GREENLAND®

Erosion Control and Advanced Sedimentation Pilot Project - Federation of Canadian Municipalities Green Municipal Fund

Prepared for: The Town of Innisfil
Prepared by: Greenland International Consulting Ltd.

Date: December 2021

Municipal Infrastructure

Water Resources

Landscape Architecture

Environmental Management

Monitoring

Information Systems

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Glossary

Catchment Area	Area of land where precipitation collects and drains into a common outlet point, including a stormwater pond, river, lake or other body of water.
Chloride:	The concentration of chloride ions in water measured in milligrams of chloride per litre of water (or parts per million).
Conductivity:	Ability of water to conduct an electric current, based on the concentration of ions, at the ambient temperature measured in micro-Siemens.
Composite Sample:	A mixture of individual samples (grab samples) collected over a specific period of time (e.g., 24 hours for a daily composite). The water characteristics in a composite sample represent average conditions in the sampled flow during a specific time period.
Grab Sample	Individual sample collected at a specific period of time and without the addition or compositing of any other collected samples.
LSRCA	Lake Simcoe Region Conservation Authority
LSPOP	Lake Simcoe Phosphorus Offsetting Policy
LSPP	Lake Simcoe Protection Plan
MECP	Ministry of Environment, Conservation and Parks
MOE	Ministry of Environment
Particle size (µm)	Unit of measurement for classifying the size of a particulate (usually by average diameter). A micron is 1/1000 mm. or 1/25,400 in.
Particle Distribution	Proportional breakdown that defines the relative amount, typically by mass, of particles present in a collected sample according to size.
Sewershed	Area of land where all sewers and input points flow to a singular end / outlet point.
Stormwater Management Facility (SWMF)	Artificial water body designed and installed to collect and manage runoff from urban development areas. Important functions include the prevention of flooding and downstream erosion, as well as the treatment of stormwater to capture a variety of pollutants and nutrients.
Total phosphorus:	The concentration of all phosphorus forms measured in micrograms of phosphorus per litre of water (or parts per billion).
Total Suspended Solids	Particulates that float or are suspended in a water column and are typically < 2 µm in size.

Treated Geo-Jute	Erosion control blanket comprised of traditional loose weave geo-jute material and infused with Lynx UltraBind^{TM}, facilitating binding to the underlying soil for superior surface erosion control.
Turbidity	A measure of water clarity based on the presence of suspended particulates in the water, measured as Nephelometric Turbidity Units (NTU).
Water Lynx^{TM} (Gel Flocculant blocks)	An advanced sedimentation technology product that has been shown to effectively remove TSS suspended in stormwater, using flow energy along with particle size, shape, and density to release or strip flocculant.

Executive Summary

The Town of Innisfil (the Town) retained the Greenland International Consulting Ltd. (Greenland) to implement a Pilot Project, funded through the Federation of Canadian Municipalities' (FCM) Green Municipal Fund (GMF), to assess advanced sedimentation technologies (ASTs) designed to reduce the sediment and nutrient loading rates to Lake Simcoe from stormwater runoff generated by development sites.

The subject development site included the Sleeping Lion Subdivision (Study Area), which is located in the Town of Innisfil, Ontario on the west shore of Lake Simcoe. Within the Study area are three (3) active stormwater management facilities (SWMFs) with upstream catchment areas under various stages of development.

- SWMF 4 represents a pre-servicing construction condition, not stabilized but with SWMF infrastructure already installed (e.g., storm sewer drainage pipes);
- SWMF 7 represents an un-stabilized site undergoing area-grading with topsoil stripped;
- SWMF 6 represents a partially stabilized (fully developed) subdivision condition and partially under house construction with all SWM infrastructure installed, including storm sewer drainage system.

All three (3) SWMF's ultimately discharge to Lake Simcoe.

While MECP SWMF design guidelines are effective at removing TSS greater than 40 microns (µm) in size from contributing catchment areas, smaller sized particulates in stormwater influent have been documented in drainage catchment areas with fine grained soils (e.g. silt and clay soils). Due to the nature of SWMF design limitations in Ontario, these smaller sized influent TSS will move through the SWMFs without removal and adversely impact the receiving watercourse.

When designing SWMFs, it is important for Engineers to assess the potential for small TSS in SWMF influent, but also to have a solution to this problem in the design of SWMFs themselves. Therefore, this Pilot Project aimed to determine a verifiable and replicable methodology to further refine the ability of existing SWMF's to capture TSS particulate sized less than 40µm in size with the use of advanced sedimentation technology, namely, The Clearflow Group Inc.'s (Clearflow's) Water Lynx (Gel Flocculant Blocks) and Treated Jute, jointly referred to as Advanced Sedimentation Technologies (ASTs). These products can be installed upstream of target SWMFs to promote significant flocculation of finer TSS / sediment particulates prior to entering the permanent pool areas, reducing settling time requirements for SWMFs downstream of a variety of site stabilization states, and through enhanced sedimentation, greatly improve water quality exiting these facilities.

The Town therefore undertook this project to assist in achieving its long-term goals, and potential policy changes, for sediment management and site stabilization within Municipal borders. This is especially relevant when addressing the issue of un-stabilized development sites and impacts associated with runoff from construction activity. As the Town is ultimately responsible for approving site plans and subdivisions, development phasing and managing associated site runoff, the overall intent of this Project was threefold:

- Demonstrate the effectiveness of advanced sedimentation technologies applied towards un-stabilized sites (construction);

- Reduce erosion and discharge of sediment (and associated nutrients) from new development to watercourses within the Town of Innisfil and tributary to Lake Simcoe; and,
- By achieving the previous two (2) goals, directly contribute to a net reduction in future municipal liability when complying with Lake Simcoe Protection Plan (LSPP) requirements.

Performance results of the Clearflow Products utilized for this Project (Gel Flocculant Blocks and Treated Jute) were analyzed as it relates to the removal of TSS, phosphorus and chlorides in the summer, fall and spring seasons, with a site-specific removal efficiency for each parameter also determined under this analysis.

As previously noted, Clearflow's unique core technology Gel Flocculant Blocks, was utilized in this Pilot Project for its enhanced flocculation characteristics to help improve the efficiency of TSS capture in the target SWMFs. This product increases sedimentation rates during normal SWMF operation by reacting with very fine particles held in stormwater runoff to coagulate/ bind the sediment together, thus allowing the finer sediment to settle out more quickly in the forebays of receiving SWMFs.

For facilities where flow is conveyed primarily via overland channel and/or temporary stormwater conveyance means, and alternative approach was required. To maximize impacts of the sedimentation process under such conditions and stabilize the slopes of any temporary inlet channels, the installation of Gel Flocculant Blocks combined with Clearflow™ Treated Geo-Jute (Treated Jute) is required. This secondary product functions as an erosion control blanket and is comprised of traditional loose weave geo-jute material, making it fully biodegradable within 2-3 years of initial application. What differentiates this product from traditional geo-jute is a secondary treatment process whereby Clearflow's proprietary Lynx UltraBind™ (Lynx Ultrabind) is infused into the woven material, helping to further bind the applied geo-jute to the underlying soil for superior surface erosion control.

As part of the water quality analysis, continuous flow monitoring stations were installed at the inlet and outlet points of each SWMF and included pressure transducers (Levelogger® Edge Water Level Dataloggers) affixed via secured stilling wells. A single barometric pressure transducer datalogger (Levelogger® Edge Barologger) was also installed within the Subject Site to record ambient barometric pressure in order to barometrically correct data recorded by the pressure transducers installed at each of the three (3) SWMFs.

Five weir-based flow monitoring stations were required for installation at the inlet monitoring and pressure transducer installation points of each SWMF.

Water quality samples were collected at the inlets and outlets of each SWMF over the course of a one (1) year period. Sampling activities for all events were typically completed during (or immediately after) local area storm events (5mm+ precipitation events) that resulted in the flow of stormwater entering and exiting each SWMF. The full array of parameters analyzed under this Study include:

- Total Suspended Solids (TSS);
- Total Phosphorus (TPs);
- Chlorides;
- Turbidity (in-field); and,
- TSS Particle Distribution Analysis.

The first three (3) sample parameters outlined above were analyzed by Bureau Veritas Laboratories (BV Labs) for analysis, with the final parameter analyzed by the School of Environmental Sciences at the University of Guelph (UofG) for analysis. Finally, while the baseline sampling initiative analyzed TSS, turbidity and the particle distribution analysis for all collected samples, sampling post-product installation included an analysis of all five (5) parameters listed above.

Based on the results of the sampling, a series of calculations were completed to determine:

- TSS, phosphorus and chloride reduction (BV Labs results);
- TSS reduction of each measured particle size (UofG results);
- The expected (as-designed) TSS removal efficiency of the SWMF without ASTs; and,
- A theoretical reduction if the SWMF performed to MECP guidelines.

Results from the analysis are summarized below.

Table ES-1 Average TSS Reduction

	Average TSS Removal			
	Removal Efficiency - Guelph	**Removal Efficiency- BV Labs**	**As-Designed Efficiency**	**Removal Efficiency – Theoretical, MECP Guidelines**
SWMF 4	85%	94%	65%	28%
SWMF 6	26%	85%	65%	1%
SWMF 7	95%	98%	92%	31%

Note: Average values do not include sampling results where there was no flow recorded at the outlet, or where negative TSS removal efficiencies were observed.

Table ES-2 Average Phosphorus and Chloride Reduction

	Average Phosphorus Removal	**Average Chloride Removal**
SWMF 4	94%	40%
SWMF 6	80%	-215%
SWMF 7	98%	81%

Note: Average values do not include sampling results where there was no flow recorded at the outlet, or where negative TSS removal efficiencies were observed.

A cost analysis for the installation of the AST versus conventional methods of SWM was completed, based on the results from the water quality analysis. From a water quality approach, this was completed for phosphorus loading due to the sensitivity of the Lake Simcoe watershed, and increasing awareness of phosphorus loading ramifications province-wide. The Lake Simcoe Phosphorus Offsetting Policy (LSPOP) is relevant to all new development in the watershed and has the goal of eliminating 100% of phosphorus loads (based on pre development levels). For any development that is unable to eliminate phosphorus loads, an offset ratio is applied to any excess amounts. This includes a one-time fee passed along to the developer for any excess loadings and is based on the annual post development phosphorus loads. The offset ratio and unit cost of phosphorus is 2.5, and $35,000/kg, respectively.

The cost comparison for the Sleeping Lion Subdivision based on the expected pre and post development phosphorus loads is summarized below in **Table ES-3**. Pre-development loads are based off the original phosphorus budget calculation completed for the subdivision, while phosphorus removals for the SWMF only condition are based on the values recommended in the MECP's Phosphorus Budget Tool Guidance Report. The SWMF + AST condition removal scenario is an area weighted average calculated from the phosphorus removal observed from the in-field sampling completed.

Table ES-3 Phosphorus Offsetting Cost Comparison

Development Scenario	Area (ha)	Pre-Development Load (kg/yr)	Post Development Load (kg/yr)	Excess Phosphorus (kg/yr)	Value ($ CAD)*
Post Development: only SWMF (63% removal)	94.6	19.882	43.212	23.33	$ 2,041,375.00
Post Development: SWMF + AST (87% removal)	94.6	19.882	15.182	-4.7	$ -

** excl. HST*

With respect to TSS, the majority of TSS loading from a development site occurs during the unstabilized construction period, when the site is undergoing area grading, servicing and house construction. The Town of Innisfil has proposed re-seeding unstabilized sites as a potential method of controlling TSS loading of area waterbodies (e.g. Lake Simcoe) from development project sites. Therefore, a second high-level analysis was completed for the potential costs of seeding un-stabilized sites versus the implementation of ASTs during the construction phase of development. The cost of seeding the Subject Site versus the implementation of AST at each SWMF is explored below in **Table ES-4**. Assumptions include an eight (8) year construction phase, with three (3) cycles of AST per year required (as per this Project Methodology). Again, all costs associated with ASTs include both product and installation costs.

Table ES-4 Construction Cost Comparison (excl. HST)

SWMF	Drainage Area	Seeding	AST annual cost*	AST total cost*
	ha	$8/m^2	3 cycles per year	3 cycles per year* 8 years
SWMF 4	17.6	$ 1,408,000.00	$ 10,980.63	$ 87,845.00
SWMF 6	49.1	$ 3,928,000.00	$ 85,239.13	$ 681,913.00
SWMF 7	27.6	$ 2,208,000.00	$ 37,321.58	$ 298,572.67

** excl. HST*

Therefore, **with only considering site stabilization seeding and nutrient benefit** to the subject Subdivision, using a 50-year life of the SWMFs, the benefit cost ratio would be greater than 1.44. This is calculated by dividing the sum of the costs of seeding and phosphorus offsetting of the Subject Site ($9.6 million) by the implementation costs of the AST over the lifespan of the SWMF (annual cost of $133,000 * 50 years).

The ASTs provided a clear improvement on TSS removal on un-stabilized sites (SWMF's 4 and 7). While minor improvements were calculated for the majority of the small events sampled (<15mm), when compared to the as-designed efficiencies, a large reduction in the discharge of sediments was calculated for the August 02 2020 event (95.4 mm). Per the SWMF design, a TSS removal efficiency of 36.2% and 79.7% was expected for SWMF's 4 and 7 respectively without AST; however, actual removal efficiencies were calculated to be 74% and 95% with AST installed. Overall, the average TSS removal efficiency for SWMF 7 was determined to be 95% with AST over the sampling period, compared to the as-designed efficiency of 92%; while the removal efficiency in SWMF 4 with AST was calculated to be 85%, compared to the as-designed efficiency of 65%.

In addition to significantly reducing sediment release from SWMFs, another primary objective of the project was to reduce discharge of the associated metals and nutrients that bond strongly to fine particulates. As summarized above, discharge of sediments was notably reduced at both construction sites (SWMF's 4 & 7). Phosphorus removal was also calculated to be high at these sites, generally following the trend of TSS removal. While not tested as part of this study, similar results are expected from other metals that are known to sorb to sediment, such as: lead, zinc, magnesium, aluminum, silicon and organic compounds. Further testing and analysis are required to confirm the role of Clearflow ASTs in removal of these compounds, which is beyond the scope of this study.

Similar results were not observed in the connection between sediment removal and chloride reduction. From the results of the sampling initiative, no distinct conclusions on the relationship between the AST implementation and chloride reduction could be drawn. As the relationship between chloride reduction and TSS removal could not be conclusively proven with the implementation of AST, alternative methods to reduce chloride application should be taken by the Town to minimize chloride loading in downstream waterbodies until such a time that the implementation of AST provides a clear benefit. As an example, this could include changing the method of application (liquid salt brine as a deicer prior to snow events, pre-wetting road salts prior to application) or changing the type of material used in winter maintenance (sand-salt mixtures, alternative liquid brines).

Through the Study performance monitoring and cost evaluation analysis, an AST implementation strategy can also assist the Town in achieving its long-term goals surrounding policy changes for sediment management and site stabilization within Municipal borders. This is most notably demonstrated by the significant performance and cost savings for both phosphorus and TSS. The demonstrated improvement to sediment removal on construction sites with the implementation of AST can also help to reduce any financial liability on the part of the Town or developer for non-compliance of the LSPP policies, in particular policies 4.20DP d): "minimize sediment that is eroded offsite during construction" and 4.20DP f): "ensure erosion and sediment controls are implemented effectively" [1]. The implementation of AST will also help meet the target of reducing phosphorus loadings to achieve dissolved oxygen levels of 7 mg/L.

Our Project Team also found the implementation of these AST products to be relatively straightforward and efficient at the Project Site, indicating ease of replicability in similar un-stabilized sites across the Town of Innisfil, Ontario and Canada. Anecdotally, it should also be noted that there have been no known resident complaints of discoloration by TSS in receiving waterbodies (e.g. shore of Lake Simcoe) since the installation of the AST products at the Sleeping Lion Subdivision and which was a concern in the previous years of development.

Per the stated objectives of this Study, the AST products provided a demonstrated improvement to TSS removal in SWMFs at un-stabilized sites, and were proven effective at removing sediment <40µm in diameter, which are unaccounted for in MECP design standards for TSS removal. In addition, high-levels of phosphorus removal were observed at both SWMFs under active construction, following the trend of TSS removal. Based on estimates from the Sleeping Lion Subdivision in Innisfil, this AST approach would have a minimum benefit cost ratio of 1.44 and can also assist the Town in achieving its long-term goals surrounding policy changes for sediment management and site stabilization within Municipal borders. Finally, the implementation of these AST products was found to be relatively straightforward and efficient at the Project Site, indicating ease of replicability in similar un-stabilized sites across the Town of Innisfil, Ontario and Canada.

1 Introduction

The Town of Innisfil (the Town) retained the Greenland Group of Companies (Greenland) to implement a Pilot Project, funded through the Federation of Canadian Municipalities' (FCM) Green Municipal Fund (GMF), to assess advanced sedimentation technologies (ASTs) designed to reduce the sediment and nutrient loading rates to Lake Simcoe from stormwater runoff generated by development sites. The ASTs proposed for use in this Pilot Project are produced and sold by the Clearflow Group Inc. (Clearflow).

For the purposes of this investigation, the subject development site was the Sleeping Lion Subdivision (Study Area), which is located in the Town of Innisfil, Ontario on the west shore of Lake Simcoe (**Figure 1**). Within the Study area are three (3) active stormwater management facilities (SWMFs) with upstream catchment areas under various stages of development, along with approximately 500 residential units currently built out and another approximately 350 planned for development in Phase 3 (2021-2022) (**Figure 2**). The Study Area is bound by Sixth Line to the south and the former Metrolinx tracks to the west, the Previn Court Subdivision to the north and the Town of Innisfil (Town) Wastewater Treatment Plant (WWTP) to the east.

Figure 1: Study Area in Relation to Surrounding Municipalities

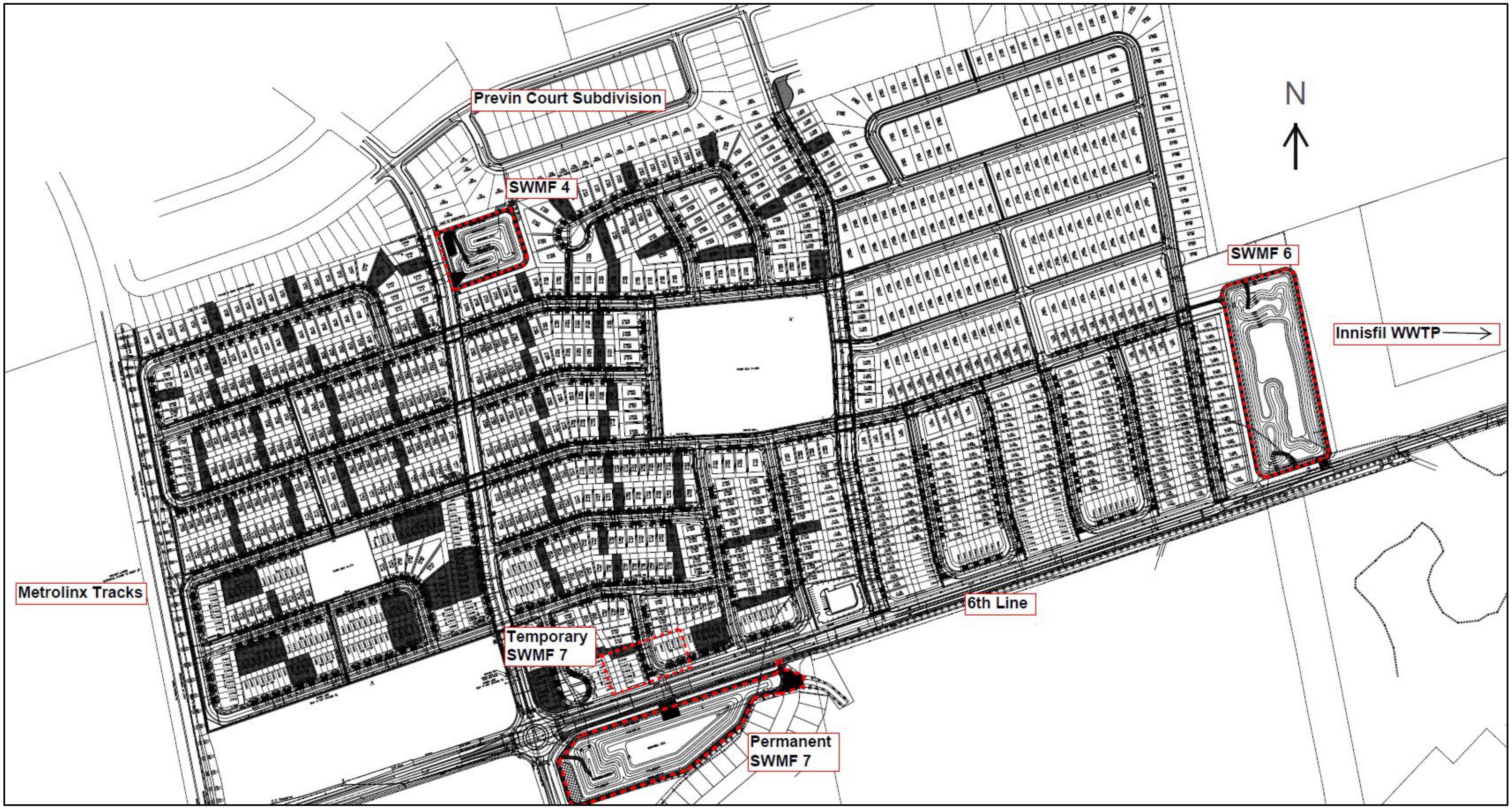


Figure 2: Sleeping Lion Subdivision (Study Area) and Subject SWMFs

The Innisfil Heights area, under which the Sleeping Subdivision Study Area is located, was identified as a Settlement Employment Area under the “Growth Plan for the Greater Golden Horseshoe (2017)” and significant growth to the area is expected over the next decade. This population growth will require new residential and commercial development to facilitate the population growth, both of which will lead to temporary un-stabilized ground cover and potentially significant loading rates of total suspended solids (TSS) generated by stormwater runoff. As identified in the Ministry of Environment Conservation and Parks (MECP) Stormwater Management (SWM) Planning and Design Guidelines (2003), total suspended solids (TSS) in stormwater are efficient vectors to carry nutrients and pollution to receiving watercourses [1]. The Town will need to implement additional environmental strategies, including proper management of sedimentation and phosphorus release, to ensure protection of receiving watercourses and to comply with legislation set forth in the Lake Simcoe Protection Plan (LSPP).

Based on the foregoing, the Town of Innisfil has obtained funding from the Federation of Canadian Municipalities (FCM) and retained the Greenland Group of Companies (Greenland) to implement a Pilot Project that includes the installation, monitoring and analysis of Clearflow Inc. advanced sedimentation technology (AST)to reduce TSS and phosphorous loading from the Sleeping Lion Subdivision and discharged to receiving water bodies, ultimately including Lake Simcoe. It is expected that the results, conclusions and recommendations of this Pilot Project will form a template to develop a specification for TSS removal (as well as pollutant and nutrient) in all development sites and stormwater management facilities (SWMFs) within the Town of Innisfil and eventually the Nottawasaga River and Lake Simcoe Watersheds.

1.1 Problem Description

Fine and insoluble particulates (TSS) that are suspended in stormwater are generally considered the largest vector and source of water pollution from land development projects. High concentrations of such particulates can have significant adverse effects on aquatic habitats in terms of reducing visibility, impacting photosynthesis, disrupting food webs and acting as a primary transport vector for a number of heavy metals and nutrients. While MECP SWMF design guidelines are effective at removing TSS greater than 40 microns (μm) in size from contributing catchment areas, smaller sized particulates in stormwater influent can be seen in drainage catchment areas with fine grained soils (e.g. silt and clay soils). These smaller sized influent TSS will move through the SWMFs without removal and aversely impact the receiving watercourse.

It is important for Engineers to assess the potential for small influent TSS in SWMF design, but it is also important to have a solution to this problem in the design of SWMFs themselves. This Pilot Project therefore aims to determine a verifiable and replicable methodology to further refine the ability of SWMF’s to capture TSS particulate sized less than 40μm in size with the use of AST, namely, The Clearflow Group Inc.’s (Clearflow’s) Water Lynx (Gel Flocculant Blocks) and Treated Jute). As outlined in **Section 1.2.1**, these products can be installed upstream of target SWMFs to promote significant flocculation of finer TSS / sediment particulates prior to entering the permanent pool areas, reducing settling time requirements for SWMFs downstream of a variety of site stabilization states, and through enhanced sedimentation, greatly improving water quality exiting these facilities.

Individual characteristics for each facility must also be taken into consideration when scoping out the extent of overall measures required for effective treatment. This includes a detailed review of the upstream catchment areas, associated land use, state of stabilization for the development site and storm sewer infrastructure, as well as pond design storage volumes and downstream environmental conditions.

With respect to stormwater impacts on receiving watercourses, the Town of Innisfil has previously received public complaints regarding sediment discharges from SWMFs, specifically from sites under construction and including the SWMFs at Sleeping Lion. However, through DFO reviews of the sediment releases, it was determined that at least the Sleeping Lion facilities were designed and operating as per existing MECP guidelines. A follow-up review also indicated that these sediment releases were comprised of particulates smaller than what is treated by SWMFs designed to MECP guidelines (e.g., <20-40µm). The Town of Innisfil is not in isolation with respect to this issue, as Greenland has been approached by other municipalities and private entities who are also facing similar challenges with existing or newly constructed SWMFs. Greenland first began studying the challenge of fine sediment releases in 2005 through a detailed analysis of a site within the City of Toronto. Under this investigation it was determined that 97% of sediment in influent flows by mass were smaller than 20µm and therefore treatment by facilities designed to MECP guidelines was not viable due to space limitations.

The Town is therefore undertaking this project to assist in achieving its long-term goals surrounding potential policy changes for sediment management and site stabilization within Municipal borders. This is especially relevant when addressing the issue of un-stabilized development sites and impacts associated with runoff from construction activity. As Municipalities are ultimately responsible for approving site plans, development phases and managing associated site runoff, the overall intent of this Project is threefold:

- Demonstrate the effectiveness of advanced sedimentation technologies (ASTs) using Clearflow products applied towards un-stabilized sites (construction);
- Reduce erosion and discharge of sediment (and associated nutrients) from new development to watercourses within the Town of Innisfil and tributary to Lake Simcoe; and,
- By achieving the previous two (2) goals, directly contribute to a net reduction in future municipal liability when complying with Lake Simcoe Protection Plan (LSPP) requirements.

Performance results of the Clearflow ASTs utilized for this Project (Gel Flocculant Blocks and Treated Jute) were analyzed as it relates to the removal of TSS, phosphorus and Chlorides in the summer, fall and spring seasons, with a site-specific removal efficiency for each parameter also determined under this analysis.

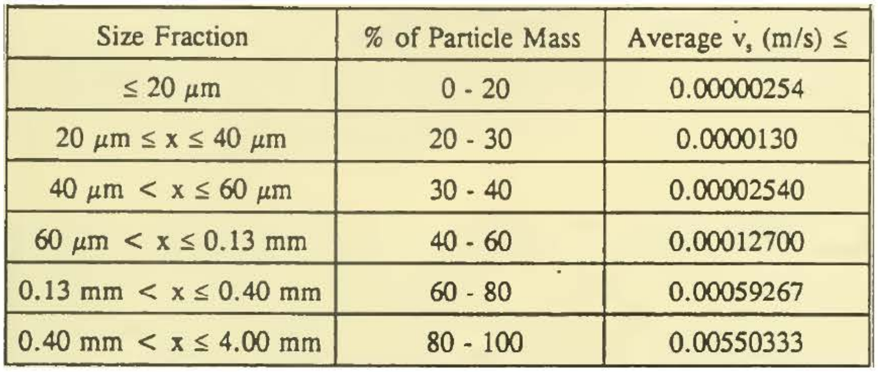
The following subsections provide further detail on each parameter targeted under this investigation.

1.1.1 *Total Suspended Solids (TSS)*

SWMFs are designed via “Stokes Law” to utilize treatment approaches heavily reliant on both the velocity of storm flows, length-width-depth of the facility, gravity, and the size of particulates transported in such flows. While larger particulates require short settling times and to be effectively captured, particulates falling under the 40µm threshold typically do not have sufficient time to settle with the minimum detention time criteria necessitated by existing regulatory standards. The Ministry of Natural Resources (MNR) 1991 Interim Stormwater Quality Control Guidelines for New Development also acknowledged this when outlining a variety of standard erosion and sediment control measures, concluding that soil particles > 40µm could be settled out from sediment laden runoff particularly within temporary sediment ponds[2]. However, removal of sediment particles under this threshold was considered impractical when utilizing erosion and sediment control measures proposed at the time.

This approach is also utilized in the MECP SWMP Design Manual (1994) which mandates that SWMFs be designed to settle suspended solids with an influent particle size distribution as detailed in **Table 1**. For a SWMF that is designed to provide Enhanced Level Water Quality Protection, the facility design should theoretically remove 80% of all influent TSS [3]. Based on the influent TSS mass distribution detailed in **Table 1**, any particle that has a size of 20µm or less would theoretically pass through a SWMF designed to the MECP Guidelines (i.e., gravity settling design).

Table 3: Particle Size Distribution in Stormwater Runoff (1994 MECP SWMP Guidelines) [3]



Size Fraction	% of Particle Mass	Average v_s (m/s) ≤
≤ 20 µm	0 - 20	0.00000254
20 µm ≤ x ≤ 40 µm	20 - 30	0.0000130
40 µm < x ≤ 60 µm	30 - 40	0.00002540
60 µm < x ≤ 0.13 mm	40 - 60	0.00012700
0.13 mm < x ≤ 0.40 mm	60 - 80	0.00059267
0.40 mm < x ≤ 4.00 mm	80 - 100	0.00550333

A site's distribution profile can vary greatly depending on soil characteristics in the upstream catchment area(s). For example, high concentrations of fine silt and clay particles entrained in stormwater runoff could cause the majority of TSS to be less than 20µm in size (by mass), thereby limiting the amount able to be captured in MECP design SWMFs. A larger problem can also arise when SWMFs do not capture this smaller sized TSS, as higher concentrations of smaller sized particulates will result in greater surface area by mass (when compared to larger counterparts), thus increasing the potential for transporting and not treating additional constituents such as heavy metals and nutrients.

Construction activities can also greatly increase the occurrence of erosion and sedimentation by removing vegetative cover and exposing soil surfaces to rainfall impact and runoff. While sediment control measures have been required on construction sites for over 20 years, high levels of sediment can continue to be discharged at concentrations above those required to protect aquatic life, even on sites where recommended practices are applied. Even in instances where permanent SWMFs are used as (oversized) erosion and sediment control basins, sediment has still been found to discharge at concentrations above those required to protect downstream recreational activities and aquatic life (including in the Lake Simcoe watershed) [4].

The removal of TSS at a sub-40µm level is therefore very important, and achieving this goal means either stabilizing construction sites, making permanent and temporary SWMFs larger or by enhancing sedimentation in SWMFs using ASTs (e.g., Clearflow products). The latter option is the primary focus of this Pilot Project.

1.1.2 *Phosphorous*

As previously mentioned, TSS in stormwater (and especially smaller particulates) can be an efficient vector for carrying a variety of nutrients, heavy metals and pollution, thereby increasing overall concentration levels and producing a net negative effect on downstream receiving watercourses. Theoretically, enhanced removal of TSS in SWMFs should also result in the removal of nutrients and pollution in effluent stormwater. Such reductions are especially important in the Lake Simcoe Watershed, as the LSPP has previously identified SWMFs as contributing approximately 5 tonnes / year of Phosphorus (7% of total contributions) to the Lake in 2008. These excessive loading rates are of significant concern to the Lake Simcoe Region Conservation Authority (LSRCA) and surrounding municipalities due to a number of adverse environmental effects, such as promoting excessive growth of plants and algae, each of which "contributes to the depletion of dissolved oxygen in the deep waters of the lake and degradation of the critical habitat of cold-water species"[5].

1.1.3 *Chlorides*

The prevalent use of rock salt for managing winter driving conditions results in large volumes of sodium chloride entering the surrounding environment via surface water runoff and infiltration into groundwater, with the most notable receiver connected to the Study Area being Lake Simcoe. High concentrations of sodium chloride in the environment can also affect the potability of water and take an increasing toll on ecosystem function and diversity. As such, the enhanced removal of chlorides, along with other pollutants by enhancing the removal of TSS though ASTs, was an important secondary of goal of this project. This included developing a baseline of the chloride loads and index of removal efficiencies at each target SWMF (post product installation). Chloride loading removal rates for each SWMF in the winter, spring, summer, and autumn were also analyzed to understand and provide rationale for the Town in the potential update of their salt management plans.

1.2 Clearflow Group Inc.

The Clearflow Group Inc. (Clearflow) was established in December 2004 with a primary focus of specializing in water treatment solutions. Their vision is to provide industry with products and wholistic solutions for water treatment and solids management that are innovative, process orientated, and cost effective. Protected by 10 registered patents including international patents, Clearflow currently manufactures and sells eight (8) core proprietary product lines of specialty polymers and mechanical reactor systems for water treatment, soil stabilization and solids management. In 2005, Clearflow realized that traditional treatment train practices utilized by the mining industry were not effectively mitigating the impacts of downstream cumulative effects. To address this identified treatment gap, the company worked to optimize the initial two (2) formulations of its flagship water quality treatment product, Water Lynx^{TM} gel block flocculant (Gel Flocculant Blocks), while continuing to validate product success through field trials via a group of various mining industry clients. These Gel Flocculant Blocks are an advanced sedimentation / flocculation technology product that has been shown to effectively remove TSS suspended in industrial stormwater from mining operations, of which there are very stringent discharge criteria required to release into the downstream environment. Due to the performance success Gel Flocculant Blocks achieved in this industry, it was postulated that the product would also have similar and transferrable applications for removing TSS in stormwater generated by urban development.

1.2.1 *Gel Flocculant Blocks*

As previously noted, Clearflow's unique core technology Gel Flocculant Blocks, was utilized in this Pilot Project for its enhanced flocculation characteristics to help improve the efficiency of TSS capture in the target SWMFs. This product increases sedimentation rates during normal SWMF operation by reacting with very fine particles held in stormwater runoff to coagulate/ bind the sediment together, thus allowing the finer sediment to settle out more quickly in the forebays of receiving SWMFs. This process is also passive in nature and completely self-dosing and self-limiting, dependent primarily on the volume and velocity of water flowing around the sequence of installed blocks. The velocity of stormwater required for optimal performance can range from 0.3 – 1.5 m/s with a solids content ideally limited to less than 1% or 10,000 NTU's.

To maximize the effectiveness of this product in a stormwater infrastructure setting however, important site-specific variables must be taken into account. These primarily include the soil types and land uses in the upstream catchment area, each of which can have significant impacts to the characteristics of downstream stormwater runoff. As each of these potential variables can impact stormwater chemistry and the subsequent performance of traditional flocculant products, Clearflow has created a number of different anionic product blends to handle a wide variety of applications across Canada. There are 2 main types, the 400 series which initiates the reaction, and the 300 series which binds the particulates together for faster settling. Selection of the ideal product chemistry for a particular site requires laboratory testing of influent and effluent stormwater in advance of product installation. For this Project, the proprietary blends chosen to maximize performance included a split of WLB 494 and WLB 360 blocks (**Figure 3**).

Figure 3: Gel Flocculant Blocks (WLB 494 and WLB 360)

As a part of this initial analysis, it was also important to ensure that the influent runoff entering each downstream SWMF had sufficient contact time with the Gel Flocculant Blocks without overwhelming its optimal treatment concentration range for solids (1% or 10,000 NTU's). Care must therefore be taken to determine the location and quantities of Gel Flocculant Blocks that are strung in-sequence upstream of the target facilities in the native inlet stormwater piping (**Section 4.1**). If the above is not taken into consideration during in the planning phase in advance of installation, product results for net sedimentation performance will likely be sub-optimal. Visual examples of the product installation process and final configurations can be found in **Photograph 1- Photograph 5,** while a more detailed step-by-step Site Instruction referencing this procedure can be found in **Appendix A**.

Photograph 1	Gel Flocculant Blocks arrive on site packaged in boxes of six (6). Upon arrival of shipment, the contractor receives and stores in a covered and dry place.
Photograph 2	When ready for field implementation, the Gel Flocculant Blocks are removed from their storage boxes and fastened via carabiner to MH specific rope configurations.
Photograph 3 **Photograph 4**	When all required product quantities and blends are fastened to their respective rope configurations, each is lowered into the MH structure.
Photograph 5	Upon successful installation of all specified product at a MH, the end of the rope configuration is fastened to the MH ladder rung to hold in place and prevent loss of product during high flow conditions.

Photograph 1: Initial shipment packaging for Gel Flocculant Blocks (WLB 494 & WLB 360)

Photograph 2: Gel Flocculant Blocks block rope configuration and connections to product (WLB 494)

Photograph 3: Installation of Gel Flocculant Blocks (WLB 494 and WLB 360) in a MH structure upstream of SWMF 6

Photograph 4: Lowering of Gel Flocculant Blocks (WLB 494) at select MH

Photograph 5: Securing of Gel Flocculant Blocks (WLB 494 & WLB 360) at select MH ladder rung

1.2.2 *Treated Jute*

While the above installation approach utilizing only Gel Flocculant Blocks is appropriate for SWMFs that have established upstream stormwater conveyance infrastructure piping (SWMF 4 and 6), an alternative approach is required for facilities where flow is conveyed primarily via overland channel and/or temporary stormwater conveyance means. To maximize impacts of the sedimentation process under such conditions and stabilize the slopes of any temporary inlet channels, the installation of Gel Flocculant Blocks combined with Clearflow™ Treated Geo-Jute (Treated Jute) is required.

This secondary product functions as an erosion control blanket and is comprised of traditional loose weave geo-jute material, making it fully biodegradable within 2-3 years of initial application. What differentiates this product from traditional geo-jute is a secondary treatment process whereby Clearflow's proprietary Lynx UltraBind^{TM} (Lynx Ultrabind) is infused into the woven material, helping to further bind the applied geo-jute to the underlying soil for superior surface erosion control. For the purposes of this Project, Treated Jute was applied to the overland inlet channels conveying flow into SWMF 7 at the Subject Site, along with the installation of Gel Flocculant Blocks to enhance sedimentation and minor rock-check dams to extend product contact time with influent stormwater in advance of discharge to the facility. Visual examples documenting the installation and final configuration of this product can be found in **Photograph 6 - Photograph 11**, while a more detailed step-by-step Site Instruction referencing this procedure can be found in **Appendix A**.

Photograph 6	Treated Jute arrives on site packaged in bundles of four (4). Upon arrival of shipment, the contractor receives and stores in a covered and dry place.
Photograph 7	Contractor is rolling out the Treated Jute product in the middle section of an overland channel at temporary SWMF 7.
Photograph 8	Sidewalls of the overland channel are partially covered with Treated Jute, with one additional roll to be applied at the top of each channel wall.
Photograph 9	Inlet Channel partially stabilized with Treated Jute (final sidewall applications outstanding) and filled with water from recent rain event.
Photograph 10	Contractor installing rock check dams and individual Gel Flocculant Blocks to further increase sedimentation process within SWMF 7. Channel walls are now sufficiency stabilized.
Photograph 11	Final installation configuration of all sedimentation products at inlet channel of SWMF 7 (Treated Jute, Gel Flocculant Blocks and Rock Check Dams).

Photograph 6: Treated Jute (pre-packaged)

Photograph 7: Installation of Treated Jute at SWMF #7 (west channel)

Photograph 8: Fully lined channel with Treated Jute at SWMF #7 (west channel)

Photograph 9: SWMF 7 (west channel) backfilled with water from recent rain event

Photograph 10: SWMF #7 (east channel) with rock check dams, Treated Jute and Gel Flocculant Blocks installed

Photograph 11: Final Installation Configuration at SWMF 7 (Treated Jute, Gel Flocculant Blocks and Rock Check Dams)

1.2.3 *Alignment with Federal and Provincial Regulations*

Clearflow has also engaged the Province of Alberta, Province of Ontario and relevant Federal regulators (including Environment Canada and Department of Fisheries and Oceans) on the effectiveness of their products and recorded treatment results.

From 2007 to 2012, a series of research studies were conducted with project support from National Research Council/IRAP, University of Alberta and University of Guelph to determine the product's environmental impact to aquatic ecosystem. The multi- year research projects were conducted at two (2) sites, one being the Bamfield Department of Fisheries and Oceans salmon farm located in Nitnat, BC. This research was critical in verifying the Gel Flocculant Block products produced no immediate harmful effects to fish, fish eggs, nor fry during hatching. Testing also revealed no negative long-term impact to the osmosis process as the fish fry transitioned from fresh water to salt water, verifying no toxic effects were evident. Please refer to **Appendix B** for additional information on this testing.

In addition, Soil Lynx^{TM}, Gel Flocculant Blocks and Treated Jute were a key part of a separate and approved Environmental Compliance Approval (ECA) application for a previous SWMF sediment removal and retrofit project in Ontario. Undertaken in the City of Waterloo and accepted by the Ministry of Environment, Conservation and Parks (MECP) in 2017 (previously the Ministry of Environment and Climate Change), these products have been approved for field use in Ontario with successful results to date.

2 Objectives and Future Potential

As previously outlined in **Section 1.1**, the main goal of this Pilot Project was to demonstrate the effectiveness of advanced sedimentation technologies to enhance TSS removal in SWMFs when applied in the stormwater collection systems in a variety of site stabilization conditions (e.g., fully developed, house construction, area grading construction). This approach was hypothesized as an effective solution to minimizing discharge of TSS (and associated nutrients) from new development to receiving watercourses within the Town of Innisfil and ultimately Lake Simcoe.

Upon demonstrating achievable success of this initial Pilot Project, our Project Team is of the opinion that this approach can be applied to the remaining SWMFs in Innisfil, the Lake Simcoe Watershed and potentially the entire Province of Ontario. It is also anticipated that this model will be replicable across the entire Country of Canada in areas with physical and environmental conditions closely related to that of the Study Area. The scale of implementation for this proposed strategy is therefore limited only by the number of SWMFs in a watershed with un-stabilized sites present in their respective catchment areas, as well as the availability of necessary site data required to accurately quantify such product requirements. Due to increased development as a result of Ontario's Growth Plan recommendations, it is expected that in the Province of Ontario, both the number of SWMFs and associated un-stabilized sites will continue to increase necessitate the implementation of effective strategies to mitigate the downstream water quality impacts caused by such rapid growth.

3 Target Stormwater Management Facilities (SWMFs)

The Study Area for this Project (Sleeping Lion Subdivision) includes three (3) individual Stormwater Management Facilities (SWMFs), each of which capture stormwater runoff from upstream catchment areas under various stages of development and states of site stabilization (with respect to erosion and sedimentation of runoff). What differentiates each of these facilities is the current development condition for each of their upstream catchment areas, allowing for product testing to occur under a wide variety of site stabilization conditions.

3.1.1 *Stormwater Management Facility #4*

SWMF 4 is a wet pond facility with: a permanent pool of 2589 m^3; water quality and 100 Year extended detention volumes of 1657 m^3 and 8349 m^3, respectively; and an upstream catchment area of 17.5 ha. The maximum proposed imperviousness for the contributing development upstream of this facility is approximately 52%. The facility itself contains one inlet and one outlet point, along with one emergency overflow. The primary inlet to SWMF 4 consists of a 1050 mm diameter concrete pipe, located on the southwest boundary of the SWM Block, and conveys flow from the northwest drainage system of the Sleeping Lion Subdivision (17.5 ha). The inlet pipe invert is set at the permanent pool elevation of 229.50m with influent stormwater discharging to a sediment forebay which deepens and widens over its length of 45m before connecting to the permanent pool. Stormwater captured by this facility discharges into a single control manhole which includes a reversed slope inlet pipe at the northeast base of the permanent pool. An emergency overflow weir is also located on the northeast corner of the SWMF. Please refer to **Figure 4** for a visual overview of this SWMF.

For the purposes of this Project, SWMF 4 represents a pre-servicing construction condition, not stabilized but with SWMF infrastructure already installed (i.e., storm sewer drainage pipes connected to the SWMF).

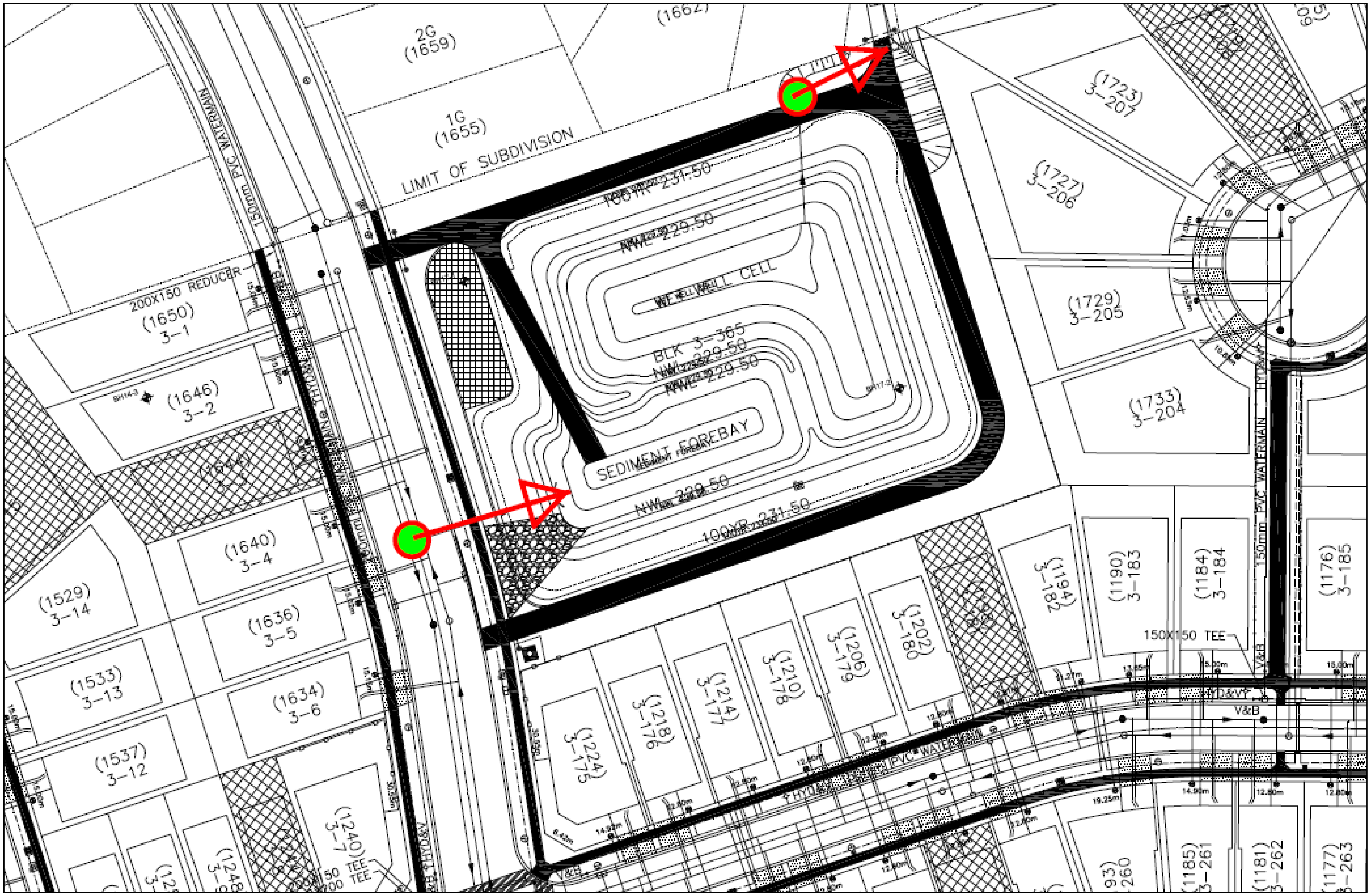


Figure 4: Stormwater Management Facility #4

3.1.2 *Stormwater Management Facility #7*

SWMF 7 is an interim sediment pond (upstream of the final constructed SWMF 7 wet pond facility) that has been constructed to temporarily provide erosion and sediment control for on-going development from Phases 3-5 of the Subject Site. As such, no permanent infrastructure has been constructed to convey stormwater into this facility and the upstream catchment area (27.6 ha) is almost entirely undeveloped, but stripped of top soil. Flow into this facility is conveyed via an open eastern inlet channel (130m length) and an open western inlet channel (150m length). The temporary SWMF has: a permanent pool of 4332 m^3; water quality extended detention volumes of 3521 m^3; which meets with the requirements of temporary SWMFs as detailed in the Town of Innisfil / LSRCA Standards. Discharge from this facility is conveyed via a permanent stormwater infrastructure outlet point (hickenbottom outlet structure) to the permanent SWMF 7 located just downstream on the southern boundary of the 6th Line. Upon completion of the upstream development phases at the Sleeping Lion Subdivision, this temporary SWMF will be filled in and developed with all future stormwater flows directly conveyed to the downstream permanent SWMF 7 via the proposed future storm sewer drainage infrastructure. Please refer to **Figure 5** for a visual overview of this SWMF.

For the purposes of this Project, SWMF 7 represents an un-stabilized site undergoing area-grading with topsoil stripped.

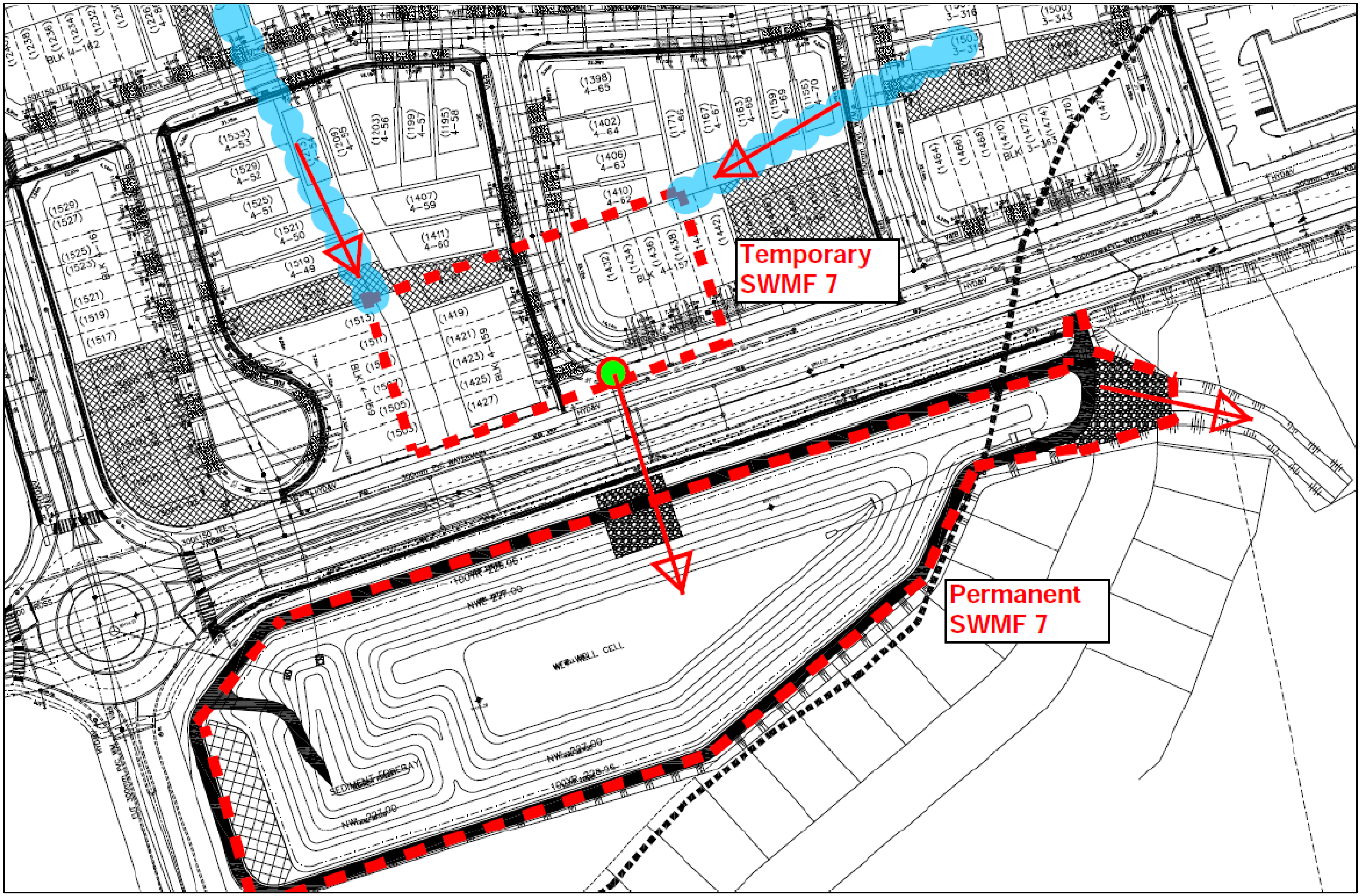


Figure 5: Stormwater Management Facility #7 (Temporary and Permanent SWMFs)

3.1.3 *Stormwater Management Facility #6*

SWMF 6 is a wet pond facility with: a permanent pool of 10632 m^3; water quality and 100 Year extended detention volumes of 5135 m^3 and 34066 m^3, respectively; and an upstream catchment area of 49.1 ha at 49% imperviousness. The facility contains two primary inlets and one outlet point, along with one emergency overflow weir.

The south inlet to SWMF 6 is comprised of a 1050 mm diameter circular pipe which conveys flow from the southeast drainage system of the Sleeping Lion Subdivision as well as the 6th Line. This inlet discharges to a targeted sediment forebay which deepens and widens over its 49m length. The north inlet is located on the northwest corner of the SWM Block and is comprised of a 1350 mm diameter circular pipe which conveys flow from the northeast drainage system of the Sleeping Lion Subdivision to SWMF#6 including all roads and developed blocks. The inlet discharges to a sediment forebay which deepens and widens over its 74 m, meeting the required dispersion length. Water is then directed over a short berm from the 1.0-metre-deep forebay to the main wet pond area.

The single outlet point of this facility consists of a manhole structure (MH199) containing two 100mm square orifices. These feed into a common 600mm diameter pipe which flows to a second structure (MH2) and ultimately to the downstream Sixth Line ditch system. A water quality control structure is also contained within MH2. Finally, this SWMF contains one emergency overflow weir. Please refer to **Figure 6** for a visual overview of this SWMF.

For the purposes of this Project, SWMF 6 represents a partially stabilized (fully developed) subdivision condition and partially under house construction with all SWM infrastructure installed, including storm sewer drainage system.

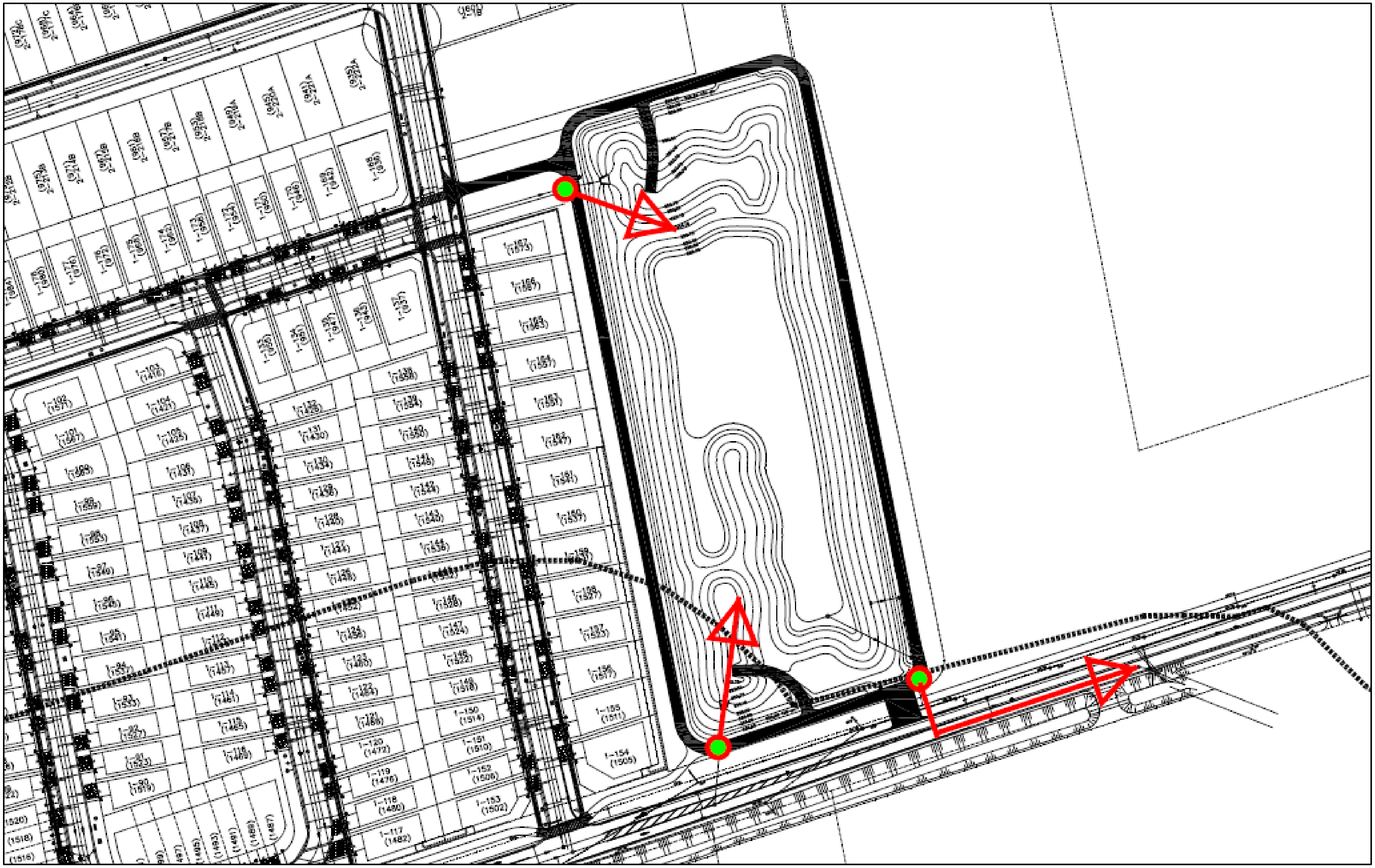


Figure 6: Stormwater Management Facility #6

4 Implementation Strategy

In order to carry out this Pilot Project, several steps were required to ensure an accurate and complete undertaking. The following tasks thereby identify processes and actions, completed under this Pilot Project, that are measurable and transferable to other locations throughout the watershed and Province.

4.1 Task #1: Baseline Monitoring and Product Determinations

4.1.1 *Baseline Monitoring*

In advance of formally initiating this Project, a sampling initiative was first undertaken in the winter of 2018 to ascertain the baseline quality of stormwater entering and leaving SWMF 6 during periods of high flow (including rain and corresponding snowmelt events). As previously referenced in **Section 1.2.1**, these baseline water quality samples were shipped to Clearflow for in-house analysis to determine which blend(s) of Gel Flocculant Blocks could maximize reductions of the currently high TSS / sediment volumes exiting the Subject Site.

4.1.2 *Product Calculations*

Once the preferred product blends were chosen, our Project Team's next task was to determine both the locations and quantities of product to be installed upstream of each SWMF to ensure maximum effectiveness. Undertaking this process required the completion of a number of steps, each of which has been outlined below.

Step 1. Identify Total Flow entering SWMF from Each Inlet.

The first item clarified was the total amount of flow (m^3/s) the downstream SWMF is receiving based off of the 25 mm storm event from the entire upstream storm drainage system, which represents greater than 80% of all annual runoff events in the Study Area. For each of the Study Area SWMFs, these values were readily available from each of the facility's existing design reports. After extensive testing undertaken by Clearflow with regards to Gel Flocculant Blocks performance, which included baseline water quality samples collected for in-house analysis, it was determined that one Gel Flocculant Block is typically required for every 189 – 379 litres per minute of incoming flow. This range can be further refined however based on the site-specific requirements, with the required number of blocks scaled up for longer reaction times or scaled down for treatment in primarily cold waters. The Total Flow for the storm event is then used to calculate the total number of blocks for the system:

$$Total\ \#\ of\ Blocks = \frac{Total\ flow\ at\ SWMF\ Inlet\ \left({}^{m^3}/_{s}\right) \times 1000\ \left({}^{L}/_{m^3}\right) \times 60\left({}^{s}/_{min}\right)}{x\ \left({}^{L/min}/_{Block}\right)}$$

Where x = design criteria (189 - 379 litres per minute per block), determined by lab testing.

Step 2. Identify Storm Distribution Network

To initiate this Step, existing design drawings from the upstream storm sewer system of each target SWMF must be available for review. Utilizing these drawings and the aforementioned 25mm storm event values, a number of variables must then be determined at each upstream MH node. This includes individual pipe lengths, slopes and materials, along with the contributing catchment areas upstream of each individual MH. This information is then organized into a chart for use in the subsequent Steps.

Step 3. Identify 25 mm event flow (m^3/s) for each Network MH Node

With the data organized as per Step #2, the accumulated stormwater flow at each MH node in the storm drainage system can then be cumulatively determined, starting at the predetermined baseline MH until exiting at the corresponding downstream SWMF inlet point(s). The baseline MH is the manhole far enough upstream to result in sufficient product contact time with the 25mm storm flows. As with Step #1, the storm event applied to these calculations will be the 25mm event.

Step 4. Calculate Segment Velocities (based on flow and diameter of pipe)

The purpose of this step is to determine the point(s) upstream of the SWMF where it would take 2 minutes for influent stormwater to enter the facility (based on flows from the 25mm event). These distances are important because lab testing determines the reaction time required by the blocks. If the blocks are placed too far upstream then sediment deposition could occur in the pipe, but if the blocks are placed too close to the SWMF incomplete flocculation may occur resulting in sub-optimal water clarity. Once identified, this MH node point(s) will represent the most upstream location(s) for installing the Gel Flocculant Blocks, identified as the baseline MH.

Step 5. Determine block distribution based on segment flows and segment velocities

The total number of Gel Blocks for an upstream storm sewer network is determined by the flow at either the SWMF inlet or the flow at the final MH before the SWMF, both the SWMF inlet and the final MH node should be the same value. The number of blocks is determined as in Step #1. First determine the MH nodes where the 30-second, 1-minute and 2-minute flow points are closest to, if the storm sewer system branches, then there may be multiple points of 30 second, 1-minute or 2-minute points. Another consideration is that all of the stormwater needs to flow over blocks, if the storm sewer system has inflows downstream of the 30-second, 1- or 2-minute points, block distribution should be shifted to account for this condition. The 2-minute point is the farthest point from the SWMF that blocks should be placed. Beyond this the reaction may start to cause deposition inside the pipes. Downstream of the 2-minute point, blocks should be distributed according to flow rate at each MH node. For the first placement (farthest from the SWMF, at or near the 2-minute point) the flow at the MH node[s] is used to calculate the number of blocks to be installed at the MH node using the calculation:

$$\left\{\frac{(Predetermined\ total\ \#\ of\ blocks)}{(total\ flow\ at\ SWMF\ inlet)}\right\} \times (flow\ at\ MH\ node)$$

For MH nodes downstream of the farthest MH node from the SWMF that has blocks assigned to it, the flow at the node needs to subtract the flow[s] of the previous node with blocks assigned to it. This calculation is performed to account for any flow added to the system after the last block placement. This calculation is the same calculation as above but the last term (flow at MH node) is changed to reflect the added flow:

$$\left\{\frac{(Predetermined\ total\ \#\ of\ blocks)}{(total\ flow\ at\ SWMF\ inlet)}\right\} \times \{(flow\ at\ MH\ node) - (flow\ at\ previous\ MH\ node)\}$$

The second equation may be used in place of the first equation. The last term (flow at previous MH node) would simply be zero (0) for the MH node where blocks are installed farthest from the SWMF. Another way to explain the foregoing is: flow at previous MH node is flow already treated with blocks.

Step 6. Incorporate Lab Gel Block Load Distribution:

In most applications, Clearflow WLB 494 Gel Blocks are placed upstream in the flow of water (front load) and Clearflow WLB 360 Gel Blocks are placed downstream in the flow of water (back load). This means the WLB 494 Gel Blocks come into contact with the flowing water first to initiate the flocculation reaction, the WLB 360 Gel Blocks come into contact with the water second and finish the flocculation reaction. Clearflow recommends testing at their lab to confirm optimal placement and distribution of the WLB Gel Blocks."

Step 7. Finalize MH Table with Type and Number of Blocks:

With all of the data and corresponding calculations in hand, including stormwater flow velocities and volumes at each MH node, the optimal distribution of Gel Flocculant Blocks across the entire upstream storm sewer infrastructure is then determined. Identifying the optimal distribution of product across the storm sewer system requires calculating the block distribution for each MH node as per the calculations in Step 5.

After the number of blocks for each MH node is determined, the distribution of 494 and 360 for each node needs to be determined. For short branches in the farther upstream sections of the system, 494 can be used for all block placement. In the farthest downstream main trunks 360 can be used for all product placement, assuming no or very little new (untreated) water is added to the system. Anywhere that flow is added to the system, 494 should be used for the product placement to ensure proper treatment of all new flow. Any remaining MH nodes can split the remining blocks evenly, and if an excess of one block type remains so that even splitting is not possible, it is important to skew the higher number of 494 upstream or the higher number of 360 downstream in the system.

4.2 Task #2: Clearflow Product Installation

Upon completion of Task #1 by our Project Team, field activities commenced in order install the Gel Flocculant Blocks at each of the three (3) targeted SWMFs and Treated Jute at SWMF 7. The Maacon Construction Corporation (Maacon) was engaged for this task in order to receive, store and install all Clearflow Product for the duration of this assignment. Installation procedures, as summarized herein, were prescribed via a Site Instruction Document (**Appendix A**) to ensure prescribed product quantities and blends were installed as required.

Steps required to install Gel Flocculant Blocks (SWMF 4 and 6) include the following:

1. Utilize the Site Instruction document (**Appendix A**) to determine the location of each target MH and associated product quantity to be installed. This document also prescribes the type (using the gel block Colour Identification resource) and number of Gel Flocculant Blocks to be installed at each subject MH.
2. With reference to the Site Instruction document, identify the pre-built rope configuration for each target MH through the attached label references. Note that a MH may have up to 3 ropes in series.
3. Attach the appropriate colour coded Gel Flocculant Blocks (WLB494 & WLB360) to the corresponding colour coded carabiners secured on the identified pre-built rope configuration. Upon completion of this activity, ensure quantities for both blends of Gel Flocculant Blocks (WLB494 & WLB360) correspond to the values prescribed in the Site Instruction document for the target MH.

4. Lower the completed gel block configuration into the target manhole and push downstream by hand / rod as best as possible.
5. Attach the leader rope (length to be determined by Contractor), which anchors the rope to the MH ladder rung, with the provided D-Link shackle.
6. Ensure the first block will be submerged in low flow conditions.
7. Repeat Steps #1 – 6 for each additional target MH until installation at the target SWMF is completed. Repeat for additional SWMFs if necessary.
8. All work is to be completed in accordance with Ontario Health and Safety Regulations, including confined space entry, where applicable.

Steps required to install Treated Jute and Gel Flocculant Blocks (SWMF 7) include the following:

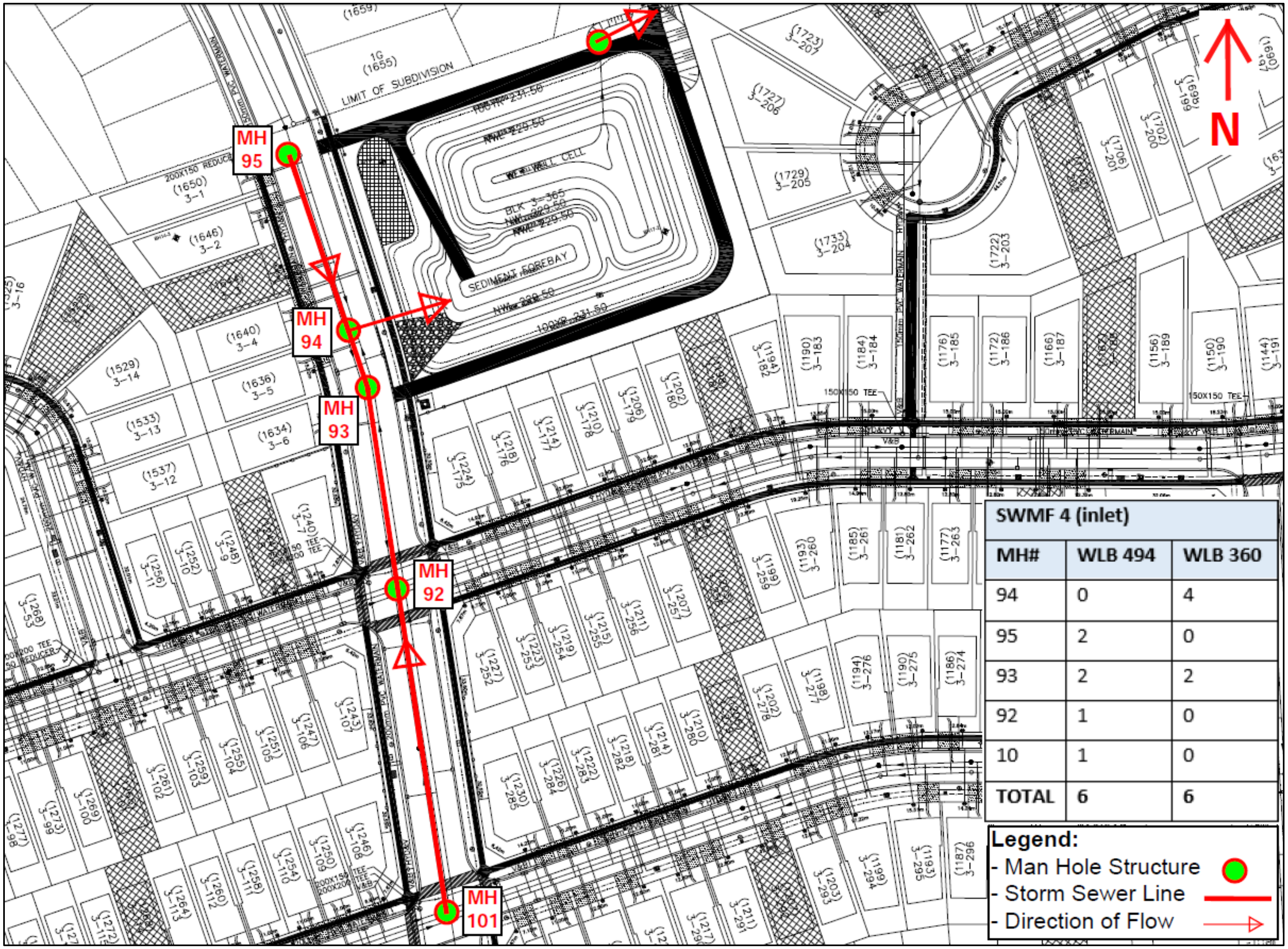
1. Attach Treated Jute to soil with staples along edges approximately every 30 cm, add staple in centre of roll width every 1 m.
2. Install check dams to focus flow over Gel Flocculant Blocks.
3. Place Gel Flocculant Blocks and secure with stakes.
4. Add check dams of washed rock or other permeable structure downstream of Blocks, use excess jute (for North/East channel) or additional rolls of jute (for West channel) to cover the check dams. This will create a curtain-like polishing system.
5. All work is to be completed in accordance with Ontario Health and Safety Regulations, including confined space entry, where applicable.

4.2.1 *SWMF #4: Product Quantity Determinations and Install Locations*

For the inlet point of this facility, a total of five (5) upstream MH structures were identified with a maximum scaled flow rate of 1.44 m^3/minute (m^3/min). Please refer to **Table 2** for an itemized list of the upstream storm sewer network identified for product installation at this facility, and **Figure 7** for a visual representation of all SWMF #4 product installation locations.

Table 4: Sewer Network Details, Flow Rates and Product Quantities (SWMF 4)

SWMF 4 (primary inlet)			
MH#	**Sewer length (m)**	**Design flow (m^3/min)**	**# of WL Blocks**
94	25	1.44	4
95	50	0.12	4
93	20	1.32	4
92	63	1.14	1
10	95	0.30	1
TOTAL	**253**	**-**	**14**



SWMF 4 (inlet)		
MH#	WLB 494	WLB 360
94	0	4
95	2	0
93	2	2
92	1	0
10	1	0
TOTAL	6	6

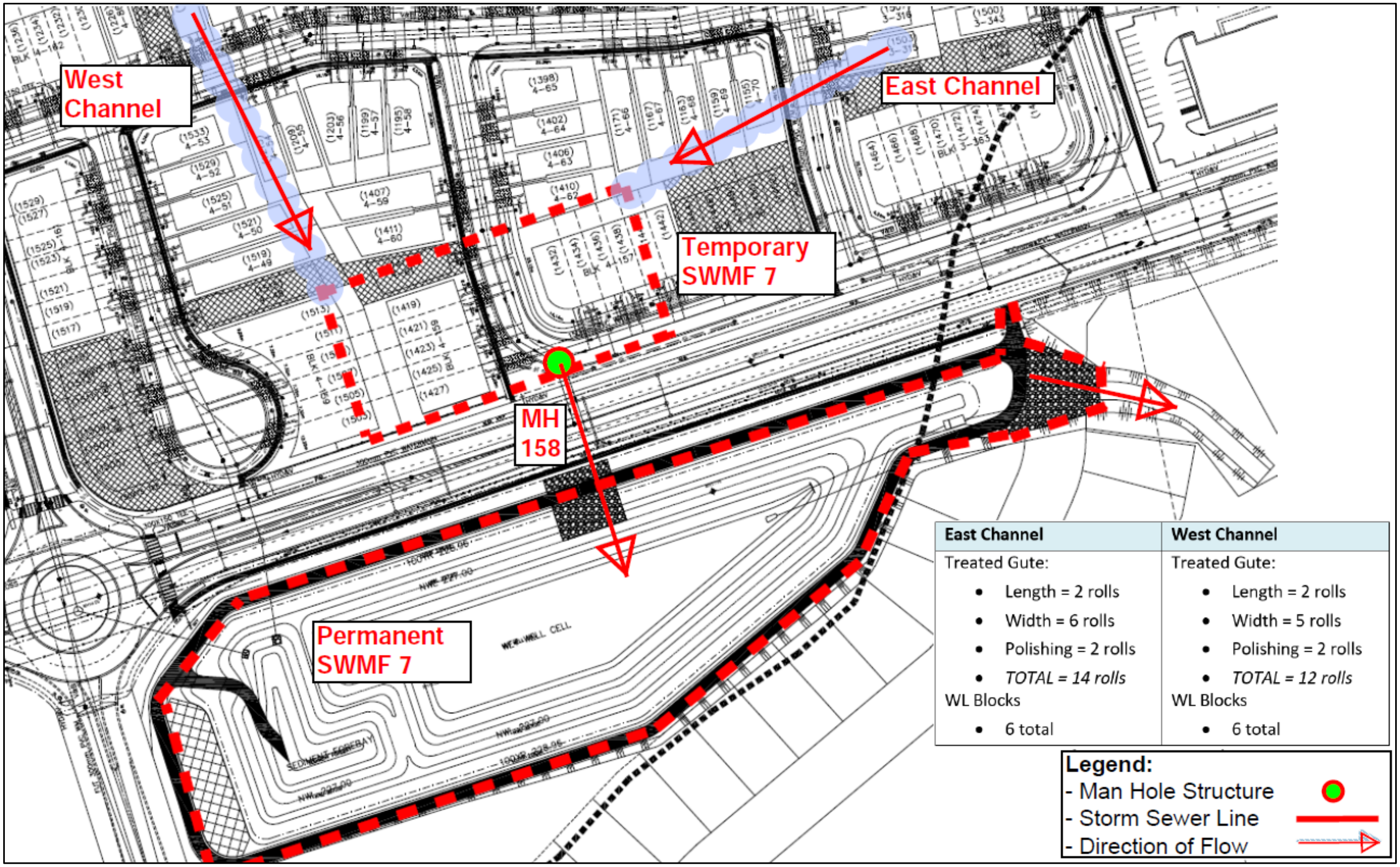
Figure 7: Gel Flocculant Blocks Installation: Product Quantities and Locations (SWMF 4)

4.2.2 *SWMF #7: Product Quantity Determination and Installation*

As SMWF 7 has two (2) overland channels conveying flow from the upstream un-stabilized catchment area, product quantities and installation locations needed to be determined for each. To ensure maximum sedimentation results due to its unique status as a temporary erosion and sediment control facility, a blend of both Gel Flocculant Blocks, rock check dams and treated Jute were specified for installation at each inlet channel. With a maximum scaled flow rate of 0.54 m^3/min identified for the 130m long East inlet channel, 12 rolls of Treated Jute and six (6) Gel Flocculant Blocks were prescribed. With a matching flow rate for the slightly longer 150m long West inlet channel, 14 rolls of Treated Jute and six (6) Gel Flocculant Blocks were prescribed. Finally, six (6) rock check dams were installed between each Gel Flocculant Blocks to facilitate further product interaction with influent stormwater and increase overall contact time. Please refer to **Table 3** for an itemized list of the upstream storm sewer network identified for product installation at this facility, and **Figure 8** for a visual representation of all SWMF #7 product installation locations.

Table 5: Inlet Channel Details, Flow Rates and Product Quantities (SWMF 7)

SWMF 7 (East Channel)				SWMF 7 (West Channel)			
Channel length (m)	Design flow (m^3/min)	Rolls of Treated Jute	# of WL Blocks	Channel length (m)	Design flow (m^3/min)	Rolls of Treated Jute)	# of WL Blocks
130	0.54	12	6	150	0.54	14	6



East Channel	West Channel
Treated Gute: • Length = 2 rolls • Width = 6 rolls • Polishing = 2 rolls • *TOTAL = 14 rolls* WL Blocks • 6 total	Treated Gute: • Length = 2 rolls • Width = 5 rolls • Polishing = 2 rolls • *TOTAL = 12 rolls* WL Blocks • 6 total

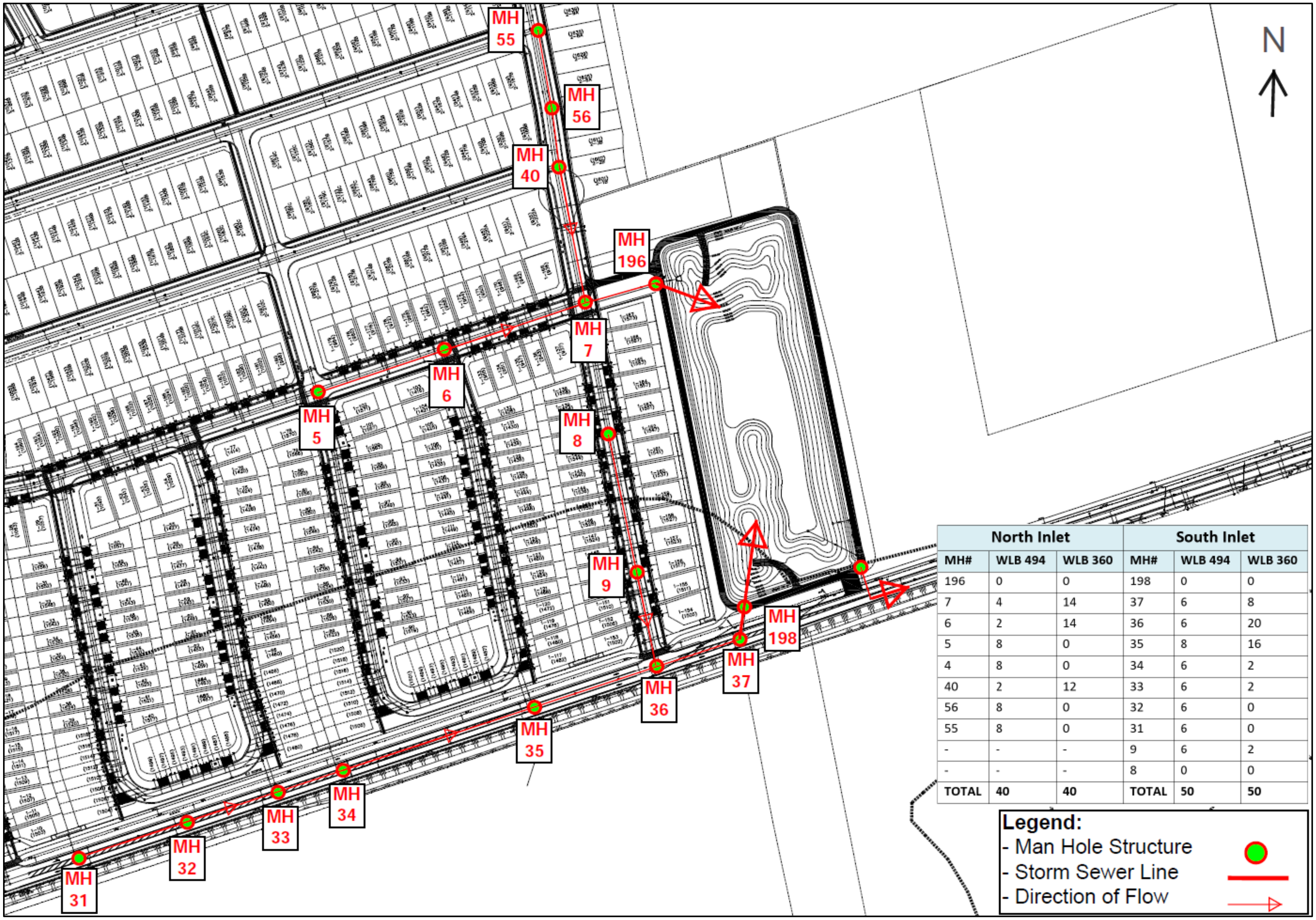
Figure 8: Gel Flocculant Blocks and Treated Jute Installation: Product Quantities and Locations (SWMF 7)

4.2.3 *SWMF #6: Product Quantity Determination and Installation*

As SMWF 6 has two (2) inlet points and corresponding upstream sewer networks, product quantities and installation locations needed to be determined for each inlet. For the North inlet point, a total of eight (8) upstream MH structures were identified with a maximum scaled flow rate of 42.72 m^3/min. A total of nine (9) MH structures, with a maximum scaled flow rate of 39.84 was identified for the South Inlet. Please refer to **Table 4** for an itemized list of the upstream storm sewer network identified for product installation at SWMF #6, and **Figure 9** for a visual representation of all SWMF #6 product installation locations.

Table 6: Sewershed Details, Flow Rates and Product Quantities (SWMF 6)

North inlet					South Inlet				
MH#	**Sewer length (m)**	**Design flow (m^3/min)**	**Scaled Flow (gpm)**	**# of WL Blocks**	**MH#**	**Sewer length (m)**	**Design flow (gpm)**	**Scaled Flow (gpm)**	**# of WL Blocks**
196	20	9.70	3962	0	198	20	9.05	5,040	0
7	45	9.69	3956	18	37	22	9.05	5,040	14
6	98	4.42	1803	16	36	57	7.90	4,403	26
5	88	3.43	1402	8	35	88	7.94	4,425	24
4	93	2.85	1163	8	34	88	5.27	2,938	8
40	91	16.80	1558	14	33	88	5.27	2,938	8
56	40	3.82	924	8	32	62	2.25	1,252	6
55	51	2.26	924	8	31	62	2.25	1,252	6
-	-	-	-	-	9	90	1.34	744	8
-	-	-	-	-	8	65	0.07	38	0
TOTAL	**526**	**-**	**-**	**80**	**TOTAL**	**642**	**-**	**-**	**100**



North Inlet			South Inlet		
MH#	**WLB 494**	**WLB 360**	**MH#**	**WLB 494**	**WLB 360**
196	0	0	198	0	0
7	4	14	37	6	8
6	2	14	36	6	20
5	8	0	35	8	16
4	8	0	34	6	2
40	2	12	33	6	2
56	8	0	32	6	0
55	8	0	31	6	0
-	-	-	9	6	2
-	-	-	8	0	0
TOTAL	**40**	**40**	**TOTAL**	**50**	**50**

Figure 9: Gel Flocculant Blocks Installation: Product Quantities and Locations (SWMF 6)

4.2.4 *Product Replacement Cycles*

As previously noted, the Gel Flocculant Blocks use flow dynamics along with particle size, shape, and density to release flocculant in the storm sewer system. As this process is passive by nature and completely self-dosing and self-limiting, the rate at which installed Gel Flocculant Blocks deteriorate and lose efficacy is primarily dependent on the volume and velocity of water flowing over the sequence of installed blocks. Similarly, the Treated Jute will lose its efficacy over time as it becomes saturated with sediment, dependant on the volume of sediment and velocity of water flowing over the Treated Jute. Product replacement is necessary to ensure continual and optimal performance throughout the duration of the development project. Visual documentation of the fully spent product and its replacement is provided in **Photograph 12** - **Photograph 15.** Per previous in-lab and in-situ testing, Gel Flocculant Blocks typically last approximately three (3) months under gravity flow conditions. To reduce complexity in on-going site inspections and scheduling of the contractor, it was decided to use this average replacement cycle for this project. A general formula based off volume of flow, TSS readings and product conditions could potentially be created to notify contractor of upcoming block replacements for future initiatives. Please refer to the below **Table 5** for the dates associated with product cycle replacements at each facility.

Table 7: Product Cycle Replacement Dates

Pond #	Maintenance Cycle #1	Maintenance Cycle #2	Maintenance Cycle #3
SWMF 4	June 10, 2020	September 25, 2020	March 18, 2021
SWMF 6	June 10, 2020	September 25, 2020	March 18, 2021
SWMF 7	June 11, 2020	October 29 – November 3, 2020[1]	N/A

[1] Treated Jute replacement

Photograph 12: Fully spent Gel Flocculant Blocks

Photograph 13: Fully Spent Gel Flocculant Blocks removed from MH

Photograph 14: Removal and replacement of spent Gel Flocculant Blocks

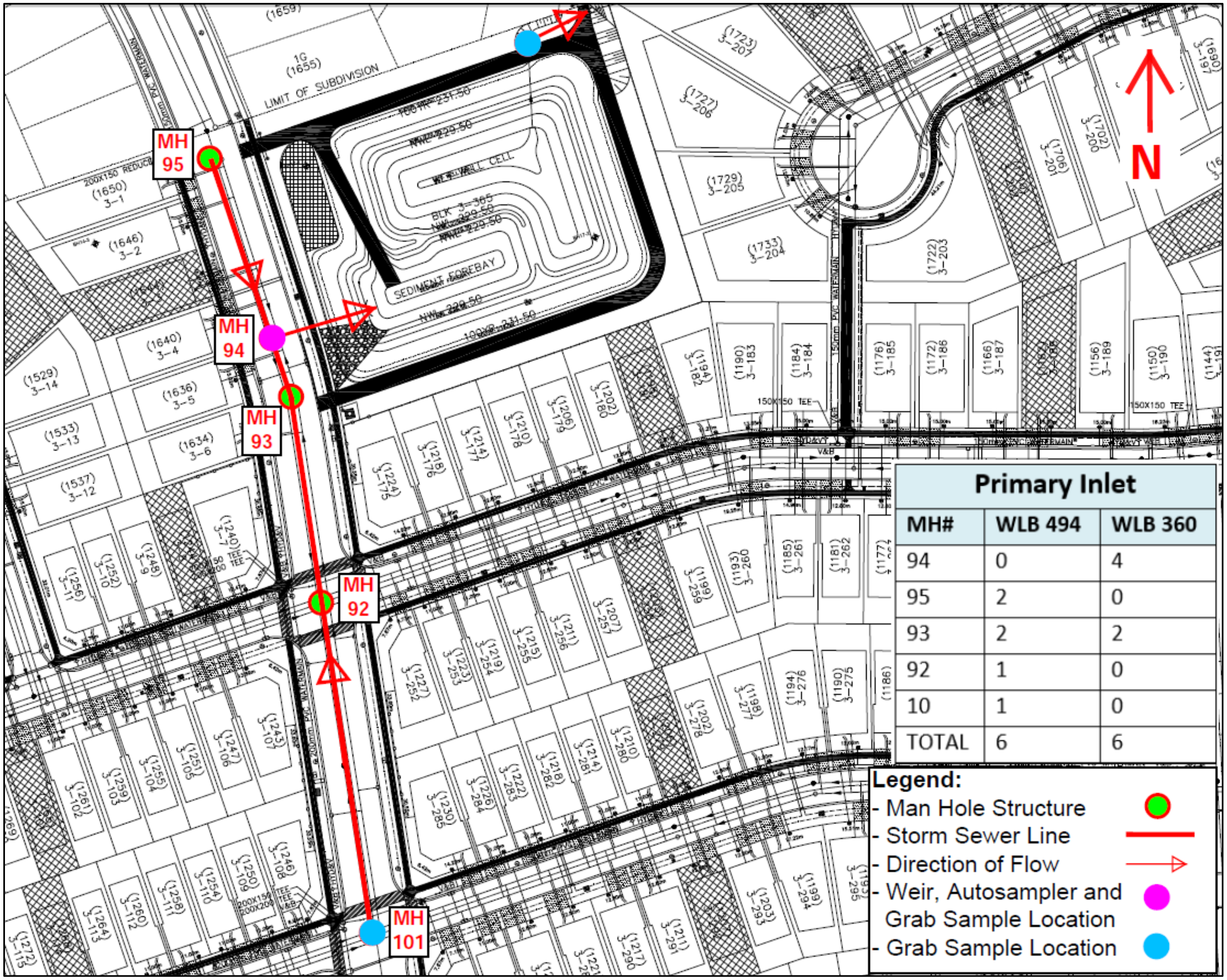
Photograph 15: Treated Jute fully saturated with Sediment

4.3 Task #3: Continuous Flow Monitoring and Weir Stations

Continuous flow monitoring stations were installed at the inlet and outlet points of each SWMF and included pressure transducers (Levelogger® Edge Water Level Dataloggers) affixed via secured stilling wells. More specifically, the locations of each continuous flow monitoring station are outlined below:

- **SWMF 4**: Continuous flow monitoring occurred upstream of the inlet point of this SWMF, with a pressure transducer installed directly upstream of the sampling point at MH94. A secondary pressure transducer was installed at the outlet point (MH2) of this SWMF. Custom weirs were also installed at the aforementioned inlet MH to provide flow control and a pool of water for the pressure transducer to function properly. Please refer to **Figure 10** for a visual overlay of these monitoring locations at SWMF 4.
- **SWMF 6**: Continuous flow monitoring occurred upstream at each of the two (2) inlet points. For the South Inlet, a pressure transducer is installed at MH198. For the North Inlet, a pressure transducer was installed at MH196. A pressure transducer was also installed at the outlet point downstream of the Water Quality Riser structure at MH2. Custom weirs were also installed at each of the aforementioned inlet MHs to provide flow control and a pool of water for the pressure transducer to function properly. Please refer to **Figure 11** for a visual overlay of these monitoring locations at SWMF 6.
- **SWMF 7**: This SWMF was constructed for temporary water quality protection purposes during site construction, and therefore does not include any permanent infrastructure conveying stormwater into or out of the SWMF. Rather, the stormwater conveyed into this SWMF from two (2) overland ditch systems. As such, a pressure transducer was installed in both the inlet channels as well as the southwestern outlet point of this SWMF in the hickenbottom outlet structure (MH158). Custom weirs were also installed at each of the aforementioned inlet channels to provide flow control and conditions necessary for the pressure transducer to properly function and record accurate data. Please refer to **Figure 12** for a visual overlay of these monitoring locations at SWMF 7.

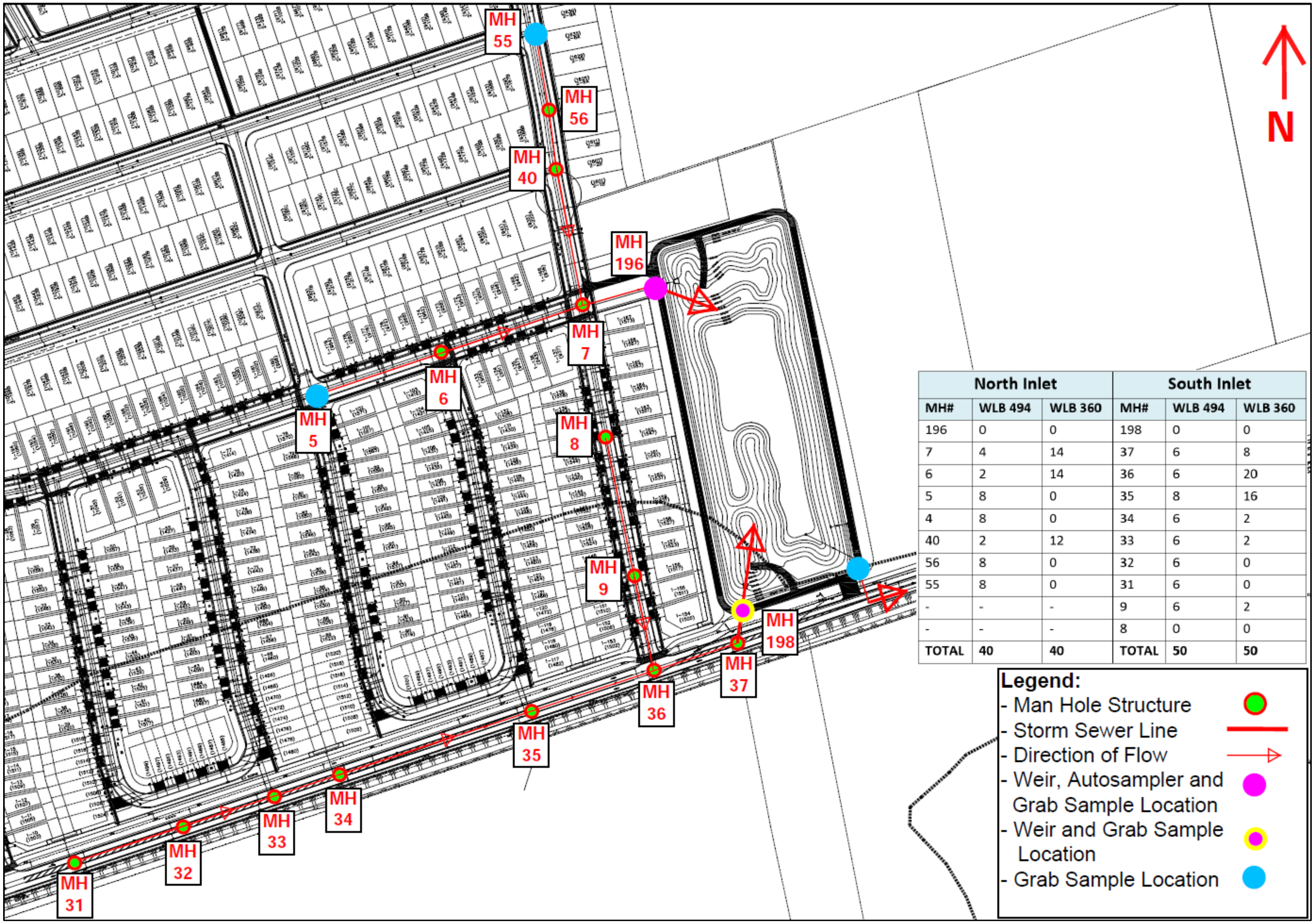
A single barometric pressure transducer datalogger (Levelogger® Edge Barologger) was also installed within the Subject Site to record ambient barometric pressure in order to barometrically correct data recorded by the pressure transducers installed at each of the three (3) SWMFs. Due to the ability of these devices to cover a radius of up to 30 km (20 miles) and/or every 300 m (1000 ft) elevation change, the installation of a single device at the Subject Site was deemed sufficient.



Primary Inlet

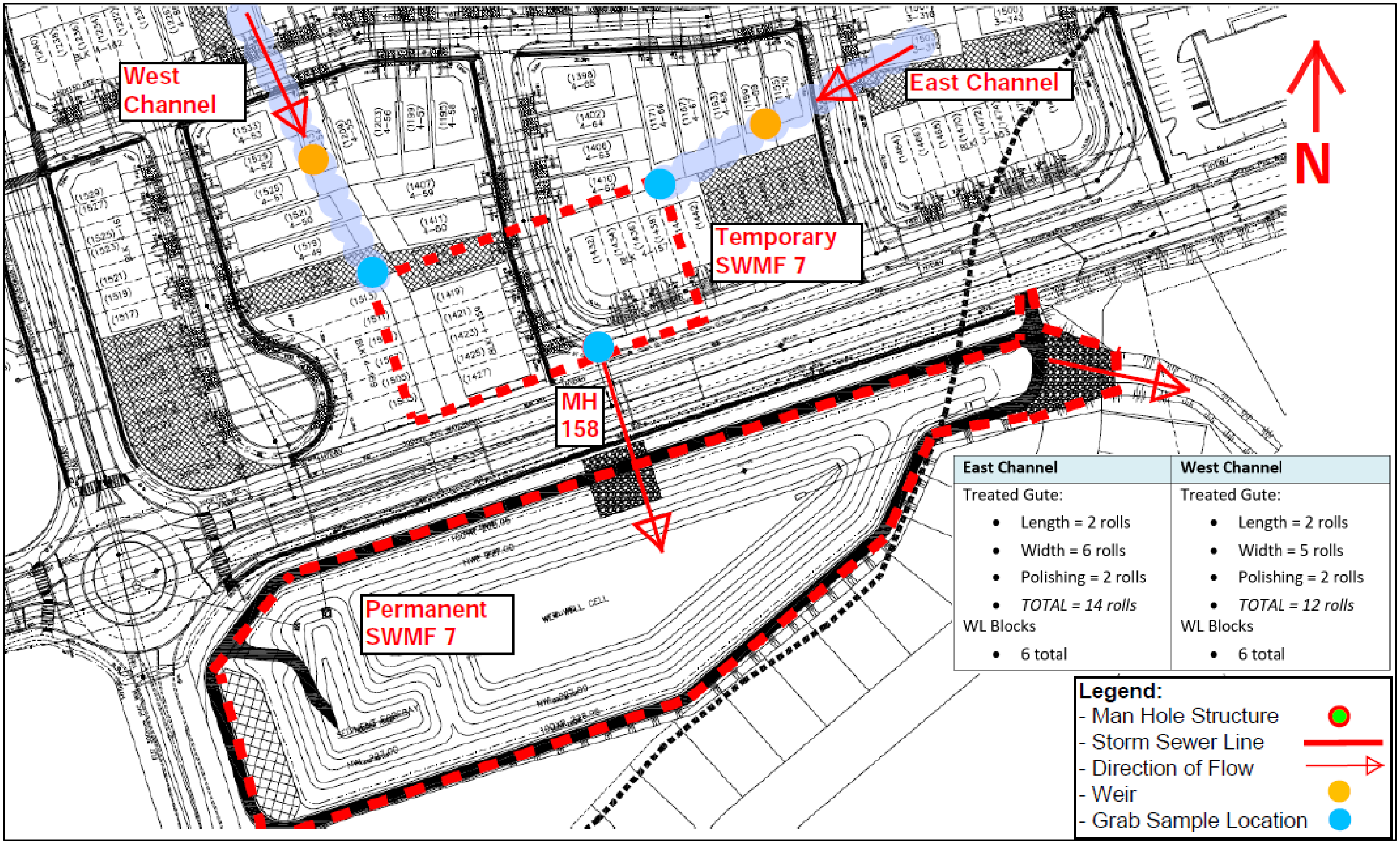
MH#	WLB 494	WLB 360
94	0	4
95	2	0
93	2	2
92	1	0
10	1	0
TOTAL	6	6

Figure 10: SWMF 4 - Water Quality Sampling Locations



North Inlet			South Inlet		
MH#	**WLB 494**	**WLB 360**	**MH#**	**WLB 494**	**WLB 360**
196	0	0	198	0	0
7	4	14	37	6	8
6	2	14	36	6	20
5	8	0	35	8	16
4	8	0	34	6	2
40	2	12	33	6	2
56	8	0	32	6	0
55	8	0	31	6	0
-	-	-	9	6	2
-	-	-	8	0	0
TOTAL	**40**	**40**	**TOTAL**	**50**	**50**

Figure 11: SWMF 6 - Water Quality Sampling Locations



East Channel	West Channel
Treated Gute:	Treated Gute:
- Length = 2 rolls	- Length = 2 rolls
- Width = 6 rolls	- Width = 5 rolls
- Polishing = 2 rolls	- Polishing = 2 rolls
- *TOTAL = 14 rolls*	- *TOTAL = 12 rolls*
WL Blocks	WL Blocks
- 6 total	- 6 total

Figure 12: SWMF 7 - Water Quality Sampling Locations

4.3.1 *Monthly Inspections: Flow Monitoring Stations*

To ensure proper recording of flow monitoring data and functionality of the inlet weirs, regular maintenance check-ups of the pressure transducer dataloggers and inlet weirs were completed on a monthly basis and included the following tasks:

- Field downloads of all recorded data from each installed pressure transducer datalogger at the SWMF inlet and outlet points (8 total) and the singular barologger;
- Physical water level measurements obtained at each monitoring location at the point in which the pressure transducer datalogger had been installed. These measurements were also recorded in relation to the offset point of each weir (inlet points) or manhole structure (outlet points), and were cross-referenced with the field downloaded continuous flow data to ensure proper functioning of equipment throughout the entire monitoring period.
- Visual inspections of each overall flow monitoring station configuration, including stilling wells, pressure transducers and flow monitoring weirs (with required maintenance initiated when necessary); and,
- Contingency plans for the immediate replacement of any data logging equipment should an equipment malfunction be discovered during a routine inspection.

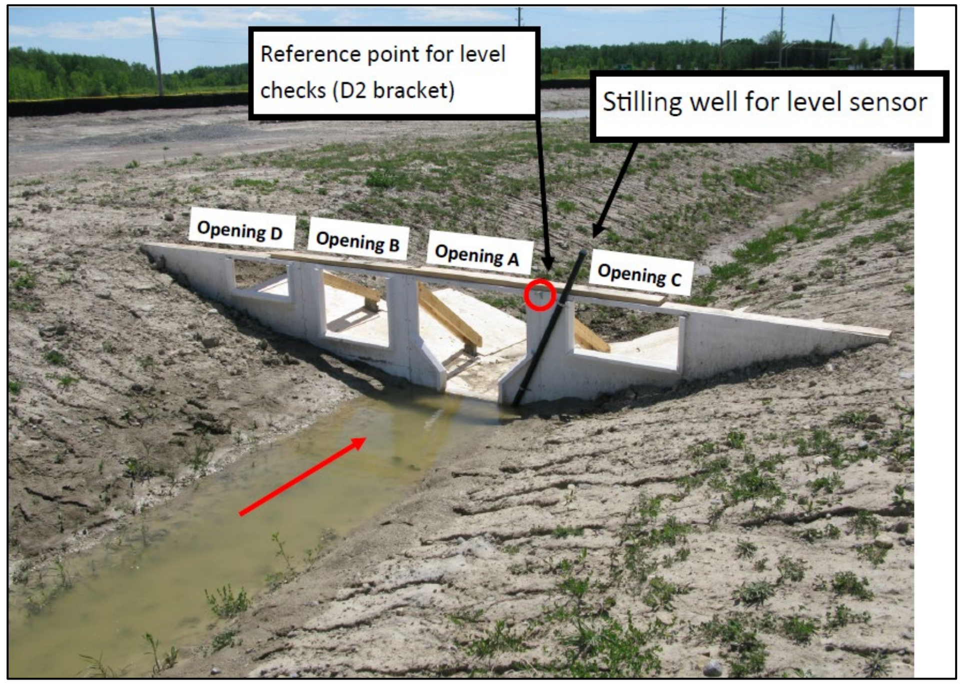
Photograph 16: Technician Removing Pressure Transducer for Monthly Data Download

4.3.2 *Weir Installations*

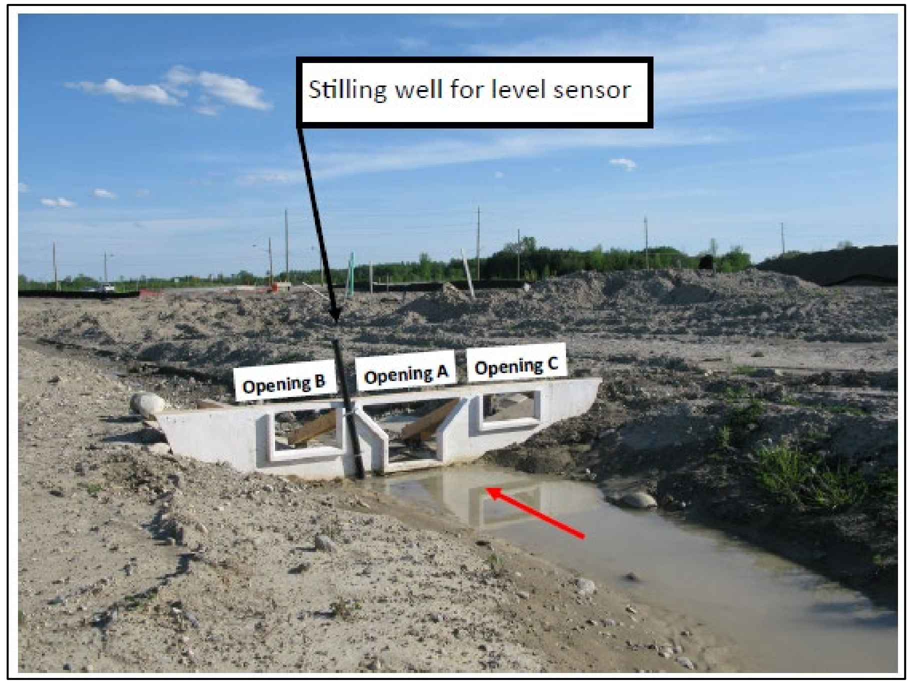
Five weir-based flow monitoring stations were required for installation at the inlet monitoring and pressure transducer installation points of each SWMF. This included the three (3) inlet MH's at SWMF 4 and 6, as the hydraulic flows for each of these MH structures are impacted because of MH benching (smoothed infill concrete placed between the channel pipes and the chamber walls of a manhole). As the shape contours for the overland inlet channels at SWMF 7 also vary throughout, weir installations were also required to accurately quantify incoming flows.

Utilizing the services of Thompson Flow Investigations (TQI), each of these five (5) weirs were commissioned for installation in early June 2020 and in advance of the baseline monitoring period. Stilling wells were also affixed to each constructed weir to house and protect each inlet pressure transducer. Please refer to **Appendix C** for a report outlining the technical installation details of each weir, and **Photograph 17** - **Photograph 21** for details of each installation at the target SWMFs.

Specific locations of each weir-based flow monitoring station, in relation to each SWMF, can also be found in **Figure 10 - Figure 12.**



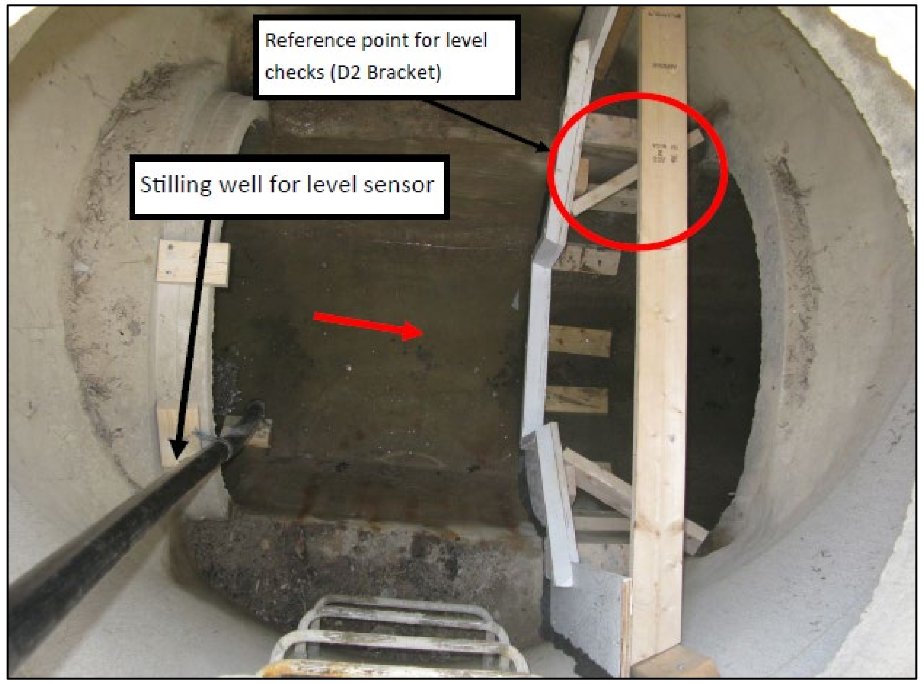
Photograph 17: SWMF #7 (East Inlet Weir)



Photograph 18: SWMF #7 (West Inlet Weir)

Photograph 19: SWMF # 4 (Inlet Weir)

Photograph 20: SWMF #6 (South Inlet Weir)



Photograph 21: SWMF #6 (South Inlet Weir)

4.4 Task #4: Water Quality Monitoring Initiative

Water quality samples were collected at a number of locations at the three (3) existing SWMFs (4, 6 and 7) located within the Subject Site over the course of a one (1) year period. Initial "Baseline Sampling" first occurred in advance of Product installation at each of the target SMWFs to determine native TSS and Phosphorus concentrations. This included the collection of samples from two (2) precipitation events on May 15, 2020 and May 29, 2020. Upon installation of all Gel Flocculant Blocks and Treated Jute products on June 11, 2020, a "Post Product Installation" sampling initiative was then undertaken to determine product performance throughout the Summer, Fall, and Winter seasons with a total of 10 precipitation events captured. The monitoring initiative terminated on March 26, 2021.

Sampling activities for all events were typically completed during (or immediately after) local area storm events (≥5mm precipitation events) that resulted in the flow of stormwater entering and discharging from each SWMF. Each sampling event was completed over a period of two (2) days, with samples collected at the inlets to each SWMF, as well as the outlet from SWMF 7 on the first day of sampling (during the storm event) and samples collected at the outlets from SWMF's 4 and 6 on the second day of sampling, (approximately 18-24 hours after the initial sampling). This delay in sampling at the outlet points corresponds to the size of each facility and the length of time required for water to pass through each, thus allowing for a stronger correlation between the quality of water entering and existing each SWMF. Finally, one (1) duplicate water quality sample was also collected at each SWMF for each completed sampling event.

While the primary target in the study is +80% TSS removal efficiency, a wider spectrum of water quality analysis was also completed to identify secondary target impacts.

The full array of parameters analyzed under this Study include:

- Total Suspended Solids (TSS);
- Total Phosphorus (TPs);
- Chlorides;
- Turbidity (in-field); and,
- TSS Particle Distribution Analysis.

The first three (3) sample parameters outlined above were analyzed by Bureau Veritas Laboratories (BV Labs) for analysis, turbidity was measured in-field, and the final parameter analyzed by the School of Environmental Sciences at the University of Guelph (UofG) for analysis. Finally, while the baseline sampling initiative analyzed TSS, turbidity and the particle distribution analysis for all collected samples, sampling post-product installation included an analysis of all five (5) parameters listed above.

4.4.1 *Water Quality Sampling Locations*

As each SWMF receives flow from a unique network of stormwater conveyance infrastructure, it was important to determine specific grab sample and time weighted composite sampling (TWCS) locations at each facility to accurately capture the full extent of product and facility performance.

These monitoring locations for each SWMF can be found in **Figure 10 - Figure 12**, which also identify the locations of all time weighted composite samples (TWCS), weir installations and associated continuous flow monitoring stations. For additional information on the sampling program, please refer to **Sections 4.4.2** and **4.4.3**.

The sampling locations for the baseline and general sampling procedures at each SWMF are outlined below:

- **Stormwater Management Facility #4**:
    - *Baseline Sampling:* Sampling occurred at the single inlet point (MH94) and single outlet point (MH 2) of facility.
    - *Post Product Installation Sampling:* Sample points included all locations identified in the Baseline Sampling Plan.
    - Note that samples from this SWMF represents a pre-servicing construction condition, not stabilized but with SWMF (storm sewer drainage) infrastructure already installed.

- **Stormwater Management Facility #7**:
    - *Baseline Sampling:* Sampling occurred at each of two temporary open channel inlet points of this facility, while sampling at the outlet point was undertaken from the primary hickenbottom outlet structure (MH158).
    - *Post Product Installation Sampling*: There were no changes to the sampling point locations identified in the Baseline Sampling Plan.
    - Note that sampling at this SWMF represents an un-stabilized site undergoing area-grading.

- **Stormwater Management Facility #6**:
    - *Baseline Sampling*: Sampling occurred at each of the SWMF inlet points (MH196 for South Inlet and MH198 for North inlet), while sampling at the outlet point was undertaken downstream of the Water Quality Riser structure at MH2.
    - *Post Product Installation Sampling*: Sample points included all locations identified in the Baseline Sampling Plan, as well as upstream of the Clearflow Product installation at the North Inlet MH5 and MH55) for comparison purposes.
    - Note that sampling at this SWMF represents a partially stabilized subdivision condition and partially under construction with all SWMF storm sewer drainage infrastructure installed.

Grab Samples and Sample Preparation

Prior to initiating any sampling field activities, each of the laboratory prepared sample collection bottles (unique for each sampling event) were labeled and organized to avoid confusion in the field. Grab samples at each MH structure were obtained via the use of a collection bucket affixed to a rope, with the collection bucket sufficiently rinsed with stormwater prior to sampling at each target location. To account for the aforementioned staggered sampling schedule, collected samples for all parameters (excluding Particle Distribution Analysis) were shipped to the appropriate laboratory no-more than two (2) days after collection and kept sufficiently cool throughout. For the collected samples scheduled for Particle

Distribution Analysis, samples were stored in a fridge for up to four (4) weeks prior to laboratory submission. To ensure sample preservation during this interim period, three drops of hydrochloric acid were added to each bottle (post collection on same day) to eliminate any potential for organic proliferation.

4.4.2 *Composite Sampling Sub-Initiative*

Two (2) Autosampler devices (ISCO 6712 Water Sampler) were utilized for a portion of the water quality sampling initiative and installed at the inlet and outlet points of SWMF 4 (October 21 – November 15, 2020) and North inlet and outlet point of SWMF 6 (November 16 – November 30, 2020). These devices were utilized to obtain time-weighted composite samples (TWCS) and further strengthen the quality of collected data and associated product performance analysis. **Photographs 22** to **Photograph 24** depict the installation of the Autosampler device. A total of two (2) precipitation events were captured at each SWMF via this approach, with each TWCS including a blend of individual grab samples collected over a 24-hour period (1 hour sampling intervals). For a more detailed outline of the TWCS extraction and measurement process, please refer to **Appendix D** of this report.

Photograph 22: Autosampler Bottles (24 total) Utilized for Composite Sampling

Photograph 23:Preparing Autosampler Device for Installation

Photograph 24: Installed Autosampler Device at Target SWMF Inlet Point

5 Field Sampling Results

A total of 10 precipitation events were sampled between the periods of 15 May 2020 and 26 March 2021 with events varying in size from 1.6 mm to 95.4mm over a 24-hour period. Precipitation levels were recorded at 5-minute intervals via a nearby LSRCA Climate Station (Innisfil Reservoir) situated approximately 3.5km to the Northwest of the Study Area. The following subsections provide an overview of all water quality data collected and provide interpretations in the context of Product performance and SWMF removal efficiencies of all parameters analyzed. For additional information on sampling methodologies, approaches and monitoring equipment utilized, please refer to **Section 4.4** and **Appendix E** of this report.

5.1 Data Interpretation and Limitations of Analysis

In order to analyze the collected data (water level, water quality sampling, particle distribution analysis) to determine the benefits of the Clearflow products, a series of calculations was completed. The purpose of these calculations was to compare the reduction in load of TSS (and Phosphorus and Chlorides) over each sampled precipitation event between SWMF influent and effluent water samples (and where the influent stormwater is treated with Clearflow products). The performance calculations completed for each event are outlined below:

SWMF Calculations (TSS, Phosphorus, Chlorides Reduction)

1. Downloaded level logger data is adjusted to account for weir offsets (inlet) and storm sewer offsets (outlet);
2. Flow rate (m^3/s) is calculated from the adjusted level data for the sampling location. For the inlets this was done by the weir rating curve developed by TQI. For the outlets, rating curves were developed from the partially full pipe flow equation:

   $$\mathbf{Q = (1.00/n)A(R_h^{2/3})S^{1/2}}$$

   Where:
   Q is the Flow Rate (m^3/s)
   n is the Manning's roughness coefficient
   A is the cross-sectional area of flow (m^2)
   R_h is the hydraulic radius
   S is the pipe slope
3. The start and finish time of each event is determined through the flow hydrograph: each event starts when flow rate begins to increase and ends when flow rate is at a stable minimum or at 0 (no longer decreasing);
4. Flow volume is calculated for each 5-minute timestep of the event at the inlet and outlet locations;
5. Each water quality parameter (concentrations) from the BV Labs results is multiplied by the flow volume for each timestep of the event and added together to result in a total TSS load for the event; and,
6. Load reduction efficiency is calculated by the equation:
   Reduction Efficiency = 1 – [(Outlet Load)/ (Total Inlet Load)] *100

SWMF Calculations (Particle Distribution)

A similar process was undertaken to determine the removal efficiency of each TSS particle size. The results from the University of Guelph laboratory were provided as a weight of sediment of each sample and a percentage of each particle size (<2µm, 2 – 20µm, 20 – 40µm, >40µm). This information was then used to calculate the total load of each particle size entering and leaving the SWMF, per the steps below:

1. Convert mass of sediment in sample to concentration (samples were either 500ml or 1000ml);
2. Using calculated flow volume for each timestep from Step 4. (SWMF Calculations (TSS, Phosphorus, Chlorides Reduction)), multiply the sediment concentration by the flow volume and percent of particles <2µm;
3. Repeat for each particle size;
4. Sum the sediment loads for each timestep to determine the total sediment load for the event for each particle size.
5. Sediment load reduction efficiency for each particle size and total reduction is calculated by the equation:
   Reduction Efficiency = 1 – [(Outlet Load)/ (Total Inlet Load)] *100

SWMF Calculations (Theoretical Removal Efficiency)

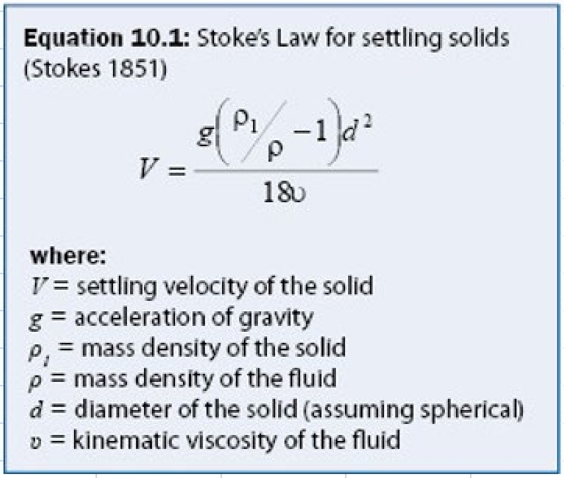
The theoretical removal efficiency, as presented in the results tables in the following sections**,** demonstrates the expected TSS removal efficiency of the SWMF if it performed as per the MECP SWMP Guidelines outlined in **Section 1.1.1**. These guidelines assume that any particle size less than 20µm will not be captured by the SWMF. This was calculated using the results of the particle distribution analysis, using the following process:

1. Using the results from the Particle Distribution Calculations above (Step 4), sediment loads for particle sizes < 2µm and 2-20µm are added together, as are loads for particles 20-40µm and >40µm for both the inlet(s) and outlet;
2. The outlet load of particles <20µm is adjusted to equal the total inlet load of particles <20µm (no removal of particles <20µm);
3. The outlet load of particles >20µm is left the same as calculated for the Particle Distribution (Step 4); and,
4. Theoretical sediment load reduction efficiency for each particle size and total reduction efficiency is calculated by the equation:
   Reduction Efficiency = 1 – [(Outlet Load)/ (Total Inlet Load)] *100

SWMF Calculations (As-Designed Efficiency)

In order to clearly demonstrate the benefit of the addition of Clearflow products to remove TSS, a calculation was completed to determine what the design efficiency of the SWMF would have been for each event and influent TSS, without the Clearflow products. This was done using the particle distribution of sediment entering the pond and applying Stoke's Law for settling solids. Steps include:

1. Using the flow rates at the inlet(s) and outlet of the SWMF, determine the volume of water in the SWMF for each timestep;
2. Calculate the minimum settling velocity for the SWMF:
   V= Qout/A
   Where:
   V is the settling velocity
   Qout is the flow rate of water leaving the SWMF, and
   A is the surface area of the SWMF, as determined by the volume of water in the SWMF and the Stage-Storage-Discharge Rating Curve;
3. Using the minimum settling velocity, rearrange Stokes Law to calculate the minimum particle size that can be settled in the SWMF;



Equation 10.1: Stoke's Law for settling solids (Stokes 1851)

$$V = \frac{g\left(\rho_1/\rho - 1\right)d^2}{18\upsilon}$$

where:
V = settling velocity of the solid
g = acceleration of gravity
ρ_l = mass density of the solid
ρ = mass density of the fluid
d = diameter of the solid (assuming spherical)
υ = kinematic viscosity of the fluid

4. From the Particle Distribution of sediment entering the SWMF (% distribution), calculate the percent of sediment that exceeds the minimum particle size that will be settled in the SWMF;
5. Multiply the percent of sediment settled by the outlet flow volume (calculated during TSS Reduction process) to get a removal efficiency for each time step; and,
6. Sum the removal efficiencies for each timestep to calculate the total removal efficiency of the SWMF for the precipitation event.

Data Interpretations for TSS and Particle Distribution:

When reviewing and interpreting the results figures provided herein, it was important to consider the following:

- For each sampled precipitation event at each target SWMF in the Study Area, an individual column chart has been developed to visually outline the full particle distribution and TSS load (kg) entering and exiting each SWMF;
- Particle size fractions of TSS have been segregated in accordance with the 1994 MECP SWMP Guidelines, with further analysis completed for TSS falling under the 2 µm size fraction;
- For the calculated TSS load at each sampling location (under each sampled event), the following calculations and inputs were utilized:
  - Flow calculations were completed from water level measurements obtained at 5-minute timesteps for the duration of the event flow period; and,

  - Particle distribution analysis results from the University of Guelph provide insight into both the percentage of each particle distribution as well as the corresponding mass values in the sample.
- A comparison of the removal efficiencies for particle distribution analysis is made with respect to TSS concentration results (and corresponding TSS load).

Additionally, **Figure 13** below provides a visual overview of the bar charts presented in **Sections 5.2.1, 5.3.1 and 5.4.1** which compare the particle distribution analysis and TSS load results. Labels have been added where necessary to assist the reader in interpreting these bar charts correctly.

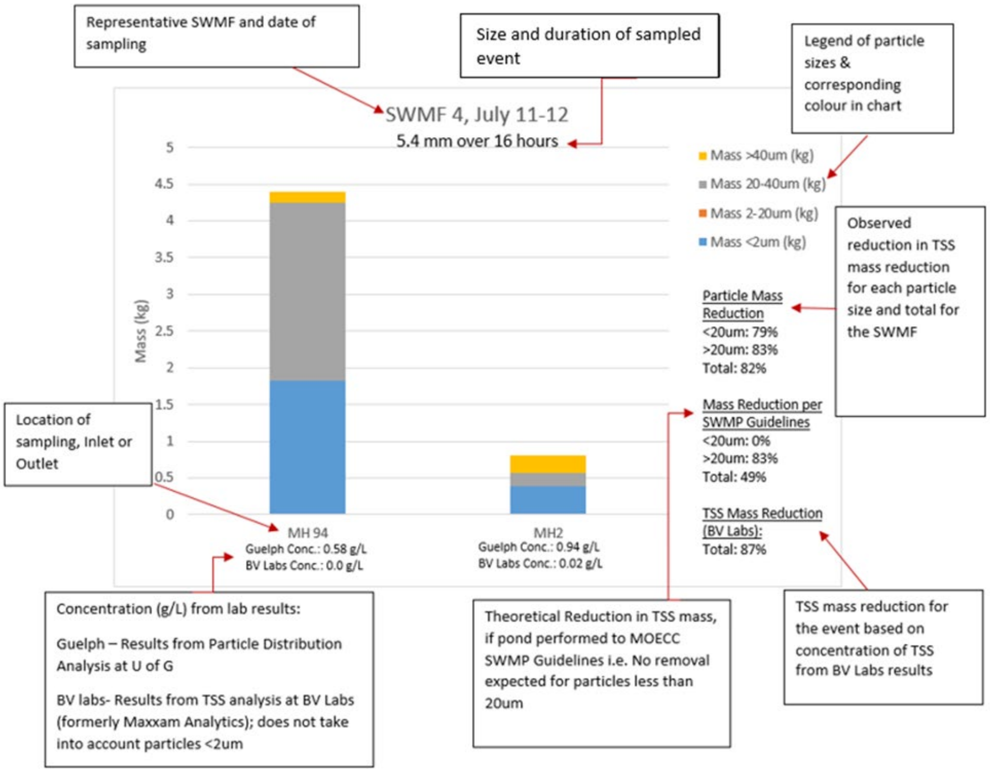


Figure 13: Overview of Water Quality Sampling Graphs (TSS and Particle Distribution Analysis)

Limitations of Data Analysis: Please note that for the analysis of Total Suspended Solids (TSS), samples were analyzed by an accredited laboratory in accordance with CAM SOP-00428. As the filtration sieves utilized to extract particulates from the collected TSS samples were noted to have a minimum pore size of 2 µm however, the resulting TSS analysis excludes all particulates falling under this size fraction. The analysis methodology utilized for the particle size distribution analysis did not have this limitation, rather particulates down to a minimum size fraction of <2 µm were able to be quantified. As previously noted, particulates <2µm in size are extremely difficult for SWMFs to capture and can make up a significant portion of the influent sediment by mass. Therefore, the actual removal efficiencies captured by the particle distribution analysis results can be much lower than corresponding removal values presented by TSS. This distinction should therefore be noted when reviewing **Sections 5.2.1, 5.4.1 and 5.3.1** and when comparing SWMF removal efficiencies between TSS and particle distribution TSS values.

5.2 SWMF 4: Water Quality Sampling

5.2.1 *Particle Distribution Analysis, TSS and Turbidity*

As outlined below in **Table 6**, a total of nine (9) events were sampled at SWMF 4 in 2020, one (1) event was sampled in 2021, with the Clearflow product installed for seven (7) of the events. Time weighted composite sampling was also completed for two (2) events in the fall of 2020 at this facility.

Please refer to **Section 5.1** for justification regarding the distinction between TSS and Particle Size Distribution removal efficiencies.

Table 8: SWMF 4 TSS Reduction

Date	Event Precipitation Depth (mm)	Removal Efficiency – Particle Distribution (Guelph)			Removal Efficiency – Theoretical, MECP Guidelines			As-Designed Efficiency	Removal Efficiency - BV Labs
		<20µm	>20µm	Total	<20µm	>20µm	Total		
15-May[1,2]	16	-	-	-	-	-	-		89%
29-May[2]	17	50%	56%	52%	0%	56%	14%		96%
11-Jul	5.4	79%	83%	82%	0%	83%	49%	81.8%	87%
2-Aug	95.4	74%	68%	74%	0%	68%	9%	36.2%	93%
17-Aug[3]	5.5	-	-	-	-	-	-	-	-
21-Oct[4,5]	1.6	33%	63%	52%	0%	63%	40%	95%	95%
15-Nov[5]	9	100%	100%	100%	0%	100%	51%	97.7%	100%
25-Nov[6]	10.2	-	-	-	-	-	-	-	-
30-Nov[6]	11.2	-	-	-	-	-	-	-	-
26-Mar (2021)	28.4	89%	28%	82%	0%	28%	3%	43.1%	99%

Notes: *1- Baseline event was not sampled for Particle Distribution Analysis*
2 - Baseline sampling, pre Clearflow installation
3 - Event generated no flow at the inlet of the SWMF facility, no sampling completed
4- SWMF was seeded day prior to event, with loose topsoil in the SWM Block
5 – Composite Sampling was completed for this event
6- Due to pumping of the SWMF during event, sampling results are inconsistent, therefore not included in the analysis

From the results presented in **Table 6,** it can be observed that calculated removal efficiency (particle distribution) varied greatly for events, despite similar sizes of precipitation events. As SWMF 4 was in an active construction zone for much of the year, part of the variation of TSS reduction efficiency can be attributed to construction activities impacting results. For example, immediately prior to the event on 21 October 2020, a large portion of the SWM Block was seeded with hydroseed, while fresh topsoil was placed on the remaining section (north of the permanent pool). While the following event was quite small, it is likely that loose sediment from the surrounding SWM Block was washed directly into the SWMF and through the outlet without time to settle, resulting in lower-than-expected TSS removal efficiency. Similarly, the SWMF was pumped down during the November 25th and 30th 2020 events, invalidating outlet sample results, as the pumping eliminated the possibility of sediment settling in the SWMF, and resulted in higher-than-normal water levels at the outlet.

Despite the variation in removal efficiencies, the SWMF performed better with the Clearflow products, than it would be expected to without the products installed (TSS reduction was greater than the As-Designed and MECP Theoretical Efficiency), with the exception of the 21 October 2020 event (1.6mm event following SWMF topsoil / seeding). A small improvement for the 11 July 2020 event was observed, which was anticipated due to the small nature of the event. The SWMF is capable of settling smaller particles during smaller events, therefore potential improvement with the addition of the Clearflow product is reduced. During the 02 August 2020 event, a significant improvement was noted in the actual TSS removal, in comparison to the As-Designed efficiency. The actual removal efficiency was calculated to be 74% total, while only 36.2% of TSS would have been removed had the SWMF performed per its design. It should be noted, that the outflow was higher than expected compared to the inflow during the 02 August 2020 event. Due to the size of the event (nearly a 25-year storm), there is the possibility that a backwater effect resulted in higher-than-expected outflow values. Adjusting for this resulted in an As-Designed efficiency of 48.5%, still significantly lower than the actual TSS reduction.

SWMF 4 is designed to have an extended detention time of greater than 48 hours, which results in higher removal efficiencies than those expected if the SWMF performed to the MECP guidelines (24 hours) described in **Section 1.1.1**. The theoretical removal efficiencies are significantly lower than the actual removal efficiency of the SWMF, with the maximum TSS reduction being 51%, and the lowest only removing 3% of the total TSS. This demonstrates that the amount of TSS removed can be significantly lower than expected removal efficiency at SWMF's designed to the MECP standard for Enhanced Protection (80% removal of TSS). This is largely due to the fact that particles <20µm comprise a large percentage of the TSS entering the SWMF (see **Figure 14** and **Figure 15** below), in the case of the Sleeping Lion Subdivision. If these particles are not being settled by the SWMF, then they will continue to flow straight into the receiving watercourse, which in the context of this project, means significant potential sediment loads flowing into Lake Simcoe (despite various SWMFs performing per the Enhanced Protection MECP guidelines).

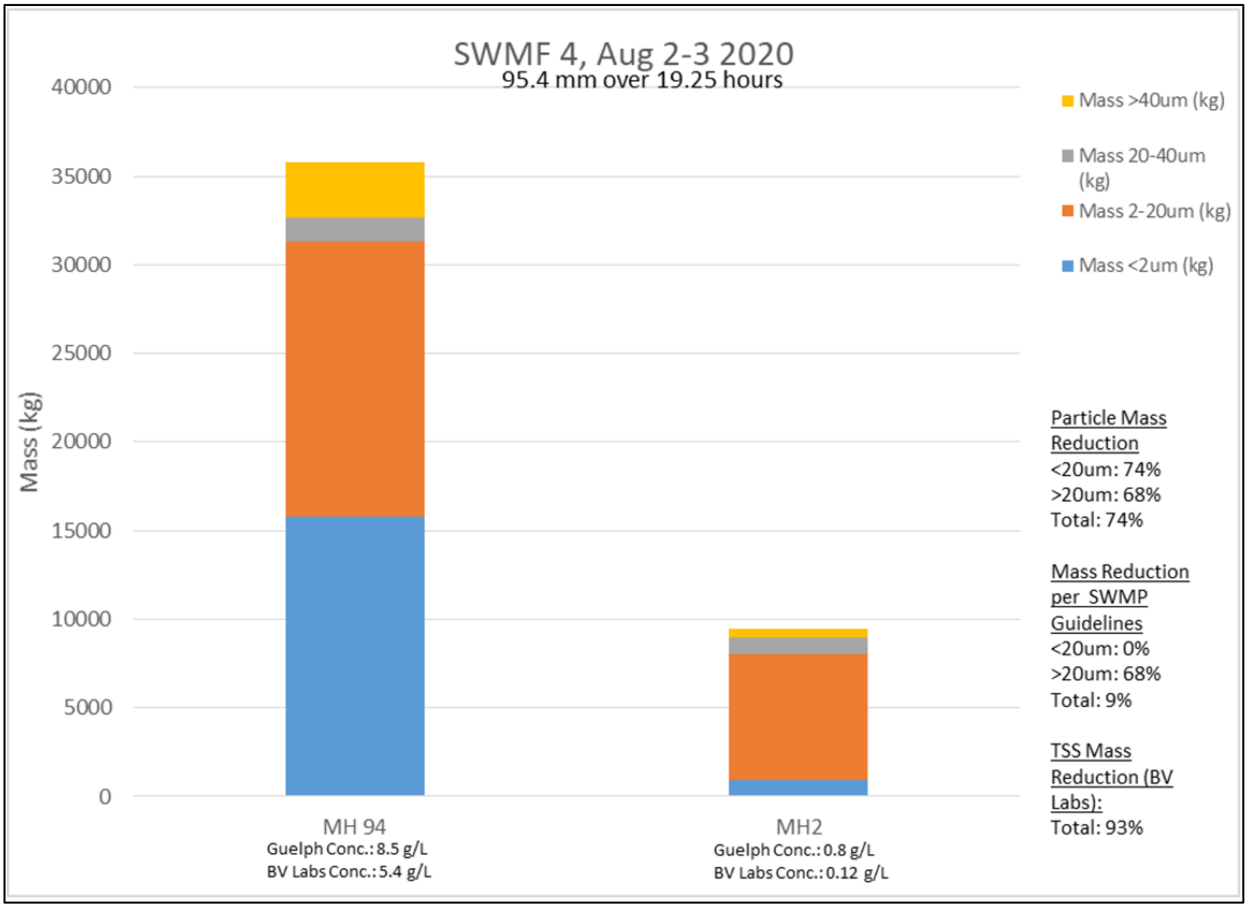


Figure 14: SWMF 4 (August 2-3, 2020) – Particle Distribution Analysis

This graph demonstrates the removal efficiency of the sediment load at SWMF 4 during a significant rainfall event: 95.4mm. The vast majority of sediment entering the SWMF is <20µm in diameter. The sediment load flowing out of the SWMF is still mostly <20µm, however the mass of each sediment size flowing out of the SWMF has been greatly reduced. In particular, sediment <2µm is greatly reduced, likely due to flocculation of sediment in the SWMF, due to the Gel Flocculant Blocks product. Actual reduction of sediment load (74%) is significantly higher than the theoretical TSS reduction if no particles <20µm were settled (9%). During large rainfall events, very high loads of sediment are flowing into the SWMF. More than 35,000 kg of sediment was calculated to flow into the SWMF during the 02 August 2020 event.

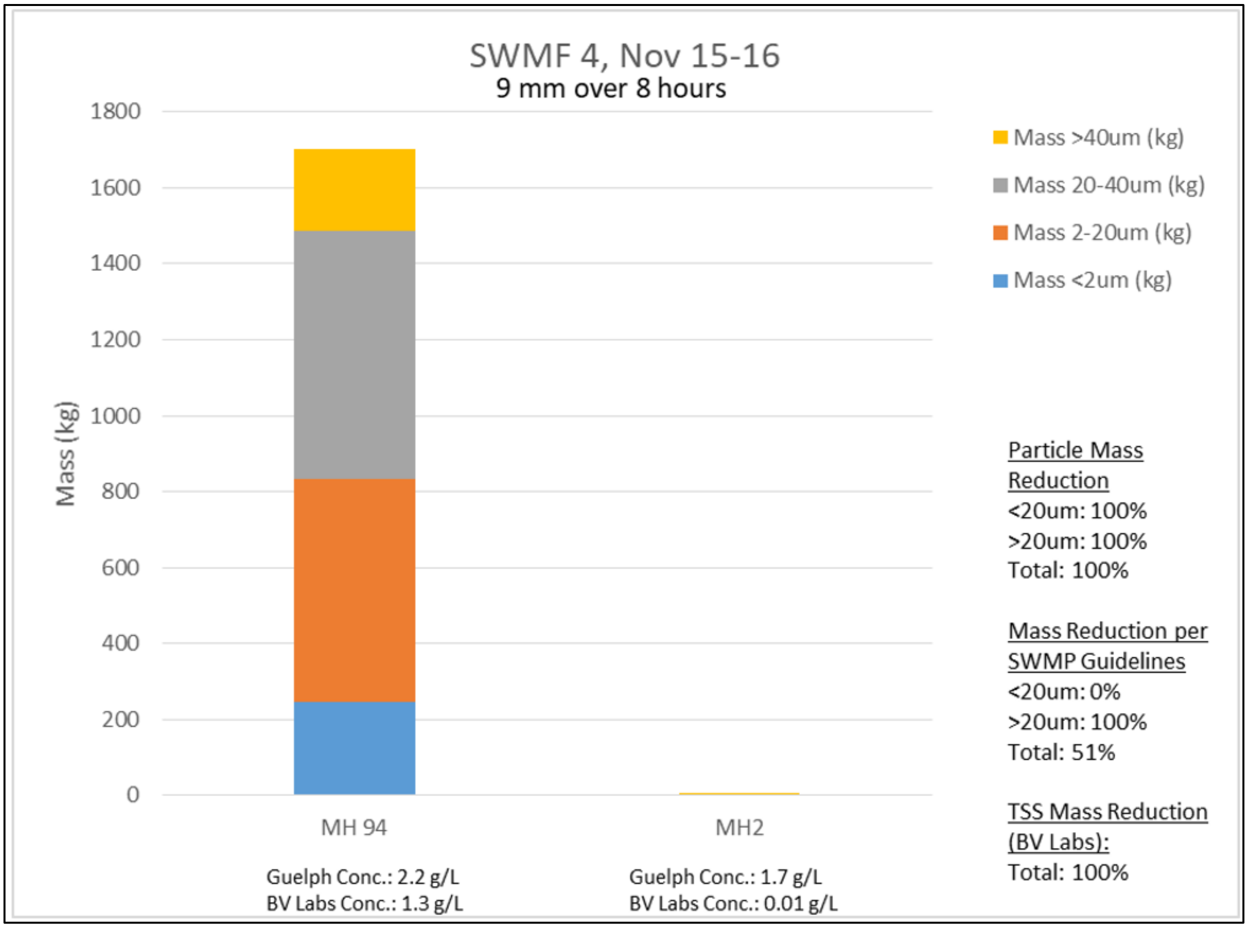


Figure 15: SWMF 4 (November 15-16, 2020) – Particle Distribution Analysis

During the 15 November 2020 event, the particle distribution of sediment entering the SWMF is more evenly distributed, as presented in **Figure 15**. Approximately half of all sediment is <20µm. A much smaller load is also entering the SWMF (~1700kg) as compared to a larger event like 02 August 2020 event (lower concentration of TSS and lower flow rate). The smaller event results in a very high reduction of sediment, nearly 100% of sediment is settled in the SWMF. TSS reduction efficiency would be only be half (51%) the Clearflow treated storm flows if the SWMF performed only to the MECP SWMP Guidelines, settling TSS with a particle size >20µm.

5.2.2 *Phosphorus and Chloride Reduction*

A summary of the removal efficiencies recorded for both phosphorus and chlorides, from all precipitation events monitored, can be found below in **Table 7.**

Table 9: SWMF 4 Phosphorus and Chloride Reduction

Date	Event Precipitation Depth (mm)	Removal Efficiency (%)	
		Phosphorus	Chlorides
15-May[1]	16	-	-
29-May[1]	17	-	-
11-Jul	5.4	N/A[2]	94%
2-Aug	95.4	82%	-34%
17-Aug[3]	5.5	-	-
21-Oct[4,5]	1.6	30%	32%
15-Nov[5]	9	100%	100%
25-Nov[6]	10.2	-	-
30-Nov[6]	11.2	-	-
26-Mar (2021)	28.4	99%	1%

Notes: *1- Baseline event was not sampled, pre Clearflow installation*
2 – Phosphorus concentration was below detection limit
3 - Event generated no flow at the inlet of the SWMF facility, no sampling completed
4- SWMF was seeded day prior to event, with loose topsoil in the SWM Block
5 – Composite Sampling was completed for this event
6- Due to pumping of the SWMF during event, sampling results are inconsistent, therefore not included in the analysis

As shown in **Table 7**, phosphorus reduction generally follows the trend of TSS reduction. While not exact, phosphorus removal increases with greater TSS reduction (15 November 2020 event) and is lower during events with lower TSS removal (21 October 2020 event). This is not unexpected, as a significant portion of phosphorus is likely absorbed to the influent sediment, so as the sediment flocculates and settles in the SWMF, the phosphorus is also settled and removed from the outflow. As the Clearflow Gel Flocculant Blocks resulted in greater removal efficiency of TSS, as described in **Section 5.2.1**, it can also be attributed to an increase in phosphorus reduction, based on the observed trends in the results. In addition to low TSS removal on 21 October 2020, the low phosphorus removal efficiency can also be attributed to the fertilizer used in the hydroseed mix, used to seed the SWM Block. Any wash-off of the hydroseed during the precipitation event would have increased phosphorus concentration in the SWMF, and downstream in the outlet.

From the current results, a similar conclusion cannot be reached for the chloride removal. While there was an increase of chloride removal efficiency with TSS removal (15 November 2020), the 02 August 2020 event resulted in an increase of chlorides in the outflow of the SWMF. Due to the large fluctuation of chloride removal efficiencies versus TSS removal for the different sampled events, a correlation between TSS removal (and therefore the benefits of ASTs), and chloride removal cannot be confirmed based on the results of the sampling initiative for this SWMF.

5.3 SWMF 7: Water Quality Sampling

5.3.1 *Particle Distribution Analysis, TSS and Turbidity*

As outlined below in **Table 8**, a total of seven (7) events were sampled at SWMF in 2020, one (1) event was sampled in 2021, and the Clearflow product was installed for seven (7) of the events. Due to the nature of the temporary SWMF (open ditch inlets), no composite sampling was completed at this location.

Table 10: SWMF 7 TSS Reduction

Date	Event Precipitation Depth (mm)	Removal Efficiency - Guelph			Removal Efficiency – Theoretical, MECP Guidelines			As-Designed Efficiency	Removal Efficiency - BV Labs
		<20µm	>20µm	Total	<20µm	>20µm	Total		
15-May[1,2]	16	-	-	-	-	-	-		100%
29-May[1]	17	98%	92%	94%	0%	92%	55%		98%
11-Jul	5.4	98%	99%	98%	0%	99%	14%		100%
2-Aug	95.4	95%	95%	95%	0%	95%	7%	79.7%	94%
17-Aug[3]	5.5	-	-	-	-	-	-	-	-
21-Oct	1.6	99%	98%	98%	0%	98%	50%	97.4%	100%
15-Nov	9	92%	99%	97%	0%	99%	65%	96.1%	100%
25-Nov	10.2	94%	82%	93%	0%	82%	8%	93.4%	97%
30-Nov	11.2	79%	98%	87%	0%	98%	42%	91.6%	99%
26-Mar (2021)	28.4	-153%	30%	-101%	0%	30%	9%	74.0%	-81%

Notes: *1- Baseline Sampling, pre Clearflow installation*
2- Baseline event was not sampled for Particle Distribution Analysis
3- Event generated no flow at the inlet of the SWMF facility, not sampled

From the results presented in **Table 8**, it can be observed that SWMF 7 consistently had high removal rates of TSS, with the lowest removal efficiency being 87% of sediment load on 30 November 2020 (with the exception of the 26 March 2021 event). In particular, removal of sediment particles <20µm in diameter remained very high (>90% for most events), despite the varying magnitude of events. This is demonstrated for the 02 August 2020 event, when removal of particles both <20µm and >20µm was 99%. The high removal efficiency of particles <20µm was critical for the 02 August 2020 event as these small particles comprised most of the sediment entering the SWMF. This can be seen in the Theoretical removal efficiency, where if the SWMF had performed per MECP guidelines, only 7% of total TSS would have been settled in the SWMF, even with 95% of particles >20µm being captured. Although most notable for 02 August 2020, consistently low removal efficiencies of TSS would be expected if the SWMF performed per the MECP guidelines, with the highest expected removal efficiency of 65%; still significantly lower than the 80% minimum removal expected according to its design.

The improvement of observed SWMF performance for large events, compared to the As-Designed efficiency is also shown in the results. For the 02 August 2020 event, removal of 79.7% of sediment would have been expected if the Clearflow geo-jute had not been installed. However, a 95% removal was observed, based on the particle distribution results. The increased SWMF performance observed, compared to its As-Designed efficiency, provides clear evidence that the installation of Clearflow products resulted in increased TSS removal efficiency. The high As-Designed removal efficiency of the SWMF during the 02 August 2020 event is due to a delayed flow response at the outlet. This delayed response resulted in lower outflow rates over a longer duration, allowing for increased settling of small particles in the SWMF. During small events a negligible difference between the observed and As-designed efficiencies is noted, due to the very high design removal efficiency (>90%) of the SWMF.

The negative removal efficiency calculated for the 26 March 2021 event is likely due to extraneous flows entering the SWMF from overland sheet flow and additional inlet ditches that have eroded paths to the SWMF. Flow volume calculated to be leaving the SWMF was greater than the total flow entering from the two (2) inflow ditches. This resulted in higher sediment loads exiting the SWMF, although TSS concentrations were lower at this location than at the inlets. Results from this event cannot be relied upon for analysis of the SWMF performance.

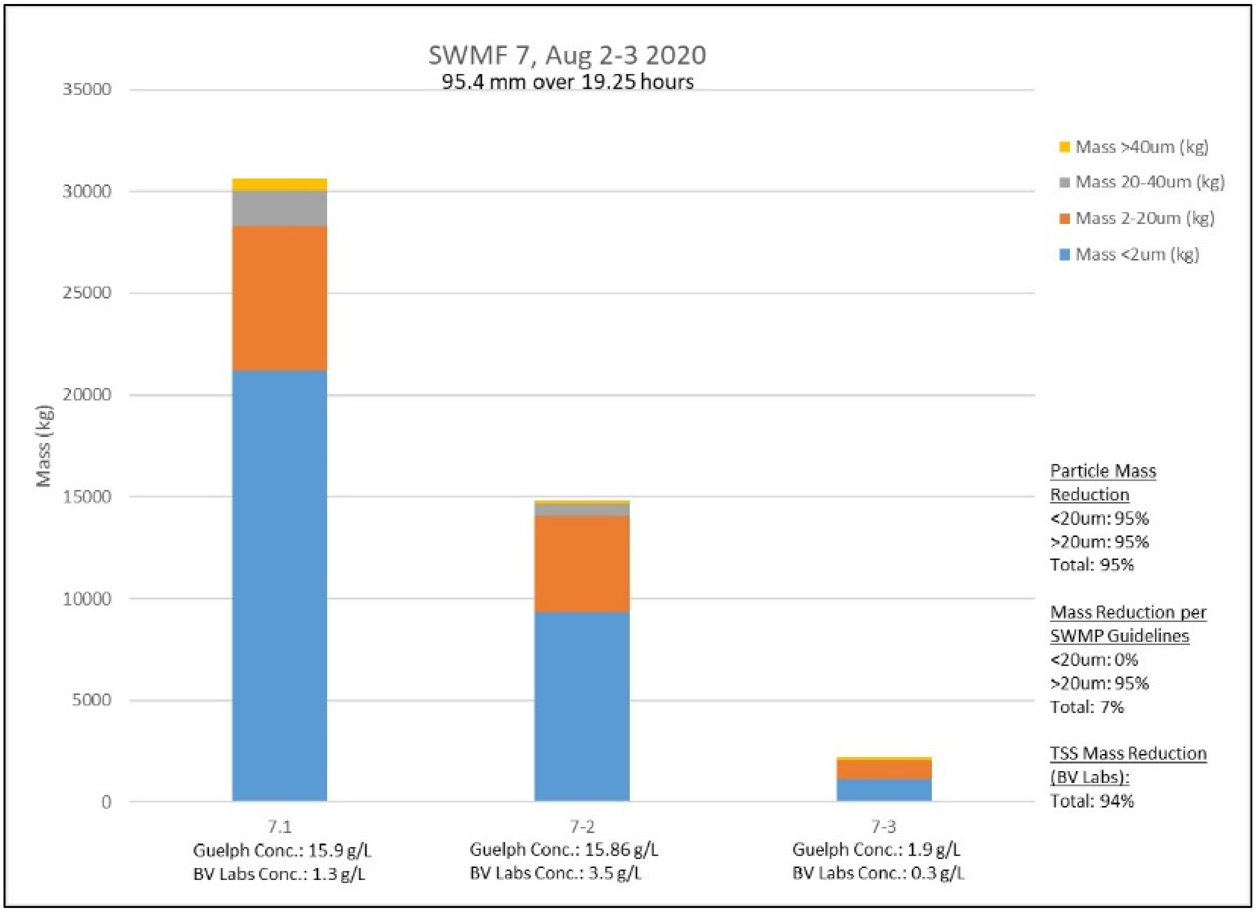


Figure 16: SWMF 7 (August 2-3, 2020) – Particle Distribution Analysis

Sediment loads and particle distribution at each sampling location for SWMF 7 during the 02 August 2020 event is presented in **Figure 16**. During this event, nearly all sediment entering the SWMF is <20µm. Both high volume of flow and very high concentrations of TSS resulted in a high sediment load flowing into the SWMF. Total load entering the SWMF was in excess of 45,000kg, approximately 42,000kg of which was less than <20µm in diameter. Despite the majority of TSS entering the SWMF being <20µm, 95% of the sediment flowing into the SWMF was settled, including 95% of these small particles.

<u>The SWMF performed well beyond expected removal efficiencies, which would have resulted in 80% removal of TSS.</u>

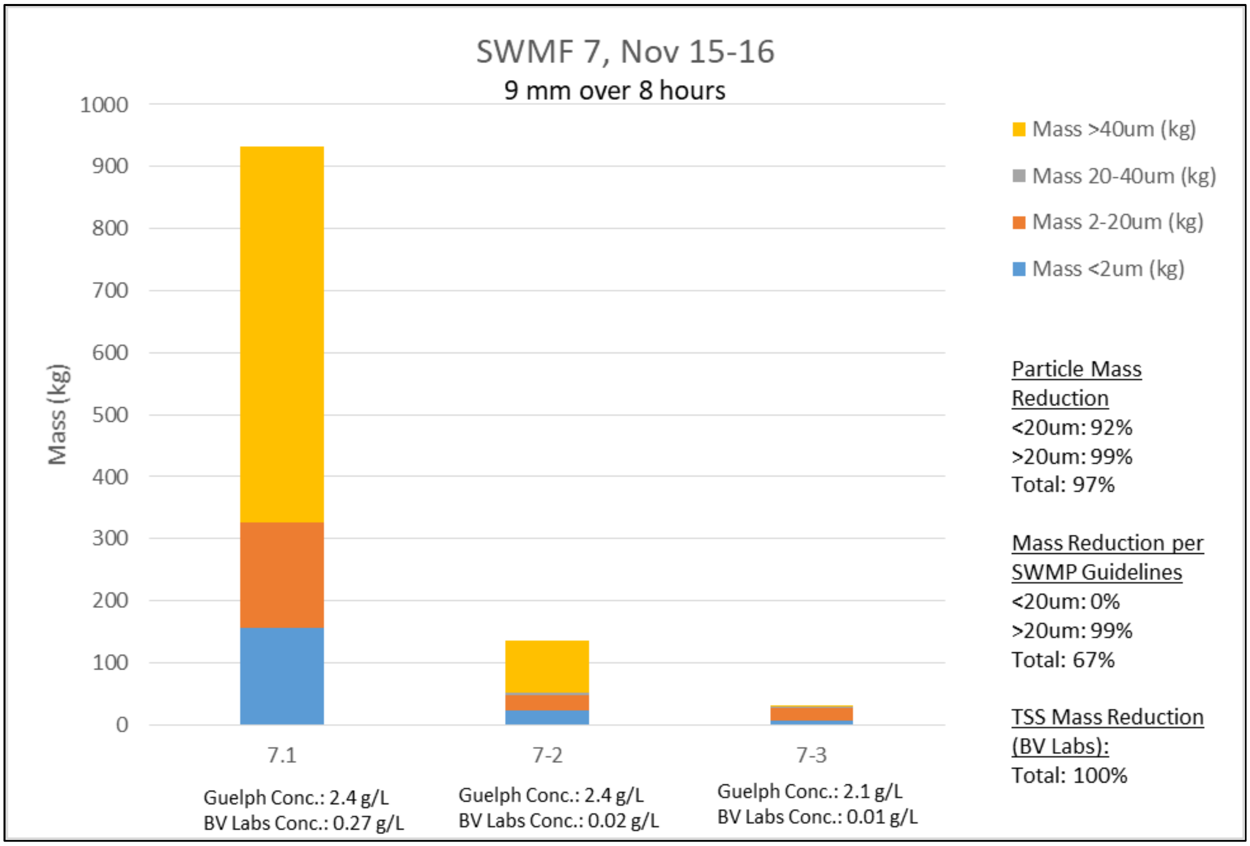


Figure 17: SWMF 7 (November 15-16, 2020) – Particle Distribution Analysis

The results of the particle distribution analysis at SWMF 7 for the 15 November 2020 event are displayed in **Figure 17.** Most of the sediment entering the SWMF during the 15 November 2020 event is >40µm in size. Although proportionally most sediment is comprised of larger sized particles, due to the large volume of sediment flowing in from the west inlet (7-1), a large amount of sediment <20µm in size is entering the SWMF as well.

A total load of more than 1,000kg is calculated to have discharged to the SWMF from the two (2) inlets, however, less than 50kg of sediment is exiting the SWMF to flow into the permanent SWMF downstream, mostly made up of particles 2-20µm in diameter. This results in a total removal efficiency of 97% of sediment.

5.3.2 *Phosphorus and Chloride Reduction*

A summary of the removal efficiencies recorded for both phosphorus and chlorides, from all precipitation events monitored, can be found below in **Table 9.**

Table 11: SWMF 7 Phosphorus and Chloride Reduction

Date	Event Precipitation Depth(mm)	Removal Efficiency (%)	
		Phosphorus	Chlorides
15-May[1]	16	-	-
29-May[1]	17	-	-
11-Jul	5.4	99%	81%
2-Aug	95.4	95%	12%
17-Aug[2]	5.5	-	-
21-Oct	1.6	100%	98%
15-Nov	9	100%	98%
25-Nov	10.2	95%	98%
30-Nov	11.2	100%	96%
26-Mar (2021)	28.4	-15%	-152%

Notes: *1- Baseline event (pre Clearflow installation) was not sampled for phosphorus and chloride analysis*
2 – Event generated no flow at the inlet of the SWMF, not sampled

As with the TSS removal efficiency, phosphorus and chloride removal efficiency was consistently high for every sampled event at SWMF 7. Similar to SWMF 4, phosphorus removal generally followed the trend of TSS removal efficiency in SWMF 7. The lowest phosphorus removal efficiency observed on 02 August 2020 and 25 November 2020, coincide with a slightly lower TSS removal efficiency (95% and 93%, respectively). Similarly, during events with higher TSS removal efficiency (97-98%), higher phosphorus removal efficiency was also observed (99-100%). The exception to this trend is the 30 November 2020 event, when TSS removal efficiency was 87%, while 100% of phosphorus was removed. Based on the sampling results, it can be concluded that phosphorus removal is closely correlated with TSS removal. As determined in **Section 5.3.1**, Clearflow products resulted in an increased removal of TSS than would be expected without the products installed. Therefore, it can be concluded that these products also resulted in an increase of phosphorus removal efficiency for SWMF 7.

Chloride removal efficiency, while consistently high for small events, does not appear to closely follow the trends of TSS and phosphorus removal. For example, during the events on 11 July 2020 and 02 August 2020, chloride removal efficiency was the lowest observed of all sampled events, excepting the 26 March 2021 event (see **Section 5.3.1** for explanation), (81% and 12%, respectively), however TSS removal efficiency was the well above 90% (98% and 95%). Conversely, during the 25 November 2020 and 30 November 2020 events, which saw high chloride removal efficiencies (98% and 96%), TSS removal was at its lowest observed removal efficiencies (93% and 87%). Chloride removal efficiency remained high at SWMF 7, which was not observed at SWMFs 4 or 6, which may be attributed to the Treated Jute; however, it does not appear to be closely connected with TSS removal efficiencies. Any correlation between the Treated Jute and chloride removal, or with chloride removal efficiencies and TSS removal efficiencies must be further tested to confirm, which is beyond the scope of this project.

5.4 SWMF 6: Water Quality Sampling

5.4.1 *Particle Distribution Analysis, TSS and Turbidity*

As outlined below in **Table 6**, a total of nine (9) events were sampled at SWMF 6 in 2020, one (1) event was sampled in 2021, and the Clearflow product was installed for eight (8) of the events. For two (2) events in the fall of 2020, composite sampling was completed.

Table 12: SWMF 6 TSS Reduction

Date	Event Precipitation Depth (mm)	Removal Efficiency - Guelph			Removal Efficiency – Theoretical, MECP Guidelines			As-Designed Efficiency	Removal Efficiency - BV Labs
		<20µm	>20µm	Total	<20µm	>20µm	Total		
15-May[1]	16	100%	100%	100%	0%	100%	92%		100%
29-May[1]	17	71%	87%	79%	0%	87%	42%		98%
11-Jul[2]	5.4	100%	100%	100%	0%	100%	100%	100%	100%
2-Aug	95.4	57%	-14%	32%	0%	-14%	-5%	62.6%	93%
17-Aug[2]	5.5	100%	100%	100%	0%	100%	100%	100%	100%
21-Oct[2]	1.6	100%	100%	100%	0%	100%	100%	100%	100%
15-Nov[2]	9	100%	100%	100%	0%	100%	100%	100%	100%
25-Nov[3,4]	10.2	-297%	-380%	-318%	0%	-380%	-96%	83.3%	86%
30-Nov[4]	11.2	5%	47%	21%	0%	47%	18%	86.3%	67%
26-Mar[3] (2021)	28.4	34%	-625%	24%	0%	-625%	-10%	47.3%	96%

Notes: *1- Baseline sampling pre Clearflow installation*
2- 100% removal is due to no flow present at the outlet of the SWMF
3 – Particle Distribution Analysis indicates an increase in TSS leaving the pond, resulting in non-rational removal efficiencies when calculating removal efficiency of each particle size
4 – Composite Sampling was completed for event

Due to the large size and outlet design of SWMF 6, during small precipitation events, there is no flow generated at the outlet of the SWMF. Based on the magnitude of events sampled when the Gel Flocculant Blocks were installed, four (4) of eight (8) resulted in no flow leaving the facility. This creates difficulty interpreting results, with inconsistency in the results make it difficult to identify any trends.

No clear conclusions can be drawn from the results of TSS Removal at SWMF 6. Of the four (4) events where flow was generated at the outlet (post Clearflow installation), three (3) resulted in very low TSS removal, and the final event resulted in an increase of TSS leaving the SWMF when considering the particle distribution analyzed samples. While low removal efficiencies would be expected for the 02 August 2020 event due to its magnitude, the observed TSS removal efficiency (Guelph composite sampling results) was lower than the As-Designed efficiency. This appears to be attributed to the increase in sediment load of particles >20µm at the outlet. However, based on the results from BV labs analysis, which takes into account all particles >2µm, there was still a high efficiency of TSS removal for all four (4) events which generated outflow, which cannot be fully attributed to particles <2µm in the samples. There is a disconnect in the results of TSS removal efficiency for this SWMF, which at this point remains unexplained.

There are several possible explanations for the negative or low efficiency observed for the events at SWMF 6, at the end of November 2020 and the following March 2021. However, determining which of the possible causes was the primary factor, is not feasible at this time. It is possible that each contributed to the anomalies in the data results. Potential factors include:

- *Settlement in storm sewer piping:* For the large event in August 2020, it is possible that any sediment that settled in the conveyance system and behind the flow weirs could have been washed into the SWMF during the large event, however, the discrepancy between the Guelph and BV lab sample analysis, as detailed herein, remains unexplained.
- *Sanding or salting of roadways:* Towards the end of November 2020 enough snowfall had occurred for snow to remain on the ground. It is possible that sanding of 6th Line resulted in wash-off during subsequent precipitation events that flowed directly into the SWMF and bypassed sample collection at the inlet points. In addition, the event at the end of March 2021 was the first large precipitation event post snowmelt which would have resulted in large amounts of wash-off;
- *Resuspension of fine Sediments:* Since small events at SWMF 6 do not result in outflow from the SWMF, it is possible that during events where flow is great enough to cause flow at the outlet, that this magnitude of flow also results in resuspension of fine sediments that had settled in the SWMF or at the outlet. Please refer to **Section 6.2** for additional information related to maintenance requirements.
- *Vegetative die-off and re-release of organics and sediments*: By the end of November 2020, vegetation in the SWM Block had died and any loose organic matter from the die-off or sediment that had been captured in the vegetation throughout the year would have washed off into the SWMF during precipitation events, resulting in high sediment concentrations (and associated loads) compared to values at the inlets. SWMF 6 is an older and large SWMF with more vegetative growth so vegetative die off is a possible explanation for the low and negative removal efficiencies, particularly given the time of year poor removal efficiencies were observed.

5.4.2 *Phosphorus and Chloride Reduction*

A summary of the removal efficiencies recorded for both phosphorus and chlorides, from all precipitation events monitored, can be found below in **Table 11.**

Table 13: SWMF 6 Phosphorus and Chloride Removal

Date	Event Precipitation Depth (mm)	Removal Efficiency (%)	
		Phosphorus	Chlorides
15-May[1]	16	-	-
29-May[1]	17	-	-
11-Jul[2]	5.4	100%	100%
2-Aug	95.4	83%	-635%
17-Aug[2]	5.5	100%	100%
21-Oct[2]	1.6	100%	100%
15-Nov[2]	9	100%	100%
25-Nov	10.2	31%	-43%
30-Nov	11.2	61%	-46%
26-Mar (2021)	28.4	95%	35%

Notes: *1 - Baseline event was not sampled for Phosphorus or Chloride analysis (pre Clearflow installation)*
2 - Event generated no flow at the outlet of the SWMF, resulting in 100% removal

As described in **Section 5.4.1**, for several events there was no outflow observed in SWMF 6 due to its design, which in turn resulted in 100% removal of phosphorus and chlorides. From the remaining four (4) events, the phosphorus removal efficiency is much greater than TSS removal efficiency (based on the particle distribution analysis).

The negative removal efficiencies for chlorides for the events that generated outflow indicate that the Clearflow Gel Flocculant Blocks products provided no benefit to increase removal efficiency of chlorides in SWMF 6. The results also suggest that reduction in sediment loads and chloride removal are not closely linked at this location. For both the 02 August 2020 event and 30 November 2020 event, although removal efficiency of TSS was low, it was expected that chloride load would also be reduced. However, as shown in **Table 11** above, chloride removal did not follow this trend. Instead, a greater load of chlorides was determined to be leaving the SWMF than entering the SWMF for both events.

However, due to the small sample size of events that generated outflow, no firm conclusions of the benefit, or lack there-of, of the Gel Flocculant Blocks in removing chlorides can be made from this SWMF. An alternative explanation for the negative removal efficiencies observed, is the external factors explored in **Section 5.4.1** that resulted in the lower TSS removal efficiencies. This would indicate that even if the Gel Flocculant Blocks are increasing the removal of chlorides from water flowing into the SWMF from the inlets, because of external factors, such as re-suspension of fine sediments and sanding or salting of roadways, this reduction in chlorides is not being observed in the sampling results. This explains why when TSS removal is low (or negative), chloride removal efficiencies were also negative, lending support to the conclusion that TSS removal and chloride removal are related. Further laboratory testing and in-situ sampling is required to confirm the relationship between TSS removal and chloride reduction, and the efficacy of Gel Flocculant Blocks in reducing chlorides, which is beyond the scope of this project.

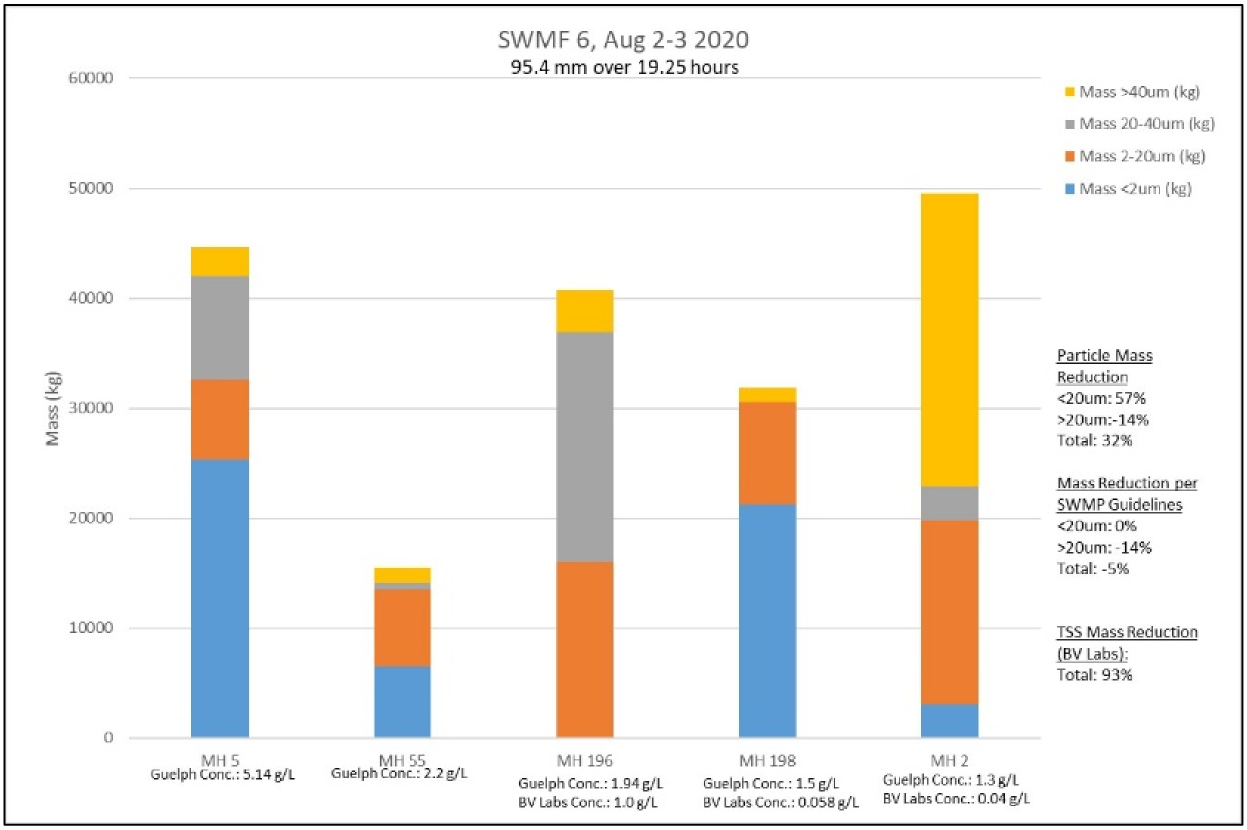


Figure 18: SWMF 6 (August 2-3, 2020) – Particle Distribution Analysis

Figure 18 demonstrates the relative sediment loads and particle distribution at each sample location for the 02 August 2020 event. The sample location upstream (MH 5) of the North Inlet (MH 196) is shown to have a greater load of sediment than the manhole downstream, despite the flow rate being approximately 41% of that at MH 196. The reduced load downstream may indicate that sediment is beginning to fall out of suspension as it makes contact with the Gel Flocculant Blocks, before it reaches the inlet of the SWMF. This is also supported by the shift in particle distribution between the manholes to a higher proportion of larger particles downstream.

A significant load of sediment is flowing out of the SWMF (MH 2) during the 02 August 2020 event. Between the two inlets (MH 196 and MH 198), only 32% of sediment flowing into the SWMF is settled out. The particle distribution has also shifted to larger particles (>40µm). This indicates that the Gel Flocculant Blocks have caused the sediment to flocculate, but due to the large nature of the event, they are not settled in the SWMF, instead flowing downstream into the receiving watercourse.

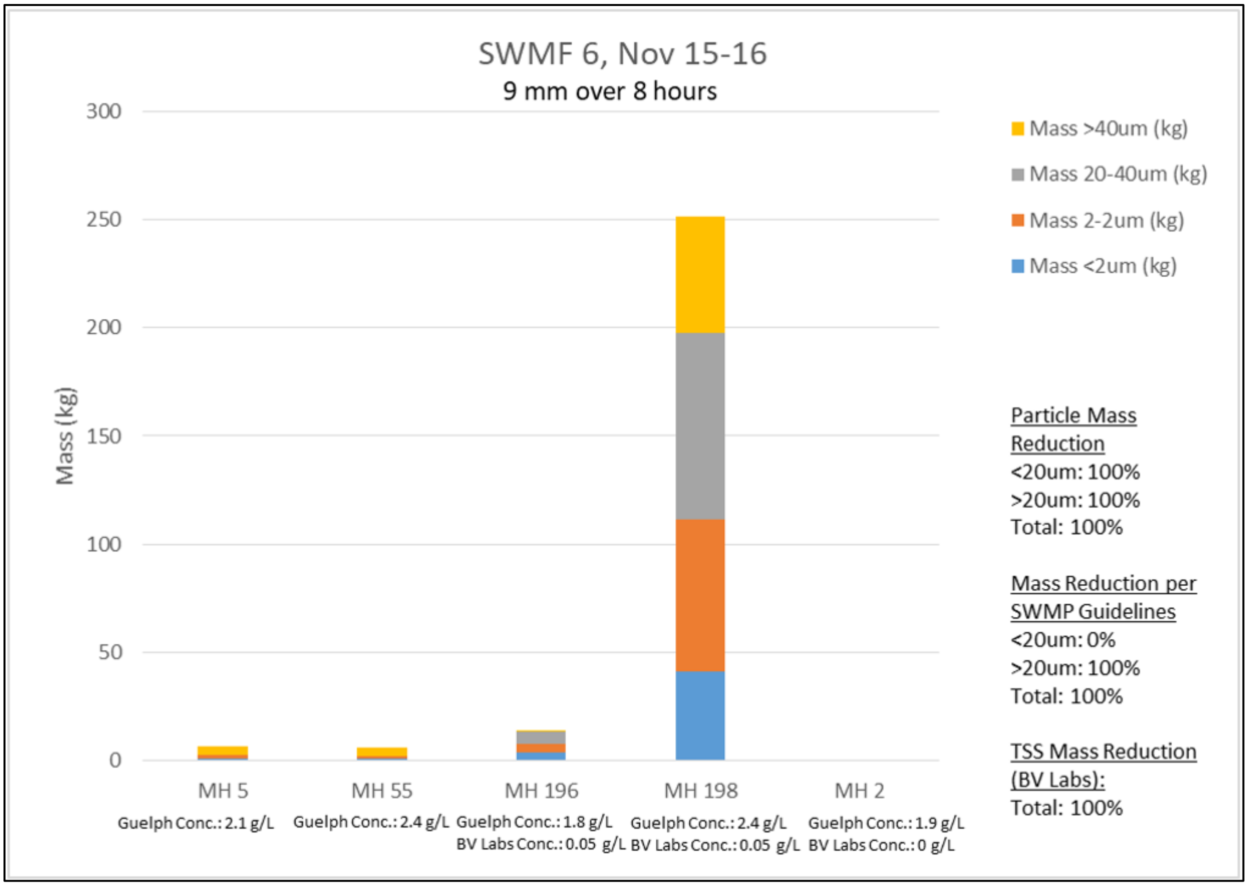


Figure 19: SWMF 6 (November 15-16, 2020) – Particle Distribution Analysis

As shown in the particle distribution analysis results presented in **Figure 19**, very small loads of sediment were observed to be entering the SWMF from the north inlet (MH 196) during the 15 November 2020 event. More than ten times (10x) the sediment load entered through the south inlet (MH 198) than at the north inlet. Although a fairly sizeable event, no outflow was observed for this event which resulted in a 100% removal efficiency of TSS.

6 Product Maintenance & Requirements

6.1 Baseline Product Testing and Required Specification Variables

When considering the site-specific application and maintenance requirements for the Gel Flocculant Blocks, it is important to first ensure that the chosen product blend matches the site-specific water chemistry of the target site. This is ideally determined by collecting samples (1L each) from the target SWMF inlet point(s) during a rain event to capture a baseline "snapshot" of the stormwater requiring treatment. Alternatively, the collection of stormwater and sediment within the pond itself can be used to assess treatment requirements of the stormwater. With this secondary approach however, please note that samples collected within the SWMF permanent pool have already been exposed to treatment via settling and may not be fully representative of influent stormwater. Each sample should be visibly turbid with suspended solids present (to enable flocculation), and shipped to the Clearflow head office for product testing at their in-house laboratory to identify the optimum reaction to the block chemistry. While a detailed analysis of water chemistry is not necessary to determine the optimal product blend due to the sheer number of variables present, if specific parameters are of concern for a project application (i.e., Phosphorus, other nutrients, various metals), this baseline data can be helpful in setting a benchmark to quantify future product performance.

As previously discussed in **Section 4.1.2**, a number of sewershed related variables are required to effectively calculate the amount of product specified, summarized in **Table 12**:

Table 14: Required Sewershed Variables for Product Specification

Variable	Input
Volumetric Flow Rate	– Required for each MH node in the target sewershed to identify the design rain event (e.g. 25mm, 5-year, etc.) and quantity of gel blocks required to treat expected stormwater volume.
Flow Velocity at each MH Node	– Used to determine the optimal placement of product in the sewershed. – Required to ensure the correct amount of mixing time is achieved from initial to final contact with gel blocks at the settling pond (or other catchment system, ex. jute dispersion field).
Distance between each MH Node	– Required to calculate the necessary product contact time in upstream stormwater infrastructure.
Map or Diagram of Target Sewershed	– Helps determine the optimal placement of gel blocks as certain node pathways can merge, allowing for mixing of both treated and untreated stormwater by the gel blocks.
Stormwater pipe and/or ditch dimensions	– Closed structures (e.g., pipe or reactor) have tighter spaces which limit access and also better focus flow energy into higher velocities. – Open ditch systems provide easier access and the ability to install higher concentrations of gel blocks in a smaller area.
External influences on load factors	– Un-stabilized catchment areas in sites currently under construction will likely provide higher influxes of TSS to receiving SWMF(s). Primary point of entry to upstream SWMF sewershed will be existing catch basins near active construction activity. – Important to understand the timing of active construction window and incorporate into product quantity calculations over an extended period of time.
Storm sewer or combined sewer	– Determine if target sewershed receives only stormwater, or a mix of stormwater and sanitary (combined sewer). The latter will result in additional water chemistry variables and flows (rate and total volume), thereby necessitating modified product quantities and blends.

6.2 Product Maintenance Indicators

Post-installation of the Gel Flocculant Blocks and Treated Jute, there are a number of performance indicators that can signal the requirement for corrective maintenance or replacement activities. This includes, but is not limited to the following indicators as detailed with corrective actions in **Table 13**:

Table 15: Product Maintenance (Indicators and Corrective Actions)

Product Type	Indicator	Corrective Action(s)
Treated Jute	Visible damage to product	– Tears in product can occur due to impacts from hard objects (e.g., sticks, rocks) caught in high stormwater flows. – Upon discovery of any such damage, schedule for repair or replacement of affected product to ensure uninterrupted treatment performance.
Treated Jute	Product saturation	– Sediment buildup and saturation will become more visible near the end of the product's lifecycle. – Schedule replacement cycle upon discovery to ensure uninterrupted treatment performance.
Gel Flocculant Blocks	Sediment has buried or partially covered gel blocks	– Remove sediment covering gel blocks via water flushing or manipulating position by pulling attached rope configuration.
Gel Flocculant Blocks	Film of solids develops over gel blocks	– Scrub or rub film from gel blocks to reinstate maximum amount of available surface area for contact with stormwater. – Easiest to complete when blocks are installed in an open ditch system.
Gel Flocculant Blocks	Gel blocks appear partially or fully dissolved	– It is recommended that periodic check-ups of product be completed to determine state of decay in advance of expiration. – Upon discovery of imminent gel block decay, schedule replacement cycle to ensure uninterrupted treatment performance.
Gel Flocculant Blocks	Sediment buildup in downstream storm sewer	– It is important to check for areas of potential sedimentation in the downstream storm sewer system or flow control weir device (if present), as low flow conditions may allow for any untreated solids to deposit in these areas. A subsequent large storm event can then flush such sediment into to receiving SWMF / watercourse and bypass the product treatment effect before exiting the facility. – Can occur in extremely low flow precipitation events, as the flow energy may not be substantial enough to facilitate the release and reaction of flocculant from the gel blocks.

6.3 Operation and Maintenance – Final Recommendations

After observing both the installation and subsequent field performance of the Clearflow products utilized in this Project, a number of recommendations were noted in order to improve efficiencies for future applications. This insight is informed through input from the contractor responsible for product installation, Greenland's site inspector, as well as an analysis of the collected water quality data for each SWMF. Recommendations for each stage of the Product lifecycle is presented as follows:

Project Planning:

- Identify and account for and all baseline product testing and specification variables identified in **Section 6.1.**
- Where possible in daylit inlet channels (e.g. temporary SWMF 7), install strategic rock check dams over a continuous rip-rap layer. This will allow for up-front sediment capture and prevent saturation of the rip-rap layer across the entire surface area of the ditch system floor. This approach will also facilitate more effective sediment removal activities.

Product Installation Fieldwork:

- The rope / carabiner configurations to be installed at each sewer leg should be colour-coded to match the colour of each Gel Flocculant Block blend. This will better ensure the correct placement and quantity of product to be installed by the contractor.
- Utilize secure knots (no slip knots) when creating a rope loop for fastening the Water Lynx and corresponding carabiner.
- Confined Spaces Guidelines and Standards must be adhered to if any contractor personnel are required to enter the subsurface stormwater piping during the installation process.
- Utilizing a water truck can be helpful when installing Water Lynx by introducing flow upstream of the target MH node, which can then can assist in “pushing” the blocks downstream as they are fed into the sewer system. Alternatively, a tether line can be floated down the stormwater piping segment to the downstream MH Node. This tether line can then be used to pull the product rope configuration into place. Either option can help to either avoid or minimize confined space requirements.

Product Performance:

- Upon the occurrence of any precipitation events in exceedance of 25mm, it is important to perform spot check inspections of the product to ensure product integrity remains unaffected. This can be completed by reviewing product installed at both the first upstream and final downstream MH node of each inlet point.
- Periodic inspections during small storm runoff events to check for sediment accumulation in the storm sewer (Gel Block installations) and flushing completed as required to move trapped sediment into the downstream SWMF.

Product Removal:

- Disposal logistics should be coordinated in advance of any field removal activities for the Gel Flocculant Blocks and Treated Jute. This is important to ensure a sufficient amount of storage space is provided for the spent product upon immediate removal. For example, each gel block can increase in weight and volume by up to 200 – 300%, and as this project required up to 26 individual Gel Flocculant Blocks to be installed in a single sewer leg (SWMF 6, MH35), issues of immediate product storage and removal can be compounded rather significantly.
- A mini-excavator can therefore be helpful for the immediate collection of removed Gel Flocculant Blocks, allowing for easy transfer to a larger disposal bin. Additionally, a mini-excavator can also be helpful for removing these larger (and heavier) quantities of block and Treated Jute configurations, which can otherwise be too difficult to be pulled up by hand.

Performance Monitoring:

- As previously referenced in **Table 13**, the deposition of untreated sediment in the downstream storm sewer piping and/or weir structure can impair future performance monitoring of the receiving SWMF. This was noted in SWMF 6 by our field inspector and also supported by the data and potential causal analysis in **Section 5.4.1**.

In addition to the maintenance requirements of the AST products, there is potential for changes to the regular SWMF maintenance to be implemented. The flocculation of sediment increases its mass, resulting in a quicker settling time. It is theorized that this will result in sediment being better captured within the forebay, potentially minimizing the disruption to the SWMF during clean-out, i.e., regular clean out could be limited to the forebay, with a full clean-out of the permanent pool at a reduced interval. This was not tested as part of this project, however could be studied as a potential benefit in a future study.

7 Cost Evaluation

A cost analysis for the installation of the AST versus conventional methods of SWM has also been completed, based on the values noted in **Section 5**. From a water quality approach, this was completed for phosphorus loading due to the sensitivity of the Lake Simcoe watershed, and increasing awareness of phosphorus loading ramifications province-wide. The Lake Simcoe Phosphorus Offsetting Policy (LSPOP) is relevant to all new development in the watershed and has the goal of eliminating 100% of phosphorus loads (based on pre development levels). For any development that is unable to eliminate phosphorus loads, an offset ratio is applied to any excess amounts. This includes a one-time fee passed along to the developer for any excess loadings and is based on the annual post development phosphorus loads. The offset ratio and unit cost of phosphorus is 2.5, and $35,000/kg, respectively.

The cost comparison for the Sleeping Lion Subdivision based on the expected pre and post development phosphorus loads is summarised in **Table 14**. Pre-development loads are based off the original phosphorus budget calculation completed for the subdivision, while phosphorus removals for the SWMF only condition are based on the values recommended in the MECP's Phosphorus Budget Tool Guidance Report. The SWMF + AST condition removal scenario is an average calculated from the phosphorus removal observed from the in-field sampling completed under this Project in **Section 5**.

Table 16 Phosphorus Offsetting Cost Comparison

Development Scenario	Area (ha)	Pre-Development Load (kg/yr)	Post Development Load (kg/yr)	Excess Phosphorus (kg/yr)	Value ($ CAD)*
Post Development Condition- only SWMF (63% removal)	94.6	19.882	43.212	23.33	$ 2,041,375.00
Post Development Condition- SWMF + AST (87% removal)	94.6	19.882	15.182	-4.7	$ -

** excl. HST*

Based on the LSPOP, if there were no BMPs installed other than the SWMF's, then the developer would have been expected to pay approximately $2 million to the LSRCA to offset the Subject Site's post development phosphorus loads. With the addition of ASTs however, the total post-development loads are less than pre-development, thus no offset is required. If the $2 million was applied to purchasing and implementing these AST measures at the Subject Site, approximately 15 years of product could be funded. This includes both product and installation costs (as required for this Project). It should be noted, that it is expected that the majority of the phosphorus loading occurs during the high sediment loading period during construction of the site and when the site is unstabilized.

With respect to TSS, and as discussed above, the majority of TSS loading from a development site occurs during the unstabilized construction period, when the site is undergoing area grading, servicing and house construction. In addition to AST methods, conventional methods of addressing TSS loading from a construction site include standard erosion and sediment controls (sediment traps, silt fence, rock check dams, end of pipe protection systems), making temporary SWM facilities larger or seeding unstabilized areas of a development if they will remain unstabilized for a period of time (e.g. greater than 30 days).

The Town of Innisfil has proposed re-seeding unstabilized sites as a suggested method of controlling TSS loading of area waterbodies (e.g. Lake Simcoe) from development project sites. Therefore, a second high-level analysis was completed for the potential costs of seeding un-stabilized sites versus the implementation of ASTs during the construction phase of development. The cost of seeding the Subject Site versus the implementation of AST at each SWMF is explored in **Table 15**. Assumptions include an eight (8) year construction phase, with three (3) cycles of AST per year required (as per this Project Methodology). Again, all costs associated with ASTs include both product and installation costs.

Table 17 Construction Cost Comparison (excl. HST)

SWMF	Drainage Area	Seeding	AST annual cost*	AST total cost*
	ha	$8/m^2	3 cycles per year	3 cycles per year
SWMF 4	17.6	$ 1,408,000.00	$ 10,980.63	$ 87,845.00
SWMF 6	49.1	$ 3,928,000.00	$ 85,239.13	$ 681,913.00
SWMF 7	27.6	$ 2,208,000.00	$ 37,321.58	$ 298,572.67

** excl. HST*

As shown in **Table 15**, a significant amount of savings (83-94%) would be expected when using ASTs when compared to a more traditional approaches like site seeding for temporary site stabilization. Please note, however, this assumes there is some form of detention pond already constructed (temporary or permanent) where the AST can be installed upstream. In addition, the cost comparison presented above likely under values the savings provide by ASTs when compared to site seeding stabilization, as it does not factor in the cost of re-stripping the seeded areas to permit development in areas requiring engineered fill (e.g. house building envelopes).

Therefore, **with only considering site stabilization seeding and nutrient benefit** to the subject Subdivision, using a 50-year life of the SWMFs, the benefit cost ratio would be greater than 1.44. This is calculated by dividing the sum of the costs of seeding and phosphorus offsetting of the Subject Site ($9.6 million) by the implementation costs of the AST over the lifespan of the SWMF (annual cost of $133,000 * 50 years).

8 Stakeholder Engagement

Given the results outlined in **Section 5** of this report, our Project Team recognizes the importance of engaging a wide variety of provincial stakeholders including local / surrounding municipalities, the LSRCA and other Conservation Authorities in Ontario, as well as relevant regulatory agencies (MECP among others). Engagement efforts for these aforementioned stakeholders will be completed through digital means (FCM Project announcement), applications to present at various conferences, and an email newsletter or other forms of media as determined by the Town. This stakeholder engagement will be undertaken in accordance with our Project Team's long-term vision of implementing this methodology for additional SWMFs in Innisfil, and then eventually the entire Lake Simcoe Watershed, Province of Ontario and Country at large.

9 Closure

This study provides an effective case for AST implementation particularly in un-stabilized development sites and mitigating downstream environmental impacts associated with runoff (TSS and nutrients) from construction activities.

The ASTs provided a clear improvement on TSS removal on un-stabilized sites (SWMF's 4 and 7). While minor improvements were calculated for the majority of the small events sampled (<15mm) when compared to the as-designed efficiencies, a large reduction in the discharge of sediments was calculated for the August 02 2020 event (95.4 mm). Per the SWMF design, a TSS removal efficiency of 36.2% and 79.7% was expected for SWMF's 4 and 7 respectively without AST; however, actual removal efficiencies were calculated to be 74% and 95% with AST installed. Overall, the average TSS removal efficiency for SWMF 7 with AST was determined to be 95% over the sampling period, compared to the as-designed efficiency of 92%; while the removal efficiency in SWMF 4 with AST was calculated to be 85%, compared to the as-designed efficiency of 65%.

Based on the results from SWMF 6, no clear conclusions could be determined regarding the efficiency of the Clearflow products installed at the stabilized site. Four (4) of the eight (8) events sampled did not produce flow at the outlet, and the remaining four (4) events had removal efficiencies lower than the as-designed efficiencies, which could be caused by a number of factors, such as resuspension of sediments, as discussed in **Section 5.4.1**.

In addition to significantly reducing sediment release from SWMFs, another primary objective of the project was to reduce discharge of the associated metals and nutrients that bond strongly to fine particulates. As summarized above, discharge of sediments was notably reduced at both construction sites (SWMF's 4 & 7). Phosphorus removal was also calculated to be high at these sites, generally following the trend of TSS removal, i.e., when sediment removal was high, phosphorus removal was also high, and vice versa. High efficiencies of phosphorus removal were observed at both SWMF's 4 and 7, with removals between 82% and 100% at SWMF 4 (excepting the 21 October 2020 event) and between 95% and 100% at SWMF 7. While not tested as part of this study, similar results are expected from other metals that are known to sorb to sediment, such as: lead, zinc, magnesium, aluminum, silicon and organic compounds. Further testing and analysis are required to confirm the role of Clearflow ASTs in removal of these compounds, which is beyond the scope of this study.

Similar results were not observed in the connection between sediment removal and chloride reduction. From the results of the sampling initiative, no distinct conclusions on the relationship between the AST implementation and chloride reduction can be drawn. In contrast to the phosphorus results, at each of the SWMFs variation between levels of sediment removal and chloride reduction were observed. While chloride reduction remained high at SWMF 7 throughout the sampling period, similar results were not observed at SWMFs 4 or 6. This could be attributed to the Treated Jute installed at SWMF 7, however further testing to confirm the relation between the treated Jute and chloride reduction is required. Further laboratory testing and in-situ sampling is also required to confirm the efficacy of Gel Flocculant Blocks in reducing chlorides, which is beyond the scope of this project. As the relationship between chloride reduction and TSS removal could not be conclusively proven with the implementation of AST, alternative methods to reduce chloride application should be taken by the Town to minimize chloride loading in downstream waterbodies until such a time that the implementation of AST provides a clear benefit. As an example, this could include changing the method of application (liquid salt brine as a de-icer prior to snow events, pre-wetting road salts prior to application) or changing the type of material used in winter maintenance (sand-salt mixtures, alternative liquid brines).

As presented herein, for the Sleeping Lion Subdivision in Innisfil, this AST approach would have a minimum benefit cost ratio of 1.44 (assuming a 50-year SWMF design). Additionally, through the Study performance monitoring and cost evaluation analysis, an AST implementation strategy can also assist the Town in achieving its long-term goals surrounding policy changes for sediment management and site stabilization within Municipal borders. This is most notably demonstrated by the significant performance and cost savings for both phosphorus and TSS as outlined in **Section 7**. The demonstrated improvement to sediment removal on construction sites with the implementation of AST can also help to reduce any financial liability on the part of the Town or developer for non-compliance of the LSPP policies, in particular policies 4.20DP d): “minimize sediment that is eroded offsite during construction” and 4.20DP f): “ensure erosion and sediment controls are implemented effectively” [5]. The implementation of AST will also help meet the target of reducing phosphorus loadings to achieve dissolved oxygen levels of 7 mg/L.

Our Project Team also found the implementation of these AST products to be relatively straightforward and efficient at the Project Site, indicating ease of replicability in similar un-stabilized sites across the Town of Innisfil, Ontario and Canada. Anecdotally, it should also be noted that there have been no known resident complaints of discoloration by TSS in receiving waterbodies (e.g. shore of Lake Simcoe) since the installation of the AST products at the Sleeping Lion Subdivision and which was a concern in the previous years of development. The AST products were shown to be effective at removing fine particulates (<40um) from stormwater, in particular at un-stabilized sites, most of which would not be removed under a typical “Enhanced Protection” designed SWMF. As these fine sediments are responsible for adverse effects observed in aquatic habitats such as: reducing visibility, impacting photosynthesis, disrupting food webs and acting as a primary transport vector for a number of heavy metals and nutrients, their removal from stormwater will reduce their impact on downstream watercourses. This has a secondary benefit of increasing the enjoyment of Lake Simcoe by reducing public complaints regarding sediment discharges from SWMFs, specifically those under construction.

Throughout the entire Project process, a number of improvements to the system and process were documented. By considering following suggested improvements, further efficiencies can potentially be realized in future AST installation projects:

- Streamlining the calculation process for determining product quantities at new development sites would be helpful in facilitating market uptake for this AST approach. Utilizing a variety of baseline monitoring and infrastructure data variables (as outlined in **Section 4.1.2**), a template Site Data Sheet would be completed and sent to Clearflow. Specific site data would be recorded in an organized manner to allow for fast and efficient calculations on both the locations and quantities of product to be installed upstream of each SWMF.
- The preparation of standardized stormwater drawing details and product specification sheets would allow for seamless integration of this AST approach into future development projects. Target audience would be Engineers, Consultants and Contract Administrators who specify erosion and sediment control strategies in development projects across Canada.
- Further laboratory testing and in-situ sampling is recommended to confirm the relationship between TSS removal and chloride reduction, and the efficacy of Gel Flocculant Blocks in reducing chloride levels in stormwater below baseline levels.
- Review existing SWMF design criteria to determine the implications of soil distribution profiles on Enhanced Level Water Quality Protections (80% TSS removal) mandated in the MECP SWMP Design Manual (1994). Design modifications undertaken in combination with AST approaches can potentially address treatment gaps in sites were high concentrations of fine silt and clay particles entrained in stormwater runoff could cause the majority of TSS to be less than 20µm in size (by mass). In areas, with fine grained soils, the ASTs used in this project will have the greatest potential benefit to the receiving waterbody and cost savings to developers.
- Future research initiatives could investigate the potential to include in-situ, and eventually real-time measurements through an Internet of Things (IoT) and Smart City approach during future project expansions in the Town of Innisfil. This would allow for more effective tracking of AST performance and remaining effectiveness before a replacement is deemed necessary.
- Where negative or low TSS removal efficiencies were observed in the monitoring data, particularly for SMWF 6, a number of contributing factors were hypothesized (**Section 5.4.1**). Further research into these causal relationships can help further mitigate downstream sediment release and improve the performance of AST approaches.
- Further laboratory and in-situ testing of how reduced settling time of sediments could impact SWMF maintenance programs. Limiting regular SWMF clean-outs to the forebay could reduce maintenance costs for municipalities.

Overall, this study was successful at achieving it's three primary goals:

- Demonstrate the effectiveness of advanced sedimentation technologies using Clearflow products applied towards un-stabilized sites (construction);
- Reduce erosion and discharge of sediment (and associated nutrients) from new development to watercourses within the Town of Innisfil and tributary to Lake Simcoe; and,
- By achieving the previous two (2) goals, directly contribute to a net reduction in future municipal liability when complying with LSPP requirements.

The AST products provided a demonstrated improvement to TSS removal in SWMFs at un-stabilized sites, and were proven effective at removing sediment <40µm in diameter, which are unaccounted for in MECP design standards for TSS removal. In addition, high-levels of phosphorus removal were observed at both SWMFs under active construction, following the trend of TSS removal. Based on estimates from the Sleeping Lion Subdivision in Innisfil, this AST approach would have a minimum benefit cost ratio of 1.44

and can also assist the Town in achieving its long-term goals surrounding policy changes for sediment management and site stabilization within Municipal borders. Finally, the implementation of these AST products was found to be relatively straightforward and efficient at the Project Site, indicating ease of replicability in similar un-stabilized sites across the Town of Innisfil, Ontario and Canada.

10 References

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[5] Ministry of the Environment (MOE), "Lake Simcoe Protection Plan," MOE, 20 March 2014. [Online]. Available: https://www.ontario.ca/page/lake-simcoe-protection-plan. [Accessed June 2020].