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Monitoring Fluvial Sediment Transport in the Gorge Creek Estuary in Esquimalt Gorge Park, Victoria BC

ABSTRACT

The Gorge Creek waterway is scheduled to undergo another transformative restoration project, adding to its long history of anthropogenic influence. While the plan remains in its developmental stage, the Gorge Waterway Action Society (GWAS) aims to obtain a variety of ecological baseline data on the creek to act as foundation for the restoration framework. Little is currently known of the sediment dynamics within the creek aside from purely visual observation of fledgling sand bars and substantial sediment deposit within the catchment ponds. Anthropogenic fluvial sedimentation can result in covered spawning areas, suffocated vegetation, smothered eggs and larvae, reduced microorganism diversity, reduced fish visibility and light penetration, and decreased Carbon capture, as well as the introduction of excess nutrients and contaminants (Rex, 2002). Understanding fluvial sediment transport and deposition within the Gorge Creek will help to shed light on its ecological dynamics and provide insight for informed rehabilitation and management. Additionally, the findings can be integrated into the broader Gorge Waterway Baseline Analysis project.

1.0 SITE DESCRIPTION

Situated on the Southern coast of Vancouver Island, the study area is in the Township of Esquimalt, on the traditional, ancestral, and unceded territory of the Songhees people. The city exhibits a sub-Mediterranean climate promoted by its location on the west coast of the Salish Sea, in the rain shadow cast by the mountains of the Olympic Range and the Vancouver Island Ranges. The area receives over 2000 hours of sunshine annually, an average precipitation of 705mm, and an average temperature of 10°C. Set alongside the Gorge Waterway within Esquimalt Gorge Park, the sample sites stretch upward through a 500m brackish estuary until the creek tunnels beneath Craigflower road, beyond the park boundary. Figure 1 shows the downstream view from each of the six sampling sites along this section of creek.

Figure 1. Downstream views from each sediment sapling site on Gorge Creek in Esquimalt Gorge Park, Esquimalt, BC. Pictured in each photo is the measuring tape used to measure stream width and mark locations for bathymetric measurements. A) Downstream from site 1a. B) Downstream from site 1b. C) Downstream from site 2. D) Downstream from site 3. E) Downstream from site 5. F) Downstream from site 6.

2.0 METHODOLOGY

2.1 Site Selection

Gorge Creek has a series of inflows, drainages, and catchment ponds (hereby referred to as sediment influences) that spread along the estuary's expanse as it runs north from Craigflower road. To achieve an understanding of sediment dynamics within the system, multiple sites were established above and below these sediment influences. For consistency and simplicity, the eight sites of the Gorge Waterway Extended Baseline Project (GWEBA) were selected and parsed into six for this study. These sites are highlighted in red in Figure 2. GWEBA collects baseline stream quality data, and the selected sites were chosen for their positions relative to the sediment influences. Beginning at the Craigflower culvert, the first site of the GWEBA project is separated in two (1A & 1B), as a concrete storm-overflow divider splits the Creek in two. Sampling occurs on each adjacent side as one offshoot travels through a sediment catchment pond while the other bypasses it completely, both converging again 40m below at site two. Site three lies further downstream, below a drainage from Gosper Crescent known to input hazardous foreign particulate and sediments into the system. The last two sites of the study, sites 5 and 6, lie above and below the final sediment catchment pond in the creek; Site 4 was not suitable for the study.

Figure 2.
The sites selected for sediment sampling in Esquimalt Gorge Park, Esquimalt BC. The map shows the sampling points used for the Gorge Waterway Extended Baseline Project. Of these, six sites were chosen for sediment sampling (seen in red boxes). The first two points, 1a and 1b, are both at the Gorge Creek Craigflower Culvert.

2.2 Volumetric Sediment & Stream Velocity Measurement

To estimate the rate of sediment discharge, the flow velocity and suspended load transport (amount of suspended sediment per volume) were collected at each sample point following United States Geological Survey (USGS) guidelines (Diplas *et al. 2008)*. At each of the cross-sectional point samples, stream basic bathymetry characteristics were recorded using a wading rod and field tape, and the width of the channel was divided into three equal segments for separate velocity and suspended sediment measurements. Streamflow was measured in each segment using a SWOFFER 2100 Handheld Open Stream Current Velocity Meter at 2/5ths of the total water column's height above the stream bed, as this is roughly the averaged speed of a column's velocity (Diplas *et al. 2008)*. Figure 3 represents a large theoretical stream divided into several equal segments in which each ideal flow sampling height is displayed in red. As Gorge Creek is significantly smaller than the model presented in Li *et al.* (2005), the model was simplified and three sampling points were used.

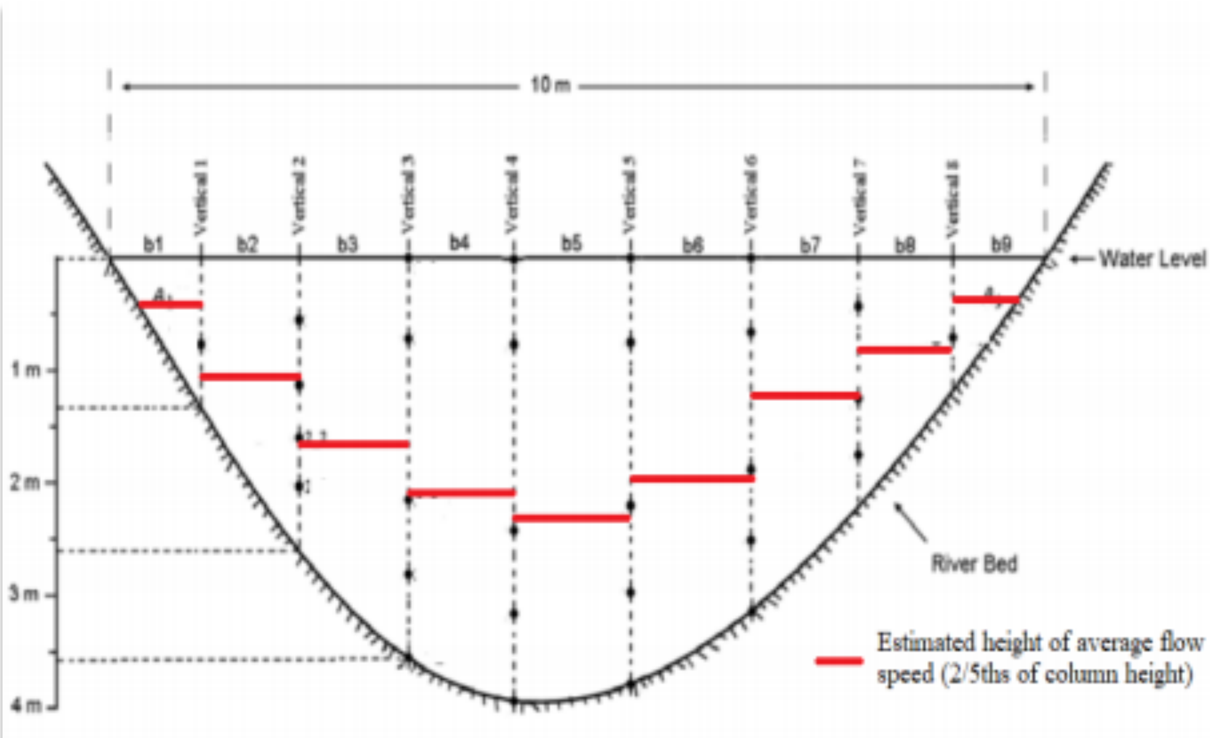

Figure 3. Theoretical river model from *Quality control of 21 years of monthly meteorological and hydrological data in the Coarse Sandy Hilly Catchments of the Loess Plateau, China* written by Li *et al.* (2005). The river, shown in cross section, is 10m wide and 4m deep with vertical segments used to separate each theoretical water column. The estimated height of average flow speed has been highlighted in red.

Mechanical volumetric sampling is a sampling method for the measurement of suspended sediment. This study used a home-made mechanical bottle trap to capture sediment. It was modeled on the USGS DH-48 bottle (See Figure 4). With predetermined entry dimensions and catchment volume, the bottle is lowered vertically into the center of each stream segment at a constant rate and is then returned at the same rate to the surface after reaching the bottom of the water column. The instrument is designed as an isokinetic sampler, resulting in a uniform flow rate of sediment into the catchment that is equal to streamflow velocity, eliminating eddies and disturbed flows that skew accurate sediment collection. The collected sample is then analyzed through an Imhoff cone as a sediment concentration: the amount of sediment per water volume (ml/L). Given area (m^2) through bathymetric measurements and velocity (m/s) through streamflow recording, total stream discharge (m^3/s) can be obtained and applied to the sediment concentration (ml/L) for total sediment transport.

Figure 4. Instruments for the isokinetic sampling of suspended sediment in flowing waterways. A) The United States Geological Survey DH-48 bottle used to sample suspended sediment across North America. B) The home-made bottle constructed to sample the suspended sediment load of Gorge Creek in Esquimalt Gorge Park, Esquimalt, BC.

The sampling regiment aims to obtain data equally during high, low, and mid tide events throughout the week. It is visually evident that flow rate changes significantly with tide height and precipitation, so additional measurements during and after large rainfall and snowmelt events help to quantify the dynamic relationship between sediment transport and the surrounding ecosystem. In order to accomplish all these goals, stream width, three bathymetric depths, flow velocity, and suspended sediment concentration were measured at each site. Each sample entry was also accompanied by environmental data (*i.e.* date, location, time, tide height, relative tide range, and time since last precipitation event).

3.0 RESULTS & DISCUSSION

3.1 Limitations

The suspended sediment sampler was completed February 18th and the velocity meter was obtained on February 23rd, leaving little time for an adequate diversity of tide height samples. From late February to the end of March a total of 18 days were sampled, and 90 data points were recorded. Due to these time constraints, the scope of the project shrunk, and streamflow velocity sampling could occur only at the stream input and output sites. The most impactful limitation of the research project, however, was the inability to accurately measure sediment concentration at the low volumes collected. There were two days where a visibly measurable amount of suspended sediment was obtained during sampling. Those days were during and after the peak of a large snowstorm melt that occurred near the beginning of February. Otherwise, every sample taken throughout the rest of the program revealed a sediment concentration so minute it was not measurable by mass calculation or observation through an Imhoff cone. Additionally, February and March were unseasonably dry and lacked the precipitation common to the area in late winter. It was expected that precipitation would be higher, and the resulting flow would produce measurable sediment samples. Sediment discharge values were recorded as 0 throughout the sampling period as a result of the unexpected conditions.

3.2 Data Analysis

Table 1 below shows the summarized stream velocity data obtained between February 23rd and March 25th. Figures 5 and 6 display the relationship between tide height and stream discharge. The full dataset can be found in the GWAS google drive.

Table 1. Rate of stream discharge for Gorge Creek in Esquimalt Gorge Park, Esquimalt, BC. Discharge rate was measured at the culvert where the daylighted segment of the creek begins (labelled Input), and where the creek flows into the Gorge Waterway (labelled Output). Average water volume discharged per second and per day were calculated using these measurements.

Site	Avg. Discharge per second (L)	Avg. Daily Discharge (L)
1A&B (Input)	43.8	3.78 million
6 (Output)	49.1	4.24 million

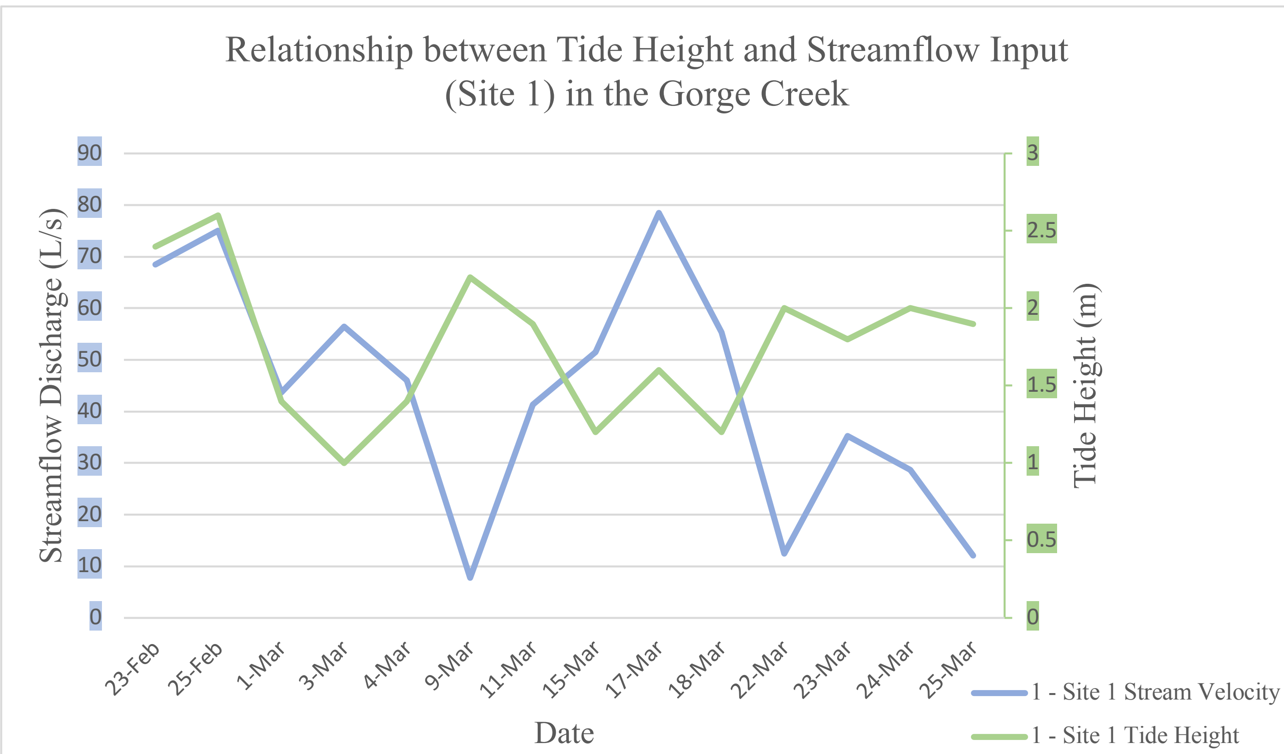

Figure 5. Stream flow of Gorge Creek in Esquimalt Gorge Park, Esquimalt, BC at the Craigflower Culvert plotted beside local tide height at the time of sampling for the sampling period. Streamflow discharge, measured in litres per second, can be seen in blue. Tide height, measured in metres, can be seen in orange.

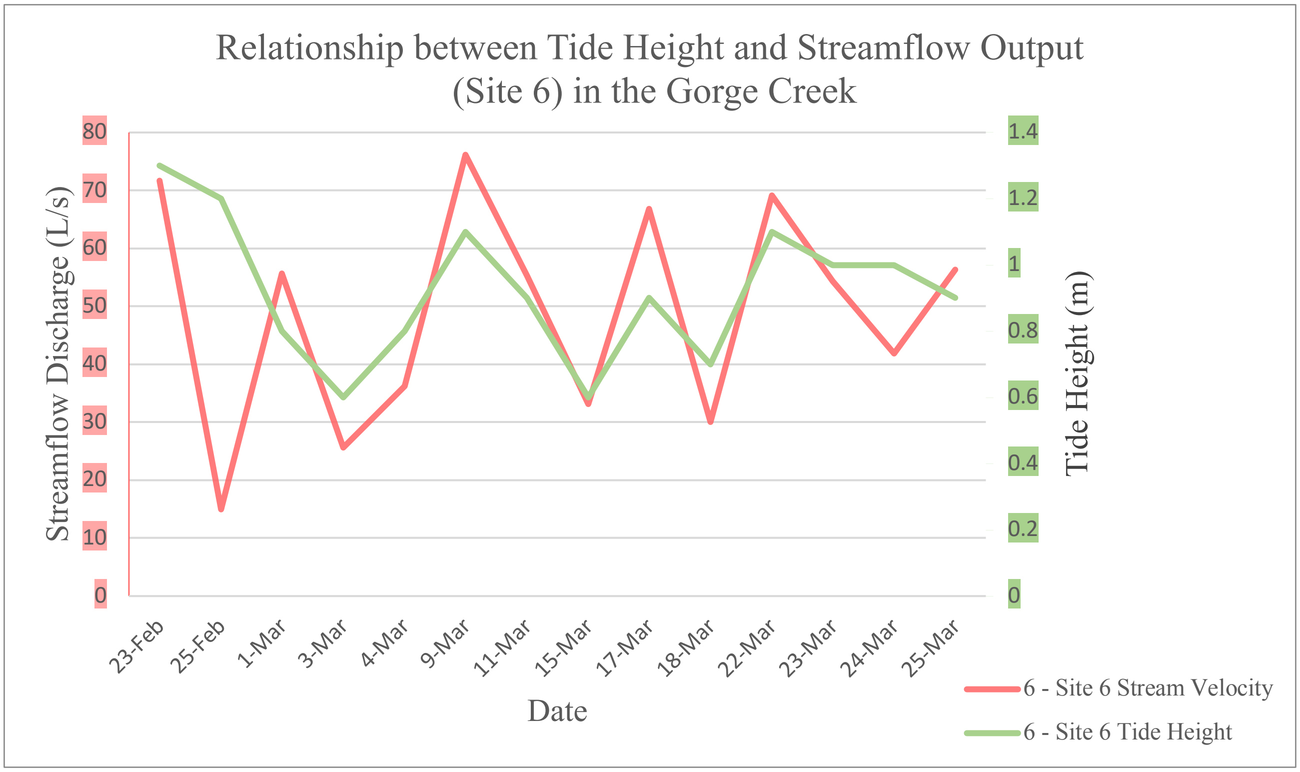

Figure 6. Stream flow of Gorge Creek in Esquimalt Gorge Park, Esquimalt, BC at the mouth of the estuary plotted beside local tide height at the time of sampling for the sampling period. Streamflow discharge, measured in litres per second, can be seen in red. Tide height, measured in metres, can be seen in orange.

Tide height appears to have a positive relationship with streamflow discharge at site 6 and a negative relationship at site 1. Due to such a short sampling period and broadly estimated bathymetry values, however, there is not enough data for interpretation and these relationships cannot be supported statistically.

3.3 Recommendations

It is recommended that the sampling method be refined and implemented over a longer period. The best sediment-dynamics research projects use long term monitoring and consistent methodologies to accurately model fluvial systems. To produce meaningful results, future surveys should use more sensitive sampling techniques and collect more data. Due to the low levels of observed sediment, leaving a volumetric sampler for an extended period of time would allow the collection of more sediment, providing better data resolution. This would more accurately represent the transit fluctuations and true average of transported sediment over time. Additionally, a bedload sampler would provide data on a currently unrepresented section of the stream.

More sensitive measurement equipment should be used. In the case of Gorge Creek, the fine sediment could be measured to a far greater degree with an in-situ or optical laser instrument. Though expensive, an Optical Backscatter Sensor (OBS) or Acoustic Doppler Current Profilers (ADCPs) could be used to great effect due to their continuous data capture and high resolution (0.2μm). These devices would require little maintenance, making them ideal for an organization with seasonal staff. The project would benefit greatly by observing sediment deposition (sedimentation) directly by incorporating direct measurement instruments. Sediment pins are poles installed on the streambed, and the height of the pole is continuously measured to show sediment gain or loss at millimetre resolution. Sediment plates are pallets deposited in areas of soft sediment at surface level and measured for sediment accumulation over time. Both are easy, inexpensive, direct, and can be used to calculate sedimentation and erosion.

Outside of field data, complementary open-source data obtained from the LANDSAT series could provide high resolution spectral data for sedimentation and turbidity analysis within the creek. Using the visible spectrum, and band combinations 4, 5, and 1, sedimentation in water bodies can be easily identified and a general severity can be inferred. It is recommended that spectral analysis of LANDSAT images be investigated as a complementary study method.

4.0 CONCLUSION

Despite the limitations, a solid foundation of sampling procedure and baseline values have been attained. Additionally, GWAS now possesses solid estimates of stream bathymetry and velocity throughout Gorge Creek. Accurately measuring sediment dynamics is not something that can be done well within a month. The nature of sediment research is protracted and requires continuous all-season monitoring to create a large and high-resolution database to be adequate for analysis. Like most environmental work, it will require sustained effort by determined researchers.

5.0 ACKNOWLEDGEMENTS

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6.0 REFERENCES

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Tide Data retrieved from: https://www.tides.gc.ca/eng/station?sid=7125

7.0 APPENDIX

7.1 Materials

Type and number of (labeled) bottles and containers, extras

Field equipment such as meters (with adequate trouble-shooting equipment) Wading rod, measuring tape, stakes

Log books

Personal gear (for all possible weather conditions, e.g., rubber boots, raincoats, First aid kit

Camera or video equipment as required for site pictures and GPS

Scale, Imhoff cone, sediment jars

Rainfall Sampling: Aim to sample during or within 2 hours of significant rainfall event; ideally just after peak precipitation

7.2 Sediment Database Guidelines

There are important issues to consider when navigating the spreadsheet. This file is on the GWAS google drive, labeled Sediment Database.

-Don't delete or rearrange any vertical columns: There is a recorded macro that implements the text to columns function (separates multiple values within the same cell to separate columns) and its code is designated to specific column characters.

-Tide Range is as follows: 0-0.6 Low
0.7-1.0 Mid
1.1-… High

-Last Precipitation values: 0 – Currently raining
2< Rained within last 2 hours
12< Rained within last 12 hours
24< Rained within last 24 hours
Blank – Hasn't rained for over a day

-Depth and Velocity values (3 within each cell) are separated by one space, as that is how the macro identifies and divides the values into the columns to the right (W/X/Y

AA/AB/AC).

-Macro: After placing your values, press Ctrl+Q, and click yes to overwrite data. This will populate the columns to the right outside of the main table, and the Water Discharge Column should auto populate using the formula. The formula format can be dragged down and extended automatically to cells below.

-Themes: If you care about color coding, use the themes “Custom :D” and “Normal.”

-General: The dates and sample sites can also be copied and dragged down, and they maintain theme and auto-population capability.

7.3 Upstream Pictures

Upstream views from each sediment sapling site on Gorge Creek in Esquimalt Gorge Park, Esquimalt, BC. Pictured in each photo is the measuring tape used to measure stream width and mark locations for bathymetric measurements. A) Upstream from site 1a. B) Upstream from site 1b. C) Upstream from site 2. D) Upstream from site 3. E) Upstream from site 5. F) Upstream from site 6.


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