Appendix L

Fluvial Geomorphology Assessment

GEO Morphix, June 28, 2024

Fluvial Geomorphology Assessment and Conceptual Natural Corridor Designs

DRAFT

Alloa Secondary Plan Area
Caledon, Ontario

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1 Introduction

GEO Morphix Ltd. (GEO Morphix) was retained to complete the fluvial geomorphology assessment supporting the Alloa Secondary Plan Area in the Town of Caledon, Ontario. The Secondary Plan Area, hereafter referred to as the subject lands, is generally bounded by the future Highway 413 footprint to the north and west, Mayfield Road to the south, and Chinguacousy Road to the east (**Appendix A**). The subject lands are located within four (4) watersheds/subwatersheds: Etobicoke Creek, Fletchers Creek, East Huttonville Creek and West Huttonville Creek. The Alloa Drain is located within the Etobicoke Creek watershed and flows generally west-to-east in the central portion of the subject lands. Two additional municipal drains are located north of and flow into the Alloa Drain, known as Lyons Drain and Fraser Drain. The headwaters of Fletchers Creek, East Huttonville Creek and West Huttonville Creek are located in the southern extent of the subject lands, and generally flow from north to south, exiting the subject lands at Mayfield Road.

This report serves as a vital supporting document to the Local Subwatershed Study (LSWS). The LSWS is a significant undertaking that guides land use planning by confirming and/or refining the extent and management of the natural heritage system. This, in turn, directs development within the subject lands. The LSWS and our fluvial geomorphology assessment are built upon the Scoped Subwatershed Study (SSWS) (Wood, 2022) conducted by the Region of Peel as part of the Settlement Area Boundary Expansion (SABE). Furthermore, several planning-level studies have been or are being conducted on lands east of Chinguacousy Road and south of Mayfield Road. This report provides a summary of the relevant components of these studies.

The fluvial geomorphology assessment is a comprehensive study that includes watercourse characterization and delineation of erosion hazards under both existing and proposed conditions. This information is crucial to identifying the opportunities and constraints to development. The report also reviews erosion mitigation targets to address stormwater management requirements. Additionally, it provides conceptual natural corridor designs for proposed watercourse and drainage feature realignments. The assessment, as summarized in this report, is in full accordance with the Terms of Reference prepared by the Consultant Team and reviewed by the Town of Caledon, Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation (CVC).

Specifically, the following activities were completed by GEO Morphix as part of the fluvial geomorphology assessment and are summarized in this report:

- Review of available background reports and mapping (i.e., watershed/subwatershed studies, geology, topography, conceptual development plans)
- Delineate watercourse reaches based on a desktop assessment of available data and confirmed through field reconnaissance.
- Review of recent and historical aerial photographs to understand historical changes in channel form and function.
- Conduct reach-level rapid geomorphological field assessments following standard protocols (e.g., RGA, RSAT) to evaluate instream and riparian conditions.
- Complete detailed geomorphological field surveys to support the overall erosion mitigation plan for stormwater management and conceptual natural corridor designs
- Conduct event-based baseline surface water quality sampling between the months of April and November at established monitoring locations
- Delineate limits of the meander belt width/erosion hazard on a reach basis using results of the desktop and field assessments
- Provide technical input and recommendations for proposed watercourse crossings with consideration to crossing span and location
- Provide support in the development of an erosion mitigation approach for the future stormwater management plan
- Prepare preliminary conceptual natural corridor design plans for proposed channel realignments (planform, cross-sections, floodplain features, and bioengineering details)

In addition to the above, GEO Morphix is completing headwater drainage feature assessments during the 2024 field season following TRCA and CVC (2014) guidelines. The results of the first two assessment rounds and preliminary management recommendations are provided under separate cover.

2 Background Review

2.1 Settlement Area Boundary Expansion Scoped Subwatershed Study

The SSWS is one of a series of technical studies completed to provide input to the larger Settlement Area Boundary Expansion (SABE) Study to develop a Regional Official Plan Amendment (ROPA) to accommodate growth to 2051. The SSWS was completed in three phases, Parts A to C. The western extent of the SWSS Focus Study Area (FSA) included the Alloa Secondary Plan Area. Part A provided an initial characterization of existing conditions and was primarily based on a desktop review of available information. Part B included more detailed studies and an overview of anticipated impacts due to future development while also providing general guidance for management opportunities and future study requirements at subsequent planning stages. Part C, the Implementation Plan, provided an overview of the recommendations and guidance for management, monitoring programs, and general requirements for future planning stages and design.

Concerning fluvial geomorphology, the SSWS identified surface water feature types and extents, characterized general form and function, delineated preliminary erosion hazards, assessed erosion sensitivity for features that may be impacted by development, and provided recommendations and approaches for mitigation. Reaches were delineated for both watercourses and headwater drainage features based on a desktop assessment and a windshield survey, whereby channels were reviewed in the field from road crossings to confirm presence/absence and general conditions. Due to the extensive study area and limited fieldwork, the reaches were to be refined during future planning stages. The SSWS also acknowledged that additional HDFs may be present within the FSA that could not be identified at the scale of study. Furthermore, it was recommended that reaches be fully assessed in the field using standard rapid assessment tools and following TRCA and CVC (2014) HDF guidelines, as appropriate.

Preliminary meander belt widths were delineated for unconfined reaches by drawing parallel lines tangential to the outside bends of laterally extreme meanders. A 20% safety factor was then applied in place of calculated 100-year migration rates. The erosion hazard for confined reaches was delineated based on Table 3 in the MNR (2002) guideline and a review of the Mayfield West Phase 2 Comprehensive Environmental Implementation Plan (CEISMP) (AMEC, 2014b). Where the channel was within 15 m of the valley toe, toe erosion allowances of 2 m (no active erosion) and 8 m (evidence of active erosion) were delineated for all confined reaches. A stable slope allowance and erosion access allowance were then applied, consistent with MNR (2002) guidelines and Conservation Authority requirements.

A desktop erosion sensitivity assessment was largely completed by air photo interpretation and windshield assessments. Erosion mitigation assessments completed for the Mayfield West Phase 2 Secondary Plan Area and the Mount Pleasant lands were also summarized. Stream power mapping was prepared to identify sensitive reaches within and downstream of the FSA that were to be prioritized for future field assessment and monitoring to evaluate potential impacts to instream erosion due to future development. Preliminary watercourse constraint rankings were also developed based on the desktop assessment and windshield surveys and were subject to refinement at future planning stages.

The Part C report provided a series of management considerations for fluvial geomorphology. Considerations included identifying erosion hazards to minimize or eliminate risk to public and private property, maintenance of natural cover along stream corridors, and maintenance of natural channel structure, rates of adjustment, and channel length. Concerning stormwater management, maintenance of critical flow exceedance from pre- to post-development for erosion-sensitive reaches and maintenance of pre-development runoff volumes were recommended.

2.2 Etobicoke Creek Watershed Plan

In March 2024, the TRCA released the updated watershed plan for Etobicoke Creek titled *Etobicoke Creek Watershed Plan 2024-2034*. This document outlined current and potential future watershed conditions and identified measures to protect, enhance and restore watershed health with specific consideration given to climate change. Key issues identified by the TRCA (2024) in the Etobicoke Creek watershed include:

- Poor aquatic conditions and instream barriers
- High amounts of runoff (402 mm/yr)
- Limited, poor-quality natural cover that is vulnerable to changes in climate
- Relatively poor surface water quality
- Flood Vulnerable Clusters (508 ha) with medium to high erosion sensitivity

Four (4) different scenarios were reviewed to assess the potential impacts of various land use settings, climate change, and enhancements and the associated watershed response. The results of this review are to be used to inform municipal planning decisions, including direction for land use and infrastructure. A management framework was then developed collaboratively by the TRCA, municipalities within the watershed, the Mississaugas of the Credit First Nation (MCFN), and the Greater Toronto Airports Authority (GTAA). The framework identified goals, objectives, indicators, and management actions to protect, enhance and restore watershed health and build resilience to changes in land use and climate. The framework focused on achieving more sustainable land use and infrastructure patterns by implementing low impact development (LID), green infrastructure, improved stormwater management, mitigation of flood and erosion risk and improving rural land stewardship. Other environmental considerations included protecting, enhancing and restoring water resources and natural heritage systems, improving aquatic habitat connectivity, and increasing urban forest cover (TRCA, 2024).

The Alloa Secondary Plan Area is located within the Headwaters subwatershed of Etobicoke Creek. The Watershed Plan indicates that the Town of Caledon and the TRCA are to require the completion of HDF assessments and associated management approach recommendations following TRCA and CVC (2014) guidelines prior to planning approvals in this subwatershed. GEO Morphix is undertaking the HDF assessment during the 2024 field season. Preliminary management recommendations following TRCA and CVC (2014) guidelines are outlined under separate cover. Findings and management recommendations may require revisions pending the results of the Round 3 assessment in July/August of 2024.

Priority Restoration Site Area 1 includes the Alloa Drain, wetlands, and woodlands within the subject lands. The Watershed Plan noted that should urban expansion occur within the Headwaters subwatershed, most restoration opportunities will be through stewardship, and areas with high ecological function should be retained in the natural heritage system (TRCA, 2024). The Town of Caledon is also to establish policies to maintain less than 25% effective impervious cover to minimize impacts to aquatic ecosystem health and to demonstrate through a subwatershed plan that key hydrologic features will be protected (where possible) and hydrologic functions will be maintained. The Watershed Plan defines effective impervious cover as a portion of the total impervious area that releases stormwater directly to a waterbody or storm drain without being treated (TRCA, 2024). Where avoidance of hydrologic features is not possible, mitigation measures must be implemented to maintain downstream functions. In addition, there are to be no negative downstream impacts, such as increased flooding and erosion and degraded water quality (TRCA, 2024).

3 Subwatershed Characteristics

3.1 Etobicoke Creek

The Etobicoke Creek watershed is highly urbanized (approximately 60% as of 2019) and contains predominantly industrial and commercial land uses with significant amounts of impervious cover. This watershed has one of the lowest amounts of natural cover within the TRCA's jurisdiction (TRCA, 2024). The only remaining rural portions of the watershed are located within the Town of Caledon (TRCA, 2024). The subject lands are in the Headwaters subwatershed, which is the only subwatershed with less than

50% impervious cover. The headwaters of Etobicoke Creek originate south of Inglewood and drain south into Etobicoke Creek, which ultimately discharges into Lake Ontario. Land use within the watershed is dominated by approximately 60% of urban land cover, 28% rural land cover, and 12% natural land cover. The predominance of urban land cover leaves the majority of watercourses with a narrow to moderate vegetated riparian corridor. Approximately 50% of watercourses within the watershed have a riparian buffer consisting of either forests, meadows, or wetlands. However, the canopy cover within the Headwaters subwatershed is quite low due to agricultural practices (TRCA, 2021).

The subject lands are comprised of agricultural lands and rural development, and contain multiple tributaries to Etobicoke Creek and numerous HDFs. The Alloa Drain flows west to east through the centre of the subject lands, while the Lyons Drain flows north to south through the northern central portion of the subject lands. The Fraser Drain flows north to south through the western portion of the subject lands. Most drainage features and watercourses traverse cultivated agricultural fields and have been straightened and channelized to promote drainage and maximize arable lands/pasture.

3.2 Fletchers Creek

Fletchers Creek is located within the lower portion of the Credit River watershed and has a drainage area of approximately 45 km^2. Only 9% of the subwatershed is situated in the Town of Caledon with agriculture being the predominant land use. As of 2012, approximately 62% of the overall subwatershed was developed (CVC, 2012), with residential being the predominant land use. Because development commenced in the upper watershed largely after the year 2000, contemporary stormwater management measures and best practices have been used in engineering and natural heritage designs for recently constructed development. Conversely, in the middle portion of the subwatershed, development largely predates the use of contemporary stormwater controls, and as such, there are fewer stormwater management measures in place. Development in the lower subwatershed, south of Highway 401, commenced in the mid-90s, and therefore, this area contains an increased level of stormwater control relative to older developments in the middle portion of the subwatershed (CVC, 2012).

Reach delineation was completed as part of overall subwatershed characterization work and is documented in CVC (2012); however, due to low-order drainage features within the subject lands, limited geomorphic information is available for these reaches. CVC also established several monitoring locations along Fletchers Creek as part of their Effectiveness Monitoring Program, including sites EM5 and SW4, reviewed in subsequent planning studies and noted in this report, where appropriate.

The headwaters of Fletchers Creek originate in predominantly agricultural lands north of Mayfield Road and drain south into the Credit River and ultimately into Lake Ontario. Several HDFs were identified in the southeastern extent of the subject lands within the Fletchers Creek subwatershed. These features flow through agricultural fields, which generally lack canopy cover and a natural riparian zone.

3.3 Huttonville Creeks

Huttonville Creek is known as Subwatershed 7 of the Credit River. The upper portions of this subwatershed are located in southwestern extent of the Alloa Secondary Plan Area, extending a relatively short distance north of Mayfield Road. The subwatershed has a drainage area of approximately 12.45 km^2 (TSH et al,, 2004). Broad-scale reach delineation was completed as part of the Credit Valley Subwatershed Study (TSH et al. 2004); however, limited information is available for drainage features within the subject lands due to their position within the upper subwatershed and the scale of the study. The upper reaches of Huttonville Creek were generally characterized as highly channelized, having a limited vegetation buffer and an intermittent flow regime, and having active agriculture to the edge of bank (TSH et al. 2004).

Within the subject lands, the headwaters of East and West Huttonville Creeks originate in predominantly agricultural lands north of Mayfield Road. A single low order drainage feature within the East Huttonville Creek subwatershed outlets to a constructed natural heritage corridor south of Mayfield Road. Two low order drainage features associated with West Huttonville Creek flow south of Mayfield Road and traverse agricultural lands. These reaches were not reviewed in the field as they are located on non-participating lands.

3.4 Physiography and Surficial Geology

Surficial geology and physiography act as constraints to channel development and tendency. These factors determine the nature and quantity of the availability and type of sediment. Secondary variables that affect the channel include land use and riparian vegetation. These factors are explored as they not only offer insight into existing conditions, but also potential changes that could be expected in the future as they relate to a proposed activity.

The subject lands are located within the South Slope physiographic region and drumlinized till plains landform, although no drumlins are mapped in the subject lands (Chapman and Putnam, 2007). The South Slope region is characterized by gently sloping glacial till plain deposits (Chapman and Putnam, 1984). Surficial geology mapping indicates deposits within the subject lands are of glaciolacustrine origin and comprised of primarily clay to silt-textured till. Along the downstream extent of the main channel and tributaries of the Alloa Drain, modern alluvial deposits comprised of clay, silt, sand, gravel and organic remains are noted in published mapping (OGS, 2010). Along the main channel of the Lyons Drain, Fraser Drain, and mid to upstream of the Alloa Drain, fine-textured glaciolacustrine deposits comprised of clay, silt, with minimal sand and gravel are noted in mapping records. These deposits may also have interbedded layers of pebbly till and rainout deposits (OGS, 2010). Published mapping is generally consistent with field observations, where all channels and drainage features contained predominantly fine-grained substrates and bank materials.

4 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics and potentially how past changes may affect channel planform in the future. Aerial photographs from 1946 (1:20,000) and 1974 (1:25,000) from the National Air Photo Library and recent satellite imagery for the years 2005, 2015 and 2024 from Google Earth Pro were reviewed to understand site history and inform the erosion hazard assessment. Historical aerial photographs are provided in **Appendix B** for reference.

Since prior to 1946, the subject lands have been actively cultivated. The 1946 aerial imagery shows that the majority of the Alloa drain and its tributaries had been straightened, and natural riparian vegetation had been removed from the landscape with the exception of somewhat isolated, generally rectangular woodlots. Lands north of Mayfield Road within the Fletchers Creek and East and West Huttonville Creeks subwatersheds were also actively cultivated, with the drainage network faintly visible in cropped agricultural fields. These extensive modifications likely contributed to limited channel form, increases in instream temperatures, and fine sediment inputs due to a lack woody riparian vegetation having a relatively deep root network. Drainage features were also likely routinely disturbed/disrupted due to cultivation activities.

There was limited change in land use and channel planform between 1946 and 1974. The Alloa Drain, Lyons Drain and Fraser Drain appeared to maintain a planform consistent with 1946 imagery. A portion of what appears to be the historical meandering planform of the lower Lyons Drain is visible west of Creditview Road in 1974. The dug pond west of Chinguacousy Road in the northeastern corner of the subject lands was visible in the 1974 image and appeared to be connected to the adjacent channel via a drainage feature at its eastern extent. A second dug pond is visible south of the Alloa Drain, west of Chinguacousy Road, but direct connection was visible in imagery. The subject lands continued to be cultivated, and additional rural residences were present when 1946 and 1974 images were compared.

Between 1974 and 2005, there were limited changes in channel planform and land use. The majority of the subject lands remained under active cultivation, coupled with rural residential development. By 2015, urban residential development, multiple stormwater management facilities and formalized natural heritage corridors were apparent south of Mayfield Road. Since approximately 2019, residential development has largely directly abutted Mayfield Road. Construction within the Mayfield West lands east of Chinguacousy Road commenced in 2020.

In summary, there has been limited change to land uses within the subject lands during the period of available record. Channels and drainage features within the subject lands were largely straightened and channelized prior to 1946, with retained natural vegetation limited to isolated woodlots. More recently, residential development has steadily encroached from the south and east.

5 Watercourse Characteristics

5.1 Reach Delineation

Reaches are homogeneous segments of channel used in geomorphological investigations. Reaches are studied semi-independently as each is expected to function in a manner that is at least slightly different from adjoining reaches. This method allows for a meaningful characterization of a watercourse as the aggregate of reaches, or an understanding of a reach, for example, as it relates to a proposed activity. Reaches are typically delineated based on changes in the following:

- Channel planform
- Channel gradient
- Physiography
- Land cover (land use or vegetation)
- Flow, due to tributary inputs
- Soil type and surficial geology
- Historical channel modifications

This follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004). Reaches are first delineated as a desktop exercise using available data and information such as aerial photography, topographic maps, geology information and physiography maps. The results are then verified in the field.

Reaches within the subject lands were previously delineated at a high-level of assessment as part of the SSWS prepared by Wood (2022) via a desktop review and windshield survey. Due to the identification of multiple new reaches (largely HDFs) based on site-specific detailed field work, the reach naming convention and reach breaks have been revised as part of the current study. Several reaches were delineated along the Alloa Drain, which flows centrally in a west to east orientation, as well as the lower portions of the Fraser and Lyons Drains in the western and central portions of the study area, respectively. All watercourse reaches are located within the Etobicoke Creek watershed. Drainage features identified in the southern portion of the subject lands near Mayfield Road are located within the Fletchers Creek and Huttonville Creek subwatersheds and are characterized as HDFs. Watercourse reach delineation is graphically presented in **Appendix A**.

5.2 Reach Observations

Field investigations were completed on May 2, 2024, and included the following observations on a reach basis:

- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Determination of bed and bank material composition and structure
- Confirmation of valley form (i.e., unconfined, partially confined, confined)
- Observations of erosion, scour, or deposition
- Collection of photographs to document watercourses, riparian areas, adjacent land use, and channel disturbances such as crossing structures

These observations and measurements are summarized in **Table 1**. Field descriptions are supplemented and supported with representative photographs included in **Appendix C**. Field sheets, including those completed for reach characterization and rapid assessments, are provided in **Appendix D**.

Table 1: General reach characteristics

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Bed Substrate	Bank Materials	Valley Type	Dominant Riparian Conditions	Notes
Alloa Drain							
***AD1-2**	2.99	0.21	**Clay, silt and sand		Unconfined	Narrow buffer of established grasses at the downstream extent. Wide forested buffer of trees and grasses at the upstream extent.	Channel flowed through a wetland and was straightened. Wetland vegetation present in the downstream portion of the reach.
***AD-2**	4.05	0.42	*Clay, silt and sand		Unconfined	Narrow riparian buffer consisting of grasses with isolated trees	Run-dominant straightened channel between agricultural fields.
AD3	3.64	0.82	Sand, gravel, and cobbles	Clay, silt, sand	Unconfined	Narrow riparian buffer consisting of shrubs and grasses.	Straightened channel with poor longitudinal substrate sorting. Run-dominant system with few riffles.
***AD4**	5.37	0.52	**Clay, silt, and sand		Unconfined	Narrow riparian buffer consisting of grasses	Straightened channel through agricultural fields. Multiple crossings.
***AD5**	3.97	0.42	**Clay, silt, and sand		Unconfined	Narrow riparian buffer of grasses with a few trees	Channel moderately entrenched with moderate encroachment of grasses in the channel.
AD6	3.96	1.01	**Clay, silt, and sand		Unconfined	Narrow riparian buffer consisting of grasses	Channel had a low sinuosity with irregular meanders. Attached algae and rooted emergent vegetation present.
AD7	3.67	0.63	**Clay, silt, and sand		Unconfined	Wide mature forested buffer dominated by trees and shrubs	Water in the channel was turbid and had an organic smell.
Lyons Drain							
LD1	3.93	0.77	**Clay, silt to gravel		Unconfined	Narrow fragmented buffer consisting of mature trees and shrubs.	Straightened channel with sand/silt substrate. One artificial riffle was present following the culvert at the road.

Reach Name	Avg. Bankfull Width (m)	Avg. Bankfull Depth (m)	Bed Substrate	Bank Materials	Valley Type	Dominant Riparian Conditions	Notes
***LD2**	6.47	0.38	Clay, silt, gravel, cobbles	Clay, silt, gravel	Unconfined	Narrow riparian buffer consisting of established grasses	Ditch along Creditview Road containing predominantly runs with some artificial riffles present. Undercutting common along the reach.
LD3	4.96	0.78	**Clay, silt, and sand		Unconfined	Moderate mature riparian buffer of trees and shrubs along the left bank upstream. Narrow riparian buffer of mature trees and shrubs on both banks in downstream section.	Run-dominant with a few riffles and pools mid-reach. Generally straight, entrenched channel with minimal erosion.
LD4	3.80	0.61	**Clay, silt, and sand		Unconfined	Narrow fragmented riparian buffer consisting of established trees and grasses.	Short reach with moderate entrenchment and minimal erosion. Watercress was present and grasses were encroaching the channel.
LD4-1	2.80	0.63	**Clay, silt to gravel and minimal cobbles		Unconfined	Moderate riparian buffer of mature trees and grasses.	Erosion, undercutting, and steep banks were observed in the upstream portion of the reach in the forest.
Fraser Drain							
FD1	2.71	0.51	**Clay, silt and sand		Unconfined	Wide mature riparian buffer of trees in the upstream section and downstream along the right bank. Narrow riparian buffer of grasses on the left bank.	Straightened channel between a forested buffer and an agricultural field. Film present on water surface at various locations where woody debris was present. The bed was also heavily silted.
FD2	3.42	0.67	Gravel and cobbles	Clay, silt and sand	Unconfined	Wide mature riparian buffer of trees along the right bank. Narrow riparian buffer of established grasses on the left bank.	channel was dominated by runs with riffles for approximately 25% of the reach. Runs were dominated by clay, silt, and sand.

* Bankfull dimensions based on detailed geomorphological assessment
** Uniform channel bed, substrate observations reflective of full channel condition

Rapid assessments were completed to identify dominant geomorphic processes, document stream health, and to identify any areas of concern regarding erosion or instability. Channel instability was objectively quantified through the application of the Ontario Ministry of the Environment's (2003) Rapid Geomorphic Assessment (RGA). Observations were quantified using an index that identifies channel sensitivity based on evidence of aggradation, degradation, channel widening, and planimetric adjustment. The index produces values that indicate whether a channel is stable/in regime (score <0.20), stressed/transitional (score 0.21-0.40), or adjusting (score >0.41).

The Rapid Stream Assessment Technique (RSAT) was also employed to provide a broader view of the system as it considers the ecological function of the watercourse (Galli, 1996). Observations were made of channel stability, channel scouring or sediment deposition, instream and riparian habitats, and water quality. The RSAT score ranks the channel as maintaining a poor (<13), fair (13-24), good (25-34), or excellent (35-42) degree of stream health.

Although the RGA and RSAT tools are intended to be generally used on natural systems, which are largely not present in the subject lands, results are reported below as they still provide an assessment of channel stability and overall stream health. A summary of the reach classifications and rapid assessment scores is provided in **Table 2**.

Table 2: Summary of rapid assessment results

Reach	RGA (MOE, 2003)		RSAT (Galli, 1996)		
	Score	Condition	Score	Condition	Limiting Feature(s)
Alloa Drain					
AD1-2	0.098	In Regime	24	Fair	Physical Instream Habitat
AD-2	0.174	In Regime	23	Fair	Riparian Habitat Conditions
AD3	0.170	In Regime	23	Fair	Riparian Habitat Conditions
AD4	0.176	In Regime	24	Fair	Riparian Habitat Conditions
AD5	0.145	In Regime	24	Fair	Riparian Habitat Conditions
AD6	0.103	In Regime	23	Fair	Riparian Habitat Conditions
AD7	0.165	In Regime	23	Fair	Water Quality
Lyons Drain					
LD1	0.067	In Regime	25	Good	Riparian Habitat Conditions
LD2	0.180	In Regime	22	Fair	Riparian Habitat Conditions
LD3	0.143	In Regime	25	Good	Physical Instream Habitat and Riparian Habitat Conditions
LD4	0.103	In Regime	23	Fair	Physical Instream Habitat and Riparian Habitat Conditions

Reach	RGA (MOE, 2003)		RSAT (Galli, 1996)		
	Score	Condition	Score	Condition	Limiting Feature(s)
LD4-1	0.130	In Regime	20	Fair	Physical Instream Habitat
Fraser Drain					
FD1	0.197	In Regime	20	Fair	Physical Instream Habitat
FD2	0.165	In Regime	20	Fair	Physical Instream Habitat and Riparian Habitat Conditions

The Alloa Drain is an artificial feature that has been straightened and entrenched along its entire length within the subject lands. The channel has a low gradient and generally flows between agricultural fields. The riparian vegetation buffer is narrow but continuous, consisting of isolated trees and grasses that moderately encroach the channel. Limited erosion was present along the drain. Bed substrates consisted of primarily clay, silt, and sand and evidence of channel aggradation was observed due to accumulations of fine-grained sediments along the drain bed. The banks were steep, ranging from 60 – 90 degrees. Watercress was often present in the channel in most reaches. An absence of bar forms was observed in all reaches, indicating they are either poorly formed or otherwise removed from the channel. All reaches were classified to be "In Regime" based on the RGA and in "Fair" condition based on the RSAT.

Reach AD2 is the furthest downstream reach of the Alloa Drain. Multiple tile drains were observed to outlet to the channel. Widening was observed at the outlets of a couple of the tile drains. Woody debris was present, with two woody debris jams identified. Localized undercutting was also observed in one location while minimal erosion was observed elsewhere in the reach. The reach was run-dominant, with a few rifles consisting of gravel and cobbles. The bed substrate was poorly sorted longitudinally. RGA score was 0.174 due to a lack of bar forms, exposed tile drain, siltation on the bed, and poor longitudinal sorting of bed materials.

Reach AD3 flowed through a wetland area; however, due to entrenchment, the wetland area was not directly connected to the channel. This reach had poor longitudinal substrate sorting and bed materials ranged from clay/silt to cobbles, although sand, gravel, and cobbles were generally dominant. This reach had some irregular meanders, and one localized area of dredging was observed at the downstream extent. The RGA score was 0.170 based on the lack of bar forms, exposed tile drain, siltation on the bed, and poor longitudinal sorting of bed materials.

Reach AD4 had multiple field crossings and tile drains that outlet to the channel. Scour pools were present on the downstream side of the culverts. Minimal woody debris was found in this reach, with one localized woody debris jam. A hedgerow lined the channel at the downstream extent, which included some leaning trees. Minimal erosion was observed along the reach. The RGA score was 0.176 based on the lack of bar forms, scour pools downstream of culverts, exposed tile drain, siltation on the bed, and leaning trees.

Reach AD5 was straight with isolated trees in the riparian buffer that occasionally leaned towards the channel. A fence was observed to be crossing and leaning into the channel approximately mid-reach. A scour pool was also identified downstream of the culvert at Mississauga Road. The RGA score was 0.145 based on the lack of bar forms, scour pool downstream of a culvert, siltation on the beds, and leaning trees and fence posts.

Reach AD6 had a few tile drains that outlet to the channel and a field crossing. Woody debris was not found within this reach. Instream vegetation generally consists of cattails and a localized area of algae. The RGA score was 0.103 based on the lack of bar forms, exposed tile drain, and siltation on the bed.

Reach AD7 is the furthest upstream reach of the Alloa Drain that access was permitted. The channel flowed through a wide, mature riparian buffer consisting primarily of trees and shrubs. Leaning trees, exposed roots, and large organic debris were observed along the channel. Turbid standing water had a strong organic odour. The RGA score was 0.165 based on the lack of bar forms, leaning trees, exposed roots, large organic debris, and siltation on the beds. The limiting feature in this reach (water quality) differed from the remainder of the Alloa Drain.

Reach AD1-2 is a tributary of the Alloa Drain that flowed through a wetland and woodlot. The channel is sinuous with a low gradient and low entrenchment. At the upstream extent, the channel flows as a single pathway through a riparian buffer consisting of a forest with established trees. At the forest edge, the single channel transitioned to multiple flow paths and had a riparian buffer consisting of grasses that heavily encroached on the channel. Instream wetland vegetation was present throughout the downstream extent. The reach was run-dominant and lacked riffle pool morphology. The bed and bank substrates consisted of clay, silt and sand. Minimal erosion was observed throughout the reach. Leaning trees were observed in the upstream extent of the reach and organic debris was observed throughout the reach. The RGA score was 0.098 based on the change in form from a single thread channel to a multi-thread system, leaning trees and large organic debris.

Reach LD1 is a furthest downstream reach of the Lyons Drain and connects to the Alloa Drain. The reach was relatively short and had been artificially straightened. The channel was moderately entrenched with a low gradient. The riparian vegetation was a narrow, fragmented buffer of mature trees and shrubs. The bed substrate and bank materials were primarily clay, silt, sand, and gravel, with sand being dominant. Bank angles ranged from 30 – 60 degrees. Minimal erosion was present throughout the reach. Watercress was observed in some areas of the reach. The reach was run-dominant with one artificial riffle at the upstream reach extent at Creditview Road. The reach was evaluated as "Good" based on the RSAT but could be evaluated with a higher score if the riparian buffer was more substantial. The RGA score was 0.067 based on the fallen and leaning trees and accretion on point bars; however, it should be noted that a limited number of bars were present.

Reach LD2 flowed south alongside Creditview Road as a roadside ditch. The channel had a low gradient and transitioned from being multi-threaded in the upstream extent to a single channel in the downstream extent. Riparian vegetation consists of a narrow, continuous buffer of grasses. The substrate in riffles was observed to be clay, silt, gravel, and cobble with clay, silt, and gravel in the pools and banks. The reach was run-dominant with some riffles and very few pools. Most riffles were artificial, likely to mitigate erosion near the culverts. A scour pool was measured to be 0.60 metres deep following the culvert at the upstream extent of the reach. Basal scour was observed throughout the reach, including undercuts measuring up to 0.55 m deep. The reach RSAT scored "Fair" based due to the narrow riparian buffer and lack of canopy cover. The RGA score was 0.180 due to embedded coarse materials in riffles, a scour pool downstream of a culvert, basal scour throughout the reach, the transition from a multi-thread channel to a single thread channel, and the lack of bar forms.

Reach LD3 was a generally straight channel and moderately entrenched. Channel banks were relatively high in the upstream extent of the reach when compared to banks in the downstream extent. The riparian vegetation was generally a narrow, fragmented buffer consisting of mature trees and shrubs. The reach was run-dominant with a few riffles identified mid-reach. The bed and bank substrate primarily consisted of clay, silt and sand. Limited erosion was observed along the reach with the exception of a few locations localized locations. Woody debris was observed within the channel at a low density. The reach was scored as "Good" based on the RSAT. The RGA score was 0.143 due to the presence of fallen and leaning trees, minimal exposed tree roots, and accretion on point bars; however, it should be noted that a limited number of bars were present.

Reach LD4 is the furthest upstream reach of the Lyons Drain. The reach is relatively short and straight, with bank angles ranging from 30 – 60 degrees. Riparian vegetation generally consisted of a narrow, fragmented buffer of established trees and grasses. Aquatic instream vegetation consisting primarily of fragmented patches of cattails and watercress. The reach was run-dominant and the channel substrate and bank materials consisted primarily of clay, silt and sand. Erosion was minimal throughout the reach. A tile drain also discharged to the top of this reach. The reach was scored as "Fair" based on the RSAT due to a lack of canopy cover and riffle-pool morphology. The RGA score was 0.103 based on the presence of fallen and leaning trees, siltation in pools, and a lack of bar forms.

Reach LD4-1 is a tributary of Lyons Drain and consisted of a short, sinuous reach with moderate entrenchment. Riparian vegetation was comprised of a generally moderately wide, continuous buffer of mature trees and grasses. The reach was run-dominant and channel bed materials consisted of clay to gravel with minimal cobbles observed. Bank materials consisted of clay, silt, sand, and gravel and bank angles ranged from 60 – 90 degrees. In the downstream extent of the reach, bank angles were significantly lower and ranged from 0 – 30 degrees. Erosion was observed primarily at the upstream extent of the reach and was evidenced by exposed roots and leaning and fallen trees. The reach was assigned an RSAT score of "Fair" due to the absence of riffle pool morphology. The RGA score was 0.130 due to fallen and leaning trees, exposed roots, the presence of large organic debris, poor longitudinal sorting of bed materials, and accretion on point bars.

Reach FD1 is a furthest downstream reach of the Fraser Drain and connects to the Alloa Drain. The channel was straight, moderately entrenched and had a low gradient. Riparian vegetation consisted of a wide forested buffer with mature trees on the right bank. On the left bank, the riparian buffer was narrow and consisted of grasses that were minimally encroaching the channel. Woody debris was present in the channel, along with multiple fallen trees. The bed substrate contained primarily clay, silt, sand throughout the reach. The banks ranged from 30 – 60 degrees and materials consisted of clay, silt, and predominantly sand. The reach was scored as "Fair" based on the RSAT due to a lack of riffle-pool morphology. The RGA score was 0.197 due to a lack of bar forms, fallen and leaning trees, exposed roots, the presence of large organic debris, exposed tile drain, and siltation on the bed.

Reach FD2 is a furthest upstream reach of the Fraser Drain. It was straight, with a low gradient and moderate entrenchment. The riparian vegetation consisted of a wide forested buffer with mature trees on the right bank. On the left bank, the riparian buffer was narrow and consisted of established that minimally encroached the channel. Some trees were observed to be leaning and large organic debris was observed throughout the channel. Bed and bank materials consisted primarily of clay, silt, and sand. The reach was scored as "Fair" based on the RSAT due to a lack of riffle-pool morphology and the narrow riparian buffer on one bank. The RGA score was 0.165 based on the lack of bar forms, fallen and leaning trees, the presence of large organic debris, exposed tile drain, and siltation on the bed.

5.3 Detailed Geomorphological Assessments

Obtaining detailed geomorphological measurements and observations allows for a more complete characterization of channel geometry, flow, and sediment characteristics. The data obtained are used to inform the natural corridor designs. In the interest of maintaining or improving channel conditions with regard to stability and fluvial function, the most natural and sensitive reaches within a study area are typically assessed; however, given the extent of historical channel modification within and downstream of the Secondary Plan Area, historically modified reaches were surveyed and then evaluated in the context of hydrology modelling provided by Urbantech (2024), our previous experience designing naturalized corridors in the watershed, our understanding of natural heritage system targets and agency expectations.

Reaches AD1, AD1-2, AD2, AD4, AD5, AD5-1, and **LD2** were selected for detailed assessments in support of the proposed realignment and restoration of the Alloa Drain and associated tributaries. The selected reaches serve as reference locations for the existing drain that may be used to inform future design approaches and criteria.

The surveys were completed between May 24, 2024, to June 3, 2024 and included the following:

- Longitudinal survey of the channel centre line
- Detailed surveys of up to eight to ten detailed cross-sections
- Instream measurements of bankfull channel geometry, riparian conditions, bank material, bank height/angle, and bank root density at each surveyed cross-section
- Bed material sampling at each cross-section following a modified Wolman (1954) pebble count or substrate sample, as appropriate

The results of the detailed assessments are presented below in **Table 3**. A full summary of each detailed assessment is provided in **Appendix E**.

Table 3: Detailed Assessment Summary

Channel parameter	Reach AD1	Reach AD1-2	Reach AD2	Reach AD4	Reach AD5	Reach AD5-1	Reach LD2
Bankfull Conditions							
Average bankfull width (m)	4.90	2.99	4.05	5.37	3.97	2.87	6.47
Average bankfull depth (m)	0.25	0.21	0.42	0.52	0.42	0.10	0.38
Channel gradient (%)	0.25	0.88	0.01	0.15	0.10	0.49	0.38
D_{50} (mm)	0.145	0.284	0.219	0.099	0.169	0.169	0.084
D_{84} (mm)	1.334	0.718	0.766	0.456	0.564	0.659	0.534
Manning's n roughness coefficient	0.035	0.035	0.035	0.035	0.035	0.035	0.035
Calculated Bankfull discharge (m^3/s)*	0.73	0.60	1.66	2.05	0.89	0.11	2.66
Calculated Bankfull velocity (m/s)*	0.60	0.98	0.98	0.73	0.53	0.39	1.08

*Based on Manning's equation

6 Baseline Surface Water Quality Sampling

Five (5) surface water quality sampling locations were established during spring 2024 at road crossings in the subject lands to characterise baseline water quality (**Appendix F**) . These sampling sites align with surface water quantity monitoring being conducted by others. The sampling program is event-based, capturing at least one (1) wet (10 mm of rain in 24 hours) and one (1) dry event (48 hours with no precipitation), seasonally (spring, summer, fall). During wet weather sampling two samples are collected, during the rising and falling limbs of the hydrograph. To ensure appropriate conditions are captured in sampling, the rising limb of the hydrograph is captured using automatic composite samplers equipped with water level triggers to initiate sampling, while a second sample is collected during the receding limb of the hydrograph. The following parameters are being measured at each monitoring location during each sampling event:

- Ammonia
- Anions (Nitrate, Nitrite, Phosphate, Chloride)
- BOD5 (Biochemical Oxygen Demand)
- Conductivity
- Dissolved Oxygen
- Metals (Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, P, K, Se, Si, Ag, Na, Sr, Tl, Sn, Ti, W, U, V, Zn, Zr)
- PAH (Polycyclic Aromatic Hydrocarbons)
- pH / Alkalinity
- Total Kjeldahl Nitrogen (TKN)
- Total Phosphorous
- Total Suspended Solids (TSS)
- Turbidity

Daily precipitation data for 2024 was acquired from a Brampton Weather Underground station located approximately 2.5 km southeast of the subject site. During the 2024 monitoring period (to-date) (April

1st – June 20th), precipitation was recorded on 40 of 81 monitoring days and there were 10 occurrences of daily rainfall ≥10 mm. A summary of sampling events is presented in **Table 4**.

Table 4. Wet and Dry Event Sampling Conditions

Event	Date (yyyy-mm-dd)	Event Type	Prior 24-Hour Rainfall (mm)	Total Rainfall on day (mm)
1	2024-05-27 12:20 PM 2024-05-28 9:00 AM	Rain	0.79	39.90
2	2024-06-12	Dry	0.00	0.00

Discrete water measurements of several water quality parameters (listed above) were collected at each monitoring location. During the spring wet event sampling results were similar across all sites. As anticipated, concentrations of many parameters were significantly higher during the ascending limb than during the receding limb. Average TSS during the ascending and receding limbs were 535 mg/L and 18 mg/, respectively. The maximum TSS observed during the May 2024 wet event was 1,740 mg/L at ASW4. PWQO exceedances were noted for a number of metals during the ascending limb including aluminum, cadmium, copper, iron, lead, vanadium, and zinc at all sites. In addition to the metals noted, nickel and arsenic were also observed in exceedance at ASW4. During the receding limb, only three metals remained in exceedance of PWQO including aluminum, copper, iron. These three metals are widely observed in exceedance as they are closely related to urban road dust associated with vehicle wear.

Results of the dry event sampling continue to show lower concentrations of most parameters; however, copper remained in exceedance at all sites, iron was in exceedance at sites ASW 3, 4, and 5, and aluminum was in exceedance at sites ASW 4 and 5. Water quality sampling will continue to the fall of 2024 to characterise baseline water quality during a variety of seasonal conditions. A complete record of water quality analyses is provided in **Appendix F**.

7 Existing Conditions Erosion Hazard Delineation

Most watercourses in southern Ontario have a natural tendency to develop and maintain a meandering planform, provided there are no spatial constraints. A meander belt width or erosion hazard assessment estimates the lateral extent that a meandering channel has historically occupied and will likely occupy in the future. This assessment is therefore useful for determining the potential hazard to proposed activities in the vicinity of a watercourse.

When defining the erosion hazard for a watercourse, Ministry of Natural Resources (MNR, 2002) guidelines treat unconfined and confined systems differently. Unconfined systems are those with poorly defined valleys or slopes well outside where the channel could realistically migrate. Confined systems are those where the watercourse is contained within a defined valley, where valley wall contact is possible. Partially confined systems are those where meander bends are adjacent to only one valley wall and the watercourse is therefore restricted in migration and floodplain occupation on one side of the valley system.

All watercourse reaches within the Secondary Plan Area were characterized as unconfined. In unconfined systems, the limit of the erosion hazard and migration potential can be delineated based on the meander amplitude. Meander amplitude is defined by Leopold et al. (1964) as the lateral distance between tangential lines drawn to the center channel of two successive meander bends. This differs from meander belt, which is measured for a reach between lines drawn tangentially to the outside bends of the laterally extreme meander bends (TRCA, 2004). Both the meander belt width and amplitude quantify the lateral extent of a river's occupation on the floodplain (TRCA, 2004). Because all watercourse reaches have been historically straightened to accommodate agricultural land uses, natural meanders are not present on the landscape. A suite of empirical equations was therefore used to delineate meander belt widths.

Meander belt widths were also calculated using empirical modelling for comparison purposes. The bankfull channel dimensions observed during field reconnaissance were used to inform both the Williams (1986) and Ward (2002) models outlined below.

The empirical relations from Williams (1986) were modified to include channel width, and applied using the bankfull channel dimensions such that:

$$B_w = 18A^{0.65} + W_b \quad \text{[Eq. 1]}$$

$$B_w = 4.3{W_b}^{1.12} + W_b \quad \text{[Eq. 2]}$$

where Bw is meander belt width (m), A is bankfull cross-sectional area (m^2), and W_b is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values. This addresses issues of under prediction.

The Ward et al. (2002) bankfull width model was also used to determine a meander belt width (ft), Bw:

$$B_w = 6{W_b}^{1.12} \quad \text{[Eq. 3]}$$

The resulting value was then converted to the metric system (m). A 20% factor of safety was not applied to this value due to the approach used in the modelling (i.e., hazard envelope rather than a linear relationship).

Lastly, meander belt widths were also calculated based on TRCA's (2004) empirical model:

$$B_w = -14.827 + 8.319 \ln(\rho g Q S * DA) \quad \text{[Eq. 4]}$$

where ρ is water density (1000 kg/m^3), g is acceleration due to gravity (9.8 m/s^2), Q is discharge (m^3/s), S is channel slope (m/m), and DA is drainage area (km^2). Reach gradients were determined using topographic data derived from LiDAR. Drainage areas were obtained from the Ontario Watershed Information Tool (OWIT), while the 2-year discharge for each reach was provided by Urbantech (2024). **Table 5** provides a summary of parameters used in the TRCA (2004) model.

Table 5: Parameters used in TRCA (2004) empirical model

Reach	Discharge (m^3/s)	Slope (m/m)	Drainage Area (km^2)
Alloa Drain			
AD1-2	0.23	0.0050	3.30
AD-2	3.74	0.0015	9.83
AD3	3.42	0.0015	9.48
AD4	2.50	0.0015	6.31
AD5	2.08	0.0007	5.57
AD6	1.53	0.0008	2.85
AD7	0.66	0.0029	1.15
Lyons Drain			
LD1	0.96	0.0084	2.03
LD2	0.96	0.0035	2.02
LD3	0.96	0.0028	1.98
LD4	0.96	0.0059	1.85
LD4-1	0.96	0.0092	0.11

Reach	Discharge (m^3/s)	Slope (m/m)	Drainage Area (km^2)
Fraser Drain			
FD1	0.53	0.0008	2.24
FD2	0.53	0.0004	0.77

Empirical modelling results are summarized in **Table 7**, below. The extents of all meander belt widths based on existing conditions are illustrated in **Appendix G**. With regard to the Alloa Drain, calculated meander belt widths range from 19 m to 58 m. With the exception of **Reach AD1-2** in the eastern extent of the subject lands, values determined using the TRCA (2004) model are recommended as the final meander belt widths. These values include one (1) standard error (8.63) as a factor of safety. A meander belt width of 19 m based on the modified Williams (1986) width equation and a 20% factor of safety is recommended for **Reach AD1-2** under existing conditions. This reach is proposed for realignment as part of future development and the designed channel and associated meander belt width are to be accommodated in the constructed corridor. Refer to **Section 9.5** for additional information.

Calculated meander belt widths along Lyons Drain range from 13 m to 49 m. Values calculated using the modified Williams (1986) width equation are generally selected as appropriate. Typically, meander belt widths decrease in the upstream direction due to reduced drainage areas, relatively lower discharges and in turn, smaller bankfull channel geometries. The modified Williams (1986) width equation resulted in a narrow meander belt width for **Reach LD2** relative to adjoining reaches. Therefore, the 29 m meander belt width calculated upstream and downstream was adopted for this reach. In addition, the TRCA (2004) model resulted in a 29 m meander belt width for **Reach LD2**. **Reaches LD1** and **LD2** are proposed for realignment as part of future development and therefore the designed channel and associated meander belt widths are to be accommodated within their constructed corridors. Refer to **Section 9.5** for additional information.

Meander belt widths calculated for Fraser Drain ranged from 12 m to 41 m. A negative value resulted from the TRCA (2004) model for Reach **FD2** and was therefore disregarded. A meander belt width of 25 m is recommended for both watercourse reaches using the modified Williams (1986) equation and a 20% factor of safety. This value represents the approximate median of the range of modelled belt widths and adequately addresses the potential erosion hazard.

Table 6: Summary of modelled meander belt widths for watercourse reaches for existing conditions

Reach	Modified Williams (1986) Area*	Modified Williams (1986) Width*	Ward Width (2002)	TRCA (2004)**	Recommended Meander Belt Width (m)
Alloa Drain					
AD1-2	27	19	21	24	19
AD-2	55	31	34	46	46
AD3	48	26	29	45	45
AD4	51	32	36	39	39
AD5	54	29	33	30	30
AD6	58	29	32	23	23
AD7	42	27	30	19	19
Lyons Drain					
LD1	49	29	32	36	29

Reach	Modified Williams (1986) Area*	Modified Williams (1986) Width*	Ward Width (2002)	TRCA (2004)**	Recommended Meander Belt Width (m)
LD2	42	21	23	29	29
LD3	47	29	33	27	29
LD4	42	28	31	32	28
LD4-1	35	20	22	13	20
FD1	30	19	21	12	25
FD2	41	25	27	-2	25

** Includes 20% factor of safety*
*** Includes one standard error (8.63 m) for factor of safety*

8 Erosion Mitigation Approach

Multiple stormwater management ponds are proposed to service the subject lands. A total of ten (10) SWMPs are proposed to discharge to the Alloa Drain and Lyons Drain. Two (2) SWMPs are proposed to discharge to tributaries of Fletchers Creek, and a single SWMP is proposed to discharge to East Huttonville Creek. A relatively small portion of the southwestern extent of the subject lands will discharge to the West Huttonville Creek subwatershed (**Appendix H**).

In erosion exceedance analyses, erosion thresholds can be used to determine the magnitude of flow required to potentially entrain and transport bed and/or bank materials and are often expressed as a critical discharge. Changes in the magnitude, duration, and frequency of streamflow may alter the pattern and rates of channel erosion. As such, erosion thresholds can be used to inform erosion mitigation strategies for channels proposed to receive stormwater discharge. Due to variability between bed and bank composition and structure, erosion thresholds are generally determined for both bed and bank materials. The lower of the bed and bank erosion thresholds is adopted, as it provides the more conservative and limiting estimate. The erosion threshold can then be converted into a unitary discharge (i.e., m^3/s/ha) based on the drainage area.

Notably, the majority of the Alloa Drain and the downstream portion of Lyons Drain with the subject lands are proposed for realignment. As such, the ten (10) SWMPs proposed within the Etobicoke Creek drainage area will discharge to constructed corridors. In addition, the three (3) SWMPs proposed within the Fletchers Creek and East Huttonville Creek subwatersheds will discharge to natural corridors constructed within the Mount Pleasant lands south of Mayfield Road. These corridors contain hydraulically sized substrates based on post-development flows. A small proportion of the southwestern extent of the subject lands will discharge to West Huttonville Creek within the Heritage Heights lands.

Detailed studies have been conducted downstream of the subject lands within the Etobicoke Creek watershed and the Fletchers Creek and East Huttonville Creek subwatersheds. For West Huttonville Creek, Phase 1 of the Heritage Heights SWS is approved, and it is understood that Phase 2 of the SWS is currently being updated and Phase 3 of the SWS has been initiated. A summary of previously completed studies is provided below.

8.1 Etobicoke Creek - Mayfield West Phase 2 Lands

Within the subject lands, all proposed SWMPs discharging to the Alloa Drain or its tributaries will outlet to realigned natural corridors with substrates that will be hydraulically sized based on post-development flows. As such, no erosion concerns are anticipated within the subject lands due to stormwater discharge. Post-development flows will eventually traverse the Mayfield West lands east of Chinguacousy Road, where multiple studies have been approved. Parts A to C of a Comprehensive Environmental Impact Study and Management Plan (CEISMP) were undertaken by AMEC (2014a, 2014b, and 2014c) for the Mayfield West lands and included the determination of a series of erosion thresholds along erosion-sensitive reaches to inform SWMP release rates. Unitary release rates were defined for the system and, as such, were independent of any specific land use scenario. The AMEC (2014b) approved erosion threshold analysis provides an erosion control target volume of 325 m^3/impervious ha, released at a rate of 0.00031 m^3/s/ha. This target was adopted for the Phase 2 Stage 2 CEISMP and is recommended that this be carried forward to the current study.

8.2 Huttonville Creek and Fletchers Creek Subwatershed Study

The Huttonville and Fletchers Creek Subwatershed Study (HFSWS) (AMEC, 2011) included subwatershed characterization and identification of potential impacts associated with future land use scenarios. Management recommendations were then developed for consideration as part of the secondary plan process. A long-term effectiveness monitoring plan was also undertaken. Detailed geomorphological assessments and long-term monitoring were initiated on Reaches of Fletchers Creek and Huttonville Creek downstream of the subject lands.

Erosion thresholds were calculated as part of the HFSWS for sites EM10 and SW4 (refer to **Appendix H**) due to their anticipated sensitivity to changes in land use and hydrology. Unitary storage and release rates were also determined to inform SWMP sizing for erosion control, assuming no LID measures were in place. Concerning Huttonville Creek, 200 m^3/imp. ha was identified for extended detention/erosion storage and 0.00052 m^3/s/ha was identified as the unitary release rate (Site EM10 in **Appendix H**). Notably, the release rate was calculated using empirical methods and was, therefore, subject to refinement. Concerning Fletcher's Creek, 250 m^3/imp/ ha was identified for extended detention/erosion storage and 0.00052 m^3/s/ha was identified as the unitary release rate (Site SW4 in **Appendix H**). As detailed further in **Section 8.3**, the release rates were further refined as part of planning-level studies specific to the Mount Pleasant lands.

8.3 East Huttonville Creek and Fletchers Creek Subwatersheds - Mount Pleasant Lands

Two (2) SWMPS are proposed to discharge to the headwaters of Fletchers Creek and one (1) SWMP is proposed to discharge to East Huttonville Creek south of Mayfield Road. An erosion mitigation assessment was conducted for tributaries of Fletchers Creek and East Huttonville Creek as part of the EIRs for Mount Pleasant Sub-Areas 51-1 and 52-1, prepared by Stonybrook Consulting Inc. et al. (2011) and Urbantech et al. (2016). Additional analyses were required as part of the Sub-Area 51-1 EIR to finalize the erosion mitigation assessment. Based on additional study, including sediment sampling and velocity measurements at SW4, a target release rate of 0.000409 m^3/s/ha was determined. It is recommended that this approved erosion control target be carried forward to the current study for all SWMPs discharging to Fletchers Creek and East Huttonville Creek.

Notably, the receiving reaches of East Huttonville Creek and Fletchers Creek downstream of Mayfield Road are largely constructed corridors with substrates hydraulically sized to accommodate post-development flows, providing additional resilience to potential erosion that may result from upstream development.

8.4 West Huttonville Creek Subwatershed - Heritage Heights Lands

The secondary planning process was initiated by The City of Brampton for the Heritage Heights (HH) lands, which are located west of Mississauga Road, north of the Credit River valley, south of Mayfield Road and east of Winston Churchill Boulevard. The secondary plan area includes lands within the West Huttonville Creek subcatchment and multiple smaller subcatchments that drain directly to the Credit River, referred to as the Credit River Tributaries. The Heritage Heights Subwatershed Study (HHSWS) includes four (4) phases. It is understood that Phase 1 of the HH SWS is complete, Phase 2 is being revised/updated, and Phase 3 has been initiated.

Detailed assessments were conducted along two reaches of Huttonville Creek to inform erosion threshold calculations as part of Phase 1 of the HHSWS (i.e., HV4 and HV9 in **Appendix H**). The erosion thresholds were considered preliminary and highly conservative as the reaches consisted of largely poorly-defined channels by virtue of their location in the upper subwatershed. In Phase 1 HHSWS, the critical discharge for entrainment for HV9 was noted as "to be determined" as the feature was ploughed shortly before field reconnaissance was conducted. The critical discharge for entrainment for HV4 was reported to be 0.0.071 m^3/s. Phase 1 reports that this value could likely be refined based on a field verification exercise.

It is understood that fieldwork was undertaken as part of the Phase 2 HHSWS to determine an appropriate erosion threshold for HV9 and potentially refine the erosion threshold for HV4. Based on available information, a preliminary erosion control target of 0.00061 $m^3/s/ha$ has been determined. It is recommended that this erosion control target be carried forward to the current study on a preliminary basis as it is understood that Phase 2 of the study has not been approved.

9 Conceptual Natural Corridor Design

9.1 Design Objectives

The majority of the Alloa Drain (i.e., watercourse **Reaches AD2** to **AD6**) within the subject lands is proposed for realignment. The Alloa Drain currently services the surrounding agricultural fields and is proposed to be restored with a nested channel system to provide a self-maintaining low-flow channel while enhancing connection to the floodplain. The proposed design will continue supporting low-flow conditions and storm events with channel form and function enhancements. Watercourse reaches **AD1-2**, **LD1** and **LD2** are also proposed for realignment. In addition, a portion of HDF **Reach AD1-3**, HDF Reach **LD5**, HDF Reach **LD4-4**, HDF Reach **LD4-3D** and HDF Reaches **AD5-1** to **AD5-4** are proposed for realignment.

The proposed realignments provide an opportunity to replace the morphologically-limited and impacted channels and headwater drainage features with naturalized watercourses and enhanced corridors. The proposed designs have cross-sectional dimensions closer to a naturalized watercourse conveying similar flows and will significantly improve morphologic form and function per unit length. The realignment and naturalization designs provide opportunities for improved riparian conditions and well-developed bankfull channels with morphological variability. Improvement in morphology and function will benefit sediment balance, floodplain storage, vegetation communities, aquatic and terrestrial habitat, water balance, fish passage and water quality. Preliminary conceptual design drawings are provided in **Appendix I** to illustrate functionality and are subject to refinement as the LSWS proceeds.

The primary objectives of the designs are to:

- Reinstate a more natural physical form, including planform and instream characteristics
- Improve the function of the channels by increasing flow interactions with the floodplain
- Provide a mix of coarse and fine sediment sources throughout the low-flow channels and floodplain
- Enhance aquatic habitat through the provision of morphologically diverse channels with spatially varied flows
- Improve riparian habitat by installing woody plantings and dynamic floodplain features
- Mitigate potential hazards to the development as well as lands surrounding the development
- Replicate existing Wetlands 6 and 7 within the realigned corridors

HDF Reaches **LD4-3E** and **AD4-3** are to be realigned as a dry swale feature. These features are classified as Mitigation and No Management, respectively, following TRCA and CVC (2014) guidelines. Features classified as Mitigation have contributing functions that can be replicated or enhanced using lot-level conveyance measures. Features classified as No Management can be removed from the landscape.

The proposed conceptual design consists of a sinuous swale feature with a porous substrate underlying the topsoil. The goals of this design are to provide surface and subsurface storage as well as to convey flows to downstream HDFs and watercourses. The realigned features will enhance terrestrial habitat by increasing diversity and providing a more natural floodplain form. Further functional benefits, such as water retention, infiltration, evapotranspiration, and sediment banking, will also be provided in the proposed design. Technical details are provided in subsequent sections to outline the approach used for channel sizing and habitat restoration.

9.2 Bankfull Channel

The restoration design focuses on a riffle-pool system, which provides significant improvements to not only the channel as it essentially replicates a natural system but also to the aquatic habitat. When it is assessed to be an appropriate channel type, a riffle-pool system offers numerous benefits, namely:

- Channel bed relief for flow variability
- Water aeration in riffle sections
- Relatively quiescent flows in pool sections to provide refuge for fish during high flows
- In-channel energy dissipation

Channel design dimensions are determined by bankfull discharge, as this represents what is generally referred to as the "*channel-forming discharge*" or the "*dominant discharge*". Several methods can be applied to select an appropriate bankfull discharge. Back calculation of discharge from a reference reach and support from hydrological modelling is usually the most appropriate. Given the significant historical channel modifications due to agricultural activities and anticipated hydrology changes likely to occur due to the proposed development, discharges based on hydrologic modelling were determined for all reaches proposed for realignment. These discharges were then used to define channel bankfull geometries. The bankfull discharge used to size the channel was assumed to be equivalent to the modelled 2-year flow return period post-development flow. The following sections describe the discharge and bankfull geometries for each channel proposed for realignment.

9.2.1 Alloa Drain Reaches (AD Reach 1 to AD Reach 6)

To maintain a defined low-flow channel and efficiently transport sediment, a nested channel is proposed. This design will provide a self-maintaining low-flow channel while also providing a connection to the floodplain and reducing aggradation. The larger channel carries the bankfull discharge, equivalent to the modelled 2-year return post-development flow. The smaller channel carries a portion of the bankfull discharge in a concentrated arrangement, which will increase sediment transport at lower flow events. The 2-year discharges used to size the bankfull channel were provided by Urbantech (2024) and are summarized in **Table 7**. Bankfull capacity for channels generally ranged from the 1- to 2-year return events. The channel has been subdivided into six design reaches based on changes in flow magnitude.

Table 7: Alloa Drain 2-year return period discharges used in conceptual design based on hydrologic modelling (Urbantech, 2024)

Reach	2-year return period discharge (m^3/s)
AD Reach 1	1.53
AD Reach 2	2.08
AD Reach 3	2.50
AD Reach 4	3.26
AD Reach 5	3.42
AD Reach 6	3.74

A simple Manning's approach was used to iteratively back-calculate bankfull dimensions for the designs. Since pool sections are designed to contain ineffective space, this model over-predicts the amount of discharge they convey. The modelled values for the riffle sections better predict the channel's capacity. Channel riffle and pool geometries and bankfull conditions for the proposed channel are provided in **Table 8** to **Table 13**.

Design reach **AD Reach 1** has an overall bankfull gradient of 0.10% for 759 m. The width and depth of the low-flow channel range from 3.20 m to 3.95 m and 0.45 m to 0.65 m for the riffles and pools, respectively. The width and depth of the larger, bankfull channel range from 5.75 m to 7.20 m and 0.80 m to 1.15 m, respectively, for the riffles and pools. The average riffle gradient for **AD Reach 1** is 0.45%.

Design reach **AD Reach 2** has an overall bankfull gradient of 0.10% for 842 m. The width and depth of the low-flow channel range from 4.05 m to 4.10 m and 0.55 m to 0.75 m for the riffles and pools, respectively. The width and depth of the larger, bankfull channel range from 6.30 m to 7.80 m and 0.90 m to 1.35 m, respectively, for the riffles and pools. The average riffle gradient for **AD Reach 2** is 0.46%.

Design reach **AD Reach 3** has an overall bankfull gradient of 0.10% for 1453 m. The width and depth of the low-flow channel range from 4.10 m to 4.90 m and 0.55 m to 0.75 m for the riffles and pools, respectively. The width and depth of the larger, bankfull channel range from 6.80 m to 8.60 m and 0.95 m to 1.35 m, respectively, for the riffles and pools. The average riffle gradient for **AD Reach 3** is 0.45%.

Design reach **AD Reach 4** has an overall bankfull gradient of 0.10% for 320 m. The width and depth of the low-flow channel range from 4.50 m to 5.15 m and 0.60 m to 0.85 m for the riffles and pools, respectively. The width and depth of the larger, bankfull channel range from 7.35 m to 9.10 m and 1.05 m to 1.50 m, respectively, for the riffles and pools. The average riffle gradient for **AD Reach 4** is 0.45%.

Design reach **AD Reach 5** has an overall bankfull gradient of 0.10% for 473 m. The width and depth of the low-flow channel range from 4.35 m to 5.25 m and 0.60 m to 0.80 m for the riffles and pools, respectively. The width and depth of the larger, bankfull channel range from 7.25 m to 9.40 m and 1.10 m to 1.50 m, respectively, for the riffles and pools. The average riffle gradient for **AD Reach 5** is 0.45%.

Design reach **AD Reach 6** has an overall bankfull gradient of 0.10% for 681 m. The width and depth of the low-flow channel range from 4.30 m to 5.65 m and 0.60 m to 0.80 m for the riffles and pools, respectively. The width and depth of the larger, bankfull channel range from 7.65 m to 9.80 m and 1.10 m to 1.50 m, respectively, for the riffles and pools. The average riffle gradient for **AD Reach 6** is 0.45%.

Table 8: Bankfull parameters for AD Reach 1 of the proposed channel

Channel parameter	Low-flow Channel		Bankfull Channel	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	3.20	3.95	5.75	7.20
Average bankfull depth (m)	0.31	0.39	0.49	0.64
Maximum bankfull depth (m)	0.45	0.65	0.80	1.15
Bankfull width-to-depth ratio	10.30	10.16	11.71	11.33
Channel gradient (%)	0.45	0.10	0.46	0.10
Bankfull gradient (%)	0.10		0.10	
Radius of curvature (m)*	16			
Riffle-pool spacing (m)**	46			
Manning's roughness coefficient, *n*	0.07	0.05	0.07	0.05
Mean bankfull velocity (m/s) †	0.39	0.30	0.54	0.42
Bankfull discharge (m^3/s)	0.39	0.46	1.53	1.92
Discharge to accommodate (m^3/s)	--		1.53	
Tractive force at bankfull (N/m^2)	20	6	36	11

Channel parameter	Low-flow Channel		Bankfull Channel	
	Riffle††	Pool†	Riffle††	Pool†
Stream power (W/m)	17	5	69	19
Unit stream power (W/m²)	5	1	12	3
Froude Number (unitless)	0.22	0.15	0.25	0.17
Maximum grain size entrained (m)	0.02	0.01	0.04	0.01
Mean grain size entrained	0.01	0.00	0.02	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

Table 9: Bankfull parameters for AD Reach 2 of the proposed channel

Channel parameter	Low-flow Channel		Bankfull Channel	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	4.05	4.10	6.30	7.80
Average bankfull depth (m)	0.39	0.43	0.56	0.72
Maximum bankfull depth (m)	0.55	0.75	0.90	1.35
Bankfull width-to-depth ratio	10.29	9.57	11.19	10.81
Channel gradient (%)	0.46	0.10	0.45	0.10
Bankfull gradient (%)	0.10		0.10	
Radius of curvature (m)*	17			
Riffle-pool spacing (m)**	49			
Manning's roughness coefficient, *n*	0.07	0.05	0.07	0.05
Mean bankfull velocity (m/s) †	0.46	0.32	0.59	0.45
Bankfull discharge (m³/s)	0.74	0.56	2.08	2.56
Discharge to accommodate (m³/s)	--		2.08	
Tractive force at bankfull (N/m²)	25	7	40	13
Stream power (W/m)	33	5	92	25
Unit stream power (W/m²)	8	1	25	6
Froude Number (unitless)	0.24	0.16	0.25	0.17
Maximum grain size entrained (m)	0.03	0.01	0.04	0.01
Mean grain size entrained	0.02	0.00	0.03	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

Table 10: Bankfull parameters for AD Reach 3 of the proposed channel

Channel parameter	Low-flow Channel		Bankfull Channel	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	4.10	4.90	6.80	8.60
Average bankfull depth (m)	0.39	0.47	0.60	0.77
Maximum bankfull depth (m)	0.55	0.75	0.95	1.35
Bankfull width-to-depth ratio	10.42	10.47	11.30	11.13
Channel gradient (%)	0.45	0.10	0.45	0.10
Bankfull gradient (%)	0.10		0.10	
Radius of curvature (m)*	19			
Riffle-pool spacing (m)**	53			
Manning's roughness coefficient, *n*	0.07	0.05	0.07	0.05
Mean bankfull velocity (m/s) †	0.46	0.34	0.61	0.48
Bankfull discharge (m^3/s)	0.73	0.78	2.50	3.17
Discharge to accommodate (m^3/s)	--		2.50	
Tractive force at bankfull (N/m^2)	24	7	41	13
Stream power (W/m)	32	8	109	31
Unit stream power (W/m^2)	8	2	16	3
Froude Number (unitless)	0.23	0.16	0.25	0.17
Maximum grain size entrained (m)	0.02	0.01	0.04	0.01
Mean grain size entrained	0.02	0.00	0.03	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

Table 11: Bankfull parameters for AD Reach 4 of the proposed channel

Channel parameter	Low-flow Channel		Bankfull Channel	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	4.50	5.15	7.35	9.10
Average bankfull depth (m)	0.44	0.51	0.68	0.84
Maximum bankfull depth (m)	0.60	0.85	1.05	1.50
Bankfull width-to-depth ratio	10.34	10.01	10.89	10.85
Channel gradient (%)	0.45	0.1	0.45	0.10
Bankfull gradient (%)	0.10		0.10	
Radius of curvature (m)*	20			
Riffle-pool spacing (m)**	57			
Manning's roughness coefficient, *n*	0.07	0.05	0.07	0.05
Mean bankfull velocity (m/s) †	0.49	0.36	0.66	0.50
Bankfull discharge (m^3/s)	0.95	0.95	3.26	3.83
Discharge to accommodate (m^3/s)	--		3.26	
Tractive force at bankfull (N/m^2)	26	8	46	15
Stream power (W/m)	42	9	143	38
Unit stream power (W/m^2)	9	2	20	4
Froude Number (unitless)	0.24	0.16	0.26	0.18
Maximum grain size entrained (m)	0.03	0.01	0.05	0.02
Mean grain size entrained	0.02	0.01	0.03	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

Table 12: Bankfull parameters for AD Reach 5 of the proposed channel

Channel parameter	Low-flow Channel		Bankfull Channel	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	4.35	5.25	7.25	9.40
Average bankfull depth (m)	0.43	0.50	0.70	0.86
Maximum bankfull depth (m)	0.60	0.80	1.10	1.50
Bankfull width-to-depth ratio	10.07	10.45	10.36	10.89
Channel gradient (%)	0.45	0.10	0.45	0.10
Bankfull gradient (%)	0.10		0.10	
Radius of curvature (m)*	20			
Riffle-pool spacing (m)**	57			
Manning's roughness coefficient, *n*	0.07	0.05	0.07	0.05
Mean bankfull velocity (m/s) †	0.49	0.36	0.67	0.51
Bankfull discharge (m^3/s)	0.91	0.94	3.42	4.15
Discharge to accommodate (m^3/s)	--		3.42	
Tractive force at bankfull (N/m^2)	26	8	49	15
Stream power (W/m)	40	9	152	41
Unit stream power (W/m^2)	9	2	21	4
Froude Number (unitless)	0.24	0.16	0.26	0.18
Maximum grain size entrained (m) ††	0.03	0.01	0.05	0.02
Mean grain size entrained	0.02	0.01	0.03	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

Table 13: Bankfull parameters for AD Reach 6 of the proposed channel

Channel parameter	Low-flow Channel		Bankfull Channel	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	4.30	5.65	7.65	9.80
Average bankfull depth (m)	0.43	0.52	0.72	0.89
Maximum bankfull depth (m)	0.60	0.80	1.10	1.50
Bankfull width-to-depth ratio	9.99	10.91	10.67	11.06
Channel gradient (%)	0.45	0.10	0.45	0.10
Bankfull gradient (%)	0.10		0.10	
Radius of curvature (m)*	21			
Riffle-pool spacing (m)**	60			
Manning's roughness coefficient, *n*	0.07	0.05	0.07	0.05
Mean bankfull velocity (m/s) †	0.48	0.36	0.68	0.52
Bankfull discharge (m^3/s)	0.90	1.06	3.74	4.53
Discharge to accommodate (m^3/s)	--		3.74	
Tractive force at bankfull (N/m^2)	26	8	48	15
Stream power (W/m)	40	10	163	44
Unit stream power (W/m^2)	9	2	21	5
Froude Number (unitless)	0.24	0.16	0.26	0.18
Maximum grain size entrained (m) ††	0.03	0.01	0.05	0.02
Mean grain size entrained	0.02	0.01	0.03	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

9.2.2 Lyons Drain (Reaches LD-1, LD-2, LD4 and LD5)

The 2-year discharges used to size the bankfull channel were provided by Urbantech (2024) and are summarized in **Table 14,** below. Bankfull capacity for channels generally has a range from the 1- to 2-year return events. The Lyons Drain has been subdivided into 2 design reaches based on changes in channel gradient and flow magnitude, where **Reach LD4** and **LD5** are one whole reach each.

Table 14: Lyons Drain 2-year return period discharges used in conceptual design based on hydrologic modelling (Urbantech, 2024)

Reach	2-year return period discharge (m^3/s)
Reach LD-1	0.96
Reach LD-2	0.96
Reach LD4	0.50
Reach LD5	0.96

A simple Manning's approach was used to iteratively back-calculate bankfull dimensions for the proposed designs. Since pool sections are designed to contain ineffective space, this model over-predicts the amount of discharge they convey. The modelled values for the riffle sections better predict the channel's capacity. Channel riffle and pool geometries and anticipated bankfull conditions for the proposed channel are provided in **Table 15** and **Table 16**.

Design **Reach LD-1** has an overall bankfull gradient of 0.55% for 237 m. The bankfull width and depth range from 2.65 m to 3.25 m and 0.35 m to 0.55 m, respectively. The average riffle gradient for **Reach LD-1** is 2.21%. Design **Reach LD-2** has an overall bankfull gradient of 0.60% for 237 m. The bankfull width and depth range from 2.60 m to 3.20 m and 0.35 m to 0.55 m, respectively. The average riffle gradient for **Reach LD-2** is 2.40%.

Design **Reach LD4** has an overall bankfull gradient of 0.25% for 264 m. The bankfull width and depth range from 2.25 m to 2.85 m and 0.35 m to 0.55 m, respectively. The average riffle gradient for **Reach LD4** is 1.00%. Design **Reach LD5** has an overall bankfull gradient of 0.45% for 349 m. The bankfull width and depth range from 2.75 m to 3.45 m and 0.35 m to 0.55 m, respectively. The average riffle gradient for **Reach LD5** is 2.00%.

Table 15: Bankfull parameters for designed Reach LD-1 and Reach LD-2

Channel parameter	LD-1		LD-2	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	2.65	3.25	2.60	3.20
Average bankfull depth (m)	0.27	0.33	0.26	0.33
Maximum bankfull depth (m)	0.35	0.55	0.35	0.55
Bankfull width-to-depth ratio	9.98	9.72	9.87	9.64
Channel gradient (%)	2.21	0.55	2.40	0.60
Bankfull gradient (%)	0.55		0.60	
Radius of curvature (m)*	7		7	
Riffle-pool spacing (m)**	22		21	
Manning's roughness coefficient, *n*	0.04	0.03	0.04	0.03
Mean bankfull velocity (m/s) †	1.36	1.05	1.41	1.09
Bankfull discharge (m^3/s)	0.96	1.14	0.96	1.16
Discharge to accommodate (m^3/s)	0.96	0.96	0.96	0.96
Tractive force at bankfull (N/m^2)	76	30	82	32
Stream power (W/m)	207	62	227	68
Unit stream power (W/m^2)	78	29	87	21
Froude Number (unitless)	0.84	0.58	0.88	0.61
Maximum grain size entrained (m)	0.08	0.03	0.08	0.03
Mean grain size entrained	0.06	0.02	0.06	0.02

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

Table 16: Bankfull parameters for designed Reach LD4 and Reach LD5

Channel parameter	Reach LD4		Reach LD5	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	2.25	2.85	2.75	3.45
Average bankfull depth (m)	0.26	0.31	0.27	0.35
Maximum bankfull depth (m)	0.35	0.55	0.35	0.55
Bankfull width-to-depth ratio	8.82	9.62	10.29	9.98
Channel gradient (%)	1.00	0.25	2.00	0.45
Bankfull gradient (%)	0.25		0.45	
Radius of curvature (m)*	6		8	
Riffle-pool spacing (m)**	19		23	
Manning's roughness coefficient, *n*	0.04	0.03	0.04	0.03
Mean bankfull velocity (m/s) †	0.88	0.67	1.30	0.98
Bankfull discharge (m^3/s)	0.50	0.59	0.96	1.16
Discharge to accommodate (m^3/s)	0.50		0.96	
Tractive force at bankfull (N/m^2)	34	13	69	24
Stream power (W/m)	49	14	188	51
Unit stream power (W/m^2)	22	5	68	14
Froude Number (unitless)	0.56	0.38	0.81	0.53
Maximum grain size entrained (m)	0.04	0.01	0.07	0.03
Mean grain size entrained	0.03	0.01	0.05	0.02

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

9.2.3 Alloa Drain Tributaries (Reaches AD1 and AD5)

The 2-year discharge used to size the bankfull channel was provided by Urbantech (2024) and is summarized in **Table 17**, below. Bankfull capacity for channels generally has a range from the 1- to 2-year return events.

Table 17: Alloa Drain tributary 2-year return period discharges used in conceptual design based on hydrologic modelling (Urbantech, 2024)

Reach	2-year return period discharge (m^3/s)
Reach AD1	0.23
Reach AD5	0.38

A simple Manning's approach was used to iteratively back-calculate bankfull dimensions for the proposed designs. Since pool sections are designed to contain ineffective space, this model over-predicts the amount of discharge they convey. The modelled values for the riffle sections better predict the channel's capacity. Channel riffle and pool geometries and anticipated bankfull conditions for the proposed channel are provided in **Table 18**.

Design **Reach AD1** has an overall bankfull gradient of 0.51% for 748 m. The bankfull width and depth range from 1.50 m to 2.10 m, and 0.25 m to 0.45 m, respectively. The average riffle gradient for **Reach AD1** is 1.70%. **Design AD5** has an overall bankfull gradient of 0.25% for 1125 m. The bankfull width and depth range from 2.45 m to 3.10 m, and 0.40 m to 0.60 m, respectively. The average riffle gradient for **Reach AD5** is 1.00%.

Table 18: Bankfull parameters for designed Reach AD1 and Reach AD5

Channel parameter	Reach AD1		Reach AD5	
	Riffle††	Pool†	Riffle††	Pool†
Bankfull width (m)	1.50	2.10	2.45	3.10
Average bankfull depth (m)	0.18	0.23	0.29	0.33
Maximum bankfull depth (m)	0.25	0.45	0.40	0.60
Bankfull width-to-depth ratio	8.57	9.05	8.47	9.33
Channel gradient (%)	1.70	0.51	1.00	0.25
Bankfull gradient (%)	0.51		0.25	
Radius of curvature (m)*	4		7	
Riffle-pool spacing (m)**	14		21	
Manning's roughness coefficient, *n*	0.04	0.03	0.04	0.03
Mean bankfull velocity (m/s) †	0.89	0.79	0.54	0.42
Bankfull discharge (m^3/s)	0.23	0.23	0.38	0.43
Discharge to accommodate (m^3/s)	0.23		0.38	
Tractive force at bankfull (N/m^2)	42	21	39	15
Stream power (W/m)	39	19	38	11

Channel parameter	Reach AD1		Reach AD5	
	Riffle††	Pool†	Riffle††	Pool†
Unit stream power (W/m^2)	26	9	15	4
Froude Number (unitless)	0.68	0.52	0.32	0.23
Maximum grain size entrained (m)	0.04	0.02	0.04††	0.02
Mean grain size entrained	0.03	0.01	0.03	0.01

† Based on bankfull gradient
†† Based on riffle gradient
* Based on Manning's equation; as pools contain ineffective space, the velocity and discharge conveyed in them are not presented
** Based on Shields equation (Miller et al. (1977)), assuming Shields parameter equals 0.06 (gravel)

9.3 Channel Substrate Hydraulic Sizing

The sizing of the proposed substrate materials was guided by a review of hydraulic conditions (i.e., tractive force, flow competence) in the typical channel cross sections. The channel bed substrate is derived by balancing the average shear stress acting on the bed with the critical shear stress for the material. When the critical shear stress slightly exceeds the average shear stress acting on the bed, sediment transport is initiated.

Reaches **AD Reach 1** to **AD Reach 6, AD1, AD5,** and **LD4** have a proposed mix of granular 'B', and native material for the riffles to provide for a stable bed and level of sorting. Pools will consist of native material.

For reaches **LD-1** and **LD-2,** a mix of 100 mm – 150 mm diameter riverstone with granular 'B' and native material is proposed for the riffles and a mix of 50 mm – 100 mm diameter riverstone with granular 'B' and native material for the pools. These materials will provide for a stable bed and level of sorting.

For reach **LD5,** a mix of 70% 50 mm – 100 mm diameter riverstone with a granular 'B' and native material is proposed for the riffles provide for a stable bed and level of sorting. Pools will consist of native material.

Granular 'B' consists of a mix of stone where approximately 20% - 50% of the stone is greater than 0.005 m in diameter but nothing larger than 0.15 m in diameter. The Granular 'B' is to be derived from pit-run material and contains no post-construction materials. This material maintains and enhances the character of the native material while providing slightly higher stability and opportunity for sediment sorting. The gravel also provides opportunities for infiltration, filtration, and detention of water within the pore spaces to provide additional benefits by elongating the hydroperiod. The proposed mix will also improve aquatic habitat by increasing diversity between the riffle and pool substrates.

9.4 Channel Planform

The initial channel planform layout was created using the modelled radius of curvature value (*Rc*) as a guide. The radius of curvature (*Rc*) of meanders can be used to evaluate channel stability. For example, stable meanders typically exhibit larger *Rc* values as opposed to lower values that indicate increased channel bank erosion and avulsion. Bankfull width is often an appropriate indicator of this instability. Hickin and Nanson (1984) note that channel avulsions are common when meander *Rc* is approximately 1-2 times the channel's bankfull width. For larger *Rc* (e.g., >5), the upstream limb of the meander will migrate more rapidly than the downstream limb (Hooke, 1975). Based on the above bankfull widths, the radius of curvatures and feature spacing were determined.

Williams (1986) was used to derive values for the channel radius of curvature using the following equation (Eq. 2):

$$Rc = 2.43 \times w \qquad \text{[Eq. 5]}$$

where *Rc* is the radius of curvature and *w* is the average bankfull width.

Empirical models derived by Hey and Thorne (1986) were followed to determine riffle spacing. Hey and Thorne's (1986) modelled values are often applied in larger watercourses. As such, multiple methods (Eq. 6-8) were considered in order to provide a range of riffle spacing values. These are:

$$Z = 6.31 \times w \qquad \text{[Eq. 6]}$$

$$Z = 9.1186 \times w^{0.8846} \qquad \text{[Eq. 7]}$$

$$Z = 7.36 \times w^{0.896} \times S^{-0.03} \qquad \text{[Eq. 8]}$$

where *Z* represents riffle spacing.

Stream power and unit stream power were calculated as a function of bankfull discharge and channel gradient (Eq. 9-10). Stream power values are important to determine the need for mitigating channel bank and bed erosion. Stream power is given by:

$$\Omega = \rho \times g \times d \times S \qquad \text{[Eq. 9]}$$

where ρ is the density of water (kg/m^3), *g* is the acceleration due to gravity (m/s^2), and *Q* and *S* are discharged (m^3/s) and channel gradient, respectively.

Stream power per unit width (Eq. 10) is given by:

$$\omega = \frac{\Omega}{w} \qquad \text{[Eq. 10]}$$

whereas before Ω and ω are stream power and bankfull width, respectively.

The final channel planform was established through an iterative process. First, a cross-section with defined bankfull geometry was developed to calculate parameters for the planform (i.e., radius of curvature, riffle-pool spacing). The cross-section was then further refined, based on the final channel gradient. Once the cross-section dimensions were refined, hydraulic sizing for the channel substrate was completed, as outlined in **Section 9.3** above.

In developing a natural channel design, the length of the watercourse proposed to be realigned is typically replicated or exceeded to provide an overall gain in habitat. The existing total length of the Alloa Drain Reaches **AD2**, **AD3**, **AD4**, **AD5**, and **AD6** proposed for rehabilitation is approximately 4,024 m, with the realigned corridor providing a total linear length of approximately 4,528 m.

The existing total length of the Lyons Drain Reaches **LD1**, **LD2**, **LD4-4**, **LD4-3D** and **LD5** proposed for rehabilitation is approximately 896 m, with the realigned corridors providing a total linear length of approximately 1,087 m.

The existing total length of Reaches **AD1, AD5-1**, **AD5-2**, **AD5-3**, and **AD5-4** proposed for rehabilitation is approximately 1,290 m, with the realigned corridors providing a total linear length of approximately 1,874 m. The realigned sinuous channels will produce systems more similar to what would occur in nature, resulting in an increased total channel length of 1,279 m for all reaches. Therefore, the proposed channels will significantly increase the restored and enhanced habitat area.

9.5 Channel Corridor Requirements

9.5.1 Corridor Size

As part of the design, the meander belt widths were calculated based on design bankfull dimensions to ensure that the planforms have meander belt widths that fall within their corridor requirements. Given the scale of the watercourses and the limited migration potential for each system, the hazard limits calculated can be considered conservative. The meander belt widths provided are based on modelled relations from Williams (1986), which were modified to include channel width and a factor of safety and applied using the designed bankfull channel dimensions such that:

$$B_w = (4.3{W_b}^{1.12} + W_b) \times 1.2 \quad \text{[Eq. 13]}$$

where B_w is meander belt width (m), and W_b is bankfull channel width (m). An additional 20% buffer, or factor of safety, was applied to the computed belt width values. This addresses issues of under prediction and provides a factor of safety.

9.5.2 Alloa Drain AD Reach 1 to AD Reach 6

The average bankfull widths of the designed **AD Reach 1**, **AD Reach 2, AD Reach 3, AD Reach 4, AD Reach 5** and **AD Reach 6** are 6.48 m, 7.05 m, 7.70 m, 8.23 m, 8.33 m, and 8.73m, respectively. The resulting meander belt width estimates are provided in **Table** 19 and **Table 20**.

Table 19: Meander belt widths for the proposed Alloa Drain channel – AD Reach 1 to AD Reach 3

Channel parameter	AD Reach 1	AD Reach 2	AD Reach 3
Channel gradient (%)	0.10	0.10	0.10
Discharge to accommodate (m^3/s)	1.53	2.08	2.50
Average bankfull width (m)	6.48	7.05	7.70
Average bankfull depth (m)	0.98	1.13	1.15
Meander belt width (m)	50	54	60

Table 20: Meander belt widths for the proposed channel Alloa Drain channel – AD Reach 4 to AD Reach 6

Channel parameter	AD Reach 4	AD Reach 5	AD Reach 6
Channel gradient (%)	0.10	0.10	0.10
Discharge to accommodate (m^3/s)	3.26	3.42	3.74
Average bankfull width (m)	8.23	8.33	8.73
Average bankfull depth (m)	1.28	1.30	1.35
Meander belt width (m)	65	65	69

Once the channel planforms were finalized through the iterative process of determining bankfull widths, radius of curvature and riffle-pool spacing, the meander belt widths were overlain to ensure the channel fits within the corridor. The proposed valley bottom widths for **AD Reach 1** is 97 m, for **AD Reach 2** to **AD Reach 4** and **AD Reach 6** are 90 m, and **AD Reach** is 91 m, respectively, adequately addressing the erosion hazard.

9.5.3 Lyons Drain LD-1, LD-2 LD4 and LD5

The average width of the designed **Reach LD-1, Reach LD-2, Reach LD4,** and **Reach LD5** are 2.95 m, 2.90 m, 2.75 m and 3.10 m, respectively. The resulting meander belt width estimates are provided in Error! Reference source not found. **Table 21**.

Table 21: Meander belt widths for proposed channels LD-1, LD-2 LD4 and LD5

Channel parameter	LD-1	LD-2	LD4	LD5
Channel gradient (%)	0.55	0.60	0.25	0.45
Discharge to accommodate (m^3/s)	0.96	0.96	0.50	0.96
Average bankfull width (m)	2.95	2.9	2.75	3.10
Average bankfull depth (m)	0.45	0.45	0.45	0.45
Meander belt width (m)	21	20	19	21

Once the channel planforms were finalized through the iterative process of determining bankfull widths, radius of curvature and riffle-pool spacing, the meander belt widths were overlain to ensure the channel fits within the corridor. The proposed valley bottom widths for **Reach LD-1**, **Reach LD-2, Reach LD4,** and **Reach LD5** are 27 m, 45 m, 44 m and 62 m, respectively, adequately addressing the erosion hazard.

9.5.4 Alloa Drain Tributary AD1 and AD5

The average width of the designed **Reach AD1** and **Reach AD5** are 1.80 m and 2.78 m, respectively. The resulting meander belt width estimates are provided in **Table 22**.

Table 22: Meander belt widths for proposed channels AD1 and AD5

Channel parameter	AD1	AD5
Channel gradient (%)	0.51	0.25
Discharge to accommodate (m^3/s)	0.23	0.38
Average bankfull width (m)	1.80	2.78
Average bankfull depth (m)	0.35	0.50
Meander belt width (m)	12	20

Once the channel planforms were finalized through the iterative process of determining bankfull widths, radius of curvature and riffle-pool spacing, the meander belt widths were overlain to ensure the channel fits within the corridor. The proposed valley bottom widths for **Reach AD1** and **Reach AD5** are 106 m and 58 m, respectively, adequately addressing the erosion hazard.

9.5.5 Corridor Wetlands

In addition to the corridor realignments, two existing wetlands (i.e., Wetlands 6 and 7) are proposed to be replicated in the newly realigned corridors. At present, both of these features are classified as provincially significant wetlands. It is understood that the Project Team is evaluating the significance of these wetlands during the 2024 field season following the Ontario Wetland Evaluation System (OWES) (MNRF, 2022). The results of the evaluation will be available in the fall of 2024, when a complete set of ecological field data is compiled.

GEO Morphix has proceeded with the preliminary wetland replication design in advance of OWES results to demonstrate that if relocation is appropriate (i.e., wetlands are evaluated to be non-significant and relocation is acceptable), the realigned corridors can accommodate these areas. Wetlands 6 and 7 have a combined area of 3.7 ha. Part of this area is replicated in the adjacent AD1 corridor, where 1.4 ha are proposed as offline wetlands. The remaining wetland areas are located in the Alloa Drain corridor, where a total of 2.9 ha of offline wetlands and stone-cored wetlands are proposed. The total area of proposed wetlands is 4.3 ha, which is 0.6 ha greater than the area of wetlands proposed for removal.

Offline wetland features are proposed within the corridor in addition to the low-flow channel. These features enhance terrestrial habitat by increasing diversity and providing a more natural floodplain form.

They also provide functional benefits such as short-term water retention, infiltration, evapotranspiration, and sediment banking. They are irregularly shaped to maximize the perimeter for a given area, which increases the potential for edge effects and increases habitat diversity. Submerged and dry mounds are proposed within the offline wetlands to increase habitat heterogeneity by providing a topographically complex bottom. A granular mix is proposed within these features and can provide future sediment sources into the channel if it migrates laterally. The granular mix will have substrate sizes similar to those proposed within the riffle features.

Stone-cored wetlands will also be installed at the proposed stormwater management ponds and on-site control outfalls throughout the corridor. The stone core refers to hydraulically sized rounded stone, the subsurface material used to ensure wetland stability. The stone should be hydraulically sized during detailed design. Like the offline wetlands, the stone core wetlands will have submerged and dry mounds are proposed to provide a topographically complex bottom that will increase habitat heterogeneity. The short-term water retention function of these wetland types helps to polish the water, increase potential infiltration, and moderate the discharge of water into the channel (in addition to the functions provided by the SWM pond).

The channel corridor will be restored using native plant species, including appropriate species for the various seed mixes and woody vegetation. The plantings are intended to enhance the terrestrial habitat by providing species and habitat diversity, increasing floodplain soil stability, and increasing floodplain roughness and sedimentation. Others will prepare the landscaping plans during the detailed design.

9.5.6 Dry Bioswale

Reaches **LD4-3D** and **AD4-3** are proposed as a realigned green corridor with a dry bioswale feature. The feature is expected to be fully vegetated, providing a corridor for wildlife connecting the woodlot to the North and the realigned Alloa Drain in the south. The bioswale will have intermittent flows and a meandering planform with variable widths and irregular shapes to maximize the feature's perimeter, increasing the potential for edge effects. Although it is anticipated to be dry most of the time, the feature will provide additional functional benefits such as short-term water retention and sediment banking. Additionally, this feature will enhance local recharge by allowing for infiltration. Mounds will be included within the wide meander areas to add morphological variation. Given the limited energy, limited flow conditions, and vegetation control, the feature has no erosion hazard.

9.5.7 Habitat Features

Several habitat elements are incorporated into the design within the channel corridors to improve riparian habitat and promote wildlife biodiversity. The habitat elements include potential overwintering pools, brush mattresses, basking logs, brush piles, raptor poles, turtle nesting sites, snake hibernacula, rock piles, root wads and terrestrial mounds. The proposed elements provide a variety of topographies and woody debris that maximize the potential for wildlife passage, forage, and residency. The accompanying conceptual design drawings in **Appendix I** provide further details and directions for the implementation**.**

Potential overwintering pools are proposed to provide critical habitat for resident fish. The overwintering pools are located within the tortuous meander pattern, which will increase scour and pool depth. This habitat feature will provide fish with potential refuge from freezing conditions in the winter and an ideal habitat during low flow periods and increase habitat heterogeneity within the channel.

Brush mattress is proposed along the outside meander bend of the tortuous meanders. This treatment consists of live brush cuttings installed parallel to the banks and tied with coir twine and stakes. The brush mattress will provide bank stability and improve aquatic habitat through shading and foraging opportunities.

Basking logs consist of a mixture of hardwood and softwood species, placed in shallow areas of wetlands and anchored with a mix of stone or limestone blocks. These logs are angled in a way that promotes turtle basking.

Brush piles consist of logs, snags and other wood debris placed in a way that forms a stable interconnected mound shaped like a pallet. The brush piles are also planted with native fruit-bearing vines, which provide foraging opportunities for wildlife. Brush piles are placed at various locations along the length of the floodplain.

Root wad bank treatments are also proposed at specific locations within the tortuous meander pattern. The treatment extends the entire length of the outside meander bends between riffles, which consists of partially buried root wads on a bedding of riverstone. The root wad bank treatment enhances bank stability while improving aquatic habitat by providing low-flow refugia and foraging opportunities.

Raptor poles are constructed from large conifer tree trunks embedded into the ground, providing perches for larger raptors.

Turtle nesting sites are installed on south or west-facing slopes away from the watercourse. These are constructed by excavating a slight depression in the ground and filling it with granular 'a' or 'm' material.

Snake hibernacula are constructed similarly to turtle nesting sites on south—or west-facing slopes away from the watercourse. The excavated depressions are filled with a mix of angular stones of various sizes and woody debris. A layer of leaf litter is installed on top to provide insulation.

Rock piles consist of stones of varying sizes piled up to create small mounds. These features provide hibernation habitat and cover from predators for various terrestrial species. The base of the piles is partially buried to prevent rock falls. Rock piles are installed at multiple locations along the corridor length within the buffer.

Terrestrial mounds consist of native material piled up to create small mounds with a small dimple on the top. The bottom of the mound is seeded with the specified seed mix, while the top has limited soil and seed on it to provide foraging opportunities.

10 Corridor Crossing Recommendations

Multiple crossings are proposed over the realigned corridors and realigned HDF features. The proposed crossings will require an opening to accommodate the realigned corridor or feature. The dimensions for the channel features through the crossings are consistent with the channel upstream and downstream of the structure to support a seamless tie-in. The future crossings should span at least three times the bankfull channel width to accommodate potential channel adjustments. The Manning's approach outlined previously was also applied to determine appropriate channel geometries through the structure. Given the increased substrate size under culverts, a nested channel approach is not recommended due to difficulties to construct. Average bankfull widths and preliminary crossing span recommendations are provided in **Table 23**. Crossing locations are illustrated in **Appendix J.**

Table 23: Preliminary crossing recommendations

Crossing ID	Design Reach	Avg Bankfull Width (m) Proposed Conditions	Preliminary Recommended Crossing Span* (m)
ADX1	**AD Reach 1**	5.55	17
ADx3	**AD Reach 3**	6.48	19
ADX4	**AD Reach 3**	6.48	19
ADX5	**AD Reach 3**	6.48	19
ADX6	**AD Reach 4**	7.03	21
ADX7	**AD Reach 6**	7.38	22

Crossing ID	Design Reach	Avg Bankfull Width (m) Proposed Conditions	Preliminary Recommended Crossing Span* (m)
ADX8	**AD Reach 6**	7.38	22
LDX1	**Reach LD-1**	2.95	9
AD6X1	**Reach AD5**	2.78	8

** Based on 3 times the proposed average channel bankfull width*

Fish passage will be addressed through the crossings by incorporating riffle-pool morphology, which provides an opportunity for low-flow refugia for fish within the pool features. However, the near-bed velocity of the channel within the crossings should also be reviewed at the detailed design stage to determine whether fish passage is possible under a range of conditions expected for the low-flow channel. The assessment should consider passage potential for species commonly found within the watershed.

11 Recommended Post-Construction Monitoring Program

A post-construction monitoring program is recommended to assess the performance of the implemented channel designs. Monitoring observations can also be used to determine the need for remedial works. Monitoring is recommended for ten full calendar years or until 80% build out (whichever is greater) and includes semi-annual (i.e., spring and fall) visual inspections and annual surveys. It is recommended that monitoring be completed in years 1, 2, 3, 5 and 9 with monitoring reports provided following completion of each monitoring period and a summary report provided in Year 10. Monitoring activities should be undertaken by a qualified fluvial geomorphologist.

The following monitoring and reporting activities are suggested for the channels and wetlands in each realigned corridor:

- Document general observations of the channel and wetland works after construction and after the first large flooding event to identify any potential areas of erosion concern
- Complete visual monitoring two times per monitoring year, after the spring freshet and prior to the onset of winter conditions for the duration of the monitoring program
- Collect a detailed photographic record of site conditions, including monumented and georeferenced photographs at various intervals along the entire length of the realigned channels and constructed wetlands
- Conduct a physical review of wetland features once during each monitoring year to ensure stability and vegetation establishment
- Complete a total station survey of the longitudinal profile and 8-10 cross sections following construction. Channel cross-section surveys should be an equal mix of geomorphic unit types. At least two (2) of the cross-section surveys should be monumented and georeferenced. The longitudinal profile and monumented channel cross sections would serve as the as-built reference condition for use in comparing surveys completed in subsequent years
- Re-survey the longitudinal profile and cross sections in subsequent monitoring years after construction
- Install erosion pins at monumented cross sections after construction and re-measure erosion pins during subsequent monitoring years
- Characterize bed material based on Wolman (1954) pebble counts at all cross sections as part of the initial total station survey and at monumented cross sections in subsequent monitoring years
- Conduct general vegetation surveys each monitoring year after construction for the duration of the monitoring period

- Prepare annual reporting to summarize construction activities (i.e., design implementation), and milestone reports in years 2, 4, 6 and 10

The above recommended monitoring plan is subject to refinement as the LSWS proceeds and during subsequent project stages.

12 Summary

GEO Morphix was retained to complete a fluvial geomorphology assessment and prepare conceptual natural corridor designs as part of the Local Subwatershed Study for the Alloa Secondary Plan Area. GEO Morphix is also completing HDF assessments during the 2024 field season generally following TRCA and CVC (2014) guidelines. The findings and preliminary management recommendations for the HDF assessment are prepared under separate cover.

Multiple planning level studies have been completed within and downstream of the subject lands in support of adjacent development, including the Mayfield West lands, the Mount Pleasant lands, and the Heritage Heights lands. In 2022, Wood, on behalf of the Region of Peel, completed a SSWS as part of the larger SABE Study, which included the Alloa Secondary Plan Area. This reporting was reviewed in detail as part of the current assessment. The desktop assessment also included a review of surficial geology and topographic mapping and historical and recent aerial imagery to understand existing conditions and inform the field work program.

All watercourse reaches within the subject lands have been impacted by agricultural land uses, with the majority of reaches consisting of municipal drains, known as the Alloa Drain, Lyons Drain and Fraser Drain. Rapid assessments using industry-accepted standard protocols such as the RGA (MOE, 2003) and RGA (Galli, 1996), were used to evaluate the stability and overall health of watercourse reaches in the subject lands. All watercourse reaches were evaluated to be stable, with erosion limited to localized areas along select reaches. Overall stream health was generally evaluated to be fair. This was largely due to limited natural riparian vegetation, limited morphologic variability, and evidence of siltation, particularly along the Alloa Drain.

Wet and dry-weather surface water quality sampling was initiated by GEO Morphix in the spring of 2024 to establish baseline conditions within the subject lands. Two rounds of sampling have been completed to date, capturing one wet event and one dry event. For the wet weather sampling event, concentrations of many parameters were significantly higher during the ascending limb of the hydrograph than during the receding limb of the hydrograph. In turn, PWQO exceedances were noted for a number of metals during the ascending limb, while a limited number of exceedances occurred during the receding limb. For the dry weather event, results show lower concentrations of most parameters; however, certain parameters remained in exceedance in the eastern half of the subject lands. Monitoring will continue to fall 2024.

Historical impacts due to agricultural land uses provide an opportunity to realign and restore watercourses and drainage features. To help inform proposed watercourse and headwater drainage feature realignments, a series of detailed geomorphological assessments were completed along sections of the Alloa Drain, Lyons Drain and associated tributaries. Overall, the proposed designs result in a significant increase in channel length, improvements to the conveyance of flow and sediment, increases in morphological and substrate variability and a more natural floodplain form when compared to existing conditions.

Wetlands 6 and 7 are proposed for removal as part of future development. This wetlands are currently classified as provincially significant and are being evaluated by the Project Team following OWES (MNRF, 2022) guidelines in 2024. GEO Morphix has proceeded with the preliminary wetland replication design in advance of OWES results to demonstrate that if relocation is appropriate (i.e., wetlands are evaluated to be non-significant and relocation is acceptable), the realigned corridors can accommodate these areas. Areas of wetland replication exceed the total wetland area proposed for removal.

We trust this report satisfies your requirements at this time. Should you have any questions or concerns, please contact the undersigned.

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