

River Morphology and GIS – An Analysis on the usage of geographic Information system techniques in Post Project Appraisals for Stoney Creek, Burnaby British Columbia

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EVSC 205

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ABSTRACT

The Stoney Creek ecological restoration project in Burnaby, British Columbia, was undertaken to address concerns regarding the health of the creek and of the surrounding riparian ecosystem. A Post-Project Appraisal was conducted to assess the progress made following the completion of the ecological restoration project, and to address a knowledge gap pertaining to the geomorphology of the stream. Stream velocity and cross-sectional area data, as well as GPS points were collected at four locations on the stream, and a segment of the stream was mapped using a GPS. The data collected was processed in ArcMap 10 software, and used to produce three maps of the study site, as well as four velocity profiles. The velocity profiles obtained from this study may be used to further our understanding of slope stability in order to predict future changes in the geomorphology of the stream. Other possible uses of the data collected include assessing changes in planform over time and assigning an index of naturalness based on pre-anthropogenic disturbance model of the stream. Moreover, the data collected in this report may help engineers and city planners to predict landslides and debris flows that could be detrimental to the salmon habitat and to nearby infrastructure and roadways. Finally, maps and 3-D visualisations may provide a way for students in EVSC 205 to learn the spatial relations of the work sites from a top down view, and would be a relevant area for future research.

INTRODUCTION

Stoney Creek, located at the base of Burnaby Mountain in British Columbia, Canada, has been an integral part of community life as well as the ecological integrity in the region. It is a place for wildlife education and nature walks for the students of Burnaby Mountain Secondary. Residents can be seen riding bikes, jogging, and walking on the forest trails on a sunny day. In addition to these recreational activities, Stoney Creek also offers a number of ecosystem services. For example, it represents an important spawning route for salmon in the fall. Recently, it has been found that the number of salmon spawning has been negatively affected by overall health of the creek (Stoney Creek Environment Committee, 2013). This has caused concern in the Stoney Creek community as well as the Faculty of Environmental Sciences at Simon Fraser University. The Stoney Creek ecological restoration project was undertaken to address some of the concerns regarding the health of the creek and surrounding riparian ecosystem (Stoney Creek Environment Committee, 2012). Ecological restoration projects, such as these, require analysis of many factors such as water toxicology, soil degradation, vegetation composition, stream invertebrates, and many more. These different measurements then need to be monitored over an extended period of time (Young, 2003). In this way, we not only understand the changes to the ecosystem health from the past to our present day, but we can also predict future fluctuations. The Stoney Creek restoration project was only recently completed and is therefore lacking in the required geospatial and geomorphological data needed to make geographic predictions of stream change. This study attempts to contribute a strong base of data that could be used for this purpose. Four stream surveys (including a velocity profile and cross sectional area of each) as well as GIS analysis was undertaken in order

to minimize the data gap that currently exists surrounding this project. Future data collection strategies and possible ways to utilize this data are also suggested. Future work could include the use of aerial photographs in the prediction of changes to stream morphology and the use of geospatial hydrology data to assess slope stability.

Many aspects of stream health and riparian ecosystem viability carry a high degree of uncertainty. For example, the urbanized nature of the upslope area could increase runoff and contribute to slope instability. This effect could be exacerbated by stream undercutting and changing soil cohesion. Sediment flux could shift away from the gravels that salmon prefer when spawning. These uncertainties are what make data collection and analysis so important.

Although human disturbance may be a factor contributing to salmon habitat degradation, water quality tests taken in the field did not reveal unsafe concentrations of anthropogenic chemicals or pollutants (Appendix A). Other factors that require consideration, and therefore monitoring, include soil composition, slope stability, and bank erodibility. The data collected in this report may help engineers and city planners avoid dangerous and detrimental events such as landslides and debris flows that may not only harm the salmon habitat, but also nearby infrastructure and roadways.

METHODS

Fieldwork was conducted at Stoney Creek in Burnaby, British Columbia and GIS analysis work was done at Simon Fraser University (Fig. 1). Two 360-degree panoramas were taken using a Samsung Galaxy Nexus at the start and end of the Stoney Creek study area. These photos were uploaded to Google Street View and Google Maps, and are now publicly accessible.

Data Collection

Global positioning system (GPS) waypoints were collected at the center of the stream at one-metre intervals, north of Lougheed highway and moving north toward Government Street using a Garmin GPSmap 78s device. The data was uploaded as a GPX file and processed in ArcMap 10 software by ESRI (see Appendix B for definitions). The GPX format uses the WGS 84 datum, with latitude and longitude recorded in decimal degrees, and allows for easy transfer between programs. Cross-sectional area, depth measurements, velocity profiles and coordinates were recorded at four transects approximately ten metres apart along the stream. For each transect wetted and bankfull widths were recorded, and stream depth was measured at one-metre intervals starting from the south bank of the stream using a tape measure. Velocity was calculated at three to four different points along each transect using the time taken for a tennis ball to travel a distance of ten metres downstream from the release point. We used a tennis ball because the water was not deep enough to allow for the use of a velocity meter. Tennis ball release occurred at the line corresponding to the transect (Fig.2). Finally, position was recorded from the south bank of each transect using the GPS device.

GIS analysis

The conversion tool *GPX to kml* was used in ArcMap 10 to process the GPS data. The data was then displayed on a base map from the ArcMap library. A map was produced to compare the collected stream data with data of the stream segment obtained from GeoBase. Coordinates recorded for the four transects were uploaded, processed and displayed following the same procedure, then used to produce a map of cross sectional areas and velocity profiles. Spatial analysis tools *slope* and *aspect* were applied using 30-metre Digital Elevation Models (DEMs) obtained from GeoBase. Geobase is a national portal that provides free access and

unrestricted use to geospatial data. Unfortunately, low resolution of the DEMs prevented us from performing detailed and conclusive analyses. As a result the layers created from the analysis were not used to generate maps.

3- D Geo-visualizations

The DEMs were imported into ArcScene to generate a 2.5-D representation of the data. The spatial analyses of *slope*, *aspect* and *hillshade* were overlaid onto the DEM. These files were then exported and used to create a 3-D representation of the EVSC 205 field site. The DEM could potentially be imported into Unity in the future to create an interactive Virtual Environment of the area.

RESULTS

GPS of Stoney Creek

From the GPS and the import of the waypoints, the line below was generated using the Points to Line feature (ESRI, 2013). The line was then cartographically simplified by removing extraneous bends while trying to preserve the shape (ESRI, 2012). As can be seen, the creek still has extraneous bends, however, the use of the *simplify* tool would have reduced the accuracy of the creek map.

From the map, we can suggest that the creek follows a gap within the tree line, which leads to the next analysis shown in Figure 2, showing that the Data collected from the GPS is much more accurate in comparison to the data collected from GeoBase, the Canadian government initiative that provides free spatial data. The GeoBase representation of the creek

is a very simplified vector of the data initially collected, which may suggest that GeoBase lowers the resolution of their hydrology data.

Velocity Profiles

The first profile measured (A) is located just south of a slight bend in the river planform (Fig. 5). River depth was greatest, 19 cm, near the east bank at the two-meter mark. It gradually became shallower towards the western bank. We found that velocities were greatest (0.72 m/s) in the deepest portion of the river, at the two-metre mark. This is typical of most fluvial systems. As the wetted depth began to decrease towards the point bar on the west side of the river, velocities decreased substantially (0.48 m/s). Velocity could not be measured between the four and five-metre mark because the flow began to diverge, possibly due to obstruction by large rocks, and pulled the tennis ball toward the bank where it continually became lodged. This divergent, slow moving flow is responsible for the sand deposition occurring on the western bank (Fig. 6).

The second profile, entitled B (Fig. 5), is located approximately ten metres north of profile A. Here, the river planform is slightly convex toward the east, suggesting that deposition should be occurring on the west bank (point bar) while erosion should occur on the east (cut bank). However, the cross sectional area shows a fairly uniform wetted depth, about 20 centimetres, and an equally homogenous velocity profile, approximately 0.5 m/s, across this section of the river. Velocity measurements could not be taken between the four-metre mark and the west bank because flow began to separate towards the west bank. This flow separation could be responsible for the slight deepening on the west bank as opposed to deposition that would normally occur on the inside of a river bend.

The third profile (C) is located about ten metres north of profile B and twenty metres north of profile A. Here, the river is fairly straight with only a very slight bend toward the west. The cross sectional area at this location shows the wetted depth as being quite shallow on the east bank and gradually deepening towards the west. Flow velocities are highest at the two-metre mark, 1.0 m/s, where depth begins to increase. Near the east bank, at the four-metre mark, flow velocities are the slowest, about 0.38 m/s. This is particularly noteworthy because we would normally expect velocities to be greatest at the deepest portion of a river. However, this is most likely the consequence of unobstructed versus obstructed flow. In the centre of the river, the tennis ball is free to move relatively unobstructed. Closer to the bank, on the other hand, large rocks, tree branches, and other vegetation create turbulent flows and physical obstructions that could slow the movement of the tennis ball. This location also possessed the greatest discrepancy between the wetted and bankfull depth of all four profiles: 38 centimetres.

The last profile (D) is located about five metres south of profile A, in a straight and relatively narrow reach of the creek. Flow velocities at this point are homogenous across the width at approximately 0.4 m/s. This relatively low flow rate is most likely due to the numerous rock obstructions occurring throughout the river. These rocks create turbulent eddy flows downstream of the obstruction (Fig. 7) and can trap the tennis ball for prolonged periods of time. At one point, the tennis ball got stuck in the wake of a large rock for nearly five seconds. Despite a number of trials, the velocity readings are likely much lower than the true value. The depth of the river is also relatively uniform (average of about 30 cm) with a slight deepening on the west bank. This deepening is likely the result of erosion driven by eddy

currents from the numerous large boulders that cover the western bank in this section of the river.

DISCUSSION

Mass Wasting

In fluvial systems, geomorphology plays a critical role in almost every aspect of biological, chemical, and ecological river function. Discharge, for instance, affects the size, distribution, and flux of incoming sediment. This in turn can affect things such as riparian vegetation composition and salmon habitat viability. The geomorphological and spatial information collected in this report could specifically be used to create an index of naturalness. A reference condition could be determined based on a pre-human disturbance model. This model would need to have information about sediment flux, channel pattern and scaling, channel morphology (riffle, pool, plane bed, etc.), and physical habitat (flow depths, run, glide, etc.). These variables could then be weighted and scored in order to index the naturalness of the river (Sear, et al., 2009). Model outputs would help determine which river sections are highest priority for additional ecological restoration by showing which sections deviate furthest from their natural state.

Changes to channel planform can also be determined with the utilization of data collected from this report. Two possible methods exist for predicting channel response: the use of hydraulic geometric and empirical equilibrium bed equations, or the use of aerial photographs. Aerial photographs from multiple years can be compared to understand past changes and use these to predict future shifts. However, it can often be difficult to obtain aerial photographs as they either do not exist, do not date back far enough, or have licensing/ownership issues surrounding them. Furthermore, the quality of aerial photograph is

often variable depending on cloud cover. Equilibrium and hydraulic geometric equations are more complicated, but do not require extensive fieldwork or instrumentation to utilize.

Understanding how the channel morphology might change in the future can be extremely beneficial in determining other factors such as sediment flux, bed and bank erodibility, and river nutrient cycling.

Geospatial data can also be utilized to understand geomorphological processes such as slope stability. Shear stress and strength could easily be determined with the following information: relief, soil cohesion, depth of the water table, soil and water density, and elevation (Hong, et al., 2011). Many of these conditions can be determined with additional fieldwork; others may exist as geospatial data. Data can then be used to determine a slope safety coefficient by dividing shear strength by shear stress. With several steep slopes surrounding the creek by the Lougheed highway area as well as a significant amount of urbanization, this could be a very useful and low cost post-project appraisal investigation.

The Display and Efficacy of 3-D Visualizations

Maps and 3-D visualisations provide a way for students in EVSC 205 to learn the spatial relations of the work sites from a top down view. Various forms of imagery already exist and have been powerful tools for modeling and analyzing landscape changes.

These visualizations would be useful to predict the future directional flow of the creek. In addition, these models can aid in local management practices to better protect the area from soil erosion, etc. The use of past to present orthophotos would have increased the viability of doing a slope erosion analysis. By using 3-Dimensional (3-D) geo-visualization on 2-Dimensional (2-D) displays, this project will be able to create depth cues and high levels of detail not seen by

2-D maps. In addition, by using 3-D visualization techniques, that are closest to the normal human perspective (Meng, 2002), more geographic variables can be shown and understood while keeping the cognitive load low to the user. 3-D visualization contented can also enhance the understanding of people perceptions of spatial knowledge (Maceachren, 1994)

Higher resolution DEMs without cloud artefacts would have provided data for an intriguing and dynamic analysis because combined with orthophotos, it is possible to plot past and future creek morphologies. Slope analysis would have also been helpful in determining the risks of slope soil erosion. These analyses can be carried out in ArcScene, a 2.5 dimensional representation of the area, to learn the risks of coastal erosion in Stoney Creek. However, with minimal previous knowledge of the end-user interface, the analysis was not feasible.

From the DEM, further 3-D visualizations can be created that are easier for an end user. DEMs can be easily imported into game engines such as Unity 3-D and Cryengine, for applying spatial analysis. This provides a unique and powerful 3-D representation. Using the game engines, a “sandbox” of Stoney Creek could have been created to allow students to first experience Stoney Creek before conducting research. This sandbox would allow students to identify areas of potential risk and model soil erosion using a dynamic and interactive approach before designing their Post Project Appraisals. In addition, they would not have the usability barrier ArcScene does. Since these game engines can export into a variety of platforms, these visualizations can be easily disseminated. However, the 3-D game engine visualizations are harder to build and require a programming skill set. Moreover, data interoperability methodologies must be in place for individuals to easily transition between ArcMap and Unity as complex analysis must still occur in GIS software before it is imported into a 3-D Game engine. Overall, there is high potential for 2-d or 3-d visualizations to be used in the ecological

restoration site of Stoney Creek. However, high-resolution data must be either collected or found for an accurate and precise analysis.

A mapping of the relative wetness and land cover in a watershed to rank the potential suitability for riparian restoration would aid in the prioritization for restoration in field site (Russel, et al., 1997). However, for this analysis to be complete, Digital Elevation Models would have been needed. However, for the project, the DEM's located were low resolution with interference from clouds. Thus, the model was not run.

Development Pressures

The region surrounding Stoney Creek is largely developed, but some areas are still awaiting residential and commercial development. This situation puts Stoney Creek at risk of development pressures such as increased flooding and increased pollutant loading (Praskievicz & Chang, 2011; Atasoy, et al., 2006). In their modeling study, Praskievicz and Chang (2011) found that flooding was more likely to occur in a development scenario, and less likely to occur in a conservation scenario in the Tualatin River Basin. Atasoy et al. (2006) found in their study that the extent of urban residential land use and the amount of conversion of land to residential use both significantly increase nutrient pollutant loadings. Our study captures Stoney Creek conditions for a moment in time. Researchers with an interest in Stoney Creek can combine the velocity and depth data we produced with construction and land use data at the same time, and then compare the information to future conditions of interest to see if the stream conditions are degrading. Researchers in the short term could take pollutant measurements in sections of the river where adjacent construction sights are known to supplement the EVSC 205 data for a comprehensive examination of Stoney Creek's development pressures.

CONCLUSIONS

With a better understanding of the morphology of Stoney Creek, we can increase the accuracy of future predictions relating to it. Predicting channel response is very complex and requires the analysis of multiple factors. In an attempt to initiate this data collection, we have begun to create a three dimensional map of the area. By comparing this map to old aerial photos of the area collected from GeoBase, and factoring slope stability, precipitation, infiltration and other soil and vegetation characteristics, we can predict future shifts in stream morphology and health.

Urbanization has contributed to making Stoney Creek prone to the urban stream syndrome (Walsh, et al., 2005). Restoration projects can never fully be successful if they do not work together with development engineers. An effective restoration will help support road infrastructure of an expanding society while maintaining the health of Stoney Creek for salmon spawning habitat. This stream is much more than a community escape of peaceful and quiet forested area. The stream provides society with a multitude of ecosystem services, as well such as fresh air, beautiful flowers, birds and animals. This is part of the reason that it is critical that a number of parties work together. This is why we must work hard to keep this stream in good health. In order to do this however, more data must be collected. Our recommendations for future investigations can be used as a guide for forthcoming students who will continue to monitor the Stoney Creek Restoration Project.

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Figures and Tables

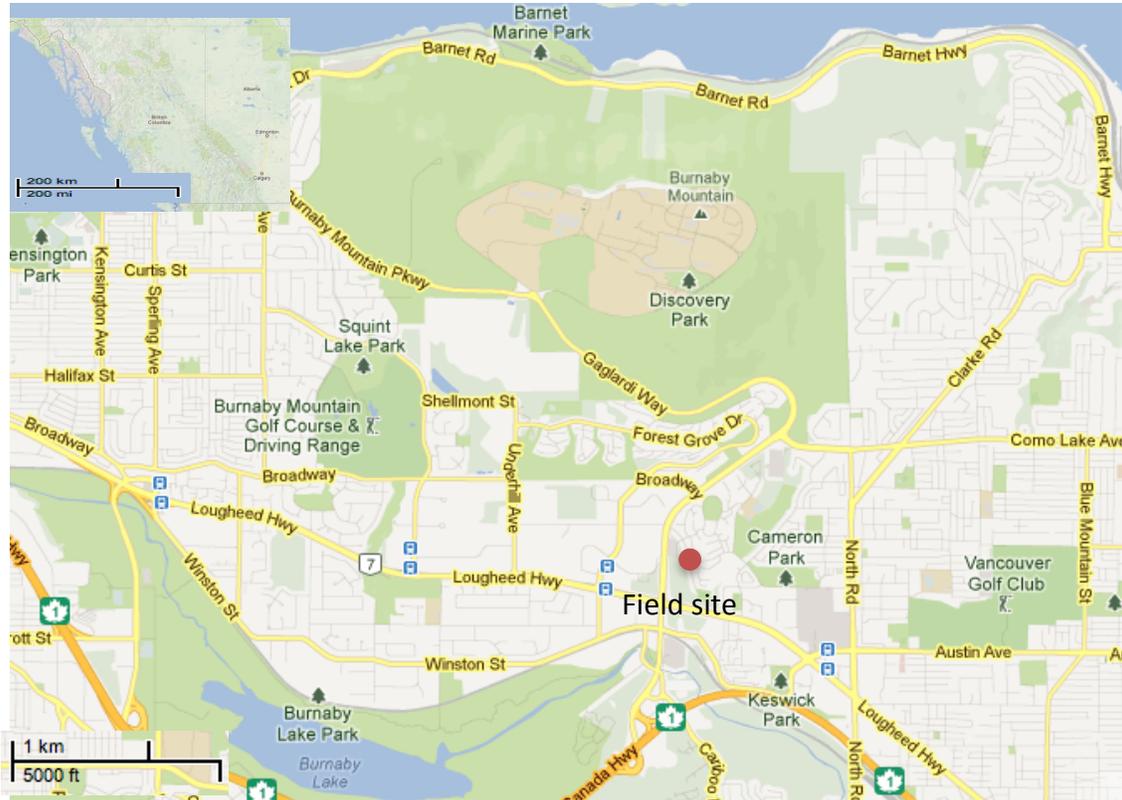


Figure 1 - Location of the field site and of SFU Burnaby in the Greater Vancouver region.



Figure 2 - Velocity profile measurements at transect B, interval four. The tennis ball was released just below the line corresponding to the cross-section. The pink tape indicates one-metre intervals along the transect.

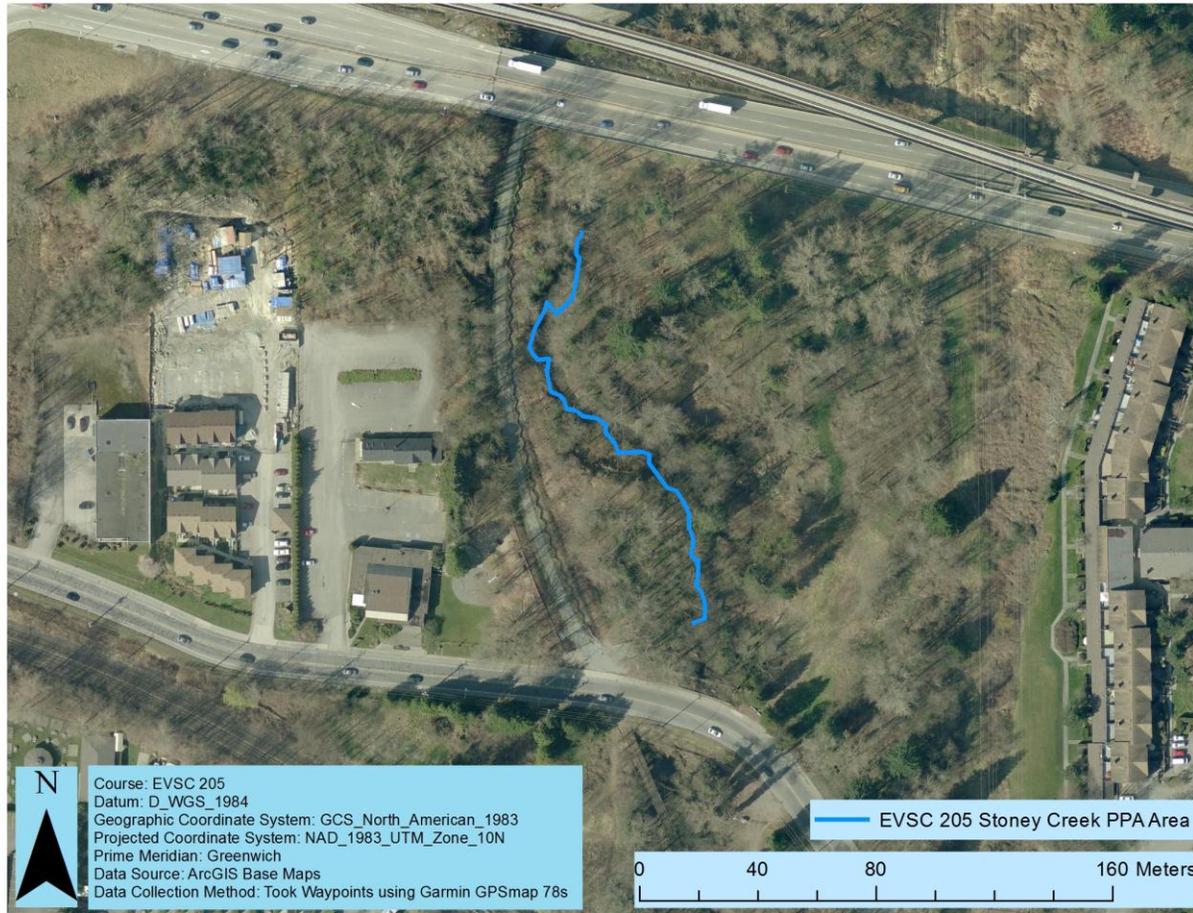


Figure 3 - A map of the post project appraisal study area at the base of Burnaby Mountain. The major street at the top of the image is Lougheed Highway.

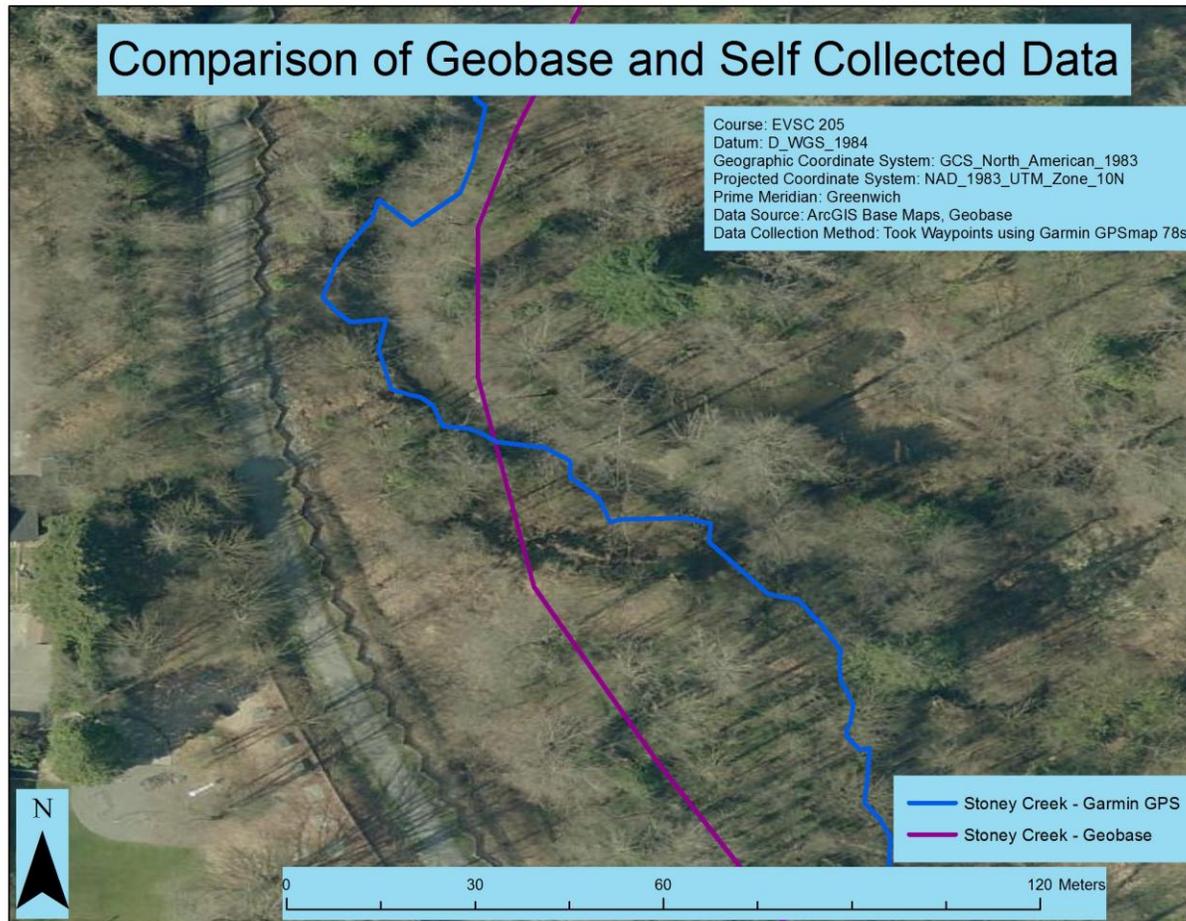


Figure 4 – This is a comparison of two datasets, one retrieved from GeoBase and one collected from a Garmin GPS.

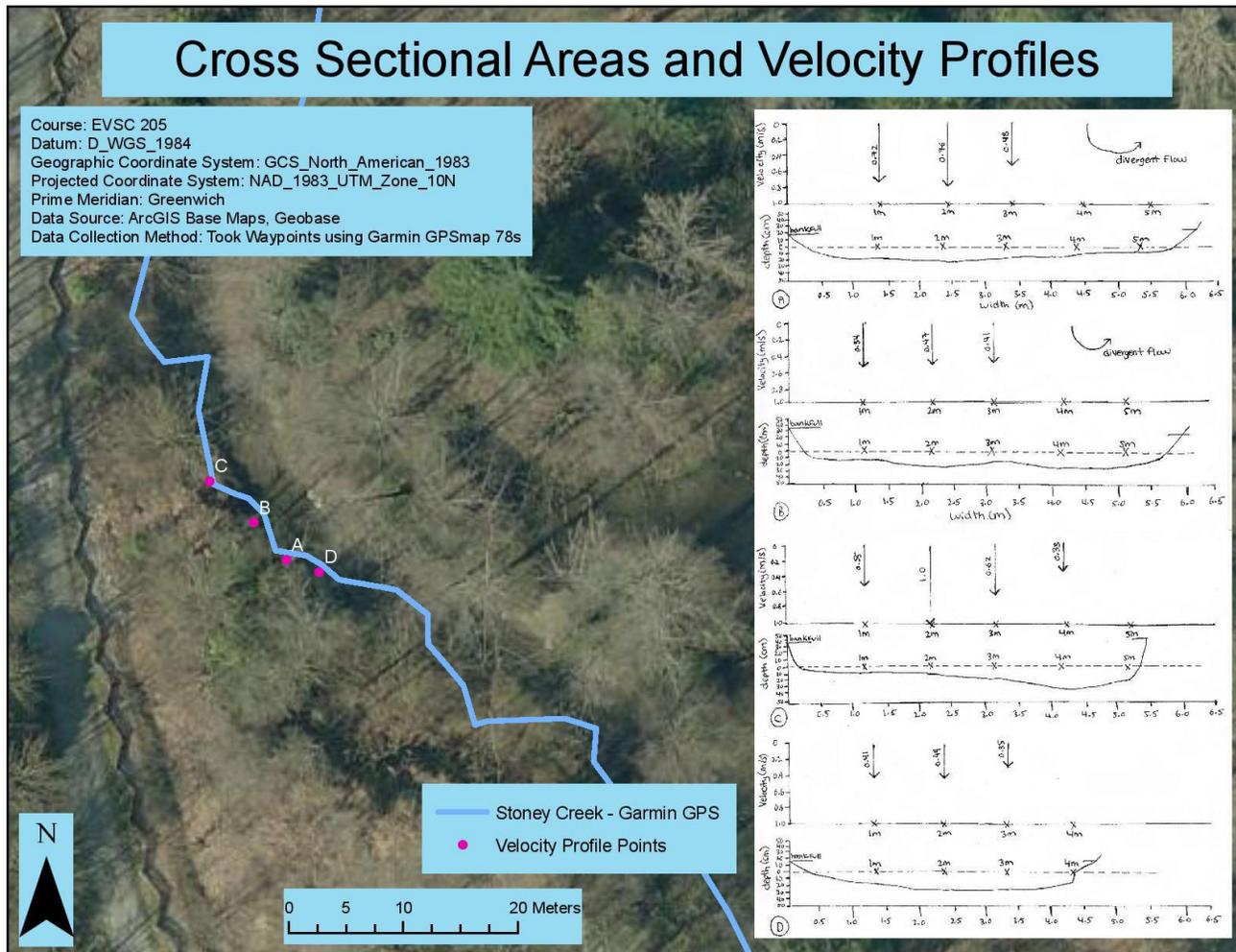


Figure 5 - Cross sectional areas and velocity profiles of four mapped locations on Stoney Creek. The velocity vectors are proportional and use the same scale in each graph. Note that the divergent flow/flow separation arrows are not to scale and only serve to indicate the direction of flow. The left side of each graph corresponds with the eastern bank.



Figure 6 Sandy deposits on the western side of creek profile A. This was most likely deposited by slow moving flow separation occurring on the west bank.

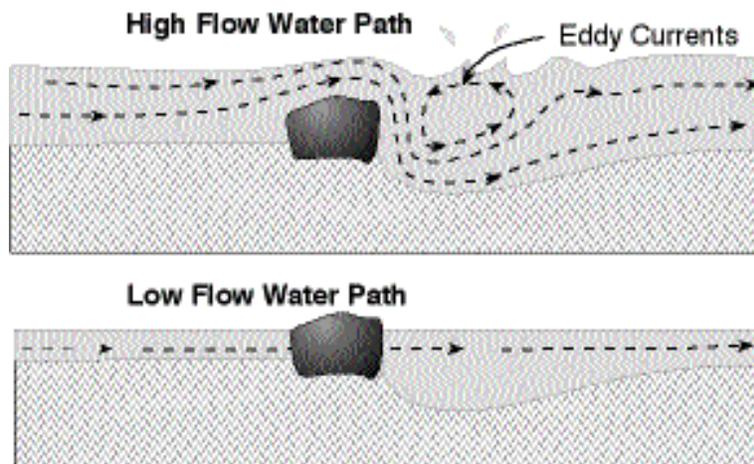


Figure 7 Example of eddy current formation due to a rock obstruction.

Source:
http://www.dnr.state.oh.us/water/pubs/fs_st/stfs20/tabid/4175/Default.aspx

Appendix A
Water Quality Lab

Indicator	Result	Weight	Q	Index
pH	7.7	0.11	80	8.8
Turbidity (ft)	2	0.08	15	1.2
Upstream Dissolved O2 (mg)	13.58	0.17	15	2.55
Downstream Dissolved O2 (mg)	13.79	0.17	15	2.55
Upstream Temp change (°C)	2.8	0.1	80	8
Downstream Temp change (°C)	2.5	0.1	80	8
Nitrate (ppm)	0	0.1		
Phosphate (ppm)	0-1	0.1		
TDS	100	0.07		

Appendix B - Definitions

GIS – Geographic Information systems are designed to capture , store, manipulate, analyze manage and present al types of geographic data

360 Degree Panoramas Generated by Google Street View and Google Map – a service provided by Google maps that uses crowdsourcing to share 360 degree panoramas of the world

Global Positioning System – a spaced based satellite navigation system that provides local and time information anywhere on or near the earth

Geovisualziation – a family of techniques that provide visualizations of spatial and spatio-temporal datasets from 2-D static maps to 3-D dynamic maps.

Waypoints – a reference point in physical space used for the purpose of navigation

GPS Exchange Format– GPX a lightweight data format based on XML used to interchange GPS data

Keyhole Markup Language – (KML) an XML notation for expressing geographic data. KML is an international standard for the Open Geospatial Consortium

WGS 84 Datum – the World Geodic System is a standard in cartography that assumes the earth is a spheroidal reference surface. The most current version is the WGS 84 Datum

GPX TO kml – a service that converts GPX to KML files <http://gpx2kml.com/>

Base Map – ArcGIS’s pre-rendered and pre-cached base maps and reference layers

ArcMap – Esri’s ArcGIS suite is a series of geospatial a processing program that is used to view, edit, create and analyze geospatial data.

GeoBase – A Canadian governmental initiatives overseen by the Canadian council on geomantic. It is a database that provides free geospatial data of Canada.

Slope –The slope tool in ArcGIS calculates the maximum rate of change between cells and their neighbours to calculate a degree of slope from a raster dataset

Aspect – an ArcGIS tool that calculates aspect that determines slope direction of a raster dataset

Hillshade – a ArcGIS too that computes hillshade values that illuminate angles and shadows

Unity – a 3-D game engine that can be adapted for geovisualization techniques.

All definitions were retrieved from Wikipedia, ESRI Help and Geospatial Analysis, A comprehensive Guide to principles, techniques and Software Tools