January 20, 2026

Department of Planning, Development and Building Services (PDBS)
City of Ottawa
110 Laurier Avenue West
Ottawa, ON K1P 1J1

Attn: **Jerrica Gilbert, RPP MCIP**
Planner II

Re: **391 Hilversum Lane Site Plan Application**
Response to City of Ottawa Comments
GEO Morphix Project N. 23100

It is our understanding that Inverness Homes has received a request from the City of Ottawa to complete a site specific fluvial geomorphological study in support of the 391 Hilversum Lane Site Plan Application. GEO Morphix Ltd. (GEO Morphix) was previously retained by The Stirling Group on behalf of Inverness Homes to complete a fluvial geomorphological assessment and erosion hazard assessment in support of the proposed development located at 147 Langstaff Drive, Carp, Ontario. The subject lands encompass the location of the proposed development site at 391 Hilversum Lane (**Attachment 1**).

As a result of the completion of this work, a report entitled *147 Langstaff Drive, Carp, Ontario, Fluvial Geomorphological and Erosion Hazard Assessment* was prepared for Inverness Homes on October 23, 2019. The final version of this report was submitted on July 19, 2023 to address comments provided by the City of Ottawa and the Mississippi Valley Conservation Authority (MVCA) (**Attachment 2**). It is our understanding that the final version of this report was accepted in 2023 by the City of Ottawa. Additionally, a technical design brief providing recommendations for bank treatments and sediment removal along a portion of a tributary of Carp River (**Reach CR-1**) adjacent to the 391 Hilversum Lane development was prepared for Inverness Homes on November 28, 2023 (latest rev. September 18, 2024), entitled *Technical Design Brief: Tributary of Carp River Remediation Plan (Reach CR-1), 147 Langstaff Road, Carp, Ontario* (**Attachment 3**). These works were constructed in 2025.

The following activities were completed in support of these assessments:

- Review available background reports and mapping (e.g., watershed/subwatershed reporting, geology, and topography) related to channel form and function and controlling factors related to fluvial geomorphology
- Delineation of watercourse reaches through a desktop assessment
- Completion of rapid geomorphological assessments on a reach basis to document channel conditions and verify the desktop assessment
- Documented areas of significant erosion and locations of valley wall contacts/valley wall systems, collect instream measurements of bankfull channel dimensions, and characterize bed and bank material composition and structure
- Delineated limits of the meander belt width/erosion hazard on a reach basis using field observations and historical aerial photography
- Developed recommendations for the potential crossing over the central tributary to ensure that natural hazards are addressed from a fluvial geomorphological perspective
- Submission of a report and mapping product to characterize the watercourse, the erosion hazard extent, and summarize all findings

In developing the channel remediation design, the following activities were also completed:

- Conducted rapid field reconnaissance along **Reach CR-1** to confirm that existing conditions and areas of erosion/aggradation had not substantially changed since 2022
- Prepared detailed design drawings that identify the extent and configuration of proposed bank treatments and sediment removals/channel sculpting
- Completed hydraulic stone sizing based on modelling to ensure any proposed treatments remain stable over the long term
- Developed recommendations for design implementation including construction timing and best management practices
- Prepared a post-construction monitoring plan

Existing Conditions and Recommendations

In support of the proposed development, field investigations were completed on July 10 and September 4, 2019 to characterize existing conditions and inform the previously completed erosion hazard assessment. The 2019 assessment included the following observations:

- Completion of reach-scale habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool), and riparian vegetation
- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Determination of bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures

In addition to the initial 2019 assessments, three other field investigations were conducted. A supplemental site visit on May 19, 2020 was completed to address comments from the Mississippi Valley Conservation Authority (MVCA). A targeted investigation was conducted on January 13, 2022 to review areas of erosion concern documented by the City of Ottawa in the central ravine and identify any additional areas of channel adjustment while onsite. A final field visit on October 20, 2023 was completed in support of the remediation plan to provide an update to existing conditions. Refer to previous reporting for a detailed description of conditions along **Reach CR-1** in **Attachments 2** and **3**.

A 2 m toe erosion allowance was determined for the majority of **Reach CR-1** with the exception of identified locations on the west side of the ravine that had observations of local channel adjustment. The site at 391 Hilversum Lane is adjacent to these specified locations and as a result a 5 m toe erosion allowance is to be applied (**Attachment 2**). Details of these observations and recommendations were included in the geotechnical report completed by the Patterson Group (*Geotechnical Recommendations; Proposed Residential Development – Phase 1 Apartment Building (Block 27); 391 Hilversum Lane – Ottawa)* that was included with the 391 Hilversum Site Application Plan package submitted by Inverness Homes. Therefore, the erosion hazard adjacent to the development has been addressed.

The restoration design focused primarily on installing bioengineered treatments along sections of the channel bank to stabilize and enhance the ravine over the long-term. The outside bank of meander bends experience relatively higher erosive flows, which under natural conditions leads to meander bend migration. As such, the channel banks identified as being of local erosion concern were protected with vegetated rip rap and brush mattress, as shown on design plans prepared by GEO Morphix (September, 2024) (**Attachment 3**). As noted previously, these works were constructed in 2025.

In summary, the extent of the work completed on the subject lands in support of the proposed development at 147 Langstaff Road satisfies the request for a fluvial geomorphology assessment specific to 391 Hilversum Lane. No additional fluvial geomorphology assessments are required in support of the Site Plan Application.

Respectfully submitted,

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Director, Principal Geomorphologist

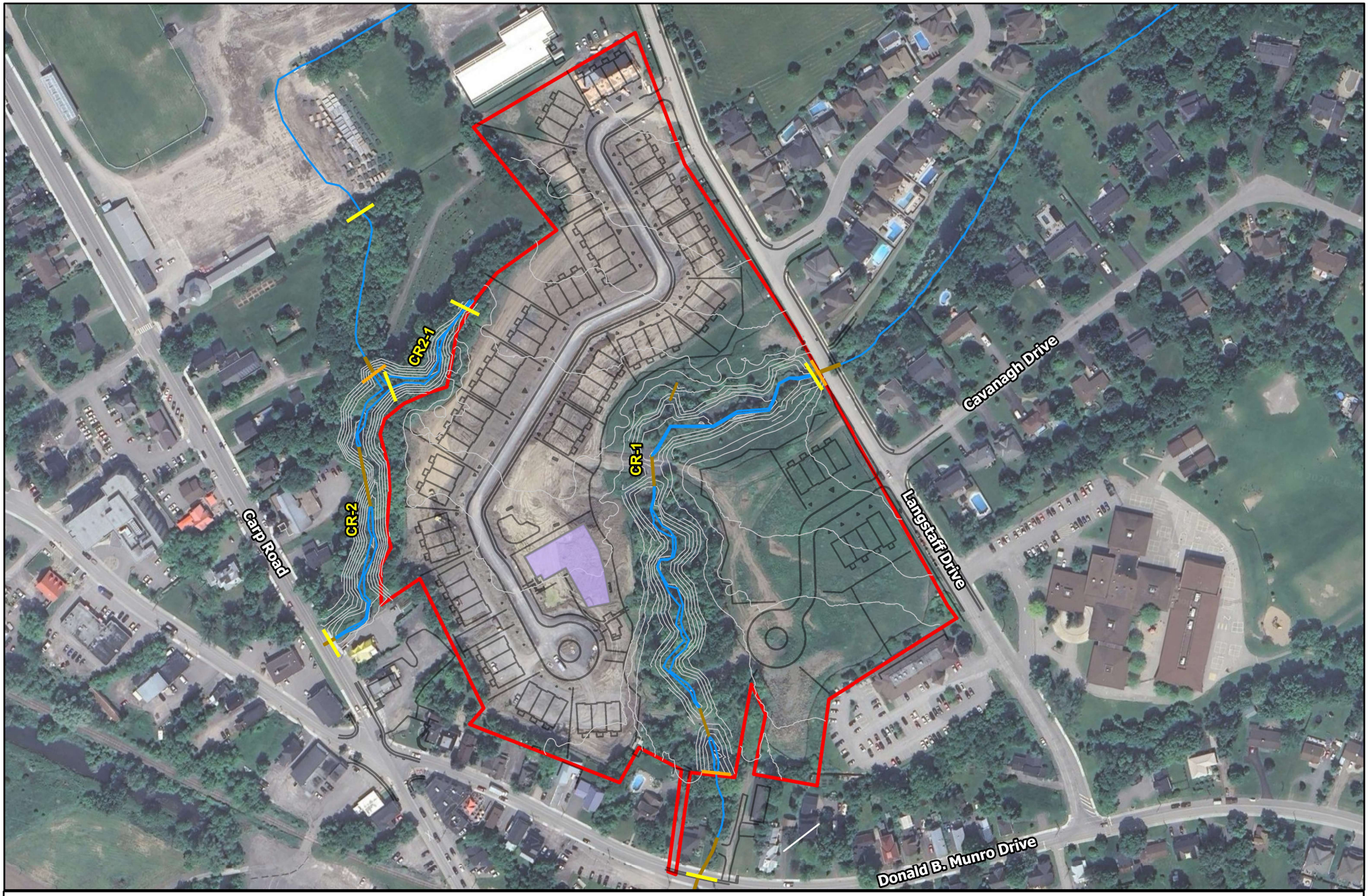
Susanne, St Onge, M. Sc.
Senior Environmental Scientist, Practice Lead

Lisa Kester, M. Sc.
Environmental Project Coordinator

References

Paterson Group. 2025. Geotechnical Recommendations; Proposed Residential Development – Phase 1 Apartment Building (Block 27); 391 Hilversum Lane – Ottawa

Attachment 1
391 Hilversum Lane, Carp



Legend

- Reach Break and ID (CR-1)
- Extent Assessed
- Contours (1 m)
- Watercourse
- Culverts
- Development Fabric
- Subject Lands
- 391 Hilversum Lane

Reach Delineation

Inverness Homes
147 Langstaff Drive
Ottawa, Ontario

GEO MORPHIX™

N

0 50 100
Metres

Imagery: Google Earth, 2025.
Watercourse: City of Ottawa, 2019. Subject Lands: Inverness Homes, 2021.
Reach Break, Extent Assessed : GEO Morphix Ltd., 2019.
Contours, Surveyed Channel and Culverts: Robinson, Land Development: 2020.
Development Fabric: Robinson Consultants, 2025.
Print Date: January 2025. PN19072. Drawn By: M.O., S.S., L.K.

Attachment 2
GEO Morphix Report: 147 Langstaff Drive, Carp, Ontario; Fluvial Geomorphological and Erosion Hazard Assessment

147 Langstaff Drive, Carp, Ontario

Fluvial Geomorphological and Erosion Hazard Assessment

Prepared for:
Inverness Homes
69 Moore Street
Richmond ON K0A 2Z0

July 19, 2023
PN19072

GEO MORPHIX
Geomorphology
Earth Science
Observations

Report Prepared by:	GEO Morphix Ltd. 36 Main Street North PO Box 205 Campbellville, ON L0P 1B0
Report Title:	147 Langstaff Drive, Carp Ontario Fluvial Geomorphological and Erosion Hazard Assessment
Project Number:	PN19072
Status:	Final
First Submission Date:	October 23, 2019
Revision Date	July 19, 2023
Prepared by:	Ben Miller, B.Sc., CAN-CISEC and Suzanne St. Onge, M.Sc.
Approved by:	Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP
Approval Date:	July 19, 2023

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1 Introduction

GEO Morphix was retained by The Stirling Group on behalf of Inverness Homes to complete a fluvial geomorphological and erosion hazard assessment for a proposed development located at 147 Langstaff Drive in the community of Carp, Ontario. The subject lands are approximately 8.2 ha in area and bounded by Langstaff Drive to the north, Carp Road and existing residences to the south and east, and existing residential and commercial/industrial development to the west. A tributary of the Carp River flows in a generally north to south orientation through the central portion of the subject lands. A second tributary flows immediately west of the subject lands. Existing land uses consist of vacant greenfield and natural areas associated with the Carp River tributaries.

The City of Ottawa, as part of the pre-application consultation, requested the completion of a Fluvial Geomorphology Report. The following activities have been completed in support of our assessment:

- Review available background reports and mapping (e.g., watershed/subwatershed reporting, geology, and topography) related to channel form and function and controlling factors related to fluvial geomorphology
- Delineate watercourse reaches through a desktop assessment
- Complete rapid geomorphological assessments on a reach basis to document channel conditions and verify the desktop assessment
- Document any areas of significant erosion and locations of valley wall contacts/valley wall systems
- Collect instream measurements of bankfull channel dimensions and characterize bed and bank material composition and structure
- Delineate limits of the erosion hazard on a reach basis using field observations and historical aerial photography
- Prepare recommendations for the two proposed trail crossings over the central tributary to ensure that natural hazards are addressed from a fluvial geomorphological perspective

This report summarizes the results of our desktop and field-based assessment. It identifies site constraints from a fluvial geomorphological perspective and should be considered in conjunction with studies being completed by other disciplines in support of the proposed development.

2 Background Review and Desktop Assessment

2.1 Geology and Physiography

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 Ottawa Valley Clay Plains physiographic region and Clay Plains physiographic landform. Areas north (upstream) of the subject lands are located within the Shallow Till and Rock Ridges physiographic landform (Chapman and Putnam, 1984 and 2007). Based on published surficial geology mapping, the majority of the subject lands contain coarse-textured glaciomarine deposits of sand, gravel, minor silt and clay. The north tip of the subject

lands and areas north of Langstaff Drive contain fine-textured glacio-marine deposits of silt and clay, minor sand and gravel that are massive to well laminated (OGS, 2010).

Published mapping is generally consistent with boreholes recovered by Paterson Group Inc. in support of the geotechnical study. A total of 13 boreholes were advanced to a maximum depth of 9.8 m. Subsurface conditions consisted of a 150 to 200 mm thick layer of topsoil overlying a compact silty sand deposit from 0.6 to 1.4 below ground surface. This was underlain by a stiff, brown silty clay that became a stiff to firm grey silty clay at 4.5 to 6 m below the ground surface. A grey silt sand to sandy silt was present from 6 to 8.5 m below the ground surface (Paterson Group Inc., 2023).

2.2 Site History

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use/cover. This information, in part, provides an understanding of the historical factors that have contributed to current channel morphodynamics. Aerial photographs from 1945, 1964, 1966, 1967, 1975, 1978, and 1989 from the National Air Photo Library (NAPL), imagery available online through the GEO Ottawa web mapping application, and recent satellite imagery from Google Earth Pro were reviewed. Refer to **Appendix A** for copies of select imagery obtained from the National Air Photo Library.

In 1946, agriculture and rural land uses were predominant. Outbuildings/agricultural facilities were visible adjacent to the top of the bank of the central tributary near what is now Langstaff Drive and near the downstream extent of the central tributary. The defined valleys were apparent, but the watercourse was not visible in the imagery. Natural riparian vegetation had been removed from the upstream portion of the central tributary, likely to facilitate agricultural uses, while the western tributary that flows adjacent to the subject lands retained natural vegetation in the immediate riparian zone. A large natural area was present upstream, which coincides with Precambrian bedrock based on published surficial geology mapping (OGS, 2010).

There were limited changes to land use and land cover by 1966, with areas within the subject lands under active cultivation; however, rural residential development had expanded westward along Carp Road. In 1967, a large industrial/commercial facility was constructed northwest of the subject lands, west of what is now Langstaff Drive, but was set well back from the central tributary. Vegetation cover along the defined valleys of the central and western tributaries remained dense and undisturbed. This eliminated channel visibility entirely.

In 1975, the subject lands remained under active cultivation, while lands to the east and west were converted from agriculture to relatively small residential subdivisions. An access road was constructed over the western most tributary immediately adjacent to the subject lands, likely to facilitate access to agricultural fields. Still, in 1975 vegetation cover along both tributaries remained constant. The channel in both cases was not discernible. This indicates that between 1946 and 1975 major channel adjustment and migration was unlikely or very minor in nature. There was no loss of trees or sign of bare slopes within the aerial imagery. This suggests limited to no channel migration activity.

By 1989, residential subdivisions had begun to encroach on the central tributary north of what is now Langstaff Road, and commercial/industrial development had expanded to the immediate west. The crossing visible in the 1975 imagery along the western tributary was no longer present, likely due to expansion of the local road network west of the subject lands. Portions of the central tributary north of the subject lands also appeared to have been straightened or modified to accommodate residential development, with landscaped rear yards of several residences abutting the central tributary upstream of the subject lands. Between 1975 and 1989, headwaters of the

western tributary appeared to be straightened to follow property boundaries or enclosed in storm sewers. These channel modifications likely resulted in limited/reduced natural channel form upstream of the subject lands, as well as potentially more rapid run-off to receiving features due to increases in impervious surfaces.

By 2004, the current alignment of Langstaff Drive had been constructed and residential development had expanded further in the upstream extents of both the central and western tributaries. An online stormwater management facility and access road were recently constructed immediately upstream of the subject lands on the north side of Langstaff Road. In addition, an access road and watercourse crossing were apparent at the upstream extent of the central tributary within the subject lands, approximately 110 m downstream of Langstaff Drive. A second access to the central tributary was visible amongst the trees in the lower third of the central tributary. The purpose of these two crossings was unclear based on the aerial photograph record but it has been confirmed that these structures provide a stormwater management function. There was limited change between 2004 and 2018, with the exception of the construction of additional residences on the west side of the central tributary upstream of Langstaff Drive.

Since 1946, vegetation cover along both tributaries has remained dense and undisturbed, preventing visibility of their channel planforms. Given that there has been no loss in tree cover, and that the channel is not discernable, there is no evidence to support that the channel has undergone active migration or widening processes. Active channel migration would result in modifications and changes in riparian vegetation, loss of tree cover, or bare erosion areas in the historical aerial record.

3 Watercourse Characteristics

3.1 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 particular 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

Reach delineation follows scientifically defensible methodology proposed by Montgomery and Buffington (1997), Richards et al. (1997), and the Toronto and Region Conservation Authority (2004) as well as others. A single reach, **CR-1**, was delineated along the central tributary that bisects the subject lands. Reaches **CR-2** and **CR-2a** were delineated along the tributary to the immediate west. Refer to **Appendix B** for the location and extent of each reach.

3.2 General Reach Observations

Field investigations were completed on July 10 and September 4, 2019 and included the following:

- Completion of reach-scale habitat sketch maps based on Newson and Newson (2000) outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool), and riparian vegetation
- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Determination of bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures

These observations and measurements are summarized below and include minor updates based on supplemental field work completed on May 19, 2020 to address comments provided by the City of Ottawa and the Mississippi Valley Conservation Authority (MVCA). In addition, existing conditions along **Reach CR-2a** are included below based on the field assessment completed in May 2020. The descriptions below are supplemented and supported with representative photographs, which are included in **Appendix C**. Field sheets, including reach summaries, habitat sketch maps and rapid assessments, are provided in **Appendix D**.

A targeted field investigation was also conducted on January 13, 2022 to review areas of erosion concern documented by the City of Ottawa in the central ravine and identify any additional areas of channel adjustment while onsite. **Appendix E** contains mapping provided by the City and areas of channel adjustment documented by GEO Morphix. City of Ottawa site identifiers were carried forward to GEO Morphix mapping where the locations were generally consistent (i.e., Sites 1 to 9). GEO Morphix also identified two areas of minor channel adjustment in the downstream and upstream extents of the central ravine (Sites A and B) and in three locations along the western ravine (Sites C to E).

Bankfull channel dimensions and channel characteristics such as substrate composition, channel form and the presence of undercut channel banks are measured during rapid field reconnaissance as these elements provide an indication of channel adjustments such as degradation, aggradation, migration or widening. When long-term monitoring programs are initiated, monumented cross sections and erosion pins are typically installed to allow repeated measurements in the same location on a seasonal or annual basis over a period of time (e.g., 2 to 5 years). This allows for the quantification of changes to channel cross sectional area, an evaluation of channel adjustments such as migration and widening, and changes to the sediment transport regime. Long-term monitoring was not required for the current study and is generally not conducted for erosion hazard assessments. As such, no monumented cross sections were installed in either ravine as part of our assessment. Bankfull channel dimensions and channel bank undercuts were measured along each reach during site visits conducted in July and September 2019 and May 2020, but were not repeated at the same locations. Measurements provided in the reach descriptions below during each field visit are provided as additional information only and do not represent channel erosion over time at a specific location.

Reach CR-1 was predominantly a single thread, irregularly meandering channel within a transfer zone. The riparian zone was continuous and consisted of established trees (5-30 years), shrubs, grasses and herbaceous species, and was approximately 4-10 channel widths. Although the reach was assessed as having a perennial flow regime during our visit in July 2019, areas of standing water were observed between the two concrete culverts associated with the online stormwater management facilities. This suggests that the flow regime may be intermittent when seasonally

dry conditions occur. Evidence of groundwater inputs (i.e., iron staining) was observed within the reach. Riffle-pool spacing was approximately 10 m, with riffle lengths ranging between 2 and 5 m. Riffle substrates consisted of sand, gravel and cobble and pool substrates consisted of clay/silt and sand. Bank materials consisted of clay, silt, sand and rootlets.

During the July 2019 assessment, minimal undercutting was observed, with the highest measured undercut being 0.05 m. Undercuts up to 0.2 m were measured along the reach during the second assessment completed May 19, 2020. As noted above, these undercuts were not repeated measurements at the same location and are therefore not representative of channel erosion at a specific location during the period between field visits.

Average bankfull channel width and depth were approximately 2.5 m and 0.4 m, respectively, based on measurements collected in July 2019 and May 2020. At the time of the assessment in July, 2019, average wetted width and depth were 0.61 m and 0.19 m, respectively. At the time of the assessment in May 2020, average wetted width and depth were 0.83 and 0.17 m, respectively. Channel bank angles ranged from 0-90°. Channel bank angle observations are limited to instream conditions and refer to the angle of the low flow channel bank.

The upstream portion of **Reach CR-1** was extensively encroached with vegetation and was situated within a partially confined valley with minimal woody debris. Meander amplitudes measured in the field ranged from 3-7 m. The downstream portion of the reach flowed through a forest within a confined valley and contained minimal vegetation encroachment. The channel became less defined and had multiple valley wall contacts and a few slumps. There was more woody debris present in the downstream portion of the reach relative to the upstream portion; however, woody debris present in the corridor did not appear to be a result of channel erosion or migration.

Areas of channel adjustment were observed but overall, the reach was assessed to be relatively stable. Refer to the mapping in **Appendix E** for locations of channel adjustment along this reach. Channel adjustment at Sites 4, 5 and 8 are interpreted to be largely due to the valley form rather than channel migration, as the ravine was relatively narrow at these locations. In addition, woody debris was directing flows towards the valley wall at Site 5 and observed channel adjustments were therefore not considered a result of erosion due to channel migration.

Reach CR-2 was a single thread, irregularly meandering channel flowing through a confined valley. The riparian zone was continuous and consisted mainly of established trees (5-30 years) and herbaceous species and was approximately 4-10 channel widths. The reach has an intermittent to perennial flow regime and had low to moderate entrenchment. A culvert located approximately mid-reach was damaged, with the upstream end of the culvert pointing upwards, suspended above the channel. Flows appeared to enter the culvert through hole(s) approximately midway in the structure. This structure may have been damaged by fill of materials from adjacent private landowners.

No true riffle-pool sequences were present but spacing between geomorphic units ranged from 5-20 m, with riffle lengths ranging between 1 and 3 m. Riffle substrates consisted mainly of sand, gravel and small cobbles and pool substrates consisted of clay/silt and sand. Bank angles ranged from 30-90° and materials consisted of clay/silt, sand and rootlets. As noted previously, bank angle estimations are limited to instream conditions and refer to the angle of the low flow channel bank. Average bankfull channel width and depth were 2.7 m and 0.36 m, respectively. At the time of the assessment in September 2019, average wetted width and depth were 0.93 m and 0.04 m, respectively. Average wetted width and depth during the May 2020 assessment were 1.25 and 0.22, respectively.

The majority of the reach contained relatively shallow channel bank angles and where it flowed coincident with the valley slope, channel adjustment was generally not observed (e.g., **Photos 37** to **40** and **43** in **Appendix C**). Importantly, the two areas of channel adjustment that were observed were located along the side of the ravine opposite the proposed development. At Site C (**Appendix E**) the channel contacted the valley slope upstream of a 90° bend in the channel near Carp Road. This area was estimated to be approximately 2 m in height and approximately 5 m in length. As this area abuts private property it is not considered to pose a hazard to the proposed development (Photo 34 in **Appendix C**). Site D consists of an area of exposed bank on the south side of a culvert outlet abutting private property near the upstream extent of the reach (Photo 45 in **Appendix C**). This bank exposure is likely a result of flows from the culvert outlet rather than natural channel processes. As this area abuts private property rather than the proposed development, it does not pose a hazard. While GEO Morphix does not consider Site D to be of long-term concern, the City may wish to investigate potential erosion mitigation measures at the existing culvert outlet.

Reach CR-2a consisted of a relatively straight channel flowing through a confined valley within a headwater zone. Flow was assessed to be intermittent to ephemeral. The riparian zone was continuous, approximately 1-4 channel widths and contained established trees and herbaceous vegetation. Woody debris was present in the channel and cutbank. The channel was assessed as entrenched by virtue of the steep valley walls along the majority of the reach. Riffle-pool sequences were absent, and channel substrate was composed of clay/silt and sand. Bank angles ranged from 0 to 60° and bank materials consisted of clay/silt and sand.

Average bankfull channel width and depth were 0.85 m and 0.25 m, respectively. Where water was present during the assessment completed in May 2020, wetted width and depth were approximately 0.1 m and 0.03 m, respectively. Evidence of minor adjustment was limited to one area along this reach (Photo 48 in **Appendix C**), and the drainage feature was notably small compared to the larger valley feature. We note that Site E was located on the bank abutting private property to the west, and therefore does not pose a hazard to the proposed development.

3.3 Rapid Assessments

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.

Reaches **CR-1** and **CR-2** were also classified according to a modified Downs (1995) Channel Evolution Model. The Downs Model describes successional stages of a channel as a result of a perturbation, namely hydromodification. Understanding the current stage of the system is beneficial as this allows one to predict how the channel will continue to evolve or respond to an alteration to the system. The results of these assessments are summarized below in **Table 1**.

The July 2019 assessment along **Reach CR-1** resulted in an RGA score of 0.19, indicating the reach was in regime. The dominant geomorphological indicator was evidence of widening, shown

by occurrences of large organic debris and exposed roots. During the May 2020 assessment, the RGA indicated that the reach was in transition, with a slightly higher score of 0.24. The dominant geomorphological indicator was evidence of degradation, shown by occurrences of scour pools downstream of culverts, headcutting and exposure of undisturbed overburden.

The July 2019 assessment of **Reach CR-1** resulted in an RSAT score of 32.5, or good. There was no definitive limiting factor, as the reach scored 'good' in all categories. The reach was given a Downs classification of 'M' for lateral migration. The May 2020 assessment resulted in an RSAT score of 29, with the limiting factor being channel scouring/sediment deposition. Similar to July 2019 observations, the reach was given a Downs classification of 'M' for lateral migration. As noted previously, meander migration rates cannot be calculated along either ravine due to the presence of tree cover (i.e., the channel planform is not visible in aerial photography). In addition, the relatively small bankfull channel width would impact the accuracy of channel migration measurements as the planforms of smaller features are more difficult to discern in imagery.

The September 2019 assessment along **Reach CR-2** resulted in an RGA score of 0.24, indicating the reach was in transition/stress. We note that this assessment was limited to the downstream portion of the reach due to access limitations. The dominant geomorphological indicator was evidence of aggradation, evidenced by siltation in pools, medial bars, accretion on point bars, and deposition in the overbank zone. The May 2020 assessment extended to the upstream reach break and resulted in an RGA score of 0.12, indicating the reach was in regime. The dominant geomorphological indicator was evidence of aggradation, as evidenced by accretion on point pars and siltation in pools.

The September 2019 RSAT for **Reach CR-2** resulted in a score of 30, or good. The limiting factor was physical instream habitat due to the few shallow pools and small riffle substrate sizes. The reach was given a Downs classification of 'M' for lateral migration. The May 2020 assessment resulted in an RSAT score of 29, with the limiting factors being channel scouring/sediment deposition and physical instream habitat. The reach was given a Downs classification of 'D' for depositional.

Rapid assessment tools were not applied to **Reach CR-2a** as there was limited evidence of fluvial processes (i.e., reach located in a headwaters zone and a portion of channel was dry at the time of assessment). The reach was given a Downs classification of 'S' for stable.

We note that it is not unusual to have slightly different rapid assessment results due to seasonal flow conditions and vegetation establishment in the mid to late summer, particularly along lower order features with relatively small bankfull channel dimensions. The scores of 0.19 and 0.24 for **Reach CR-1** are within the upper and lower limits of in regime (0.0-0.2) and in transition (0.2-0.4) categories, respectively. The more substantial difference in RGA scores along Reach **CR-2** can be attributed to the extent assessed. The September 2019 assessment was limited to the downstream extent of the reach, while the May 2020 assessment extended to the upstream reach break with **CR-2a**. Areas of minor erosion observed along the lower portion of the reach resulted in a higher score during the September 2019 assessment. When the larger reach is considered, these instances of minor erosion are of lesser significance.

Table 1: Summary of rapid assessment results

Reach	RGA (MOE, 2003)			RSAT (Galli, 1996)			Downs Channel Evolution Model (1995)
	Score	Condition	Dominant Systematic Adjustment	Score	Condition	Limiting Feature(s)	
CR-1 (July 2019)	0.19	In Regime	Widening	32.5	Good	N/A	M – lateral migration
CR-1 (May 2020)	0.24	In Transition	Degradation	29	Good	Channel Scouring/Sediment Deposition	M – lateral migration
CR-2 (Sept 2019)	0.24	In Transition	Aggradation	30	Good	Physical Instream Habitat	M – lateral migration
CR-2 (May 2020)	0.12	In Regime	Aggradation	29	Good	Physical Instream Habitat Channel Scouring/Sediment Deposition	D- depositional
CR-2a May 2020)	N/A			N/A			S- stable

4 Erosion Hazard Delineation

Most watercourses in eastern 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 stream.

When defining the meander belt width for a creek system, the TRCA (2004) and MNR (2002) protocols 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.

Based on our desktop review and field observations, the Carp River tributaries within and adjacent to the subject lands are confined systems. In confined systems where the channel is less than 15 m from the toe of the valley slope, the erosion hazard can be delineated using a toe erosion allowance, stable slope allowance, and an erosion access allowance. This is in keeping with the Provincial Policy Statement (PPS, 2020) on defining erosion hazards. Following MNR (2002) guidelines, the toe erosion allowance can be determined by:

1) calculating the average annual recession rate based on a minimum of 25 years of record

2) applying a 15 m toe erosion allowance measured inland horizontally and perpendicular to the toe of the watercourse slope,

3) based on soil types and hydraulic processes

4) use of a study that applies accepted geotechnical and engineering principles based on a minimum of 25 years of record

It is understood that the City prefers that the 100-year erosion setback be based on the approach that utilizes recession rates based on a minimum of 25 years of historical record. GEO Morphix agrees that this is the preferred approach when the channel planform is visible in aerial imagery and the historical aerials can be adequately georeferenced to minimize measurement error. As noted elsewhere in this report (refer to **Section 2.2**) and discussed with City staff, this approach is not possible given the relatively small size (limited extent) of the channel and significant level of tree cover in aerial photographs. Notably, the riparian vegetation remained intact through the period of record, indicating a lack of channel erosion or adjustment. If slope instability or creek adjustment had been occurring, there would be evidence of tree failure, riparian fragmentation, and open erosion scars. None of these characteristics were identified through the historical aerial photograph review. In addition, the central ravine has been significantly modified to accommodate the online stormwater management system.

As the annual recession of the slope toe could not be determined, approach no. 3 described above was followed. GEO Morphix Ltd. has completed numerous projects within eastern Ontario utilizing this approach and has recommended appropriate toe erosion allowances that have been accepted by regulatory review agencies and are in keeping with the Provincial Policy for erosion hazards. Table 3 in the MNR (2002) guidelines provides recommendations for an appropriate toe erosion allowance based on evidence of erosion, channel bank composition and bankfull channel width. As noted previously, the channel banks were composed of clay, silt and sand, and the average bankfull channel widths were estimated to be approximately 3.0 m and 2.3 m along the central and western tributaries, respectively. Following language in Table 3 of the MNR (2002) guidelines, channels with no active erosion, a bankfull channel width of less than 5 m and banks composed of soft/firm cohesive soils, a 1-2 m toe erosion allowance should be applied. Using MNR (2002) guidelines and selecting the upper or lower range of setback values based on evidence of erosion is an acceptable method for establishing the 100-year erosion setback, especially when the bankfull channel is not visible in aerial photographs.

Reach CR-1 had an average bankfull width of 3.0 m, with bank materials consisting of clay, silt and sand. For the majority of the reach a toe erosion allowance of 2 m is recommended. While it is GEO Morphix's opinion that the 2 m toe erosion allowance is appropriate for the entire length of the ravine, a toe erosion allowance of 5 m has been provided along the length of ravine contiguous with Sites 4 and 5 (i.e., the length of Sites 4 and 5 and section of ravine between these two locations), as well as along the length of Site 8. In these locations channel adjustment was observed in the field. This is a conservative estimate for the toe erosion allowance and has been provided to address the City's concerns.

Following MNR (2002) guidelines, a toe erosion allowance of 1 m is recommended for **Reach CR-2** as it has an intermittent to perennial flow regime, an average bankfull width of 2.3 m and bank materials consisting of clay, silt and sand. This toe erosion allowance is appropriate as although very minor areas of channel adjustment were observed along the reach, they are on the opposite side of the ravine and do not pose a hazard to the proposed development.

The watercourses within each reach assessed as part of this study are relatively small compared to their respective valley corridors. The more significant component of the erosion hazard along each ravine is the stable slope allowance, or long-term stable top of slope. It is important to note that the total erosion hazard for confined valley systems is based on the combined influence of the toe erosion allowance and the stable slope allowance. Therefore, the recommended toe erosion allowances should be considered in conjunction with the geotechnical study prepared under separate cover by the Paterson Group Inc. (2023). The stable top of slope determined by the Paterson Group Inc. includes the recommended toe erosion allowances discussed above, which were applied from the geotechnically stable top of slope rather than from the edge of the bankfull channel. This is a more conservative approach to applying the toe erosion allowance as it includes

an additional factor of safety. As such, GEO Morphix is confident that the recommended erosion setbacks are appropriate. The methodology and final toe erosion allowances provided are appropriate and consistent with both the MNRF Technical Guide (2002) and other erosion setback values that we have previously provided in Ottawa and other jurisdictions.

5 Recommendations for Proposed Crossings

Two pedestrian crossings are proposed in **Reach CR-1** where concrete culverts are currently located. No erosion concerns were documented in vicinity of either culvert during our field investigations. Comments from the City received by email on December 22, 2021 noted concerns with the culvert shown in Photo 45 of **Appendix C**; however, the culvert shown in the photo is located in the western ravine and is therefore not impacted by the proposed pedestrian crossings.

At this time, it is uncertain as to whether the pedestrian crossings will be located at these culverts or elsewhere along the central ravine. As the existing culverts and associated berms form part of the online stormwater management infrastructure in the central ravine, pedestrian crossings at these locations should be designed in a manner that avoids impacts to their stormwater management function. Regardless of their location, we recommend the pedestrian crossings consider the following from a fluvial geomorphic perspective:

- New or replacement structures should be open bottom or embedded a minimum of 0.3 m
- Where possible, avoid the need for channel armouring or adjustment
- Address potential channel migration
- Maintain flow velocities and sediment transport processes for frequent storm events
- Be located at a straight section of channel
- Cross the channel at a perpendicular angle
- Be located at a reasonably stable length of channel

The above recommendations are consistent with crossing guidelines developed by Greater Golden Horseshoe Conservation Authorities such as Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation (CVC). The TRCA (2015) recommends that crossing structures span the meander belt width, where feasible, or, at minimum, the 100-year erosion limit to avoid the migration of the channel into the crossing structure within the next 100 years. The TRCA guidelines also allow smaller crossing structures that accommodate relatively small, stable watercourses provided that they consider physical channel characteristics (e.g., alignment, width and depth) and fluvial processes (e.g., erosion and scour).

6 Summary

GEO Morphix was retained to complete a fluvial geomorphological assessment of two tributaries of the Carp River located within and adjacent to the property located at 147 Langstaff Drive, Ottawa. The desktop assessment included a review of available reporting, and surficial geology and topographic mapping, as well as reach delineation. A historical assessment was also completed using imagery available from the National Air Photo Library, the GEO Ottawa web mapping application and Google Earth Pro. The historical assessment revealed that planforms of each tributary are not visible due to substantive tree cover; however, riparian vegetation remained intact through the period of record, indicating a lack of channel erosion or adjustment. If slope instability or creek adjustment had been occurring, evidence of tree failure, riparian fragmentation, and open erosion scars would be visible. None of these characteristics were identified through the historical aerial photograph review.

The desktop assessment was confirmed through the completion of reach-based rapid field reconnaissance on July 10, 2019, September 4, 2019 and May 19, 2020. During the July 2019 assessment, **Reach CR-1** was evaluated to be in regime, with an RGA score of 0.19. The May 2020 assessment resulted in a slightly higher score of 0.24, indicating the reach was in transition. Although the RGA scores are slightly different, the results are within the upper range of in regime (0.0 - 0.2) and the lower range of in transition (0.2 - 0.4), respectively. **Reach CR-1** had RSAT scores of 32.5 and 29 during the July and May 2020 assessments respectively, indicating the reach was in good condition.

Approximately 50 m of **Reach CR-2** was assessed during the September 2019 assessment, resulting in an RGA score of 0.24 (in transition/stress). The dominant systematic adjustment was evidence of aggradation. Field work completed in May 2020 included an assessment of channel conditions to the upstream reach break and resulted in an RGA score of 0.12 (in regime). Areas of minor channel adjustment observed along the lower portion of the reach resulted in a higher score during the September 2019 assessment. When the larger reach is considered, these instances of minor erosion are of lesser significance. Overall, although the channels were in contact with the valley walls at multiple locations, there was limited evidence of channel adjustment along each tributary.

Following comments received from the City of Ottawa via email on December 22, 2021 and a meeting with the City on January 7, 2022, additional field reconnaissance was completed to review areas of erosion documented by the City in the central ravine and any other observed areas of channel adjustment in both ravines while onsite. Mapping provided by the City and areas of channel adjustment documented by GEO Morphix are contained in **Appendix E**, which were considered in delineating the erosion hazard for both ravines.

Where channel systems are confined, the erosion hazard can be defined using the 100-year erosion limit or through the selection of an appropriate toe erosion allowance based on MNR (2002) guidelines. For this study, channel migration rates could not be measured as the presence of trees along the tributary corridors obscured a clear view of the channel planforms. Other limitations included the relatively small size of the features and the resolution of available aerial photography. Using Table 3 in the MNR (2002) guideline document and selecting the upper or lower range of setback values based on evidence of erosion is an acceptable method for establishing the 100-year erosion setback, particularly when the bankfull channel is not visible in aerial imagery. A 2 m toe erosion allowance was determined for the majority of **Reach CR-1** with the exception of Sites 4, 5 and 8. Although Sites 4 and 5 are mapped separately by GEO Morphix, the 5 m toe erosion allowance is to be applied to the length of ravine between these two locations. A 1 m toe erosion allowance was determined for **Reach CR-2**. Areas of channel adjustment were noted along the valley opposite the proposed development, and as such are not considered to pose a hazard.

The watercourses within in each reach assessed as part of this study are relatively small compared to their respective valley corridors. The more significant component of the erosion hazard along each ravine is the stable slope allowance. The total extent of the erosion hazard for confined valley systems is based on the combined influence of the toe erosion allowance and the stable slope allowance. Therefore, the recommended toe erosion allowances should be considered in conjunction with the geotechnical study prepared by Paterson Group Inc. (2023), where the long-term stable top of slope includes the recommended toe erosion allowances discussed above. These values were applied from the stable top of bank rather than the edge of the bankfull channel and as such, result in a more conservative approach to delineating the erosion hazard along both ravines. The methodology and toe erosion allowances provided are appropriate and consistent with both the MNRF Technical Guide (2002) and other erosion setback values that we have previously provided in Ottawa and other jurisdictions.

We trust this report meets your requirements at this time. Should you have any questions please contact the undersigned.

Respectfully submitted,

Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP
Director, Principal Geomorphologist

Suzanne St. Onge, M.Sc.
Senior Environmental Scientist

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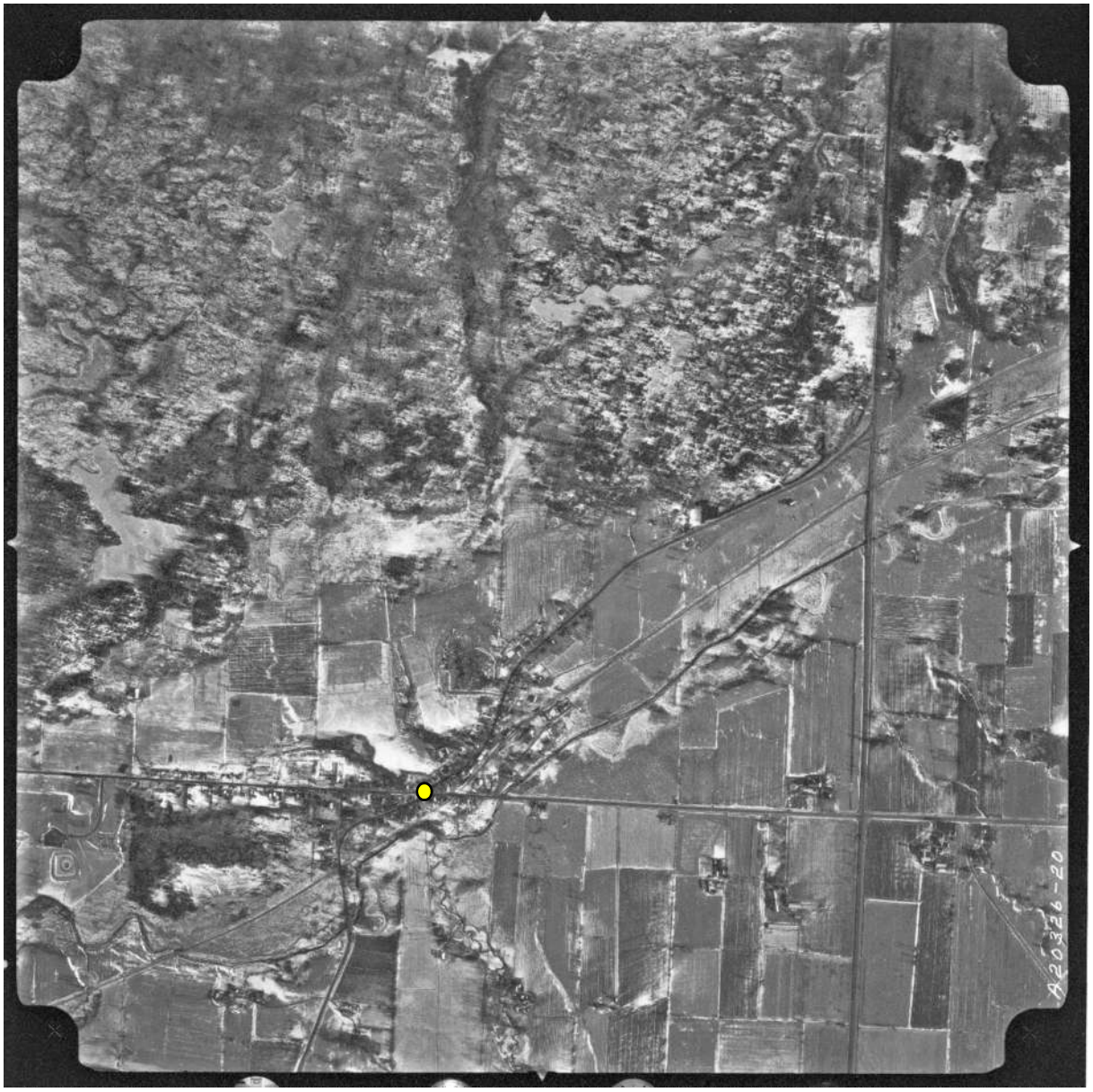
Appendix A
Historical Aerial Photographs

Location: Intersection of Carp Road and Donald B. Munro Drive (yellow dot)
Year: 1946
Scale: 1:15,000
Source: National Air Photo Library

Location: Intersection of Carp Road and Donald B. Munro Drive
Year: 1966
Scale: 1:6,000
Source: National Air Photo Library



Location: Intersection of Carp Road and Donald B. Munro Drive
Year: 1966
Scale: 1:15,000
Source: National Air Photo Library

Location: Intersection of Carp Road and Donald B. Munro Drive
Year: 1975
Scale: 1:15,000
Source: National Air Photo Library

Location: Intersection of Carp Road and Donald B. Munro Drive
Year: 1989
Scale: 1:25,000
Source: National Air Photo Library

Location: Intersection of Carp Road and Donald B. Munro Drive
Year: 2004
Scale: Not applicable
Source: Google Earth pro

Location: Intersection of Carp Road and Donald B. Munro Drive
Year: 2014
Scale: Not applicable
Source: Google Earth pro

Appendix B
Reach Delineation

Legend

- Reach Break and ID (CR-1)
- Contours (1 m)
- Watercourse
- Culverts
- Extent Assessed
- Subject Lands

Inverness Homes

147 Langstaff Drive

Reach Delineation

GEO MORPHIX™

N

0 50 100

Metres

Imagery: December, 2016.
Watercourse: City of Ottawa, 2019. Subject Lands: Inverness Homes, 2021.
Reach Break, Extent Assessed : GEO Morphix Ltd., 2019.
Contours, Surveyed Channel and Culverts: Robinson, Land Development: 2020.
Print Date: January 2022. PN19072. Drawn By: W.B., M.O., S.S.

Appendix C
Photographic Record

Photo 1 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	View of the reach downstream of Langstaff Drive. The channel was heavily encroached with vegetation at the upstream extent and was partially confined. Yellow arrow indicates flow direction.
Photo 2 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of the reach downstream of Langstaff Road during the May 2020 field investigation.

Photo 3 Tributary of Carp River: View Upstream Reach CR-1 (July 10, 2019)	
	View of the culvert conveying flows under Langstaff Drive.
Photo 4 Tributary of Carp River: View Upstream Reach CR-1 (July 10, 2020)	
	Stormwater outlet that discharged into the reach from Langstaff Drive. This outlet was located on the north side of the channel and flowed over small cobbles towards the reach.

Photo 5 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	An approximately 0.15 m knickpoint created by roots in the channel bed. There was a pool downstream of this location.
Photo 6 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	The reach was extensively encroached with vegetation and contained well-developed riffle-pool sequences at the upstream extent.

Photo 7 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of the reach where it transitioned from a multiple thread to single thread channel.
Photo 8 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of a valley wall contact with a well-vegetated slope and no evidence of channel adjustment.

Photo 9 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	Downstrem view of channel where it flowed parallel to the toe of slope.
Photo 10 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	Evidence of aggradation in the channel through accumulation of fine sediments on the bed.

Photo 11 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	Example of localized channel adjustment at a valley wall contact.
Photo 12 Tributary of Carp River: View Upstream Reach CR-1 (May 19, 2020)	
	Example of exposed parent material at the toe of the valley slope, which is indicative of sloughing.

Photo 13 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of the channel approaching the first concrete culvert installed as part of an online stormwater management facility.
Photo 14 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of the culvert inlet. The control structure was stable, with no evidence of outflanking or overtopping.

Photo 15 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	Riprap stabilization on top of a concrete culvert in the upper third of the reach. Note the channel remained extensively encroached with vegetation and flowed through a confined valley. No erosion was observed in vicinity of the crossing.
Photo 16 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of the channel downstream of the concrete culvert, where relatively minor channel adjustment along the toe of slope was observed.

Photo 17 Tributary of Carp River: View Upstream Reach CR-1 (May 19, 2020)	
	View of articial knickpoint caused by rip rap installed at concrete culvert crossing.
Photo 18 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of relatively minor channel adjustment along the toe of slope downstream of the concrete culvert. The valley slope was well-vegetated.

Photo 19 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	The reach entered a forested area with signs of slumping. Note the valley wall contact in this image.
Photo 20 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	Downstream view with a similar vantage to Photo 19, showing channel adjustment along the valley wall.

Photo 21 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	Within the forested section, the channel was less defined with multiple areas of woody debris.
Photo 22 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	The majority of trees in the valley and on the slopes were upright, suggesting that the reach was relatively stable. The channel was positioned away from the valley toe.

Photo 23 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of a valley wall contact that showed limited channel adjustment at the toe. Note the upright tree at the toe of slope (red arrow).
Photo 24 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	Woody debris within the forested section of the channel (valley wall contact circled in red). Photo 25 (below) provides a view of conditions in the spring.

Photo 25 Tributary of Carp River: View Downstream Reach CR-1 (May, 19, 2020)	
	Note the tree has fallen away from the channel rather than towards, indicating limited channel adjustment at the valley wall contact. There was no evidence suggesting that trees had fallen due to channel adjustment.
Photo 26 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	Example of where the channel has migrated away from the valley wall (historic valley wall contact noted with red arrow).

Photo 27 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	Channel temporarily loses definition before flowing through the second concrete culvert near the downstream extent of the reach.
Photo 28 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of the channel as it enters the second concrete culvert.

Photo 29 Tributary of Carp River: View Downstream Reach CR-1 (July 10, 2019)	
	Concrete culvert located in the lower third of the reach. Rip rap stabilization was observed on top of the culvert. No channel adjustment was observed in vicinity of the crossing.
Photo 30 Tributary of Carp River: View Downstream Reach CR-1 (May 19, 2020)	
	View of the channel downstream of the second concrete culvert. Relatively minor channel adjustment was observed along the toe of slope (red arrow).

Photo 31 Tributary of Carp River: View Downstream Reach CR-1 (May, 19, 2020)	
	View of the channel downstream, where it flowed through private property.
Photo 32 Tributary of Carp River: View Downstream Reach CR-2 (September 4, 2019)	
	Downstream extent of the reach at Carp Road, where the tributary flowed into a 0.90 m diameter concrete pipe.

Photo 33 Tributary of Carp River: View Upstream Reach CR-2 (September 4, 2019)	
	Downstream extent of assessed portion of reach. Channel flowed within a forested and confined valley. Bed material consisted mainly of silt, sand, and gravel.
Photo 34 Tributary of Carp River: View Upstream Reach CR-2 (September 4, 2019)	
	Eroded bank opposite the proposed development with a moderately dense root network. Several woody debris jams were present throughout the downstream extent of the reach.

Photo 35 Tributary of Carp River: View Upstream Reach CR-2 (September 4, 2019)	
	Channel flowed along the toe of slope. Minor channel adjustment and fallen trees were observed. There was no evidence that fallen trees were associated with channel adjustment.
Photo 36 Tributary of Carp River: View Upstream Reach CR-2 (September 4, 2019)	
	Flows conveyed through a compromised corrugated steel pipe that appeared overtopped during larger flows; however, erosion was not an issue.

Photo 37
Tributary of Carp River: View Downstream
Reach CR-2 (September 4, 2019)

View of left valley wall that had little evidence of channel adjustment.

Photo 38
Tributary of Carp River: View Upstream
Reach CR-2(September 4, 2019)

View of right valley wall and channel corridor. Right valley wall was more densely vegetated.

Photo 39 Tributary of Carp River: View Upstream Reach CR-2 (May 19, 2020)	
	View of the reach from the east valley slope, with a similar vantage point as Photo 38.
Photo 40 Tributary of Carp River: View Downstream Reach CR-2 (May 19, 2020)	
	Downstream view of the reach. The ravine was relatively narrow, and the channel was relatively wide and shallow.

Photo 41 Tributary of Carp River: View Upstream Reach CR-2 (May 19, 2020)	
	Downstream end of damaged corrugated steel pipe culvert (also pictured in Photo 36). Recent disturbance to the ravine was evident through the placement of fill near the top of slope to the west and debris on the slopes.
Photo 42 Tributary of Carp River: View Upstream Reach CR-2 (May 19, 2020)	
	View of damaged CSP with the inlet suspended approximately 0.9 m above the channel. Flows appear to enter the culvert through hole(s) approximately midway in the structure.

Photo 43 Tributary of Carp River: View Downstream Reach CR-2 (May 19, 2020)	
	View of the ravine adjacent to the church where the channel was poorly defined and the majority of trees on the slope were upright. The location of the damaged CSP culvert is shown by the red arrow.
Photo 44 Tributary of Carp River: View Upstream Reach CR-2 (May 19, 2020)	
	View of the confluence of CR-2 and CR-2a

Photo 45 Tributary of Carp River: View Upstream Reach CR-2 (May 19, 2020)	
	The culvert along Reach CR-2 is slightly perched, and a minor amount of rip rap has accumulated in the channel downstream. Exposed soils are likely the result of discharge from the culvert and are not related to natural channel processes.
Photo 46 Tributary of Carp River: View Downstream Reach CR-2a (May 19, 2020)	
	The feature had limited definition and no evidence of adjustment.

Photo 47 Tributary of Carp River: View Downstream Reach CR-2a (May 19, 2020	
	The feature had limited definition for most of the reach.
Photo 48 Tributary of Carp River: View Downstream Reach CR-2a (May 19, 2020	
	Evidence of relatively minor channel adjustment along the toe of the slope with undercuts measuring to approximately 0.1 m. This area was located on the bank opposite the proposed development and is therefore not considered to pose a hazard.

Photo 49 Tributary of Carp River: View Downstream Reach CR-2a (May 19, 2020	
	Downstream view of the upstream extent of the reach.
Photo 50 Tributary of Carp River: View Upstream Reach CR-2a (May 19, 2020	
	View towards the north, where the ravine significantly narrowed and terminated. No flow path could be discerned near the upstream extent of the ravine.

Appendix D
Field Assessment Sheets

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN 19072

Date:	July 10, 2019	**Stream/Reach:**	CR-1
Weather:	sunny 25°C	**Location:**	Langstaff Rd
Field Staff:	MK	**Watershed/Subwatershed:**	carp river trib

Features
- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

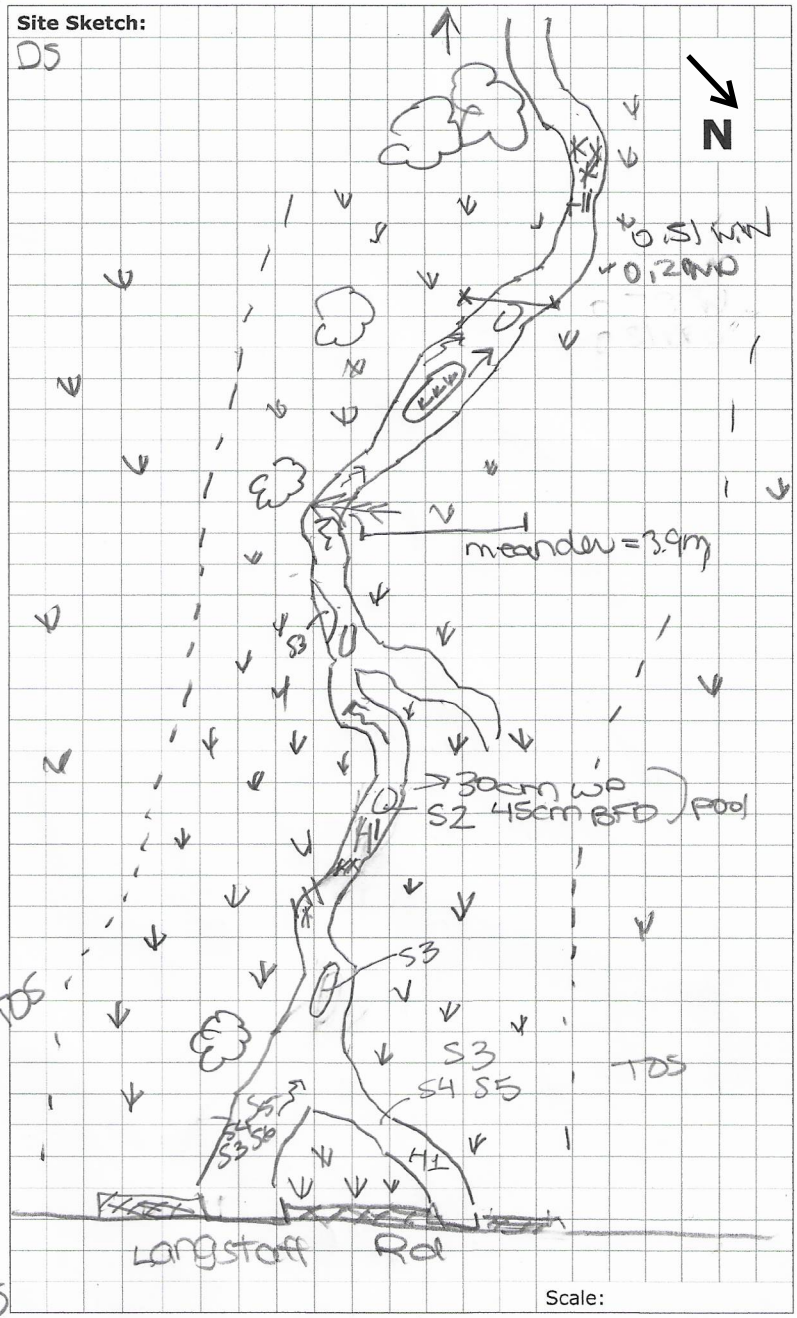
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Additional Notes: encroached
riffle length ~2m-5m

Completed by: MK/RL Checked by: R

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN 19072

Date:	July 10, 2019	**Stream/Reach:**	CR-1
Weather:	sunny 25°C	**Location:**	Langstaff Rd
Field Staff:	MK	**Watershed/Subwatershed:**	carp river TT16

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:

Scale:

Additional Notes:

Completed by: MK Checked by: RJ

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: PN 19072

Date:	July 10, 2019	**Stream/Reach:**	CR-1
Weather:	Sunny 28°C	**Location:**	Langstaff Rd
Field Staff:	MK	**Watershed/Subwatershed:**	Carp River Trib

Features

- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

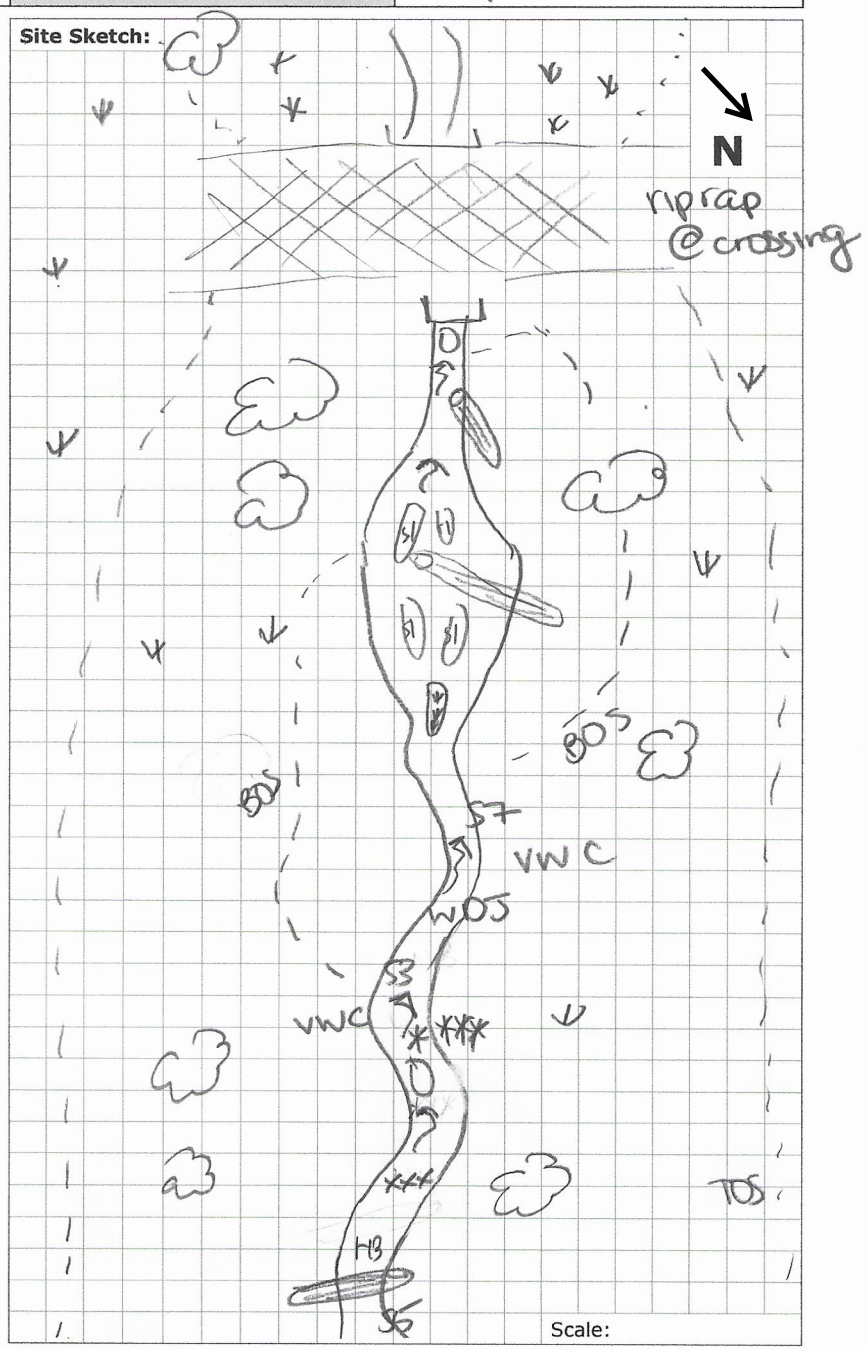
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Scale:

Additional Notes:

Completed by: MK Checked by: RL

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code: PN 19072

Date:	July 10, 2019	**Stream/Reach:**	CR-1
Weather:	sunny 25°C	**Location:**	Langstaff Rd
Field Staff:	MK	**Watershed/Subwatershed:**	Carp River (Trib)
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 1,3,7 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 7 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☑ Groundwater | Evidence: ironstaining

Riparian Vegetation

Dominant Type: (Table 6) 1,2,3,4
Species: _____

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths: ☐ 1-4 ☒ 4-10 ☐ > 10

Age Class (yrs): ☐ Immature (<5) ☒ Established (5-30) ☐ Mature (>30)

Encroachment: (Table 7) 2-4

Aquatic/Instream Vegetation

Type (Table8): ⁄ | **Coverage of Reach (%):** 0

Woody Debris: ☑ Present in Cutbank ☑ Present in Channel ☐ Not Present

Density of WD: ☒ Low ☒ Moderate ☐ High

WDJ/50m: 1

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 2 | **Sinuosity (Degree)** (Table 10): 2 | **Gradient** (Table 11): 2 | **Number of Channels** (Table 12): 1

Entrenchment (Table 13): 2 | **Type of Bank Failure** (Table 14): 2,6 | **Downs's Classification** (Table 15): M

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☒	☒	☒	☐	☐	☐
Pool Substrate	☒	☒	☐	☐	☐	☐	☐
Bank Material	☒	☒	☐	☐	☐	☐	☒

Bankfull Width (m) RU	~3.0	~3.0	~3.0	**Wetted Width (m)**	0.51	0.63	0.7
Bankfull Depth (m) RU	~0.4	~0.4	~0.4	**Wetted Depth (m)**	0.2	0.15	0.23

Riffle/Pool Spacing (m): 10m | **% Riffles:** 50 | **% Pools:** 50 | **Meander Amplitude:** 3.9

Pool Depth (m): WD 300cm BF 450cm | **Riffle Length (m):** 2-5m | **Undercuts (m):** 5cm

Velocity (m/s): ⁄ ⁄ ⁄ **Wiffle ball / ADV / Estimated**

Bank Angle
☒ 0 – 30
☒ 30 – 60
☒ 60 – 90
☐ Undercut

Bank Erosion
☐ < 5%
☒ 5 – 30%
☐ 30 – 60%
☐ 60 – 100%

Notes: minimal undercutting - multiple wdj - culverts connecting LB & RB TDS @ 2 sites

Comments: US portion - heavily encroached (low WDJ)
DS portion - more WDJ, minimally encroached

Completed by: MK/RJ Checked by: RJ

GEO | MORPHIX

Rapid Geomorphic Assessment **Project Code:** PN19072

Date:	July 10, 2019	**Stream/Reach:**	CR-1
Weather:	sunny 25°C	**Watershed/Subwatershed:**	Carp river trib
Field Staff:	MK	**Location:**	Langstaff Rd

Process	No.	Geomorphological Indicator: Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		/	1/7
	2	Coarse materials in riffles embedded		/	
	3	Siltation in pools		/	
	4	Medial bars		/	
	5	Accretion on point bars	/		
	6	Poor longitudinal sorting of bed materials		/	
	7	Deposition in the overbank zone		/	
		Sum of indices =	1	6	0.14
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	NA		1/10
	2	Exposed sanitary / storm sewer / pipeline / etc.	NA		
	3	Elevated storm sewer outfall(s)		/	
	4	Undermined gabion baskets / concrete aprons / etc.		/	
	5	Scour pools downstream of culverts / storm sewer outlets		/	
	6	Cut face on bar forms		/	
	7	Head cutting due to knickpoint migration		/	
	8	Terrace cut through older bar material		/	
	9	Suspended armour layer visible in bank		/	
	10	Channel worn into undisturbed overburden / bedrock	/		
		Sum of indices =	1	9	0.13
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	/		3/9
	2	Occurrence of large organic debris	/		
	3	Exposed tree roots	/		
	4	Basal scour on inside meander bends		/	
	5	Basal scour on both sides of channel through riffle		/	
	6	Outflanked gabion baskets / concrete walls / etc.		/	
	7	Length of basal scour >50% through subject reach		/	
	8	Exposed length of previously buried pipe / cable / etc.		/	
	9	Fracture lines along top of bank		/	
	10	Exposed building foundation	NA		
		Sum of indices =	3	6	0.33
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		/	1/7
	2	Single thread channel to multiple channel	/		
	3	Evolution of pool-riffle form to low bed relief form		/	
	4	Cut-off channel(s)		/	
	5	Formation of island(s)		/	
	6	Thalweg alignment out of phase with meander form		/	
	7	Bar forms poorly formed / reworked / removed		/	
		Sum of indices =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.19

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☑ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: MK Checked by: RJ

Rapid Stream Assessment Technique

Project Code: PN 19072

Date:	July 10, 2019	**Stream/Reach:**	CR-1
Weather:	sunny 25°C	**Location:**	Langstaff Rd
Field Staff:	MK	**Watershed/Subwatershed:**	Carp River trib

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☑ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☑ 6	☐ 7 ☐ 8

Date:	July 10 2019	Reach:	CR-1	Project Code:	PN 19072

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C N/A
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☒ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☒ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☐ 4 ☒ 5 5.5	☒ 6 ☐ 7

Total overall score (0–42) = 32.5	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: MK Checked by: RE

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: 19072a

Date:	May 19, 2020	**Stream/Reach:**	CR-1
Weather:	Sunny 23°C	**Location:**	147 Langstaff Drive
Field staff:	MM	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 1,5 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 8/4 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1,3
Species: _____

Coverage:
- ☐ None
- ☐ Fragmented
- ☑ Continuous

Channel widths
- ☐ 1-4
- ☑ 4-10
- ☐ > 10

Age Class (yrs):
- ☐ Immature (<5)
- ☑ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2-4

Aquatic/Instream Vegetation

Type (Table8): N/A | **Coverage of Reach (%):** 0

Woody Debris
- ☑ Present in Cutbank
- ☑ Present in Channel
- ☐ Not Present

Density of WD:
- ☑ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 2
Sinuosity (Degree) (Table 10): 2-3
Gradient (Table 11): 2
Number of Channels (Table 12): 1,2
Entrenchment (Table 13): 2
Type of Bank Failure (Table 14): 2,5
Downs's Classification (Table 15): M

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☐	☑	☑	☐	☐	☐
Pool Substrate	☑	☑	☐	☐	☐	☐	☐
Bank Material	☑	☑	☐	☐	☐	☐	☐

Bankfull Width (m)	2.5	1.6	2.7	**Wetted Width (m)**	1.3	0.5	0.7
Bankfull Depth (m)	0.45	0.35	0.40	**Wetted Depth (m)**	0.16	0.20	0.14

Riffle/Pool Spacing (m): 15 | **% Riffles:** 40 | **% Pools:** 40 | **Meander Amplitude:** 3-7

Pool Depth (m): 0.3-0.5 | **Riffle Length (m):** 2 | **Undercuts (m):** 0.2

Velocity (m/s): — | — | — **Wiffle ball / ADV / Estimated**

Bank Angle
- ☑ 0 – 30
- ☑ 30 – 60
- ☑ 60 – 90
- ☐ Undercut

Bank Erosion
- ☐ < 5%
- ☐ 5 – 30%
- ☑ 30 – 60%
- ☐ 60 – 100%

Comments: woody debris not a fluvial proc. headcutting through till
siltation observed throughout

Notes:
frequent VWC
In-line ponds

Completed by: MM | Checked by: SSO

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: 19072a

Date:	May 19, 2020	**Stream/Reach:**	CR-1
Weather:	Sunny, 23°C	**Location:**	147 Langstaff Drive
Field Staff:	MM	**Watershed/Subwatershed:**	Carp River

Process	Geomorphic Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		✓	2/7
	2	Coarse materials in riffles embedded		✓	
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone		✓	
		Sum of indices =	2	5	0.29
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		3/9
	2	Exposed sanitary / storm sewer / pipeline / etc.		✓	
	3	Elevated storm sewer outfall(s)		✓	
	4	Undermined gabion baskets / concrete aprons / etc.		✓	
	5	Scour pools downstream of culverts / storm sewer outlets	✓		
	6	Cut face on bar forms		✓	
	7	Head cutting due to knick point migration	✓		
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock	✓		
		Sum of indices =	3	6	0.33
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	2/9
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots	✓		
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		✓	
	7	Length of basal scour >50% through subject reach	✓		
	8	Exposed length of previously buried pipe / cable / etc.		✓	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation	N/A		
		Sum of indices =	2	7	0.22
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	1/7
	2	Single thread channel to multiple channel	✓		
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase with meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	1	6	0.14

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.24

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☑ 0.21 - 0.40	☐ 0.41

Completed by: MM Checked by: SSO

Rapid Stream Assessment Technique

Project Code: 19072a

Date:	May 19, 2020	**Stream/Reach:**	CR-1
Weather:	Sunny 23°C	**Location:**	147 Langstaff Drive
Field Staff:	MM	**Watershed/Subwatershed:**	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☑ 7 ☐ 8	☐ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☑ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Date:	May 19, 2020	Reach:	CR-1	Project Code:	19072a

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☑ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☑ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☑ 6 ☐ 7

Total overall score (0–42) = 29	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: MM Checked by: SSO

GEO MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: 19072

Date:	09-04-2019	**Stream/Reach:**	CR-2
Weather:	cloudy 20°C	**Location:**	3754 Carp Rd
Field Staff:	BM AS	**Watershed/Subwatershed:**	Carp River

Features
- Reach break
- Cross-section
- Flow direction
- Riffle
- Pool
- Medial bar
- Eroded bank
- Undercut bank
- Rip rap/stabilization/gabion
- Leaning tree
- Fence
- Culvert/outfall
- Swamp/wetland
- Grasses
- Tree
- Instream log/tree
- Woody debris
- Station location
- Vegetated island

Flow Type

H1	Standing water
H2	Scarcely perceptible flow
H3	Smooth surface flow
H4	Upwelling
H5	Rippled
H6	Unbroken standing wave
H7	Broken standing wave
H8	Chute
H9	Free fall

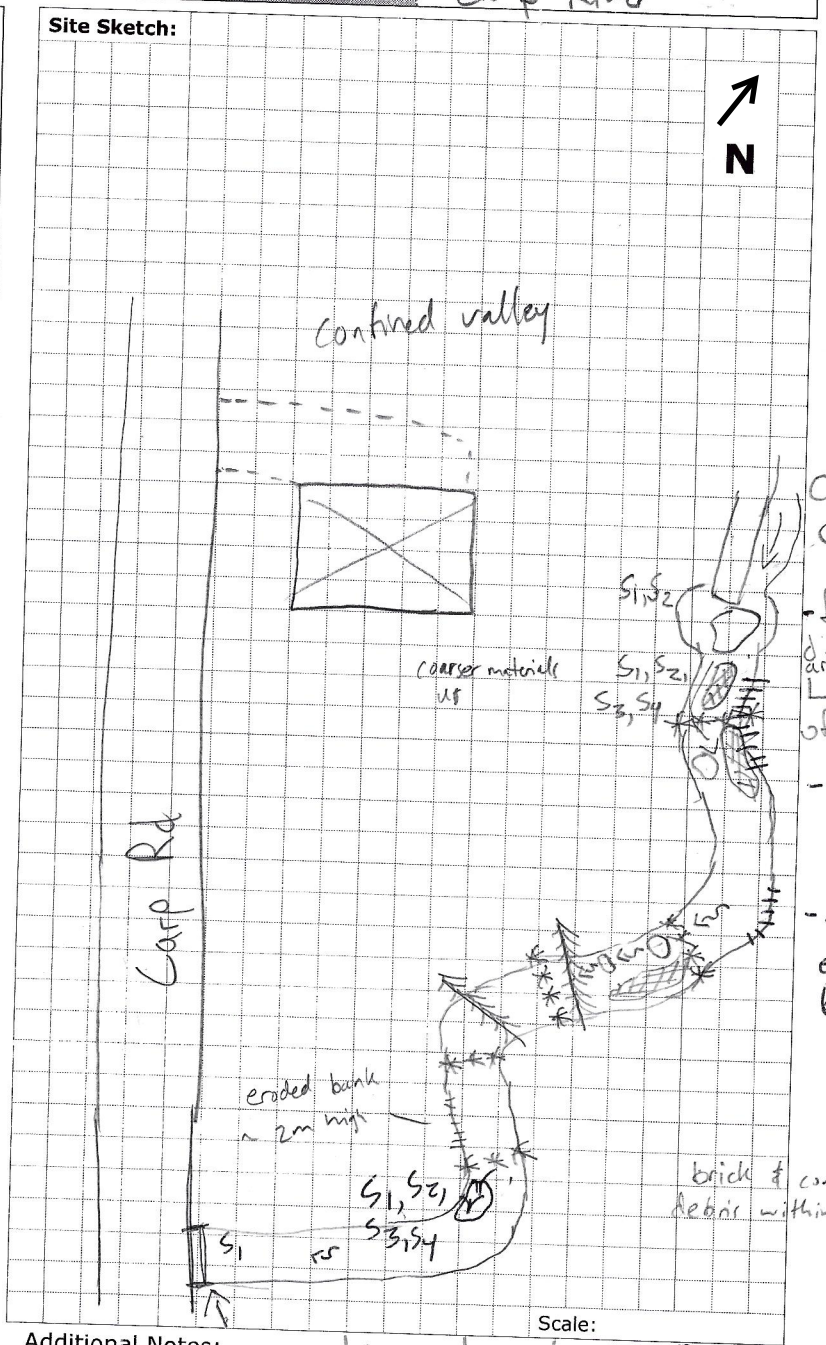
Substrate

S1	Silt	**S6**	Small boulder
S2	Sand	**S7**	Large boulder
S3	Gravel	**S8**	Bimodal
S4	Small cobble	**S9**	Bedrock/till
S5	Large cobble		

Other

BM	Benchmark	**EP**	Erosion pin
BS	Backsight	**RB**	Rebar
DS	Downstream	**US**	Upstream
WDJ	Woody debris jam	**TR**	Terrace
VWC	Valley wall contact	**FC**	Flood chute
BOS	Bottom of slope	**FP**	Flood plain
TOS	Top of slope	**KP**	Knick point

Site Sketch:



Additional Notes: concrete culvert ~0.80m
~0.90 m

→ only had access to ~ 50m of channel

Completed by: TR Checked by: _____

Reach Characteristics

GEO MORPHIX — Geomorphology Earth Science Observations

Project Code: 19072

Date:	2019-09-04	**Stream/Reach:**	CR-2
Weather:	Cloudy 20°C	**Location:**	3754 Carp Rd.
Field Staff:	TR BM2	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 1/7 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 12 | **Channel Zone** (Table 4): 2/3 | **Flow Type** (Table 5): 1/2 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1,4 | Species: _____

Coverage: ☐ None ☐ Fragmented ☒ Continuous

Channel widths ☐ 1-4 ☒ 4-10 ☐ > 10

Age Class (yrs): ☒ Immature (<5) ☒ Established (5-30) ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): N/A | Coverage of Reach (%): /

Woody Debris ☒ Present in Cutbank ☒ Present in Channel ☐ Not Present

Density of WD: ☒ Low ☐ Moderate ☐ High | WDJ/50m: 2

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 2

Sinuosity (Degree) (Table 10): 2

Gradient (Table 11): 2

Number of Channels (Table 12): 1

Entrenchment (Table 13): 1

Type of Bank Failure (Table 14): 1

Downs's Classification (Table 15): M

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☒	☒	☒	☒	☐	☐	☐
Pool Substrate	☒	☒	☐	☐	☐	☐	☐
Bank Material	☒	☒	☐	☐	☐	☐	☐

Bankfull Width (m)	2.1	2.2	2.7	**Wetted Width (m)**	0.92	1.1	0.77
Bankfull Depth (m)	0.20	0.25	0.30	**Wetted Depth (m)**	0.04	0.03	0.05

Riffle/Pool Spacing (m): ~6m | **% Riffles:** / | **% Pools:** / | **Meander Amplitude:** /

Pool Depth (m): 0.23 | **Riffle Length (m):** 1.6 | **Undercuts (m):** /

Velocity (m/s): _____ | **Wiffle ball / ADV / Estimated**

Bank Angle
☐ 0 – 30
☒ 30 – 60
☒ 60 – 90
☐ Undercut

Bank Erosion
☐ < 5%
☒ 5 – 30%
☐ 30 – 60%
☐ 60 – 100%

Comments: no true riffle pool sequences

Notes:
- some exposed tree roots
- more bank erosion at US extent but largest eroded bank at DS extent

Corridor → ~4 m from toe of slope to toe of slope

Completed by: TR | Checked by: _____

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: 19044

Date:	2019-09-04	**Stream/Reach:**	CR-2
Weather:	Cloudy 20°C	**Watershed/Subwatershed:**	Carp River
Field Staff:	TR BM2	**Location:**	3754 Carp Road

Process	No.	Geomorphological Indicator: Description	Present? Yes	Present? No	Factor Value
Evidence of Aggradation (AI)	1	Lobate bar		X	4/7
	2	Coarse materials in riffles embedded		X	
	3	Siltation in pools		X	
	4	Medial bars	X		
	5	Accretion on point bars	X		
	6	Poor longitudinal sorting of bed materials	X		
	7	Deposition in the overbank zone		X	
			X		
		Sum of indices =	4	3	0.57
Evidence of Degradation (DI)	1	Exposed bridge footing(s)		N/A	0/6
	2	Exposed sanitary / storm sewer / pipeline / etc.		N/A	
	3	Elevated storm sewer outfall(s)		N/A	
	4	Undermined gabion baskets / concrete aprons / etc.		N/A	
	5	Scour pools downstream of culverts / storm sewer outlets		X	
	6	Cut face on bar forms		X	
	7	Head cutting due to knickpoint migration		X	
	8	Terrace cut through older bar material		X	
	9	Suspended armour layer visible in bank		X	
	10	Channel worn into undisturbed overburden / bedrock		X	
		Sum of indices =	0	6	0
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.	X		3/8
	2	Occurrence of large organic debris	X		
	3	Exposed tree roots	X		
	4	Basal scour on inside meander bends		X	
	5	Basal scour on both sides of channel through riffle		X	
	6	Outflanked gabion baskets / concrete walls / etc.		N/A	
	7	Length of basal scour >50% through subject reach		X	
	8	Exposed length of previously buried pipe / cable / etc.		N/A	
	9	Fracture lines along top of bank		X	
	10	Exposed building foundation		X	
		Sum of indices =	3	8	0.38
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		X	0/6
	2	Single thread channel to multiple channel		X	
	3	Evolution of pool-riffle form to low bed relief form		X	
	4	Cut-off channel(s)		X	
	5	Formation of island(s)		X	
	6	Thalweg alignment out of phase with meander form		X	
	7	Bar forms poorly formed / reworked / removed		X	
		Sum of indices =	0	6	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.24

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☐ 0.00 - 0.20	☒ 0.21 - 0.40	☐ 0.41

Completed by: TR Checked by: _____

Rapid Stream Assessment Technique

Project Code: 19072

Date:	2019-09-04	**Stream/Reach:**	CR-2
Weather:	Cloudy 20°C	**Location:**	3754 Carp Road
Field Staff:	TR BM2	**Watershed/Subwatershed:**	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☒ 8	☐ 9 ☐ 10 ☐ 11

Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☒ 6	☐ 7 ☐ 8

Date:	2019-09-04	Reach:	CR-2	Project Code:	19072

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☒ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☒ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☐ 4 ☒ 5	☐ 6 ☐ 7

Total overall score (0–42) = 30	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: TR Checked by: _____

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: 19072a

Date:	May 19, 2020	**Stream/Reach:**	CR-2
Weather:	Sunny, 23°C	**Location:**	147 Langstaff Drive
Field staff:	MM	**Watershed/Subwatershed:**	Carp River.
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 1,4,5 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 7 | **Channel Zone** (Table 4): 2 | **Flow Type** (Table 5): 1 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1,4
Species: _____

Coverage:
- ☐ None
- ☐ Fragmented
- ☑ Continuous

Channel widths
- ☐ 1-4
- ☑ 4-10
- ☐ > 10

Age Class (yrs) :
- ☐ Immature (<5)
- ☑ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 2

Aquatic/Instream Vegetation

Type (Table8): N/A | **Coverage of Reach (%):** 0

Woody Debris
- ☐ Present in Cutbank
- ☑ Present in Channel
- ☐ Not Present

Density of WD:
- ☑ Low
- ☐ Moderate
- ☐ High

WDJ/50m: 2

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 1
Sinuosity (Degree) (Table 10): 2
Gradient (Table 11): 1
Number of Channels (Table 12): 1
Entrenchment (Table 13): 2
Type of Bank Failure (Table 14): 6
Downs's Classification (Table 15): D

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☑	☑	☑	☐	☐	☐	☐
Pool Substrate	☑	☑	☐	☐	☐	☐	☐
Bank Material	☑	☑	☐	☐	☐	☐	☐

Bankfull Width (m)	4	2.4		**Wetted Width (m)**	1.3	1.2	
Bankfull Depth (m)	0.6	0.45		**Wetted Depth (m)**	0.2	0.23	

Riffle/Pool Spacing (m): 5-20 | **% Riffles:** 20 | **% Pools:** 20 | **Meander Amplitude:** 5
Pool Depth (m): 0.4 | **Riffle Length (m):** 3 | **Undercuts (m):** N/A | **Comments:** _____
Velocity (m/s): / / / **Wiffle ball / ADV / Estimated** _____

Bank Angle
- ☑ 0 – 30
- ☐ 30 – 60
- ☐ 60 – 90
- ☐ Undercut

Bank Erosion
- ☐ < 5%
- ☑ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Notes: Major disturbances limit channel observations - few signs of active erosion

Completed by: MM Checked by: SSO

GEO | MORPHIX

Rapid Geomorphic Assessment

Project Code: 19072a

Date:	May 19, 2020	**Stream/Reach:**	CR-2
Weather:	Sunny 23°C	**Location:**	147 Langstaff Drive
Field Staff:	MM	**Watershed/Subwatershed:**	Carp River

Process	Geomorphic Indicator		Present?		Factor Value
	No.	Description	Yes	No	
Evidence of Aggradation (AI)	1	Lobate bar		✓	2/7
	2	Coarse materials in riffles embedded		✓	
	3	Siltation in pools	✓		
	4	Medial bars		✓	
	5	Accretion on point bars	✓		
	6	Poor longitudinal sorting of bed materials		✓	
	7	Deposition in the overbank zone		✓	
		Sum of indices =	2	5	0.29
Evidence of Degradation (DI)	1	Exposed bridge footing(s)	N/A		1/6
	2	Exposed sanitary / storm sewer / pipeline / etc.	N/A		
	3	Elevated storm sewer outfall(s)	N/A		
	4	Undermined gabion baskets / concrete aprons / etc.	N/A		
	5	Scour pools downstream of culverts / storm sewer outlets	✓		
	6	Cut face on bar forms		✓	
	7	Head cutting due to knick point migration		✓	
	8	Terrace cut through older bar material		✓	
	9	Suspended armour layer visible in bank		✓	
	10	Channel worn into undisturbed overburden / bedrock		✓	
		Sum of indices =	1	5	0.17
Evidence of Widening (WI)	1	Fallen / leaning trees / fence posts / etc.		✓	0/9
	2	Occurrence of large organic debris		✓	
	3	Exposed tree roots		✓	
	4	Basal scour on inside meander bends		✓	
	5	Basal scour on both sides of channel through riffle		✓	
	6	Outflanked gabion baskets / concrete walls / etc.		✓	
	7	Length of basal scour >50% through subject reach		✓	
	8	Exposed length of previously buried pipe / cable / etc.		✓	
	9	Fracture lines along top of bank		✓	
	10	Exposed building foundation		✓	
		Sum of indices =	0	9	0
Evidence of Planimetric Form Adjustment (PI)	1	Formation of chute(s)		✓	0/7
	2	Single thread channel to multiple channel		✓	
	3	Evolution of pool-riffle form to low bed relief form		✓	
	4	Cut-off channel(s)		✓	
	5	Formation of island(s)		✓	
	6	Thalweg alignment out of phase with meander form		✓	
	7	Bar forms poorly formed / reworked / removed		✓	
		Sum of indices =	0	7	0

Additional notes:

Stability Index (SI) = (AI+DI+WI+PI)/4 = 0.12

Condition	In Regime	In Transition/Stress	In Adjustment
SI score =	☑ 0.00 - 0.20	☐ 0.21 - 0.40	☐ 0.41

Completed by: MM Checked by: SSO

Rapid Stream Assessment Technique

Project Code: 19072a

Date:	May 19, 2020	**Stream/Reach:**	CR-2
Weather:	Sunny, 23°C	**Location:**	147 Langstaff Drive
Field Staff:	MM	**Watershed/Subwatershed:**	Carp River

Evaluation Category	Poor	Fair	Good	Excellent
Channel Stability	• < 50% of bank network stable • Recent bank sloughing, slumping or failure frequently observed	• 50-70% of bank network stable • Recent signs of bank sloughing, slumping or failure fairly common	• 71-80% of bank network stable • Infrequent signs of bank sloughing, slumping or failure	• > 80% of bank network stable • No evidence of bank sloughing, slumping or failure
	• Stream bend areas highly unstable • Outer bank height 1.2 m above stream bank (2.1 m above stream bank for large mainstem areas) • Bank overhang > 0.8-1.0 m	• Stream bend areas unstable • Outer bank height 0.9-1.2 m above stream bank (1.5-2.1 m above stream bank for large mainstem areas) • Bank overhang 0.8-0.9m	• Stream bend areas stable • Outer bank height 0.6-0.9 m above stream bank (1.2-1.5 m above stream bank for large mainstem areas) • Bank overhang 0.6-0.8 m	• Stream bend areas very stable • Height < 0.6 m above stream (< 1.2 m above stream bank for large mainstem areas) • Bank overhang < 0.6 m
	• Young exposed tree roots abundant • > 6 recent large tree falls per stream mile	• Young exposed tree roots common • 4-5 recent large tree falls per stream mile	• Exposed tree roots predominantly old and large, smaller young roots scarce • 2-3 recent large tree falls per stream mile	• Exposed tree roots old, large and woody • Generally 0-1 recent large tree falls per stream mile
	• Bottom 1/3 of bank is highly erodible material • Plant/soil matrix severely compromised	• Bottom 1/3 of bank is generally highly erodible material • Plant/soil matrix compromised	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material	• Bottom 1/3 of bank is generally highly resistant plant/soil matrix or material
	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally trapezoidally-shaped	• Channel cross-section is generally V- or U-shaped	• Channel cross-section is generally V- or U-shaped
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4 ☐ 5	☐ 6 ☐ 7 ☐ 8	☑ 9 ☐ 10 ☐ 11
Channel Scouring/ Sediment Deposition	• > 75% embedded (> 85% embedded for large mainstem areas)	• 50-75% embedded (60-85% embedded for large mainstem areas)	• 25-49% embedded (35-59% embedded for large mainstem areas)	• Riffle embeddedness < 25% sand-silt (< 35% embedded for large mainstem areas)
	• Few, if any, deep pools • Pool substrate composition >81% sand-silt	• Low to moderate number of deep pools • Pool substrate composition 60-80% sand-silt	• Moderate number of deep pools • Pool substrate composition 30-59% sand-silt	• High number of deep pools (> 61 cm deep) (> 122 cm deep for large mainstem areas) • Pool substrate composition <30% sand-silt
	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits common	• Streambed streak marks and/or "banana"-shaped sediment deposits uncommon	• Streambed streak marks and/or "banana"-shaped sediment deposits absent
	• Fresh, large sand deposits very common in channel • Moderate to heavy sand deposition along major portion of overbank area	• Fresh, large sand deposits common in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits uncommon in channel • Small localized areas of fresh sand deposits along top of low banks	• Fresh, large sand deposits rare or absent from channel • No evidence of fresh sediment deposition on overbank
	• Point bars present at most stream bends, moderate to large and unstable with high amount of fresh sand	• Point bars common, moderate to large and unstable with high amount of fresh sand	• Point bars small and stable, well-vegetated and/or armoured with little or no fresh sand	• Point bars few, small and stable, well-vegetated and/or armoured with little or no fresh sand
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☑ 4	☐ 5 ☐ 6	☐ 7 ☐ 8

Date:	May 19, 2020	Reach:	CR-2	Project Code:	19072a

Evaluation Category	Poor	Fair	Good	Excellent
Physical Instream Habitat	• Wetted perimeter < 40% of bottom channel width (< 45% for large mainstem areas)	• Wetted perimeter 40-60% of bottom channel width (45-65% for large mainstem areas)	• Wetted perimeter 61-85% of bottom channel width (66-90% for large mainstem areas)	• Wetted perimeter > 85% of bottom channel width (> 90% for large mainstem areas)
	• Dominated by one habitat type (usually runs) and by one velocity and depth condition (slow and shallow) (for large mainstem areas, few riffles present, runs and pools dominant, velocity and depth diversity low)	• Few pools present, riffles and runs dominant. • Velocity and depth generally slow and shallow (for large mainstem areas, runs and pools dominant, velocity and depth diversity intermediate)	• Good mix between riffles, runs and pools • Relatively diverse velocity and depth of flow	• Riffles, runs and pool habitat present • Diverse velocity and depth of flow present (i.e., slow, fast, shallow and deep water)
	• Riffle substrate composition: predominantly gravel with high amount of sand • < 5% cobble	• Riffle substrate composition: predominantly small cobble, gravel and sand • 5-24% cobble	• Riffle substrate composition: good mix of gravel, cobble, and rubble material • 25-49% cobble	• Riffle substrate composition: cobble, gravel, rubble, boulder mix with little sand • > 50% cobble
	• Riffle depth < 10 cm for large mainstem areas	• Riffle depth 10-15 cm for large mainstem areas	• Riffle depth 15-20 cm for large mainstem areas	• Riffle depth > 20 cm for large mainstem areas
	• Large pools generally < 30 cm deep (< 61 cm for large mainstem areas) and devoid of overhead cover/structure	• Large pools generally 30-46 cm deep (61-91 cm for large mainstem areas) with little or no overhead cover/structure	• Large pools generally 46-61 cm deep (91-122 cm for large mainstem areas) with some overhead cover/structure	• Large pools generally > 61 cm deep (> 122 cm for large mainstem areas) with good overhead cover/structure
	• Extensive channel alteration and/or point bar formation/enlargement	• Moderate amount of channel alteration and/or moderate increase in point bar formation/enlargement	• Slight amount of channel alteration and/or slight increase in point bar formation/enlargement	• No channel alteration or significant point bar formation/enlargement
	• Riffle/Pool ratio 0.49:1 ; ≥1.51:1	• Riffle/Pool ratio 0.5-0.69:1 ; 1.31-1.5:1	• Riffle/Pool ratio 0.7-0.89:1 ; 1.11-1.3:1	• Riffle/Pool ratio 0.9-1.1:1
	• Summer afternoon water temperature > 27°C	• Summer afternoon water temperature 24-27°C	• Summer afternoon water temperature 20-24°C	• Summer afternoon water temperature < 20°C
Point range	☐ 0 ☐ 1 ☐ 2	☑ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Water Quality	• Substrate fouling level: High (> 50%)	• Substrate fouling level: Moderate (21-50%)	• Substrate fouling level: Very light (11-20%)	• Substrate fouling level: Rock underside (0-10%)
	• Brown colour • TDS: > 150 mg/L	• Grey colour • TDS: 101-150 mg/L	• Slightly grey colour • TDS: 50-100 mg/L	• Clear flow • TDS: < 50 mg/L
	• Objects visible to depth < 0.15m below surface	• Objects visible to depth 0.15-0.5m below surface	• Objects visible to depth 0.5-1.0m below surface	• Objects visible to depth > 1.0m below surface
	• Moderate to strong organic odour	• Slight to moderate organic odour	• Slight organic odour	• No odour
Point range	☐ 0 ☐ 1 ☐ 2	☐ 3 ☐ 4	☐ 5 ☐ 6	☐ 7 ☐ 8
Riparian Habitat Conditions	• Narrow riparian area of mostly non-woody vegetation	• Riparian area predominantly wooded but with major localized gaps	• Forested buffer generally > 31 m wide along major portion of both banks	• Wide (> 60 m) mature forested buffer along both banks
	• Canopy coverage: <50% shading (30% for large mainstem areas)	• Canopy coverage: 50-60% shading (30-44% for large mainstem areas)	• Canopy coverage: 60-79% shading (45-59% for large mainstem areas)	• Canopy coverage: >80% shading (> 60% for large mainstem areas)
Point range	☐ 0 ☐ 1	☐ 2 ☐ 3	☐ 4 ☐ 5	☑ 6 ☐ 7

Total overall score (0–42) = 29	Poor (<13)	Fair (13-24)	Good (25-34)	Excellent (>35)

Completed by: MM Checked by: SSO

GEO MORPHIX
Geomorphology Earth Science Observations

Reach Characteristics

Project Code/Phase: 19672a

Date:	May 19, 2020	**Stream/Reach:**	CR-2a
Weather:	Sunny, 23°C	**Location:**	147 Langstaff
Field staff:	MM	**Watershed/Subwatershed:**	Carp River
UTM (Upstream)		**UTM (Downstream)**	

Land Use (Table 1): 1,4,5 | **Valley Type** (Table 2): 2 | **Channel Type** (Table 3): 11 | **Channel Zone** (Table 4): 1 | **Flow Type** (Table 5): 2,3 | ☐ Groundwater | Evidence: _____

Riparian Vegetation

Dominant Type: (Table 6): 1,4
Species: _____

Coverage:
- ☐ None
- ☐ Fragmented
- ☑ Continuous

Channel widths:
- ☑ 1-4
- ☐ 4-10
- ☐ > 10

Age Class (yrs):
- ☐ Immature (<5)
- ☑ Established (5-30)
- ☐ Mature (>30)

Encroachment: (Table 7): 4

Aquatic/Instream Vegetation

Type (Table8): N/A | Coverage of Reach (%): N/A

Woody Debris
- ☑ Present in Cutbank
- ☑ Present in Channel
- ☐ Not Present

Density of WD:
- ☐ Low
- ☑ Moderate
- ☐ High

WDJ/50m: 5

Water Quality

Odour (Table 16): 1

Turbidity (Table 17): 1

Channel Characteristics

Sinuosity (Type) (Table 9): 5
Sinuosity (Degree) (Table 10): 1
Gradient (Table 11): 2-3
Number of Channels (Table 12): 1
Entrenchment (Table 13): 3
Type of Bank Failure (Table 14): 4
Downs's Classification (Table 15): 5

	Clay/Silt	Sand	Gravel	Cobble	Boulder	Parent	Rootlets
Riffle Substrate	☐	☑	☐	☐	☐	☐	☐
Pool Substrate	☑	☑	☐	☐	☐	☐	☐
Bank Material	☑	☑	☐	☐	☐	☐	☐

Bankfull Width (m)	1	0.7		**Wetted Width (m)**	0.1	0	
Bankfull Depth (m)	0.3	0.2		**Wetted Depth (m)**	0.03	0	

Riffle/Pool Spacing (m): N/A | **% Riffles:** N/A | **% Pools:** N/A | **Meander Amplitude:** N/A

Pool Depth (m): N/A | **Riffle Length (m):** N/A | **Undercuts (m):** 0.1 | **Comments:** _____

Velocity (m/s): / | / | / | **Wiffle ball / ADV / Estimated**

Bank Angle
- ☑ 0 – 30
- ☐ 30 – 60
- ☐ 60 – 90
- ☐ Undercut

Bank Erosion
- ☑ < 5%
- ☐ 5 – 30%
- ☐ 30 – 60%
- ☐ 60 – 100%

Notes:

Completed by: MM Checked by: SSO

Appendix E
Areas of Channel Adjustment

Legend

- Reach Break and ID (CR-1)
- Contours (1 m)
- Watercourse
- Culverts
- Extent Assessed
- Channel Adjustment
- Subject Lands

Inverness Homes

147 Langstaff Drive

Areas of Channel Adjustment - Reach CR1

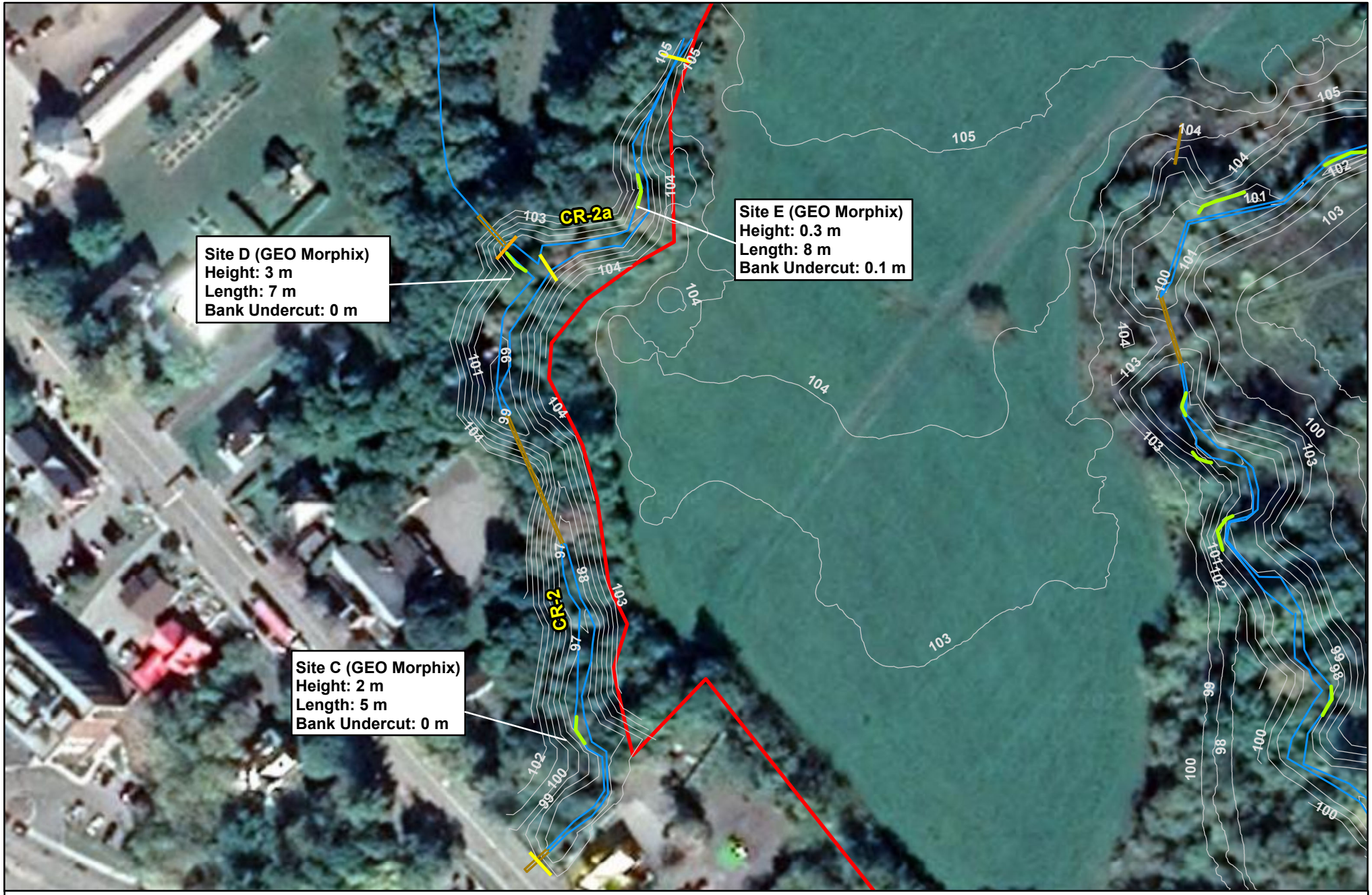
GEO MORPHIX™

N

0 25 50

Metres

Imagery: December, 2016.
Watercourse: City of Ottawa, 2019. Subject Lands: Inverness Homes, 2021.
Reach Break, Extent Assessed, Channel Adjustment : GEO Morphix Ltd., 2019.
Contours, Surveyed Channel and Culverts: Robinson, Land Development: 2020.
Print Date: January 2022. PN19072. Drawn By: W.B., M.O., S.S.



Legend

- Reach Break and ID (CR-1)
- Contours (1 m)
- Watercourse
- Culverts
- Extent Assessed
- Channel Adjustment
- Subject Lands

Inverness Homes

147 Langstaff Drive

Areas of Channel Adjustment - Reach CR2 and CR2a

GEO MORPHIX™

N

0 20 40

Metres

Imagery: December, 2016.
Watercourse: City of Ottawa, 2019. Subject Lands: Inverness Homes, 2021.
Reach Break, Extent Assessed, Channel Adjustment: GEO Morphix Ltd., 2019.
Contours, Surveyed Channel and Culverts: Robinson, Land Development: 2020.
Print Date: January 2022. PN19072. Drawn By: W.B., M.O., S.S.

Attachment 3
GEO Morphix Report: Technical Design Brief: Tributary of Carp River Remediation Plan (Reach CR-1); 147 Langstaff Road, Carp, Ontario

Technical Design Brief: Tributary of Carp River Remediation Plan (Reach CR-1)

147 Langstaff Road
Carp, Ontario

Prepared for:

Inverness Homes
69 Moore Street
Richmond ON, K0A 2Z0

November 28, 2023 (Revised February 9, 2024, July 19, 2024, September 18, 2024)
PN23100a

GEO MORPHIX
Geomorphology
Earth Science
Observations

Report Prepared by:	GEO Morphix Ltd. 36 Main Street North, PO Box 205 Campbellville, Ontario L0P 1B0
Report Title:	Technical Design Brief, Tributary of Carp River Remediation Plan (Reach CR-1) 147 Langstaff Road Carp, Ontario
Project Number:	PN23100a
Status:	Final
Version:	1.1
Prepared by:	Ben Miller, B.Sc., CAN-CISEC and Suzanne St. Onge, M.Sc.
Approved by:	Paul Villard, Ph.D., P.Geo., CAN-CISEC, EP, CERP
Approval Date:	November 28, 2023 (Revised February 9, 2024, July 19, 2024, September 18, 2024)

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1 Introduction

This technical design brief provides recommendations for bank treatments and sediment removal along a portion of a tributary of Carp River, **Reach CR-1**, located at 147 Langstaff Road in Carp, Ontario. A site map is provided in **Appendix A**, for reference. **Reach CR-1** contains two (2) online stormwater management facilities (SWMFs). It is understood that the City of Ottawa requires a remediation plan to address sediment accumulation and erosion as part of future development. This brief provides design details to address specific areas of erosion, which were identified by the City of Ottawa and subsequently investigated by GEO Morphix through field work completed in 2022 and 2023.

In developing the remediation design, the following activities were completed:

- Conducted rapid field reconnaissance along **Reach CR-1** to confirm that existing conditions and areas of erosion/aggradation had not substantially changed since 2022
- Prepared detailed design drawings that identify the extent and configuration of proposed bank treatments and sediment removals/channel sculpting
- Completed hydraulic stone sizing based on modelling to ensure any proposed treatments remain stable over the long term
- Developed recommendations for design implementation including construction timing and best management practices
- Prepared a post-construction monitoring plan

This design brief outlines the current geomorphological condition of **Reach CR-1**, design considerations, and technical details associated with the proposed bank treatments. It also provides recommendations for implementation and monitoring of the proposed works.

2 Existing Conditions

Reach CR-1 extends from the northeastern property boundary, passing under Langstaff Drive and flowing in a generally north to south orientation through the central portion of the subject lands. Existing land use consists of vacant greenfield and natural areas associated with the Carp River tributary. A summary of existing conditions documented along **Reach CR-1** is provided below based on field work completed between 2019 and 2023. A reach map showing the extent of **Reach CR-1** is provided in **Appendix A**.

2.1 Field Observations – 2019 and 2020

Field investigations were initially completed on July 10 and September 4, 2019 to characterize existing conditions and inform the previously completed erosion hazard assessment. The 2019 assessment included the following observations:

- Completion of reach-scale habitat sketch maps based on Newson and Newson (2000)
- outlining channel substrate, flow patterns, geomorphological units (e.g., riffle, run, pool),
- and riparian vegetation
- Descriptions of riparian conditions
- Estimates of bankfull channel dimensions
- Determination of bed and bank material composition and structure
- Observations of erosion, scour, or deposition
- Collection of photographs to document the watercourses, riparian areas and/or valley,

- surrounding land use, and channel disturbances such as crossing structures

These observations and measurements are summarized below and include minor updates based on supplemental field visits completed on May 19th, 2020 to address Mississippi Valley Conservation Authority comments (MVCA).

Reach CR-1 was predominantly a single thread, irregularly meandering channel within a transfer zone. The riparian zone was continuous and consisted of established trees, shrubs, grasses and herbaceous species, and was approximately 4-10 channel widths. Although the reach was assessed as having a perennial flow regime during our visit in July 2019, areas of standing water were observed between the two concrete culverts associated with the online stormwater management facilities. This suggests that the flow regime may be intermittent when seasonally dry conditions occur. Evidence of groundwater inputs (i.e., iron staining) was observed within the reach. Riffle-pool spacing was approximately 10 m, with riffle lengths ranging between 2 and 5 m. Riffle substrates consisted of sand, gravel and cobble and pool substrates consisted of clay/silt and sand. Bank materials consisted of clay, silt, sand and rootlets.

During the July 2019 assessment, minimal undercutting was observed, with the highest measured undercut being 0.05 m. Undercuts up to 0.2 m were measured along the reach during the second assessment completed May 19, 2020. These undercuts were not repeated measurements at the same location and are therefore not representative of channel erosion at a specific location during the period between field visits. Average bankfull channel width and depth were approximately 2.5 m and 0.4 m, respectively, based on measurements collected in July 2019 and May 2020. At the time of the assessment in July 2019, average wetted width and depth were 0.61 m and 0.19 m, respectively. At the time of the assessment in May 2020, average wetted width and depth were 0.83 and 0.17 m, respectively. Channel bank angles ranged from 0-90°. Channel bank angle observations are limited to instream conditions and refer to the angle of the low flow channel bank rather than the overall valley form.

The upstream portion of **Reach CR-1** was extensively encroached with vegetation and was situated within a partially confined valley with minimal woody debris. Meander amplitudes measured in the field ranged from 3-7 m. The downstream portion of the reach flowed through a forest within a confined valley and contained minimal vegetation encroachment. The channel became less defined and had multiple valley wall contacts and a few slumps. There was more woody debris present in the downstream portion of the reach relative to the upstream portion; however, woody debris present in the corridor did not appear to be a result of channel erosion or migration. Areas of channel adjustment were observed but overall, the reach was assessed to be relatively stable.

2.2 Field Observations – 2022 and 2023

A targeted field investigation was conducted on January 13, 2022 to review areas of erosion concern documented by the City of Ottawa in the central ravine and identify any additional areas of channel adjustment while onsite. Areas of channel adjustment were subsequently mapped and included in Appendix E of our Erosion Hazard Assessment Report (dated July 19, 2023). City of Ottawa site identifiers were carried forward to GEO Morphix mapping where the locations were generally consistent (i.e., Sites 1 to 9). GEO Morphix also identified two areas of minor channel adjustment in the downstream and upstream extents of the central ravine (Sites A and B). Channel adjustment at Sites 4, 5 and 8 is interpreted to be largely due to the valley form rather than channel migration, as the ravine was relatively narrow at these locations. In addition, woody debris was directing flows towards the valley

wall at Site 5 and observed channel adjustments were therefore not considered a result of erosion due to channel migration.

An additional field visit on October 20th, 2023 was completed in support of the remediation plan to provide an update to existing conditions. To provide context a photographic record of the most recent site visit can be found in **Appendix B**. Field observations collected in October 2023 are generally consistent with conditions documented by the City of Ottawa and during our January 2022 field visit. Minor updates were made to the extents of channel adjustment documented previously with revised mapping contained in **Appendix C**. For clarity, **Table 1** summarizes updates to our channel adjustment mapping based on our most recent field visit. For locations not included in the table, no differences in field conditions were observed. These updates are not interpreted as additional erosion, but rather are a result of our October field work being conducted in the absence of snow and frozen conditions. No new areas of erosion were observed. In addition, three (3) areas of deposition observed in the field have been added to the mapping, which ranged in depth from approximately 0.3 m to 0.4 m.

Table 1: Updates to channel adjustment mapping based on October 2023 field visit

Site Identifier	2022 Observations	2023 Observations
A	Height: up to 0.6 m Length: 4 m Bank Undercut: 0.1 to 0.35 m	Height: 0.6 to 1 m Length: 6 m Bank Undercut: 0.1 to 0.35 m
2 and 3	Height: 1 m Length: 8 m Bank Undercut: 0.05 to 0.2 m	Height: 0.3 to 1 m Length: 8 m Bank Undercut: No observed undercut
4	Height: up to 2.5 m Length: 11 m Bank Undercut: 0.1 to 0.2 m	Height: up to 2.5 m Length: 6 to 11 m Bank Undercut: 0.1 to 0.2 m
5	Height: up to 2.5 m Length: 6 m Bank Undercut: 0.05 to 0.1 m	Height: up to 2.5 m Length: 7 to 10 m Bank Undercut: Up to 0.3 m
8	Height: up to 0.8 m Length: 12 m Bank Undercut: 0.05 to 0.15 m	Height: 1 m Length: 12 m Bank Undercut: 0.05 to 0.15 m
9a	Height: Up to 0.4 m Length: 13 m Bank Undercut: 0.1 to 0.2 m	Height: Up to 0.4 m Length: 13 m Bank Undercut: 0.25 to 0.4 m

3 Channel Remediation Design

Based on the geomorphological assessment and observations of the erosion sites, it is recommended that bioengineering (i.e., brush mattress and vegetated rip rap) and shade-tolerant restorative plantings be implemented to increase the banks resistance to erosive forces and overall stability. Various opportunities and constraints were considered in the development of the proposed restoration design to support the stabilization of the identified banks.

The primary objectives of the design are to:

- Mitigate potential hazards to the development as well as lands surrounding the development
- Maintain the existing channel footprint and capacity for operation of stormwater management infrastructure and flow conveyance

- Avoid disturbance to existing vegetation to the extent feasible
- Enhance existing riparian habitat through the provision of live plantings and overhanging vegetation

The accompanying drawings in **Appendix D** provide design details and direction for implementation and should be reviewed in conjunction with this technical design brief.

3.1 Proposed Bank Treatments

With consideration to the above-noted design opportunities, constraints, and existing channel conditions, bioengineering bank treatments are proposed along the sections of channel bank marked for restoration. **Table 2** provides a breakdown of the approximate treatment length and height (m) at each site identified for restoration.

Table 2: Approximate restoration treatment dimensions

Erosion Site	Length (m)	Bank Height (m)
A	14	0.6 - 1
B	5	0.3
1	7	1
2 and 3	8	0.3 - 1
4	11	2.5
5	10	2.5
6 and 7	6	1.2
8	12	1
9a	13	0.4
9b	6	0.4

The proposed restoration design focuses primarily on installing bioengineered treatments along sections of the channel bank to stabilize and enhance the ravine over the long-term. The outside bank of meander bends experiences relatively higher erosive flows, which under natural conditions leads to meander bend migration. As such, the channel banks identified as being a priority erosion concern are proposed to be bioengineered with either a brush mattress bank treatment with toe stone protection or a vegetated riprap treatment. These proposed treatments both help to protect against future erosion within the ravine by using a mixture of hard stone and vegetation. The noted restoration treatment dimensions are approximate, and a level of field fit is expected during construction to ensure the treatments tie into the appropriate location to limit future erosion.

Drawing **GEO-2** shows the location of the Huntley Medical-Dental Centre 375 mm diameter storm sewer outlet downstream of the downstream stormwater management control structure in the ravine. The bank restoration treatments in the vicinity of this infrastructure have been expanded to protect the outlet and should also be field-fit / blended to allow for an appropriate transition between existing infrastructure and installed bioengineered bank treatments. The final treatment extents are to be determined during construction by the Contract Administrator.

The brush mattress bank treatment consists of lower lifts of large subrounded stone, 400-500 mm in diameter, with live brush cuttings above which are layered, compressed, and installed parallel to the channel bank using stakes. The live brush cuttings will provide immediate erosion protection, while adding long-term stability through root generation. This bioengineering treatment will also aid in

enhancing aquatic habitat and providing shade and foraging opportunities through overhanging vegetation.

Vegetated riprap is also proposed as a treatment to reduce erosion along the channel banks and consists of a combination of stones and woody vegetation. The treatment will consist of 100 - 150 mm riprap with container grown plants staggered between the stones, spaced horizontally 1 m apart. The strength of the proposed treatment will be augmented through vegetation establishment, and it will reduce the potential for erosion. Additionally, the plantings will provide additional thermal mitigation though shade, but will also provide a source of organic matter.

Ideally, the bottom lift of stones for the toe protection should be embedded to account for potential scour. In this case, embedment of a minimum of 200 mm is likely appropriate as the observed channel bed was competent material with limited accumulated sediment.

For immediate erosion protection, mechanical stabilization in the form of biodegradable erosion control blankets (i.e., coir cloth, jute mat, etc.) is proposed. As the blankets will biodegrade over time, this serves as a short-term stabilization measure.

Live stakes are proposed along the overbank of the proposed bioengineering treatments to provide long-term soil stability through root generation. Live stakes consist of native flood-tolerant species and are planted at a density of 3 per square metre. Live stakes should be harvested and planted during the dormant period, between late fall and early spring, prior to bud-out. Live staking will also provide thermal mitigation through shading, foraging opportunities, and will provide a source of coarse organic matter to the system.

The opposite channel bank to the identified restoration zones may need to be modified to ensure the same channel cross sectional area is maintained between pre- and post-construction conditions. In instances where this is required, the channel bank will be graded and stabilized with biodegradable erosion control blanket, seed, and live stakes.

3.1.1 Hydraulic Stone Sizing

The stone for the proposed bioengineering treatments was hydraulically sized to withstand the anticipated peak velocities at the proposed restoration locations. All hydraulic sizing has been completed using the modelled and calculated flow conditions provided by Robinson Land Development.

The toe stones for the brush mattress bank treatment are proposed to be 400 – 500 mm subrounded boulders. The rip rap for the proposed bank treatment is to consist of 100 - 150 mm diameter stone. Where required, undercuts and areas requiring backfill will be filled with a mix of 50% 100 - 150 mm rip rap, 25% granular 'B' material, and 25% 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 proposed stone listed above was hydraulically sized to limit entrainment. A range of techniques were utilized to determine the appropriate stone size, as summarized in the National Engineering Handbook (NRCS, 2007). These techniques are provided in **Table 3**. The maximum velocity of 0.86 m/s, provided by Robinson Land Development and corresponding to the Regional event, was used to determine the appropriate stone size. The proposed stone includes a factor of safety to provide increased stability at the maximum velocity. The proposed stone sizing is quite conservative in nature, as we recognize that ponding will occur within the ravine during higher flow events, but we have hydraulically sized the materials to ensure stability over a range of potential conditions.

Table 3: Substrate sizes for the bank treatments based on a range of techniques

Model	Formula	Velocity (m/s)	Stone Size* (mm)
Stone Core Pool and Riffle			
Isbash Method (Isbash, 1936)	$D_{50} = \left(\frac{V_c}{C * \left(2 * g * \frac{\gamma_S - \gamma_w}{\gamma_w}\right)^{0.5}}\right)^2$	0.86	37
USBR Method (Peterka, 1958)	$D_{50} = 0.0122 * V^{2.06}$	0.86	38
Maynord's Method (Maynord, 1988)	$D_{100} = C_s * C_v * C_T * d * \left[\left(\frac{\gamma_W}{\gamma_S - \gamma_w}\right)^{0.5} * \frac{V}{\sqrt{K_1 * g * d}}\right]^{2.5}$	0.86	24

*Includes 20% factor of safety

The Isbash method (Isbash, 1936) was developed for the construction of dams by placing rock into moving water. This model predicts the median stone size (D_{50}; ft) under the given flow conditions, given by:

$$D_{50} = \left(\frac{V_c}{C*(2*g*\frac{\gamma_S-\gamma_w}{\gamma_w})^{0.5}}\right)^2 \quad \text{[Eq.1]}$$

Where:

V_c = critical velocity (ft/s)

C = Isbash constant (dimensionless)

g = gravity (ft/s)

γ_s = stone density (lb/ft^3)

γ_w = water density (lb/ft^3)

The USBR Method (Peterka, 1958) was developed for sizing riprap below a stilling basin. This model predicts the median stone size (D_{50}; ft) under the given flow conditions, given by:

$$D_{50} = 0.0122 * V^{2.06} \quad \text{[Eq.2]}$$

Where:

V = average channel velocity (ft/s)

Maynord's Method (Maynord, 1988) was developed for sizing riprap in open channel flows. This model predicts the largest stone size (D_{100}; ft) under the given flow conditions, given by:

$$D_{100} = C_s * C_v * C_T * d * \left[\left(\frac{\gamma_W}{\gamma_S-\gamma_w}\right)^{0.5} * \frac{V}{\sqrt{K_1*g*d}}\right]^{2.5} \quad \text{[Eq.3]}$$

Where:

d = water depth (ft)

C_s = stability coefficient

C_v = velocity distribution coefficient

C_T = thickness coefficient

γ_s = stone density (lb/ft^3)

γ_w = water density (lb/ft^3)

V = velocity (ft/s)

g = gravity (ft/s)

K_1 = side slope correction, calculated by:

$$K_1 = \sqrt{1 - \frac{sin^2\theta}{sin^2\emptyset}} \quad \text{[Eq.4]}$$

Where:

θ= angle of rock from the horizontal

∅ = angle of repose (typically 40°)

The values used for each variable in the Isbash method, USBR method, and Maynord's method are provided in **Table 4.**

Table 4: Variables and values associated with sizing stone for bank treatments

Variable	Value*
Critical velocity (V_c) (ft/s)	2.82
Isbash constant (C) (unitless)	0.86
Gravity (g) (ft/s^2)	32.2
Stone density (γ_s) (lb/ft^3)	165.43
Water density (γ_w) (lb/ft^3)	62.43
USBR Method	
Velocity (V) (ft/s)	2.82
Maynord Method	
Water depth (d) (ft)	0.82
Stability coefficient (C_s) (unitless)	0.375
Velocity distribution coefficient (C_v) (unitless)	1
Thickness coefficient (C_T) (unitless)	1
Stone density (γ_s) (lb/ft^3)	165.43
Water density (γ_w) (lb/ft^3)	62.43
Velocity (V) (ft/s)	2.82
Gravity (g) (ft/s^2)	32.2
Side slope correction (K_1) (unitless)	1
Θ (°)	20
∅ (°)	40

Variable	Value*

*Note: Values used in modelling are in imperial units.
Final values for stone size have been converted to SI units.

3.2 Proposed Sediment Removal/ Channel Sculpting

During the October 2023 field visit three locations were noted in the ravine where fine sediments have deposited and accumulated within the channel. To keep the channel and stormwater facility functioning as designed, it is proposed that these fine sediments be removed from the channel. Minor channel sculpting will be required during this process and a level of field fit is to be expected.

3.3 Restoration of Disturbed Surfaces

Following the installation of the proposed bioengineering treatments, natural surfaces affected by construction are to be restored to original condition through application of a 150 mm layer of topsoil, which is to be seeded with a native riparian mix. In addition, and as required, a biodegradable erosion control blanket is proposed to cover the seeded area to offer short-term (e.g., 1-2 year) erosion protection while the soil revegetates.

4 Design Implementation

4.1 Recommendations for Implementation

Instream construction should be carried out only during low-flow conditions, and as regulated by the fisheries warmwater timing window (July 15th – March 15th), as set out by MNRF. Construction supervision should be performed by an inspector with experience overseeing channel works, as this type of work differs considerably from engineering projects. The inspector should be a certified fluvial geomorphologist or an experienced environmental inspector under direction from the designer. An experienced inspector will be able to provide quick and appropriate response to issues that may arise and ensure that construction proceeds in accordance with the approved design and contract. Erosion and sediment control monitoring should be performed by a CAN-CISEC certified monitor.

The limits of construction should be delineated to prevent unanticipated impacts to natural surroundings, including trees and the watercourse. Should flow be present where in-channel works are required, the work area must be fully isolated from the active flow area using cofferdams. All isolated work areas will be unwatered to perform the work under dry conditions. Water will be pumped through a fish screen, and if required, to a sediment filtration system located at least 30 m from the receiving creek (if feasible) and be allowed to naturally flow over a well-vegetated surface and ultimately return to the channel. This will allow particles to settle before reaching the watercourse. The weather forecast will be monitored prior to construction to ensure favourable working days (e.g., low flow conditions). All temporary isolation materials are to be removed from the creek following their use.

All materials and equipment will be stored and operated in such a manner that prevents any deleterious substances from entering the water. Vehicle and equipment re-fuelling and/or maintenance will be conducted away from the watercourse and be free of fluid leaks and externally cleaned/degreased to prevent the release of deleterious substances. Inspection and cleaning of all machinery and equipment should be performed in accordance with the procedures, checklists, and diagrams outlined within *Clean Equipment Protocol for Industry* (Halloran et al., 2013).

4.2 Post-Construction Monitoring

A post-construction monitoring program is recommended to assess the performance of the implemented works. Monitoring observations can also be used to determine the need for remedial works and warranty any plantings. Monitoring is recommended for two full calendar years after construction and includes bi-annual (i.e., spring and fall) visual inspections and annual surveys.

Post-construction monitoring should be completed as follows:

- Complete an as-built survey of the remediation works
- Conduct site reconnaissance, including collection of site photographs, immediately following construction completion
- Complete site reconnaissance after the first significant storm event (e.g., 5-year event) and after the first freshet to identify any potential areas of concern
- Document site conditions during the growing season, including observations of the stability of constructed features and overall vegetation health
- Prepare a report summarizing construction activities (i.e., design implementation), and subsequent year-end reports at the end of the first and second years of monitoring

Monitoring activities should be undertaken by or under the direction of a qualified fluvial geomorphologist. Monitoring should commence shortly after construction and be reviewed annually.

We trust the above information and supporting drawings satisfy your requirements at this time. Should you have any questions or concerns please contact the undersigned.

Respectfully submitted,

Paul Villard Ph.D., P.Geo., CAN-CISEC, EP, CERP
Director, Principal Geomorphologist

Ben Miller, B.Sc., CAN-CISEC
River Scientist, Project Manager

5 References

Halloran, J., Anderson, H. and Tassie, D. 2013. Clean Equipment Protocol for Industry. Peterborough Stewardship Council and Ontario Invasive Council. Peterborough, Ontario.

Isbash, S.V. 1936. Construction of dams by depositing rock in running water. Transactions, Second Congress on Large Dams. Washington, D.C.

Maynord, S.T. 1988. Stable Riprap size for open channel flows. Technical Report HL-88-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

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Newson, M. D. & Newson C. L. 2000. Geomorphology, ecology and river channel habitat: Mesoscale approaches to basin-scale challenges. Progress in Physical Geography, 2: 195–217.

Peterka, A.J. 1958. Hydraulic Design of Stilling Basins and Bucket Energy Dissipators. USBR Engineering Monograph 25. U.S. Department of the Interior, Bureau of Reclamation, Denver.

Appendix A
Reach Delineation

Legend

- Reach Break and ID (CR-1)
- Contours (1 m)
- Watercourse
- Culverts
- Extent Assessed
- Subject Lands

Inverness Homes

147 Langstaff Drive

Reach Delineation

GEO MORPHIX™

N

0 50 100

Metres

Imagery: December, 2016.
Watercourse: City of Ottawa, 2019. Subject Lands: Inverness Homes, 2021.
Reach Break, Extent Assessed : GEO Morphix Ltd., 2019.
Contours, Surveyed Channel and Culverts: Robinson, Land Development: 2020.
Print Date: January 2022. PN19072. Drawn By: W.B., M.O., S.S.

Appendix B
Photographic Record

Photo 1 Tributary of Carp River: Site B Reach CR-1	
	Photograph taken at **Site B** during the Fall 2023 site visit. Channel banks were composed of fine materials and angular cobble. The valley wall and right bank were well-vegetated. The yellow arrow depicts direction of flow.
Photo 2 Tributary of Carp River: Erosion Zone 2 Reach CR-1	
	Photograph taken at **Site 9b** during Fall 2023 site visit. The channel bed and banks were composed of fine materials. Minor sediment deposition was observed along the right bank.

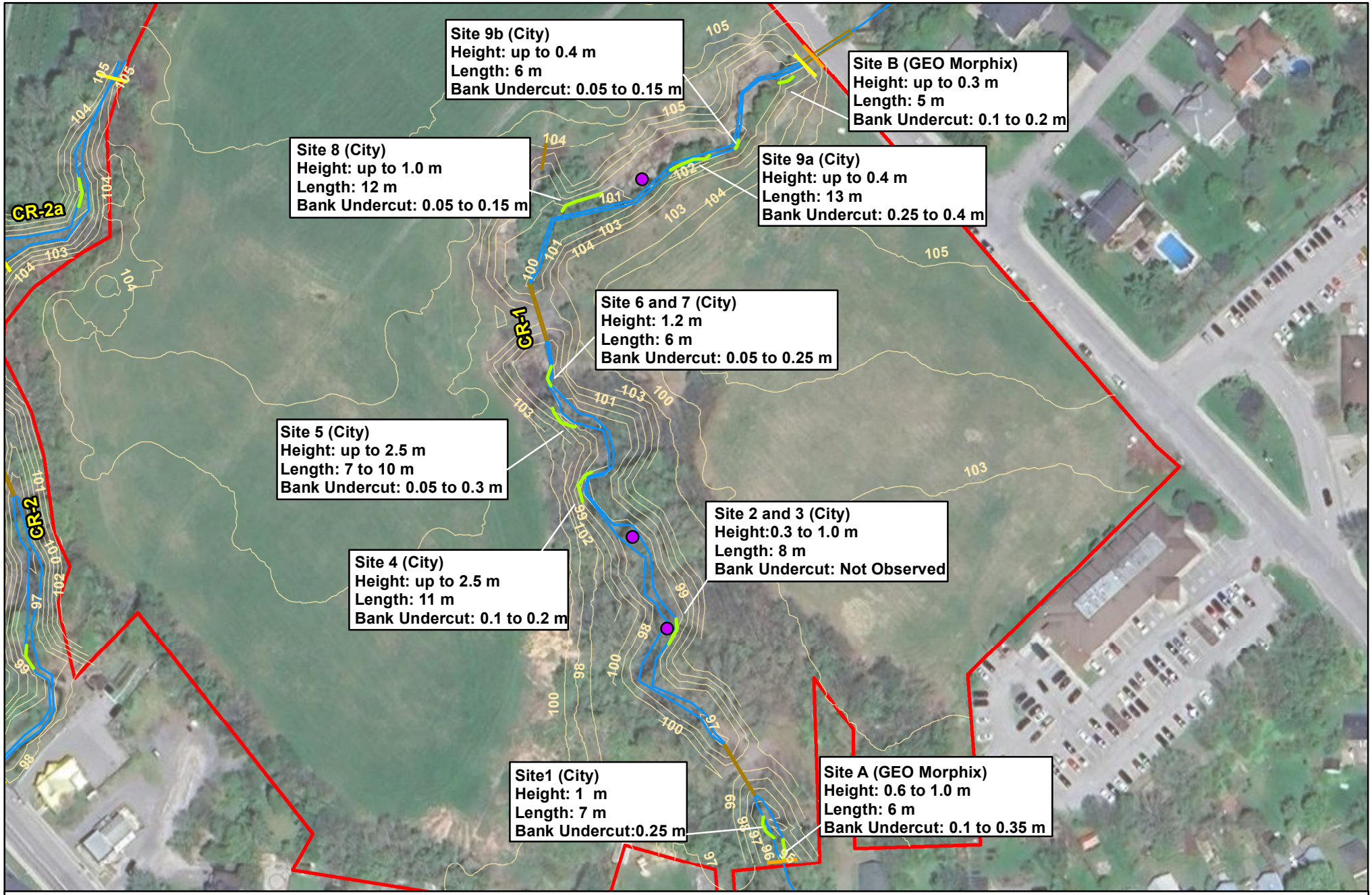
Photo 3 Tributary of Carp River Reach CR-1	
	Photograph taken between **Sites 9b** and **8**. A large depositional zone was identified with measurements of up to 0.4 m of sediment accumulation. The channel lost definition and multiple flow paths were present downstream of the zone.
Photo 3 Tributary of Carp River: Site 8 Reach CR-1	
	Photograph taken at **Site 8** during the Fall 2023 site visit. Channel bed and banks were composed of fine materials, and root density was significant (60-80%). Several small knickpoints from large roots and accumulated debris were present within the channel.

Photo 4 Tributary of Carp River: Site 6 and 7 Reach CR-1	
	Photograph taken at **Sites 6 and 7** during Fall 2023 site visit. Channel bed and bank materials were composed of fine materials. This site was located downstream of a crossing and small knickpoint where the gradient increased.
Photo 5 Tributary of Carp River: Site 5 Reach CR-1	
	Photograph taken at **Site 5** during the Fall 2023 site visit. Channel bed was composed of fine materials up to large angular cobble. The channel bank was composed of fine materials. A few relatively small 'J' hooked trees were observed at the top of the cutbank.

Photo 6 Tributary of Carp River: Site 4 Reach CR-1	
	Photograph taken at **Site 4** during the Fall 2023 site visit. Channel bed and bank materials were composed of fine materials. Well established pool-riffle features were located up and downstream of the site.
Photo 7 Tributary of Carp River: Site 2 and 3 Reach CR-1	
	Photograph taken at **Sites 2 and 3** during the Fall 2023 site visit. Little bank erosion was observed; however, zones of deposition (up to 0.3 m) were present within the channel. Woody debris was common in this portion of the reach.

Photo 8 Tributary of Carp River: Site 1 Reach CR-1	
	Photograph taken on the right bank of **Site 1** during the Fall 2023 site visit. The channel bed was composed of angular cobble, and the banks were composed of fine materials. An accumulation of riprap in the center of the channel had diverted flows, which were eroding the left and right bank at this site.
Photo 8 Tributary of Carp River: Site 1 Reach CR-1	
	Photograph taken facing the left bank at **Site A** during the Fall 2023 site visit. Riprap in the center of the channel appeared to have diverted flows to the left and right banks.

Appendix C
Areas of Channel Adjustment



Legend

- Reach Break and ID (CR-1)
- Area of Deposition
- Contours (1 m)
- Watercourse
- Culverts
- Extent Assessed
- Channel Adjustment
- Subject Lands

Inverness Homes

147 Langstaff Drive

Areas of Channel Adjustment - Reach CR1

GEO MORPHIX™

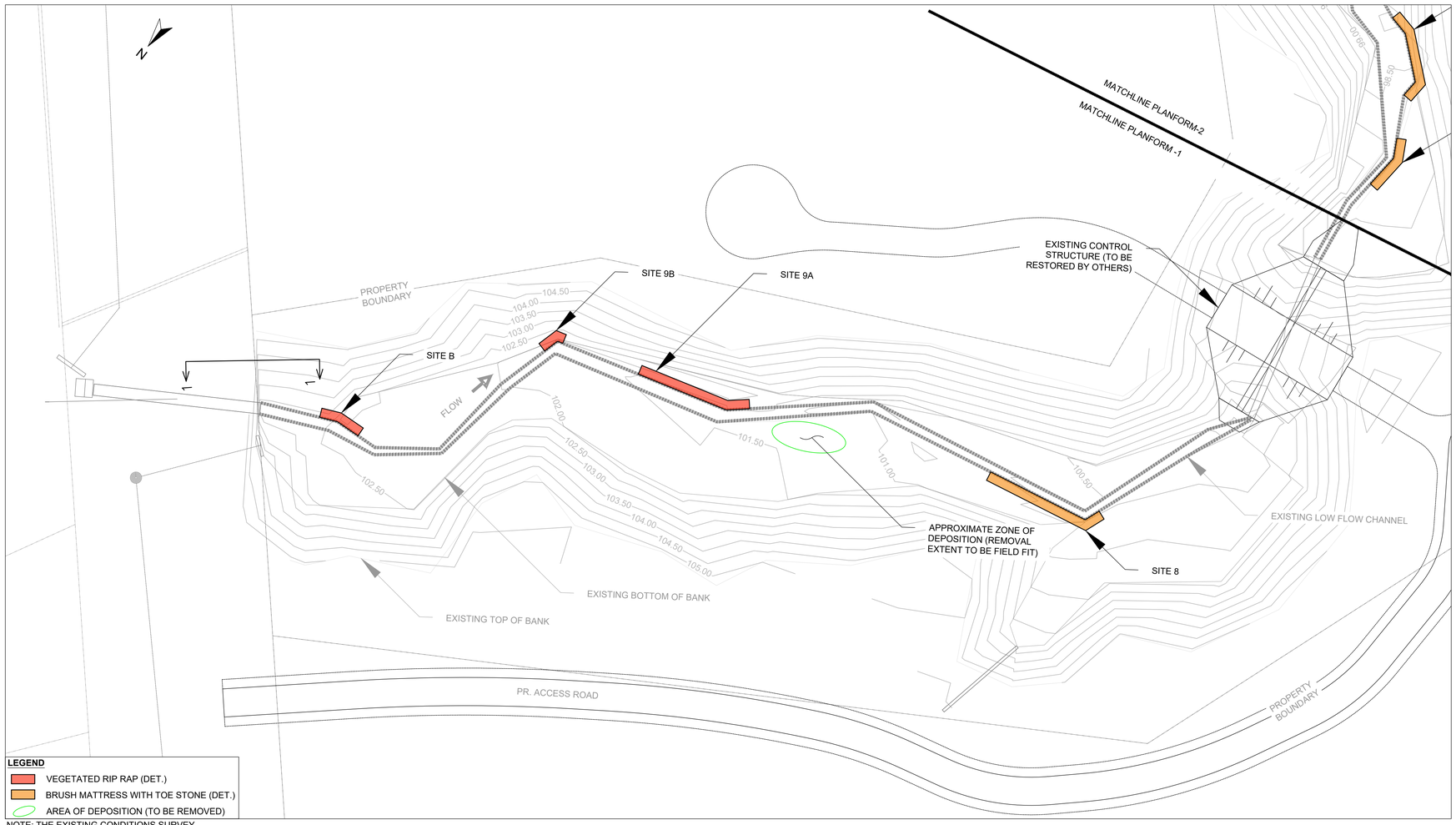
N

0 25 50

Metres

Imagery: December, 2016.
Watercourse: City of Ottawa, 2019. Subject Lands: Inverness Homes, 2021.
Reach Break, Extent Assessed, Channel Adjustment : GEO Morphix Ltd., 2019.
Contours, Surveyed Channel and Culverts: Robinson, Land Development: 2020.
Print Date: November 2023. PN23100. Drawn By: K.M., M.O., S.S.

Appendix D
CR-1 Remediation Plan



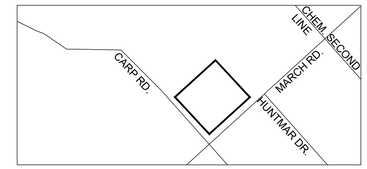
LEGEND

- VEGETATED RIP RAP (DET.)
- BRUSH MATTRESS WITH TOE STONE (DET.)
- AREA OF DEPOSITION (TO BE REMOVED)

NOTE: THE EXISTING CONDITIONS SURVEY LINEWORK SHOWN WAS PROVIDED BY OTHERS

PLANFORM-1
1:250

SCALED FOR PLOT ON 'ARCH D'



N
N.T.S.

KEY MAP
N.T.S.

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	DATE	BY	REVISIONS

DESIGNED BY:PV/BM	CHECKED BY:PV
DRAWN BY:OC	DATE: SEPTEMBER 2024

PROFESSIONAL GEOSCIENTIST
PAUL V. VILLARD
PRACTISING MEMBER
0957
ONTARIO
2024-09-18

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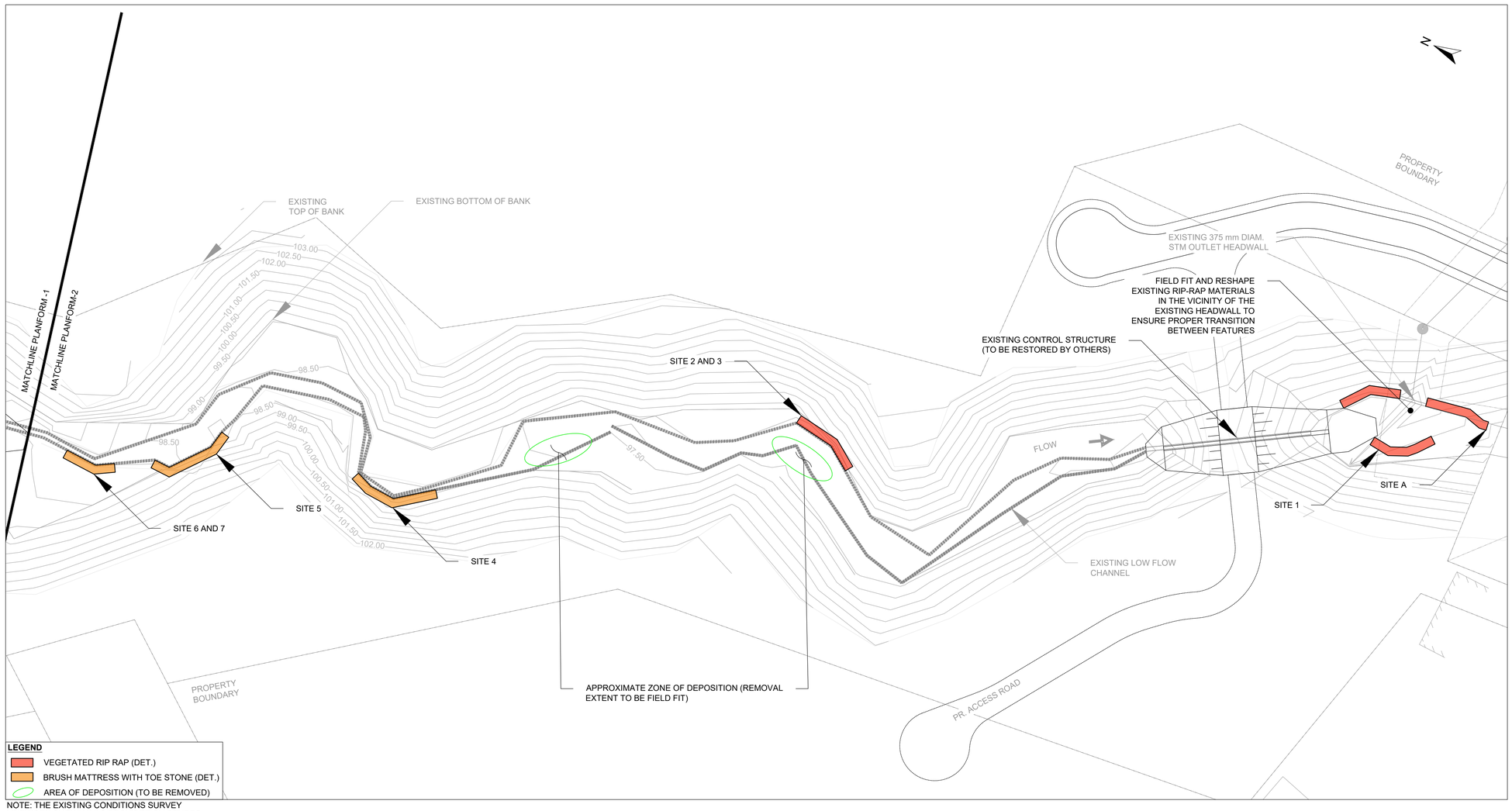
RAVINE EROSION PROTECTION
PLANFORM AND RESTORATION DETAILS

PROJECT No.: 23100	DRAWING No.: GEO-1
SCALE: AS NOTED	SHEET 1 OF 4



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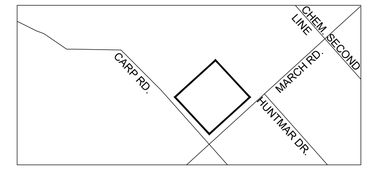
PLANFORM-2
1:250

SCALED FOR PLOT ON 'ARCH D'



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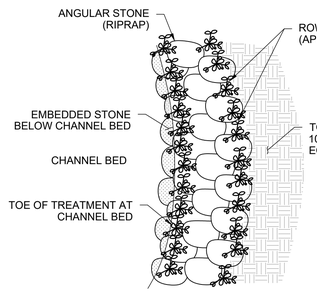
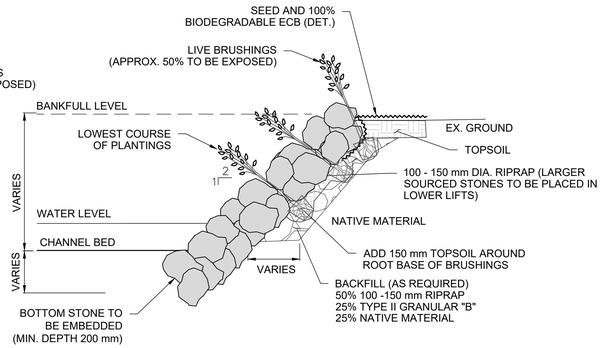
PLANFORM AND RESTORATION DETAILS

PROJECT No.: 23100	DRAWING No.: GEO-2
SCALE: AS NOTED	SHEET 2 OF 4



PLAN



CROSS SECTION

CONSTRUCTION NOTES

- VEGETATED RIPRAP TO BE INSTALLED IN LIFTS, WITH LARGER SOURCED STONES PLACED ALONG THE TOE OF THE TREATMENT.
- TOE STONES TO BE EMBEDDED INTO CHANNEL BED TO A MINIMUM DEPTH OF 200 mm.
- LIVE BRUSHINGS / PLANTINGS, TO BE INSTALLED INTO LIFTS OF BUTTRESS DURING CONSTRUCTION AND NOT AT A LATTER DATE.

SEQUENCE OF CONSTRUCTION

LOWER LIFTS:

1. EMBED LOWEST LIFTS OF STONE, BACKFILLING AS NEEDED WITH PROPOSED RIPRAP / GRANULAR MIX. MECHANICALLY COMPACT ALL MATERIALS TO PREVENT FLOW THROUGH.

MIDDLE TO UPPER LIFTS:

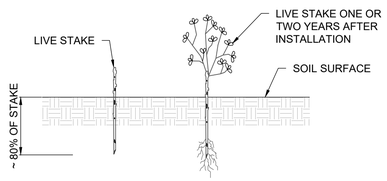
2. INSTALL SINGLE LIFT OF STONE, BACKFILLING AS NEEDED WITH PROPOSED RIPRAP / GRANULAR MIX. MECHANICALLY COMPACT ALL MATERIALS TO PREVENT FLOW THROUGH.
3. INSTALL CONTINUOUS ROW OF LIVE BRUSHINGS / PLANTINGS OVERTOP OF NEWLY PLACED STONE LIFT AND ADD 150 mm LAYER OF TOPSOIL AROUND BASE OF BRUSHINGS.
4. REPEAT STEPS 2-3 FOR ADDITIONAL LIFTS TO TOP OF BANK.

POTTED PLANTINGS SPECIFICATIONS

COMMON NAME	SCIENTIFIC NAME	QTY	CONDITION
RED-OSIER DOGWOOD	*Cornus sericea*	45	1 m, LIVE BRUSHINGS
SHINING WILLOW	*Salix lucida*	45	1 m, LIVE BRUSHINGS
SANDBAR WILLOW	*Salix interior*	45	1 m, LIVE BRUSHINGS

NOTE: LIVE BRUSHINGS TO BE REPLACED WITH CONTAINER GROWN (POTTED) PLANTINGS IF PLANTING TO OCCUR OUTSIDE THE DORMANT PERIOD (FALL / WINTER)

VEGETATED RIPRAP
N.T.S.



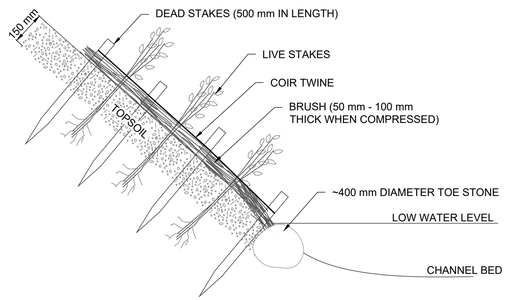
SPECIES AND QUANTITIES

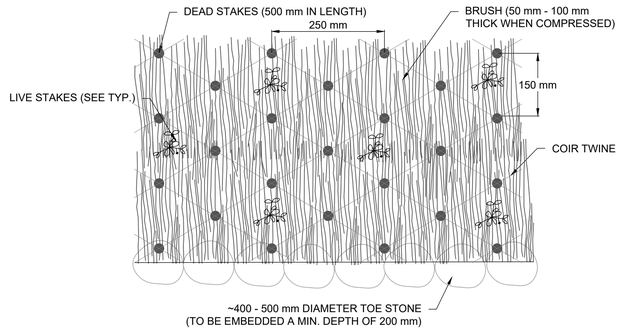
COMMON NAME	SCIENTIFIC NAME	QTY	CONDITION
RED-OSIER DOGWOOD	*Cornus sericea*	40	1 m, BARE ROOT
SHINING WILLOW	*Salix lucida*	40	1 m, BARE ROOT
SANDBAR WILLOW	*Salix interior*	40	1 m, BARE ROOT

NOTES

1. QUANTITY TO BE DETERMINED BASED ON AREA OF DISTURBANCE TO BE RESTORED
2. LIVE STAKES SHOULD BE FROM AT MINIMUM 2-YEAR OLD STOCK.
3. LIVE STAKES ARE TO BE INSTALLED AT A DENSITY OF 3 STAKES PER SQUARE METRE.
4. LIVE STAKES SHOULD BE PRE-SOAKED (SUBMERGED IN WATER) FOR AT LEAST 24 HOURS AFTER HARVESTING AND IMMEDIATELY BEFORE INSTALLATION.
5. LIVE STAKES SHOULD NOT BE STORED FOR A PERIOD LONGER THAN 2 DAYS, UNLESS THEY ARE BEING SOAKED.
6. THE CONTRACTOR SHALL PROTECT PLANT MATERIALS FROM DRYING FROM THE TIME OF HARVEST UNTIL INSTALLED.
7. LIVE STAKES ARE TO BE A MINIMUM OF 25 mm IN DIAMETER AND CUT TO A LENGTH OF 1000 mm.
8. CUT ANGLE AT THE BOTTOM OF THE STAKE AND FLAT ON THE TOP.
9. TRIM ALL SIDE BRANCHES WHILE TAKING CARE NOT TO DAMAGE THE BARK.
10. INSTALL STAKES WITH BUDS POINTING UPWARDS AND THICKER STEM IN THE BED.
11. LIVE STAKES SHOULD BE INSTALLED USING A LARGE RUBBER MALLET.
12. 80% OF THE STAKE IS TO BE BELOW SURFACE.
13. TAMP THE LIVE STAKE INTO THE GROUND AT RIGHT ANGLE TO THE SURFACE.
14. IN COMPACT SOIL A PILOT HOLE SHOULD BE USED TO LIMIT DAMAGE TO THE STAKES.
15. IF USING A PILOT HOLE REPACK SOIL AROUND THE LIVE STAKE.
16. LIVE STAKES SHOULD STAND FIRM FROM THE SOIL FOLLOWING INSTALLATION.
17. ALL STAKES NOT PLANTED TO THE SPECIFICATIONS ABOVE WILL BE REPLACED AT THE CONTRACTOR'S EXPENSE.

LIVE STAKE
N.T.S.



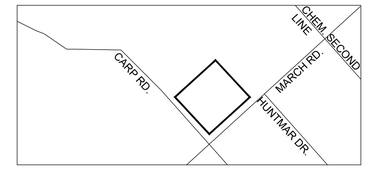


NOTES

1. LIVE BRANCHES TO CONSIST OF WILLOW AND DOGWOOD SPECIES, APPROXIMATELY 1 m IN LENGTH AND 50 mm - 100 mm IN WIDTH.
2. BRANCHES TO BE KEPT IN MOIST AND COLD UNTIL INSTALLATION.
3. BRUSH MATTRESS TO BE INSTALLED WHILE BRANCHES ARE DORMANT.
4. BRANCHES TO BE PLACED ON SLOPE WITH BUTT END TOWARDS VALLEY FLOOR AND PUSHED INTO SOIL.
5. BRANCHES MUST BE FLEXIBLE ENOUGH TO CONFORM TO THE SLOPE SURFACE IRREGULARITIES.
6. POUND DEAD STAKES TO HALF THEIR LENGTH INTO SOIL BETWEEN BRANCHES. TIE COIR TWINE AROUND DEAD STAKES AND TIGHTLY OVER BRANCHES. USE A CLOVE HITCH TO SECURE STAKES. POUND STAKES INTO SLOPE TO COMPRESS BRANCHES AGAINST GROUND.
7. TAMP LIVE STAKES BETWEEN DEAD STAKES.
8. FILL VOIDS BETWEEN BRANCHES OF THE BRUSH MATTRESS WITH SOIL TO PROMOTE ROOTING.

BRUSH MATTRESS
N.T.S.

SCALED FOR PLOT ON 'ARCH D'



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N.T.S.

KEY MAP
N.T.S.

GENERAL NOTES

1. ALL CONTRACT DRAWINGS, SPECIFICATIONS AND APPLICABLE PERMITS MUST BE KEPT ON SITE DURING CONSTRUCTION FOR REFERENCE.
2. THE CONTRACTOR MUST NOTIFY THE CONTRACT ADMINISTRATOR AND CONSERVATION AUTHORITY OF THE INTENT TO COMMENCE WORK AT LEAST 48 HOURS IN ADVANCE.
3. THE CONTRACTOR IS RESPONSIBLE FOR ALL UTILITY LOCATES.
4. LAYOUT MUST BE REVIEWED AND APPROVED BY THE CONTRACT ADMINISTRATOR.

TIMING OF WORKS

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2. TREE CLEARING SHOULD BE COMPLETED OUTSIDE THE BIRD NESTING SEASON (MARCH 1ST TO AUGUST 15TH) TO COMPLY WITH THE FEDERAL MIGRATORY BIRDS CONVENTION ACT. ANY TREES THAT REQUIRE REMOVAL OUTSIDE OF THIS TIMING WINDOW MUST FIRST BE INSPECTED BY A QUALIFIED BIOLOGIST TO DETERMINE THE PRESENCE OF NESTING BIRDS.
3. THE WEATHER FORECAST SHOULD BE CONTINUALLY MONITORED TO ENSURE THAT WORKS ARE UNDERTAKEN ONLY DURING FAVOURABLE WEATHER CONDITIONS.
4. COMPLETE THE WORKS WITH MINIMAL AVOIDABLE INTERRUPTIONS ONCE THEY COMMENCE.

SITE AND MATERIAL MANAGEMENT

1. ALL CONSTRUCTION EQUIPMENT AND MATERIALS (IMPORTED OR EXCAVATED) MUST BE STORED AT LEAST 30 m AWAY FROM ANY WATERBODY IN A STABLE AREA ABOVE THE ACTIVE FLOODPLAIN, OR IN A DESIGNATED STAGING/STORAGE AREA.
2. IN THE EVENT OF AN UNEXPECTED STORM, ALL UNFIXED ITEMS THAT HAVE THE POTENTIAL TO CAUSE A SPILL OR AN OBSTRUCTION TO FLOW MUST BE MOVED A STABLE AREA ABOVE ACTIVE FLOODPLAIN.
3. STOCKPILES MUST BE LOCATED OUTSIDE THE ISOLATED WORK AREAS.
4. STABILIZE STOCKPILED SOILS THAT ARE STORED FOR PROLONGED PERIODS WITH THE APPLICATION OF A NURSE CROP AT A RATE OF 60 kg/ha.
5. STABILIZE, TEMPORARILY OR PERMANENTLY, ANY DISTURBED AREAS AS WORK PROGRESSES, OR SOON AS CONDITIONS ALLOW. ON SOILS THAT WILL BE EXPOSED FOR PROLONG PERIODS, TEMPORARILY INSTALL A BIODEGRADABLE EROSION CONTROL BLANKET ON EXPOSED SOILS, OR APPLY A NURSE CROP AT A RATE OF 60 KG/HA.
6. MINIMIZE THE AREA OF DISTURBANCE TO THE EXTENT POSSIBLE.
7. ALL VEGETATION, ADJACENT TO THE WORK AREA, MUST BE PROTECTED AND DELINEATED WITH CONSTRUCTION FENCING OR TREE PROTECTION BARRIERS.
8. ALL GRADES IN THE AREA REGULATED BY THE CONSERVATION AUTHORITY MUST BE MAINTAINED OR MATCHED, UNLESS OTHERWISE AUTHORIZED IN THE APPLICABLE PERMIT.

EROSION AND SEDIMENT CONTROL

1. ALL TEMPORARY EROSION AND SEDIMENT CONTROL MEASURES MUST BE INSTALLED PRIOR TO START OF WORKS.
2. SEDIMENT CONTROLS MUST BE INSPECTED DAILY TO ENSURE THAT THEY ARE IN GOOD REPAIR AND FUNCTIONING AS INTENDED.
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7. ALL TEMPORARY SEDIMENT CONTROLS MUST BE REMOVED AFTER THE CONTRACT ADMINISTRATOR DEEMS THE SITE TO BE STABLE.

DELETERIOUS SUBSTANCE CONTROL/SPILL MANAGEMENT

1. PREVENT THE RELEASE OF SEDIMENT, SEDIMENT-LADEN WATER, RAW CONCRETE, CONCRETE LEACHATE OR ANY OTHER DELETERIOUS SUBSTANCES INTO ANY WATERBODY, RAVINE OR STORM SEWER SYSTEM.
2. ENSURE EQUIPMENT AND MACHINERY ARE IN GOOD OPERATING CONDITION (POWER WASHED), FREE OF LEAKS, EXCESS OIL, AND GREASE.
3. NO EQUIPMENT REFUELLING OR SERVICING SHOULD BE UNDERTAKEN WITHIN 30 m OF ANY WATERCOURSE OR SURFACE WATER DRAINAGE.
4. A SPILL CONTAINMENT KIT MUST BE READILY ACCESSIBLE ON SITE IN THE EVENT OF A RELEASE OF A DELETERIOUS SUBSTANCE TO THE ENVIRONMENT. ONSITE STAFF MUST BE TRAINED IN ITS USE.
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WORK AREA ISOLATION

1. ALL WORK IN ISOLATED WORK AREAS MUST BE COMPLETED IN THE DRY. AN ADEQUATE NUMBER OF PUMPS MUST BE USED FOR UNWATERING.
2. THE UNWATERING DISCHARGE LOCATION MUST BE LOCATED AT LEAST 30 M FROM ANY WATERCOURSE OR WETLAND IN AN AREA WITH DENSE VEGETATIVE GROUNDCOVER, AND WHERE THE DISCHARGE CAN RETURN TO THE WATERBODY DOWNSTREAM OF THE WORK AREA OVER THE GROUNDCOVER.
3. FISH MUST BE REMOVED FROM THE WORK AREA ONCE ISOLATED. FISH SALVAGE MUST BE COMPLETED BY A QUALIFIED TECHNICIAN WITH A LICENSE FROM THE ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY.

NOT FOR CONSTRUCTION

3.	2024-09-18	BM	ADDRESS MVCA COMMENTS
2.	2024-02-09	BM	SECOND SUBMISSION - DETAILED DESIGN
1.	2023-11-28	BM	FIRST SUBMISSION - DETAILED DESIGN
	DATE	BY	REVISIONS

DESIGNED BY:PV/BM	CHECKED BY:PV
DRAWN BY:OC	DATE: SEPTEMBER 2024

PROFESSIONAL GEOSCIENTIST
PAUL V. VILLARD
PRACTISING MEMBER
0957
ONTARIO
2024-09-18

GEO
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36 Main Street North, PO Box 205
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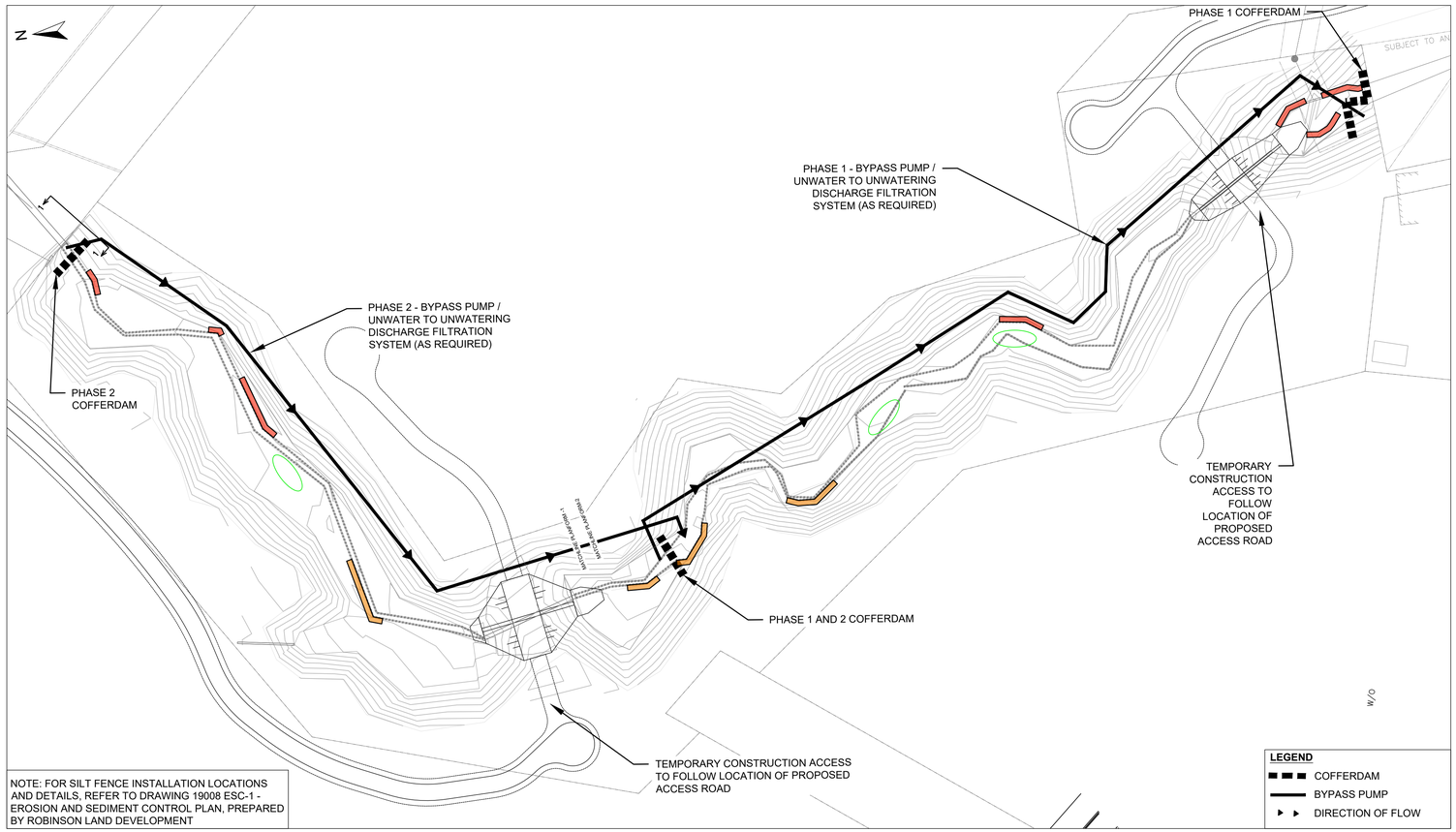
CARP RIVER TRIBUTARY
OTTAWA

RAVINE EROSION PROTECTION
PLANFORM AND RESTORATION DETAILS

PROJECT No.: 23100	DRAWING No.: DET-1
SCALE: AS NOTED	SHEET 3 OF 4

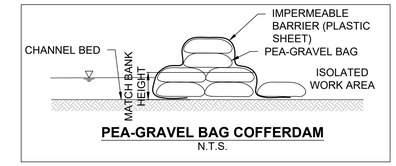


NOTE: FOR SILT FENCE INSTALLATION LOCATIONS AND DETAILS, REFER TO DRAWING 19008 ESC-1 - EROSION AND SEDIMENT CONTROL PLAN, PREPARED BY ROBINSON LAND DEVELOPMENT

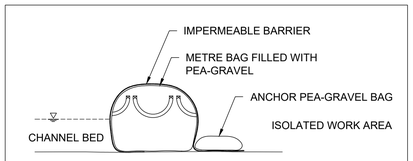
PLANFORM
1:500

EROSION CONTROL BLANKET SPECIFICATIONS

1. A BIODEGRADABLE EROSION CONTROL BLANKET (ECB) SHALL BE INSTALLED ON ALL DISTURBED NATURAL SURFACES FOLLOWING THE PLACEMENT OF TOPSOIL AND APPLICATION OF THE NATIVE SEED MIX.
2. THE ECB MUST BE CONSTRUCTED OF 100% WOVEN COCONUT FIBRE (E.G., COIR) OR STRAW MAT WITHIN A GEOJUTE NETTING (TOP AND BOTTOM) WITH BIODEGRADABLE THREAD. NON-BIODEGRADABLE MATERIAL INCLUDING POLYPROPELENE OR PLASTICS WITH A BIODEGRADABLE RATING ARE NOT ACCEPTABLE. THE MINIMUM WEIGHT OF THE ECB MUST BE 400 g/m^2 (12 oz./yd^2).
3. TO INSTALL, THE ECB MUST BE UNROLLED DOWNSLOPE OR IN DIRECTION OF WATER FLOW. ADJACENT ECBS SHOULD OVERLAP A MINIMUM OF 150 mm ALONG THE EDGES. AT THE END OF EACH ROLL, FOLD BACK 100 mm TO 200 mm OF THE ECB. OVERLAP THIS 100 mm TO 200 mm OVER THE START OF THE NEXT ROLL. SECURE THE TWO LAYERS TO THE GROUND SECURELY.
4. BIODEGRADABLE OR TAPERED WOODEN STAKES SHALL BE USED TO SECURE THE BLANKET. STAKES SHALL BE INSTALLED AT THE SPACING RECOMMENDED BY THE ECB MANUFACTURER TO PREVENT SURFACE RUNOFF FROM ERODING THE UNDERLYING SOIL.



PEA-GRAVEL BAG COFFERDAM
N.T.S.



METRE BAG COFFERDAM
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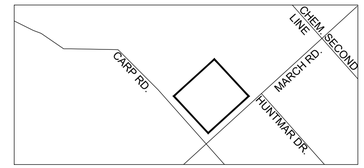

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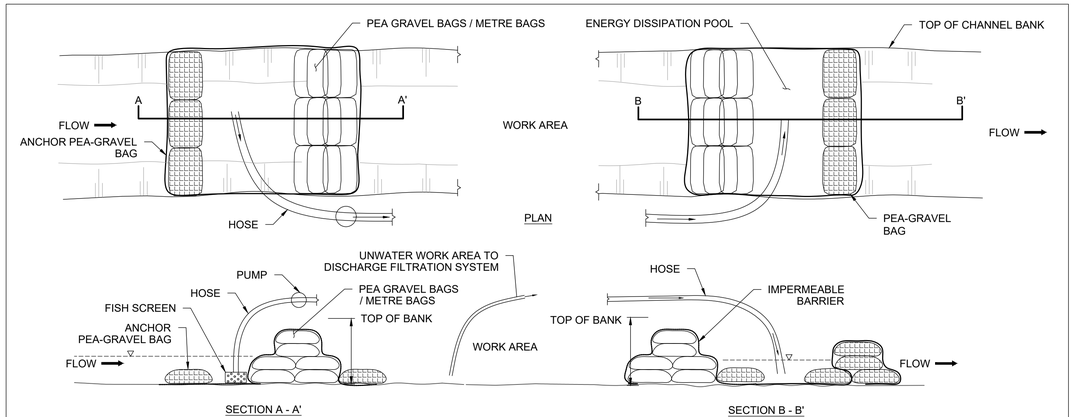
3. FISH MUST BE REMOVED FROM THE WORK AREA ONCE ISOLATED. FISH SALVAGE MUST BE COMPLETED BY A QUALIFIED TECHNICIAN WITH A LICENSE FROM THE ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY.

SUGGESTED SEQUENCE OF CONSTRUCTION

1. CONSTRUCTION CONTRACT ADMINISTRATOR TO REVIEW SITE CONDITIONS PRIOR TO COMMENCEMENT OF WORK.
2. MONITORING WEATHER TO ENSURE IN-WATER WORKS ARE COMPLETED UNDER LOW-FLOW CONDITIONS.
3. INSTALL PERIMETER CONTROL EROSION CONTROL MEASURES AROUND WORK AREA (AS DEEMED NECESSARY BY THE CONTRACT ADMINISTRATOR).
4. INSTALL COFFERDAMS ENSURING COMPLETE ISOLATION OF IN-WATER WORK AREA (SEE PLAN).
5. CONDUCT FISH AND AMPHIBIAN RESCUE FROM PHASE 1 ISOLATED WORK AREAS. FISH RESCUE MUST BE COMPLETED BY A QUALIFIED TECHNICIAN WITH A LICENSE FROM THE ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY.
6. BYPASS PUMP FLOWS / UNWATER WORK AREAS TO UNWATERING DISCHARGE FILTRATION SYSTEM AS REQUIRED TO CONDUCT WORK UNDER 'DRY' CONDITIONS.
7. INSTALL PROPOSED RESTORATION BANK TREATMENTS IN PHASE 1 (SEE PLAN).
8. STABILIZE ANY DISTURBED SURFACES WITHIN THE RAVINE WITH SEED AND BIODEGRADABLE EROSION CONTROL BLANKET, AS REQUIRED.
9. REMOVE DOWNSTREAM PHASE 1 COFFERDAM AND INTRODUCE FLOWS TO THE RESTORED CHANNEL ONCE THE SITE HAS BEEN DEEMED STABLE BY THE DESIGNER.
10. STABILIZE AREAS DISTURBED FROM CONSTRUCTION ACTIVITIES (IE. TEMP. ACCESS ROUTE) WITH SEED AND BIODEGRADABLE EROSION CONTROL BLANKET (SEE PESC-1 FOR ECB SPECIFICATIONS)
11. INSTALL UPSTREAM PHASE 2 COFFERDAM ENSURING COMPLETE ISOLATION OF IN-WATER WORK AREA (SEE PLAN).
12. CONDUCT FISH AND AMPHIBIAN RESCUE FROM PHASE 2 ISOLATED WORK AREAS. FISH RESCUE MUST BE COMPLETED BY A QUALIFIED TECHNICIAN WITH A LICENSE FROM THE ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY.
13. INSTALL PROPOSED RESTORATION BANK TREATMENTS IN PHASE 2 (SEE PLAN).
14. STABILIZE ANY DISTURBED SURFACES WITHIN THE RAVINE WITH SEED AND BIODEGRADABLE EROSION CONTROL BLANKET, AS REQUIRED.
15. REMOVE COFFERDAMS AND INTRODUCE FLOWS TO THE RESTORED CHANNEL ONCE THE SITE HAS BEEN DEEMED STABLE BY THE DESIGNER.
16. STABILIZE AREAS DISTURBED FROM CONSTRUCTION ACTIVITIES (IE. TEMP. ACCESS ROUTE) WITH SEED AND BIODEGRADABLE EROSION CONTROL BLANKET (SEE PESC-1 FOR ECB SPECIFICATIONS).
17. RESTORE SURFACES DISTURBED BY THE CONSTRUCTION WORK OR STAGING AREA(S) TO ORIGINAL CONDITION.

SEQUENCING NOTES: STEPS 4-16 CAN COINCIDE AND BE COMPLETED AT THE SAME TIME DURING CONSTRUCTION BY ONLY INSTALLING THE UPSTREAM AND DOWNSTREAM COFFERDAMS AND BYPASS PUMPING THE ENTIRE RAVINE DURING CONSTRUCTION.

GENERAL NOTES: THE LOCATIONS AND EXTENTS OF THE PROPOSED TREATMENTS ARE APPROXIMATE AND A LEVEL OF FIELD FIT IS TO BE EXPECTED DURING INSTALLATION



NOTES
1. PUMPING RATE MUST MATCH WORKING FLOW CONDITIONS.
2. BAGS TO BE FILLED WITH PEA-GRAVEL.
3. BAGS TO BE INSTALLED TO MATCH EXISTING TOP OF BANK. PEA GRAVEL BAGS OR METRE BAGS CAN BE USED TO MATCH TOP OF BANK, TO BE DETERMINED BASED ON SITE CONDITIONS.
4. IMPERMEABLE BARRIER (PLASTIC SHEET) TO COVER THE BAGS TO LIMIT SEEPAGE INTO WORK AREA.
5. BACKUP PUMP AND HOSE SHALL BE KEPT ONSITE TO ADDRESS FAILURES AND HIGH FLOW CONDITIONS.
6. PEA-GRAVEL WITHIN BAGS TO BE DISPOSED OF OFFSITE ONCE CONSTRUCTION IS COMPLETE.

PEA-GRAVEL BAG COFFERDAM AND BYPASS PUMPING
N.T.S.

NOT FOR CONSTRUCTION

3.	2024-09-18	BM	ADDRESS MVCA COMMENTS
2.	2024-02-09	BM	SECOND SUBMISSION - DETAILED DESIGN
1.	2023-11-28	BM	FIRST SUBMISSION - DETAILED DESIGN
	DATE	BY	REVISIONS

DESIGNED BY:PV/BM	CHECKED BY:PV
DRAWN BY:OC	DATE: SEPTEMBER 2024

PROFESSIONAL GEOSCIENTIST ONTARIO
PAUL V. VILLARD
PRACTISING MEMBER
0957
2024-09-18

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OTTAWA

RAVINE EROSION PROTECTION
PHASING AND EROSION &
SEDIMENT CONTROLS

PROJECT No.: 23100	DRAWING No.: PESC-1
SCALE: AS NOTED	SHEET 4 OF 4

SCALED FOR PLOT ON 'ARCH D'