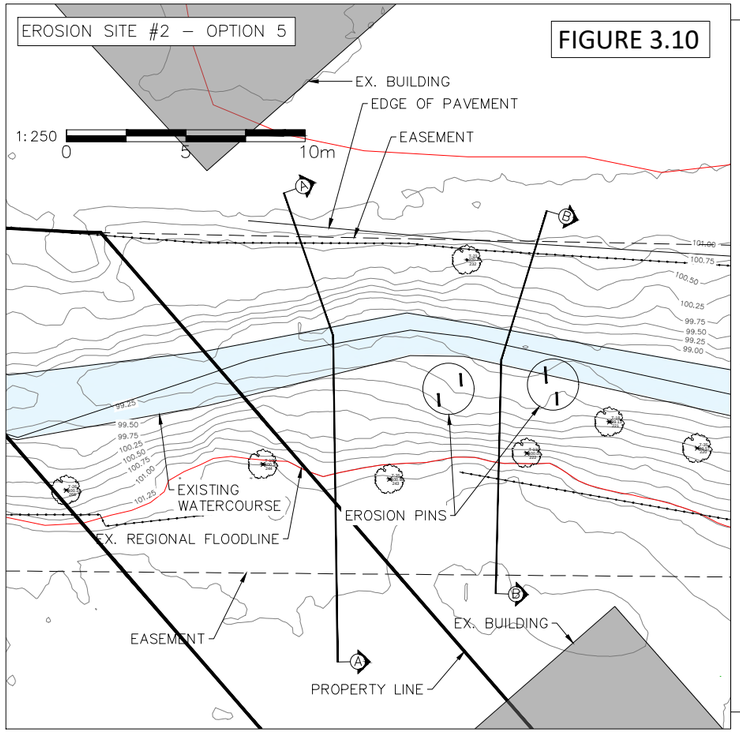
EROSION SITE #2

EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

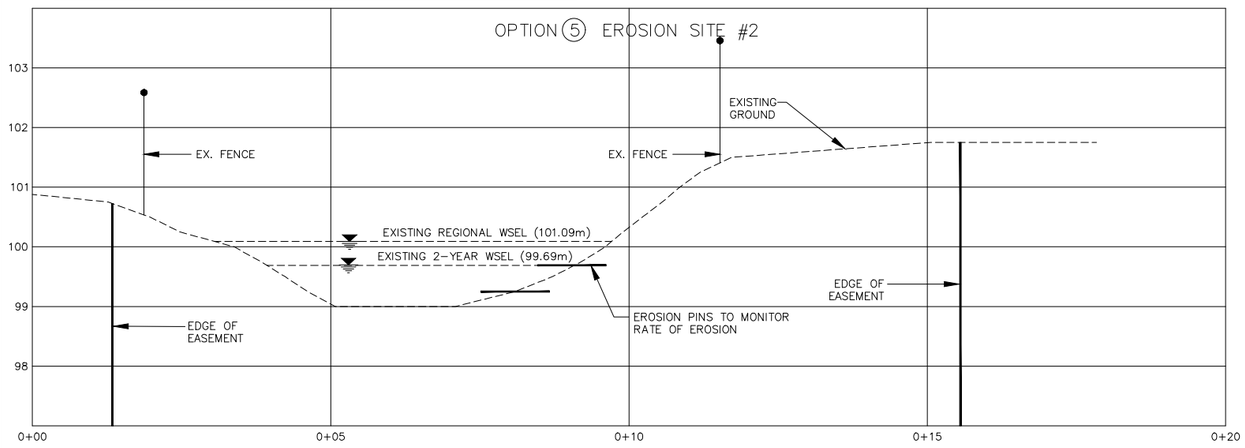
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.8 FIGURE 3.9

EROSION SITE #2 – OPTION 5

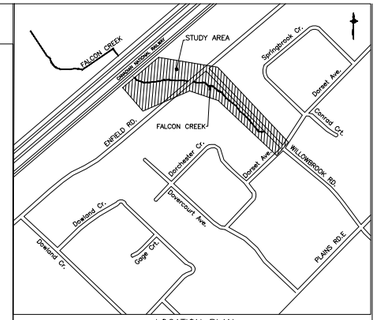
FIGURE 3.10



OPTION 5
IMPLEMENT MONITORING PROGRAM USING EROSION PINS



SECTION B–B
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

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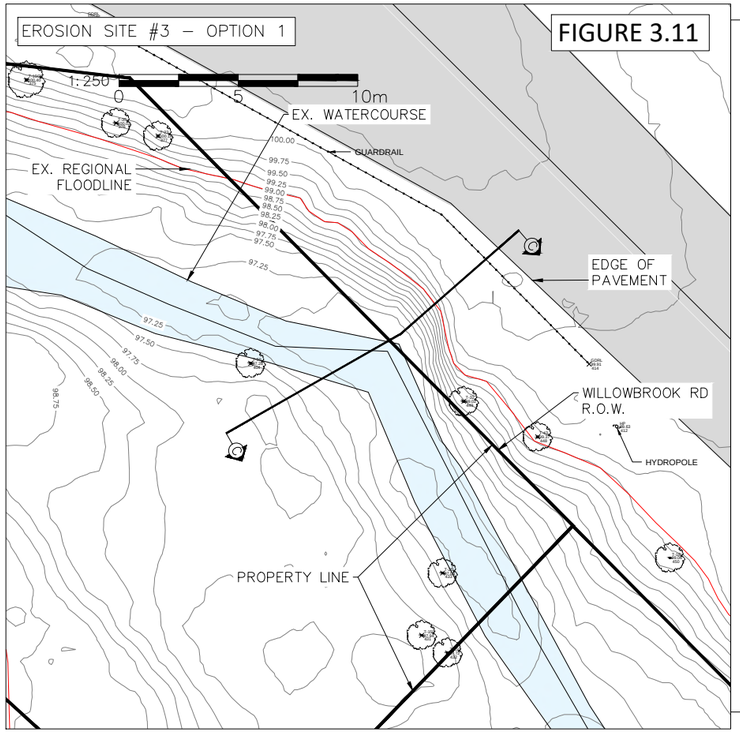
PROJECT:
FALCON CREEK
EROSION CONTROL

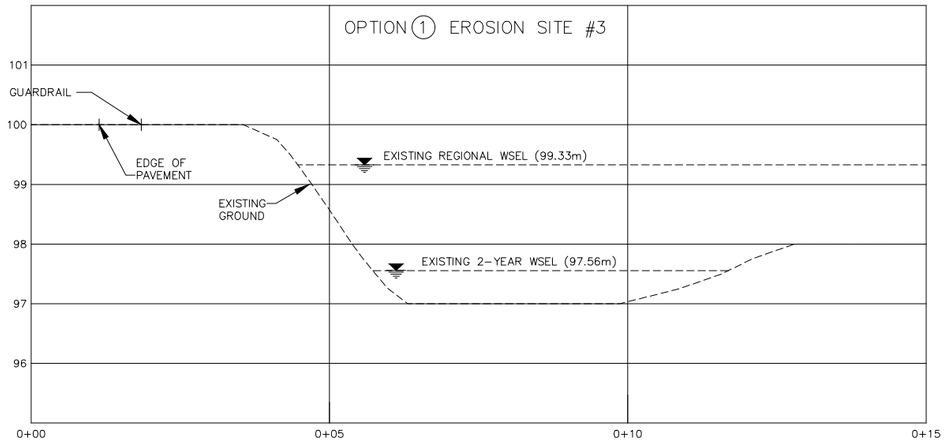
EROSION SITE #2

EROSION MITIGATION OPTIONS
CONCEPTUAL PLAN

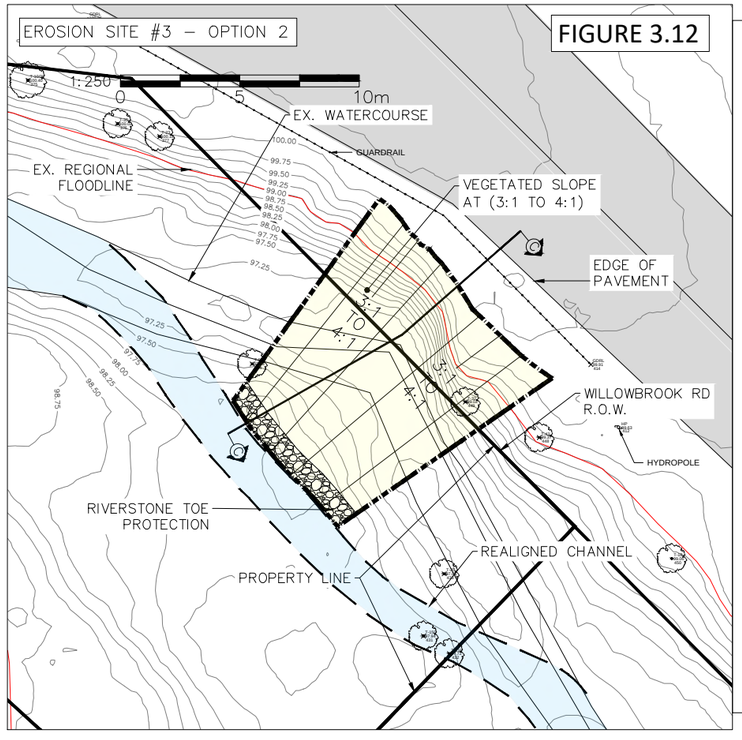
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.10



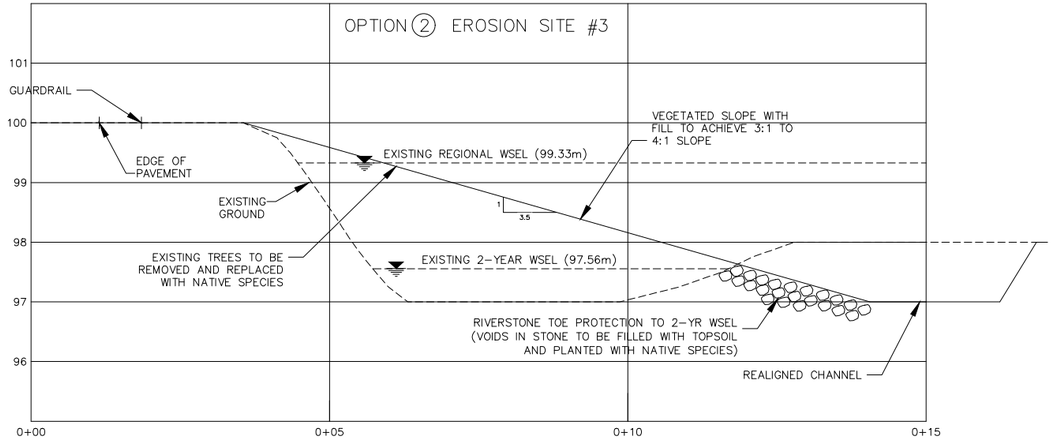
OPTION 1
DO NOTHING



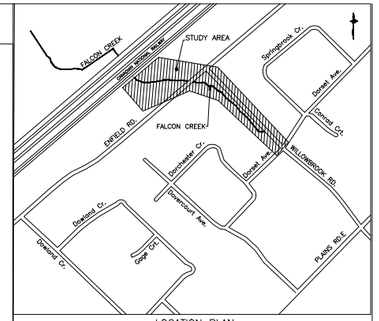
SECTION C–C
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



OPTION 2
VEGETATED SLOPE (3:1 TO 4:1) USING FILL WITH RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL WITH CHANNEL ALIGNMENT (CUT NOT POSSIBLE WITHOUT IMPACTING WILLOWBROOK ROAD)



SECTION C–C
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS

DATE	DETAILS	INIT.
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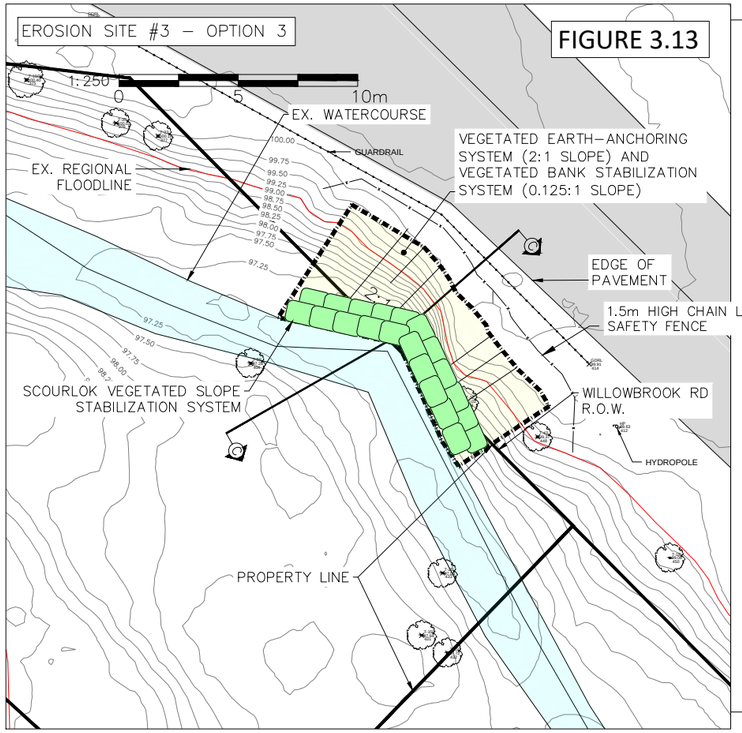
CLIENT: CITY OF BURLINGTON

PROJECT: FALCON CREEK EROSION CONTROL

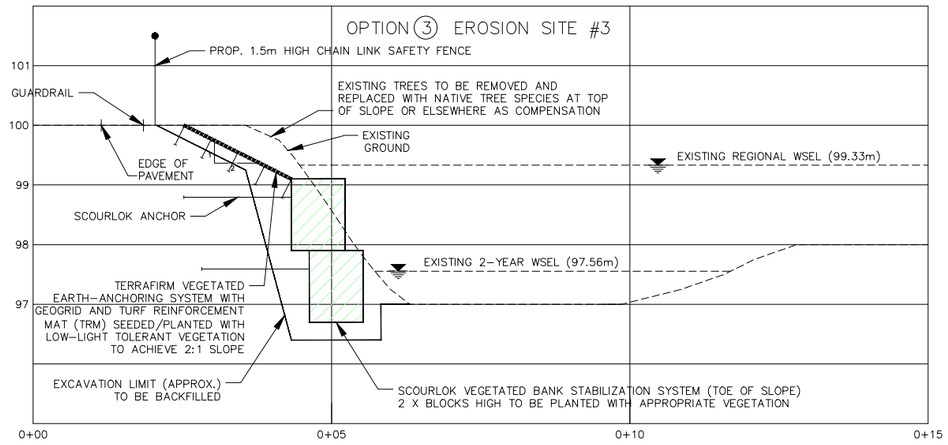
EROSION SITE #3

EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

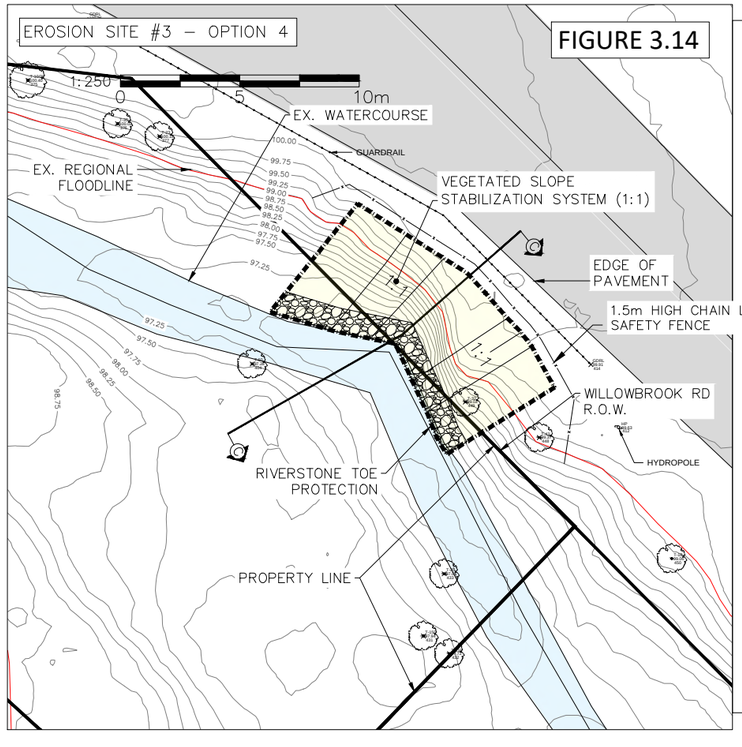
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.11 FIGURE 3.12



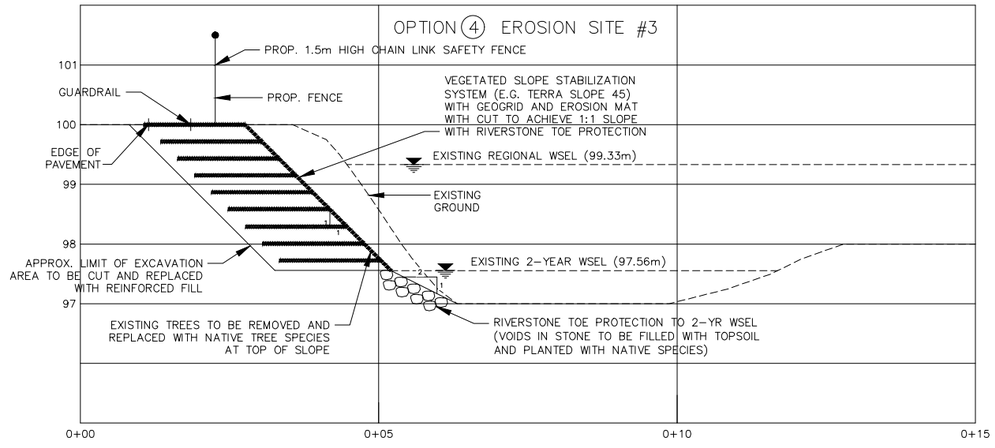
OPTION 3
VEGETATED EARTH–ANCHORING SYSTEM (2:1 SLOPE) AND VEGETATED BANK STABILIZATION SYSTEM (0.125:1 SLOPE)



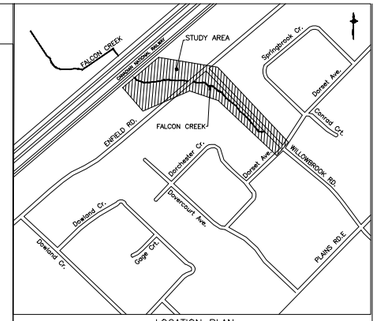
SECTION C–C
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



OPTION 4
VEGETATED SLOPE STABILIZATION SYSTEM (E.G. TERRA SLOPE 45) WITH GEOGRID AND EROSION MAT AT 1:1 SLOPE INCLUDING RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL



SECTION C–C
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

CONSULTANT:

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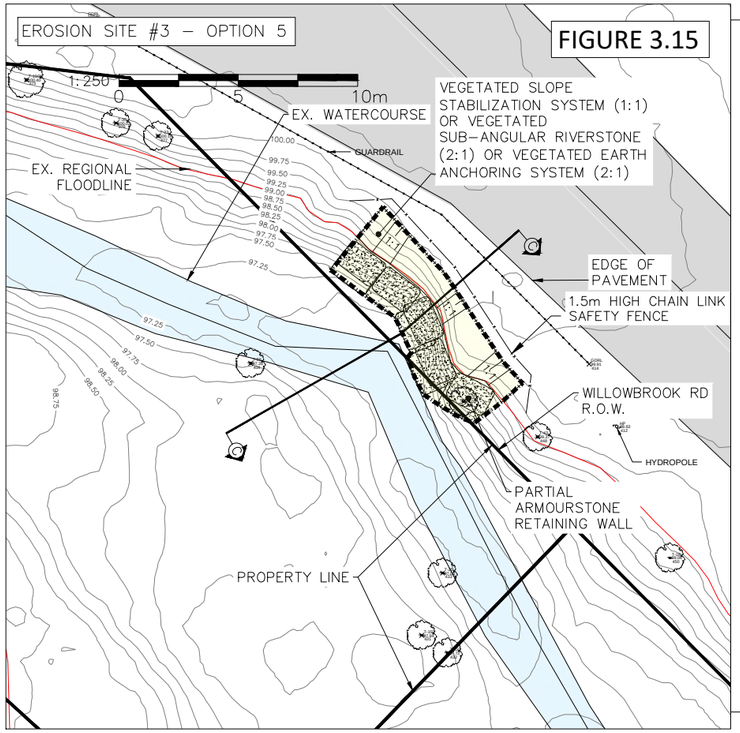
CLIENT: CITY OF BURLINGTON

PROJECT: FALCON CREEK EROSION CONTROL

EROSION SITE #3

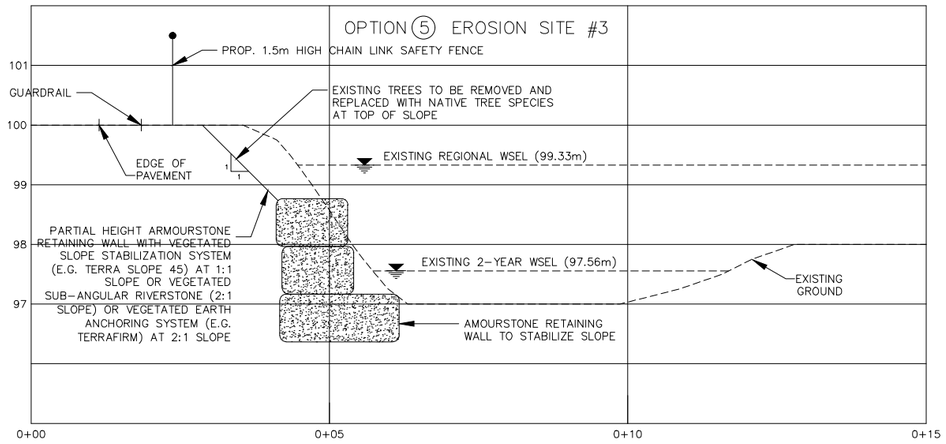
EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.13 FIGURE 3.14



OPTION 5

PARTIAL HEIGHT ARMOURSTONE RETAINING WALL FOR BOTTOM PORTION OF THE SLOPE WITH THE TOP PORTION OF THE SLOPE EITHER WITH VEGETATED SUB–ANGULAR RIVERSTONE (2:1 SLOPE) OR VEGETATED EARTH ANCHORING SYSTEM (E.G. TERRAFIRM) AT 2:1 SLOPE WITH GEOGRID AND TURF REINFORCEMENT MAT OR VEGETATED SLOPE STABILIZATION SYSTEM (E.G. TERRA SLOPE 45) WITH GEOGRID AND EROSION MAT AT 1:1 SLOPE



SECTION C–C
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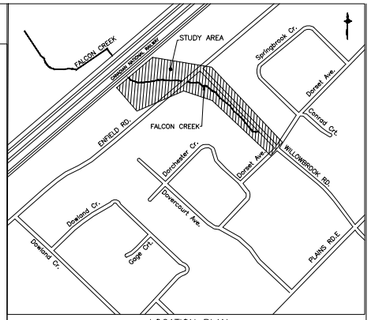
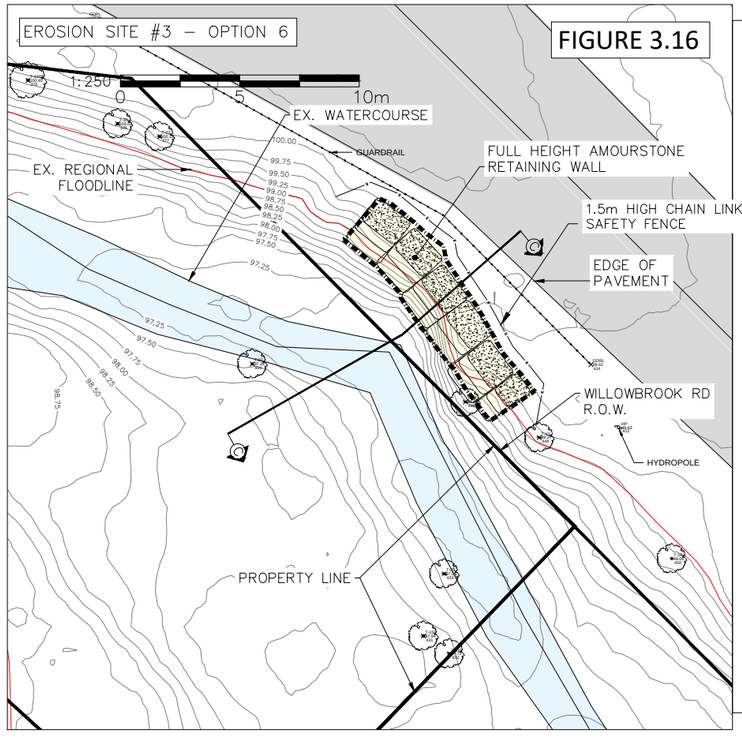
VERTICAL 1:100



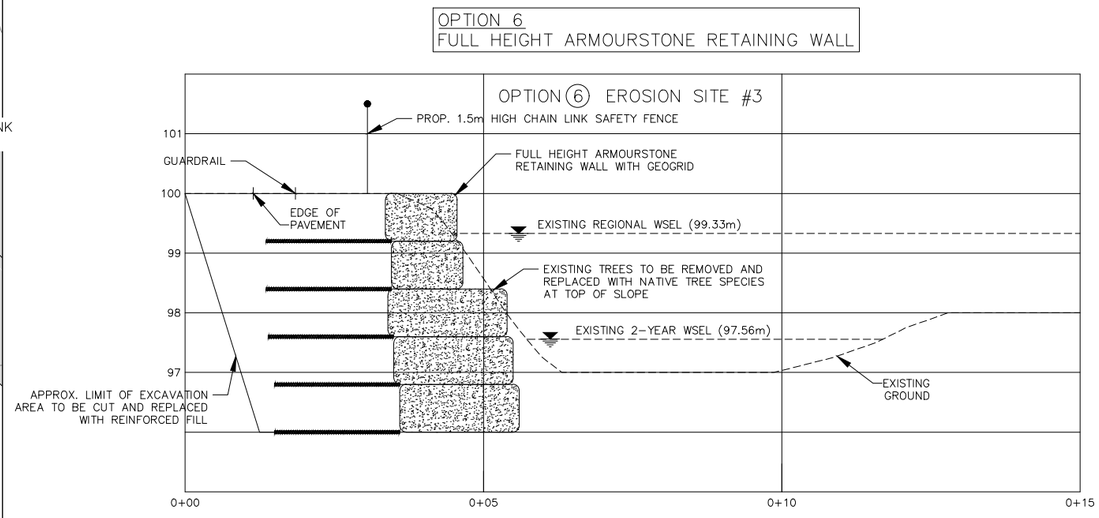
LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE



OPTION 6
FULL HEIGHT ARMOURSTONE RETAINING WALL



SECTION C–C
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

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CLIENT: CITY OF BURLINGTON

PROJECT: FALCON CREEK EROSION CONTROL

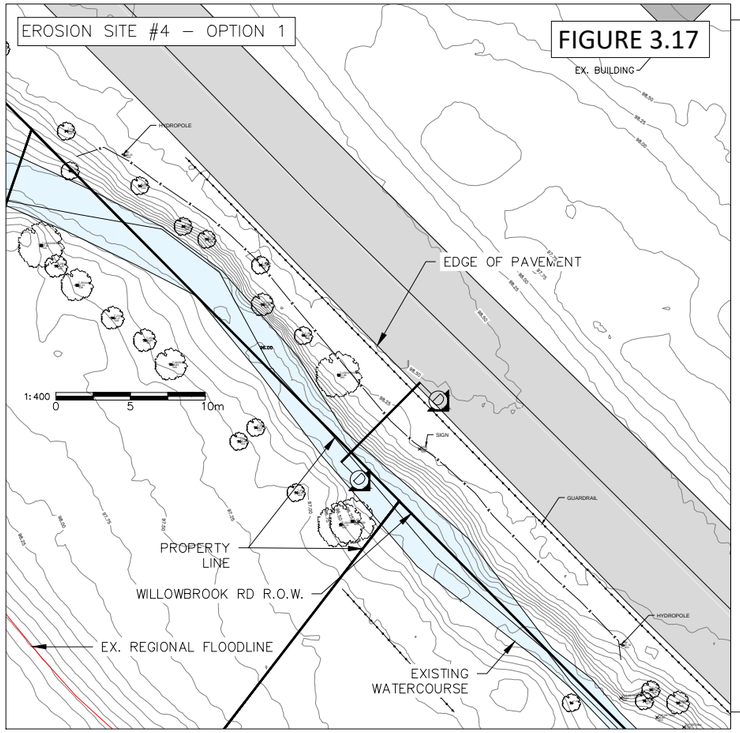
EROSION SITE #3

EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

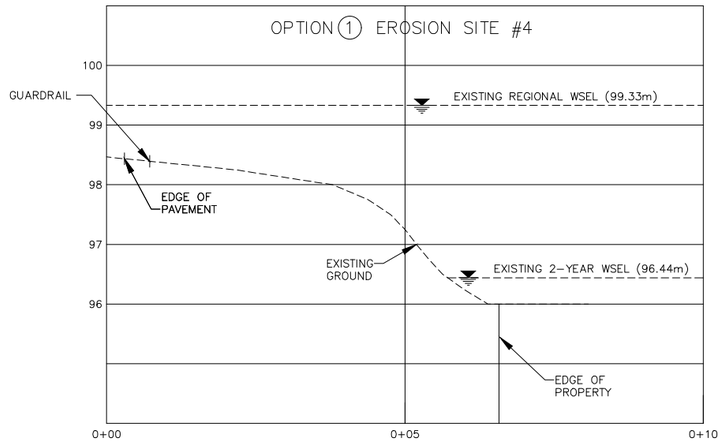
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.15 FIGURE 3.16

EROSION SITE #4 – OPTION 1

FIGURE 3.17



OPTION 1
DO NOTHING



SECTION D–D
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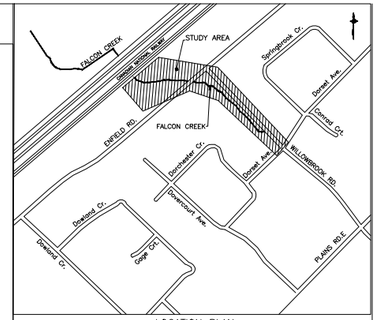


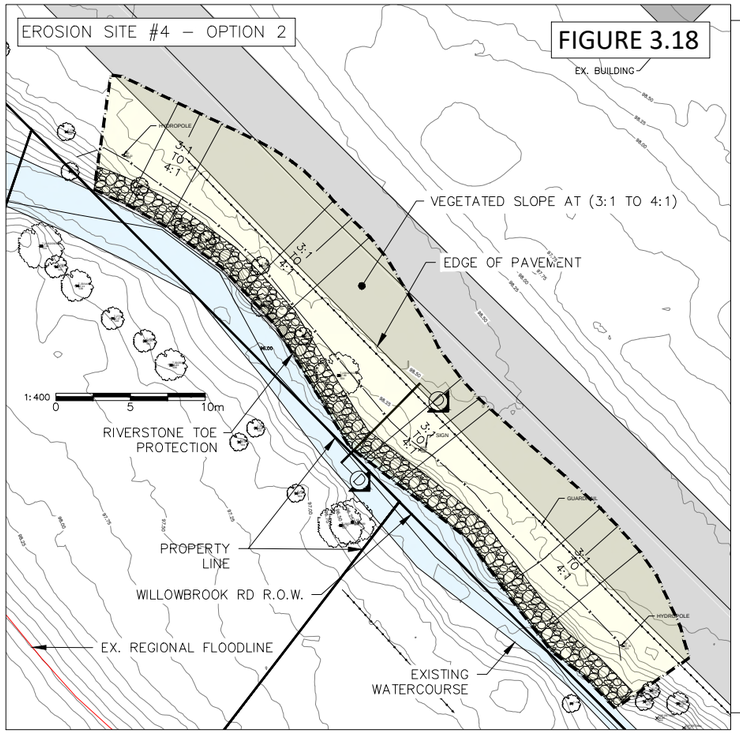
LOCATION PLAN
N.T.S.

LEGEND

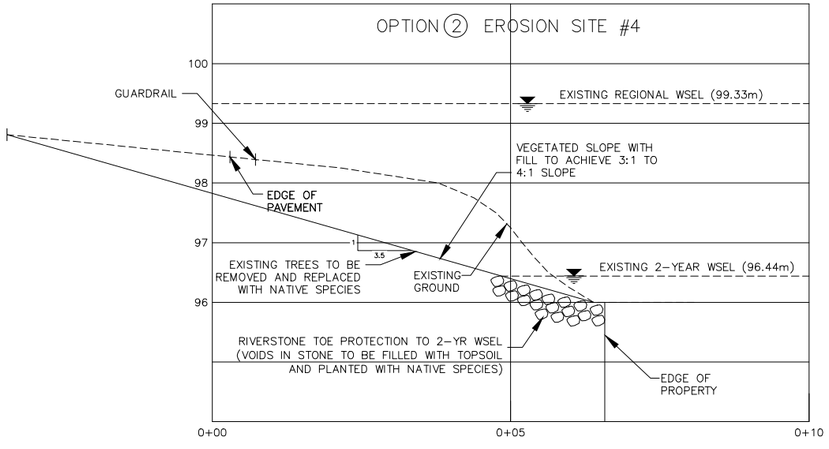
- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

EROSION SITE #4 – OPTION 2

FIGURE 3.18



OPTION 2
VEGETATED SLOPE (3:1 TO 4:1) USING CUT WITH RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL (MAY NOT BE FEASIBLE WITHOUT IMPACTING WILLOWBROOK ROAD)(FILL NOT FEASIBLE WITHOUT IMPACTING PRIVATE PROPERTY)



SECTION D–D
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

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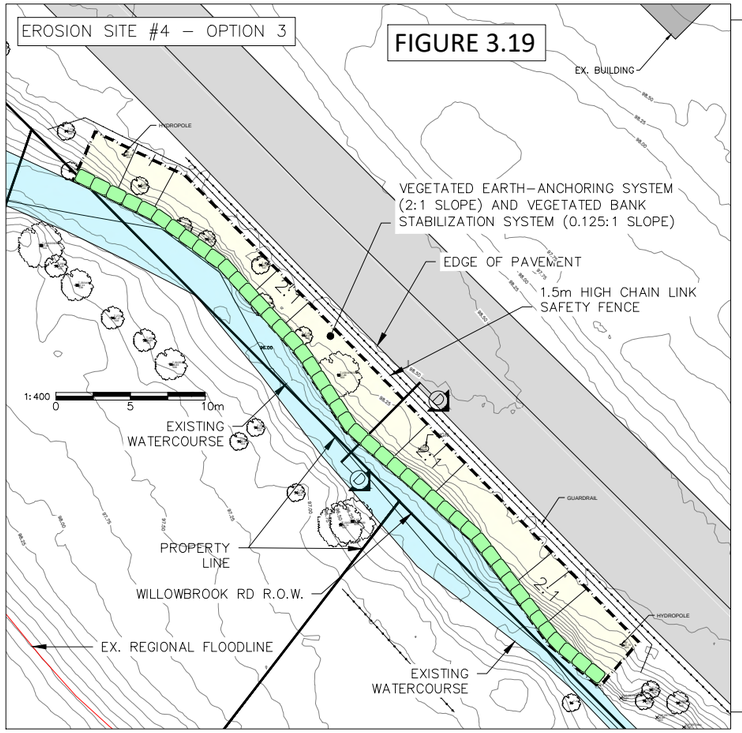
CLIENT:
CITY OF BURLINGTON

PROJECT:
FALCON CREEK
EROSION CONTROL

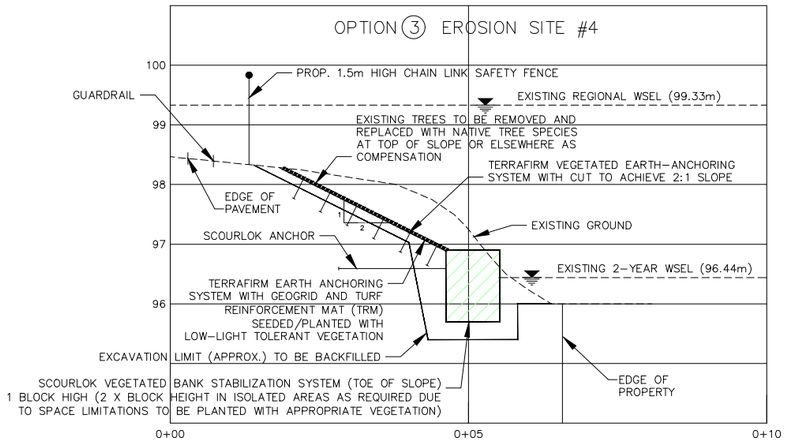
EROSION SITE #4

EROSION MITIGATION OPTIONS
CONCEPTUAL PLAN

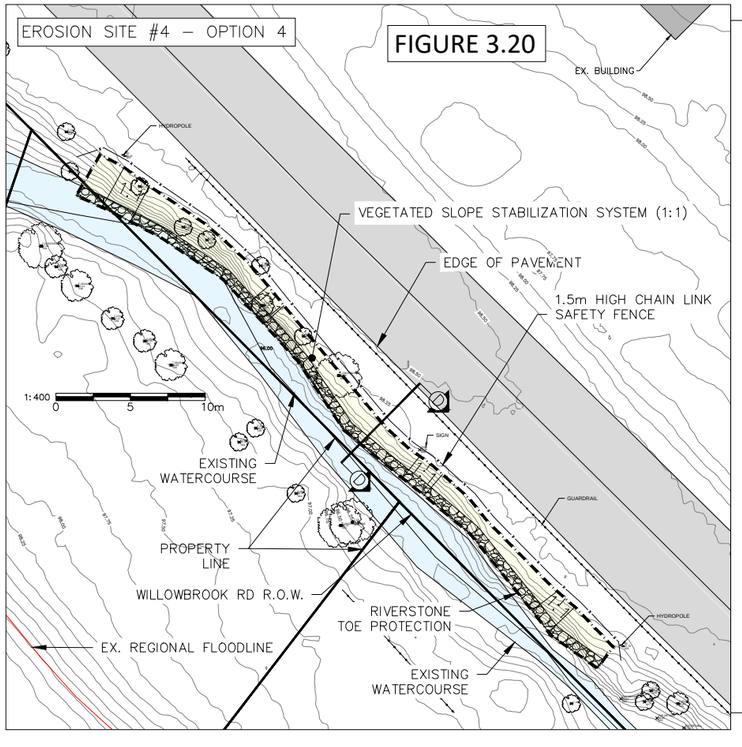
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.17 FIGURE 3.18



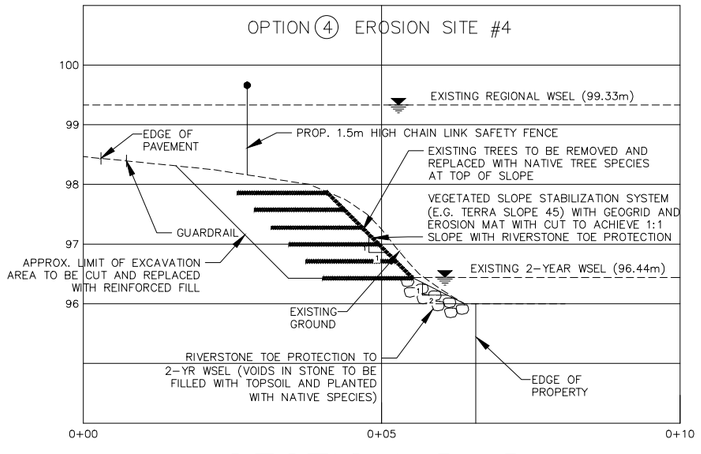
OPTION 3
VEGETATED EARTH–ANCHORING SYSTEM (2:1 SLOPE) AND VEGETATED BANK STABILIZATION SYSTEM (0.125:1 SLOPE)



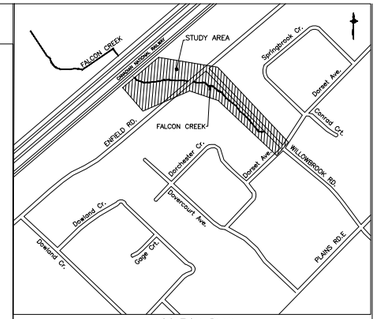
SECTION D–D
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



OPTION 4
VEGETATED SLOPE STABILIZATION SYSTEM (E.G. TERRA SLOPE 45) WITH GEOGRID AND EROSION MAT AT 1:1 SLOPE INCLUDING RIVERSTONE TOE PROTECTION TO THE 2–YR WSEL



SECTION D–D
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

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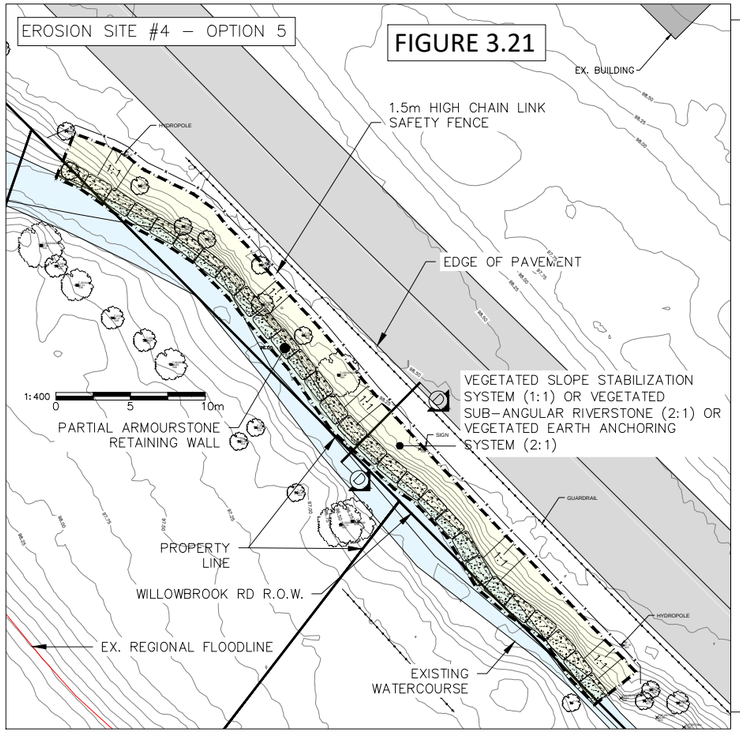
CLIENT: CITY OF BURLINGTON

PROJECT: FALCON CREEK EROSION CONTROL

EROSION SITE #4

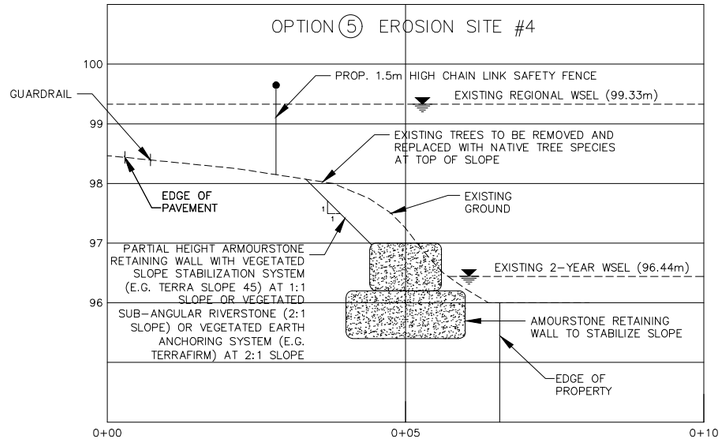
EROSION MITIGATION OPTIONS CONCEPTUAL PLAN

DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.19 FIGURE 3.20

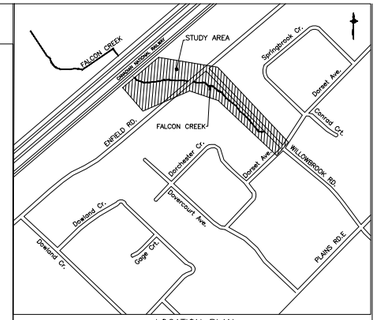


OPTION 5

PARTIAL HEIGHT ARMOURSTONE RETAINING WALL FOR BOTTOM PORTION OF THE SLOPE WITH THE TOP PORTION OF THE SLOPE EITHER WITH VEGETATED SUB–ANGULAR RIVERSTONE (2:1 SLOPE) OR VEGETATED EARTH ANCHORING SYSTEM (E.G. TERRAFIRM) AT 2:1 SLOPE WITH GEOGRID AND TURF REINFORCEMENT MAT OR VEGETATED SLOPE STABILIZATION SYSTEM (E.G. TERRA SLOPE 45) WITH GEOGRID AND EROSION MAT AT 1:1 SLOPE



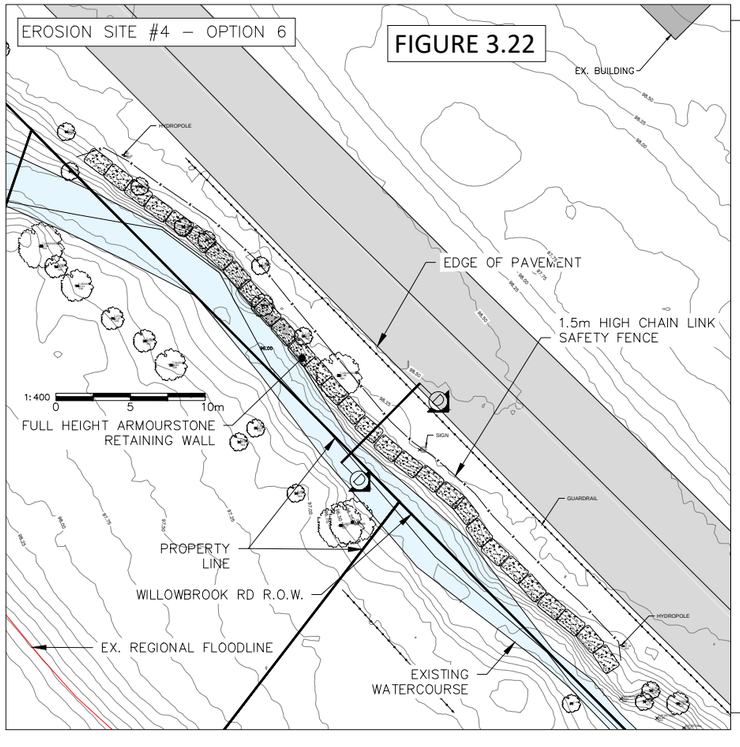
SECTION D–D
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



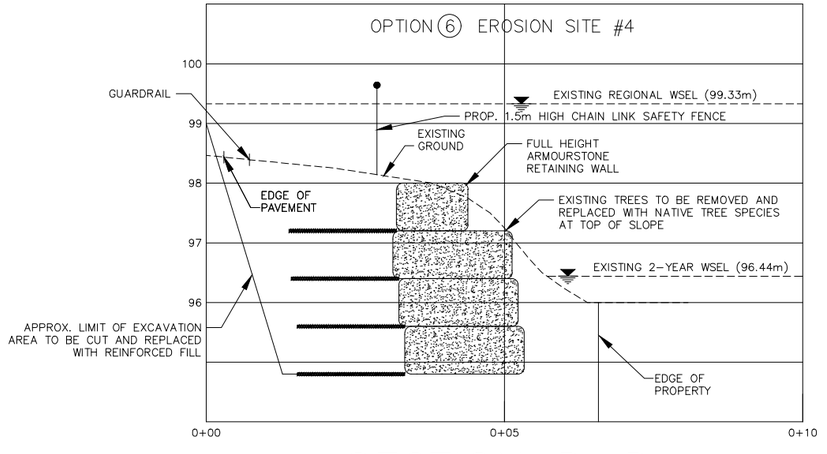
LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE



OPTION 6
FULL HEIGHT ARMOURSTONE RETAINING WALL



SECTION D–D
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

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CLIENT:
CITY OF BURLINGTON

PROJECT:
FALCON CREEK
EROSION CONTROL

EROSION SITE #4

EROSION MITIGATION OPTIONS
CONCEPTUAL PLAN

DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	FIGURE 3.21 FIGURE 3.22

4.0 CONCEPTUAL DESIGN FOR THE PREFERRED OPTIONS

After reviewing feedback from the public at the Public Information Centre (PIC), as well as subsequent discussions with the City, the preferred alternatives were determined to be Option #5 (implement monitoring program to track and assess erosion risk) at Erosion Site #1, Option #5 (implement monitoring program to track and assess erosion risk) at Erosion Site #2, Option #3 (install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1) at Erosion Site #3, and Option #3 (install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1) at Erosion Site #4. Based on the detailed analysis and evaluation of alternatives, the conceptual designs for the preferred alternatives were prepared.

4.1 Conceptual Design Details

Conceptual design drawings of the preferred retrofit option at Erosion Sites #1 to #4 are provided in Drawings **DWG 4.1** through **DWG 4.4**. The conceptual design for the preferred alternative consists of the following elements:

Erosion Site #1 (Option #5) and Erosion Site #2 (Option #5)

1. A total of eight (8) erosion pins will be installed at Erosion Site #1 and Erosion Site #2 (*i.e.* 4 erosion pins at each erosion site).

2. Bi-annual erosion measurements will be completed for a period of 3 years at each erosion site.

3. A summary report will be prepared by a qualified fluvial geomorphologist including the calculation of *in situ* erosion recession rates and recommendations regarding the need for mitigation requirements at Erosion Site #1 and Erosion Site #2.

Erosion Site #3 (Option #3) and Erosion Site #4 (Option #3)

4. The existing bank will be cut back from the existing bottom of bank and top of bank to provide a naturalized erosion control solution for the existing eroded slope. The toe of the slope up to approximately mid-bank (*i.e.* up to the 2-year flood elevation or higher) will be reinforced using a bank stabilization system (*e.g.* Scourlok) planted with low-light tolerant native vegetation species to stabilize the base of the existing slope at 0.125:1 (H:V). An earth anchoring system (*e.g.* Terrafirm Armormax) planted with low-light tolerant native vegetation species will be installed to stabilize the top of the slope at 2:1 (H:V). The installation of this system will provide a durable and naturalized solution to protect Willowbrook Road and associated infrastructure for the long term from the current erosion risk. The solution will maintain floodplain characteristics and permit natural channel processes to occur while protecting private and public property. Fencing will be installed along the top of slope for public safety. A naturalized erosion mitigation design was selected in keeping with requests by CH (29 June 2022), Six Nations of the Grand River (21 October 2022) and Mississaugas of the Credit First Nation to avoid the use of hardened solutions such as armourstone (**Appendix A**).

5. To address signs of failure noted regarding the Willowbrook Road storm sewer inlet headwall and wingwalls as part of the stormsewer outfall and culvert assesssments, the existing headwall and wingwalls will be replaced using armourstone.

6. Thorny shrubs will be installed along the top of the existing bank to discourage public access along the steep areas of the slope along the SW side of Willowbrook Road between Enfield Road and the inlet to the Willowbrook Road stormsewer to improve public safety. This design element is included to address concerns raised by local residents regarding child safety as per feedback received at the 08 March 2023 PIC and 11 May 2023 on-site meeting with area residents (**Appendix A**). Reducing pedestrian access at these locations will allow for the re-establishment of riparian vegetation while maintaining a natural supply of sediment to the system. Riparian vegetation would also play a marginal role in maintaining streambank stability. From a geomorphic standpoint, the channel may continue towards the state of quasi-equilibrium.

7. Native tree species will be planted along the top of the proposed slope or within the City's creek block to replace any vegetation removed during construction.

8. Construction access to Erosion Sites #3 and #4 will be from Willowbrook Road. It is anticipated that creek access may be required and so temporary creek access points are proposed for each site from Willowbrook Road.

9. A pump by-pass and dewatering program including fish rescue is to be implemented during construction within the creek at Erosion Sites #3 and #4 to isolate the construction area, prevent ecological damage and to maintain continuous surface water drainage to the downstream watercourse.

10. Construction of the erosion mitigation works should be staged, if possible, to minimize the risk of erosion and sediment loading to the watercourse during rainfall events.

11. Based on the Natural Heritage Study prepared by NSE, construction should not proceed without suitable erosion and sediment controls that are maintained throughout construction. Tree protection fencing is to be established prior to construction for mature trees as established by a professional arborist. Only clean fill materials are to be used and standard measures shall be followed regarding the mitigation and prevention of fuel and chemical spills to prevent ground and surface water contamination. Wildlife exclusion fencing should be installed around the construction site to keep wildlife from entering the construction area (*e.g.* nesting turtles). This may consist of ESC silt fencing.

12. A Restoration Planting Plan should be prepared at detailed design. Conservation Halton has a number of applicable guidance documents including: *Guidelines for Landscaping and Rehabilitation Plans* (2021), *Seed Mixes Suitable for our Watershed* (2020), and its *Native Species List* (2018). These documents contain recommended species for restoration plantings and seed mixes. Efforts will be made to specify native medicinal plantings in the planting plan as requested at the meeting with Six Nations of the Grand River (21 October 2022) (**Appendix A**).

13. A Fish Relocation Plan should be prepared at detailed design. Further, any in-water works will require Fish Exclusion Measures to prevent harm to fish during construction. Additional guidance may be provided by the Department of Fisheries and Oceans following the submission for a Request for Review.

14. A Tree Inventory and Arborist Report should be prepared at detailed design.

The following additional consultation is recommended:

1. Submit a 'Request for Review' to the Department of Fisheries and Oceans to determine if an Authorization under the Fisheries Act is required. If an authorization is required, this must be received before any works occur that could impact fish or fish habitat.

2. Potential bat habitat trees are present at Erosion Site #4. Consultation with the Ministry of the Environment, Conservation, and Parks (MECP) is recommended. This consultation will determine the need for additional field investigations (*e.g.* 10 or more nights of acoustic calling surveys to determine species presence/absence and abundance), and to determine if a Letter of Advice, Permit, or other Authorization is required. This process may take a number of months to over a year and should be considered in project planning.

A number of construction timing constraints are applicable to the proposed erosion mitigation works at Erosion Site #3 and Erosion Site #4 as provided in **Table 4.1**. It is recommended the City consider these in scheduling the construction period.

Table 4.1: Construction Timing Windows

Species Group	Sensitive Period	Considerations for Construction
Bats (roosting)	April 1 – September 30	Tree removal should occur outside of the sensitive period. **Construction Timing Window: October 1 to March 31.**
Birds (nesting)	April 1 – August 31	Vegetation removal (trees, shrubs, ground layer) should occur outside of the nesting period. Where construction must occur within the sensitive period, if the area of disturbance is small and is considered 'simple habitat[1],' a due diligence nest search can be completed. Compliance with *Migratory Birds Convention Act* is required. **Construction Timing Window: September 1 to March 31.**
Fish (spawning)	Warmwater: March 15 to July 15	**Construction Timing Window: July 16 – March 14** In-water works are to occur within the construction timing window.

The City should consider the implementation of the following programs following construction of the proposed erosion mitigation works:

1. A post-construction monitoring program of the stabilized creek sections is recommended following construction. This program is recommended to continue at regular intervals for a period of two years after construction.

2. A public education program could also be implemented regarding the dumping of debris within the creek and the installation of LID measures.

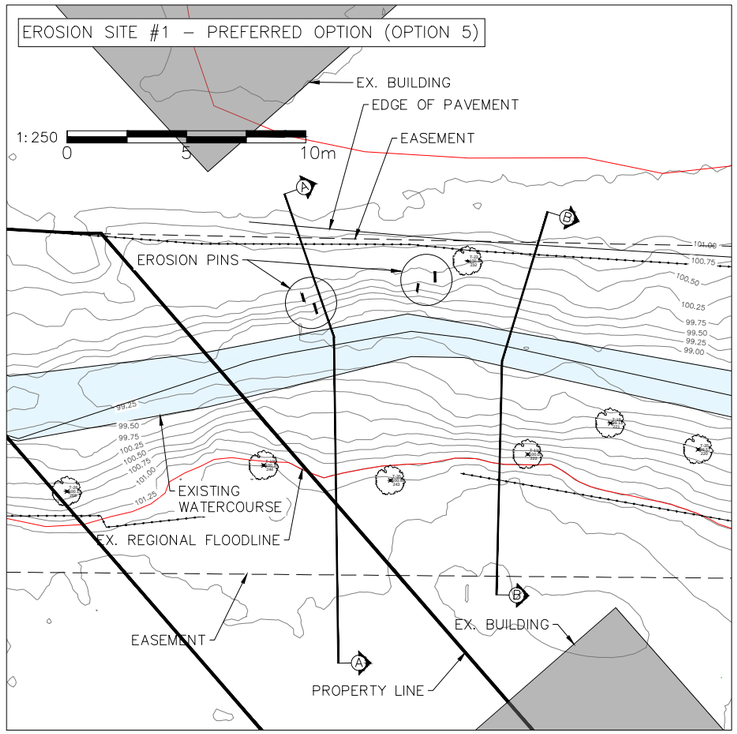
4.2 Hydraulic Assessment

The updated existing conditions hydraulic model described in **Section 2.2** will be used to perform a hydraulic assessment regarding any impacts of the proposed erosion control alternatives on the floodlines in the creek. This thorough analysis of the existing and proposed floodlines will be completed during the detailed design phase to ensure that flood levels in the creek are not negatively impacted due to the proposed erosion control strategy. It is not anticipated that the preferred alternatives will have any significant impacts to existing flood levels for the reasons identified, as follows:

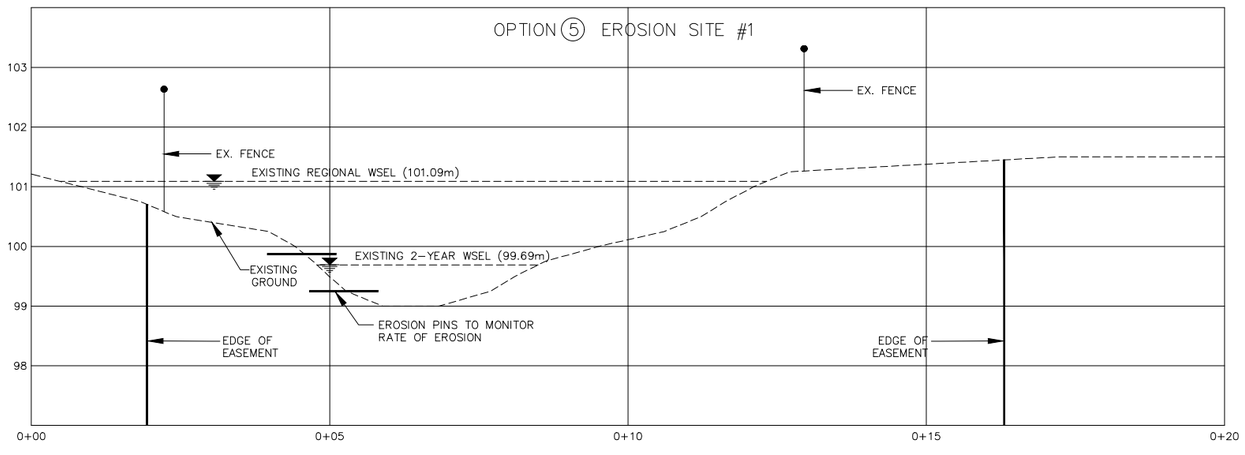
- Erosion Site #1 – (Option #5): Implement monitoring program (*e.g.* using erosion pins) to track and assess erosion risk and the requirement for erosion mitigation. Given that no mitigation works are proposed at Site #1, there will be no impacts to the existing flood levels.
- Erosion Site #2 – (Option #5): Implement monitoring program (*e.g.* using erosion pins) to track and assess erosion risk and the requirement for erosion mitigation. Given that no mitigation works are proposed at Site #2, there will be no impacts to the existing flood levels.
- Erosion Site #3 – (Option #3): Install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1 slope seeded and/or planted with native species vegetation to provide a durable and naturalized solution. Since the proposed works will result in a similar or larger cross section area within the watercourse, no increase in existing flood levels is anticipated.
- Erosion Site #4 – (Option #3): Install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1 slope seeded and/or planted with native species vegetation to provide a durable and naturalized solution. Also, the existing Willowbrook Road storm sewer inlet headwall and wingwalls will be replaced using armourstone. Since the proposed works will result in a similar or larger cross section area within the watercourse, no increase in existing flood levels is anticipated.

4.3 Preliminary Construction Cost Estimate

Based on preliminary cost calculations, the estimated total cost for the preferred options is approximately $1,105,458.00 (incl. 20% contingency and excl. HST). The cost estimate includes material and labour costs associated with mobilization, by-pass pumping and dewatering, the removal of trees, existing vegetation, earth and debris from the creek, installation of bioengineering and replanting of vegetation based on the landscape plan following construction, re-grading of banks and a 20% contingency. A detailed summary of the preliminary cost estimate for the erosion mitigation options is provided in **Table E.1** in **Appendix E**. Costs associated with the relocation of any existing underground servicing/infrastructure (if required), are *not* included. Although it is not an anticipated requirement for the preferred alternatives, costs associated with any additional land acquisition (if required) are *not* included in the estimate.



PREFERRED OPTION (OPTION 5)
IMPLEMENT MONITORING PROGRAM USING EROSION PINS



SECTION A–A
SCALE: HORIZONTAL 1:100
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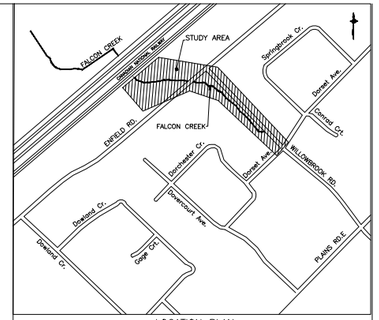

LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS		
DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

CONSULTANT:

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www.valdor-engineering.com

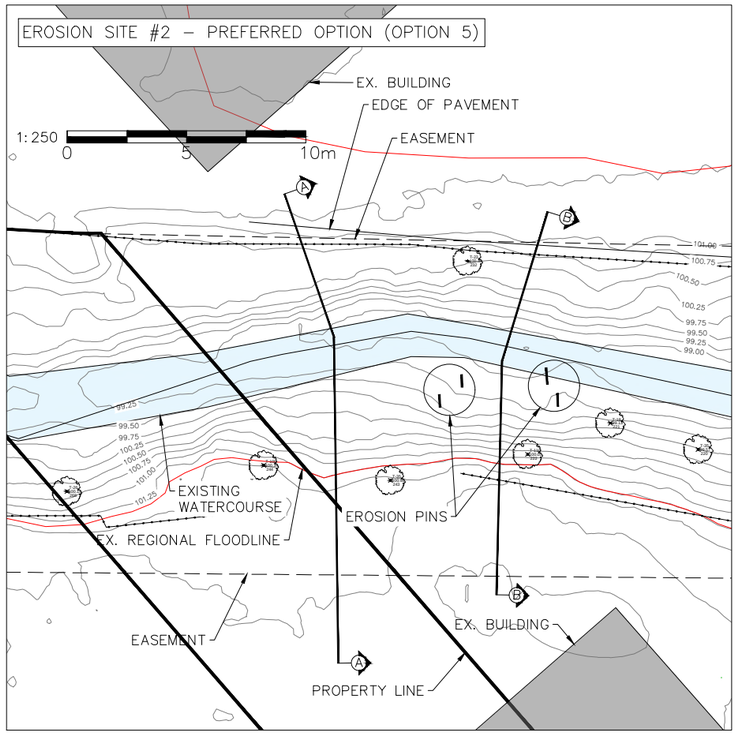
CLIENT: CITY OF BURLINGTON

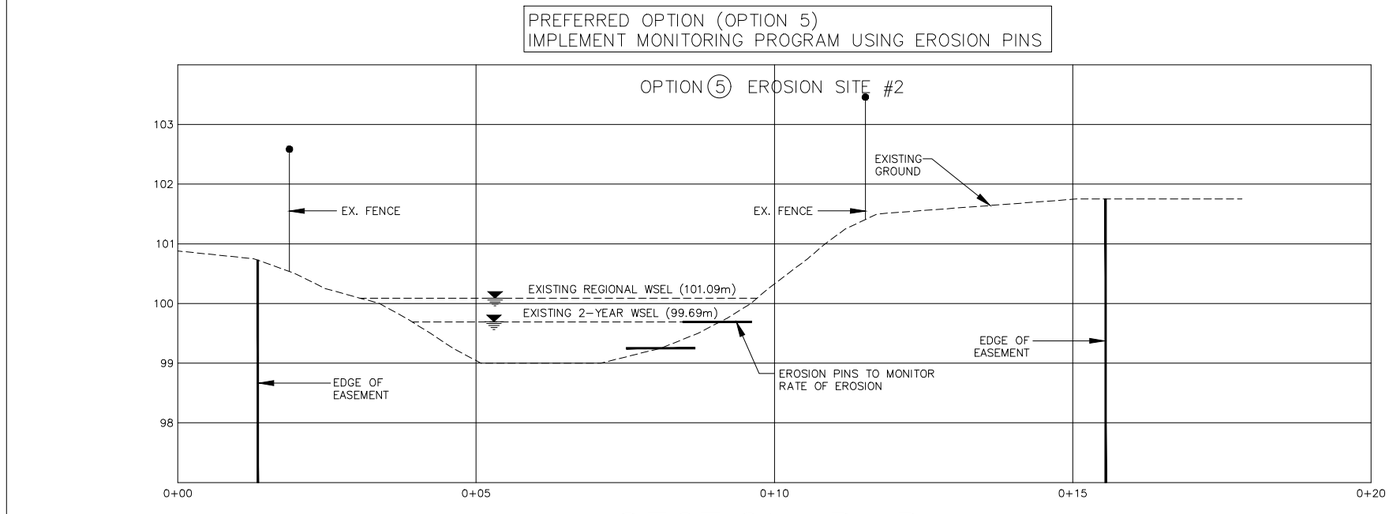
PROJECT: FALCON CREEK EROSION CONTROL

EROSION SITE #1

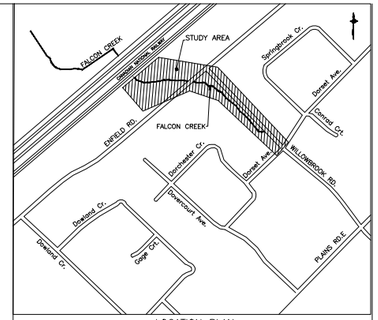
EROSION MITIGATION
PREFERRED OPTION
CONCEPTUAL PLAN

DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	DWG-4.1





SECTION B–B
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

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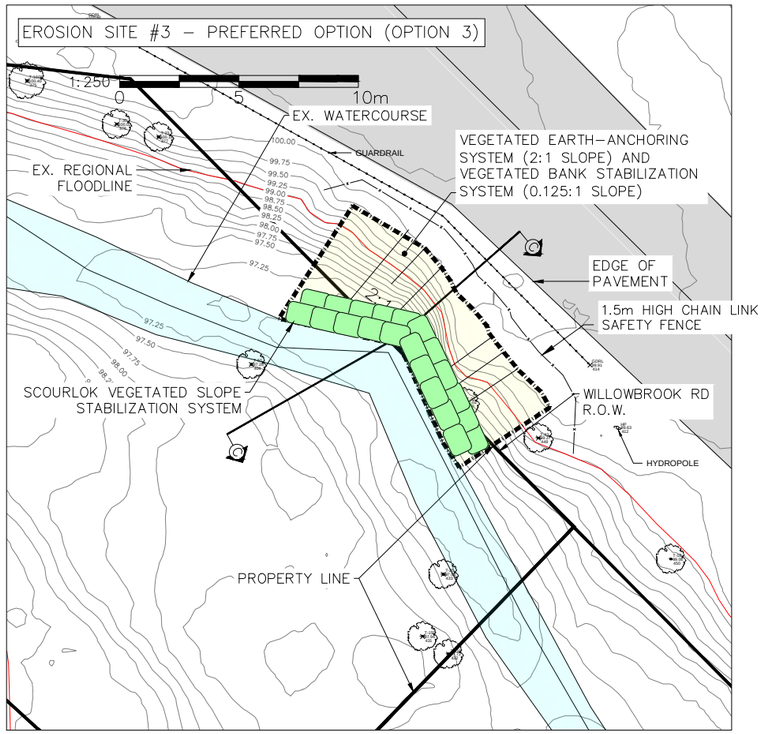
CLIENT:
CITY OF BURLINGTON

PROJECT:
FALCON CREEK
EROSION CONTROL

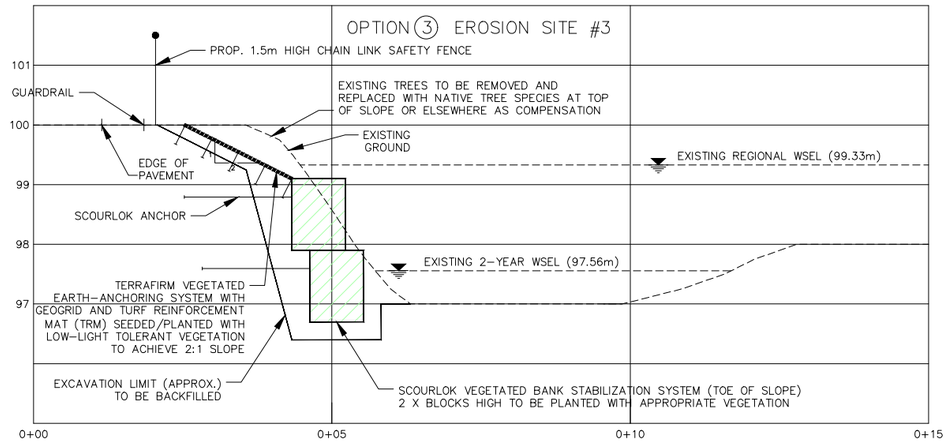
EROSION SITE #2

EROSION MITIGATION
PREFERRED OPTION
CONCEPTUAL PLAN

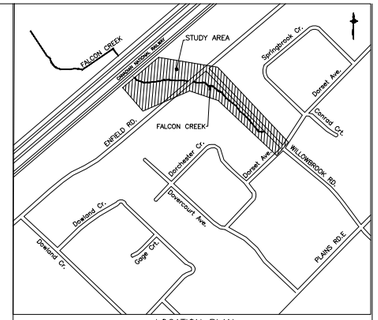
DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	DWG-4.2



PREFERRED OPTION (OPTION 3)
VEGETATED EARTH–ANCHORING SYSTEM (2:1 SLOPE) AND VEGETATED BANK STABILIZATION SYSTEM (0.125:1 SLOPE)



SECTION C–C
SCALE: HORIZONTAL 1:100
VERTICAL 1:100



LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

CONSULTANT:

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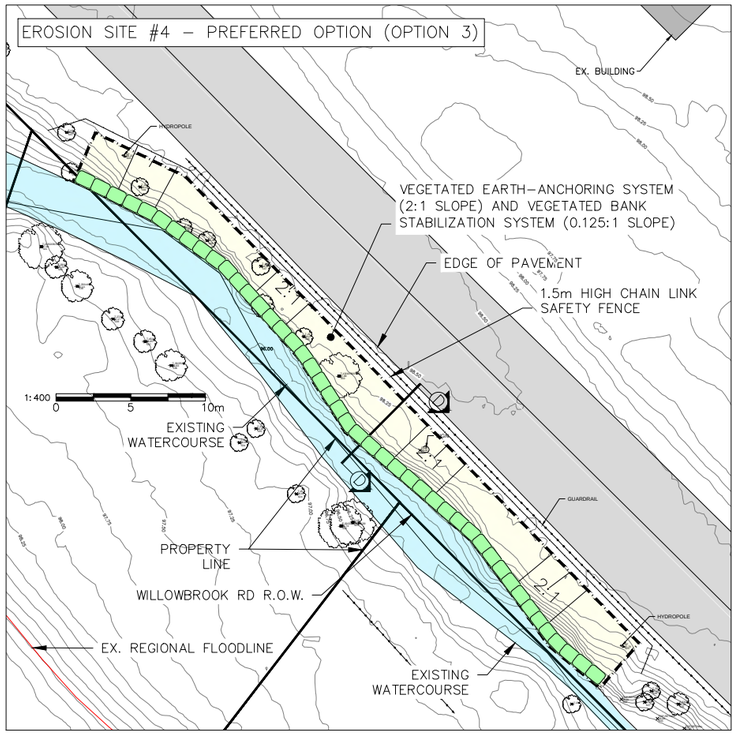
CLIENT: CITY OF BURLINGTON

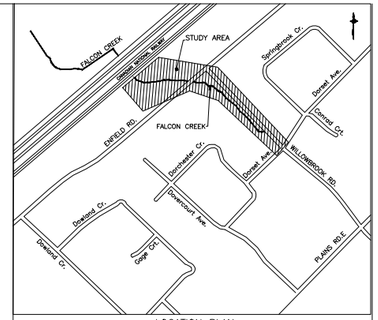
PROJECT: FALCON CREEK EROSION CONTROL

EROSION SITE #3

EROSION MITIGATION PREFERRED OPTION CONCEPTUAL PLAN

DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	DWG-4.3



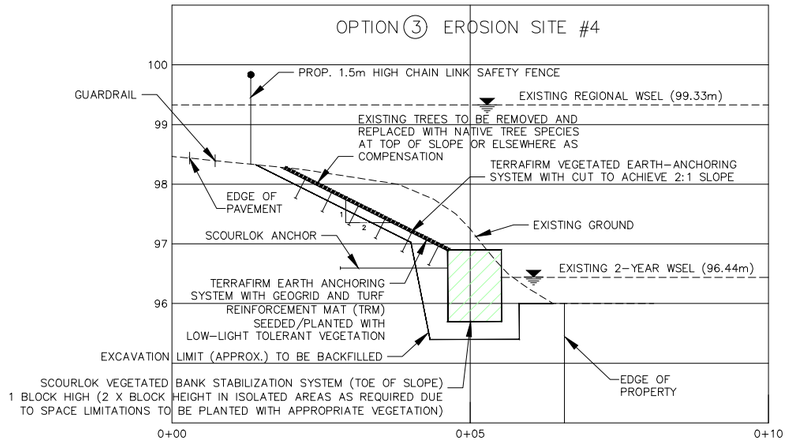


LOCATION PLAN
N.T.S.

LEGEND

- TREE
- HYDRO POLE
- FENCE/GUARDRAIL
- EX. REGIONAL FLOODLINE

PREFERRED OPTION (OPTION 3)
VEGETATED EARTH–ANCHORING SYSTEM (2:1 SLOPE) AND VEGETATED BANK STABILIZATION SYSTEM (0.125:1 SLOPE)



SECTION D–D
SCALE: HORIZONTAL 1:100
VERTICAL 1:100

REVISIONS

DATE	DETAILS	INIT.
2024 04 03	EA SUBMISSION	B.C.

CONSULTANT:

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CLIENT: CITY OF BURLINGTON

PROJECT: FALCON CREEK EROSION CONTROL

EROSION SITE #4

EROSION MITIGATION PREFERRED OPTION CONCEPTUAL PLAN

DESIGNED BY: B.C.	DATE: 2024 04 03	CHECKED BY: B.C.
DRAWN BY: P.Y.	SURVEYED BY:	APPROVED BY:
SCALE: AS SHOWN	PROJ. No. 22118	DWG-4.4

5.0 IMPLEMENTATION STRATEGY FOR THE PREFERRED OPTIONS

The following list is intended as a guide or suggested list of next steps for the City regarding the implementation of the preferred erosion mitigation options:

1. Prepare the Notice of Completion as per the Municipal Class EA process. The City may wish to obtain 1st submission comments from CH prior to issuing the Notice of Completion.
2. Allow for a 30-day review period.
3. Confirm if a DFO Request for Review is required.
4. Prepare the detailed design for the preferred design alternatives.
5. Complete an additional bat acoustic survey in June 2024 or June 2025 depending on the anticipated construction timing.
6. Obtain required construction permits from various agencies (*e.g.* CH, MNR if required).
7. Prepare tender documents and construction drawings for the proposed erosion mitigation strategy.
8. Meeting with local stakeholders to notify them of the final design for construction.
9. Review bids and award the construction contract to the successful bidder.
10. Construct the proposed erosion mitigation works.

6.0 SUMMARY AND RECOMMENDATIONS

Following the requirements of the Municipal Class EA Planning and Design Process, the Falcon Creek Erosion Control Study was completed as a Schedule B project. The following is a brief summary of the components of the study that satisfies *Phase 1* and *Phase 2* of the EA process.

1. **Identify Problem or Opportunity:** The subject reach of the existing watercourse (Falcon Creek) between the CNR and Willowbrook Road has four key locations that are in poor condition due to existing erosion. Two of these areas adjacent Willowbrook Road pose a threat to the road structure itself and potentially the infrastructure/services associated with the road and within the road ROW (*e.g.* hydro, safety railings, etc.).
2. **Identify Alternative Solutions to Problem or Opportunity:** A list of five initial erosion mitigation options was prepared for Erosion Sites #1 and #2 including: (1) do nothing (existing conditions); (2) vegetated slope (3:1 to 4:1); (3) vegetated sub-angular riverstone slope (2:1) or vegetated earth-anchoring system (*e.g.* Terrafirm) at 2:1 slope; (4) vegetated slope stabilization system (*e.g.* Terra Slope 45); and, (5) implement monitoring program. Six initial erosion control options were prepared for Erosion Sites #3 and #4 including: (1) do nothing (existing conditions); (2) vegetated slope (3:1 to 4:1); (3) vegetated earth-anchoring system (*e.g.* Terrafirm) at 2:1 slope with geogrid and turf reinforcement mat and bank stabilization system (*e.g.* Scourlok) at 0.125:1 slope with earth anchors; (4) vegetated slope stabilization system (*e.g.* Terra Slope 45); (5) partial height armourstone retaining wall; and, (6) full height armourstone retaining wall.
3. **Inventory Natural, Social, Economic Environment:** Investigations were completed to evaluate the existing conditions regarding the natural, social and economic environment within the study area. The study area consists of primarily residential dwellings including some commercial / industrial usage that contributes to the local economy. The fluvial geomorphology investigations confirmed that four significant erosion sites are present along Falcon Creek within the study area and that two of these sites are threatening public infrastructure along Willowbrook Road. Two of the identified erosion sites do not pose an imminent threat to private infrastructure based on preliminary investigations. Hydraulic investigations confirmed the subject reach of Falcon Creek is impacted by a significant floodplain with multiple spills. The geotechnical investigations revealed that the steep eroded slopes within the subject site are likely the result of shallow translational slope failure. Loss of support for the slopes was caused by toe erosion at the edge of the creek. Existing tree roots have slowed the rate of erosion of the slopes, although undercutting has exposed roots and caused trees to lean towards the slope in some cases. The natural heritage investigations revealed that the following natural heritage features are present within the study area: fish and fish habitat; species at risk; significant wildlife habitat; and, migratory bird nesting habitat. The following natural heritage features were confirmed not present: significant woodland; significant valleyland; life science area of natural and scientific interest (ANSI); natural heritage system; savannah, tallgrass prairie, alvar; and, provincially significant wetlands or other wetlands. Archaeological investigations (Stage 1 and Stage 2 Property Assessment) were completed for the study area and no archaeological resources were encountered.
4. **Identify Impact of Alternative Solutions on the Environment and Mitigating Measures:** There are no significant negative impacts anticipated from an environmental, social or economic perspective as a result of the proposed erosion mitigation design. Changes to vegetation on the site will be minimized and new and compensation plantings will be of native varieties. Efforts will be made to preserve existing vegetation and to

further intensify plantings along the tops of existing slopes in re-graded areas where possible and within the creek block owned by the City. The erosion mitigation design alternatives will have beneficial impacts regarding downstream water quality which has positive economic implications. Public safety will also be improved as a result of discouraging access to the steep slopes by planting thorny shrubs and re-grading of slopes. As such, it is anticipated that the proposed alternatives will have an overall positive social and economic benefit on the community.

5. **Evaluate Alternative Options and Identify Recommended Solution:** Five to six initial erosion mitigation options were evaluated for each erosion site with consideration given to various economic, social and environmental factors using a decision matrix and the preferred option was determined.
6. **Consult Review Agencies and Public:** A public meeting was held on 08 March 2023 to present and discuss the erosion mitigation alternatives and to solicit feedback and comments from the public and review agencies. Meetings were also held directly with the City, Conservation Halton, Six Nations of the Grand River, Mississaugas of the Credit First Nation, and area residents.
7. **Select Preferred Solution:** Based on the evaluation of options, the preferred set of alternatives includes: Option #5 (implement monitoring program to track and assess erosion risk) at Erosion Site #1; Option #5 (implement monitoring program to track and assess erosion risk) at Erosion Site #2; Option #3 (install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1) at Erosion Site #3; and, Option #3 (install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1) at Erosion Site #4. To address public safety concerns, thorny shrubs will be installed along the top of bank in the vicinity of Erosion Sites #3 and #4 along with safety railings. To address signs of failure noted regarding the Willowbrook Road storm sewer inlet headwall and wingwalls as part of the stormsewer outfall and culvert assesssments, the existing headwall and wingwalls will be replaced using armourstone. The preferred erosion mitigation strategy provides a cost-effective and compact erosion control solution that avoids disturbance to existing private properties while maintaining a naturalized channel.

The following summarizes the report recommendations:

1. Low bank erosion is naturally occurring within the reach. However, there are four (4) areas (Erosion Sites #1, #2, #3 and #4) that are exhibiting excessive erosion. Erosion Sites #1 and #2 do not pose an imminent threat to existing infrastructure on private property based on preliminary observations. It is recommended that erosion in these areas be addressed using the prepared mitigation option (Option #5) that includes monitoring to calculate *in situ* recession rates and to avoid disturbance to private property unless this is confirmed to be absolutely necessary. Option #3 (install a vegetated earth-anchoring system at 2:1 slope and bank stabilization system at 0.125:1) at Erosion Site #3 and Erosion Site #4 should be implemented as the preferred erosion mitigation strategy based on the established selection criteria and evaluation. Given the signs of failure noted regarding the Willowbrook Road storm sewer inlet headwall and wingwalls, it is recommended that the existing headwall and wingwalls be replaced using armourstone.
2. Additional items that should be included in the proposed construction works should include landscaping, erosion and sediment controls, fish rescue, dewatering and by-pass pumping.

3. An estimated construction cost for the preferred erosion mitigation strategy of $1,105,458.00 (incl. 20% contingency and excl. HST) should be considered for preliminary budgeting purposes.
4. The following plans should be prepared at detailed design:
    a. Existing conditions and removals plan;
    b. Existing and proposed plan and profile design drawings including sections;
    c. Site access and construction plan;
    d. Restoration planting plan;
    e. Fish rescue and relocation plan;
    f. Tree preservation plan including tree inventory and arborist report;
    g. Erosion and sediment control plan; and,
    h. Flow by-pass and dewatering plan.
5. Vegetation removals and grading outside the watercourse are to be completed outside of the migratory breeding bird season and the bat roosting season (*i.e.* **vegetation removals and grading outside the watercourse may occur between 01 October and 31 March**).
6. Construction work within the watercourse (*i.e.* in-stream works) is to be completed outside of the fish spawning season (*i.e.* **in-water construction works may occur between 16 July and 14 March**).
7. In compliance with the construction timing windows noted above for bats (roosting), birds (nesting), and fish (spawning), it is recommended the City consider construction of the proposed erosion mitigation works between **01 October and 14 March**. If this is not feasible, the City may consider land-based vegetation removals in the fall/winter (after 01 October and before 31 March) with in-stream works occurring the following season(s) (between 16 July and 14 March).
8. The proposed implementation strategy should be followed regarding the next steps required to prepare for construction. **It is noted that the completion of an additional bat acoustic survey is recommended in June 2024 or June 2025 depending on the anticipated construction timing.**
9. Consideration should be given to staging the channel construction works at detailed design to minimize the risk of erosion and sediment loading to the watercourse during rainfall events.
10. Tree protection and erosion and sediment controls are to be implemented and maintained during construction.
11. The removal of minor debris piles within the subject reach may be considered as a part of the detailed design to enhance the channel conveyance and sediment continuity and to minimize downstream flooding risks due to the potential blockage of conveyance structures. Debris should be removed manually rather than with large equipment. Debris should not be removed in winter and should be completed using erosion and sediment controls that will prevent the release of material downstream. Debris should be removed with caution in a way that prevents the sudden release of ponded water which may cause downstream flooding.

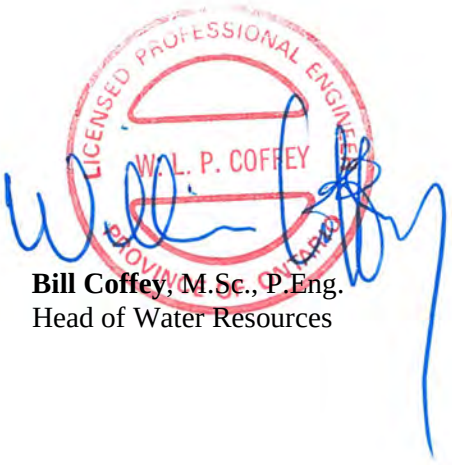
12. The design of slopes including bioengineering should ensure that the slopes are stable and able to support vegetation.
13. A post-construction monitoring program of the erosion sites and the subject reach for debris accumulation will be implemented following construction. This program will continue for a period of two years following construction.
14. Following construction, the City should consider implementing a public education program (*e.g.* flyers delivered to local residents) to inform residents about the impacts of dumping yard waste and debris within the creek including disturbance (*e.g.* raised gardens) to the City-owned creek block and to encourage the installation of LID measures.

7.0 REFERENCES

- AMICK Consultants Limited, *Stage 1-2 Archaeological Property Assessment, Component Study for Falcon Creek Erosion Control (CNR to Willowbank Road) Municipal Class EA (Schedule B)*, 06 October 2022.
- Aquafor Beech Ltd., *City of Burlington 2020 Creeks Inventory and Erosion Assessment*, 26 May 2021.
- North-South Environmental, *Natural Heritage Existing Conditions and Constraints Analysis Report, Falcon Creek Erosion Control Project*, May 2024.
- Soil Engineers Ltd., *A Geotechnical Assessment for Erosion Control Study and Rehabilitation Enfield Road and Willowbrook Road City of Burlington*, 19 January 2023.
- Soil Engineers Ltd., *Soil Characterization Report, Erosion Control Study and Rehabilitation, Falcon Creek, City of Burlington*, 14 February 2023.
- Valdor Engineering, *Falcon Creek Hydrology and Hydraulic Study*, December 2012.
- Water's Edge, *Falcon Creek (CN Rail line to Willowbrook Road) Fluvial Geomorphological & Erosion Assessment*, 15 April 2024.

Respectfully Submitted,
VALDOR ENGINEERING INC.

Abdul Baten, M.Sc.
Water Resources Analyst



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Head of Water Resources

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Water Resources Analyst