**Assessment of Past and Present Sediment Quality of Stoney Creek in Burnaby, British Columbia**

Craig Busch, Weiyi Kuang, Raffaella Marascio, and Linda Zhao

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Thomas Rodgen and Catherine Parsons

Abstract: In analyzing the sediment and water quality of the Stoney Creek habitat, four key aspects were investigated: lithology, sediment/water quality, salmon spawning/incubation, and particle size distribution. The lithology found the streambed sediment layer is 3 cm in depth (over bedrock) and consists mainly of sand and some coarser material including gravels, cobbles, and boulders. The sediment of the off-channel pond is mainly mud (fine material) with a moderate amount of sand and a very small percentage of coarser material including gravels and organic matter (leaf detritus and woody debris). Chemical analysis concluded a significant concentration of iron in the pond environment, with potential for adverse effects to salmon offspring. This report further aims to assess the influences of fine sediment on the quality of salmon spawning habitat and incubation success rate. Permeability of spawning gravels and dissolved oxygen concentrations are measured to see if they support the incubation and growth of salmon eggs. Particle size distributions are found significantly different between upstream pool and pond side. And the difference of particle size distributions can influence salmon production in the off-channel site.

**Introduction**

Several components of creek ecosystems, from invertebrates and their habitats to water quality are related to sediment quality (RAMP, 2013). Evaluating the chemical and physical aspects of sediments in creeks sheds lights on the dynamics and overall health of fluvial ecosystems (RAMP, 2013). Furthermore, measurements of sediment quality can also lead to findings regarding anthropogenic influence on aquatic ecosystems (RAMP, 2013).

The following is an assessment of the past and present sediment quality of a Stoney Creek field site off of the Burnaby Mountain Urban Trail (49.251329, -122.909557) in Burnaby, British Columbia, that investigates whether sediment quality has been restored or improved in the area (by the Stoney Creek Off-Channel Habitat Improvement Project) and how salmon habitat quality and spawning activity are affected as a result.

**Methods**

The methods applied in conducting this assessment allow for insight of stream sediment quality versus that of the off-channel pond (fish habitat), past versus present sediment quality in both environments (i.e. changes over time), and the influences of sediment quality on salmon activity in the area.

The dissolved oxygen concentration of the pond and stream were recorded with a dissolved-oxygen meter on April 2$^{nd}$, 2013. According to Soulsby et al. (2001), dissolved oxygen concentration is indicative of the oxygen supply required for salmon and egg incubation and hatching/survival success rates. The water velocity of both the pond and stream were recorded with a velocity meter on April 2nd, 2013. Water velocity is a parameter for determining the infiltration of water (with required oxygen and nutrients) through pond and streambed material in terms of salmon and egg health (Barnard and McBain, 1994).

Water quality was investigated in both the stream and off-channel pond being that it is a good indicator of sediment quality (RAMP 2013). A LaMotte test kit was used in the field (April 2nd, 3012) for determining the levels of several chemicals in the water including copper, iron, nitrate, nitrite and phosphate. Levels of calcium, chlorine and iron in both the pond and stream water were recorded in the laboratory (February 26th, 2013) using a test strip water quality kit. Hardness, alkalinity, and pH were also measured using this method. Turbidity and temperature change (dissolved oxygen probe) were also recorded (April 2nd, 2013) as variables for water quality.

A sample of streambed sediment (3cm) was collected (April 9th, 2013) from the water/streambed interface and down to the underlying bedrock; the sample was stored in a clear glass vessel for further observation and qualitative analysis.

A sediment core was collected (April 9th, 2013) from the off-channel pond with a push corer following several attempts with a gravity corer that was unable to obtain a mud-core from the base of the pond. The core was removed from the southern-most region of the pond (approximately 5 meters down from the beaver dock) where fish travel to the stream through a culver installed that connects both water bodies. 1 cm-layers of the core were immediately partitioned into Whirl-Pak bags for further observation and qualitative analysis (moisture content and sediment size). A qualitative analysis of the core samples was conducted using a lithology approach.

**Lithology**

A lithology of the pond sediment core and streambed sample was synthesized to investigate various physical characteristics of the sediment layers that are indicative of sediment dynamics and quality in the pond (relation to the stream) as well as the suitability of the pond for salmon spawning (Table 1). The following summarizes the findings of the lithology conducted.

The streambed sample was 3 cm thick and consisted mainly of sand (fine-coarse colloids) with coarser material ranging in size form gravel to cobbles; a few boulders were present in the study area as well. A ribbon-test of the bed material did not form a clast i.e. there was no cohesion in the sample, indicating an absence of clay. The size of the bed material here is consistent with this section of the stream (mid-stream) being adjacent to the headwater stream just north of the study area; bed material tends to be coarser and more angular in the headwater region due to a decrease in discharge, slope and velocity, which results in decreased erosion of the grains. The grains in the sample were fairly rounded (increased erosion) but poorly sorted (inconsistent in size), further confirming the mid-stream location of the study area.

The sediment core extracted from the bed of the off-channel pond was 13 cm long (1 cm layers). The color of the core was consistent over its entire length, showing no significant changes between any of the layers. Using the Munsell Soil Color Charts, the color of the sample was determined as being 7.5YR 2.5/1 (Munsell Color, 1994); grey colors are usually indicative of bare mineral grains or anaerobic/waterlogged environments.

In general, the core consisted of mud with a small fraction (<250%) of clay (determined with the ribbon test). As expected, the moisture content of the core decreased dramatically with depth from the water/mud interface; the bottom layer (at 13cm depth) was still significantly moist, which can allow for anaerobic conditions. The sand content appears to diminish with depth and individual sand particles become finer; finer particles allow for increased compaction and reduced pore space, hence the reduction in moisture with depth. Although gravel content among the layers is relatively random, it increases with depth; this is usually the case with soil depth profiles were colloids further erode up from the bedrock. The fifth, seventh, eighth, ninth and eleventh layers from the top all contained organic matter (decomposed leaf litter and woody debris); the proximity of these layers (i.e. adjacency) is indicative of the downward decomposition of organic material falling from the surface of the pond water. Overall, the smoothest transition along the layers is seen in moisture content. Particle size and composition is quite random due to the past human disturbance in the area (including pond construction) which has prevented a typical stratification of freshwater-body sediments from forming; furthermore, the lack of major stratification observed in the core also indicates its relatively young age.

The main difference between the streambed and pond core samples is that the stream sample is mainly sand and the core is mostly mud with varying quantities of sand and gravel among the layers; this is due to the origins of both bed material i.e. the streambed sample is composed of eroded material sourced at the headwater stream. The pond (constructed during the Stoney Creek Off-Channel Habitat Improvement Project) does contain the sands and gravels observed in the streambed, however in different quantities and particulate sizes as a result of the disturbance that interrupted the distribution of streambed material into the surrounding floodplain where the pond is presently situated. Moreover, the higher velocity in the stream acts to wash finer material such as mud constituents downstream and out of the streambed, whereas the stagnant conditions in the pond allow for deposition of finer material as well aggregation and saturation, forming mud.

**Water and Sediment Quality Analysis**

Sediment quality is an important component of aquatic ecosystems, one of which can influence the waters and benthic environments surrounding it (Wood and Armitage 1997). Sediment is formally referred to as the collection of particulate matter derived from a variety of sources found in bottom deposits of aquatic environments (CCME 1995). Over a relatively small period of time, considerable portions of sediment can accumulate within a body of water, significantly altering the dynamics of the surrounding ecosystem (Macdonald *et al.* 2000). Sediment may also act as a sink for chemicals while subsequently acting as a source for marine organisms (Macdonald *et al.* 2000). Monitoring these aquatic environments for sediment quality on a consistent basis constitutes a significant portion of the overall process for the proper management of a healthy habitat. In addition, the studies conducted provide researchers with a further understanding of what factors are driving these forces, and whether they are human induced or natural (CCME 1995). This section addresses the significant findings behind our research of Stoney Creek in reference to the process of sedimentation and sediment quality. In particular, the current Canadian regulatory document ‘Water and Sediment Quality Guidelines for the Protection of Aquatic Life’ will be assessed.

The values ascertained for our analysis were conducted on March 5$^{th}$ and April 2$^{nd}$. In assessing the two locales, seven separate aspects were focused upon: cooper, iron, nitrate, nitrite, high/low phosphate, chlorine and pH. These concentrations were measured utilizing a variety of probes and test stripes. The results of our findings are tabulated and recorded in Table 3. Of all the nutrients measured, each value was within their respective concentration level as outlined by the Canadian government, with the exception of iron. As the only significant finding of the chemical analysis, iron was found to have concentrations of 0.2 ppm and 0.45 ppm for the stream and pond environments respectively. The Canadian Water and Sediment Quality Guidelines calculated value for iron was 0.3 ppm in freshwater habitats, of which is higher than the stream habitat and lower than the pond habitat. This value is typically considered to be the threshold estimate for freshwater quality. As the value for the pond habitat is higher than that of the guidelines, this would suggest potential negative effects for organisms living within the environment. Younger, smaller organisms are often more susceptible to the nutrients and chemicals within the environment. As this area is designated for salmon spawning, there is potential for irreparable damage to the salmon young, but this conclusion would require further research to evaluate the effects on salmon offspring.

**Salmon Spawning and Incubation**

According to Barnard and McBain (1994) and Soulsby et al. (2001), sediment core samples can be utilized to analyze the quality of fine streambed sediment (including that of spawning gravels) and to investigate how this sediment type affects salmon spawning and incubation. For example, rapid sediment infiltration, reduced permeability of spawning gravels, and reduced oxygen supply to eggs can all potentially decrease salmon egg survival rate (Soulsby et al., 2001).

In general, a dissolved oxygen concentration approaching saturation is indicative of an adequate oxygen supply for salmon and their eggs (Soulsby et al., 2001). Thus, in order to find out whether oxygen supply in both stream and pond is enough for supporting the survival and reproduction of salmon, dissolved oxygen concentration within the spawning zone (pools filled with spawning gravels) will be determined and recorded. According to Table 4 conducted on March 15th, 2013, the dissolved oxygen in stream was 101.1% saturation. Moreover, on April 2nd, the dissolved oxygen in the stream and in the pond was 86.8% saturation and 83.4% saturation, respectively. As can be seen, the oxygen availability is high in both the stream and pond environments.

With respect to Davis (1975), the minimal dissolved oxygen required for juvenile salmon is approximately 100%. Therefore, the stream has a higher chance of egg survival than the pond. It can be concluded that salmon eggs in stream are feasible to incubate successfully and to reach juvenile stage with abundant oxygen supply. However, on April 2nd, DO did not meet the requirements for juvenile salmon in both stream and pond. Also, as dissolved oxygen might change over time with the change in temperature, it leaves us with a question: how can the dissolved oxygen of this spawning habitat (include both stream and pond) can be maintained at 100% for satisfying the requirements of juvenile salmon.

In terms of spawning gravel quality, permeability (cm/h) can be measured via the standpipe method outlined by Barnard and McBain (1994). However, due to the limitation of accessibility to the equipment, a standpipe was unavailable for our analysis. Thus, permeability is assessed based on the qualitative analysis of the sediment composition. According to Table 2, pond sediment has a very low content of grain size ranging from gravels to cobbles, with the main component of the sediment either mud or fine materials. In contrast, Table 1 shows that stream sediment contains mainly grains like cobbles, gravels and coarse materials. In brief, stream sediment is more permeable than pond sediment because stream sediment has more spaces between grains or coarse materials to store oxygen. Additionally, stream has some safe zones with only constantly moving water instead of riffles. Therefore, salmon are more likely to spawn in non-riffle zones in stream with relatively high permeability.

Lastly, the infiltration rate of fine sediments into gravels is typically estimated with infiltration traps. Since this method is not feasible, a measurement of water velocity is conducted instead. The water velocity of the non-riffle zone in stream measured on April 2$^{nd}$ was 1.56m/s while the water velocity in pond was 0.80m/s. These relatively low velocities indicate slow infiltration rate with little sediment supply. As increased sediment supply adversely affected spawning-gravel permeability (Cover et al., 2008), small amount of sediment supply make spawning gravels more permeable. Therefore, the permeability of spawning – gravel in the stream (pond does not have too many gravels) is supposed to be high. This conclusion is consistent to the qualitative results above.

**Sediment Size Distribution**

According to the article "Turbidity as a Water Quality Standard for Salmonid Habitats in Alaska", researchers already studied the distribution of suspended sediment settling out of the stream, the effect of sediment on the composition of stream-bed gravels, and the conditions under which deposited sediments may be moved. Results show that there is no significance different of streambed gravel composition after sedimentation. Dissolved oxygen in the streambed riffles remained at near saturation levels immediately after sedimentation. High Suspended Sediment is lethal to salmons, and somewhat lower levels of Sediment and turbidity cause chronic, reduced growth, increased stress. Moreover, suspended sediment may facilitate the transport of heavy metals and other pollutants. Therefore, it is important to get approximate levels of turbidity and suspended sediments. All the measurement showed that sediment within the stream-bed reduces the rate of water flow, and the salmon production in Alaska streams is inversely related to percentage of stream-bed material that will pass a 0.833mm screen. That is, when fine sediments accumulated in the streambed, salmon production is reduced.

In order to draw the conclusion, particle size distributions of upstream pool and pond are both obtained. For the stream pond, based on the 14cm core sediments from he pond, and range from water level to 2cm depth, fine sediment is about 20% compare to the whole sediment from that level. And from core sediment depth of 2cm to 13cm, the weight of sand is decreasing from 50% to 10%, and the sample is gravelly somewhat. Expect the sand or fine sediment, the samples are more like mud without gravels inside. However, the sediment size distribution is significantly different from stream pool. Form field study on Feb2, 2013, we obtained grains from stream pool for 15m ranges, and based on recorded data, all the grains are gravels, and no fine sediments observed from water level to 5cm depth. As mentioned above, the stream sample is mainly sand and the core sediment is mostly mud with varying quantities of sand and gravel range from 20% upper to 60%.

Since the fine sediments accumulation in streambed is inversely related to salmon production, the upstream site is more suitable for salmon production than pond site. As the fine sediments are accumulated in the pond site, salmons might not prefer to spawn through the pond site.

**Conclusion**

Our chosen creek is a good spawning habitat for salmon because of low infiltration rate, high permeability of spawning gravels and available oxygen supply, which meet the requirements for salmon egg incubation and survival. However, based on the analysis, salmon are expected to spawn in stream pools rather than pond since pools have permeable gravels and relatively constant water flow.

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**Tables and Figures**

**Table 1.** Lithological description of physical characteristics (moisture content and fine/coarse material content) of stream sediment sample (boundary/thickness = 3 cm, bedrock beyond this depth).

| Sample | Lithology |
|---|---|
| 0cm (water/streambed interface)-3cm | High moisture; 70% sand; 30% gravel; no mud (very little-no silt, clay, loam) |
| Bedrock | - |

**Table 2.** Lithological description of physical characteristics (moisture content and fine/coarse material content) of pond sediment (core) sample (total thickness = 13 cm from water/mud interface and downwards).

| Sample | Lithology |
|---|---|
| Water-0cm | Very high moisture; 20% sand; 0% gravel; murky/muddy water |
| 0cm-1cm | Very high moisture; 20% sand; 0% gravel; mud (silt, clay, loam) |
| 1cm-2cm | High moisture; 50% sand; 5% gravel; mud |
| 2cm-3cm | High moisture; 50% sand; 0% gravel; mud |
| 3cm-4cm | Moderate moisture; 50% sand; 0% gravel; organic matter (<1%) and mud |
| 4cm-5cm | Low moisture; 30% sand (fine); 0% gravel; mud |
| 5cm-6cm | Low moisture; 30% sand (fine); 0% gravel; organic matter (<1%) and mud |
| 6cm-7cm | Low moisture; 30% sand (fine); 0% gravel; organic matter (<1%) and mud |
| 7cm-8cm | Very low moisture; 30% sand (fine); <1% gravel; organic matter (<1%) and mud |
| 8cm-9cm | Very low moisture; 30% sand (fine); 5% gravel; mud |
| 9cm-10cm | Very low moisture; 20% sand (fine); <1% gravel; organic matter (<1%) and mud |
| 10cm-11cm | Very low moisture; 20% sand (very fine); 5% gravel; mud |
| 11cm-12cm | Very low moisture; 20% sand (very fine); 5% gravel; mud |
| 12cm-13cm | Very low moisture; 20% sand (very fine); |

5% gravel; mud

**Table 3.** A comparison table examining the dissolved concentrations of various nutrients collected at the stream and pond environments with the Canadian Water and Sediment Quality Guidelines.

| | Stream | Pond | Canadian Guidelines |
|---|---|---|---|
| Cooper | 0 ppm | 0 ppm | - |
| Iron | 0.2 ppm | 0.45 ppm | 0.3 ppm |
| High Range Phosphate | 0 ppm | 0 ppm | - |
| Low Range Phosphate | 0 ppm | 0 ppm | - |
| Nitrate | 0 ppm | 0 ppm | - |
| Nitrite | 1 ppm | 0 ppm | 13 ppm |
| Chlorine | 0 ppm | 0 ppm | 0.0005 ppm |
| pH | 7.2 | - | 6.5 – 9.0 |

**Table 4.** Results of Dissolved Oxygen in Stream and Pond

| DATE | Temperature °C | Dissolved Oxygen (% saturation) | Stream or Pond |
|---|---|---|---|
| 2013.03.15 | 6.5-8 | 101.1 | Stream |
| 2013.04.02 | 7.8-9 | 86.8 | Stream |
| 2013.04.02 | 7.8-9 | 83.4 (average of two measurements) | Pond |