SUSPENDED SEDIMENT CONCENTRATIONS AND DISAGGREGATED INORGANIC GRAIN SIZES (DIGS) ANALYSIS OF LAKE CHARLES AND LAKE MICMAC DARTMOUTH, NOVA SCOTIA

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The undersigned hereby certify that they have read and recommend to the Department of Earth Sciences, Faculty of Science for acceptance a thesis entitled **"Suspended Sediment Concentrations and Disaggregated Inorganic Grain Size (DIGS) Analysis of Lake Charles and Lake MicMac Dartmouth, Nova Scotia"** by **Lori Ann Wrye** (BSc. Candidate) in partial fulfillment of the requirements for the degree of Combined Honours Bachelor of Science in Earth Sciences and Oceanography.

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Abstract

In the fall of 2005, a study in Dartmouth, Nova Scotia was performed on the concentration and grain size distribution of suspended particulate mass (SPM) that entered Lake Charles, the Shubenacadie Canal Park and Lake Micmac, during heavy rainfall events. The study area had a history of increased SPM concentrations due to urban development since the early 1970's. New constructions began in the spring and summer of 2005, west of the study site and public concern was raised as the sites were not required to perform provincial or federal environmental impact assessments. Spring storms provided an indication that SPM should be considered a significant problem, however, it was not resolved. In the fall of 2005 large rainfall events, again resulted in SPM entering the lakes system. Weekly sampling was carried out to determine background concentrations in the region, and event sampling was performed during heavy rainfalls. One example of a large rainfall event was during the October 7th-10th weekend when Dartmouth received over 150 mm of rain. Sampled water was highly discoloured and the resulting SPM concentrations ranging between 0.2 - 100 mg L^{-1}. During the peak of the Thanksgiving Storm SPM concentrations exceeded water quality guidelines set by the Canadian Counsel of Resource and Environment Ministers. SPM concentrations were in the higher range in the northern Canal and Grassy Brook. Measurements of the sediment grain size entering the lakes, using the Coulter Multisizer IIe showed that the sediments were clay/silt sized (ranging from 10 to less than 63 μm). Storm samples and background samples showed different DIGS distributions indicating the sources of sediment were not the same. After the Thanksgiving Storm, SPM concentrations were reduced as the methods of water retention at both construction sites were improved. After the initial Thanksgiving SPM overflow, the concentrations of sediments entering the lake system during subsequent rainfall events were reduced.

This thesis is dedicated to my parents for their continued help and support

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CHAPTER 1: INTRODUCTION

Lakes and lake systems have long been important to sustaining life, as freshwater is essential to our survival. Lake systems are used extensively for recreational purposes and for waste disposal (Mason, 1996). These natural systems are threatened by the growth of human populations and the resulting development along their shorelines. The contamination of freshwater resources is now an everyday occurrence, with more than 25,000 human deaths each day around the world, because of polluted water sources (Mason, 1996). To understand lake pollution and its effects on organisms it is essential to understand how these ecosystems are influenced by their surroundings.

1.1. Lake Hydrology

A lake is a permanent or semi-permanent body of water that occupies a basin or depression and is affected by physiology and climate (Reynolds, 2004). The physiological effects include the movement of surface water and groundwater, while the climatic effects include precipitation and evaporation (Winter, 2004). It is these factors that determine if a lake exists or not.

Lakes are features of the global hydrological system, as they interact directly with the atmosphere, surface water and groundwater. Only 9 % of the Earth's inland water is contained in freshwater lakes (Winter, 2004). More than one third of that total comes from glacial lakes similar to those found in Canada. Glacial lakes are geologically young bodies of water that fill depressions carved into bedrock by glaciers. Typically, there is no integrated drainage network between glacial lakes as, geologically speaking, they have had little time to develop (Winter, 2004).

The components of lake hydrology can be broken down into lake input and lake output as seen in Figure 1.1. Inputs into lake systems include precipitation, in-flowing streams and groundwater flow. Outputs include evaporation, out-flowing streams and groundwater (in some cases) (Winter, 2004).

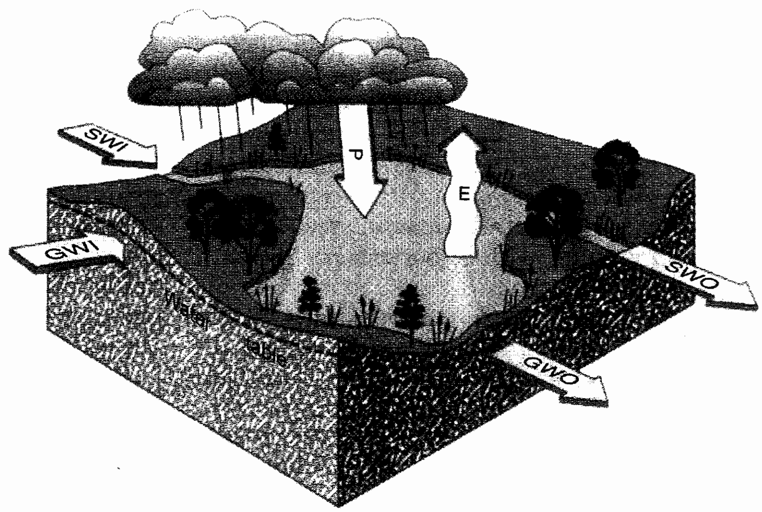


Figure 1.1: Diagram of the hydrological components of lake systems: P, precipitation; E, evaporation; SWI, surface water in; GWI, ground water in; SWO, surface water out; GWO, groundwater out. From Winter, 2004.

The input and output portions of atmospheric water are precipitation and evaporation, respectively. The simple act of measuring precipitation and evaporation can sometimes be difficult. Since precipitation gauges are not located directly over lakes one must infer the rainfall amounts using land-based stations. If the winds are strong during a particular storm, the rainfall gauges become less effective as the slant of the rain increases. It can also be difficult to measure the volume of precipitation that enters the lake as this is dependent on the catchment area and the flow of other lakes and rivers (Winter, 2004). Evaporation also has been difficult to measure as it depends on the surface area of the water body, along with the temperature of the air and water, the solar radiation received by the lake and the vapour pressure over the lake surface (Winter, 2004).

A second important factor in lake hydrology is the interaction of lakes with their entering and exiting streams. Lakes with in-flowing and out-flowing streams are usually stream-flow dominated. This means that the groundwater input is less significant, and the lake depends heavily on the river input to re-supply it with freshwater (Winter, 2004).

Finally, there is the interaction of lakes with groundwater. In most lakes, groundwater feeds or replenishes the lake as seen in Figure 1.2. This is the site of largest interaction between lakes and the hydrological system as the groundwater interface (the lake edges and bottom) is significantly larger than that of the lake surface. It is because of this large interaction that lakes are so highly influenced by local and regional groundwater flow patterns (Winter, 2004). Preferential groundwater flow through the beds of lakes is commonly the result of heterogeneous geological material (Fig. 1.2). This means that on lake shores with sediments of higher permeability, groundwater flow is less restricted than in deeper portions of the lake. These deeper regions have an accumulation of fine material of low permeability, which effectively stops the flow of groundwater (Winter,2004).

1.2. Sediment Processes and Contamination

Sediments, as defined throughout this thesis, refer to detrital inorganic minerals that are derived from bedrock and soils (Bloesch, 2004). The key mechanism for the sedimentation of lakes is the erosive force of precipitation, streams, and rivers. This natural process of sediment movement can be altered by human activities such as the removal of protective vegetation, the movement of soils and urban development. Once found within the lake or river environment, these sediments are subject to a removal process called settling or sinking. Settling or sinking processes are influenced by several factors including the particle size, shape, and specific weight, water temperature and density (Bloesch, 2004). A plot of settling velocity against particle size illustrates that larger particles have higher settling velocities than smaller particles (Fig. 1.3). This figure also illustrates the effects of the shape of the particle on the settling velocity.

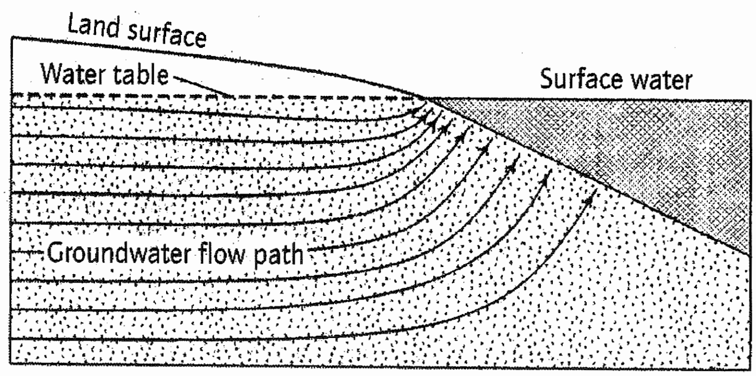


Figure 1.2: Groundwater inflow to lakes showing the decreasing volumes of seepage with distance from the shore. In this case the groundwater is feeding the lake. From Winter, 2004.

Particles can be transported significant distances before reaching the lake bottom depending on the settling velocity (i.e. the particle size and shape) and currents in the body of water (Bloesch, 2004). This explains why the fate of sand and mud differ. Sands, which have larger grain sizes than mud and are therefore heavier, require higher current speeds to be eroded and maintained in suspension. This means that as soon as current velocities slow down, sands will deposit first. This contrasts with muds that generally require lower current speeds to maintain the material in suspension, but higher current speeds than sands to mobilize the particles. This higher mobilization speed occurs because of particle aggregation, which ultimately affects the settling velocity of small particles (Hill, 1998).

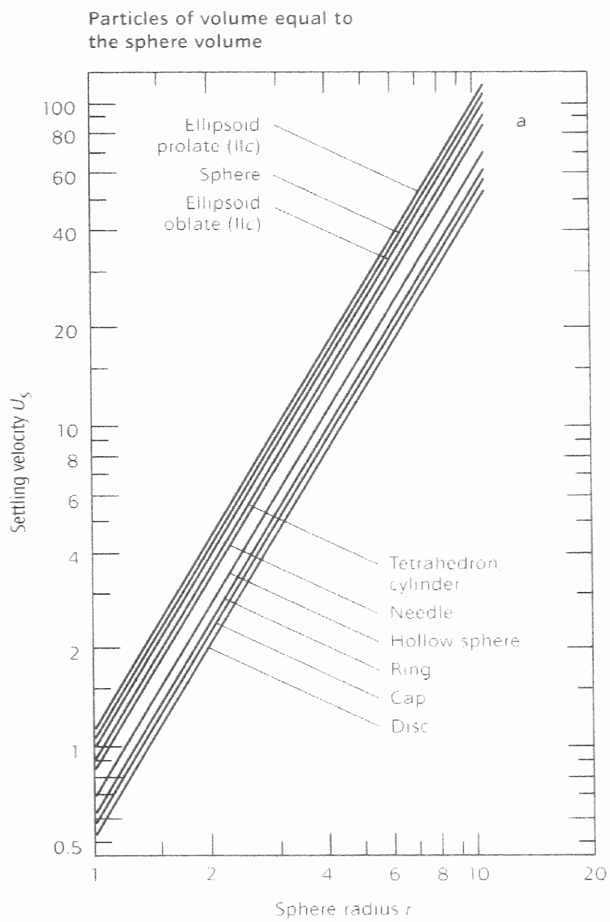


Figure 1.3: Settling velocities of particles of various shapes and radii. Units for the x-axis are: µm, and units of the y-axis are written as cm s^{-1}, however this must be a typographic error and should read µm s^{-1} . From Bloesch, 2004.

Particle aggregation occurs when particles in suspension collide and adhere to one another, forming aggregates that are larger, heavier and sink more quickly (Hill, 1998). The process of sediment aggregation can occur in both freshwater and salt water. This is controlled by the surface area of the particle, its organic coatings and the particle's electrostatic charge (Bloesch, 2004). Once particles reach the lake bottom they can either be re-suspended by strong currents or wave action, or are buried by more particles.

Sediments found within lakes or river systems in high concentrations are considered to be a pollutant (Keller, 2000). Sediments can choke streams, fill lakes, canals, harbours, and ponds. This "natural" pollutant depletes the soil at the source, while reducing the water quality of the system it enters. The increase in suspended particulate matter (SPM) in the water reduces the light available to photosynthetic organisms, which depletes the oxygen content of the water (Mason, 1996). Humans alter the natural input of sediment into lakes and streams by changing vegetation and altering the surface runoff-patterns. The resulting changes in erosion and sedimentation rates lead to changes in lakes and river bodies (Fig. 1.4).

Streams and lakes in temperate climates are generally found in heavily forested areas where the soil substrate is reasonably stable and does not yield large amounts of sediment. Vegetation is a natural precipitation interceptor that also allows water to be returned to the atmosphere by evapo-transpiration. Removal of vegetation causes more water to enter the water table and less to enter the atmosphere by evaporation. The result is that total runoff and erosion increase, causing a larger flux of sediment to streams and lakes (Keller, 2000).

Several activities produce enough sediment to be considered problematic. These include highway development, mining, and land development (Keller, 2000). These activities cause significant changes in drainage patterns. During construction, land will have increased runoff due to the removal of vegetation and the increase in exposed surface area of the soil. Deposition of the eroded material will occur in the proximal lakes and streams. After construction, when large areas are covered by buildings, parking lots and streets, there is a significant increase in runoff. There is also a significant increase in the risk of flooding as water is no longer allowed to percolate slowly into the groundwater and is dumped directly in the lake.

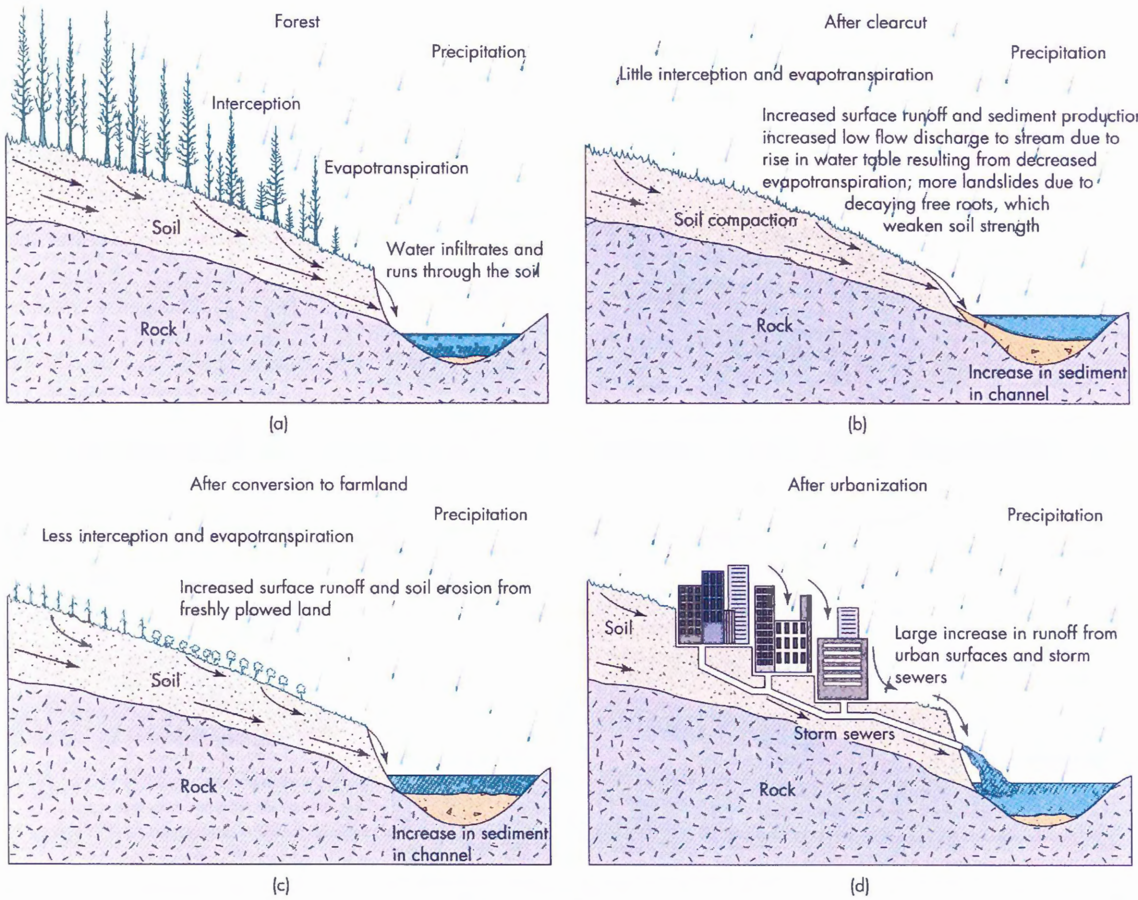


Figure 1.4: Sediment erosion processes that change because of urbanization. (a) is a normal hill slope, (b) is after clear cutting of the land, (c) is the conversion of land to farmland and (d) is land conversion to an urban environment. From Keller, 2000.

There have been advancements over recent years in the environmental sector to prevent sediments from reaching local water supplies during development or agricultural land use. These include the building of ditches, culverts, bank stabilization, silt fencing, straw bales, re-vegetation, rock riprap and settling ponds. Most of these mitigation measures are used throughout urban developments, but often do not contain sediment sufficiently. The most effective and efficient method of controlling silt run-off is to control on-site erosion (Northcutt, 2000). This includes proper land clearing processes and vegetation management. However, this is not always possible, so most developers use a combination of hydro-seeding (re-vegetation), straw bales and settling ponds (Keller, 2000; Northcutt, 2000).

Hydro-seeding, the spraying of a mixture of grass seeds, fertilizer and water, is used as a method of re-vegetating exposed soil. As the plants grow, their root systems limit the mobility of the soil (Keller, 2000). Hydro-seeding is a more permanent method of contamination prevention compared to straw bales, which are used to limit or reduce the erosive impact of raindrops.

Settling ponds catch water from the source as it is heading towards streams. Ideally, water is kept in settling ponds until the suspended material has settled. What determines if the out-flowing waters are sediment-laden or relatively clear is the volume of the settling ponds and the time that the sediment-rich water stays there (Northcutt, 2000). The settling pond residence time is a measure of the time that the water stays in the pond and is equal to the detention volume of the pond divided by the outflow rate (VanZeumeren, 2006).

The concept of residence time is not unique to sediment containment ponds. Residence time can be used for any substance that is found in a reservoir. It refers to the amount of substance in the reservoir divided by the flux into or out of the reservoir (Drever, 1997). Sediment containment ponds are built so that the residence time for a parcel of water in the pond (termed pond residence time) is longer than the average settling residence time of a particle. The settling residence time is equal to the average depth of the pond divided by the particle settling velocity. Longer pond residence times provide higher sediment removal efficiencies (VanZeumeren, 2006). When the settling residence time is smaller than the time the water spends in the settling ponds, then water leaving the pond will be relatively free of suspended sediment. If water leaves the pond more quickly than the sediment settles, the water leaving the pond will then contain suspended sediment.

1.3. Study Area

This study focuses on two lake systems and the canal that connects them, located within the boundaries of the City of Dartmouth, which is now part of Halifax Regional Municipality (HRM) in Nova Scotia. These are Lake Charles and Lake MicMac (Fig. 1.5), which are both part of the Shubenacadie Canal system that connects Halifax Harbour with the Bay of Fundy. Ten thousand years ago, glaciers carved though the bedrock to form these lake basins (Gordon, 1973).

The Shubenacadie Canal system was built to provide a trade route to the Minas Basin in the Bay of Fundy, but certain areas needed to be deepened and widened to allow for the passage of vessels. Construction began in 1824, but the task proved difficult and expensive, and the Shubenacadie Canal Co. went bankrupt in 1831 (Grantmyre, 1974). In 1854, construction resumed with the Inland Navigation Co., and in 1861 the full canal was open to commercial vessels (Billard and Hart, 2005).

The most difficult portion of the waterway to construct was the 'deep cut' region. This was a narrow canal that flowed between Lakes MicMac and Charles that spanned over a kilometer and needed to be deepened by one and a half meters (Grantmyre, 1974). Once finished, the Shubenacadie Canal connected a chain of seven lakes and operated using an arrangement of nine locks and two inclined planes (Billard and Hart, 2005). In

1870, the construction of the railway allowed for items to be transported faster and cheaper than by the canal (Grantmyre, 1974). As a result, the canal system was closed. Recently, it has been named a National Historic Civil Engineering Site and is used for a variety of recreational activities (Billard and Hart, 2005; Grantmyre, 1974).

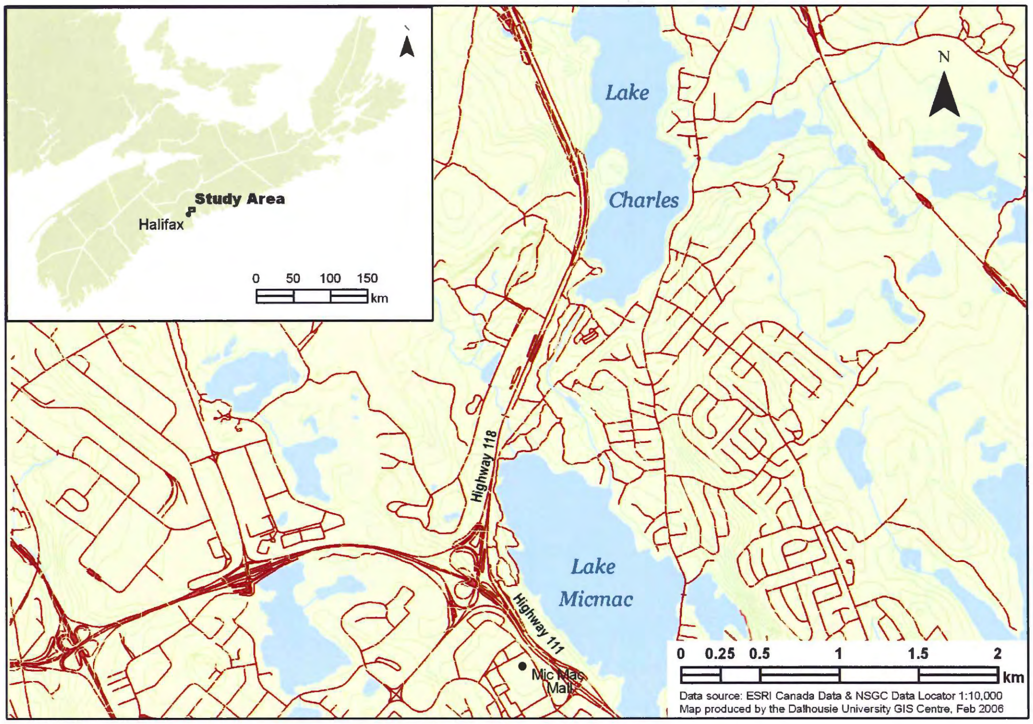


Figure 1.5: Study area in Halifax Regional Municipality, Nova Scotia. Inset shows the province of Nova Scotia and the general study area location. Larger image is of the study area including the Lake MicMac and Lake Charles portions of the Shubenacadie Canal Waterway. Included in this image are roadways, and of importance is the location of the 118 Highway to the west of the study location. Data source: ESRI Canadian Data & NSGC Data Locator. Image by: Dalhousie University GIS Centre, 2006.

1.3.1. Historical Lake Problems

Since the 1970's the areas surrounding the lakes have undergone significant residential and commercial development. This has led to many problems within the study area, including higher levels of sodium and chloride (from road salt) and changes in sedimentation patterns. Since this region is currently being used year round for recreational activities including, fishing, swimming, canoeing, water skiing, skating, ice boating, snowmobiling and cross country skiing, changes in the lake chemistry could cause significant problems (Gordon, 1973). It was these issues that sparked the establishment of the Dartmouth Lakes Advisory Board and encouraged studies of the water quality in this area.

One of the first studies performed was by Ogden in 1972 for the Metropolitan Area Planning Committee on the water quality of selected metropolitan area lakes. This study was a short synopsis on all of the lakes in the Dartmouth Area, including both Lake Charles and Lake MicMac. This study also included a description of the lake depths, shoreline, and watershed area (Ogden, 1972). Lake Charles and Lake MicMac, like most Nova Scotian lakes, are considered to be oligotrophic, or nutrient deficient. Little pollution was noted during the 1972 study, with the exception of high concentrations of salt and silt during heavy rainfall events. This material was believed to come from the nearby Steed and Evans Quarry, an increase in urbanization around the lakes and improper silt catchment systems (Ogden, 1972).

In 1973, Gordon performed a follow-up study that looked specifically at the water quality of Lakes Banook and MicMac. This study examined many different factors including the surface temperature, turbidity, suspended solids, conductivity, coliform bacteria and organic and inorganic carbon (Gordon, 1973). Of interest to this thesis are the suspended solids and turbidity measurements. A suspended solid is defined by Gordon as being any and all material in the water column that can be captured on a filter and weighed. Turbidity, which is also related to suspended sediment concentrations, is a measure of dissolved and suspended matter in water that absorb and scatter light. It essentially measures water murkiness (Gordon, 1973).

Gordon's report showed that suspended solids were mostly composed of silts, while the concentrations fluctuated depending on rainfall amounts. The researchers found that sediments entered the northwest edge of Lake MicMac causing discolouration throughout the lake. The sources for sediment were thought to be the Steed and Evans Quarry site and/or the construction of Route 118, both located west of the lake systems (Gordon, 1973).

The 1973 study found that the Quarry Company took the necessary precautions to prevent the sediment from entering the lake, and these were for the most part successful. It was believed at that time, that the highway construction was causing a more significant problem (Gordon, 1973). This was because the increase in sediment corresponded with land clearing done for the highway. Gordon concluded that in order to prevent silt from entering the lake system, the City of Dartmouth needed to prevent further development along the lake shorelines and there needed to be more careful land clearing practices (Gordon, 1973).

Subsequent studies on the sedimentation of the Lake MicMac region were also done in 1974 and 1977. The 1974 report was prepared by Ocean Science Associates Ltd. of Halifax, and attempted to determine the source of eroded sediment entering Lake MicMac. This study compared lake sediment samples and samples from various portions of both the Steed and Evans Quarry and an area located between a berm (a mound or bank of earth) surrounding the Quarry and an exit from the 118 Highway (Jenkins, 1974).

From this analysis, Jenkins (1974) found that the majority of material entering into the lake system was from the region between the berm and an exit to the 118 Highway. Jenkins (1974) noted, as did Gordon in 1973, that very fine grains did not settle out of the water and remained suspended, even as the water moved over large distances. This was responsible for the murkiness found farther away from the source in the lake water (Jenkins, 1974).

The 1977 study prepared by Charles Castell, a resident of Lake MicMac, also examined the suspended solid material in the water caused by recent urban development in the Lake Charles, Lake MicMac and Deep Cut Canal region (Fig. 1.6). During the summer of 1977, water levels in Lake MicMac were lowered by 2-3 meters for maintenance, which caused accumulated sediments on the lake bottom to be re-suspended by wave action (Castell, 1977). Throughout this study Castell found that the sediments within the water had a distinct relationship to rainfall events. After significant rainfalls, there were higher amounts of suspended particulate matter (SPM) found within the water corresponding to both source tributaries and portions of the lake (Castell, 1977).

Suspended particulate matter concentrations ranged from 0.3 mg L^{-1} during dry periods of the summer to 53 mg L^{-1} after significant rainfalls. Concentrations tended to be higher in the canal closer to Lake MicMac and the Deep Cut Canal, with concentrations remaining low as the canal waters entered Lake Charles.

Other studies on the Dartmouth Lakes by Gordon in the late 1970's and early 1980 used Secchi disk analysis (Keizer *et al*, 1993). Secchi disks are used to measure the turbidity of the water and are lowered over the side of a boat until they are no longer visible (Gordon, 1973; Keizer *et al*, 1993). In 1992, more detailed water quality studies were performed. The focus however, was on problems such as nutrient, bacterial and chlorophyll levels and not on silt accumulation, although measures of turbidity and water transparency were made. Keizer *et al.* (1993) concluded, based on these data and the work by Gordon in the late 1970's, that over the past 15 years water clarity had improved. This was most likely a result of watershed stabilization after development, a significant decrease in development activity and better erosion control practices.

1.3.2. The Current Lake Problem

The problems observed today in Lake Charles, the Deep Cut Canal which from here on is referred to as "the Canal" and Lake MicMac are similar to those seen historically. Currently, the construction of a new Interchange on Highway 118 , the development of the nearby Dartmouth Crossing Mall and the extension of the Burnside Industrial Park have caused eroded sediments to discharge once again into the study area (Fig. 1.6) (NSDOT, 2004).

In the 1970's, Highway 118 was constructed to link Highway 102 to Dartmouth. The Highway is 14 kilometers long and followed the western shores of Lake MicMac and Lake Charles, dividing what was called the 'Countryview' land into two sections, the western (now being developed) and the eastern. In 1994, a Land Use Plan designed by the City of Dartmouth recognized the need to link Highway 118 to Burnside Drive in the Burnside Industrial Park. This would allow for the expansion of 1700 acres of undeveloped area for the industrial park (west of Hwy. 118) and the addition of 43 acres (east of the Hwy.) to the Shubenacadie Canal Park (Fig. 1.6) (NSDOT, 2004).

In 2001, studies of traffic patterns on Burnside Drive showed that traffic was becoming a significant problem. To reduce traffic, a plan was proposed to extend the end of Wright Avenue to the previously planned Highway 118 interchange, allowing for another access/exit point. Before construction could begin, details regarding the placement and design were worked out. The construction was to start west of Highway

118, adjacent to the Shubenacadie Canal Park (Fig. 1.6). The presence of Lake Charles, Lake MicMac, Grassy Brook, and the Shubenacadie Canal Park along with the proximity of adjacent interchanges, restricted the options for locating the interchange (NSDOT, 2004).

In the construction plan, after public consultation, the Highway Interchange Construction was to include retaining walls on both the inside and outside of the on/off ramps. Other portions of the plan include a trail to allow people to enter the park by walking over the interchange and the addition of an embankment on the Shubenacadie Park side of the Highway. This embankment is to be landscaped with native plants to blend in with the park. Construction began in July of 2005 and is intended to be completed in October 2006 (NSDOT, 2004).

The construction of the highway interchange is not the only development ongoing west of Lake MicMac and Lake Charles. The expansion of Burnside Industrial Park and the construction of the Dartmouth Crossing Mall began development along the 118 Highway before the new interchange (NSDOT, 2004). The development of both of these areas had led to sedimentation issues in the Canal, Lake Charles and Lake MicMac during significant rainfall events.

The muddy water entering the Canal and lakes sparked a significant amount of public interest through the spring of 2005 as several rain events brought sediment-laden water to the system. In August and September of 2005, heavy rainfalls again brought sediment-laden water to the study area. On October 12th, several days after a significant rainfall that overwhelmed the silt containment measures at both construction sites, the Provincial Department of Environment issued a stop work order until the issue of silt containment could be resolved (CBC, 2005).

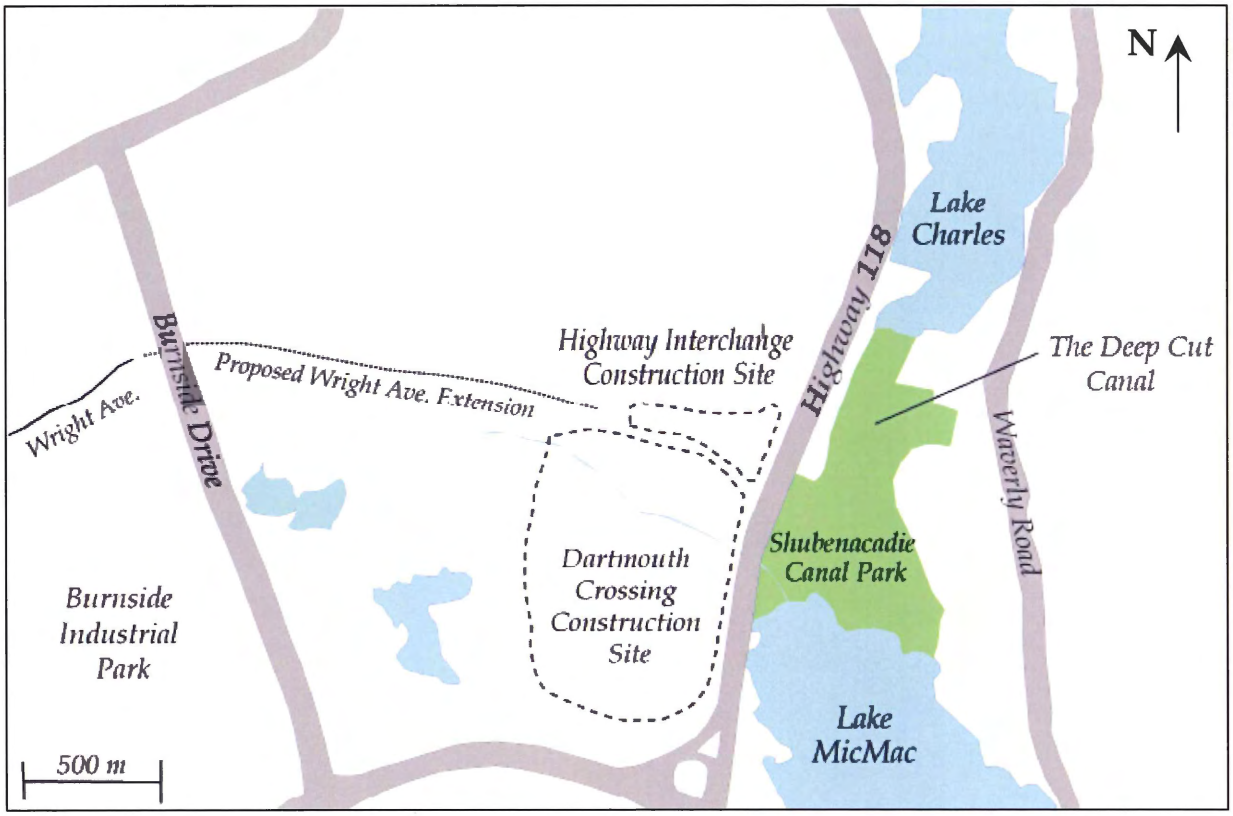


Figure 1.6: Main roads and features around the study area of Dartmouth, Nova Scotia. Through the Shubenacadie Canal Park is the Canal which connects Lake MicMac and Lake Charles in the Shubenacadie Canal Waterway. The small brook running though the Dartmouth Crossing Construction Site is Grassy Brook. Construction Sites and Roads are not to scale.

Other departments such as the Department of Fisheries and Oceans (DFO) were also concerned with sedimentation in the lake system and were assessing the concentrations of SPM concentrations entering the system. Under sections 35 and 36 of the Federal Fisheries Act, DFO is constitutionally responsible for the preservation of fish and fish habitat. The Act states that during all activities undertaken in a water course including stream crossing, culvert installation etc., no harmful alteration, disruption or destruction to fish habitat may be made. No deleterious substances (including sediment-laden waters) may be deposited in a place where they may enter the water system (Owens, 2005).

However, according to Owens (2005), to cause massive fish kills in river and lake systems, huge amounts of sediment must be dumped in the water body, smothering plants and therefore decreasing the oxygen content of the water. Observations and water quality tests performed by DFO officers showed that this was not the case in the Canal and Lakes Charles and MicMac following the fall 2005 rainfall events, as concentrations had not reached levels deleterious to fish or plants (Owens, 2005).

1.4. Research Questions

This thesis evaluated the suspended particulate matter (SPM) concentrations entering the Lake Charles, Lake MicMac and the Canal water system. Water samples were taken weekly and during heavy rainfalls from October 2005 until the end of November 2005. This was done with the purpose of answering a series of questions related to these water samples. Using the background and event-based samples the following questions were addressed in this thesis.

1. Using the samples collected, was it possible to see any recent changes in the sediment input into the study area and is there a correlation between rainfall and SPM concentrations? If elevated SPM concentrations are observed are they a result of recent construction or development in the study area?

2. Using laboratory techniques, what were the Disaggregated Inorganic Grain Size (DIGS) distributions of the high SPM concentration samples versus the low SPM concentration samples?

3. What was the settling behaviour and eventual fate of the fine-grained sediments discharged into the system?

4. Using the samples collected and historical data, how do current SPM concentrations compare to values documented in these systems in the past? Do recorded concentrations exceed regulatory standards?

CHAPTER 2: METHODS

2.1. Overview

Water samples were collected from sites in Lake MicMac, the Canal, and Lake Charles within the Shubenacadie Canal Park, Dartmouth, Nova Scotia. Sampling was undertaken to evaluate SPM concentrations and clearance rates within rainwater runoff from two construction sites located adjacent to the Shubenacadie Canal Park (Fig. 1.6). Samples were obtained from the beginning of October through November 2005. In Nova Scotia, large rainfall events typically occur over short time periods during these months.

The sampling consisted of weekly collection of water samples at the sites within the Shubenacadie Canal Park, as well as event-based sampling that occurred during rainfall events (Fig. 2.1). Sample sites were chosen based on their proximity to sediment-laden streams that discharged into Lake MicMac, the Canal, and Lake Charles, as well as locations upstream and downstream of the discharge sites.

Samples were collected from seven sites (Fig. 2.1): Grassy Brook, which is a brook discharging directly into Lake MicMac (Site 1), an overflow stream running through the Shubenacadie Canal Park (Site 2), the Canal at the entrance to Lake MicMac (Site 3), the Canal just north of Lock 2 (Site 4), the Canal just north of Lock 3 and close to the Fairbanks Centre (Site 5), the Canal between Lock 3 and Lake Charles (Sites 6a, 6b 6c, and 6d), and finally, the Canal at the opening to Lake Charles (Site 7).

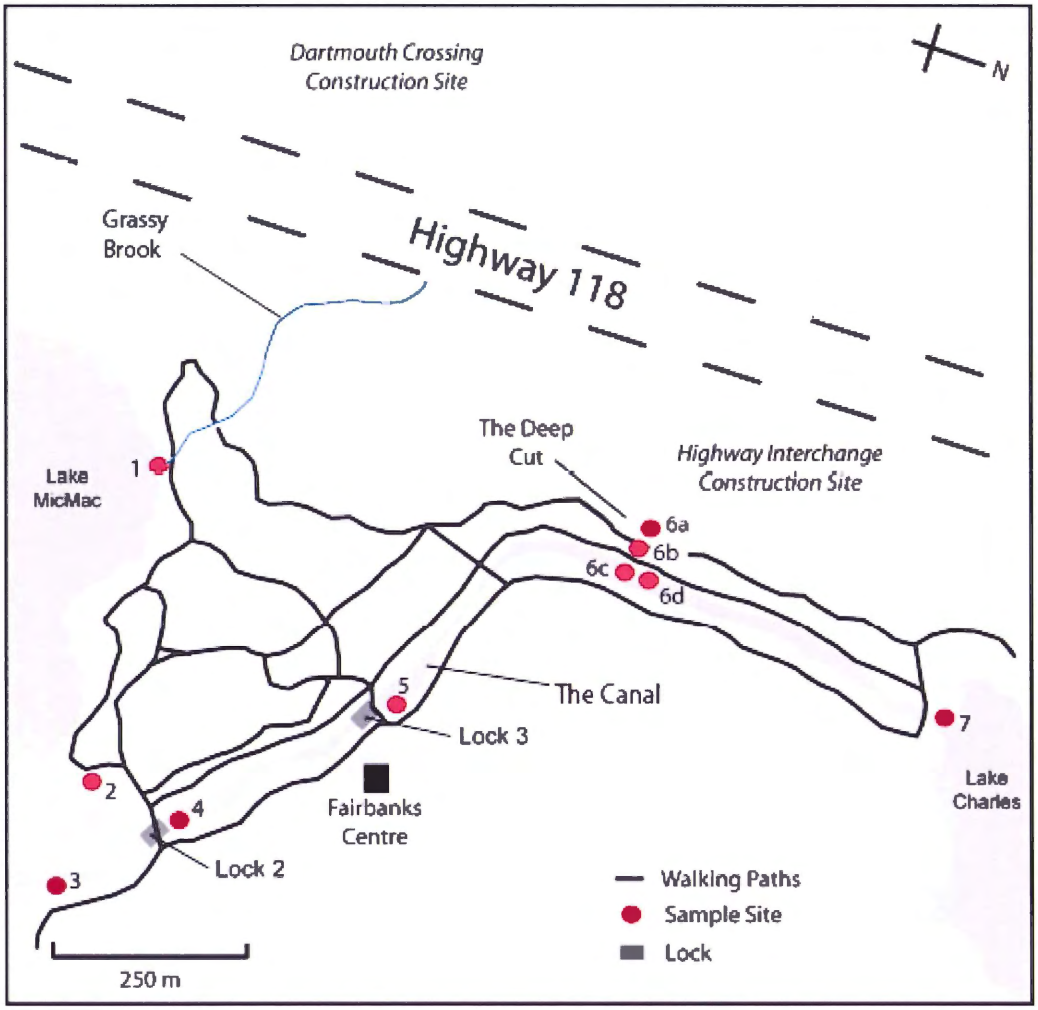


Figure 2.1 Map of the Study Area Dartmouth, Nova Scotia. Red dots represent Locations of weekly and event-based sampling.

During event sampling, water samples were collected to identify sources of increased SPM concentrations discharged into the Shubenacadie Canal Park from the adjacent construction sites. Samples were collected on the first day of the rainfall event and continued for one or two days after the rainfall ceased. During event sampling, up to three extra samples were collected around the northern portion of the Canal site if sediment-laden water was visible in the Canal stream (Sites 6a, 6b, 6c, and 6d). Site 6a was located within a natural sediment containment pond at the head of the stream and Site 6b was located in the Canal stream above the discharge location. Site 6c was located where the stream discharged into the Canal and Site 6d was located in clearer water adjacent to the discharge plume location in the Canal.

2.2. Sample Collection

At each site a pole sampler was used to collect water. The pole sampler extended up to 4 meters and permitted sample collection in areas difficult to reach. The sampler was equipped with a Purcy clamp that allowed a 1-L Nalgene sample bottle to be attached to the pole (Fig. 2.2). When collecting water samples, a 1-L sample bottle and 7.6-L Nalgene composite bottle were rinsed with water at the sample site to remove any material from the bottles.

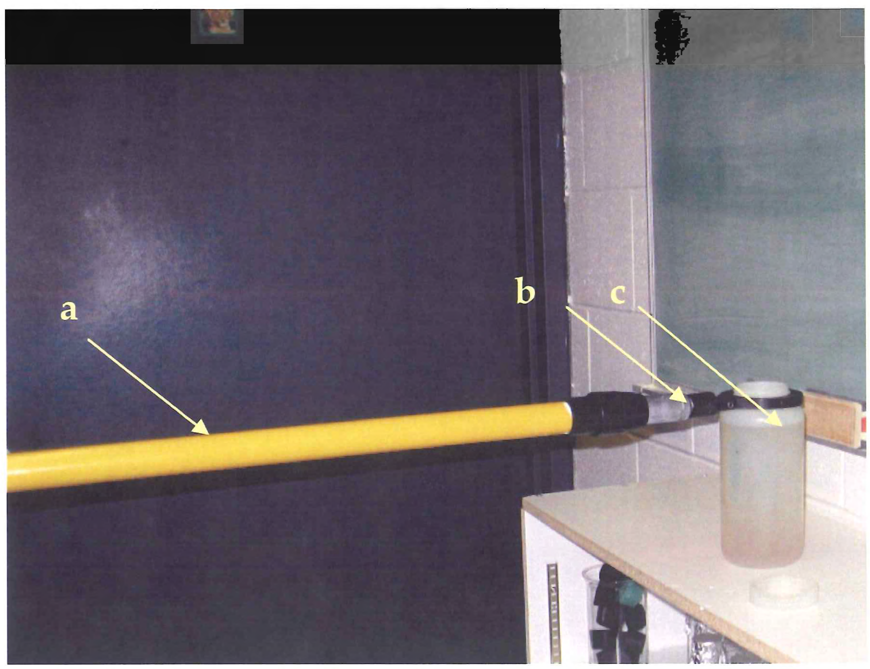


Figure 2.2: Image of a pole sampler with sample bottle attached: (a) pole sampler, (b) Purcy clamp and (c) water sample bottle.

The rinsed water was then disposed of away from the sample site to prevent contamination. Next, five 1-L samples were collected from the site and poured into the 7.6-L composite bottle, allowing for a representative water sample to be taken.

Once the five samples were poured into the large Nalgene bottle, the composite sample was swirled in two directions to re-suspend any settled material. A sub-sample was then poured back into the rinsed 1-L Nalgene bottle. Before placing the cap on the 1-L sample bottle a thermometer was used to take the water temperature, which was then recorded with the sample time in a field notebook. The sample bottle was labeled using an oil pencil. The label consisted of the year, month, day, and sample site (e.g. 2005-10-16-05), along with the water temperature and sample time.

During heavy rainfall events that yielded significant runoff from the construction sites into the Canal (e.g. weekend of October 8th, 2005) settling experiments were also performed. The settling experiments were done to determine the sediment clearance rate and were performed at sites where sediment was visible in the water. The first step in the settling experiment was to rinse four 1-L Nalgene bottles, their caps and a 4-L graduated cylinder with water from the site. The rinse water was dumped away from the experiment to prevent any contamination. The first bottle was marked with the year-month-date-sample site along with the temperature, collection time and an indication that this was the initial sample. Each successive bottle was labeled in the same manner with times of 30, 105 and 180 seconds.

To begin the settling experiment, the 4-L graduated cylinder was filled with sediment-laden water, while the pump apparatus was attached to a 1000 mL sample bottle (fig. 2.3). The pump system consisted of two plastic tubes that were connected to the hand pump. The first tube ran from the pump to a stopper and the other from the stopper to a glass tube. At the end of the plastic tubing, just before the glass area, there was a plastic clamp. The clamp was used to allow water to flow from the graduated cylinder to the sample bottle. Initially, the clamp was engaged to prevent air flow through the tubes while pumping began, to remove air from the sample bottle.

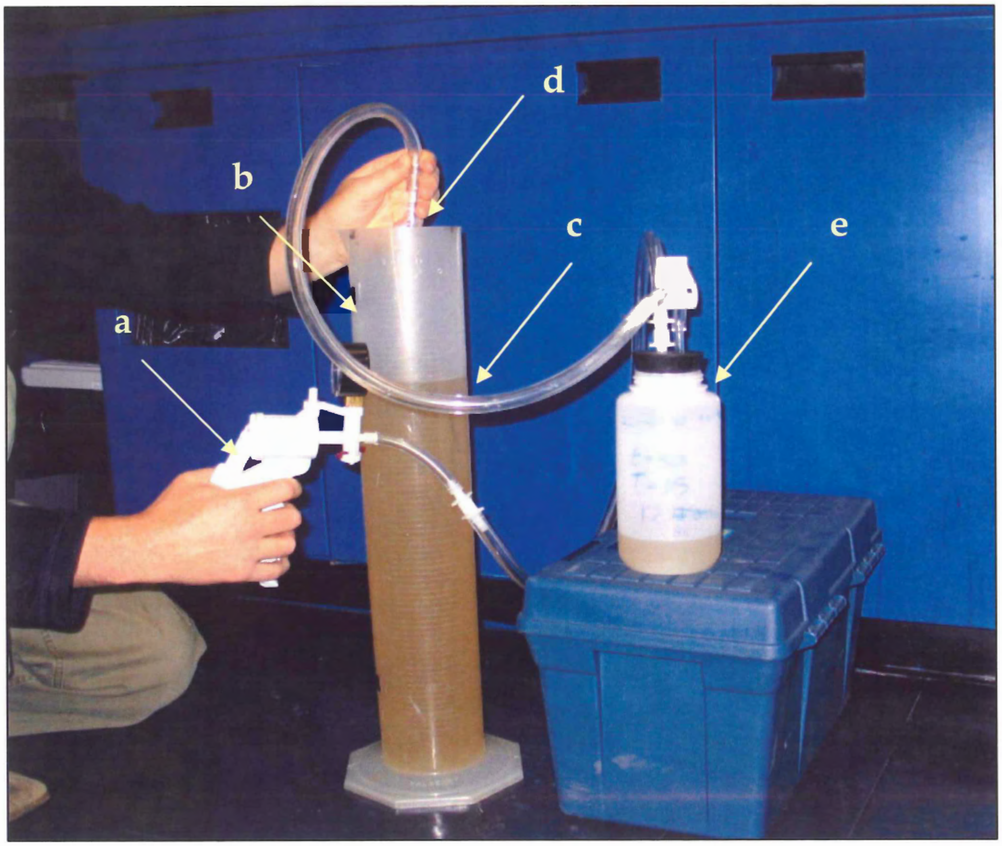


Figure 2.3 Photograph showing (a) the hand pump, (b) the 4 L graduated cylinder, (c) the rubber tubing, (d) the glass tubing and (e) the sample bottle. This apparatus was used in the field with two experimenters.

After the sample water was in the graduated cylinder for 30 seconds, the glass tube end of the pump system was placed carefully (as not to disrupt the suspended sediment) into the graduated cylinder water at a depth of 10 cm. The pressure clamp was released and approximately 200 mL of water was pumped into the sample bottle before the tube was re-clamped. This process was repeated at 105 and 180 seconds with each sample placed in a different bottle. The remaining water in the graduated cylinder was poured back into the stream. Times of 30, 105, and 180s were chosen as they allowed for a quick field assessment to determine if sediments were obviously flocculated. If the sediments were sinking at the velocity of fully flocculated particles, then in 180 seconds, flocs would have moved 180 mm or 18 cm. With a sample depth of 10 cm, the sediment would have settled out of the range of the sample.

2.3. Sample Analysis

Once the suspended sediment samples were collected, they were taken back to the laboratory for analysis. All water samples were analyzed for suspended particulate mass (SPM).

2.3.1. Filter Preparation

The desiccant, which is used to remove moisture from the filters, was first dried in an oven at 60 °C to remove any moisture. Once dried, it was distributed into 125 mL Nalgene containers and covered with aluminum weighing dishes that were used to hold the rinsed filters. Twenty-five 8.0 µm Millipore cellulose filters were then removed from their box five at a time and washed in a beaker containing SuperQ water. SuperQ water is highly distilled and purified water.

The use of 8.0 µm Millipore cellulose filters for measuring sediment grains less than 8.0 µm was first demonstrated by Swift *et al.* in 1972. His experiments showed that 8.0 µm filters can catch grains less than 1.0 µm in size as long as there were sufficient sediment grains in the water being filtered to essentially clog the filter pores. When pores became clogged with sediment, the filter was able to catch grains smaller than the given pore size on the label (Swift *et al.*, 1972).

After swirling the beaker around, the water was drained and the filters removed individually with forceps and placed on the vacuum manifold of the filtering apparatus (Fig. 2.4). The pump was turned on and the filters were washed using SuperQ water. Any filters that were dropped on the floor or torn were discarded.

Following washing, the filters were placed in small Nalgene containers to dry. Once dry, the filters were weighed and given a filter ID, and then placed in individual glassine envelopes for storage in a large desiccator. Weights were recorded to be used later when SPM or disaggregated inorganic grain size (DIGS) analysis was performed.

2.3.2. Suspended Particulate Mass (SPM)

Water samples collected at each sample site were swirled and shaken, then poured into either a 1-L, 250 mL or 100 mL graduated cylinder. The choice of cylinders depended on the amount of visible suspended sediment, if more sediment was visible then less sample water needed to be filtered. The prepared 8.0 µm Millipore filters were then placed on the vacuum manifold with the magnetic water sample cups placed over them (Fig. 2.4) (Kranck & Milligan, 1992). These sample cups hold the sample water as the vacuum pump pulls the water through the filter. Once the sediment was collected on the Millipore filter, it was oven dried at 60 °C for 24 h and stored in a large desiccator prior to being re-weighed.

The net change in mass of the filter was proportional to the sediment mass in the known volume of water that passed through the filter. Dividing the mass by the volume of sample water filtered yields the suspended particulate mass concentration (mg L^{-1}). It was proportional and not equal to the suspended particulate mass because a filter weight correction must be applied.

This correction process required that every tenth Millipore filter not be used to filter water, and was instead labeled "blank". The blanks were then weighed at the same time as filters with sediment on them to account for any changes in filter weight due to humidity in the air. The change in weight of the blank filters was the correction that was applied to all the filters weighed at that time. This procedure corrected for humidity during the day of weighing.

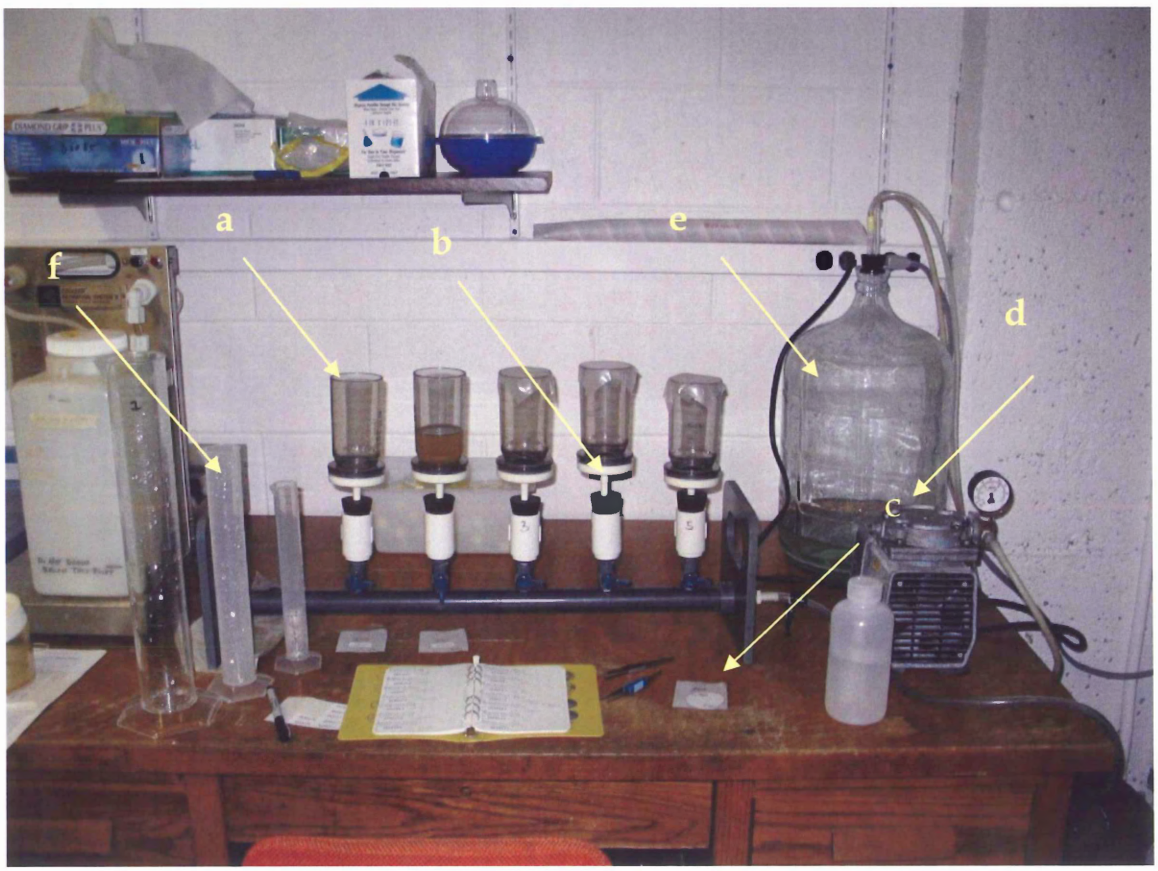


Figure 2.4 The filtering apparatus used to clean and prepare filters along with filtering the suspended sediment from the water samples: (a) water containers, (b) vacuum manifold, (c) filter in glassine envelope, (d) pump, (e) water catchment bottle and (f) graduated cylinders.

After all of the filter samples were weighed for the second time, a data table was created. This table included all the sample information along with SPM values and sample collection information (Appendix A). This information was used to create plots of SPM concentrations (mg L^{-1}) and hourly rainfall (mm h^{-1}) over the sample period.

Calculations were performed to determine whether a calculated SPM concentration could be considered "elevated" during the study period. "Background" SPM concentrations for each respective sample site were determined by taking an average of the weekly collection samples and calculating two standard deviations from the mean. Values that exceeded the two standard deviations from the mean were deemed elevated and values that were within two standard deviations or less were considered background concentrations.

Calculations were recorded as the mean ± one standard deviation, followed by the value above which SPM concentrations are considered elevated. This method of using only the weekly samples may not have been a perfectly representative technique for the determination of background samples; however, it was objective. Calculated values were compared to the Canadian Environmental Water Quality Guidelines to determine if the two construction companies met these regulations.

2.3.3. Disaggregated Inorganic Grain Size (DIGS) Distribution

A high SPM concentration filter and 'background' SPM concentration filter from Sites 1, 6a and 6c underwent additional analysis for the disaggregated inorganic grain size (DIGS) distribution. After filtering, drying, and weighing the samples, the filters were taken to the Particle Dynamics Laboratory at the Bedford Institute of Oceanography (Habitat and Ecology, Department of Fisheries and Oceans, Government of Canada). The samples were placed in a low temperature asher (< 60° C) and wet digested with hydrogen peroxide that was added to remove the filter and any organic material (Milligan and Kranck, 1991). The remaining material was then processed using a Coulter Multisizer IIe electroresistance particle size analyzer (Milligan and Kranck, 1991).

To determine the number of particles in suspension in a particular sample, the ashed material was mixed with a known amount of electrolyte. The Coulter Multisizer IIe uptakes the material, using a vacuum, through a small aperture of sizes 30 and 200 µm. Samples were first passed through a 200 µm aperture (sizing particles 4-100 µm) to remove any larger particles that could cause damage to the 30 µm aperture. Next samples were passed through a 25- µm Nitex screen to remove any large particles before being passed through the 30 µm aperture (sizing particles 0.6-15 µm) (Curran, 2002).

The aperture of the counting tube was located in an electric current. When individual particles passed through the electric current, the voltage fluctuated, and the fluctuation was proportional to the particle volume. Each pulse was counted and then the particle volume was converted to an equivalent spherical diameter by a software program (Coulter, 1979; Milligan and Kranck, 1991). Besides recording the particle counts, the software program removed counts that came from a blank electrolyte solution (baseline solution). The final output from the Coulter Multisizer was a disaggregated inorganic grain size (DIGS) distribution of the sediment in the water sample. The outputs from both apertures sizes were combined, creating a continuous size distribution of sediment.

After sample analysis the output was normalized and plotted on a log vs. log graph. The normalization process used the volume concentration (dimensionless) of particles in each size class, divided by the total volume concentration (dimensionless) for the filter, and multiplied by 100. The result was the percent volume concentration within each size class.

2.3.3.1 Un-flocculated and flocculated e-folding times

To determine experimental clearance rates for the suspensions, both the single grain settling velocity and the flocculated grain settling velocity for each grain size were determined. The calculations of both types of clearance rates for the suspension were performed to provide a time range for settling grains. The calculation of the single grain settling velocities was based on work done by Dietrich in 1982, who stated that settling velocities varied from Stokes Law. Stokes Law makes several simplifying assumptions, such as the shape of the grains being essentially spherical. Dietrich (1982) believed that the shape and roughness of the grains affected the setting velocities. Based on experimental research, Dietrich (1982) determined the general settling velocities of these non-ideal grains. Calculations of the settling velocities in this thesis follow Dietrich's concepts of non-ideal grains.

With the Dietrich settling velocities of each particle size known, the concentration of sediment was determined for different time periods. These periods were: 30 s, 90 s, 180 s, 360 s, 720 s, 1440 s, 2880 s, 5760 s, and 11520 s. The various suspended sediment concentrations at each time interval were determined with the equation;

$$C_i(t) = C_i(0)e^{\frac{-w_s(i)}{h}t} \tag{2.1}$$

where $C_i(t)$ is the mass concentration in mg L^{-1} in size class, *i* as a function of time (s), $C_i(0)$ is the initial concentration in mg L^{-1}, $w_s(i)$ is the single grain settling velocity for the class *i* in m s^{-1}, *h* is the water depth (m) (assumed 1 m) and *t* is the time (s) (Hill *et al.*, 2000). To determine the maximum clearance rate times it was assumed here that there was only single grain deposition and no flocculation.

Once the variation of concentrations of suspended sediment with time were determined based on the single grain settling velocities, the sediment concentrations for each size class (for each filter) were plotted on log-log plot to show the changes observed through time at each site. Other plots were also produced to determine the maximum clearance rates for the various grain sizes based on the sum of the suspended sediment on each filter for each time. These total concentrations were then plotted on a semi-log axis.

Total concentration as a function of time was described by the equation;

$$C_T(t) = C_T(0)e^{\frac{-w_e}{h}t} \tag{2.2}$$

where $C_T(t)$ is the total concentration at time t, $C_T(0)$ is the initial total concentration, and w_e is the effective or bulk settling velocity for the suspension. The term h is the water depth (m) which was assumed to be 1 m (as the depth of the containment pond) and t is the time (Hill *et al.*, 2000). To determine w_e, Equation 2.2 was transformed to;

$$\log C_T(t) = \frac{-w_e}{h}t + \log C_T(0) \tag{2.3}$$

on a plot that is semi-log in concentration, $\log C_T(0)$ is the y-intercept, and $-w_e/h$ is the slope of a straight line that was fit to the transformed data (Hill *et al.*, 2000).

Based on the experimental values for the components of Equation 2.3, it was re-arranged to determine the e-folding time. The e-folding time is how long the bulk suspension would have required for the concentration of sediment to reach a value of $\frac{1}{e}$ or approximately 37 % of the total concentration. The value of the e-folding time (t_e) is a function of the depth of the water body and the effective or bulk settling velocity (Eq. 2.4).

$$t_e = \frac{h}{w_e} \tag{2.4}$$

Finally, the minimum time required for the SPM concentration to reach the e-folding concentration was calculated based on the assumption that grains do not normally settle individually from suspension. Rather, grains exist as aggregates of particles, called flocs. Unlike single grain settling velocities which are well understood, settling velocities of flocs depend on the suspended particulate matter concentration, the turbulence and disaggregation by turbulence (Hill, 1998). Observations in a wide range of environments show that average settling velocities for flocs are typically 1 mm s^{-1} (e. g. Hill, 1998). This w_e value was applied to calculations that used Equation 2.4 to determine the minimum e-folding time for each sample.

2.3.3.2 Sediment containment pond residence times

Following the determination of the e-folding times for flocculated and un-flocculated sediment, the residence time of a parcel of water in the Dartmouth Crossing Construction Site settling ponds wase calculated. To do this, a map of the construction site was obtained from EDM (Environmental Design and Management Limited). Unfortunately, it was not possible to determine the scale of the map so a digital base map was obtained from the Dalhousie University GIS Centre, using the Environmental Systems Research Institute (ESRI) Canada Data and Nova Scotia Geomatics Centre (NSGC) Data Locator at a scale of 1:10,000.

The Dartmouth Crossing Construction Site map was then geo-referenced to the digital base map using a Geographic Information System (GIS) called ArcMap and a digitizing tablet. Once the Dartmouth Crossing Construction Site map was referenced to the base map, it was possible to digitize the location of the four sediment containment ponds and the associated drainage areas. Using the 'area' calculation in the ArcMap program the drainage basin area was determined. A drainage area was described by Ritter *et al.*, 2002 as a finite area where all waters drain into one discrete region. In this study, a drainage area was considered to be the land surrounding each containment pond where water flowed from the construction site to the containment pond.

Once the area was known, the minimum residence time of a parcel of water in each of the four containment ponds was determined based on the following equation;

$$R_p = \frac{V_p}{r_r * A_d} \tag{2.5}$$

where R_p is the residence time of a parcel of water in the containment pond (h), V_p is the volume of the containment pond (m^3) given in the Dartmouth Crossing Construction Site map. The terms r_r and A_d together are the volume inflow into the containment ponds, where r_r was the hourly rainfall (m h^{-1}) during the Thanksgiving Storm when the containment ponds were believed to be full. The values used for this portion of the calculation were varied to determine the effect of hourly rainfall on the settling pond residence time. A_d was the drainage area measured from the Dartmouth Crossing Construction Site map. Added to this value was the surface area of the corresponding containment pond. This was done because these ponds were exposed to the atmosphere and during rainfall events, would also receive direct input of rain.

Calculations were performed for both drainage area 1 and drainage area 2 (the largest drainage areas) only, as pond volumes were unknown for drainage areas 3 and 4. Once the calculations were performed to determine the minimum pond residence time, they were compared to the e-folding times of both flocculated and un-flocculated grains. If the e-folding time, the time required for the SPM concentration to decrease to 37 % of its original value, was less than the containment pond residence time, then waters discharged from the pond would have been relatively clear. If the e-folding time was greater than the pond residence time then discharged waters would have been murky.

CHAPTER 3: RESULTS

3.1 Overview

During the months of October and November 2005, four significant rainfall events occurred three of which were sampled (Fig. 3.1). The fourth event was missed because of its brevity and occurrence when transportation was unavailable. The dates of the sampled rainfall events were Event 1: October 8th to 17th (the Thanksgiving Weekend Storm); Event 2: October 24th to 27th and Event 3: November 23rd to 25th. In addition to these samples, eight weekly samples were taken to characterize background conditions at each site. The hourly rainfall data were obtained from the Environment Canada Meteorological Service - Atlantic Region from Shearwater Airport in Dartmouth, Nova Scotia (Appendix B). This Environment Canada Site was chosen because of its proximity to the sample site.

The following Chapter is divided up into three sections. The first section displays and describes graphical information of the various sediment concentrations and rainfall data recorded at different sample sites along Lake Charles, Lake MicMac and the Canal (Fig. 2.1). The second section is a description of the results from the settling experiments conducted after the Thanksgiving storm. Finally, the third section describes the grain size distribution at three sample sites. Filter samples of the highest sediment concentration and the average sediment concentration were used from Grassy Brook (Site 1), the natural settling pond (Site 6a) and the northern portion of the Canal (Site 6c).

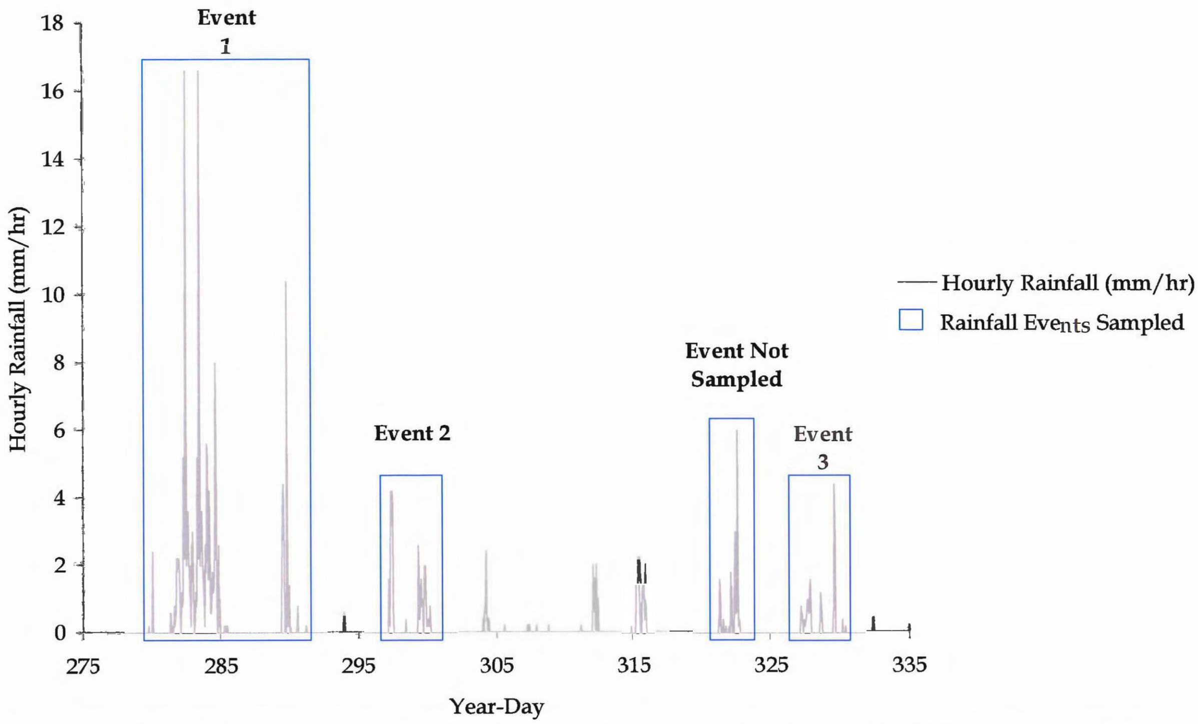


Figure 3.1: Line graph of the hourly rainfall in millimeters per hour at the Shearwater Airport in Dartmouth, Nova Scotia. The x-axis represents year-day which is a term used to describe the day of the year and the ending hour in which the sample was taken. Each hour in a day represents a fraction of the day where January 1st at 00:01 is Day 0. Blue boxes represent the different rainfall event samples and span the time in which sampling occurred. Larger rainfall events that occurred but were not sampled are labeled Event not Sampled. Besides rainfall event-based sampling there was weekly collection of water samples. Rainfall data was obtained from Environment Canada Meteorological Service of Canada-Atlantic Region.

3.2 Suspended Particulate Mass (SPM) Concentrations

Considered throughout this study, with regards to SPM concentrations, was whether the SPM concentrations exceeded regulatory values as determined by the Canadian Council of Resources and Environment Ministers (2002). The guideline concentrations for a water system that is not being used for human consumption, falls under the Canadian Water Quality Guidelines for the Protection of Aquatic Life. These guidelines were intended to protect aquatic life from anthropocentric stresses, including chemicals in the water and increased SPM concentrations (CCREM, 2002).

Background values for the following regulations were determined by monitoring of a water body during clear flow events. Clear flow is a location-specific term that refers to times when a water body has low concentrations of SPM. Background concentrations did not include high flow periods because the SPM concentrations were considered to be elevated (CCREM, 2002).

The Canadian Water Quality Guidelines state that during clear flow periods, SPM concentrations should not exceed background levels by more than 25 mg L^{-1} during a short period (approximately 24 hours). It is believed that this short-term exposure of increased SPM concentrations will have a behavioural impact on fish, but the effects are reversible. For exposures longer than 30 days, SPM concentrations should not exceed background by more than 5 mg L^{-1}. Long-term exposure to smaller increases in SPM concentrations may cause minor physiological stress to aquatic species (CCREM, 2002).

High flow events or periods when SPM is transported through water bodies (such as the spring melt) is when the most ecosystem damage occurs. When background SPM levels in a water body are between 25 and 250 mg L^{-1} and there is a high flow event, then anthropocentric activities should not increase SPM concentrations by 25 mg L^{-1}. When background concentrations exceed 250 mg L^{-1} then, increases should be no more than 10 % of background values (CCREM, 2002).

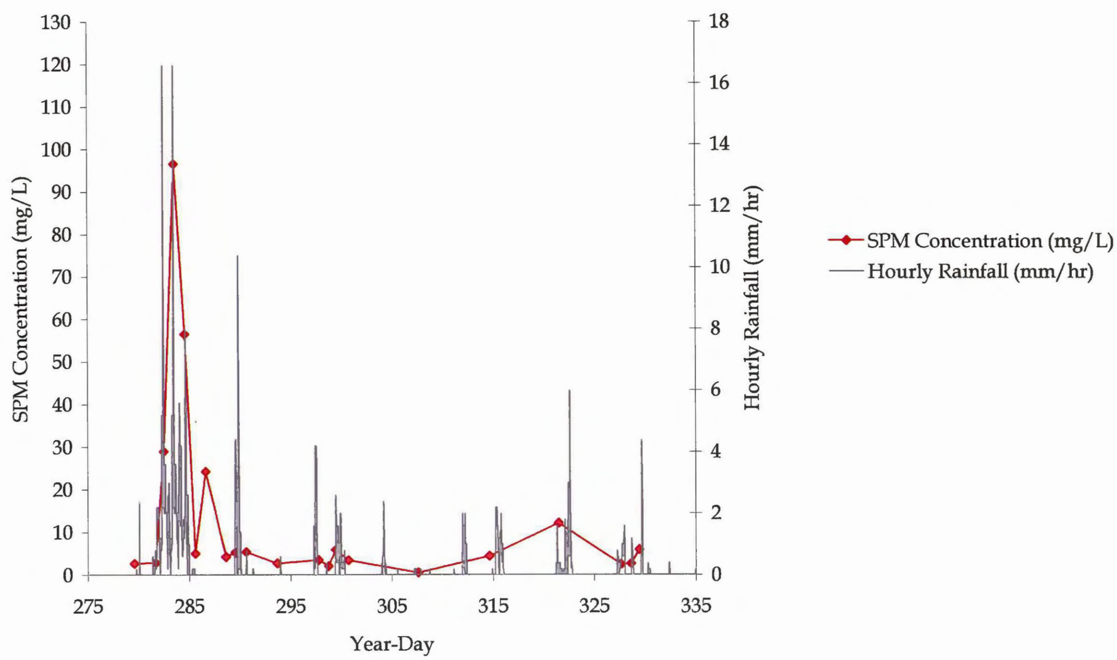
SPM concentrations were calculated for all sites during the study period, and pictures were taken periodically during fair weather to document each site. Overall, the mean background value of SPM in this entire water system was 3.50 mg $L^{-1} \pm 4.29$ mg L^{-1}. For concentrations to be considered elevated, values must have exceeded 12.09 mg L^{-1} (mean + 2 standard deviations). The peak recorded concentration was 105 mg L^{-1} at site 6a. Mean SPM concentration for each sample site was calculated along with the value of two standard deviations from the mean. Any SPM concentration above the value of two standard deviations from the mean was interpreted as being elevated.

Grassy Brook, Site 1, was a small stream that flowed from a small river network through the Dartmouth Crossing Construction Site, under the highway and into Lake MicMac. The mean background SPM concentration over the study period for this site was 6.63 mg L^{-1} ± 7.93 mg L^{-1}. To be considered elevated, values must have exceeded 22.50 mg L^{-1}. Grassy Brook data showed a distinct correlation between SPM concentrations and hourly rainfall before the mandatory closure of the construction site on October 12th, 2005 (year day 285) (Fig. 3.2). The site closure occurred after the Thanksgiving Storm that dumped over 150 mm of rain on the region over a three-day period (8th-10th of October) causing sediment to enter the lakes systems.

Before the closure, SPM concentrations at Grassy Brook reached 96 mg L^{-1} on October 10th (283). It was on this day that the Nova Scotia Government allowed the construction sites to release water from the containment systems into Grassy Brook to prevent further destruction of the site. Within twenty four hours of this event the SPM concentrations dropped to 56 mg L^{-1} (284) and on the day of closure for both construction companies, the SPM concentrations in the brook dropped to 5 mg L^{-1} (285). However, the following day the sediment concentration increased again to 24 mg L^{-1} (286). While this value was just considered to be elevated for Grassy Brook, it was interesting, as SPM concentrations doubled over one day when there was no corresponding recorded rainfall. Although this increase in SPM concentrations was unexplained, a few possibilities for its occurrence will be discussed further in Chapter 4.

(ai)

(aii)



(b)

Figure 3.2: Photographs and calculated SPM concentrations for Site 1: Grassy Brook. (ai) A low discharge photograph of the Grassy Brook Bridge where sampling took place and (aii) the entrance of Grassy Brook into Lake MicMac. (b) SPM concentrations for Site 1: Grassy Brook. Gray spikes on the graph represent hourly rainfall data from October and November 2005 and the redline represents SPM concentrations in mg L^{-1}.

Following the first significant rainfall (event 1), background SPM concentrations remained relatively constant despite fluctuations in hourly rainfall. One small fluctuation occurred during a rainfall on November 17th (321). Sampling during this small rainfall event only occurred once as significant rainfall was not predicted. SPM concentrations on this day were elevated above normal background levels for the entire lakes system, but they did not approach values seen during Event 1.

Flow rates in the brook varied depending on the timing of the last rainfall. Immediately after a rainfall event, the brook discharge increased significantly, with exception of the Thanksgiving Storm (Event 1). When there was little rainfall the brook was slow moving. During the Thanksgiving Storm the flow rates at this site were elevated due to a significant amount of water discharged from the construction site to the west when the rain waters overflowed the containment systems.

Site 2 was a small stream that ran through the southern portion of the Shubenacadie Canal Park. It was a late addition to the sample sites and was not sampled until the third survey on October 9th, 2005 (282). The mean SPM concentration over the study period for this site was 2.82 mg L^{-1} ± 2.60 mg L^{-1}. For SPM concentrations to be considered elevated at Site 2 they had to exceed 8.01 mg L^{-1}.

Samples during the first rainfall event show elevated SPM concentrations to 15 mg L^{-1} (Fig. 3.3). However, concentrations decreased to background values of less than 4 mg L^{-1} by the end of the event (Oct. 11th: day 284). Site 2 SPM concentrations were comparable to those of Site 1, as both fluctuated within the range of one standard deviation from the mean with rainfall (after the Thanksgiving Storm) over the end of October and early November. This site recorded similar fluctuations in SPM concentrations at Site 1 on November 17th (321), where sediment concentrations reached approximately 8 mg L^{-1}. This was not considered to be a statistically significant increase in SPM concentrations.

The flow rate of the water in this overflow brook was dependent on the amount of rain received during a given period of time. During significant rainfalls the stream moved quickly as the swamp region to the north became flooded. During less significant rainfall events or during regular weekly sampling, the stream flowed slowly and sometimes small pools of water were created.

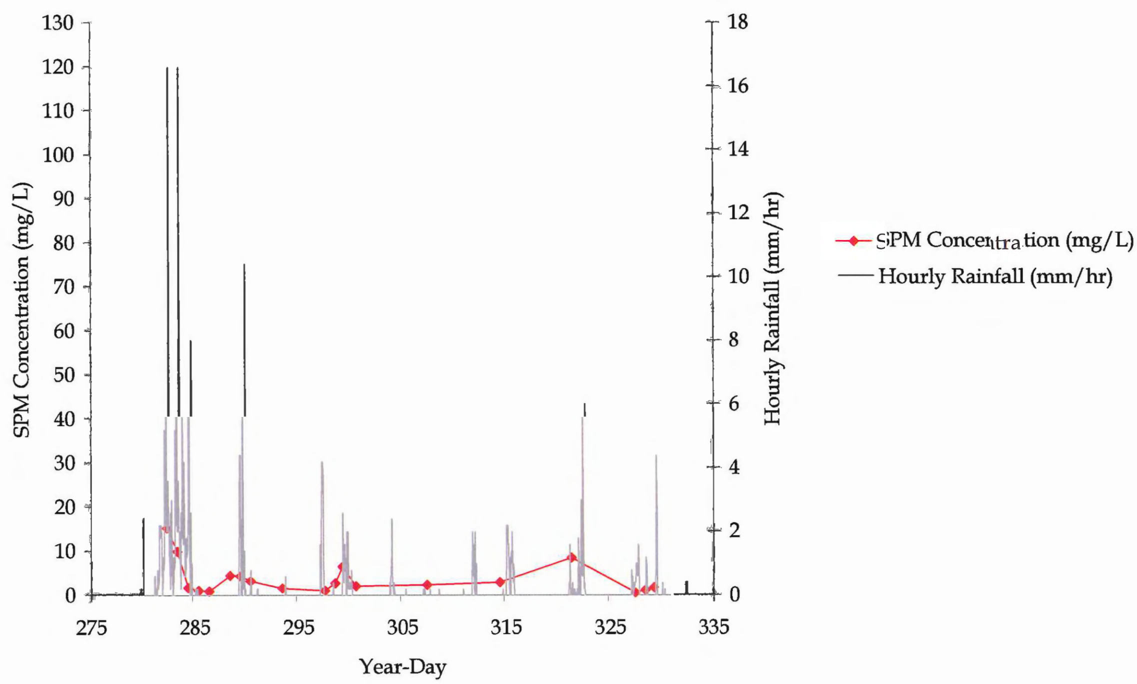
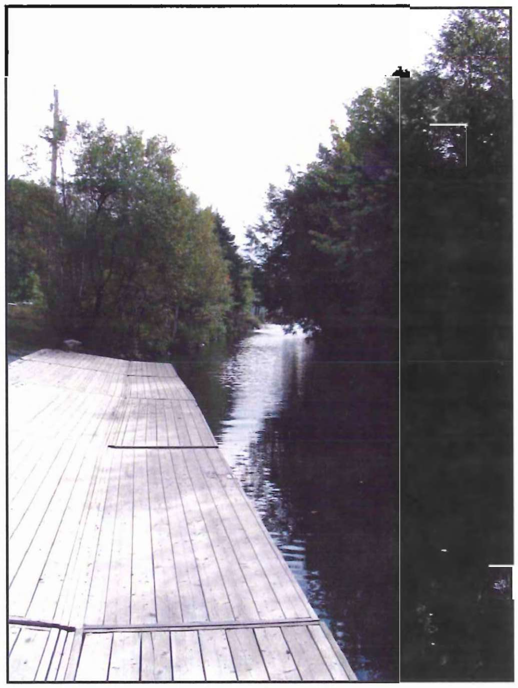


Figure 3.3: Calculated SPM concentrations for Site 2: Shubenacadie Canal Park Overflow Stream. This small stream eventually entered into Lake MicMac. Gray spikes on the graph represent hourly rainfall data from October and November 2005 and the redline represents SPM concentrations in mg L^{-1}.

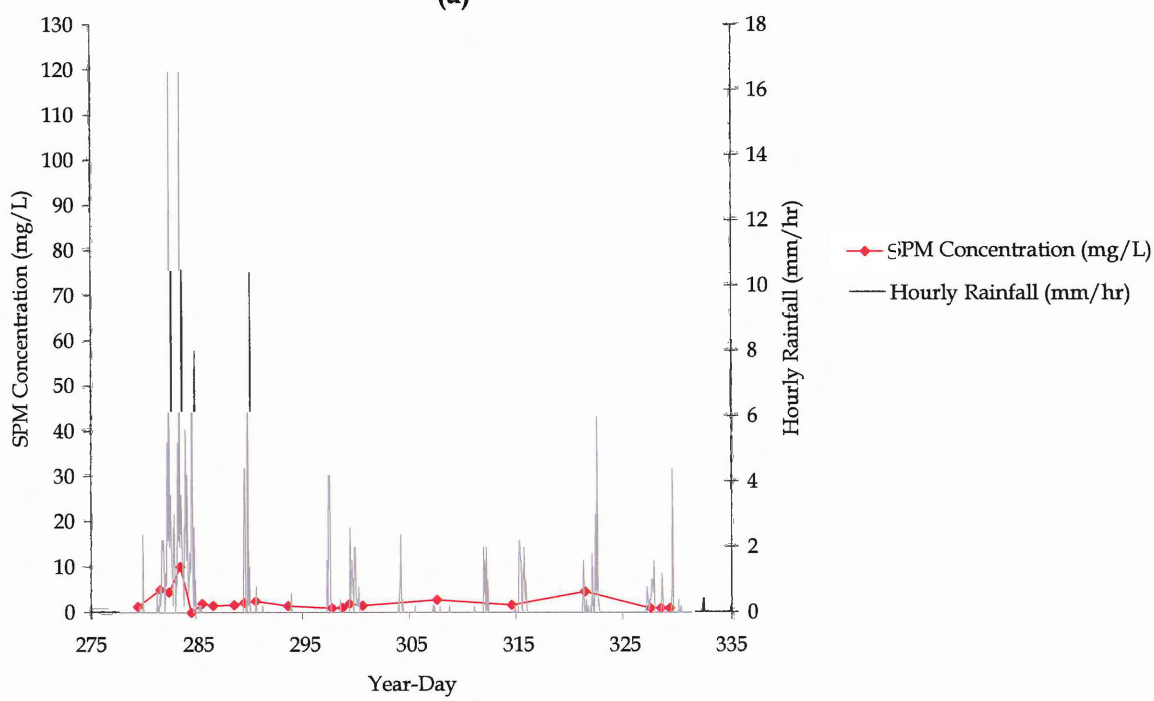
SPM concentrations in Sites 3, 4 and 5 (in the Canal) all showed similar trends through the study period. The mean SPM concentrations over the study period for these sites were 3.88 mg L^{-1} ± 2.31 mg L^{-1}, 2.15 mg L^{-1} ± 0.64 mg L^{-1}, and 1.58 mg L^{-1} ± 0.74 mg L^{-1} respectively. For SPM concentrations to be considered elevated at these sites, they needed to exceed 3.06 - 8.50 mg L^{-1}.

Site 3 was located at the entrance to Lake MicMac from the Canal, where water flowed from Lock 3 to Lock 2 down into Lake MicMac. Site 4 was located in a small pond just above Lock 2 and Site 5 was located close to the Fairbanks Centre above Lock 3. These sites were all linked by the Canal and were located along the southern portion of the Canal as it entered Lake MicMac. SPM concentrations throughout October and November did not exceeded 11 mg L^{-1} before, during or after any of the recorded rainfall events (Fig. 3.4, 3.5 and 3.6).

During the Thanksgiving Storm, all three sites (Sites 3-5) experienced a similar increase in SPM concentrations. These concentrations were elevated above background values, but were well under the Canadian Water Quality Guidelines of a 25 mg L^{-1} increase in SPM over a 24 hours period. SPM concentrations returned to background levels by October 11th (284) and from then on, only levels similar to background values were recorded. Site 3 however, recorded a slight jump in sediment concentrations on November 17th (321) reaching similar mass concentrations as seen at Sites 2 and 1, but this was not considered to be an elevated concentration.



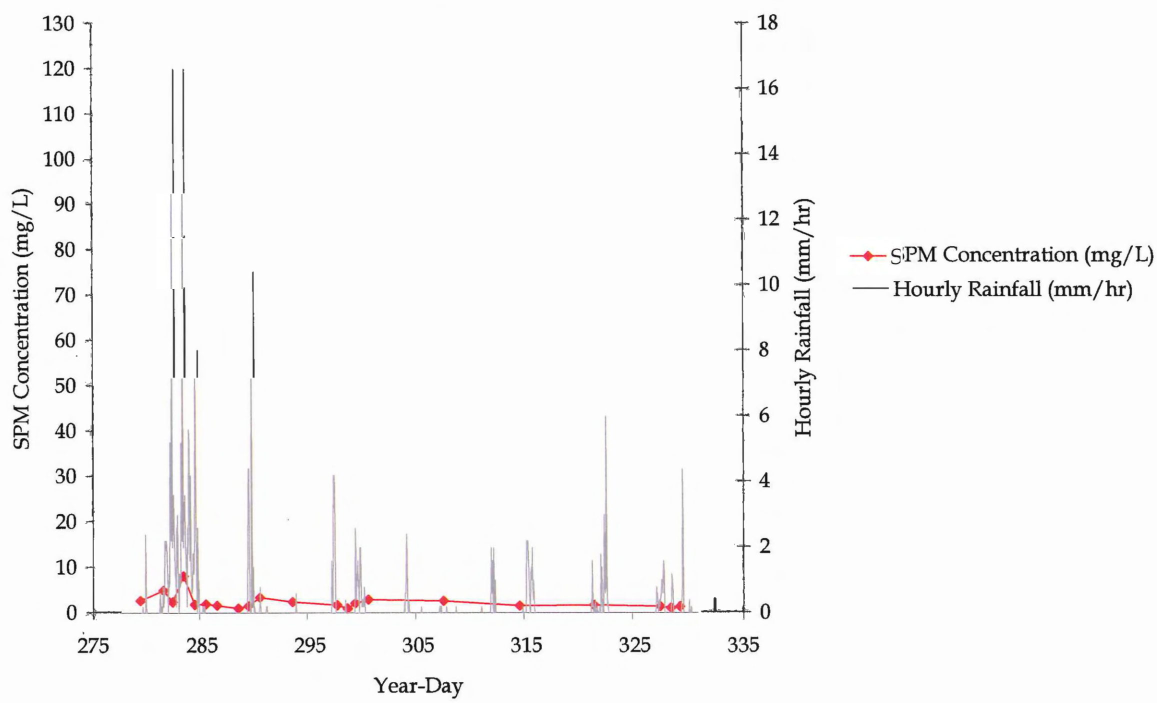
(a)



(b)

Figure 3.4: Photograph and calculated SPM concentrations for Site 3: The Canal at the entrance to Lake MicMac. (a) A low discharge photograph of the canoe dock where sampling took place looking out onto Lake MicMac and (b) SPM concentrations for Site 3: The Canal entrance to Lake MicMac. Gray spikes on the graph represent hourly rainfall data from October and November 2005 and the redline represents SPM concentrations in mg L^{-1}.

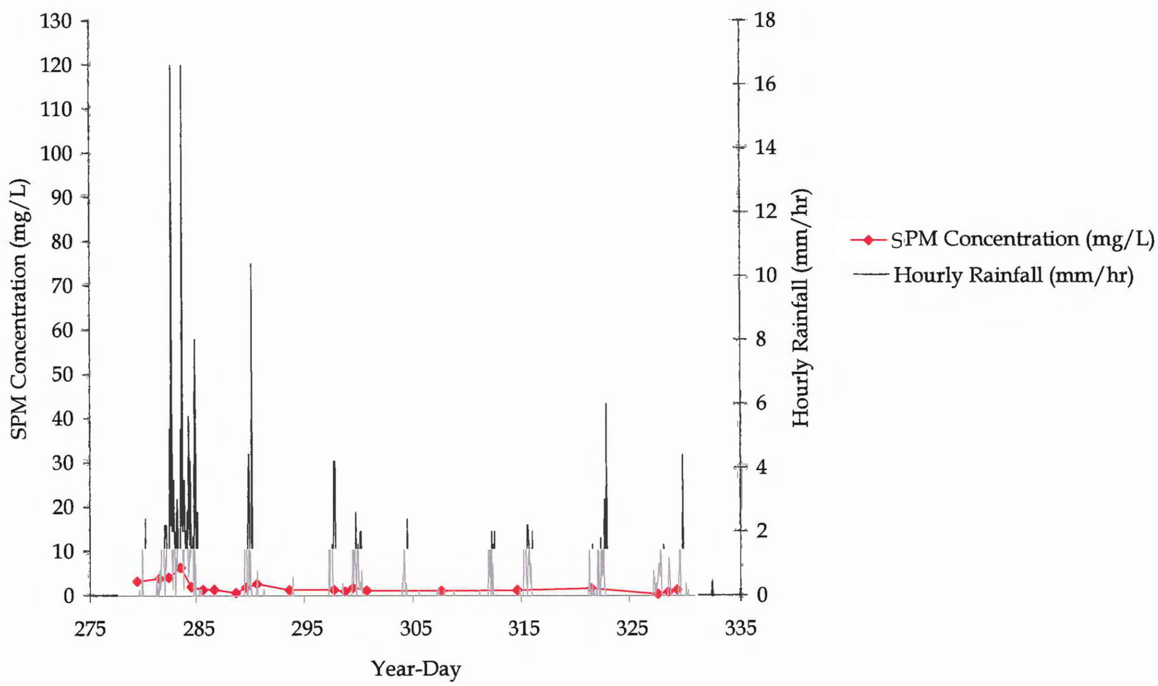
(a)



(b)

Figure 3.5: Photograph and calculated SPM concentrations for Site 4: The Canal above Lock 2, approximately half way between Site 3 and Site 5. (a) A photograph of the canoe dock where sampling took place looking out onto the small pond and (b) SPM concentrations for Site 4: The Canal above Lock 2. Gray spikes on the graph represent hourly rainfall data from October and November 2005 and the redline represents SPM concentrations in mg L^{-1}.

(a)



(b)

Figure 3.6: Photograph and calculated SPM concentrations for Site 5: The Canal above Lock 3 (a) A photograph looking across the Fairbanks Pond, the dock on the left side of the image is where sampling took place and (b) SPM concentrations for Site 5: The Canal above Lock 3. Gray spikes on the graph represent hourly rainfall data from October and November 2005 and the redline represents SPM concentrations in mg L^{-1}.

The overall agreement in SPM concentrations seen between these three sites (Fig. 3.4-3.6) suggested that there was little to no influx of sediment-rich water into this southern portion of the Canal. It could have also indicated that as water traveled from Site 5 through the two locks systems and down to Site 3, there was little to no net deposition of sediment from the water column.

As did Sites 1 and 2, Sites 3-5 experienced higher flow rates during and after storm events with an increased amount of water going through the lock system. It was also noted that after the significant rainfall event at Thanksgiving, all three of the canoe docks were underwater, and it was one or two days before the water levels receded. The flooding of the docks does not indicate higher flow rates, but it does however, provide an idea of the volume of water traveling though the system.

SPM concentrations at two of the four portions of Site 6 (Fig. 3.7) showed a similar trend in concentrations when compared to Site 1: Grassy Brook. Sites 6a and 6c were located in the northern portion of the Canal before Lake Charles. Site 6a was termed the 'natural settling pond' and was located just west of the Canal. This site was created near the end of the Thanksgiving Storm when workers from the Department of Transportation blocked a culvert, using a construction sign and sandbags. This makeshift dam was left in place for the entire study, to prevent water from flowing from the construction site (underground and by overland flow) through this region, then out into the Canal via Site 6c. Site 6a was not sampled until the end of the Thanksgiving storm on October 11 (284) as this was when it was created.

The mean background SPM concentrations for sites 6a and 6c during the study period were 8.12 mg L^{-1} ± 6.07 mg L^{-1} and 4.04 mg L^{-1} ± 2.98 mg L^{-1} respectively. Values above 20.27 mg L^{-1} and 10.01 mg L^{-1} are considered elevated for these sites. SPM concentrations during the end of the Thanksgiving Storm were recorded at 42 mg L^{-1}, higher than regulatory guidelines for a 24 hour period. However, by the next day these values were reduced to 7 mg L^{-1}. This reduction was largely due to the addition of a flocculant to the water in this pond. Flocculant causes clay and silt particles to clump together and sink rapidly from the water column. This product was dripped into the pond near the culvert at this site during periods of heavy rainfall to prevent SPM from entering directly into the Canal.

The rain storm that occurred on October 16th (289) produced the highest SPM concentrations recorded at this site. Even with the flocculant, concentrations reached 105 mg L^{-1}. This was the highest SPM concentration recorded for all sample sites during this study. After the October 16th storm, concentrations of SPM decreased significantly and fluctuated only slightly with rainfall until November 23rd (327). On this day pumps were used to move water from the settling pond to the new sediment containment sites. This procedure likely stirred up the sediment that had fallen out of suspension, resulting in the higher observed sediment concentrations.

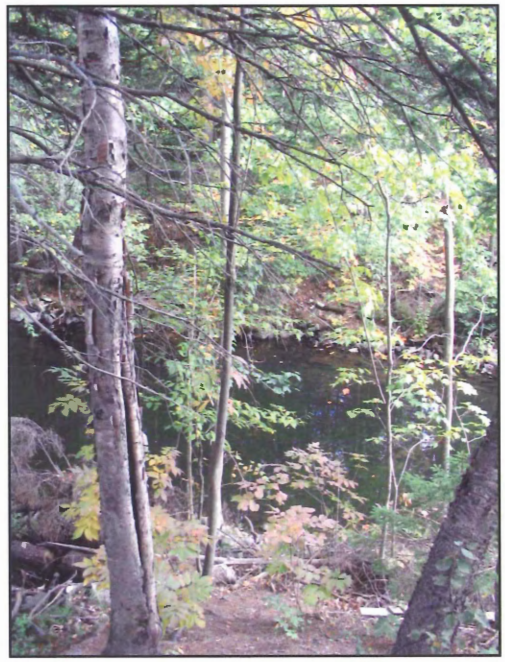
SPM concentrations for Site 6c, located in the northern region of the Canal, where waters from Site 6a entered the Canal, followed a roughly similar trend to Site 6a. The mean background SPM concentration over the study period for this site was 4.04 mg L^{-1} $\pm$ 2.98 mg L^{-1}, values in the range of 10 mg L^{-1} are considered background for this site. When rain began to fall on the October 9th weekend, SPM concentrations rose immediately to 44 mg L^{-1} and peaked on October 11th (284) near the end of the Thanksgiving Storm at 54 mg L^{-1}. This increase in SPM concentrations is above the Canadian Water Quality Guidelines for a short-term exposure. Sediment concentrations increased again during the rainfall Event 2 following a similar trend to Site 6a. The observed concentrations during Event 2 were just within the guidelines for SPM concentration increases over a short-term exposure. Other than during these two events, SPM concentrations for this site stayed within background range with minor fluctuations with rainfall.

The most significant difference noted between Site 6a and Site 6c was that SPM concentrations in 6c never reached the large values seen in 6a (54 mg L^{-1} maximum versus 105 mg L^{-1} maximum). It was interesting to note that from the time Site 6a was dammed, SPM concentrations in Site 6c were greatly reduced, as seen between October 12th (285) and October 16th (289). While concentrations at Site 6c were reduced, SPM concentrations at 6a increased dramatically to 106 mg L^{-1}.

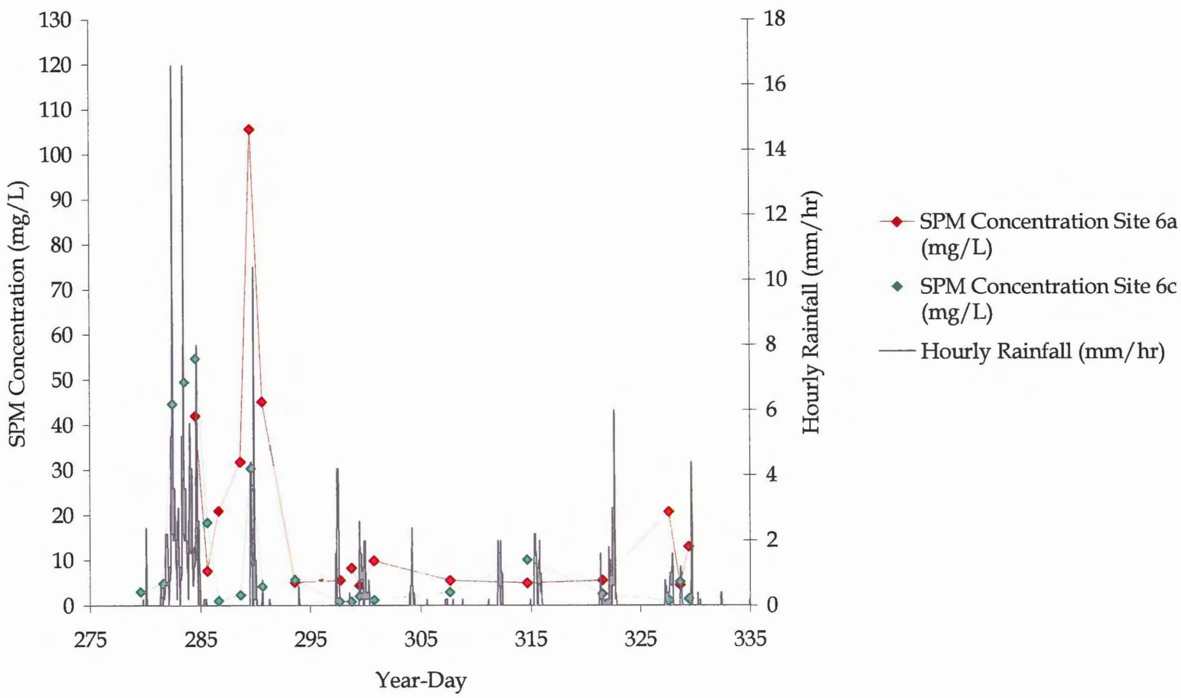
SPM concentrations at Sites 6b and 6d were only collected during Event 1: the Thanksgiving Storm. After the storm, Site 6b no longer had flowing water as a result of the blockage of the culvert at Site 6a. Because of this, no more samples could be taken from this area. Site 6d, located in the Canal approximately 10 meters north of Site 6c was sampled to determine background sediment concentrations during Event 1. Sampling stopped when another sediment plume was seen entering the Canal from a hidden brook farther to the north. The plume stretched down to Site 6d, so it could no longer provide an accurate background concentration for the water system. Figure 3.8 shows the SPM concentrations for both of these sites.

Sediment concentrations for Site 6b, over Event 1 ranged from just over 30 mg L^{-1} to 122 mg L^{-1} during the storm's peak. This peak occurred when waters were no longer flowing and pools of water had developed. It was interesting to note that the concentration of SPM in this creek peaked several days before the peak seen in either

(a)



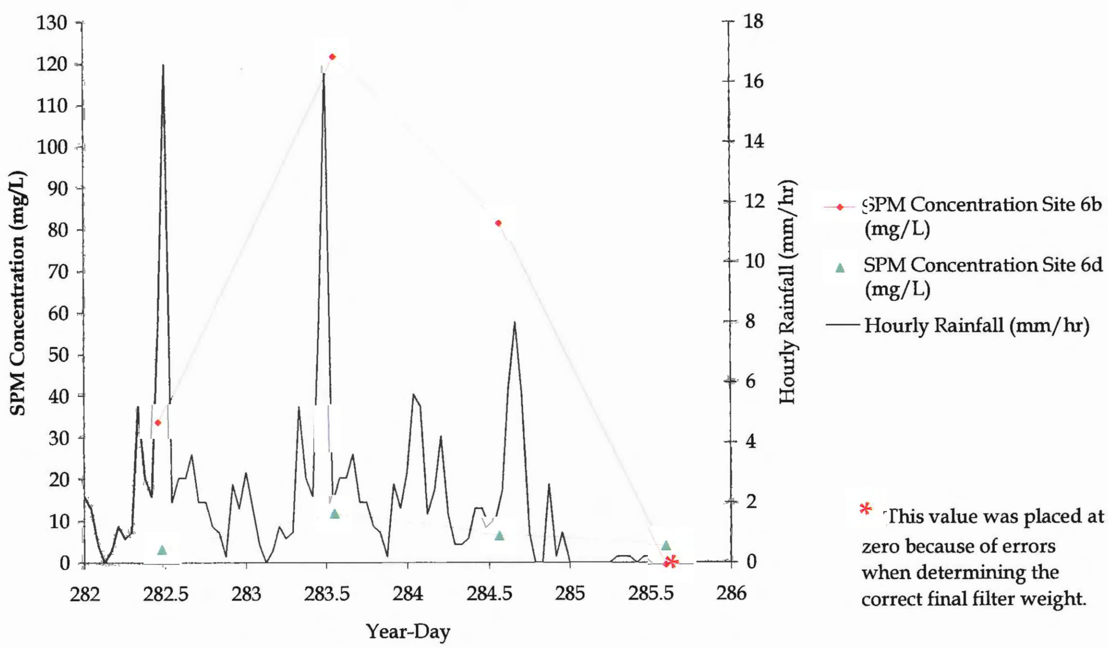
(b)



(c)

Figure 3.7: Photograph and calculated SPM concentrations for Site 6a & c: The northern portion of the Canal (a) A photograph of Site 6a, the settling pond built just west of the Canal, sampling was at the southern edge of the pond (left side of photo) To the left is of the photo is a pipe that connects the pond with the other sample sites. (b) A photograph of Site 6b, the stream entering the Canal, sampling took place at the base of the hill and (c) SPM concentrations for Site 6ac: The Canal. Gray spikes on the graph represent hourly rainfall data from October and November 2005 and the red and green lines represent SPM concentrations in mg L^{-1}.

(a)



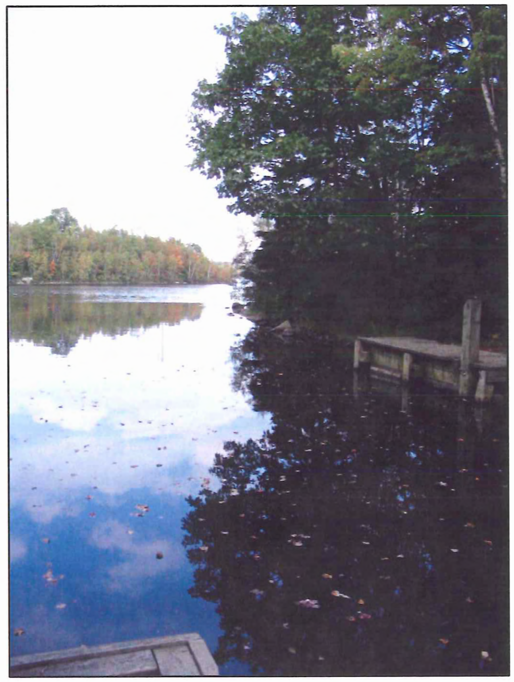
(b)

Figure 3.8: Photograph and calculated SPM concentrations for Site 6b & d: The northern portion of the Canal (a) A photograph looking directly at the small brook that carried water during Event 1, in the background is the blocked culvert and the artificial settling pond and (b) SPM concentrations for Site 6b & d: The Canal. Gray spikes on the graph represent hourly rainfall data from Event 1: Thanksgiving Storm 2005 and the red and green lines represent SPM concentrations in mg L^{-1}.

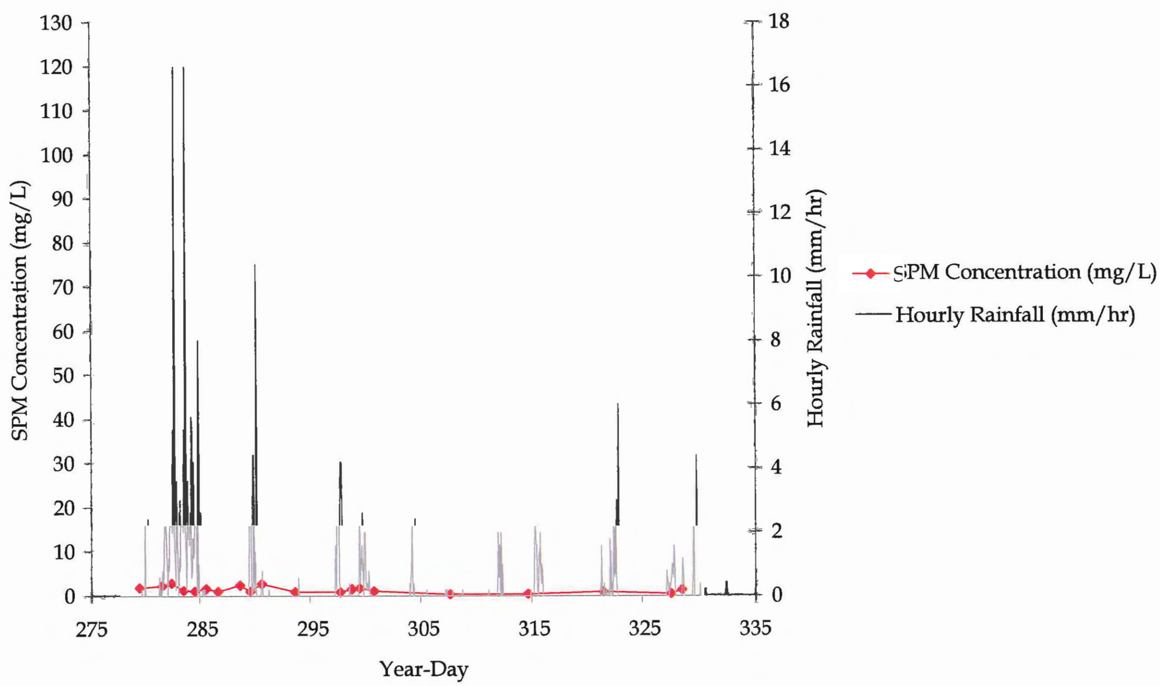
Sites 1, 6a or 6c. Concentrations from Site 6d remained fairly level during the storm, not exceeding 12 mg L^{-1}. This lack of concentration peaks in Site 6d indicated that sediment entering the canal was either diluted quickly or that the sediment settled quickly into the canal bottom.

The final site examined during the October and November study period was located near the entrance of the Canal into Lake Charles (Site 7, Fig. 3.9). This figure shows no distinct correlation between SPM concentrations and hourly rainfall. The mean background SPM concentration at this site for the study period was 1.11 mg L^{-1} ± 0.49 mg L^{-1}; values above 2.10 mg L^{-1} were considered elevated for this site. An increase above background concentrations, to between 2.5 and 3.0 mg L^{-1}, was observed on Oct 8th (281), 9th (282) and Oct 15th (288) and the 17th (290) during Event 1. These values were considered to be elevated above background as they are more than two standard deviations from the mean. However, they are substantially lower than concentrations at any other sample site during this time.

Flow of the water as it exited Lake Charles was generally undetectable. During Event 1, the increase in water in the Canal and Lake Charles and the high winds from the storm resulted in the flooding of the canoe platform and increased wave action in the canal.



(a)



(b)

Figure 3.9: Photograph and calculated SPM concentrations for Site 7: The Canal entering into Lake Charles (a) A photograph from the sample site (wooden canoe launch) looking across Lake Charles. This site is the most northerly of all the test sites. It was used to determine if the sediment plume could be tracked from the Canal region into Lake Charles and (b) SPM concentrations for Site 5: The Canal above Lock 3. Gray spikes on the graph represent hourly rainfall data from October and November 2005 and the red and green lines represent SPM concentrations in mg L^{-1}.

3.3 Settling Experiments

Settling experiments were performed on Sites 1, 6a and 6c on October 11th (284) with four samples being taken over a period of 3 minutes or 180 seconds (Fig. 3.10). For all three settling experiments, Figure 3.10 shows that at the end of the sample time SPM concentrations at Site 1 had a net decrease in concentration by 2.7 %. Site 6a had a net decrease in concentration by 5.2 % and Site 6c had changed by less than 20 % of the original concentration.

These results indicated that the suspensions were not highly flocculated as flocs typically sink at a speed of 1 mm s^{-1}, and would have sunk below the sample intake by 180s. These results are curious because during the time of sampling, waters from sites 6a and possibly 6c had come in contact with the flocculant added by the construction companies at Site 6a. The effect of this flocculant was not actually seen in the Site 6a sample as SPM concentrations increased during the last sample time in the settling experiments. It was expected that flocculated waters would show a faster decline in SPM concentrations than non-flocculated samples. However, this was not the case.

Possible explanations for this result are that the water in the settling tube was somehow stirred by temperature driven convection or by the glass sampling tube which was not always held steady. Alternatively, the flocculant may not have affected the entire natural settling pond as the sample was taken away from the region where the flocculant was administered, or the material remaining in suspension was perhaps not affected by the flocculant.

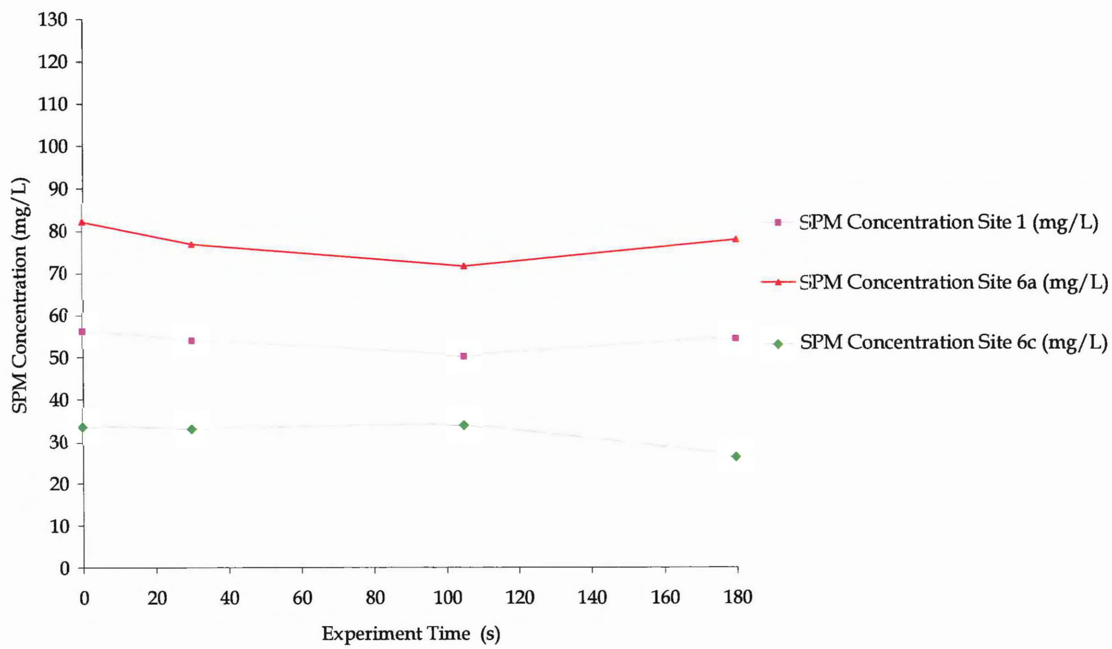


Figure 3.10: Settling experiments showing the suspended particulate matter concentrations (mg L^{-1}) over the sample time (seconds). Sites 1, 6a and 6c were sampled four times over a period of three minutes on October 11th (year-day 284) to determine the settling time of the material suspended in the water column.

3.4 Disaggregated Inorganic Grain Size (DIGS) Distribution

DIGS analyses were performed on samples from three study locations. The locations used were Grassy Brook (Site 1), the Natural Settling Pond (Site 6a) and the Canal (Site 6c). This analysis used two samples from each site to compare the grain size distribution between an event when there was the highest SPM concentration at a site and a time when there was background SPM concentration at the same site. The high SPM concentration samples for each site were taken during Event 1 (Thanksgiving Storm) while the low SPM samples were taken from any other time during the sample period when concentrations were low. Other analyses performed on the grain size data obtained from this study include the determination of clearance rates for both flocculated (min settling time) and un-flocculated (max settling time) water. Raw data from all four analyses can be seen in Appendix C.

The observed grain diameter distributions for Site 1: Grassy Brook during events with low SPM concentration and the highest SPM concentration can be seen in Figure 3.11. There are notable differences between the high and low SPM concentration distributions. The low SPM background sample had a distribution skewed towards the finer grain diameters, was poorly sorted, and had a maximum grain size of 21.11 μm. This contrasted with the better sorted and coarser distribution of the high SPM concentration event.

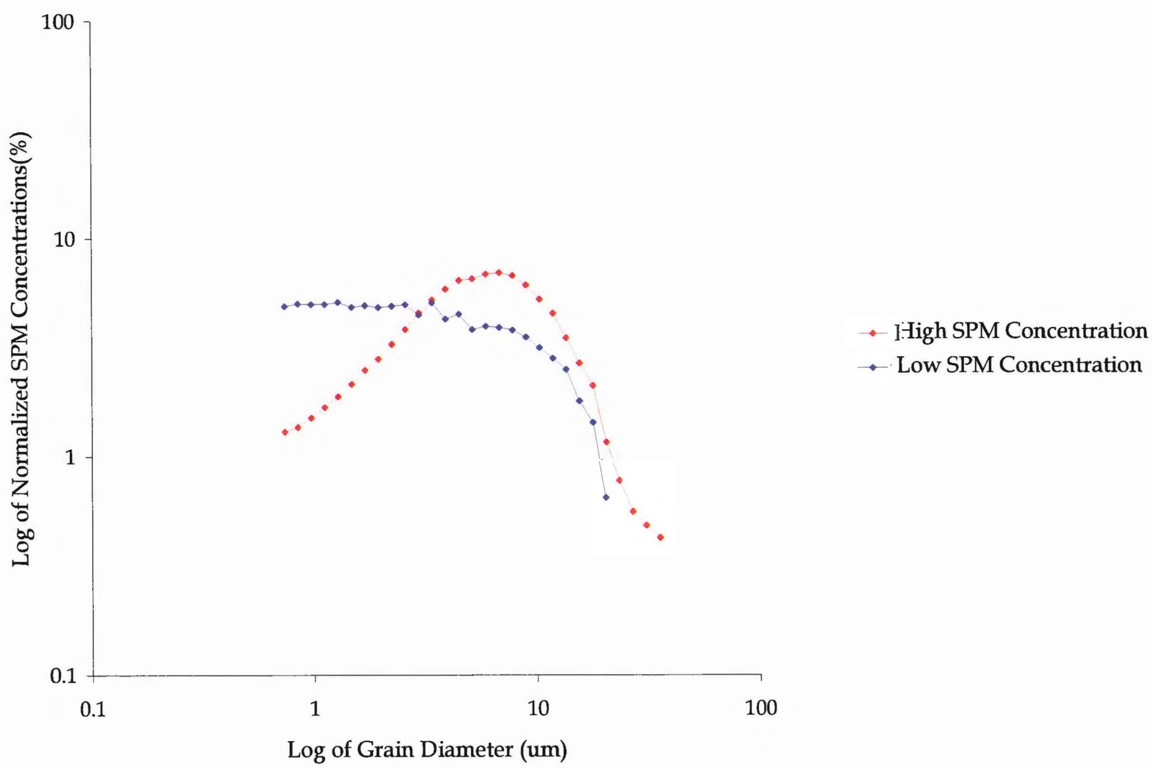


Figure 3.11: Normalized DIGS distribution for Site 1: Grassy Brook. The red line represents the highest SPM concentration recorded at this site on October 10th, 2005 when the concentration reached 96.6 mg L^{-1}. The blue line represents a background SPM concentration recorded at the site on October 20th, 2005 when concentrations were approximately 2.7 mg L^{-1}.

In the high-concentration sample, the brook was carrying larger grains, and observations confirm that the stream was flowing quite quickly. The distinct difference in the two curves suggests that there were two different sources of sediment in this brook. This would explain why the high SPM concentration did not exhibit the same distinct increase in fine grained material as seen in the background SPM concentration sample.

The observed grain diameters for Site 6a: the Natural Settling Pond during events with low SPM concentration and the highest SPM concentration can be seen in Figure 3.12. The high-concentration event SPM sample was poorly sorted, very fine

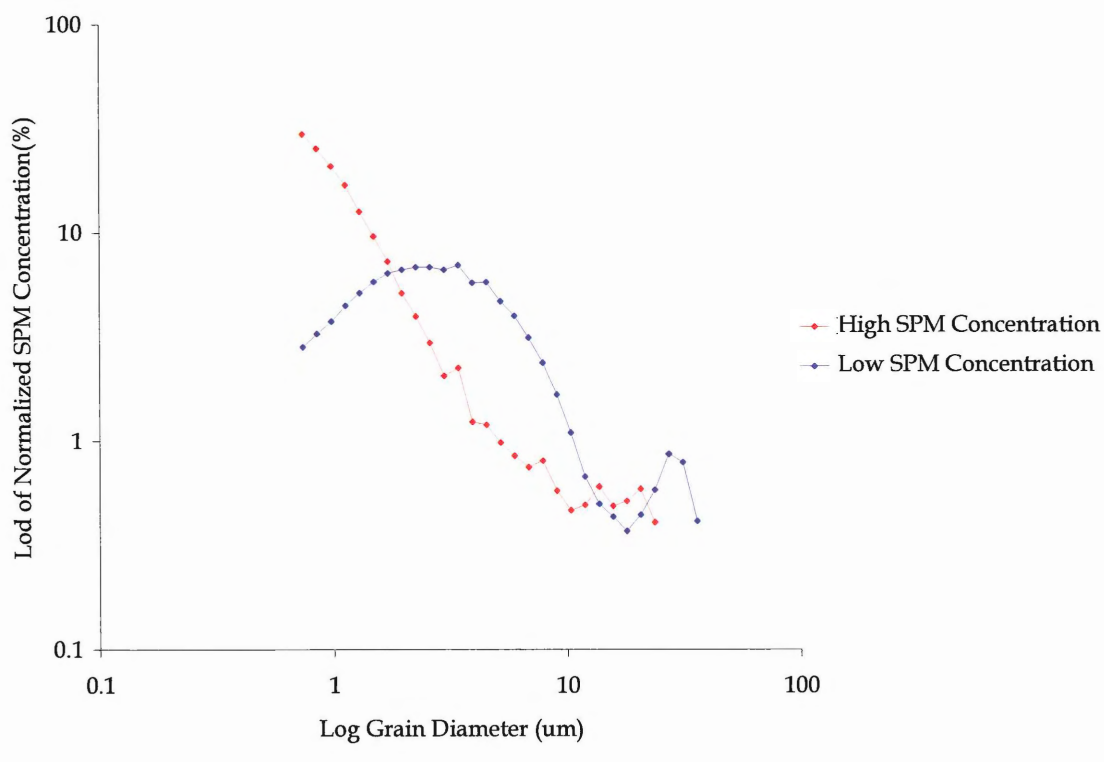


Figure 3.12: Normalized DIGS distribution for Site 6a: Natural Settling Pond. The red line represents the highest SPM concentration recorded at this site on October 10th, 2005 when the concentration reached 105.66 mg L^{-1}. The blue line represents a background SPM concentration recorded at the site on November 10th, 2005 when concentrations were approximately 5.00 mg L^{-1}.

skewed and had no distinct mode. The maximum grain size was 24.25 µm. The low background SPM was well sorted and fine skewed with a mode at approximately 2.6 µm and a maximum, grain size of 36.75 µm. The sorting in Site 6a low was similar to Site 1 high, but the mode was finer.

The background sample showed low values for the normalized concentration at large grain diameters with a decrease between 21 and 18 µm diameters. The decrease in normalized concentration was un-explained but could be due to the effects of the flocculant being used in the pond. After the decrease in normalized concentration, the background concentration increased to 2.6 µm, then dropped as grain diameters continued to decrease.

The observed grain diameters for Site 6c: the northern portion of the Canal during events with low-concentration and the high-concentration samples can be seen in Figure 3.13. There are some differences between the high and low SPM concentration distributions for this site, and between the distributions seen at other test sites. The low SPM background sample was poorly sorted with a weak mode at 4.6 µm and a maximum grain size of 24.25 µm.

The high SPM concentration sample from Site 6c showed a unique distribution as it exhibited a bi-modal distribution with peaks in normalized concentration at both 6.1 µm and at 0.75 µm with a maximum grain size of 27.86 µm. The high SPM concentration sample was poorly sorted and fine skewed. In comparison, the low-concentration distribution showed lower normalized concentrations at smaller grain diameters and higher normalized concentrations at larger grain diameters. This pattern was the opposite of what was observed in Grassy Brook.

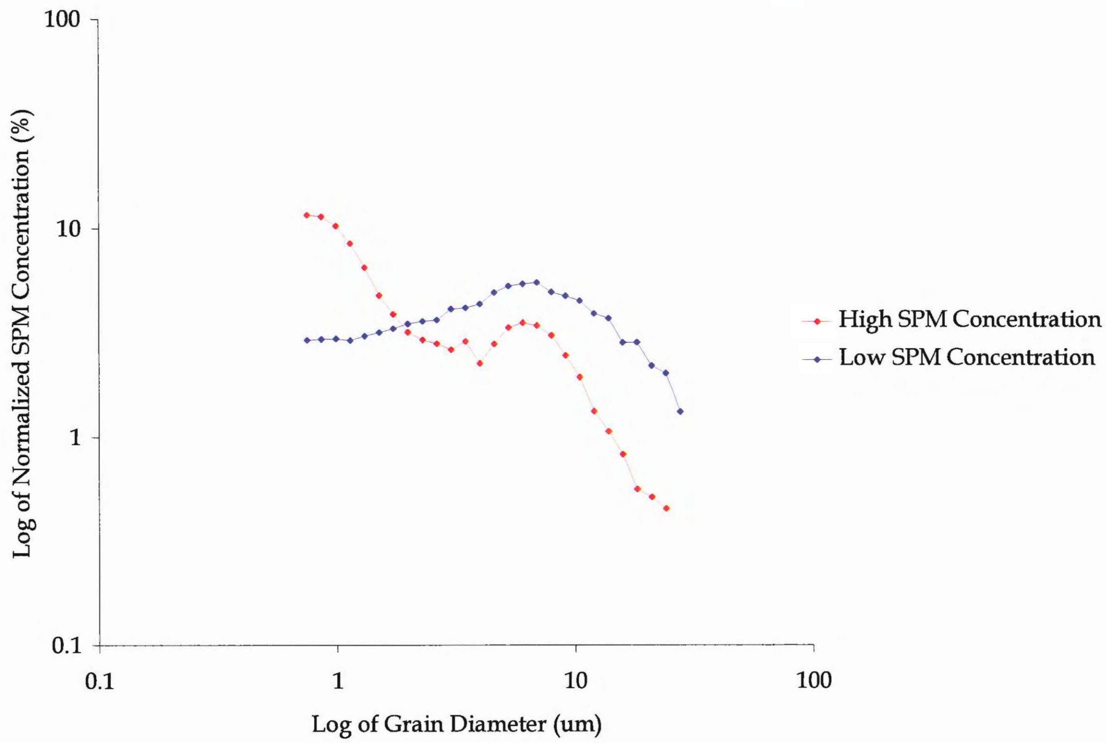


Figure 3.13: Normalized DIGS distribution for Site 6c: the northern portion of the Canal. The red line represents the highest SPM concentration recorded at this site on October 11th, 2005 when the concentration reached 54.76 mg L^{-1}. The blue line represents a background SPM concentration recorded at the site on November 3rd, 2005 when concentrations were approximately 3.00 mg L^{-1}.

It was possible that the flocculant administered at Site 6a had an effect on the size distribution at Site 6c, as the distribution of the high SPM concentration was similar to that of a special type of clay called "bentonite" or "swelling clay" (Fig. 3.14) (Milligan *et al.*, 2005). Some types of commercial flocculants use bentonite clays in their mixture, so the bentonite-like size distribution may indicate the presence of flocculant. The bentonite clay signature was bi-modal with a peak at 3.03 µm and at the end of the distribution (0.87 µm), with the maximum grain size of 42 µm.

Flocculant was administered on rainy days throughout the study period to Site 6a which eventually flows into Site 6c. The first day the flocculant was added to Site 6c was October 11th, the day of peak SPM concentration in Site 6c. This could explain why the signature was only detected in this sample as during the low sample day, no flocculant was in use.

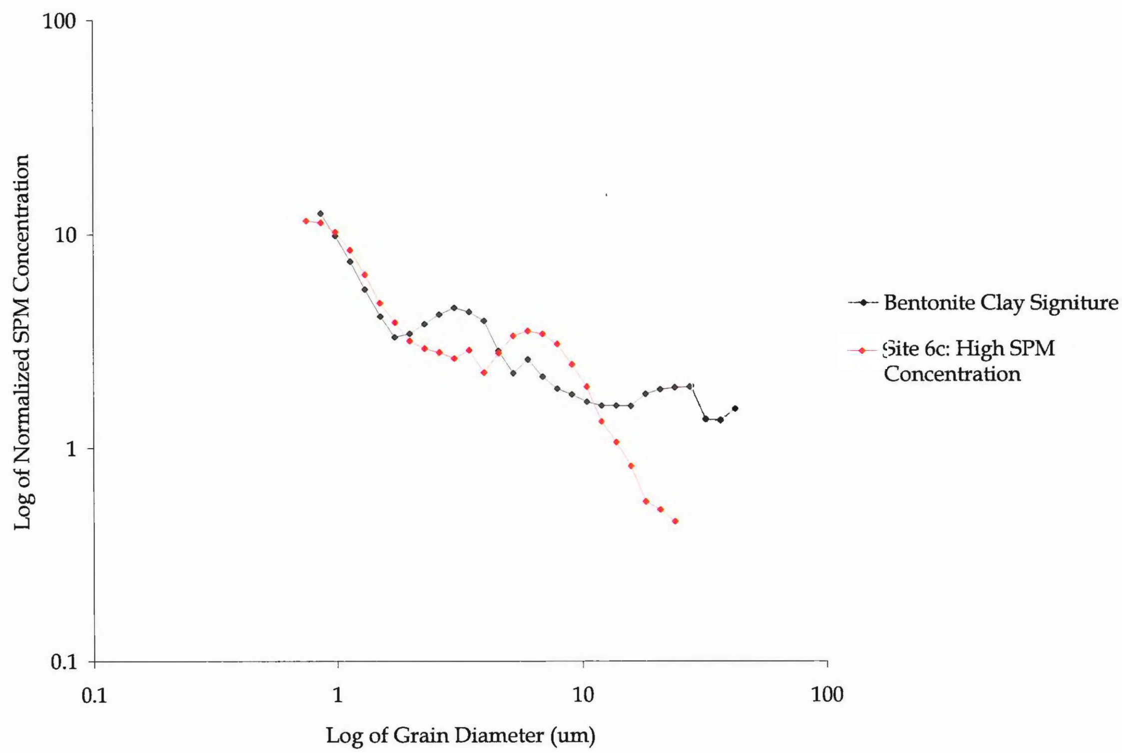


Figure 3.14: Normalized DIGS distribution for Site 6c: High SPM Concentration and the Bentonite signature from Milligan *et al.*, 2005. The red line represents the highest SPM concentration recorded at Site 6c on October 11th, 2005 when the concentration reached 54.76 mg L^{-1}. The black line represents a typical bentonite signature as based on bentonite drilling mud analysed by Milligan *et al.*, 2005.

3.4.1 Un-flocculated and Flocculated E-Folding Times

After analysing the normalized DIGS distribution for each of the three sample sites and determining the various normalized SPM concentrations at different time periods, it was possible to ascertain both the maximum and minimum e-folding times using Equation 2.4 (Tables 3.1 and 3.2 respectively). These tables were derived from

Figures 3.15-3.20 which shows the log of the total SPM concentrations with time and exponential regression curves. From these tables it was easy to see that there was a significant difference between the time required for the SPM to be removed from suspension during single grain settling with size specific settling velocities and when all grains are removed in flocs at a constant velocity.

At Site 1, the sample with the high SPM concentration (and larger grain diameters) required approximately 7 hours for material to be reduced to 37 % of the original concentration in a 1 m deep settling pond by single grain size dependent settling. This compared to 17 minutes if 37 % of the SPM grains were to settle from suspension in flocs. The sample with low SPM concentration (and smaller grain diameters) required a maximum time of 14 hours for 37 % of the SPM grains to be removed from suspension and a minimum of 17 minutes if the grains settled in flocs.

Table 3.1: Parameters used in Equation 2.4 to determine the maximum e-folding time based on size specific settling velocities (Figs. 3.15-3.17). Column data refer to the total SPM concentrations. The two time columns show the output from Equation 2.4.

Study Site	h (m)	w_s (ms^{-1})	t (seconds)	t (hours)
Site 1 (High)	1	4×10^{-5}	2.5×10^{4}	6.94
Site 1 (Low)	1	$2 \mathrm{X} 10^{-5}$	5.0×10^{4}	13.89
Site 6a (High)	1	2×10^{-6}	5.0×10^{5}	138.89
Site 6a (Low)	1	1×10^{-5}	1.0×10^{5}	27.78
Site 6c (High)	1	1×10^{-5}	1.0×10^{5}	27.78
Site 6c (Low)	1	3×10^{-5}	3.3×10^{4}	9.26

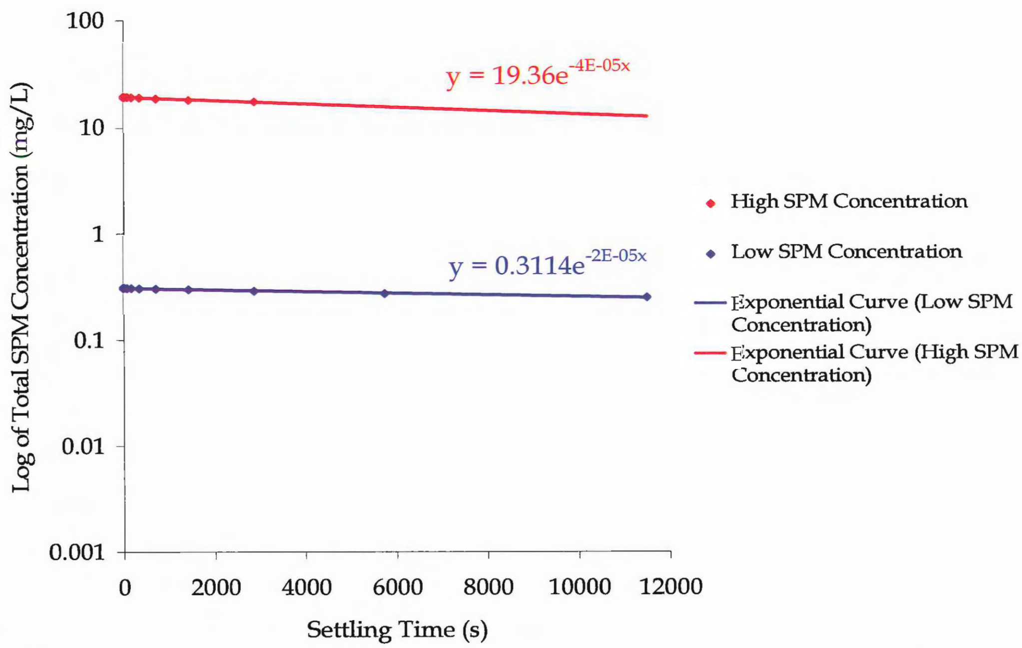


Figure 3.15: Modelled total SPM concentration as a function of time for Site 1: Grassy Brook. The model assumes that all particles sink as single grains and not in flocs. Straight lines represent exponential curves fit to the data. Red dots and line represents the sample with a high SPM concentration and the blue points and line represents the sample with a low SPM concentration.

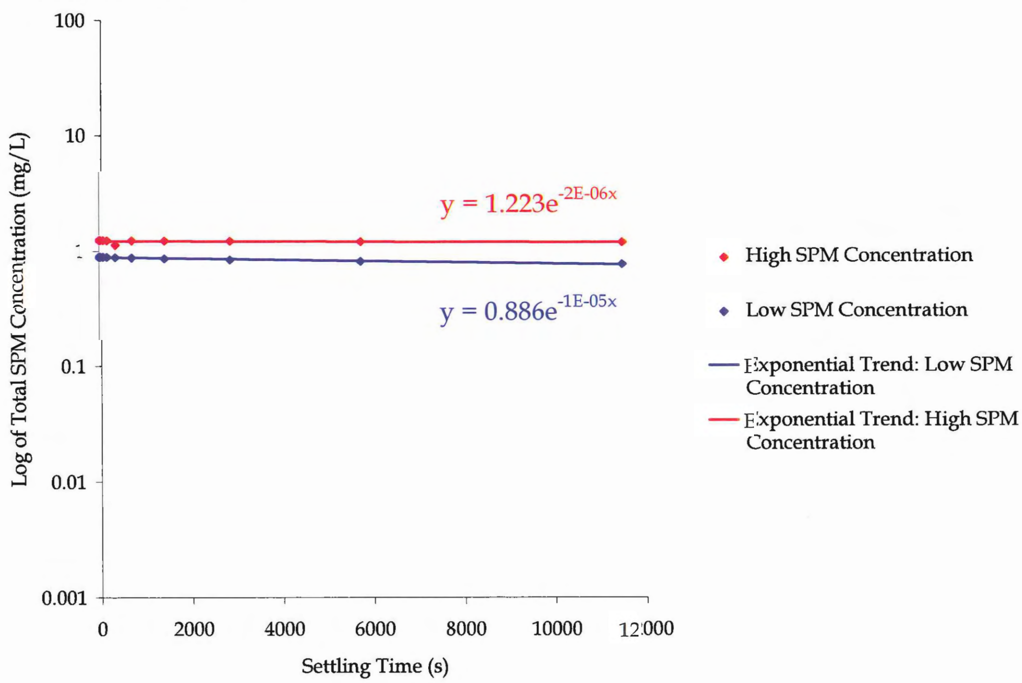


Figure 3.16: Modelled total SPM concentration as a function of time for Site 6a: the Natural Settling Pond. The model assumes that all particles sink as single grains and not in flocs. Straight lines represent exponential curves fit to the data. Red dots and line represents the sample with a high SPM concentration and the blue points and line represents the sample with a low SPM concentration.

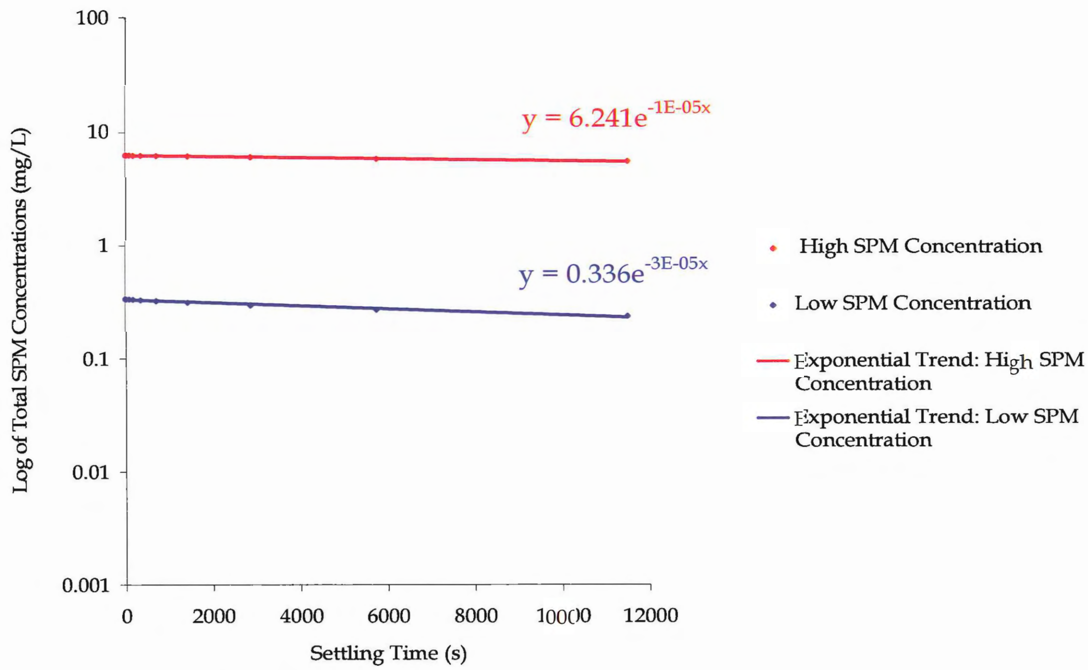


Figure 3.17: Modelled total SPM concentration as a function of time for Site 6c: the northern portion of the Canal. The model assumes that all particles sink as single grains and not in flocs. Straight lines represent exponential curves fit to the data. Red dots and line represents the sample with a high SPM concentration and the blue points and line represents the sample with a low SPM concentration.

Table 3.2: Parameters used in Equation 2.4 to determine the minimum e-folding time based on flocculated grain settling velocities of 1 mm/s (Figs. 3.18-3.20). The two time columns show the output from Equation 2.4, note that the second column is now in minutes.

Study Site	h (m)	w_e (ms^{-1})	t (seconds)	t (minutes)
Site 1 (High)	1	1×10^{-3}	1000	16.67
Site 1 (Low)	1	1×10^{-3}	1000	16.67
Site 6a (High)	1	1×10^{-3}	1000	16.67
Site 6a (Low)	1	1×10^{-3}	1000	16.67
Site 6c (High)	1	1×10^{-3}	1000	16.67
Site 6c (Low)	1	1×10^{-3}	1000	16.67

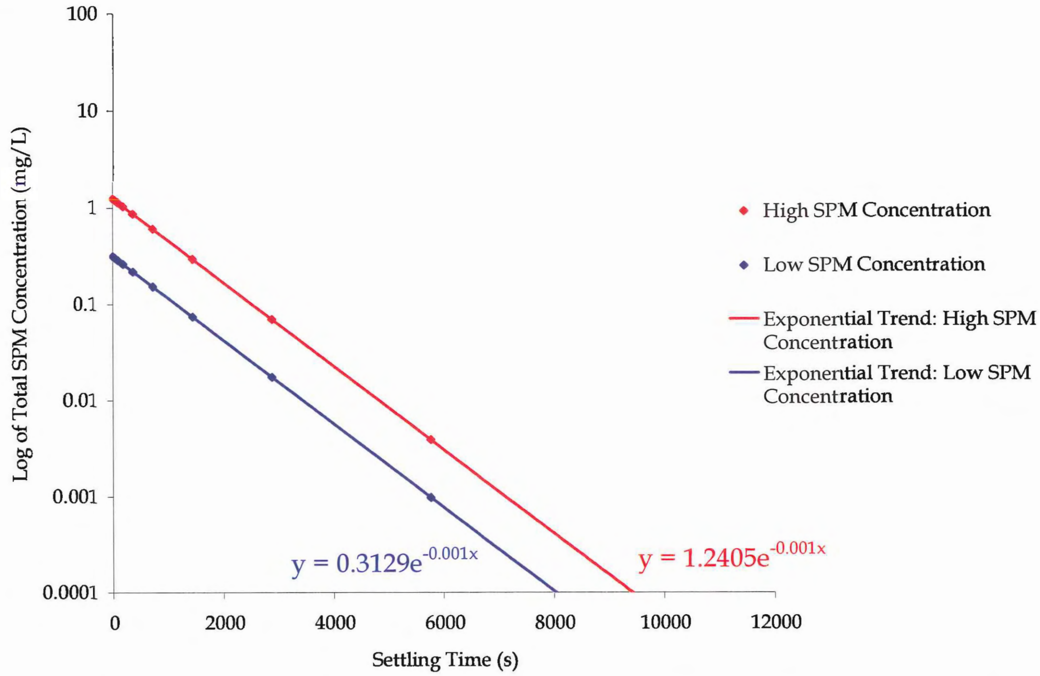


Figure 3.18: Modelled total SPM concentration as a function of time for Site 1: Grassy Brook. The model assumes that all particles sink as flocs and not as single grains. Straight lines represent exponential curves fit to the data. Red dots and line represents the sample with a high SPM concentration and the blue points and line represents the sample with a low SPM concentration.

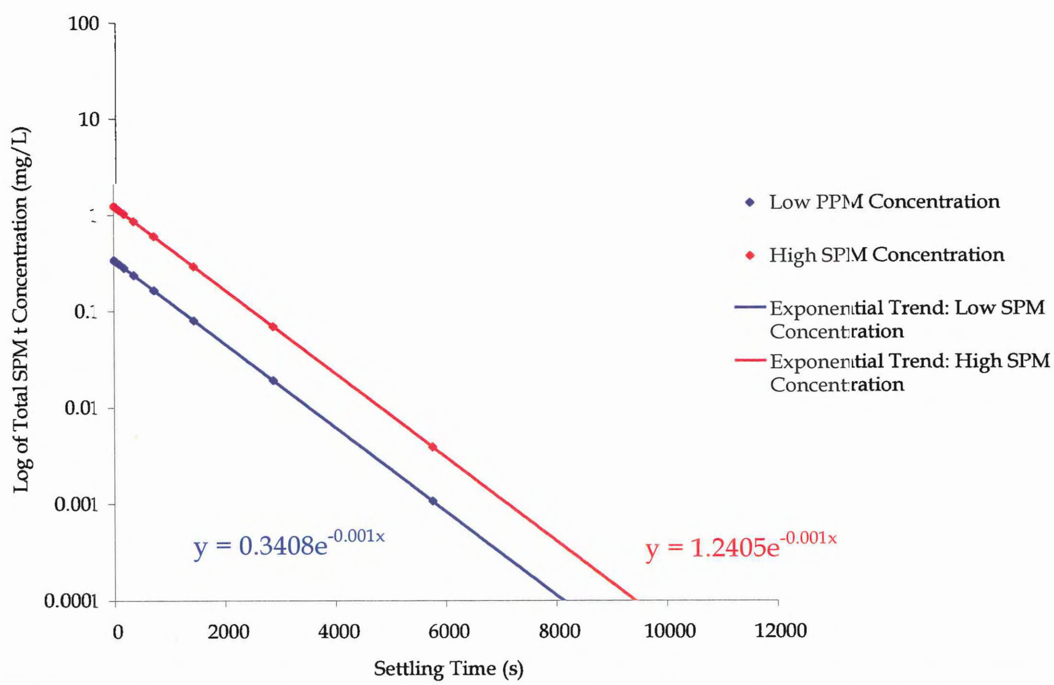


Figure 3.19: Modelled total SPM concentration as a function of time for Site 6a: the Natural Settling Pond. The model assumes that all particles sink as flocs and not as single grains. Straight lines represent exponential curves fit to the data. Red dots and line represents the sample with a high SPM concentration and the blue points and line represents the sample with a low SPM concentration.

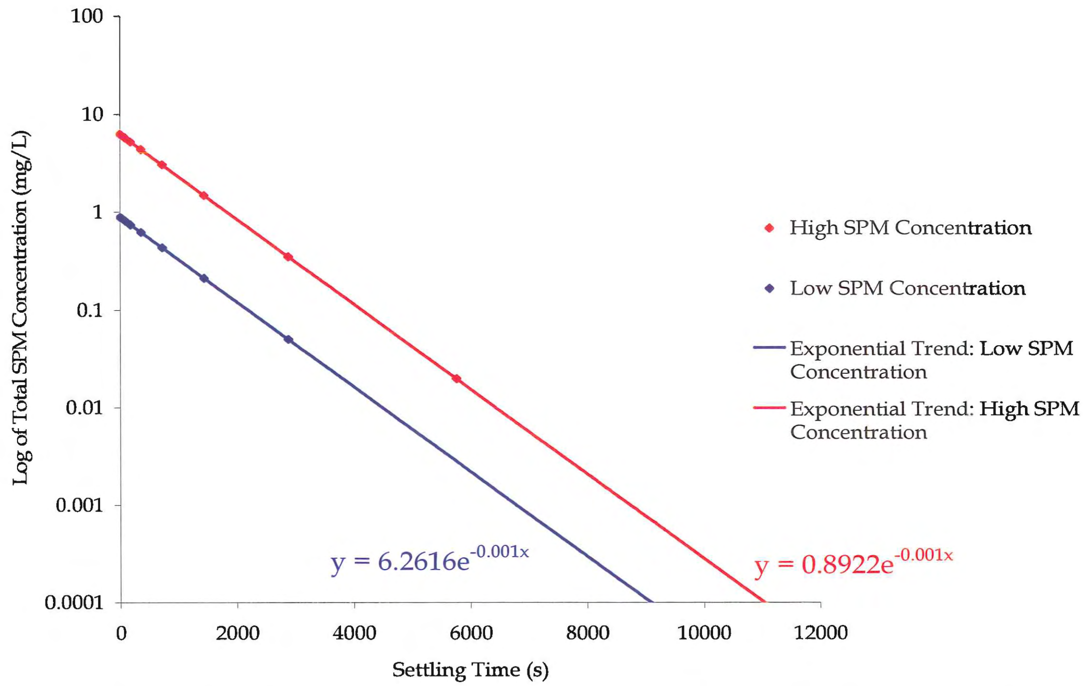


Figure 3.20: Modelled total SPM concentration as a function of time for Site 6c: the northern portion of the Canal. The model assumes that all particles sink as flocs and not as single grains. Straight lines represent exponential curves fit to the data. Red dots and line represents the sample with a high SPM concentration and the blue points and line represents the sample with a low SPM concentration.

This was interesting as the low SPM sample (with less material suspended in the water) required more time for grains to settle from suspension. This can be explained by the observation that the low SPM sample had high concentrations of finer grained material which had significantly slower settling velocities compared to the high SPM sample from Site 1.

When comparing the high and low SPM concentrations as a function of time at Sites 6a and 6c, it was apparent that the high concentration samples required more time for the suspended material to be reduced to 37 % of the total concentration than the low SPM samples. This was the opposite of what was seen at Site 1. However, the simple explanation for this was that the high SPM samples for both sites had a similar grain size distribution to the low SPM sample at Site 1. Both sites 6a and 6c had fine skewed grain size distributions in their high SPM sample which resulted in higher maximum e-folding times of between 9 and 140 hours.

3.4.2 Sediment Containment Pond Residence Times

After referencing, digitizing and analyzing the map provided by Environmental Management and Design (Appendix D), it was possible to determine the drainage areas for containment ponds 1 and 2 and then calculate their respective sediment residence times. Figure 3.21 shows the location of the Dartmouth Crossing Construction Site along with the location of each containment pond with respect to its drainage area. Input values for Equation 2.5 can be seen in Table 3.3 along with the output of minimum containment pond residence times. From this Table, it was easy to see the effect of increasing the size of containment pond 1, after the Thanksgiving Storm.

Three values for the hourly rainfall were chosen to demonstrate the difference between containment pond residence times. This process assumed that the containment ponds were full of rain water so that residence time could be calculated. When rainfall was 5 mm h^{-1}, half-way through the Thanksgiving Storm (Appendix B), containment pond 1 had a residence time of approximately 3.5 hours, compared to 14.5 hours in containment pond 2. When the rainfall rate was increased to 16.6 mm h^{-1}, a value obtained during the height of the storm, the containment pond residence time dropped dramatically in containment pond 1 to just over 1 hour, where as containment pond 2 residence time was reduced to 4. 5 hours.

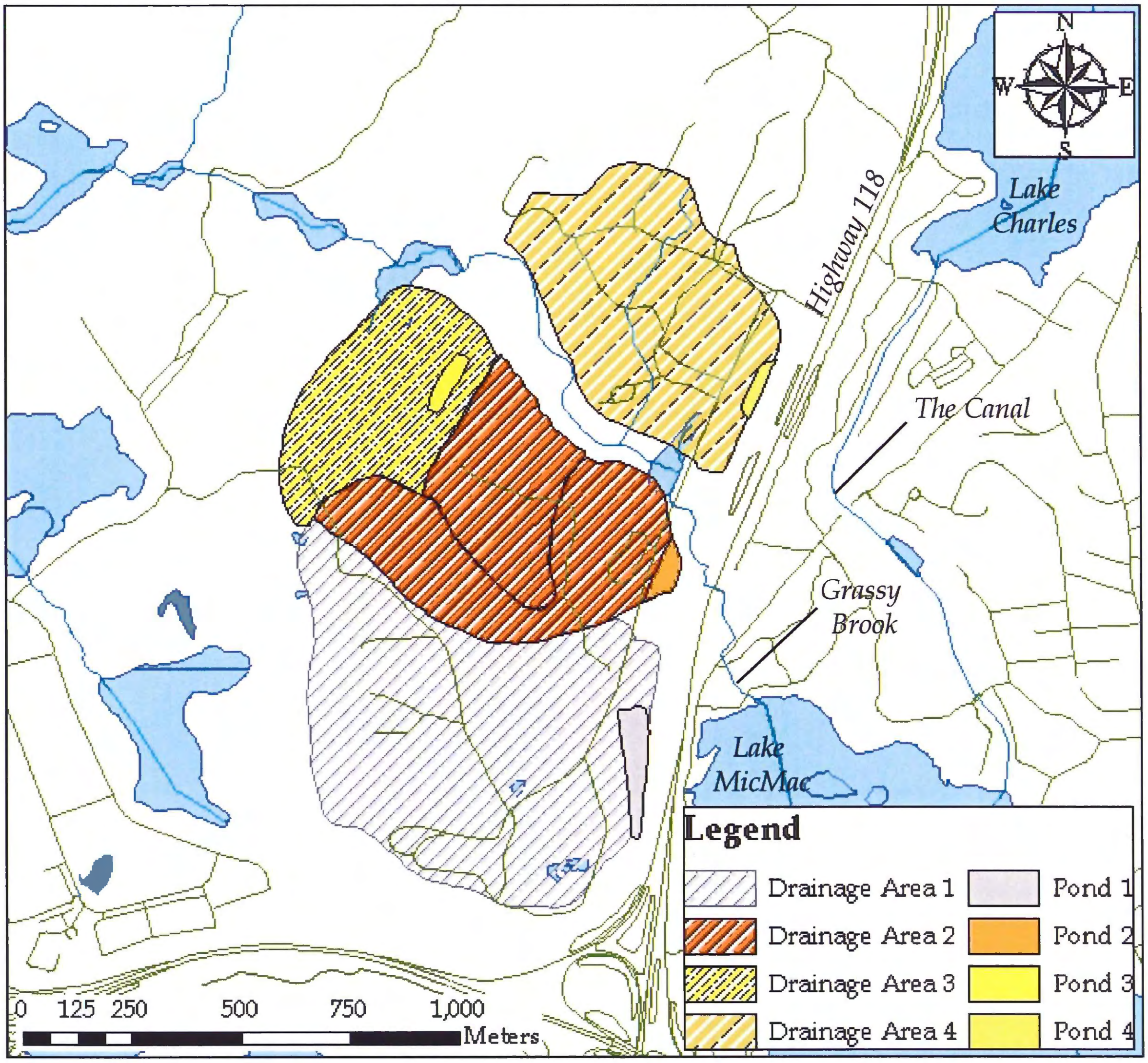


Figure 3.21: Location and area of the sediment containment ponds for the Dartmouth Crossing Construction Site. Image was produced by geo-referencing a Dartmouth Crossing Construction Site then digitizing the locations of the sediment containment ponds and the drainage areas. The number of data transformations resulted in the area of each drainage basin being a general order of magnitude value. Drainage area 3 is incorporated with drainage area 2, as pond 3 was a natural low area and not a designed containment pond. Data Sources: ESRI Canada Data & NSGC Data Locator and Environmental Design and Management Limited (EDM, 2005).

Table 3.3: Equation 2.5 input values for the determination of the containment pond residence time. Containment pond and drainage basin area locations can be seen in Figure 3.21. The terms "Old Pond Volume" and "New Pond Value" refer to for drainage area 1 where after the Thanksgiving Storm the Nova Scotia Department of Environment required the enlargement of the containment ponds to deal with more significant rainfalls. The containment pond was enlarged from accommodating103 mm of rain in a continuous event, to 190 mm of rain during a continuous event. In the following calculations, drainage area 2 and 3 were considered to be drainage area 2 as Pond 3 was a natural depression and not a typical sediment containment pond.

Type	Map Area (m^2)	Hourly Rainfall ($m\ h^{-1}$)	Volume inflow ($m^3\ h^{-1}$)	Old Pond Volume (m^3)	Old Pond Residence Time (h)	New Pond Volume (m^3)	New Pond Residence Time (h)
Drainage Area 1	4.79×10^5	0.003	1.44×10^3	8.50×10^3	5.92	3.10×10^4	21.58
Drainage Area 1	4.79×10^5	0.005	2.40×10^3	8.50×10^3	3.55	3.10×10^4	12.95
Drainage Area 1	4.79×10^5	0.0166	7.95×10^3	8.50×10^3	1.07	3.10×10^4	3.09
Drainage Area 2	4.80×10^5	0.003	1.44×10^3	3.50×10^4	24.30	*	*
Drainage Area 2	4.80×10^5	0.005	2.40×10^3	3.50×10^4	14.58	*	*
Drainage Area 2	4.80×10^5	0.0166	7.97×10^3	3.50×10^4	4.39	*	*

* means that this containment pond was not enlarged after the Thanksgiving Storm.

The approximate average rainfall rate during the Thanksgiving Storm was 3 mm h^{-1}. This produced containment pond residence times of 6 hours in pond 1 and a residence time of 24 hours in pond 2. Once the construction at the Dartmouth Crossing Site was shut down, after the Thanksgiving Storm, the containment pond sizes were increased from being able to hold 105 mm of rain per continuous event, to being able to hold 190 mm of rain per continuous event. The increased pond size resulted in a dramatic increase in residence times for pond 1 (pond 2 size remained constant). The result was that pond 1 residence times were then similar to those calculated for containment pond 2.

Since it was unknown if the grains were fully flocculated or settled as single grains while in the containment ponds, the two e-folding times calculated in Section

3.4.2, gave a range of time when 37 % of the concentration would have been reached. This range was between 17 minutes (all flocculated grains) and 28 hours (single grain deposition) for all samples except one. The one sample with an elevated e-folding time was Site 6a (high), but the DIGS analysis (Fig. 3.12) revealed that this sample had a high proportion of very fine grains. A higher proportion of very fine grains would increase the single grain e-folding time as fine grain settling velocities are very small.

The values for the containment pond residence times were then compared to the above e-folding times for flocculated and un-flocculated grains. If the e-folding time was less than the containment pond residence time, then waters discharged from the pond would have been relatively clear. If the e-folding time was greater than the pond residence time then discharged waters would have been murky.

Based on observations of murky sample waters taken during and directly after the Thanksgiving Storm, it can be assumed that the sediment grains were not fully flocculated. Flocculant was known to have been added to the site containment ponds, but the grains were not fully flocculated. This made the e-folding time of the sediments in suspension in-between the calculated values for flocculated and un-flocculated grains. Even with the addition of some flocculant to the containment ponds, the residence time in the ponds was not long enough to remove most of the SPM from suspension during the Thanksgiving Storm.

After the Thanksgiving Storm, once the containment ponds were enlarged, SPM concentrations did not fluctuate as dramatically with heavy rains. This was because the e-folding time of the suspended sediments remained constant, while the pond residence time was increased. The result was that waters stayed in the pond long enough for most of the SPM to settle from suspension.

3.5 Summary

This Chapter can be summarized by a few key points. The first point underlined the clear relationship between SPM concentrations and rainfall during Event 1 in both the northern Canal sites and Grassy Brook. The five other test sites did not show a strong relationship between these two variables. The second point showed that normalized grain diameter distributions varied between high and low SPM concentration samples as well as between sample sites. This could be attributed to the addition of flocculant to the waters or possibly a different source of sediment.

Finally, it was possible to see a distinct difference between the e-folding times of un-flocculated versus flocculated sediment. When sediment grains settle from suspension by single grain deposition, the e-folding time varied from 6 to 140 hours. When all grains in suspension settle with the maximum velocity of flocculated grains, the e-folding time was reduced to 17 minutes. Since the proportion of single grains and flocs in the suspension is unknown, it was difficult to determine using the pond residence time, if waters discharged from the Dartmouth Crossing Construction Site were murky or clear. Observations of murky water entering the study area during the Thanksgiving Storm indicated that grains were not fully flocculated in the containment ponds.

CHAPTER 4: DISCUSSION

4.1 The Problem

Concerns about suspended sediment entering the study area because of urban and commercial development have been ongoing in this region. Measurements of the SPM concentrations have been taken from the 1970's onwards by several different groups. One of the more relevant studies that collected data from Lake Charles, Canal and Lake MicMac region was performed by Charles Castell in 1977. He systematically took samples from several different places in this area, including some areas that matched samples taken during this study.

Samples from Grassy Brook taken in 1977 showed little correlation between rainfall and suspended sediment concentrations. Even during heavy rainfall events in the summer of 1977, concentrations of suspended material in the brook were approximately 20 mg L^{-1} which are considered to be low. During these same rainfall events, concentrations of SPM reached several hundreds of mg L^{-1} in culverts and other brooks located around Grassy Brook and the Canal region. SPM concentrations in the Lake Charles region remained at background levels even during rainfall fluctuations (Castell, 1977).

The muddy water entering Lake Charles, the Canal and Lake MicMac sparked a significant amount of public and political interest through the spring and early fall of 2005 as several rain events brought sediment-laden water to the water system. The public immediately saw the sediment runoff from the construction sites as a significant problem and believed that it was a warning of problems to come if the issues of erosion and containment were not resolved. Unfortunately, in September and October of 2005, heavy rainfalls again brought sediment-laden water again to the study area.

Samples taken during the fall of 2005 study showed that during small rainfall events, SPM concentrations in Grassy Brook could increase from background levels to between 10- 20 mg L^{-1}, consistent with results obtained by Mr. Castell. SPM concentrations during small rainfall events in the Canal regions were not similar to those observed by Castell (1977). They reached a maximum of 60 mg L^{-1} in the northern Canal region during major storms, but during small storms remained within background concentrations (or just above). Recorded SPM concentrations in the Lake Charles region were similar to those observed by Castell in 1977.

Based on the previous work in this area, samples taken from Grassy Brook during this study are very important, as the brook runs directly though the Dartmouth Crossing Construction Site (Figs. 1.6; 3.21). Elevated SPM concentrations in Grassy Brook would most likely be the result of disturbances that occurred on the construction site. During the Thanksgiving Storm of 2005 (Event 1) the HRM region received over 150 mm of rain over a three-day period.

The sediment containment ponds, which were part of both the Sediment and Erosion Control Plan for both the Dartmouth Crossing Construction Site and the Highway Interchange Construction Site, were overwhelmed by the rain entering from the exposed portions of the sites. The sediment containment ponds were originally built to withstand a typical large fall storm, holding 105 mm of rain per rainfall event, depending on the event intensity and duration (VanZeumeren, 2006). When the area received 150 + mm of rain over the Thanksgiving Weekend, the system was unable to keep up with the water entering into the ponds.

The purpose of these containment ponds was to catch waters coming off the construction site and store the water while allowing for the flocculation and settling of sediment before the water was discharged from the construction sites. The settling pond residence time (detention volume of the pond divided by the outflow rate) was used by the containment pond designers to determine if the time that the water stays in the pond is less than, equal to or greater than the settling velocity of the particles. The Dartmouth Crossing Construction Site had two large containment ponds and three smaller ponds located on site (Fig. 3.21). The two larger ponds held 8,500 m^3 and 35,000 m^3 of water at a time, while the volumes of the other smaller ponds were unknown (EDM, 2005).

During the Thanksgiving Storm (Event 1) both construction sites were unable to contain the waters entering into the settling ponds and had to release the excess water directly into adjacent streams and culverts. Waters from the Highway Interchange Construction Site containment ponds were released directly into Grassy Brook where there was no other measures in place to prevent contamination of Lake MicMac. Waters from the Dartmouth Crossing Construction Site were released into a small culvert that entered into Lake MicMac. At the mouth of the culvert was a silt fence to facilitate the deposition and containment of sediment (VanZeurmen, 2006).

Both construction sites had the consent of the Nova Scotia Government to release sediment-laden waters into the surrounding water systems, as the rain had the potential to cause significant damage to both the construction sites and the adjacent highway (CBC, 2005). If rain waters were allowed to overtop the containment ponds, it could have caused erosion of the pond walls, and eventually resulted in a flood of water as containment pond stability was lost. If this flood had been allowed to happen, recorded

SPM concentrations in the adjacent waterways would have been much higher, and the cost of the damage to the Highway and construction sites would have been significant.

The result of releasing sediment-laden waters from the Highway Interchange Construction Site to Site 1: Grassy Brook (Fig. 2.1), was a significant spike in the recorded SPM concentrations to approximately 100 mg L^{-1} (Fig. 3.2). This was the highest recorded SPM concentration at Site 1. A comparison of the DIGS between a typical background sample and this high SPM sample revealed two very different signatures. The high SPM sample had a well sorted distribution with a distinct mode at 7 μm and a higher proportion of larger grain diameters. The background sample collected from this site was poorly sorted and fine skewed (Fig. 3.11).

This difference can be attributed to the sediment in these samples coming from different sources. The background SPM sample with the higher proportion of small grains was typical of suspensions derived from unsorted "raw" source material that had not undergone repeated cycles of erosion and deposition (Kranck *et al.*, 1996). The flow velocity of Grassy Brook was slower when this sample was collected, as it had not rained in several days. As a result, larger grains did not remain in suspension. The high SPM sample with higher proportion of larger grains, suggests a faster current capable of eroding sorted sediment from the brook's bottom (Kranck *et al.*, 1996). One would expect that if these two samples were of the same origin they would have similar proportions of finer material.

After the beginning of Event 1 at Grassy Brook, another SPM concentration increase occurred two days after the initial SPM high. Concentrations reached approximately 25 mg L^{-1} (below regulatory limits for a 24-hour period) even though it had not rained that day. A possibility for the increase in SPM concentrations was that once the construction sites were shut down and the companies ordered to enlarge their sediment containment ponds, they moved surface material around the sites. Since Grassy Brook runs directly through the site, some of this material may have reached the nearby brook, resulting in increased SPM concentrations.

To the west of the northern Canal area (Sites 6) was a depression or swampy region with a culvert that led to a stream and eventually into the Canal. During the Thanksgiving storm, on-site workers prevented the further contamination of the Canal by blocking the small culvert that allowed sediment-laden water to enter into Site 6c. Groundwater flow through fractured rock in an area likely caused the flow of sediment-laden waters to the site, thus bypassing the containment ponds. By blocking the culvert, a natural settling pond was created, thus catching the groundwater flow and reducing the SPM entering into the Canal during the rest of the sample period.

After the establishment of the natural settling pond, SPM concentrations in the northern portion of the Canal dropped significantly (Fig. 3.7). The decrease was partially due to the detainment of water in the natural settling pond and the addition of flocculant to the water. Blocking off the culvert, which allowed for waters to stay longer in the depression, did not completely prevent the flow of water into Site 6c. Groundwater flow caused a slow release of water, allowing flocculant to reach the Canal.

Grain size analysis for Site 6a during the Thanksgiving Storm showed no distinct mode, and was finely skewed (Fig. 3.12). This distribution was expected, as the presence of flocculant would remove the larger material from suspension while the water was stagnant in the pond. The background SPM sample from this site showed a different distribution as there was a distinct mode at 2.6 μm; the sample was better sorted, and finely skewed.

The analysis of Site 6c grain sizes showed an interesting signature (Fig. 3.13). The low SPM sample had a distribution similar to the Site 1, low SPM sample but the high SPM sample was unique. It displayed a distribution similar to bentonite clay (Fig. 3.14), which has been described by Milligan *et al.*, 2005 in drill mud samples from the offshore of Nova Scotia. Currently, this signature can not be fully explained. It could have been due to the inclusion of bentonite clays in the flocculant used at Site 6a. Alternatively, it was possible that the fineness of the size distribution was due to the removal of larger grains in response to the addition of the flocculant.

After Event 1, the Government of Nova Scotia shut the construction sites down until the containment pond sizes were increased to prevent similar problems from occurring during subsequent storms. The size of the containment ponds at the Dartmouth Crossing Construction Site were increased from a 100 year storm capacity (approximately 100 mm of rain in one event) to a over a 150 year storm capacity . The containment ponds can now hold 190 mm of rain during a rainfall event (VanZeumeren, 2006). It is believed that the new containment ponds will prevent further damage to the study area by increasing the residence time in the containment ponds.

Other than increasing the surface water containment, additional techniques used to prevent the contamination of the nearby lakes included hydro seeding, silt fences and the spreading of hay over the site (VanZeumeren, 2006). These measures were expanded considerably after the Thanksgiving Storm. Groundwater flow through the fractured bedrock typical of this region, was a problem that was unexpected by both operations. Surface waters had a tendency to simply "disappear" on the western side of the highway, and re-appear days or hours later on the eastern side of the Highway (VanZeumeren, 2006). Once the local groundwater flow was recognized as a concern, it needed to be dealt with by reducing or stopping the disturbance of sediment on the surface. This was done by hydro-seeding and spreading straw over regions where land was exposed.

The purpose of hydro seeding was to grow vegetation on exposed portions of land. Vegetation would bind the soil with its roots and prevent erosion. The effects of vegetation could also be seen in the groundwater, as the rain drops would pass more slowly though the soil and would be less likely to carry sediments (Keller, 2000). Hydro seeding would need to be done before significant rainfalls, as the plants would need to be well rooted in the soil. Spreading straw across the exposed portions of the construction sites can also be used to reduce SPM concentration in the ground and surface water as it reduces the energy and erosive impact of the rain droplets as they hit the exposed ground (Keller, 2000; NSDOT, 2001). This would reduce the amount of sediment being suspended by the water as it traveled towards the containment ponds.

The addition of flocculant to containment ponds was another method used at both construction sites to reduce outflow of sediment to the study area. The effect of flocculant was to reduce all grain sizes suspended in the water. The result was cloudy water that occurred because of the presence of fine grains. Murky water with low SPM concentration is analogous to the difference between driving in the rain versus driving in the fog. In the fog, light is scattered by the many small water particles in the air, making it difficult to see even though there is little water in the atmosphere. When driving in the rain, there may be more water in the atmosphere, but the water droplets are larger so there is actually less scattering of light, making it easier to see. This was similar to what was observed when flocculant was added to the water. The water appeared cloudy, but the actual concentration of material in the water was low. This is significant as the presence of fine grained SPM looked bad, the nature of the problem become one of esthetics rather than environmental.

After these additional measures were taken to prevent further sediment from entering the lake systems, there was a reduction in fluctuations of SPM in response to rainfall events throughout the area. It was not possible to differentiate the effects of the new, larger sediment containment ponds from any of the other preventative measures in place. However, all methods, combined with less intense rainfall events allowed for the significant reduction of SPM concentrations during storms in the study area.

It was possible to calculate the e-folding time (time to reach 37 % of the original SPM concentration) using the settling velocity of fully-flocculated grains and compare the result to using single grain deposition based on grain size specific settling velocities (Hill *et al.*, 2000) (Figs. 3.15-3.20; Tables 3.1-3.2). The results showed that the clearance rate of single grains were on the order of hours to tens of hours as opposed to less than twenty minutes for large flocs. Since fine sediment rarely settles in nature entirely as single grains or within large flocs it is assumed that the clearance rate of sediment is somewhere between that of single grains and mature flocs, and is determined by the presence of flocculant in the water.

E-folding times were then compared to the residence time for waters in the sediment containment ponds. If the containment ponds were full and the e-folding time was shorter than the pond residence time, then waters discharged from the pond would have been relatively clear. If the e-folding time was greater than the pond residence time then discharged waters would have been murky.

Calculations of the containment pond residence time during the Thanksgiving Storm showed that, depending on the rainfall rate, a parcel of water could remain in a pond between 1 and 24 hours. If flocculant was used in the ponds then the e-folding time would have been reduced to less than 20 minutes, well under the fastest residence time. However, from observations of Lake MicMac and Grassy Brook, it was evident that SPM concentrations were elevated in the waters during the Thanksgiving Storm and during other smaller rainfall events. This indicated that the e-folding time for SPM in the water was longer than the pond residence time so sediment grains coming from the containment ponds were not fully flocculated.

The result of un-flocculated grains entering the adjacent water system could be problematic. When fine grained material enters a water system, it can take an extended period of time to settle from suspension (Fig. 1.3). If SPM concentrations in the water are high, then the sediment can inhibit photosynthetic processes by reducing the light available to plants. As oxygen levels decrease in the system, fishes and other aquatic species can become stressed (CCREM, 2002).

Increased SPM concentrations in the Lake Charles and Lake MicMac water systems caused concern over destruction of fish habitat during the study period. After the Thanksgiving Storm the Department of Fisheries and Oceans (DFO) visited the site, as part of the Fisheries and Oceans Act, to assess the severity of contamination. Upon arriving at the Shubenacadie Park, DFO needed to determine if criminal charges should be laid against the construction companies under the Fisheries Act. After looking at the water in the Canal and at Grassy Brook, DFO Officers decided that charges would not be laid as concentrations in the study area were not deleterious to fishes or fish habitat (Owens, 2005).

During the course of this study, SPM concentrations did exceed regulatory limits set by the Canadian Water Quality Guidelines for the Protection of Aquatic Life. The guidelines state that for a clear flow or high flow water system, SPM concentrations should not exceed 25 mg L^{-1} above background levels during a short-term exposure. When long-term exposures occur (greater than 30 days), SPM concentrations should not be more than 5 mg L^{-1} above background values as determined by clear flow days (CCREM, 2002).

During the Thanksgiving Storm, SPM concentrations at Sites 2, 3, 4, 5, and 7 did not exceed the short-term exposure guidelines. However, sites 1, 6a and 6c were well above the 25 mg L^{-1} increase for short-term exposure. Once the additional measures were taken to reduce the sediment entering the lake systems, SPM concentrations were drastically reduced and fluctuated by a minor amount with rainfall.

The increased SPM concentrations observed during the course of this study showed that the sediment containment concerns were regulatory in nature. The area historically has had a problem with sediments entering the water system, so proper precautions should have been taken by both construction companies and the Nova Scotia Department of Environment prior to the onset of construction to prevent any contamination of the area. Once the size of the sediment containment ponds was increased, SPM concentrations discharged into the study area decreased significantly. This showed that, if sediment containment pond size had been regulated for a 150 year storm, it would have been possible to prevent SPM concentrations entering the system.

Environmental impact assessments (EIA) were not required for either construction company before construction was allowed to begin in the summer of 2005. Under the Provincial Environment Act, EIA's are performed on projects that fall under either Class I, Class II undertakings or as determined by the Minister of Environment. Class I undertakings include mining operations of metallic and non-metallic minerals, permanent commercial waste management facilities or highway construction between 2 and 10 kilometers. Class II operations include industrial facilities that deal with radioactive wastes, highways that are longer than 10 kilometers, or any facility that will be used for the incineration of municipal wastes.

The Dartmouth Crossing Construction Site did not fall under any heading in the Class I or Class II undertaking and therefore did not require an EIA. The Highway Interchange Development fell under the Transportation Section of the EIA class system. However, it was less than 2 km in length and was therefore excluded from the assessment. Federally, EIA's are triggered when any Federal Government Department or agency becomes involved in a project or provides funding for a project. Since neither construction site had federal involvement or federal money, this EIA did not apply.

The public perception of the problem was unchanged from the spring to the fall of 2005. Newspapers and news broadcasts showed how appalled the public was that the Department of Environment and the Government of Nova Scotia allowed this to happen and that no EIA was performed. The general public and local politicians could see the muddy water entering into the Shubenacadie Canal Park region and were furious that more effort was not made by either construction company or the government to reduce the impact on this environmentally sensitive area. The past problems around the lakes should have acted as a guide to show the sensitivity of the region to development and the need for a more effective sediment and erosion control plan.

4.2 Summary

During the study period of October and November 2005, the sampled rainfall events produced significant results concerning both grain size distribution and SPM concentration in Lake Charles, the Canal, and Lake MicMac. Throughout the Thanksgiving Weekend, a strong storm hit Nova Scotia with high winds and heavy rains. During this time, two construction sites were in operation close to the Lake Charles, Canal, and Lake MicMac region. The torrential rains prevented both construction sites from containing the waters that flowed from the exposed areas to the containment ponds. In order to protect the stability of the ponds and prevent damage to the adjacent Highway 118, sediment-laden waters were released into both a small culvert and Grassy Brook. Both enter into Lake MicMac.

The purpose of this study was to observe spatial variability in SPM concentrations with high rainfall events. Samples were taken throughout the intense Thanksgiving Storm revealed high SPM concentrations in Grassy Brook (Site 1) and the northern portion of the Canal (Sites 6 a & c) during and closely after the four-day period. DIGS analysis of these high SPM concentration samples showed that the sediment was from a source different than natural "raw" erosion seen in background samples. Two of the high SPM samples showed a distinct relationship to flocculant, which is a chemical that is added to sediment-laden waters to prevent sediment from entering the water system. Flocculant causes sediment grains to stick together, and as they become larger, their settling velocity increases.

The observed SPM concentrations during the Thanksgiving Storm did exceed regulatory values set out by the Canadian Council of Resources and Environment

Ministers in Grassy Brook (Site 1) and the northern portions of the Canal (Sites 6a & c). After the Thanksgiving Storm, both construction sites were required, by the Department of Environment, to increase their containment pond size. Once the containment pond size was increased, SPM concentrations fluctuated by only a minor amount with rainfall. It was not possible to differentiate the effects of the new, larger sediment containment ponds from any of the other preventative measures in place. However, all methods, combined with less intense rainfall events, allowed for the significant reduction of SPM concentrations during storms in the study area.

The elevated SPM concentrations observed during this study showed that the sediment containment problem was regulatory in nature. Both the Nova Scotia Environment Act and the Federal Environmental Assessment Act are pieces of legislation that are meant to protect environmentally sensitive regions such as those discussed in this study. Under both pieces of legislation, however, the two construction sites did not require environmental impact assessments. If these assessments had been performed, it is possible that more strict containment measures would have been enforced and that contamination of the study site by SPM would have been reduced.

CHAPTER 5: CONCLUSIONS

The goal of this thesis was to evaluate the SPM concentrations and disaggregated inorganic grain size distribution (DIGS) from water samples in Lake Charles, the Canal and Lake MicMac. In Chapter 1, the following four questions were introduced;

1. Using the samples collected, was it possible to see any recent changes in the sediment input into the study area and is there a correlation between rainfall and SPM concentrations? If elevated SPM concentrations are observed are they a result of recent construction or development in the study area?
2. Using laboratory techniques, what were the Disaggregated Inorganic Grain Size (DIGS) distributions of the high SPM concentration samples versus the low SPM concentration samples?
3. What was the settling behaviour and eventual fate of the fine-grained sediments discharged into the system?
4. Using the samples collected and historical data, how do current SPM concentrations compare to values documented in these systems in the past?

Based on the data collected during this study, a positive correlation between SPM concentrations and rainfall was evident at of the seven sample sites. Two sample sites, in particular, showed significant increases in SPM concentrations during the Thanksgiving Storm. The SPM concentrations at these two sites exceeded regulatory guidelines set out by the Canadian Council of Resources and Environment Ministers. The five other sample sites displayed increases in SPM concentrations during heavy rainfalls, but these were small in comparison and were within regulatory limits.

Elevated SPM concentrations observed in the study area during the Thanksgiving Storm coincided with increased rainfall and the release of containment pond waters from both construction sites in the area. It was not possible to say conclusively if sediments in the sample waters were from the construction site however, the proximity of the construction sites to the study area showed that this was probable.

The Dartmouth Crossing Construction Site and the Highway Interchange Construction Site both took precautions to prevent the contamination of the study area from sediments. Preventative measures taken included containment ponds to catch sediment-laden run-off from the site, hydro-seeding, spreading straw over exposed lands and the building of ditches and culverts. However, the precautions taken were not enough for a fall storm as intense as the one observed over the Thanksgiving Weekend. Once the containment pond size was increased, SPM concentrations fluctuated by only a minor amount with rainfall. With the new sediment control plan, it was not possible to differentiate the effects of the new containment ponds and the other preventative measures. Together, all methods combined with less intense rainfall events allowed for the significant reduction of SPM concentrations during storms in the study area.

Newspapers and television broadcasts after the Thanksgiving Storm showed streams and culverts with very cloudy, sediment-laden water. This raised many concerns by environmentalists, lake residents, and local politicians. However, the actual concentration of SPM material in most of the sample sites was low. SPM concentrations were well below regulatory guidelines in these 'low' sites. The use of flocculant to control SPM concentrations reduced the proportions of larger grains, but left behind small amounts of fine grains that reflect the light, making the water appear cloudy. This was significant as the presence of low SPM looks bad, but the nature of the problem becomes one of esthetics rather than environmental. In the eyes of the public, building the sediment containment ponds to withstand a 100 year storm and not a 150 year storm was a mistake, as large episodic storms are normal in Nova Scotia during the spring and fall seasons.

The results from the DIGS analysis did not provide a clear link between high SPM samples and low SPM samples in the study area. However, each pair of high and low samples showed unique DIGS traits. Based on the two distinct DIGS analyses of high and low flow events at Site 1, it was possible that there were two different sources of sediment. Comparison between high and low SPM samples in northern Canal region displayed a signature related to the use of flocculant on the day when high SPM concentrations were recorded. It is unknown if the source of the high SPM material was from the construction site, but it was unlikely from the local streams as it coincided with the release of sediment-laden waters from the containment construction sites.

It was not possible to determine the actual settling behaviour and eventual fate of the fine-grained sediments discharged into the system based on the DIGS analysis, as this process disaggregated or separated individual grains from one another. It was possible however, to obtain a general idea of the e-folding time of these samples. The e-folding time is a measure of the time required for a sample to be reduced to 37 % of its original SPM concentration.

The e-folding calculations were based on both single grain and flocculated grain settling velocities. If the grains were removed from suspension only by flocculation, then the e-folding time was less than 20 minutes. This compared to single grain deposition e-folding times of between 6 and 28 hours, depending on the proportion of very fine material in the water. Since in nature one rarely sees either extreme situation, it was possible to conclude that the e-folding settling time was somewhere in-between the scale of twenty minutes to twenty hours.

Calculations of the containment pond residence time for the Thanksgiving Storm showed that, depending on the rainfall rate, a parcel of water could remain in a pond between 1 and 24 hours. Observations of murky water entering the study area during the Thanksgiving Storm indicated that grains were not fully flocculated before leaving the containment ponds during the storm. This means that e-folding times were greater than 20 minutes but less than 20 hours.

Increased SPM concentrations due to sediment-laden runoff entering these lake systems have long been a problem in the study area. Comparing the data obtained during this study to work by others in the region from the 1970's onwards showed that during rainfall events, sediment-rich water entered the study area in much more significant concentrations in the past. Historical SPM concentrations reached at high as 90 mg L^{-1} in the Canal and exceeded several hundred mg L^{-1} in Lake MicMac during the 1977 Castell study. Historical concentrations in Lake Charles were similar to those observed during this study and historically, Grassy Brook SPM concentrations were significantly lower.

This project has shown that changes need to be made to regulatory bodies in Nova Scotia to make sure that environmentally sensitive regions, such as the Lake Charles and Lake MicMac area, are fully protected from the impact of urban and commercial development. Through the proper regulation and management of nearby development, the problem of sediment-laden runoff entering nearby lakes systems can be prevented. Future work in this type of environment should include more regular monitoring of sediment containment areas, so sources of sediment could be determined. By implementing a project of this scope, one might be able to prevent the re-occurrence of this problem.

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Appendix A

Suspended Sediment Mass (SPM) Concentrations

Suspended Sediment Concentrations and Filter Data

Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
3	-	1	279	279.58	2005	10	6	14	NaN	68.51	1122	69.66	1.51	1.3458
3	-	2	281	281.68	2005	10	8	16	19.5	63.36	550	65.78	2.78	5.0545
3	-	3	282	282.50	2005	10	9	12	15.5	55.24	637	57.74	2.86	4.4898
3	-	4	283	283.56	2005	10	10	13	17	66.10	510	71.17	5.17	10.1373
3	-	5	284	284.58	2005	10	11	14	17.5	63.59	530	62.9	-0.59	0.0000
3	-	6	285	285.59	2005	10	12	14	-	63.40	950	65.01	1.89	1.9895
3	-	7	286	286.63	2005	10	13	15	15.5	63.68	1020	65	1.6	1.5686
3	-	8	288	288.59	2005	10	15	14	15.5	63.63	1109	65.38	1.9	1.7133
3	-	9	289	289.55	2005	10	16	13	16	63.12	949	65.05	2.08	2.1918
3	-	10	290	290.63	2005	10	17	15	15	55.93	998	56.49	2.57	2.5752
3	-	11	293	293.64	2005	10	20	15	14	58.93	740	59.52	1.12	1.5135
3	-	12	297	297.76	2005	10	24	18	12	58.65	979	59.53	0.99	1.0112
3	-	13	298	298.72	2005	10	25	17	11	55.43	990	56.37	1.05	1.0606
3	-	14	299	299.43	2005	10	26	10	12	58.41	972	59.56	1.95	2.0062
3	-	15	300	300.64	2005	10	27	15	12	57.43	878	58.01	1.38	1.5718
3	-	16	307	307.60	2005	11	3	14	9.5	57.33	809	58.81	2.28	2.8183
3	-	17	314	314.61	2005	11	10	14	-	54.13	900	55.16	1.53	1.7000
3	-	18	321	321.47	2005	11	17	11	11	56.95	779	60.09	3.64	4.6727
3	-	19	327	327.59	2005	11	23	14	9	54.21	826	54.81	0.82	0.9927
3	-	20	328	328.58	2005	11	24	14	8	57.46	650	57.9	0.66	1.0154
3	-	21	329	329.41	2005	11	25	9	8	53.29	545	53.43	0.55	1.0092
4	-	1	279	279.58	2005	10	6	14	-	66.48	1111	69.16	3.04	2.7363
4	-	2	281	281.68	2005	10	8	16	19.5	63.52	549	65.9	2.74	4.9909
4	-	3	282	282.52	2005	10	9	12	16	63.85	582	64.92	1.43	2.4570
4	-	4	283	283.56	2005	10	10	13	17	63.57	614	68.49	5.02	8.1759
4	-	5	284	284.58	2005	10	11	14	17	67.97	653	69.09	1.22	1.8683
4	-	6	285	285.59	2005	10	12	14	-	62.73	960	64.36	1.91	1.9896
4	-	7	286	286.63	2005	10	13	15	16	55.27	933	56.66	1.6	1.7149
4	-	8	288	288.62	2005	10	15	14	16	62.81	973	63.7	1.04	1.0689
4	-	9	289	289.55	2005	10	16	13	15.5	63.71	970	65.08	1.52	1.5670
4	-	10	290	290.63	2005	10	17	15	15	58.3	998	59.71	3.42	3.4269
4	-	11	293	293.65	2005	10	20	15	14	57.78	675	58.93	1.68	2.4889
4	-	12	297	297.75	2005	10	24	18	12	57.78	990	59.41	1.74	1.7576
4	-	13	298	298.74	2005	10	25	17	11	55.21	738	55.85	0.75	1.0163
4	-	14	299	299.43	2005	10	26	10	12	58.03	978	59.38	2.15	2.1984

Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
4	-	15	300	300.64	2005	10	27	15	12	57.84	850	59.55	2.51	2.9529
4	-	16	307	307.61	2005	11	3	14	9	57.66	815	59.06	2.2	2.6994
4	-	17	314	314.61	2005	11	10	14	-	54.15	640	54.72	1.07	1.6719
4	-	18	321	321.47	2005	11	17	11	11	56.69	750	57.51	1.32	1.7600
4	-	19	327	327.59	2005	11	23	14	9	54.34	612	55.04	0.92	1.5033
4	-	20	328	328.59	2005	11	24	14	8	56.62	521	56.83	0.62	1.1900
4	-	21	329	329.41	2005	11	25	9	9	57.34	505	57.66	0.73	1.4455
5	-	1	279	279.58	2005	10	6	14	-	64.17	430	65.24	1.43	3.3256
5	-	2	281	281.64	2005	10	8	15	19	63.76	538	65.53	2.13	3.9591
5	-	3	282	282.50	2005	10	9	11	17	63.81	560	65.81	2.36	4.2143
5	-	4	283	283.59	2005	10	10	14	17	64.23	601	67.99	3.86	6.4226
5	-	5	284	284.58	2005	10	11	14	16.5	66.89	600	68.05	1.26	2.1000
5	-	6	285	285.63	2005	10	12	15	-	63.79	920	64.85	1.34	1.4565
5	-	7	286	286.67	2005	10	13	16	16.5	67.97	980	69.22	1.46	1.4898
5	-	8	288	288.68	2005	10	15	16	15	55.33	982	55.95	0.77	0.7841
5	-	9	289	289.60	2005	10	16	14	15.5	55.56	971	57.35	1.94	1.9979
5	-	10	290	290.65	2005	10	17	15	15	58.61	980	59.32	2.72	2.7755
5	-	11	293	293.63	2005	10	20	15	15	55.7	570	55.96	0.79	1.3860
5	-	12	297	297.74	2005	10	24	17	12	57.97	1000	59.28	1.42	1.4200
5	-	13	298	298.76	2005	10	25	18	11.5	56.04	848	56.78	0.85	1.0024
5	-	14	299	299.48	2005	10	26	11	12	57.24	959	58.22	1.78	1.8561
5	-	15	300	300.75	2005	10	27	17	12	56.85	960	57.25	1.2	1.2500
5	-	16	307	307.61	2005	11	3	14	10	53.63	578	53.99	0.66	1.1419
5	-	17	314	314.66	2005	11	10	15	-	53.86	629	54.22	0.86	1.3672
5	-	18	321	321.52	2005	11	17	12	11	52.75	801	53.63	1.38	1.7228
5	-	19	327	327.65	2005	11	23	15	9	54.25	678	54.31	0.28	0.4130
5	-	20	328	328.62	2005	11	24	14	8	56.86	529	56.97	0.52	0.9830
5	-	21	329	329.44	2005	11	25	10	9	51.85	531	52.21	0.77	1.4501
7	-	1	279	279.58	2005	10	6	14	-	63.42	558	64.17	1.11	1.9892
7	-	2	281	281.63	2005	10	8	15	18.8	63.14	519	64	1.22	2.3507
7	-	3	282	282.49	2005	10	9	11	17	66.01	512	67.18	1.53	2.9883
7	-	4	283	283.58	2005	10	10	13	18	63.47	497	64.04	0.67	1.3481
7	-	5	284	284.58	2005	10	11	14	17	66.47	965	67.55	1.18	1.2228
7	-	6	285	285.61	2005	10	12	14	-	54.88	548	55.56	0.96	1.7518
7	-	7	286	286.67	2005	10	13	16	16	63.67	961	64.54	1.08	1.1238

Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
7	-	8	288	288.67	2005	10	15	16	16	53.38	982	55.69	2.46	2.5051
7	-	9	289	289.59	2005	10	16	14	15.5	54.98	785	55.72	0.89	1.1338
7	-	10	290	290.64	2005	10	17	15	15	57.28	859	57.67	2.4	2.7939
7	-	11	293	293.63	2005	10	20	15	14	57.96	775	58.27	0.84	1.0839
7	-	12	297	297.73	2005	10	24	17	13	58.58	981	59.41	0.94	0.9582
7	-	13	298	298.75	2005	10	25	18	12	53.71	758	54.84	1.24	1.6359
7	-	14	299	299.47	2005	10	26	11	12	57.83	622	58.16	1.13	1.8167
7	-	15	300	300.76	2005	10	27	18	12	57.08	816	57.27	0.99	1.2132
7	-	16	307	307.65	2005	11	3	15	10	54.16	679	54.19	0.33	0.4860
7	-	17	314	314.65	2005	11	10	15	-	53.58	686	53.43	0.35	0.5102
7	-	18	321	321.51	2005	11	17	12	11	57.54	778	57.84	0.8	1.0283
7	-	19	327	327.64	2005	11	23	15	9	56.9	621	57.03	0.35	0.5636
7	-	20	328	328.61	2005	11	24	14	8.5	52.45	595	52.93	0.89	1.4958
7	-	21	329	329.42	2005	11	25	10	9.5	56.44	505	56.71	0.68	1.3465
1	-	1	279	279.58	2005	10	6	14	-	62.75	666	64.2	1.81	2.7177
1	-	2	281	281.69	2005	10	8	16	18	55.03	539	56.19	1.52	2.8200
1	-	3	282	282.51	2005	10	9	12	15	62.96	246	69.74	7.14	29.0244
1	-	4	283	283.55	2005	10	10	13	15	67.07	224	88.6	21.63	96.5625
1	-	5	284	284.58	2005	10	11	14	15	66.68	229	79.52	12.94	56.5066
1	-	6	285	285.60	2005	10	12	14	-	67.73	236	68.65	1.2	5.0847
1	-	7	286	286.63	2005	10	13	15	13	55.57	378	64.54	9.18	24.2857
1	-	8	288	288.63	2005	10	15	15	13.5	55.44	569	57.71	2.42	4.2531
1	-	9	289	289.56	2005	10	16	13	14	63.73	228	64.79	1.21	5.3070
1	-	10	290	290.63	2005	10	17	15	13	55.61	634	57.01	3.41	5.3785
1	-	11	293	293.65	2005	10	20	15	14	57.89	660	59.16	1.8	2.7273
1	-	12	297	297.75	2005	10	24	17	10	55.58	252	56.35	0.88	3.4921
1	-	13	298	298.73	2005	10	25	17	10	56.26	650	57.49	1.34	2.0615
1	-	14	299	299.44	2005	10	26	10	10.5	58	580	60.64	3.44	5.9310
1	-	15	300	300.72	2005	10	27	17	10	53.71	232	53.71	0.8	3.4483
1	-	16	307	307.62	2005	11	3	14	9	58.24	770	58.38	0.44	0.5714
1	-	17	314	314.62	2005	11	10	14	-	54.15	517	55.95	2.3	4.4487
1	-	18	321	321.49	2005	11	17	11	11	52.29	222	54.77	2.7	12.1622
1	-	19	327	327.60	2005	11	23	14	9	54.34	598	55.61	1.49	2.4916
1	-	20	328	328.59	2005	11	24	14	8	56.72	408	57.39	1.08	2.6471

Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
2	-	1	-	-	-	-	-	-	-	-	-	-	-	-
2	-	2	-	-	-	-	-	-	-	-	-	-	-	-
2	-	3	282	282.53	2005	10	9	12	16	63.11	302	67.36	4.61	15.2649
2	-	4	283	283.55	2005	10	10	13	15	63.64	245	65.99	2.45	10.0000
2	-	5	284	284.58	2005	10	11	14	15	54.32	244	54.67	0.43	1.7623
2	-	6	285	285.60	2005	10	12	14	-	55.20	720	55.72	0.8	1.1111
2	-	7	286	286.64	2005	10	13	15	13.5	54.92	845	55.51	0.8	0.9467
2	-	8	288	288.64	2005	10	15	15	14	54.27	521	56.44	2.32	4.4530
2	-	9	289	289.61	2005	10	16	14	14	61.12	237	60.15	1.04	4.3882
2	-	10	290	290.63	2005	10	17	15	13	58.08	722	58.4	2.33	3.2271
2	-	11	293	293.66	2005	10	20	15	11	57.95	533	58.28	0.86	1.6135
2	-	12	297	297.75	2005	10	24	18	10.5	58.4	773	59.15	0.86	1.1125
2	-	13	298	298.73	2005	10	25	17	10	54.08	892	55.75	2.47	2.7691
2	-	14	299	299.43	2005	10	26	10	10.5	58.55	840	63.23	5.48	6.5238
2	-	15	300	300.74	2005	10	27	17	10	57.06	612	57.55	1.29	2.1078
2	-	16	307	307.63	2005	11	3	15	8	57.76	729	59.2	1.74	2.3868
2	-	17	314	314.63	2005	11	10	15	-	54.38	482	55.3	1.42	2.9461
2	-	18	321	321.50	2005	11	17	12	11	57	220	58.65	1.87	8.5000
2	-	19	327	327.61	2005	11	23	14	9	53.15	669	53.34	0.41	0.6129
2	-	20	328	328.60	2005	11	24	14	7	56.88	510	57.1	0.63	1.2353
2	-	21	329	329.42	2005	11	25	10	8	57.25	589	57.91	1.07	1.8166
6a	-	1	-	-	-	-	-	-	-	-	-	-	-	-
6a	-	2	-	-	-	-	-	-	-	-	-	-	-	-
6a	-	3	-	-	-	-	-	-	-	-	-	-	-	-
6a	-	5	284	284.58	2005	10	11	14	15	64.50	95	68.41	3.99	42.0000
6a	-	6	285	285.63	2005	10	12	15	-	55.23	91	55.65	0.7	7.6923
6a	-	7	286	286.66	2005	10	13	15	12	55.34	168	58.65	3.52	20.9524
6a	-	8	288	288.65	2005	10	15	15	13	67.97	90	70.68	2.86	31.7778
6a	-	9	289	289.59	2005	10	16	14	13	60.87	166	78.26	17.54	105.6627
6a	-	10	290	290.64	2005	10	17	15	12	57.38	98.5	59.82	4.45	45.1777
6a	-	11	293	293.62	2005	10	20	14	11	56.1	214	57.1	1.11	5.1869
6a	-	12	297	297.72	2005	10	24	17	10	55.11	242	56.36	1.36	5.6198
6a	-	13	298	298.74	2005	10	25	17	11	55	242	56.22	2.02	8.3471
6a	-	14	299	299.46	2005	10	26	11	10.5	57.99	246	58.29	1.1	4.4715

Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
6a	-	15	300	300.76	2005	10	27	18	9	57.12	240	58.7	2.38	9.9167
6a	-	16	307	307.64	2005	11	3	15	7	58.94	218	59.85	1.21	5.5505
6a	-	17	314	314.64	2005	11	10	15	-	54.08	585	56.51	2.93	5.0085
6a	-	18	321	321.50	2005	11	17	12	10	56.77	241	57.9	1.35	5.6017
6a	-	19	327	327.61	2005	11	23	14	9	52.3	316	58.64	6.56	20.7595
6a	-	20	328	328.61	2005	11	24	14	8	57.3	555	59.45	2.56	4.6126
6a	-	21	329	329.42	2005	11	25	10	8.5	56.54	231	59.15	3.02	13.0736
6b	-	1	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	2	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	3	282	282.47	2005	10	9	11	14	63.27	196	69.56	6.65	33.9286
6b	-	4	283	283.57	2005	10	10	13	15	62.93	94	74.3	11.47	122.0213
6b	-	5	284	284.58	2005	10	11	14	15	55.43	230	74.17	18.84	81.9130
6b	-	6	285	285.62	2005	10	12	14	-	54.26	94	102.33	48.35	*
6b	-	7	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	8	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	9	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	10	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	11	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	12	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	13	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	14	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	15	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	16	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	17	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	18	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	19	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	20	-	-	-	-	-	-	-	-	-	-	-	-
6b	-	21	-	-	-	-	-	-	-	-	-	-	-	-
6c	-	1	279	279.58	2005	10	6	14	-	62.81	520	64.07	1.62	3.1154
6c	-	2	281	281.63	2005	10	8	15	19	64.21	570	66.66	2.81	4.9298
6c	-	3	282	282.47	2005	10	9	11	14	63.58	208	72.51	9.29	44.6635
6c	-	4	283	283.57	2005	10	10	13	16	67.30	245	79.33	12.13	49.5102
6c	-	5	284	284.58	2005	10	11	14	15	66.71	187	76.85	10.24	54.7594
6c	-	6	285	285.62	2005	10	12	14	-	62.72	625	73.92	11.48	18.3680

Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
6c	-	7	286	286.66	2005	10	13	15	16	67.44	965	68.33	1.1	1.1399
6c	-	8	288	288.65	2005	10	15	15	16	63.36	971	65.52	2.31	2.3790
6c	-	9	289	289.58	2005	10	16	13	15	63.91	148	68.26	4.5	30.4054
6c	-	10	290	290.63	2005	10	17	15	15	58.38	619	59	2.63	4.2488
6c	-	11	293	293.61	2005	10	20	14	13	58.53	555	61.19	3.19	5.7477
6c	-	12	297	297.64	2005	10	24	15	12	57.77	939	58.52	0.86	0.9159
6c	-	13	298	298.75	2005	10	25	17	11	55.68	980	56.47	0.9	0.9184
6c	-	14	299	299.46	2005	10	26	11	12	57.6	653	58.2	1.4	2.1440
6c	-	15	300	300.76	2005	10	27	18	12	57.78	982	58.2	1.22	1.2424
6c	-	16	307	307.64	2005	11	3	15	9.5	57.75	711	59.57	2.12	2.9817
6c	-	17	314	314.64	2005	11	10	15	-	53.72	605	59.38	6.16	10.1818
6c	-	18	321	321.50	2005	11	17	12	10	52.28	708	53.63	1.85	2.6130
6c	-	19	327	327.63	2005	11	23	15	10	57.53	660	58.05	0.74	1.1212
6c	-	20	328	328.61	2005	11	24	14	8.5	52.55	568	55.14	3	5.2817
6c	-	21	329	329.42	2005	11	25	10	9	57.01	523	57.4	0.8	1.5296
6d	-	1	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	2	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	3	282	282.50	2005	10	9	11	17	62.81	540	64.31	1.86	3.4444
6d	-	4	283	283.57	2005	10	10	13	17	63.89	582	70.77	6.98	11.9931
6d	-	5	284	284.58	2005	10	11	14	17	68.11	920	74.28	6.27	6.8152
6d	-	6	285	285.62	2005	10	12	14	-	67.76	550	69.93	2.45	4.4545
6d	-	7	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	8	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	9	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	10	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	11	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	12	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	13	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	14	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	15	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	16	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	17	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	18	-	-	-	-	-	-	-	-	-	-	-	-
6d	-	19	-	-	-	-	-	-	-	-	-	-	-	-

Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
6d	-	21	-	-	-	-	-	-	-	-	-	-	-	-
-	-	B	-	-	-	-	-	-	-	54.94	-	54.86	0	0.0000
-	-	B	-	-	-	-	-	-	-	56.94	-	56.74	0	0.0000
-	-	B	-	-	-	-	-	-	-	56.9	-	56.66	0	0.0000
-	-	B	-	-	-	-	-	-	-	54.05	-	53.64	0	0.0000
-	-	B	-	-	-	-	-	-	-	54.05	-	53.64	0	0.0000
-	-	B	-	-	-	-	-	-	-	66.43	-	66.07	0	0.0000
-	-	B	-	-	-	-	-	-	-	62.97	-	-	0	-
-	-	B	-	-	-	-	-	-	-	66.64	-	66.4	0	0.0000
-	-	B	-	-	-	-	-	-	-	67.99	-	67.94	0	0.0000
-	-	B	-	-	-	-	-	-	-	67.49	-	67.54	0	0.0000
-	-	B	-	-	-	-	-	-	-	63.22	-	63.3	0	0.0000
-	-	B	-	-	-	-	-	-	-	62.97	-	62.69	0	0.0000
-	-	B	-	-	-	-	-	-	-	55.22	-	55.01	0	0.0000
-	-	B	-	-	-	-	-	-	-	64.14	-	64.09	0.1	0.0000
-	-	B	-	-	-	-	-	-	-	63.00	-	62.8	-0.05	0.0000
-	-	B	-	-	-	-	-	-	-	64.66	-	64.07	-0.44	0.0000
-	-	B	-	-	-	-	-	-	-	63	-	62.8	0	0.0000
-	-	B	-	-	-	-	-	-	-	58.5	-	57.62	0	0.0000
-	-	B	-	-	-	-	-	-	-	62.59	-	57.62	0	0.0000
-	-	B	-	-	-	-	-	-	-	57.96	-	57.43	0	0.0000
-	-	B	-	-	-	-	-	-	-	57.19	-	57.08	0	0.0000
-	-	B	-	-	-	-	-	-	-	58.08	-	58.05	0	0.0000
-	-	B	-	-	-	-	-	-	-	53.97	-	53.66	-0.01	0.0000
-	-	B	-	-	-	-	-	-	-	53.36	-	53.08	0.02	0.0000
-	-	B	-	-	-	-	-	-	-	58.55	-	58.09	0.04	0.0000
-	-	B	-	-	-	-	-	-	-	57.85	-	57.48	0.13	0.0000
-	-	B	-	-	-	-	-	-	-	53.96	-	53.29	-0.17	0.0000
-	-	B	-	-	-	-	-	-	-	52.43	-	52.29	-	0
-	-	B	-	-	-	-	-	-	-	56.44	-	56.39	-	0
-	-	B	-	-	-	-	-	-	-	57.46	-	57.34	-	0

		Settling Experiments												
Station ID	Time Series	Survey Number	Year-day	Year-time	Year	Month	Day	Hour (GMT)	Temp (degC)	Filter Weight (mg)	Filter Vol (mL)	Filter + Sed (mg)	Corrected Sed (mg)	SPM (mg/L)
1	0	5	284	284.58	2005	10	11	14	15	67.32	232	80.3	13.08	56.3793
1	30	5	284	284.58	2005	10	11	14	15	67.19	212	78.57	11.48	54.1509
1	105	5	284	284.58	2005	10	11	14	15	68.02	130	74.49	6.57	50.5385
1	180	5	284	284.58	2005	10	11	14	15	62.58	162	71.37	8.89	54.8765
6a	0	5	284	284.58	2005	10	11	14	15	64.23	91	71.64	7.49	82.3077
6a	30	5	284	284.58	2005	10	11	14	15	55.06	110	63.45	8.47	77.0000
6a	105	5	284	284.58	2005	10	11	14	15	63.23	96	70.04	6.89	71.7708
6a	180	5	284	284.58	2005	10	11	14	15	62.84	137	73.45	10.69	78.0292
6c	0	5	284	284.58	2005	10	11	14	15	66.97	222	74.35	7.48	33.6937
6c	30	5	284	284.58	2005	10	11	14	15	67.71	152	72.66	5.05	33.2237
6c	105	5	284	284.58	2005	10	11	14	15	63.88	246	72.19	8.41	34.1870
6c	180	5	284	284.58	2005	10	11	14	15	67.37	147	71.21	3.94	26.8027

Appendix B

Hourly Rainfall Data

When an hour is not stated the rainfall during this time was equal to zero

Year-Time	Rainfall (mm)	Year-Time	Rainfall (mm)	Year-Time	Rainfall (mm)
279.7916667	0.2	283.5416667	2	290.5833333	0.2
280.0833333	2.4	283.5833333	2.8	290.625	0.4
280.125	0.2	283.625	2.8	290.6666667	0.8
281.375	0.6	283.6666667	3.6	291.25	0.2
281.4166667	0.6	283.7083333	2	291.2916667	0.2
281.5416667	0.2	283.75	2	293.9583333	0.6
281.625	0.2	283.7916667	1.2	294	0.2
281.6666667	0.8	283.8333333	1	297.2916667	1.6
281.7083333	0.2	283.875	0.2	297.3333333	0.6
281.75	0.4	283.9166667	2.6	297.375	0.2
281.7916667	0.6	283.9583333	1.8	297.4166667	2.4
281.8333333	2.2	284	3	297.4583333	4.2
281.875	1.8	284.0416667	5.6	297.5	3.2
281.9166667	2.2	284.0833333	5.2	297.5416667	4.2
281.9583333	2	284.125	1.6	297.5833333	3.8
282	2.2	284.1666667	2.4	297.625	0.8
282.0416667	1.8	284.2083333	4.2	298.5416667	0.4
282.0833333	0.6	284.25	1.6	299.4166667	0.8
282.1666667	0.4	284.2916667	0.6	299.4583333	2.6
282.2083333	1.2	284.3333333	0.6	299.5	1.8
282.25	0.8	284.375	0.8	299.5416667	0.4
282.2916667	1	284.4166667	1.8	299.5833333	1.2
282.3333333	5.2	284.4583333	1.8	299.625	1
282.375	2.8	284.5	1.2	299.6666667	1.6
282.4166667	2.2	284.5416667	1.4	299.7083333	0.8
282.4583333	8	284.5833333	2.4	299.75	1
282.5	16.6	284.625	5.8	299.875	2
282.5416667	2	284.6666667	8	299.9166667	1.8
282.5833333	2.8	284.7083333	5.6	299.9583333	2
282.625	2.8	284.75	1	300	1
282.6666667	3.6	284.875	2.6	300.0416667	0.2
282.7083333	2	284.9166667	0.2	300.0833333	0.2
282.75	2	284.9583333	1	300.125	0.4
282.7916667	1.2	285.2916667	0.2	300.1666667	0.4
282.8333333	1	285.3333333	0.2	300.2083333	0.2
282.875	0.2	285.375	0.2	300.25	0.2
282.9166667	2.6	285.4583333	0.2	300.2916667	0.8
282.9583333	1.8	285.5	0.2	300.3333333	0.4
283	3	289.5	1.8	304	0.4
283.0416667	1.8	289.5416667	3.6	304.0833333	0.6
283.0833333	0.6	289.5833333	4.4	304.125	0.6
283.1666667	0.4	289.625	4.4	304.1666667	1.2
283.2083333	1.2	289.6666667	2.4	304.2083333	2.4
283.25	0.8	289.8333333	0.6	304.25	0.6
283.2916667	1	289.875	10.4	304.2916667	0.2
283.3333333	5.2	289.9166667	3.6	304.375	0.4
283.375	2.8	289.9583333	0.2	304.4166667	0.2
283.4166667	2.2	290	0.6	305.5416667	0.2
283.4583333	8	290.0416667	1.4	307.2083333	0.2
283.5	16.6	290.125	0.2	307.3333333	0.2

Year-Time	Rainfall (mm)	Year-Time	Rainfall (mm)
307.375	0.2	322.3333333	0.4
307.875	0.2	322.4166667	1.8
308.75	0.2	322.4583333	3
311.125	0.2	322.5	0.8
307.3333333	0.2	322.5416667	0.6
307.375	0.2	322.5833333	0.8
307.875	0.2	322.625	6
308.75	0.2	322.6666667	2
311.125	0.2	322.7083333	0.2
311.9583333	0.8	322.75	0.4
312	2	322.7916667	0.2
312.0416667	0.6	327.2083333	0.2
312.0833333	0.6	327.25	0.8
312.125	1.6	327.2916667	0.4
312.1666667	0.2	327.3333333	0.6
312.25	2	327.375	0.2
312.2916667	0.2	327.4583333	0.2
312.375	1	327.5	0.4
314.9166667	0.2	327.5416667	0.2
315.25	0.8	327.5833333	0.4
315.2916667	2.2	327.625	0.4
315.3333333	2	327.6666667	0.6
315.375	2.2	327.7083333	1
315.4166667	1.6	327.75	1
315.4583333	1.6	327.7916667	0.8
315.5	0.8	327.8333333	0.6
315.5416667	0.2	327.875	1.2
315.6666667	1.2	327.9166667	1.6
315.7083333	1.4	327.9583333	1.2
315.75	1	328.625	0.4
315.7916667	2	328.6666667	1.2
315.8333333	0.8	328.7083333	1
315.875	0.4	328.75	0.6
315.9166667	1	328.7916667	0.2
315.9583333	0.8	329.5833333	0.6
316	0.2	329.625	0.8
321.25	0.4	329.6666667	4.4
321.2916667	0.2	329.7083333	2.8
321.3333333	1.6	330.25	0.4
321.375	0.8	330.4583333	0.2
321.4583333	0.2	332.3333333	0.4
321.5833333	0.4	332.375	0.4
321.625	0.2	334.9583333	0.2
321.7916667	0.2		
322	0.2		
322.0416667	0.2		
322.125	1.8		
322.1666667	0.2		
322.2083333	1.4		

Appendix C

Disaggregated Inorganic Grain Size (DIGS) Data

Diameter (um)	Ws (m/s)	Filter Concentration (ppm)						Filter Concentration (ppm) t= 30s						Filter Concentration (ppm) t=90s					
		13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069
0.7579	3.852E-07	0.2538	0.7339	0.2476	0.0154	0.0100	0.0254	0.2538	0.7339	0.2476	0.0154	0.0100	0.0254	0.2538	0.7339	0.2476	0.0154	0.0100	0.0254
0.8705506	5.083E-07	0.2665	0.7196	0.2117	0.0158	0.0101	0.0294	0.2664	0.7196	0.2117	0.0158	0.0101	0.0294	0.2664	0.7196	0.2117	0.0158	0.0101	0.0294
1	6.706E-07	0.2942	0.6501	0.1742	0.0158	0.0102	0.0337	0.2942	0.6501	0.1742	0.0158	0.0102	0.0337	0.2942	0.6501	0.1742	0.0158	0.0102	0.0337
1.1486984	8.849E-07	0.3289	0.5364	0.1413	0.0158	0.0100	0.0402	0.3289	0.5364	0.1413	0.0158	0.0100	0.0402	0.3289	0.5363	0.1413	0.0158	0.0100	0.0402
1.3195079	1.168E-06	0.3685	0.4116	0.1054	0.0161	0.0105	0.0462	0.3685	0.4116	0.1054	0.0161	0.0105	0.0462	0.3684	0.4116	0.1054	0.0161	0.0105	0.0462
1.5157166	1.541E-06	0.4206	0.3026	0.0801	0.0153	0.0109	0.0523	0.4206	0.3026	0.0801	0.0153	0.0109	0.0523	0.4205	0.3026	0.0801	0.0153	0.0109	0.0523
1.7411011	2.033E-06	0.4871	0.2455	0.0607	0.0155	0.0114	0.0574	0.4871	0.2455	0.0607	0.0155	0.0114	0.0574	0.4870	0.2455	0.0607	0.0155	0.0114	0.0574
2	2.683E-06	0.5492	0.2016	0.0427	0.0152	0.0120	0.0597	0.5491	0.2016	0.0427	0.0152	0.0120	0.0597	0.5490	0.2016	0.0427	0.0152	0.0120	0.0597
2.2973967	3.540E-06	0.6415	0.1853	0.0331	0.0155	0.0124	0.0615	0.6415	0.1853	0.0331	0.0155	0.0124	0.0615	0.6413	0.1853	0.0331	0.0155	0.0124	0.0615
2.6390158	4.671E-06	0.7506	0.1779	0.0247	0.0157	0.0125	0.0615	0.7505	0.1779	0.0247	0.0157	0.0125	0.0614	0.7503	0.1779	0.0247	0.0157	0.0125	0.0614
3.0314331	6.163E-06	0.8934	0.1666	0.0172	0.0141	0.0142	0.0598	0.8933	0.1666	0.0172	0.0141	0.0142	0.0597	0.8929	0.1665	0.0172	0.0141	0.0141	0.0597
3.4822023	8.132E-06	1.0272	0.1822	0.0187	0.0160	0.0143	0.0629	1.0269	0.1821	0.0187	0.0160	0.0143	0.0628	1.0264	0.1820	0.0187	0.0160	0.0143	0.0628
4	1.073E-05	1.1489	0.1431	0.0103	0.0135	0.0150	0.0517	1.1485	0.1431	0.0103	0.0135	0.0150	0.0517	1.1478	0.1430	0.0103	0.0134	0.0150	0.0517
4.5947934	1.416E-05	1.2605	0.1770	0.0100	0.0142	0.0170	0.0521	1.2600	0.1769	0.0100	0.0142	0.0170	0.0521	1.2589	0.1767	0.0100	0.0142	0.0170	0.0520
5.2780316	1.868E-05	1.2849	0.2124	0.0082	0.0120	0.0182	0.0422	1.2841	0.2123	0.0082	0.0120	0.0182	0.0422	1.2827	0.2120	0.0082	0.0120	0.0182	0.0421
6.0628663	2.465E-05	1.3481	0.2239	0.0071	0.0125	0.0187	0.0359	1.3471	0.2237	0.0071	0.0125	0.0187	0.0359	1.3451	0.2234	0.0071	0.0125	0.0186	0.0359
6.9644045	3.253E-05	1.3696	0.2170	0.0062	0.0123	0.0190	0.0282	1.3683	0.2168	0.0062	0.0123	0.0190	0.0282	1.3656	0.2164	0.0062	0.0123	0.0189	0.0281
8	4.292E-05	1.3261	0.1946	0.0067	0.0120	0.0171	0.0214	1.3244	0.1943	0.0067	0.0120	0.0170	0.0214	1.3210	0.1938	0.0067	0.0119	0.0170	0.0213
9.1895868	5.664E-05	1.2019	0.1562	0.0048	0.0111	0.0164	0.0151	1.1999	0.1559	0.0048	0.0111	0.0164	0.0150	1.1958	0.1554	0.0048	0.0111	0.0163	0.0150
10.556063	7.473E-05	1.0326	0.1228	0.0039	0.0100	0.0155	0.0099	1.0302	0.1225	0.0039	0.0099	0.0155	0.0099	1.0256	0.1219	0.0039	0.0099	0.0154	0.0098
12.125733	9.861E-05	0.8899	0.0843	0.0041	0.0089	0.0135	0.0061	0.8873	0.0841	0.0041	0.0089	0.0134	0.0061	0.8820	0.0836	0.0041	0.0088	0.0133	0.0060
13.928809	1.301E-04	0.6856	0.0675	0.0050	0.0079	0.0128	0.0045	0.6830	0.0673	0.0050	0.0079	0.0127	0.0045	0.6777	0.0667	0.0050	0.0078	0.0126	0.0044
16	1.717E-04	0.5252	0.0523	0.0041	0.0057	0.0098	0.0039	0.5225	0.0520	0.0040	0.0056	0.0097	0.0039	0.5171	0.0515	0.0040	0.0056	0.0096	0.0038
18.379174	2.191E-04	0.4134	0.0356	0.0043	0.0045	0.0098	0.0033	0.4107	0.0353	0.0043	0.0045	0.0097	0.0033	0.4053	0.0349	0.0042	0.0044	0.0096	0.0033
21.112127	2.940E-04	0.2271	0.0327	0.0049	0.0021	0.0076	0.0040	0.2251	0.0324	0.0049	0.0020	0.0075	0.0039	0.2211	0.0318	0.0048	0.0020	0.0074	0.0039
24.251465	3.929E-04	0.1532	0.0287	0.0034		0.0070	0.0052	0.1514	0.0284	0.0034		0.0069	0.0052	0.1479	0.0277	0.0033		0.0067	0.0051
27.857618	5.230E-04	0.1107				0.0046	0.0078	0.1090				0.0045	0.0077	0.1056				0.0043	0.0074
32	6.932E-04	0.0959					0.0071	0.0939					0.0070	0.0901					0.0067
36.758347	9.145E-04	0.0842					0.0037	0.0819					0.0036	0.0776					0.0034
		19.4391	6.2616	1.2405	0.3128	0.3404	0.8922	19.4079	6.2583	1.2402	0.3126	0.3399	0.8914	19.3462	6.2518	1.2397	0.3121	0.3387	0.8899
		1 (high)	6c(high)	6a(high)	1 (low)	6c(low)	6a(low)												

Diameter	Filter Concentration (ppm) t=180s						Filter Concentration (ppm) t=360						Filter Concentration (ppm) t=720					
(um)	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069	**13727**	**13738**	**13781**	**20014**	**20057**	**20069**
0.7579	0.25376	0.73389	0.24760	0.01541	0.01004	0.02543	0.25374	0.73384	0.24758	0.01541	0.01004	0.02543	0.25371	0.73374	0.24755	0.01541	0.01003	0.02543
0.8705506	0.26643	0.71958	0.21164	0.01583	0.01014	0.02943	0.26640	0.71951	0.21162	0.01583	0.01014	0.02943	0.26636	0.71938	0.21158	0.01582	0.01014	0.02942
1	0.29420	0.65007	0.17416	0.01576	0.01020	0.03373	0.29417	0.64999	0.17414	0.01576	0.01019	0.03373	0.29409	0.64983	0.17409	0.01576	0.01019	0.03372
1.1486984	0.32883	0.53629	0.14132	0.01577	0.01003	0.04017	0.32878	0.53620	0.14130	0.01577	0.01003	0.04016	0.32867	0.53603	0.14125	0.01577	0.01002	0.04015
1.3195079	0.36839	0.41152	0.10540	0.01613	0.01051	0.04615	0.36831	0.41143	0.10538	0.01612	0.01051	0.04614	0.36815	0.41126	0.10534	0.01612	0.01050	0.04612
1.5157166	0.42047	0.30254	0.08011	0.01527	0.01094	0.05231	0.42035	0.30246	0.08009	0.01527	0.01094	0.05230	0.42012	0.30229	0.08004	0.01526	0.01093	0.05227
1.7411011	0.48695	0.24544	0.06066	0.01554	0.01140	0.05742	0.48677	0.24535	0.06064	0.01553	0.01139	0.05739	0.48642	0.24517	0.06060	0.01552	0.01138	0.05735
2	0.54889	0.20151	0.04267	0.01524	0.01201	0.05969	0.54863	0.20141	0.04265	0.01523	0.01200	0.05967	0.54810	0.20122	0.04261	0.01521	0.01199	0.05961
2.2973967	0.64113	0.18522	0.03304	0.01546	0.01235	0.06150	0.64072	0.18510	0.03302	0.01545	0.01234	0.06146	0.63990	0.18487	0.03298	0.01543	0.01233	0.06138
2.6390158	0.74994	0.17780	0.02469	0.01568	0.01254	0.06140	0.74931	0.17765	0.02467	0.01567	0.01253	0.06135	0.74805	0.17735	0.02463	0.01565	0.01250	0.06125
3.0314331	0.89243	0.16642	0.01715	0.01406	0.01414	0.05969	0.89144	0.16623	0.01713	0.01404	0.01413	0.05963	0.88946	0.16586	0.01709	0.01401	0.01409	0.05949
3.4822023	1.02568	0.18192	0.01866	0.01599	0.01432	0.06277	1.02418	0.18165	0.01863	0.01596	0.01430	0.06268	1.02118	0.18112	0.01858	0.01592	0.01426	0.06250
4	1.14670	0.14286	0.01030	0.01343	0.01494	0.05163	1.14449	0.14258	0.01028	0.01340	0.01492	0.05153	1.14008	0.14203	0.01024	0.01335	0.01486	0.05133
4.5947934	1.25732	0.17652	0.00996	0.01415	0.01697	0.05198	1.25412	0.17607	0.00994	0.01411	0.01693	0.05185	1.24775	0.17517	0.00989	0.01404	0.01684	0.05159
5.2780316	1.28054	0.21169	0.00817	0.01200	0.01815	0.04204	1.27624	0.21098	0.00814	0.01196	0.01809	0.04189	1.26768	0.20957	0.00808	0.01188	0.01797	0.04161
6.0628663	1.34216	0.22290	0.00706	0.01243	0.01860	0.03579	1.33622	0.22192	0.00703	0.01238	0.01852	0.03563	1.32441	0.21996	0.00697	0.01227	0.01835	0.03531
6.9644045	1.36162	0.21576	0.00621	0.01226	0.01887	0.02806	1.35367	0.21450	0.00617	0.01219	0.01876	0.02790	1.33791	0.21200	0.00610	0.01204	0.01854	0.02757
8	1.31594	0.19306	0.00666	0.01190	0.01694	0.02123	1.30581	0.19157	0.00661	0.01181	0.01681	0.02106	1.28579	0.18863	0.00651	0.01163	0.01655	0.02074
9.1895868	1.18970	0.15458	0.00477	0.01102	0.01622	0.01491	1.17763	0.15301	0.00472	0.01091	0.01605	0.01476	1.15387	0.14992	0.00463	0.01069	0.01573	0.01447
10.556063	1.01876	0.12112	0.00383	0.00982	0.01531	0.00975	1.00515	0.11951	0.00378	0.00969	0.01511	0.00962	0.97847	0.11633	0.00368	0.00944	0.01471	0.00936
12.125733	0.87423	0.08286	0.00404	0.00874	0.01322	0.00597	0.85885	0.08140	0.00397	0.00859	0.01299	0.00586	0.82889	0.07856	0.00384	0.00829	0.01254	0.00566
13.928809	0.66977	0.06596	0.00492	0.00773	0.01249	0.00439	0.65427	0.06443	0.00480	0.00755	0.01220	0.00429	0.62433	0.06148	0.00458	0.00720	0.01164	0.00409
16	0.50921	0.05072	0.00394	0.00548	0.00949	0.00379	0.49371	0.04918	0.00382	0.00531	0.00920	0.00367	0.46412	0.04623	0.00359	0.00500	0.00865	0.00345
18.379174	0.39737	0.03420	0.00413	0.00433	0.00943	0.00320	0.38200	0.03287	0.00397	0.00416	0.00906	0.00308	0.35303	0.03038	0.00367	0.00384	0.00837	0.00284
21.112127	0.21537	0.03097	0.00466	0.00196	0.00718	0.00378	0.20427	0.02938	0.00442	0.00186	0.00681	0.00358	0.18375	0.02643	0.00398	0.00167	0.00612	0.00322
24.251465	0.14272	0.02677	0.00317		0.00650	0.00489	0.13298	0.02494	0.00295		0.00605	0.00456	0.11544	0.02165	0.00256		0.00526	0.00395
27.857618	0.10075				0.00415	0.00708	0.09170				0.00378	0.00645	0.07596				0.00313	0.00534
32	0.08463					0.00627	0.07470					0.00553	0.05820					0.00431
36.758347	0.07143					0.00315	0.06059					0.00268	0.04359					0.00193
	19.25532	6.24217	1.23894	0.31139	0.33706	0.88760	19.07920	6.22318	1.23747	0.30997	0.33379	0.88330	18.74749	6.18649	1.23466	0.30721	0.32764	0.87547

Diameter	Filter Concentration (ppm) t=1440						Filter Concentration (ppm) t=2880						Filter Concentration (ppm) t=5760					
(um)	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069
0.7579	0.2536	0.7335	0.2475	0.0154	0.0100	0.0254	0.2536	0.7331	0.2473	0.0154	0.0100	0.0254	0.2532	0.7323	0.2471	0.0154	0.0100	0.0254
0.8705506	0.2663	0.7191	0.2115	0.0158	0.0101	0.0294	0.2661	0.7186	0.2114	0.0158	0.0101	0.0294	0.2657	0.7175	0.2110	0.0158	0.0101	0.0293
1	0.2940	0.6495	0.1740	0.0158	0.0102	0.0337	0.2938	0.6489	0.1738	0.0157	0.0102	0.0337	0.2931	0.6476	0.1735	0.0157	0.0102	0.0336
1.1486984	0.3285	0.5357	0.1412	0.0158	0.0100	0.0401	0.3282	0.5350	0.1410	0.0157	0.0100	0.0401	0.3272	0.5336	0.1406	0.0157	0.0100	0.0400
1.3195079	0.3678	0.4109	0.1052	0.0161	0.0105	0.0461	0.3675	0.4102	0.1051	0.0161	0.0105	0.0460	0.3660	0.4088	0.1047	0.0160	0.0104	0.0459
1.5157166	0.4197	0.3020	0.0800	0.0152	0.0109	0.0522	0.4191	0.3013	0.0798	0.0152	0.0109	0.0521	0.4169	0.3000	0.0794	0.0151	0.0108	0.0519
1.7411011	0.4857	0.2448	0.0605	0.0155	0.0114	0.0573	0.4849	0.2441	0.0603	0.0155	0.0113	0.0571	0.4815	0.2427	0.0600	0.0154	0.0113	0.0568
2	0.5470	0.2008	0.0425	0.0152	0.0120	0.0595	0.5458	0.2001	0.0424	0.0151	0.0119	0.0593	0.5407	0.1985	0.0420	0.0150	0.0118	0.0588
2.2973967	0.6383	0.1844	0.0329	0.0154	0.0123	0.0612	0.6364	0.1835	0.0327	0.0153	0.0122	0.0609	0.6286	0.1816	0.0324	0.0152	0.0121	0.0603
2.6390158	0.7455	0.1768	0.0245	0.0156	0.0125	0.0610	0.7426	0.1756	0.0244	0.0155	0.0124	0.0606	0.7307	0.1732	0.0241	0.0153	0.0122	0.0598
3.0314331	0.8855	0.1651	0.0170	0.0139	0.0140	0.0592	0.8810	0.1637	0.0169	0.0138	0.0139	0.0587	0.8623	0.1608	0.0166	0.0136	0.0137	0.0577
3.4822023	1.0152	0.1801	0.0185	0.0158	0.0142	0.0621	1.0083	0.1780	0.0183	0.0156	0.0140	0.0614	0.9802	0.1738	0.0178	0.0153	0.0137	0.0600
4	1.1313	0.1409	0.0102	0.0133	0.0147	0.0509	1.1212	0.1388	0.0100	0.0130	0.0145	0.0502	1.0801	0.1346	0.0097	0.0126	0.0141	0.0486
4.5947934	1.2351	0.1734	0.0098	0.0139	0.0167	0.0511	1.2205	0.1699	0.0096	0.0136	0.0163	0.0500	1.1618	0.1631	0.0092	0.0131	0.0157	0.0480
5.2780316	1.2507	0.2068	0.0080	0.0117	0.0177	0.0411	1.2313	0.2013	0.0078	0.0114	0.0173	0.0400	1.1538	0.1907	0.0074	0.0108	0.0164	0.0379
6.0628663	1.3011	0.2161	0.0068	0.0121	0.0180	0.0347	1.2744	0.2085	0.0066	0.0116	0.0174	0.0335	1.1697	0.1943	0.0062	0.0108	0.0162	0.0312
6.9644045	1.3069	0.2071	0.0060	0.0118	0.0181	0.0269	1.2717	0.1976	0.0057	0.0112	0.0173	0.0257	1.1356	0.1799	0.0052	0.0102	0.0157	0.0234
8	1.2467	0.1829	0.0063	0.0113	0.0160	0.0201	1.2025	0.1719	0.0059	0.0106	0.0151	0.0189	1.0357	0.1519	0.0052	0.0094	0.0133	0.0167
9.1895868	1.1078	0.1439	0.0044	0.0103	0.0151	0.0139	1.0563	0.1327	0.0041	0.0095	0.0139	0.0128	0.8673	0.1127	0.0035	0.0080	0.0118	0.0109
10.556063	0.9272	0.1102	0.0035	0.0089	0.0139	0.0089	0.8708	0.0990	0.0031	0.0080	0.0125	0.0080	0.6714	0.0798	0.0025	0.0065	0.0101	0.0064
12.125733	0.7721	0.0732	0.0036	0.0077	0.0117	0.0053	0.7107	0.0635	0.0031	0.0067	0.0101	0.0046	0.5043	0.0478	0.0023	0.0050	0.0076	0.0034
13.928809	0.5685	0.0560	0.0042	0.0066	0.0106	0.0037	0.5096	0.0464	0.0035	0.0054	0.0088	0.0031	0.3240	0.0319	0.0024	0.0037	0.0060	0.0021
16	0.4102	0.0409	0.0032	0.0044	0.0076	0.0031	0.3551	0.0319	0.0025	0.0034	0.0060	0.0024	0.1954	0.0195	0.0015	0.0021	0.0036	0.0015
18.379174	0.3015	0.0259	0.0031	0.0033	0.0072	0.0024	0.2508	0.0189	0.0023	0.0024	0.0052	0.0018	0.1170	0.0101	0.0012	0.0013	0.0028	0.0009
21.112127	0.1487	0.0214	0.0032	0.0014	0.0050	0.0026	0.1162	0.0140	0.0021	0.0009	0.0032	0.0017	0.0418	0.0060	0.0009	0.0004	0.0014	0.0007
24.251465	0.0870	0.0163	0.0019		0.0040	0.0030	0.0625	0.0093	0.0011		0.0022	0.0017	0.0159	0.0030	0.0004		0.0007	0.0005
27.857618	0.0521				0.0021	0.0037	0.0336				0.0010	0.0017	0.0054				0.0002	0.0004
32	0.0353					0.0026	0.0197					0.0010	0.0018					0.0001
36.758347	0.0226					0.0010	0.0105					0.0003	0.0004					0.0000
	18.1519	6.1177	1.2295	0.3020	0.3166	0.8622	17.5447	5.9957	1.2206	0.2927	0.2984	0.8419	15.6273	5.7959	1.2068	0.2774	0.2720	0.8123

Diameter (um)	Filter Concentration (ppm) t=11520					
	13727	13738	13781	20014	20057	20069
0.7579	0.25265	0.73069	0.24652	0.01534	0.00999	0.02532
0.8705506	0.26490	0.71544	0.21043	0.01574	0.01008	0.02926
1	0.29197	0.64514	0.17284	0.01564	0.01012	0.03348
1.1486984	0.32555	0.53093	0.13991	0.01562	0.00993	0.03977
1.3195079	0.36354	0.40611	0.10402	0.01591	0.01037	0.04554
1.5157166	0.41319	0.29730	0.07872	0.01501	0.01075	0.05141
1.7411011	0.47585	0.23984	0.05928	0.01518	0.01114	0.05611
2	0.53245	0.19547	0.04139	0.01478	0.01165	0.05791
2.2973967	0.61590	0.17793	0.03174	0.01485	0.01187	0.05908
2.6390158	0.71126	0.16863	0.02341	0.01488	0.01189	0.05824
3.0314331	0.83219	0.15518	0.01599	0.01311	0.01319	0.05566
3.4822023	0.93532	0.16589	0.01702	0.01458	0.01306	0.05724
4	1.01533	0.12649	0.00912	0.01189	0.01323	0.04571
4.5947934	1.07082	0.15033	0.00849	0.01205	0.01445	0.04427
5.2780316	1.03606	0.17128	0.00661	0.00971	0.01468	0.03401
6.0628663	1.01484	0.16854	0.00534	0.00940	0.01406	0.02706
6.9644045	0.94158	0.14920	0.00430	0.00848	0.01305	0.01940
8	0.80882	0.11866	0.00409	0.00732	0.01041	0.01305
9.1895868	0.62592	0.08133	0.00251	0.00580	0.00853	0.00785
10.556063	0.43656	0.05190	0.00164	0.00421	0.00656	0.00418
12.125733	0.28574	0.02708	0.00132	0.00286	0.00432	0.00195
13.928809	0.15314	0.01508	0.00112	0.00177	0.00286	0.00100
16	0.07268	0.00724	0.00056	0.00078	0.00135	0.00054
18.379174	0.03311	0.00285	0.00034	0.00036	0.00079	0.00027
21.112127	0.00768	0.00110	0.00017	0.00007	0.00026	0.00013
24.251465	0.00166	0.00031	0.00004		0.00008	0.00006
27.857618	0.00027				0.00001	0.00002
32	0.00003					0.00000
36.758347	0.00000					0.00000
	13.51900	5.49998	1.18692	0.25533	0.23868	0.76851

SPM concentration with Time (single grain settling)						
Time (s)	1 Low	1 High	6a High	6a Low	6c High	6c Low
0	0.31284	19.43915	1.24045	0.89221	6.26160	0.34045
30	0.31259	19.40794	1.24020	0.89142	6.25833	0.33987
90	0.31211	19.34623	1.23969	0.88987	6.25183	0.33873
180	0.31139	19.25530	1.23894	0.8876	6.24217	0.33706
360	0.30997	19.07920	1.12747	0.88330	6.22318	0.33379
720	0.30721	18.747	1.235	0.875	6.186	0.328
1440	0.30201	18.152	1.230	0.862	6.118	0.317
2880	0.29268	17.545	1.221	0.842	5.996	0.298
5760	0.27740	15.62726	1.2068	0.81228	5.79588	0.27205
11520	0.25533	13.51900	1.1869	0.76851	5.49998	0.23868

Minimum Settling Times (Flocculated grains)																				
Diameter	Diameter	Ws	Filter Concentration (ppm)						Filter Concentration (ppm) t= 30s						Filter Concentration (ppm) t=90s					
(um)	(m)	(m/s)	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069
0.7579	7.579E-07	1.000E-03	0.2538	0.7339	0.2476	0.0154	0.0100	0.0254	0.2463	0.7123	0.2403	0.0150	0.0097	0.0247	0.2319	0.6708	0.2263	0.0141	0.0092	0.0232
0.8705506	8.706E-07	1.000E-03	0.2665	0.7196	0.2117	0.0158	0.0101	0.0294	0.2586	0.6984	0.2054	0.0154	0.0098	0.0286	0.2435	0.6577	0.1934	0.0145	0.0093	0.0269
1	1.000E-06	1.000E-03	0.2942	0.6501	0.1742	0.0158	0.0102	0.0337	0.2855	0.6309	0.1690	0.0153	0.0099	0.0327	0.2689	0.5942	0.1592	0.0144	0.0093	0.0308
1.1486984	1.149E-06	1.000E-03	0.3289	0.5364	0.1413	0.0158	0.0100	0.0402	0.3192	0.5205	0.1372	0.0153	0.0097	0.0390	0.3006	0.4902	0.1292	0.0144	0.0092	0.0367
1.3195079	1.320E-06	1.000E-03	0.3685	0.4116	0.1054	0.0161	0.0105	0.0462	0.3576	0.3994	0.1023	0.0157	0.0102	0.0448	0.3368	0.3762	0.0964	0.0147	0.0096	0.0422
1.5157166	1.516E-06	1.000E-03	0.4206	0.3026	0.0801	0.0153	0.0109	0.0523	0.4082	0.2937	0.0778	0.0148	0.0106	0.0508	0.3844	0.2766	0.0732	0.0140	0.0100	0.0478
1.7411011	1.741E-06	1.000E-03	0.4871	0.2455	0.0607	0.0155	0.0114	0.0574	0.4727	0.2383	0.0589	0.0151	0.0111	0.0557	0.4452	0.2244	0.0555	0.0142	0.0104	0.0525
2	2.000E-06	1.000E-03	0.5492	0.2016	0.0427	0.0152	0.0120	0.0597	0.5329	0.1956	0.0414	0.0148	0.0117	0.0580	0.5019	0.1843	0.0390	0.0139	0.0110	0.0546
2.2973967	2.297E-06	1.000E-03	0.6415	0.1853	0.0331	0.0155	0.0124	0.0615	0.6226	0.1799	0.0321	0.0150	0.0120	0.0597	0.5863	0.1694	0.0302	0.0141	0.0113	0.0562
2.6390158	2.639E-06	1.000E-03	0.7506	0.1779	0.0247	0.0157	0.0125	0.0615	0.7284	0.1727	0.0240	0.0152	0.0122	0.0596	0.6860	0.1626	0.0226	0.0143	0.0115	0.0562
3.0314331	3.031E-06	1.000E-03	0.8934	0.1666	0.0172	0.0141	0.0142	0.0598	0.8670	0.1617	0.0167	0.0137	0.0137	0.0580	0.8165	0.1523	0.0157	0.0129	0.0129	0.0546
3.4822023	3.482E-06	1.000E-03	1.0272	0.1822	0.0187	0.0160	0.0143	0.0629	0.9968	0.1768	0.0181	0.0155	0.0139	0.0610	0.9388	0.1665	0.0171	0.0146	0.0131	0.0575
4	4.000E-06	1.000E-03	1.1489	0.1431	0.0103	0.0135	0.0150	0.0517	1.1150	0.1389	0.0100	0.0131	0.0145	0.0502	1.0500	0.1308	0.0094	0.0123	0.0137	0.0473
4.5947934	4.595E-06	1.000E-03	1.2605	0.1770	0.0100	0.0142	0.0170	0.0521	1.2233	0.1717	0.0097	0.0138	0.0165	0.0506	1.1520	0.1617	0.0091	0.0130	0.0155	0.0476
5.2780316	5.278E-06	1.000E-03	1.2849	0.2124	0.0082	0.0120	0.0182	0.0422	1.2469	0.2061	0.0080	0.0117	0.0177	0.0409	1.1743	0.1941	0.0075	0.0110	0.0166	0.0385
6.0628663	6.063E-06	1.000E-03	1.3481	0.2239	0.0071	0.0125	0.0187	0.0359	1.3083	0.2173	0.0069	0.0121	0.0181	0.0349	1.2321	0.2046	0.0065	0.0114	0.0171	0.0329
6.9644045	6.964E-06	1.000E-03	1.3696	0.2170	0.0062	0.0123	0.0190	0.0282	1.3291	0.2106	0.0061	0.0120	0.0184	0.0274	1.2517	0.1983	0.0057	0.0113	0.0173	0.0258
8	8.000E-06	1.000E-03	1.3261	0.1946	0.0067	0.0120	0.0171	0.0214	1.2870	0.1888	0.0065	0.0116	0.0166	0.0208	1.2120	0.1778	0.0061	0.0110	0.0156	0.0195
9.1895868	9.190E-06	1.000E-03	1.2019	0.1562	0.0048	0.0111	0.0164	0.0151	1.1664	0.1515	0.0047	0.0108	0.0159	0.0146	1.0984	0.1427	0.0044	0.0102	0.0150	0.0138
10.556063	1.056E-05	1.000E-03	1.0326	0.1228	0.0039	0.0100	0.0155	0.0099	1.0020	0.1191	0.0038	0.0097	0.0151	0.0096	0.9437	0.1122	0.0036	0.0091	0.0142	0.0090
12.125733	1.213E-05	1.000E-03	0.8899	0.0843	0.0041	0.0089	0.0135	0.0061	0.8636	0.0819	0.0040	0.0086	0.0131	0.0059	0.8133	0.0771	0.0038	0.0081	0.0123	0.0056
13.928809	1.393E-05	1.000E-03	0.6856	0.0675	0.0050	0.0079	0.0128	0.0045	0.6654	0.0655	0.0049	0.0077	0.0124	0.0044	0.6266	0.0617	0.0046	0.0072	0.0117	0.0041
16	1.600E-05	1.000E-03	0.5252	0.0523	0.0041	0.0057	0.0098	0.0039	0.5097	0.0508	0.0039	0.0055	0.0095	0.0038	0.4800	0.0478	0.0037	0.0052	0.0089	0.0036
18.379174	1.838E-05	1.000E-03	0.4134	0.0356	0.0043	0.0045	0.0098	0.0033	0.4011	0.0345	0.0042	0.0044	0.0095	0.0032	0.3778	0.0325	0.0039	0.0041	0.0090	0.0030
21.112127	2.111E-05	1.000E-03	0.2271	0.0327	0.0049	0.0021	0.0076	0.0040	0.2204	0.0317	0.0048	0.0020	0.0073	0.0039	0.2075	0.0298	0.0045	0.0019	0.0069	0.0036
24.251465	2.425E-05	1.000E-03	0.1532	0.0287	0.0034		0.0070	0.0052	0.1487	0.0279	0.0033		0.0068	0.0051	0.1400	0.0263	0.0031		0.0064	0.0048
27.857618	2.786E-05	1.000E-03	0.1107				0.0046	0.0078	0.1074				0.0044	0.0076	0.1012				0.0042	0.0071
32	3.200E-05	1.000E-03	0.0959					0.0071	0.0930					0.0069	0.0876					0.0065
36.758347	3.676E-05	1.000E-03	0.0842					0.0037	0.0817					0.0036	0.0770					0.0034
	Total (ppm)		19.4391	6.2616	1.2405	0.3128	0.3404	0.8922	18.8646	6.0765	1.2038	0.3036	0.3304	0.8658	17.7660	5.7227	1.1337	0.2859	0.3111	0.8154

Diameter	Filter Concentration (ppm) t=180s						Filter Concentration (ppm) t=360						Filter Concentration (ppm) t=720					
(um)	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069	**13727**	**13738**	**13781**	**20014**	**20057**	**20069**
0.7579	0.2120	0.6130	0.2068	0.0129	0.0084	0.0212	0.1771	0.5121	0.1728	0.0108	0.0070	0.0177	0.12353	0.35725	0.12053	0.00750	0.00489	0.01238
0.8705506	0.2226	0.6011	0.1768	0.0132	0.0085	0.0246	0.1859	0.5021	0.1477	0.0110	0.0071	0.0205	0.12970	0.35029	0.10303	0.00771	0.00494	0.01433
1	0.2458	0.5430	0.1455	0.0132	0.0085	0.0282	0.2053	0.4536	0.1215	0.0110	0.0071	0.0235	0.14322	0.31646	0.08478	0.00767	0.00496	0.01642
1.1486984	0.2747	0.4480	0.1181	0.0132	0.0084	0.0336	0.2295	0.3742	0.0986	0.0110	0.0070	0.0280	0.16008	0.26108	0.06880	0.00768	0.00488	0.01956
1.3195079	0.3078	0.3438	0.0881	0.0135	0.0088	0.0386	0.2571	0.2872	0.0736	0.0113	0.0073	0.0322	0.17935	0.20035	0.05132	0.00785	0.00512	0.02247
1.5157166	0.3513	0.2528	0.0669	0.0128	0.0091	0.0437	0.2934	0.2111	0.0559	0.0107	0.0076	0.0365	0.20472	0.14730	0.03900	0.00744	0.00533	0.02547
1.7411011	0.4069	0.2051	0.0507	0.0130	0.0095	0.0480	0.3399	0.1713	0.0423	0.0108	0.0080	0.0401	0.23711	0.11951	0.02954	0.00757	0.00555	0.02796
2	0.4587	0.1684	0.0357	0.0127	0.0100	0.0499	0.3831	0.1407	0.0298	0.0106	0.0084	0.0417	0.26730	0.09813	0.02078	0.00742	0.00585	0.02907
2.2973967	0.5359	0.1548	0.0276	0.0129	0.0103	0.0514	0.4476	0.1293	0.0231	0.0108	0.0086	0.0429	0.31227	0.09021	0.01609	0.00753	0.00602	0.02995
2.6390158	0.6269	0.1486	0.0206	0.0131	0.0105	0.0513	0.5237	0.1242	0.0172	0.0110	0.0088	0.0429	0.36534	0.08662	0.01203	0.00764	0.00611	0.02991
3.0314331	0.7462	0.1392	0.0143	0.0118	0.0118	0.0499	0.6233	0.1162	0.0120	0.0098	0.0099	0.0417	0.43487	0.08109	0.00836	0.00685	0.00689	0.02909
3.4822023	0.8580	0.1522	0.0156	0.0134	0.0120	0.0525	0.7166	0.1271	0.0130	0.0112	0.0100	0.0439	0.49998	0.08868	0.00910	0.00779	0.00698	0.03060
4	0.9597	0.1196	0.0086	0.0112	0.0125	0.0432	0.8016	0.0999	0.0072	0.0094	0.0104	0.0361	0.55924	0.06967	0.00502	0.00655	0.00729	0.02518
4.5947934	1.0529	0.1478	0.0083	0.0118	0.0142	0.0435	0.8794	0.1235	0.0070	0.0099	0.0119	0.0364	0.61357	0.08614	0.00486	0.00691	0.00828	0.02537
5.2780316	1.0732	0.1774	0.0068	0.0101	0.0152	0.0352	0.8964	0.1482	0.0057	0.0084	0.0127	0.0294	0.62540	0.10339	0.00399	0.00586	0.00886	0.02053
6.0628663	1.1261	0.1870	0.0059	0.0104	0.0156	0.0300	0.9406	0.1562	0.0050	0.0087	0.0130	0.0251	0.65621	0.10898	0.00345	0.00608	0.00909	0.01750
6.9644045	1.1440	0.1813	0.0052	0.0103	0.0159	0.0236	0.9555	0.1514	0.0044	0.0086	0.0132	0.0197	0.66666	0.10564	0.00304	0.00600	0.00924	0.01374
8	1.1077	0.1625	0.0056	0.0100	0.0143	0.0179	0.9252	0.1357	0.0047	0.0084	0.0119	0.0149	0.64550	0.09470	0.00327	0.00584	0.00831	0.01041
9.1895868	1.0039	0.1304	0.0040	0.0093	0.0137	0.0126	0.8385	0.1090	0.0034	0.0078	0.0114	0.0105	0.58502	0.07601	0.00235	0.00542	0.00797	0.00733
10.556063	0.8625	0.1025	0.0032	0.0083	0.0130	0.0083	0.7204	0.0857	0.0027	0.0069	0.0108	0.0069	0.50260	0.05976	0.00189	0.00485	0.00756	0.00481
12.125733	0.7433	0.0704	0.0034	0.0074	0.0112	0.0051	0.6209	0.0588	0.0029	0.0062	0.0094	0.0042	0.43315	0.04105	0.00200	0.00433	0.00655	0.00296
13.928809	0.5727	0.0564	0.0042	0.0066	0.0107	0.0038	0.4784	0.0471	0.0035	0.0055	0.0089	0.0031	0.33374	0.03287	0.00245	0.00385	0.00622	0.00219
16	0.4387	0.0437	0.0034	0.0047	0.0082	0.0033	0.3664	0.0365	0.0028	0.0039	0.0068	0.0027	0.25564	0.02546	0.00198	0.00275	0.00476	0.00190
18.379174	0.3453	0.0297	0.0036	0.0038	0.0082	0.0028	0.2884	0.0248	0.0030	0.0031	0.0068	0.0023	0.20120	0.01731	0.00209	0.00219	0.00477	0.00162
21.112127	0.1897	0.0273	0.0041	0.0017	0.0063	0.0033	0.1584	0.0228	0.0034	0.0014	0.0053	0.0028	0.11053	0.01590	0.00239	0.00100	0.00368	0.00194
24.251465	0.1279	0.0240	0.0028		0.0058	0.0044	0.1069	0.0200	0.0024		0.0049	0.0037	0.07456	0.01399	0.00165		0.00339	0.00255
27.857618	0.0925				0.0038	0.0065	0.0772				0.0032	0.0054	0.05388				0.00222	0.00379
32	0.0801					0.0059	0.0669					0.0050	0.04667					0.00346
36.758347	0.0703					0.0031	0.0588					0.0026	0.04099					0.00181
	16.23694	5.23013	1.03611	0.26130	0.28437	0.74524	13.56223	4.36857	0.86543	0.21826	0.23752	0.62247	9.46205	3.04785	0.60379	0.15227	0.16571	0.43428

Diameter	Filter Concentration (ppm) t=1440						Filter Concentration (ppm) t=2880						Filter Concentration (ppm) t=5760					
(um)	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069	13727	13738	13781	20014	20057	20069
0.7579	0.0601	0.1739	0.0587	0.0037	0.0024	0.0060	0.0260	0.0412	0.0139	0.0009	0.0006	0.0014	0.0008	0.0023	0.0008	0.0000	0.0000	0.0001
0.8705506	0.0631	0.1705	0.0501	0.0038	0.0024	0.0070	0.0273	0.0404	0.0119	0.0009	0.0006	0.0017	0.0008	0.0023	0.0007	0.0000	0.0000	0.0001
1	0.0697	0.1540	0.0413	0.0037	0.0024	0.0080	0.0301	0.0365	0.0098	0.0009	0.0006	0.0019	0.0009	0.0020	0.0005	0.0000	0.0000	0.0001
1.1486984	0.0779	0.1271	0.0335	0.0037	0.0024	0.0095	0.0336	0.0301	0.0079	0.0009	0.0006	0.0023	0.0010	0.0017	0.0004	0.0000	0.0000	0.0001
1.3195079	0.0873	0.0975	0.0250	0.0038	0.0025	0.0109	0.0377	0.0231	0.0059	0.0009	0.0006	0.0026	0.0012	0.0013	0.0003	0.0001	0.0000	0.0001
1.5157166	0.0996	0.0717	0.0190	0.0036	0.0026	0.0124	0.0430	0.0170	0.0045	0.0009	0.0006	0.0029	0.0013	0.0010	0.0003	0.0000	0.0000	0.0002
1.7411011	0.1154	0.0582	0.0144	0.0037	0.0027	0.0136	0.0498	0.0138	0.0034	0.0009	0.0006	0.0032	0.0015	0.0008	0.0002	0.0000	0.0000	0.0002
2	0.1301	0.0478	0.0101	0.0036	0.0028	0.0142	0.0562	0.0113	0.0024	0.0009	0.0007	0.0034	0.0017	0.0006	0.0001	0.0000	0.0000	0.0002
2.2973967	0.1520	0.0439	0.0078	0.0037	0.0029	0.0146	0.0656	0.0104	0.0019	0.0009	0.0007	0.0035	0.0020	0.0006	0.0001	0.0000	0.0000	0.0002
2.6390158	0.1778	0.0422	0.0059	0.0037	0.0030	0.0146	0.0768	0.0100	0.0014	0.0009	0.0007	0.0034	0.0024	0.0006	0.0001	0.0000	0.0000	0.0002
3.0314331	0.2117	0.0395	0.0041	0.0033	0.0034	0.0142	0.0914	0.0094	0.0010	0.0008	0.0008	0.0034	0.0028	0.0005	0.0001	0.0000	0.0000	0.0002
3.4822023	0.2434	0.0432	0.0044	0.0038	0.0034	0.0149	0.1051	0.0102	0.0010	0.0009	0.0008	0.0035	0.0032	0.0006	0.0001	0.0001	0.0000	0.0002
4	0.2722	0.0339	0.0024	0.0032	0.0035	0.0123	0.1175	0.0080	0.0006	0.0008	0.0008	0.0029	0.0036	0.0005	0.0000	0.0000	0.0000	0.0002
4.5947934	0.2987	0.0419	0.0024	0.0034	0.0040	0.0123	0.1289	0.0099	0.0006	0.0008	0.0010	0.0029	0.0040	0.0006	0.0000	0.0000	0.0001	0.0002
5.2780316	0.3044	0.0503	0.0019	0.0029	0.0043	0.0100	0.1314	0.0119	0.0005	0.0007	0.0010	0.0024	0.0040	0.0007	0.0000	0.0000	0.0001	0.0001
6.0628663	0.3194	0.0530	0.0017	0.0030	0.0044	0.0085	0.1379	0.0126	0.0004	0.0007	0.0010	0.0020	0.0042	0.0007	0.0000	0.0000	0.0001	0.0001
6.9644045	0.3245	0.0514	0.0015	0.0029	0.0045	0.0067	0.1401	0.0122	0.0004	0.0007	0.0011	0.0016	0.0043	0.0007	0.0000	0.0000	0.0001	0.0001
8	0.3142	0.0461	0.0016	0.0028	0.0040	0.0051	0.1356	0.0109	0.0004	0.0007	0.0010	0.0012	0.0042	0.0006	0.0000	0.0000	0.0001	0.0001
9.1895868	0.2848	0.0370	0.0011	0.0026	0.0039	0.0036	0.1229	0.0088	0.0003	0.0006	0.0009	0.0008	0.0038	0.0005	0.0000	0.0000	0.0001	0.0000
10.556063	0.2446	0.0291	0.0009	0.0024	0.0037	0.0023	0.1056	0.0069	0.0002	0.0006	0.0009	0.0006	0.0033	0.0004	0.0000	0.0000	0.0000	0.0000
12.125733	0.2108	0.0200	0.0010	0.0021	0.0032	0.0014	0.0910	0.0047	0.0002	0.0005	0.0008	0.0003	0.0028	0.0003	0.0000	0.0000	0.0000	0.0000
13.928809	0.1624	0.0160	0.0012	0.0019	0.0030	0.0011	0.0701	0.0038	0.0003	0.0004	0.0007	0.0003	0.0022	0.0002	0.0000	0.0000	0.0000	0.0000
16	0.1244	0.0124	0.0010	0.0013	0.0023	0.0009	0.0537	0.0029	0.0002	0.0003	0.0005	0.0002	0.0017	0.0002	0.0000	0.0000	0.0000	0.0000
18.379174	0.0979	0.0084	0.0010	0.0011	0.0023	0.0008	0.0423	0.0020	0.0002	0.0003	0.0006	0.0002	0.0013	0.0001	0.0000	0.0000	0.0000	0.0000
21.112127	0.0538	0.0077	0.0012	0.0005	0.0018	0.0009	0.0232	0.0018	0.0003	0.0001	0.0004	0.0002	0.0007	0.0001	0.0000		0.0000	0.0000
24.251465	0.0363	0.0068	0.0008		0.0017	0.0012	0.0157	0.0016	0.0002		0.0004	0.0003	0.0005	0.0001	0.0000		0.0000	0.0000
27.857618	0.0262				0.0011	0.0018	0.0113				0.0003	0.0004	0.0003				0.0000	0.0000
32	0.0227					0.0017	0.0098					0.0004	0.0003					
36.758347	0.0200					0.0009	0.0086					0.0002	0.0003					
	4.6057	1.4835	0.2939	0.0741	0.0807	0.2114	1.9883	0.3515	0.0696	0.0176	0.0191	0.0501	0.0613	0.0197	0.0039	0.0010	0.0011	0.0028

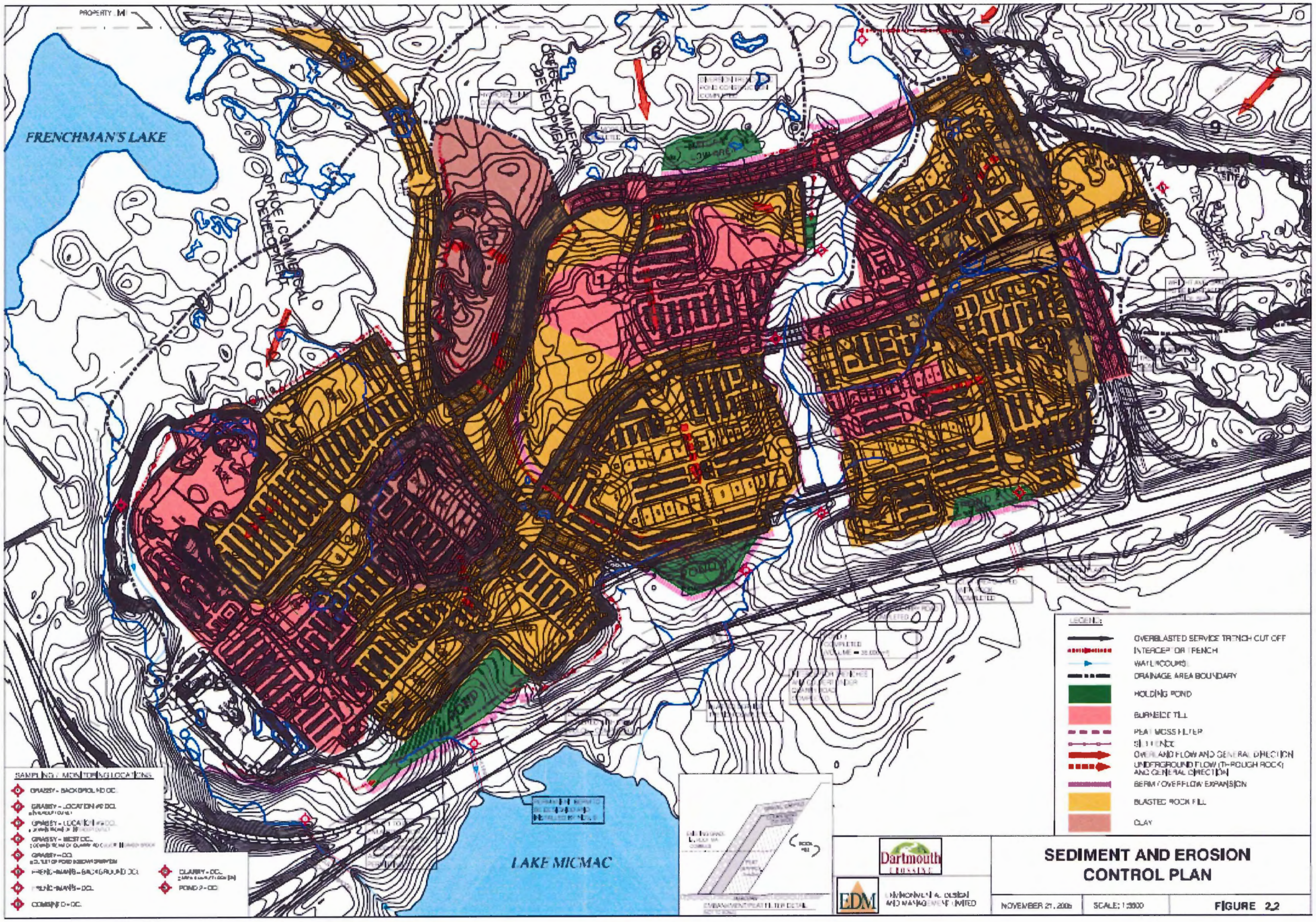
Diameter (um)	Filter Concentration (ppm) t=11520					
	13727	13738	13781	20014	20057	20069
0.7579	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000
0.8705506	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000
1	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000
1.1486984	0.00000	0.00001	0.00000	0.00000	0.00000	0.00000
1.3195079	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
1.5157166	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
1.7411011	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
2	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
2.2973967	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
2.6390158	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
3.0314331	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
3.4822023	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
4	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
4.5947934	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
5.2780316	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
6.0628663	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
6.9644045	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
8	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
9.1895868	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
10.556063	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
12.125733	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
13.928809	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
16	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
18.379174	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
21.112127	0.00000	0.00000	0.00000		0.00000	0.00000
24.251465	0.00000	0.00000	0.00000		0.00000	0.00000
27.857618	0.00000					
32	0.00000					
36.758347	0.00000					
	0.00019	0.00006	0.00001	0.00000	0.00000	0.00001

SPM concentration with Time (flocculated grain settling)						
Time (s)	1 High	1 Low	6c High	6c Low	6a High	6a Low
0	19.43915	0.3128	6.2616	0.8922	1.2405	0.3404
30	18.86464	0.3036	6.0765	0.8658	1.2038	0.3304
90	17.76604	0.2859	5.7227	0.8154	1.1337	0.3111
180	16.23694	0.2613	5.2301	0.7452	1.0361	0.2844
360	13.56223	0.2183	4.3686	0.6225	0.8654	0.2375
720	3.04785	0.1523	3.0479	0.4343	0.6038	0.16571
1440	4.60567	0.0741	1.4835	0.2114	0.2939	0.0807
2880	1.98832	0.0176	0.3515	0.0501	0.0696	0.0191
5760	0.06125	0.0010	0.0197	0.0028	0.0039	0.0011
11520	0.00019	0.0000	0.0001	0.0000	0.0000	0.0000

Appendix D

Dartmouth Crossing Construction Site, Location of Drainage Areas and Containment Ponds

(EDM, 2005)


FRENCHMAN'S LAKE
LAKE MICMAC
OFFICE / COMMERCIAL DEVELOPMENT
LEGEND:
OVERBLASTED SERVICE TRENCH CUT OFF
WATERCOURSE
DRAINAGE AREA BOUNDARY
HOLDING POND
BERM / OVERFLOW EXPANSION
CLAY
Dartmouth
EDM
SEDIMENT AND EROSION CONTROL PLAN
FIGURE 2.2