Fluvial Geomorphology and Erosion Hazard Assessment

Tay River and Grants Creek
141 Peter Street
Perth, Ontario

Prepared for:

Caivan (Perth GC) Limited
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February 19, 2023
PN22029

GEO MORPHIX™

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Approval Date:	February 19, 2023

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Appendices

1 Introduction

GEO Morphix Ltd. ("GEO Morphix") was retained to complete a fluvial geomorphology and erosion hazard assessment for the Tay River and Grants Creek in association with a future development located at 141 Peter Street ("Subject Lands") in Perth, Ontario. The Subject Lands are situated southeast of Christie Lake Road and west of Downtown Perth. The Tay River flows roughly west to east along the northern border of the Subject Lands and is located within the jurisdiction of the Rideau Valley Conservation Authority.

To complete the erosion hazard assessment, GEO Morphix completed the following tasks:

- Review of 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 via desktop assessment and confirmation of desktop reach delineation through field reconnaissance
- Review of recent and historical aerial photographs of the site to understand historical changes in channel form and function over time
- Site reconnaissance to understand general property and watercourse characteristics, and to document any potential existing bedrock outcrops
- Delineate limits of the meander belt width/erosion hazard on a reach basis using the results of the desktop and field assessments

2 Background Review and Desktop Assessment

2.1 Watershed Overview

The Subject Lands are located within the Tay River watershed, which drains a catchment area of approximately 800 km^2 (RVCA, 2017). The headwaters of the Tay River watershed, including Grants Creek, originate south of the Town of Sharbot Lake and drain a total of 55 lakes into Lower Rideau Lake, which is farther downstream of the Subject Lands (RVCA, 2017). Land use within the watershed is dominated by agricultural activity, but there is also substantive forest and natural areas (RVCA, 2017).

The Tay River flows in a semi-confined valley from west to east along the northern margin of the Subject Lands. Grant Creek, a tributary to the Tay River, flows in a northeast direction within an unconfined valley and wetland complex along the southern portion of the Subject Lands. It discharges into the main branch of the Tay River south of the Peter St. bridge that provides access to the existing Perth Golf Course. Local land cover in the area is primarily forest and wetlands, with fragmented cultivated and fallow fields, residential properties, and infrastructure associated with the Perth Golf Course. A large portion of the Subject Lands are occupied by the golf course.

2.2 Surficial Geology and Physiology

Surficial geology and physiography exert geomorphologic control on channels and can act as constraints to lateral and vertical channel mobility. These factors determine the nature and quantity of available sediment. Secondary variables that affect the channel include land use and riparian vegetation. These factors are explored as part of the assessment, 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 site is located entirely within the Algonquin Highlands Physiographic Region. This area can be characterized by clay plains found to the north and east, shallow till and rock ridges to the

west and south, and peat and muck in the central area (Chapman and Putman, 2007). Surficial geology within the study site is variable. A large portion of the Subject Lands, including the central area and the area on either side of the Tay River and Grants Creek, are situated in organic deposits comprised of peat and muck. This is to be expected given that there is significant wetland area mapped through available provincial mapping datasets. The next largest portion of the site, which includes the existing golf course, is occupied by a Precambrian bedrock-drift complex. There are also several areas occupied by granite derived silty to sandy till deposits within the Subject Lands. North of the study site, surficial geology is comprised of the Precambrian bedrock-drift complex, carbonate derived, and granite derived silty to sandy till deposits, and laminated glacial lacustrine clay deposits (Ontario Geological Survey, 2010). A geotechnical assessment was completed by GEMTEC (2023) which also confirmed the presence of bedrock on site overlaid by various materials include clay/silt, granular, and organic deposits especially.

2.3 Historical Assessment

A series of historical aerial photographs were reviewed to determine changes to the channel and surrounding land use and land cover. This information contributes to an understanding of the historical factors that have contributed to current channel morphodynamics.

Aerial photographs and satellite images from 1978 to 2022 were retrieved to complete the historical assessment and inform the updated meander belt width delineation. Specifically, aerial photographs from the years 1978 and 1991 were retrieved from the National Air Photo Library, and satellite imagery from the years 2005 and 2019 were retrieved from Google Earth Pro. All historical aerial photographs are provided in **Appendix B** for reference.

The 1978 imagery is comprised of multiple aerial photographs that include the entire extent of the Subject Lands and adjacent watercourses. The golf course is situated within the subject site at the time, and the surrounding land use consists of a residential community to the east of the Peter Street bridge, agricultural lands to the north and south and forest to the west. The two watercourses have vegetated riparian zones which appear to be mature and well established.

Between 1978 and 1991, changes to several downstream meanders along Grants Creek within the wetland complex are visible, and multiple flow paths are established through the wetland complex. The forested areas at the confluence of Grants Creek to the Tay River increases. No changes to Tay River's planform within the Subject Lands are observed. Riparian vegetation continues to mature and residential development continues to expand north of the Subject Lands.

Between 1991 and 2005, the golf course on the Subject Lands expands northwards along the south bank of the Tay River. Residential development continues to expand north of the Subject Lands. No changes to the Tay River planform were observed over this time. Changes to Grants Creek planform were minimal, and multiple flow paths through the wetland become more defined. No changes were observed between 2005 and 2019.

2.4 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. Three (3) watercourse reaches were delineated within the subject property based on a desktop assessment of available data (e.g., MNRF Stream Layer, surficial geology, historical and recent aerial photographs, and topographic data). Reach **TR-1** was confirmed through field reconnaissance. The study site, including reach delineation, is graphically defined in **Appendix A.**

We limited reach delineation and our assessment to the larger channels within the study area. Headwater drainage features within the study area were evaluated by others. Given the small drainage areas, limited erosion potential, and that in many cases the features will be removed or realigned, they were not included in this hazard assessment.

3 Field Observations

Field investigations were completed along an approximately 2.3-kilometre section of **TR-1** from the upstream to downstream extent along the northern boundary of the Subject Lands. Observations were collected on October 25, 2022, and included the following:

- Observations of riparian characteristics
- Determination of bed and bank material composition and structure
- Collection of photographs to document the watercourse, riparian areas and/or valley, surrounding land use, and channel disturbances such as crossing structures or local infrastructure

The field description below is supplemented and supported with representative photographs, which are included in **Appendix C**. Field sheets are also provided in **Appendix D**.

The section of the Tay River observed begins at the western extent of the golf course and ends just downstream of the Peter St. bridge. Note that the river is extremely wide (40-50 m) and deep, and as such, field observations were limited along the central portion of the channel bed. The southern bank of the river was walked, and observations were also collected instream by kayak.

The section of the Tay River within the Subject Lands generally flows from west to east along the northern border of the existing golf course before making an approximately 90 degree turn at the northernmost extent of the golf course and flowing south until just downstream of the confluence with Grants Creek. Riparian conditions on both banks are a mix of low-lying, vegetated wetlands, mature forest fragments, isolated mature trees, grasses, and herbaceous vegetation. The riparian zone was fragmented in places along the south bank by landscaped golf course areas directly adjacent to the channel. Beaver activity was observed throughout the adjacent wetland areas.

The banks were generally comprised of fine sediments (i.e., > 2 mm in diameter) and either intact or weathered bedrock outcrops. Where visible, the channel bed was comprised of consolidated bedrock and a wide range of sediment sizes from fine particles to boulders derived from the native bedrock. Several locations of observed bedrock outcrops are mapped in **Appendix A**.

A small weir with an approximately 1 m drop is located under a bridge crossing over the Tay River adjacent to the most northern point of the golf course. We understand that a lock system and several dams are also located downstream within the Town of Perth.

4 Erosion Hazard Delineation

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

When defining the erosion hazard for a watercourse, the Ontario Ministry of Natural Resources and Forestry (MNR, 2002) 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 or semi-defined valley, where contact between the channel and valley wall/slope is possible. Based on the desktop assessment and field reconnaissance results summarized above, the Tay River is a semi-confined channel, while Grants Creek is characterized as unconfined.

The smaller headwater features within the study area were assessed by others. Given their small drainage areas, limited erosion potential and opportunity, in many cases, for realignment, were not assessed, as part of this erosion hazard assessment.

4.1 Grants Creek

Grants Creek is a large meandering channel that flows along the southern boundary of the subject lands. The channel is unconfined based on a desktop review of channel conditions and topographic data. There are no steep or significant valley slopes on either side of the watercourse. Although, based on the available topographic data reviewed for the area, there appear to be several high points in the topography near the Grants Creek confluence with the Tay River. These are likely associated with bedrock outcrops based on our understanding of local geology on site.

In unconfined systems, the limit of the erosion hazard and channel migration potential can be delineated based on the meander amplitude. Meander amplitude is defined by Leopold et al. (1964) as the lateral distance between tangential lines drawn to the center channel of two successive meander bends. This differs from meander belt, which is measured for a reach between lines drawn tangentially to the outside bends of the laterally extreme meander bends (TRCA, 2004). Both the meander belt width and amplitude quantify the lateral extent of a river's occupation on the floodplain (TRCA, 2004).

To delineate the meander belt width for Grants Creek, several meander bends were reviewed through desktop assessment using historical and recent aerial imagery. The largest meander amplitude of 189 m was measured in a 2019 aerial photograph immediately south of the proposed development lands. A twenty percent factor of safety was added to the largest meander amplitude, resulting in a final meander belt width of 227 m. The final meander belt width for Grants Creek is graphically represented in **Appendix A**.

It should be noted that the applied meander belt width does not impact the proposed development fabric along the southern property boundary or in the vicinity of the Peter Street crossing. The meander belt width is likely conservative given that the channel sits within a large wetland complex. Presumably, the channel is low-gradient and depositional in nature with limited erosion potential. Historical aerials also indicate that there has been limited change in channel planform over time. Where Grants Creek drains into the Tay River, south of the Peter Street crossing, there are several high topographic points likely associated with local bedrock outcrops. Due to the geological constraints in this area, the meander belt width in this location is especially conservative as it is unlikely that the channel will migrate far beyond its existing footprint.

4.2 Tay River

There are certain environmental conditions other than defined valleys that can exert influence on the likelihood of the channel to laterally migrate, which can occur within unconfined and semi-confined systems. Bedrock outcrops were observed along the Tay River channel bed and banks during the geomorphic field investigation. Consolidated bedrock provides greater resistance to fluvial forces that drive change compared to unconsolidated sediment deposits. There were also no substantial changes to the Tay River channel observed during the historical assessment, nor was there substantial erosion observed during the field visit. These observations suggest that the channel is not as likely to migrate laterally compared to a channel situated in finer, unconsolidated sediments. This information was considered in the selection of an appropriate erosion hazard setback for the Tay River.

The Ontario Ministry of Natural Resources and Forestry (MNRF) outlines an approach for establishing the erosion hazard where watercourses are confined or semi-confined. This approach defines an appropriate erosion setback or toe erosion allowance where the watercourse is within 15 m of the toe of the valley slope. A toe erosion allowance can be determined in several ways: use of an average annual recession rate; application of a 15 m toe erosion allowance in areas where the channel is within 15 m of the toe of slope; or use of geological information and field observations of geomorphic processes (MNRF, 2002). The Tay River was assessed using information gathered through the geotechnical assessment and geomorphic field observations to determine the toe erosion allowance.

It should be noted that an average annual recession rate could not be determined through aerial photograph interpretation for the Tay River. Channel edges in the aerial photograph record were not always discernible; although, in places where the channel banks were visible, there was an extremely minor difference in channel location over multiple years. The differences were within the error range associated with the georeferencing process undertaken for each historical aerial photograph. This alone suggests that the channel is stable, and its planform has not adjusted over the last 40-50 years. Given that an average annual recession rate could not be calculated, a toe erosion allowance was selected based on MNRF (2002) guidelines which require geological information and field data.

Based on MNRF (2002) guidelines and the presence of bedrock along the channel, a 2-5 m toe erosion allowance is recommended for the Tay River. We understand that a geotechnical slope stability assessment was completed by GEMTEC (2023) which recommended an 8 m toe erosion allowance for the channel based on observations of clay/silt, granular, and organic overlays across the bedrock on site. During our field reconnaissance, we observed numerous areas of exposed bedrock along the channel and channel banks. Given the exposed bedrock along the reach, we would suggest that a reduced toe erosion allowance of 5 m would also be an appropriate approach to address the erosion hazard for the Tay River. Both the 5 m and 8 m toe erosion allowances are plotted in **Appendix A**, for reference. An additional 6 m erosion access allowance has also been applied to both. Note that in both cases, the erosion hazard setback and associated access allowance do not impact the proposed development fabric for the Subject Lands.

5 Summary and Recommendations

An erosion hazard assessment was completed for the Tay River and Grants Creek in support of the proposed future development located at 141 Peter Street in Perth, Ontario. GEO Morphix completed a fluvial geomorphological assessment which included a desktop review of available site information and mapping, as well as a review of historical aerial photographs to assess channel form and processes over time. The fluvial geomorphological assessment also included site reconnaissance to document existing conditions along the Tay River where access permitted.

A meander belt width was delineated for Grants Creek along the southern boundary of the property based on a review of available topographic data and a review of historical and recent aerial photographs. The meander belt width was delineated based on the largest meander amplitude measured over the period of photographic record. An additional twenty percent factor of safety was included in the final meander belt of 227 m.

A toe erosion allowance of 8 m was recommended for the Tay River through a slope stability assessment (GEMTEC, 2023) to address the erosion hazard associated with the confined river system. Based on MNRF (2002) guidelines, we agree that the 8 m setback is appropriate to address the erosion hazard. Although, based on our field observations of bedrock outcrops along the channel and channel banks, we would suggest that a reduced toe erosion allowance of 5 m would also be appropriate. Both recommendations are still conservative given that the watercourse is not expected to migrate laterally due to the geological constraint created by the existing bedrock on site.

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

Respectfully submitted,

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

Kat Woodrow, M.Sc.
Manager of Watershed Studies

6 References

Chapman, L.J. and Putnam, D.F. 2007. Physiography of southern Ontario; Ontario Geological Survey, Miscellaneous Release--Data 228.

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Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, 109 (5): 596-611.

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Toronto and Region Conservation Authority (TRCA). 2004. Belt Width Delineation Procedures.

Appendix A
Study Area Mapping

Legend

- Reach Break and ID
- Bedrock Location *(Field Surveyed)*
- 0.25 m Contour
- Watercourse
- Headwater Drainage Feature
- Meander Belt Width
- 8 m Toe Erosion Allowance
  6 m Erosion Access Allowance
- 5 m Toe Erosion Allowance
  6 m Erosion Access Allowance
- Proposed Development Fabric
- Wetland

Study Area and Erosion Hazard Delineation

Tay River and Grants Creek

Perth, Ontario

GEO MORPHIX™

0 125 250
Metres

Imagery: Google Earth Pro, 2018.
Watercourse: RVCA, 2021. 0.25 m Contour: Caivan, 2022 .
Reach Break and ID: GEO Morphix Ltd., 2023.
Bedrock Location, Meander Belt Width: GEO Morphix Ltd., 2022.
Headwater Drainage Feature, Wetland: Kilgour, 2023.
Proposed Development Fabric, 8 and 5 m Toe Erosion Allowance, 6 m Erosion Access Allowance: GEMTEC, 2023.
Printed: February 2023. PN22032. Drawn By: K.M., M.O., K.W.

Appendix B
Historical Aerial Photographs

Location: Perth, ON
Year: 1978
Scale:
Source: National Air Photo Library

Location: Perth, ON
Year: 1991
Scale:
Source: National Air Photo Library

Location: Perth, ON
Year: 2005
Scale: Digital Orthoimagery
Source: Google Earth Pro

Location: Perth, ON
Year: 2019
Scale: Digital Orthoimagery
Source: Google Earth Pro

Appendix C
Photographic Record

Photo 1 Tay River	
	A view of the Tay River channel and north bank near the upstream extent of the Perth Golf Course; perspective is facing south and downstream.
Photo 2 Tay River	
	Bedrock outcrop along the south bank of the Tay River, which borders the northwestern extent of the golf course; perspective is facing east and downstream.

Photo 3 Tay River	
	Trees and vegetation along a low-lying, marsh area bordering the golf course within the floodplain along the south bank; perspective is facing south.
Photo 4 Tay River	
	Bedrock outcrop along the south bank, which borders the northwestern extent of the golf course; perspective is facing south.

Photo 5 Tay River	
	Trees and vegetation along a low-lying, marsh area bordering the golf course within the floodplain along the south bank; perspective is facing south.
Photo 6 Tay River	
	Bedrock outcrop (yellow arrow) near the base of a mature tree along the south bank.

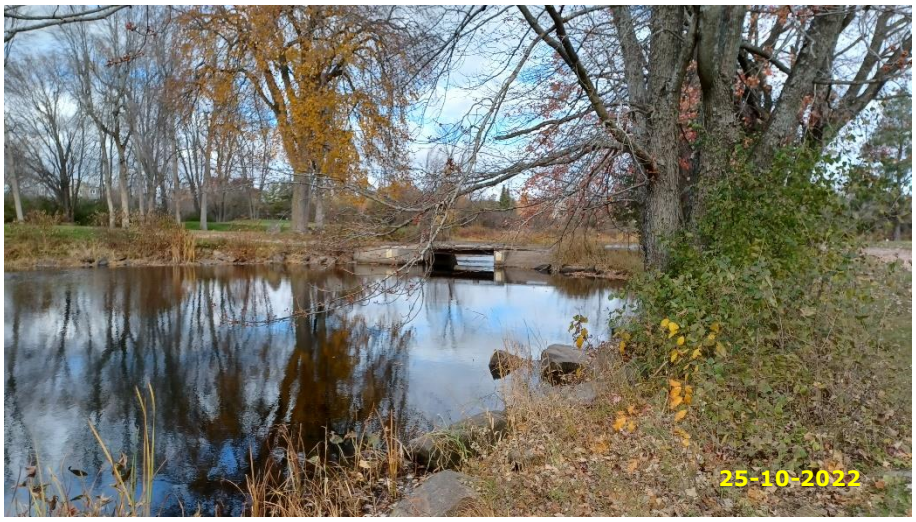
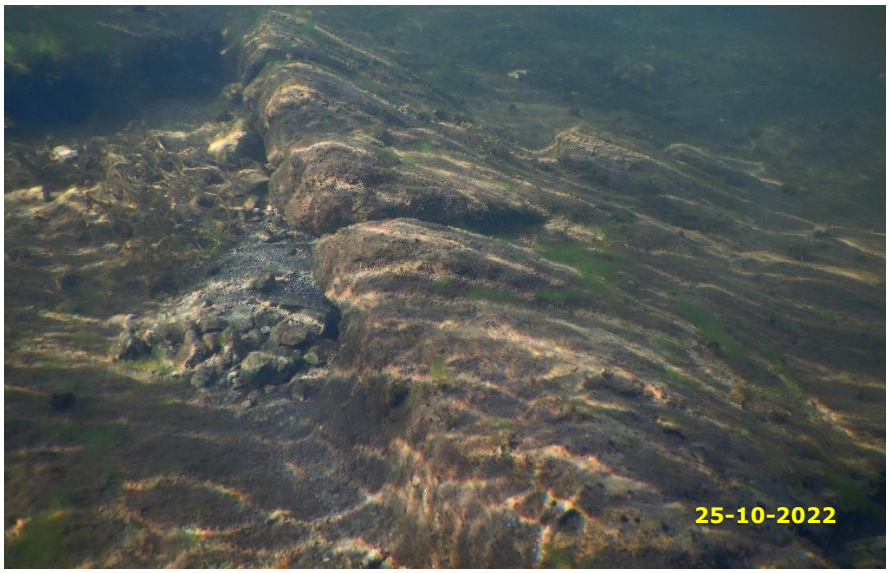
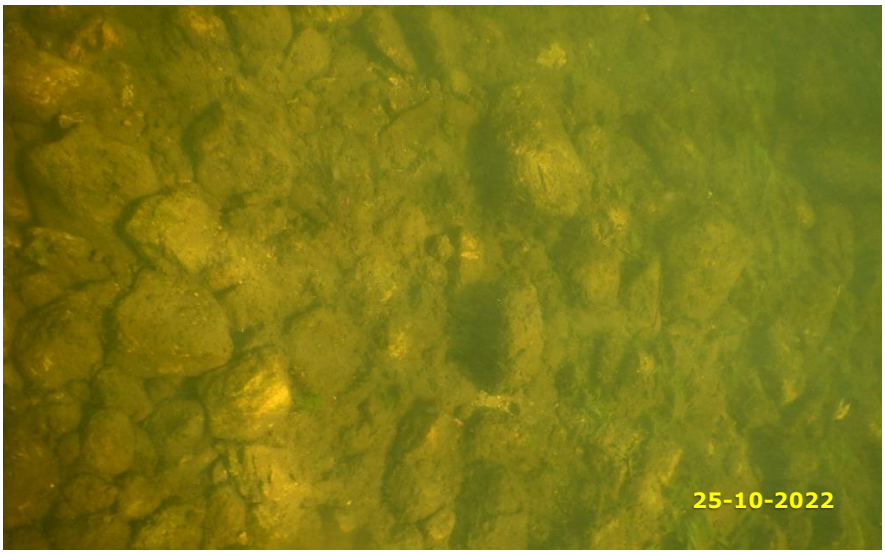
Photo 7 Tay River	
	A weir with an approximately 1-meter drop under a bridge crossing causing a backwatering effect; perspective is facing east downstream.
Photo 8 Tay River	
	Leaning trees along the southwest bank just downstream of the weir.

Photo 9 Tay River	
	Bedrock outcrop (yellow arrow) along the southwest bank.
Photo 10 Tay River	
	Bedrock outcrop (yellow arrows) along the west bank upstream of the Peter St. bridge crossing; perspective is facing southwest downstream.

Photo 11 Tay River	
	Bedrock along the channel bed.
Photo 12 Tay River	
	Cobble and boulder-sized substrate along the channel bed.

Appendix D
Field Observations

GEO | MORPHIX
Geomorphology Earth Science Observations

General Site Characteristics

Project Code: 22029

Date:	2022/10/25	**Stream/Reach:**	Tay River
Weather:	Sunny	**Location:**	Tay Valley GC
Field Staff:	PP, KM, KS	**Watershed/Subwatershed:**	Tay 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

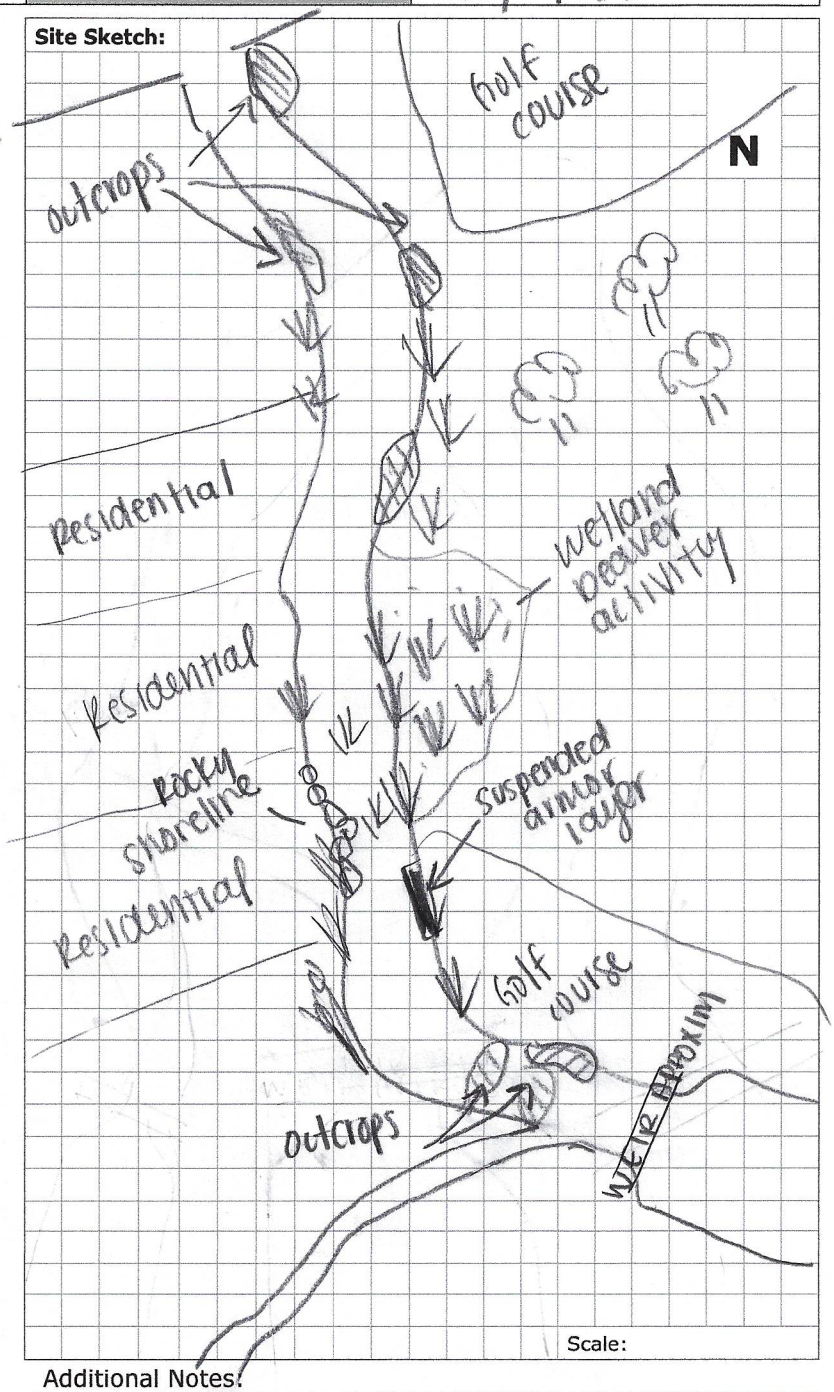
Substrate

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:

Completed by: KM Checked by: _____

GEO | MORPHIX
Geomorphology Earth Science Observations

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Weather:	sunny	**Location:**	Tay valley BC
Field Staff:	PP, KM, RS	**Watershed/Subwatershed:**	Tay river

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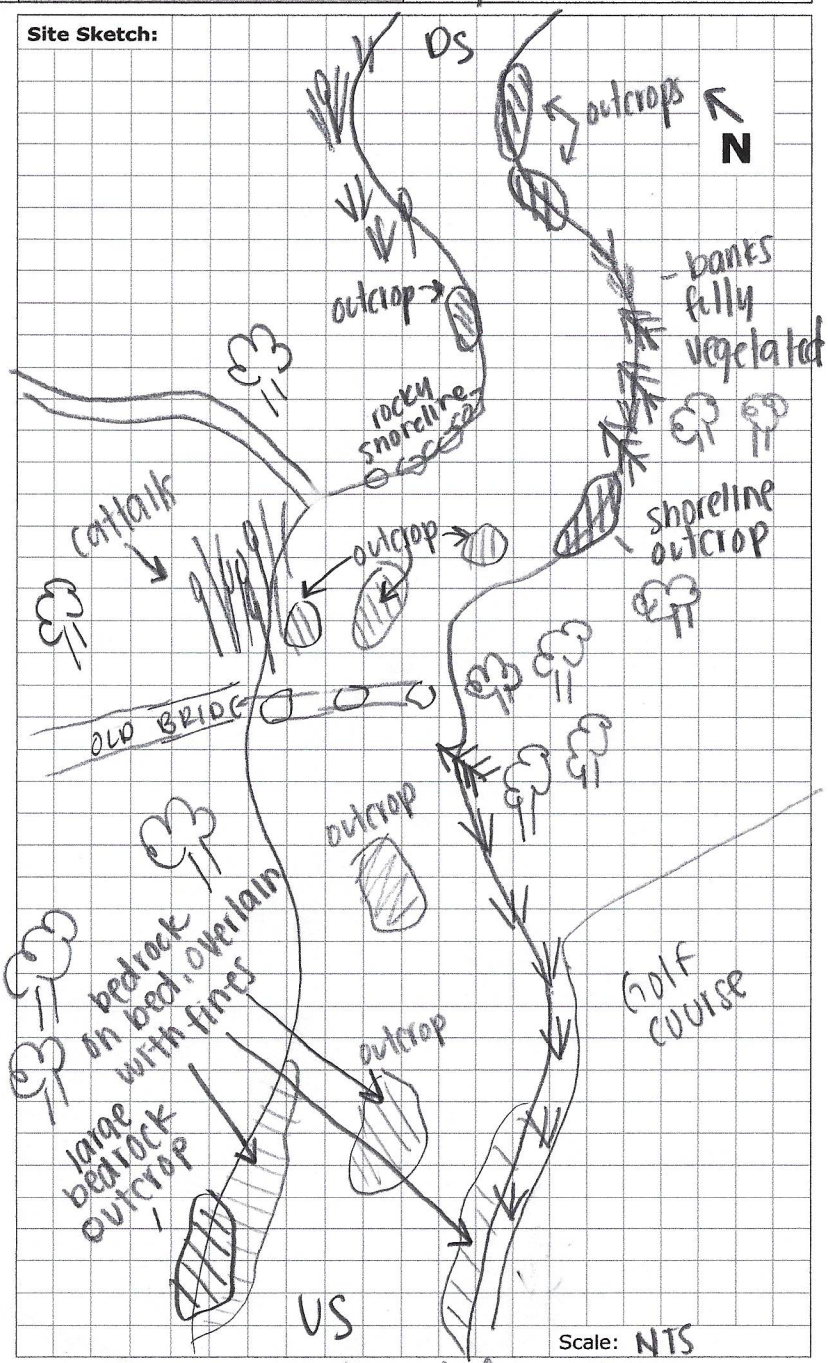
Site Sketch:



Additional Notes: us section before river

Completed by: KM Checked by: _____