Cohort 2 National Project Final Technical Report

District of Sparwood, British Columbia

February 2020

Municipal Natural Assets Initiative

Making Nature Count

INVEST IN NATURE

The Municipal Natural Assets Initiative (MNAI) is changing the way municipalities deliver everyday services, increasing the quality and resilience of infrastructure at lower costs and reduced risk. The MNAI team provides scientific, economic and municipal expertise to support and guide local governments in identifying, valuing and accounting for natural assets in their financial planning and asset management programs and developing leading-edge, sustainable and climate resilient infrastructure.

Acknowledgements

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Summary

The Sparwood Project was initiated by the District of Sparwood to improve water quality in the Elk River through improved management of natural assets.

Specifically, the Sparwood project identified a natural pond at the outlet of a culvert and explored options to manage, rehabilitate and monitor it to provide stormwater "pre-treatment" to control erosion and reduce discharge of sediment and other effluents into the Elk River. These services are understood to improve water quality, with benefits to the local recreational fishery and corresponding economic outcomes.

The pond area, along with the forested area adjacent to the pond and Elk River, provide important water quality management services for the Sparwood community. Project results indicate that the pond area provides temporary attenuation of stormwater flows and a corresponding reduction of total suspended solids (TSS). In its current state, the pond removes approximately 90.1% of TSS annually.

Hydrologic and hydraulic modelling was completed for the catchment to estimate the overall percentage of TSS removed from the water flowing into the Elk River by the pond areas on an average annual basis. The model was run under four scenarios:

1. existing geometry based on historic rainfall data;
2. existing geometry considering future rainfall with an allowance for climate change;
3. enhanced geometry based on historic rainfall data; and,
4. enhanced geometry considering future rainfall with an allowance for climate change.

Modelling demonstrated that the pond removes approximately 90.1% of TSS annually. Under a future climate change scenario, the existing pond is estimated to remove 89.8% of TSS annually.

An enhanced pond, without any allowance for climate change, would remove an estimate 94.1% of TSS annually. Under a future climate change scenario, the enhanced pond is estimated to remove 93.9% of TSS annually. For both future rainfall scenarios, the ponds are expected to experience a slight reduction in average annual removal rates as a result of climate change.

An economic analysis included an assessment of:

1. the upfront, or capital costs of three infrastructure alternatives – the existing pond, an enhanced pond, and the grey infrastructure alternative
2. the monitoring, maintenance and operations costs of each alternative, and
3. a lifecycle analysis of the three alternatives.

An engineered alternative comparator to the pond was identified through consultations with the District. Stormceptors were selected as a comparator for the purposes of economic analysis.

The comparison of the capital costs for the three infrastructure options – the existing pond, the enhanced pond, and the grey infrastructure alternative – show that:

- the pond in its current state has no capital costs,
- an enhanced pond would cost $27,549.84,
- a fully engineered alternative was estimated to cost $200,070.00.

An assessment of monitoring and operating and maintenance (O&M) costs was completed for the current pond, the enhanced pond and the engineered alternative, with the following results:

- The current pond has no associated O&M costs
- The enhanced natural asset would require annual O&M costs of $2,128/year
- The engineered alternative would require annual O&M costs of $1,600/year

A lifecycle cost comparison using a 25-year timeframe was completed using a 5% discount rate. We found the current-day costs of the natural pond to be $0, the enhanced pond to be approximately $64,000, and the engineered alternative to be roughly $248,000.

These values are focused on the value of water quality improvements, and exclude important co-benefits. Although they are not valued, this project also qualitatively addresses the role of the project area in improving: water quality for downstream communities; stream health/biodiversity; and, recreational fishing.

The foregoing information can be leveraged by the District for a variety of asset management purposes, initial elements of which are contained in the report.

The approach taken for the Sparwood project can be replicated in other areas of relevance to the District.

Introduction

The term "municipal natural assets" refers to the stock of natural resources or ecosystems that is relied upon, managed, or could be managed by a municipality, regional district, or other form of local government for the sustainable provision of one or more local government services (MNAI, 2017). By conceptualizing nature as an asset, the ways in which humans depend on and impact the environment can be codified, tracked and managed. Business and economic activity depends on natural assets to provide important inputs into production such as clean water, minerals, and timber. Natural assets are also important to human physical and social well-being. Benefits in terms of better air quality, water quality and climate stability as well as protection from flood and erosion impacts of extreme weather events are well established. Urban green space, parks, wetlands and protected areas provide important recreation spaces and buffer the effect of extreme heat in urban settings reducing the prevalence of respiratory infections and heat related illnesses. If natural assets are not managed responsibly, their value will depreciate and their ability to provide services from which humans benefit will diminish. Indeed, like any asset, natural assets need to be carefully managed to ensure a sustainable supply of services.

Communities like the District of Sparwood recognize that it is as important to understand, measure, manage and account for natural assets as it is for engineered ones. The Municipal Natural Asset Initiative (MNAI) project in Sparwood ("the Sparwood project") was initiated by Sparwood to increase their understanding of how proper management of the natural assets within the community contribute to improved water quality.

This report provides technical results of the Sparwood project and is organized as follows:

- This **Introduction** describes the project objectives, the project area and provides a brief overview of the relevant natural assets.
- The **Approach** chapter describes the modelling approach that was employed to assess the contribution of the assets to water quality as well as key data sources that informed the analysis.
- The **Natural Assets Assessment** chapter describes the quantity and condition of natural assets in the project area.
- The **Planning for Natural Assets** chapter provides direction on how to manage the natural assets for improved water quality.
- The **Implementation of Natural Assets Plan** chapter describes specific actions that should be considered as a natural asset plan to protect the natural assets of interest.
- **Appendices** contain additional information of relevance to the Sparwood project.

Goals and Objectives

The goal of the Sparwood project was to improve water quality in the Elk River through management of the natural assets in an area of Sparwood known as . In particular, the project identified natural assets that can be managed, built, rehabilitated or monitored to provide stormwater pre-treatment to help control erosion and the discharge of sediment and other effluents to improve water quality and the local recreational fishery.

Objectives in support of this goal were to:

- Understand existing or potential natural assets and their actual or potential contribution to water quality across the river system that is within Sparwood's jurisdiction.
- Understand risks to water quality such as increased frequency and intensity of storm events, and increased development in the area of Sparwood Heights.
- Identify options to manage, monitor, rehabilitate and/or build natural assets to reduce erosion and sedimentation.
- Develop a preliminary understanding of sediment sources that are outside Sparwood's jurisdiction, and potential steps to address these.

Context

The District of Sparwood is located on the Elk River in British Columbia. This is a sub-basin of the Kootenay River Basin, the second largest tributary of the Columbia River watershed. According to the 2016 Census, Sparwood is home to 3,784 people and has 2,130 private dwellings.

The District of Sparwood's Official Community Plan places a strong emphasis on protecting, enhancing and using natural assets. This includes an update to the District's Subdivision and Development Servicing Bylaw to include: integrated stormwater management practices; incorporating the use of natural systems; and developing guidelines to mitigate the loss of wetlands, wildlife habitat and indigenous vegetation areas. Currently, a master plan is being developed for water, wastewater and stormwater management.

The District of Sparwood is also finalizing a Stormwater Infrastructure Plan to develop a computer hydraulic model to evaluate the performance of the stormwater system under rainfall events of different magnitude, focusing on existing infrastructure conditions. The stormwater management plan describes two key areas of Sparwood:

- **Sparwood Proper:** This is the lower part of Sparwood. The land use in Sparwood Proper is a mixture of single and multi-family residential, commercial, institutional, and light industrial. Most of Sparwood Proper drains toward the Elk River, with some areas draining toward Michel Creek. The downtown core is situated approximately 20 metres higher than the rest of Sparwood Proper. Other than the escarpment, the remainder of the developed land in Sparwood Proper is relatively flat, with slopes typically less than 1-2%. Soils are mainly sandy loam underlain by extensive gravel and cobble stones.
- **Sparwood Heights:** Sparwood Heights is located across the Elk River from Sparwood Proper. The land use in Sparwood Heights is mainly single and multi-family residential. A golf course and resort development has been proposed for the Whiskey Jack area in Sparwood Heights. The golf development took advantage of cobble stone to provide exfiltration ponds with major system runoff for heavy events. The terrain in Sparwood Heights is generally steeper than in Sparwood Proper, with an overall relief from north to south of approximately 50 metres. The area generally drains from west to east toward Highway 43 and the Elk River. The soils in Sparwood Heights are mainly silt-clays. There are approximately 180 undeveloped lots in the area. These have been cleared and have some groundcover.

The two areas of Sparwood are shown in Figure 1. The lower part of Sparwood is Sparwood Proper. Sparwood Heights is located across the Elk River from Sparwood Proper.

Of these two areas, Sparwood Proper was selected as the area of focus. Additional details on the project area are in the section, .

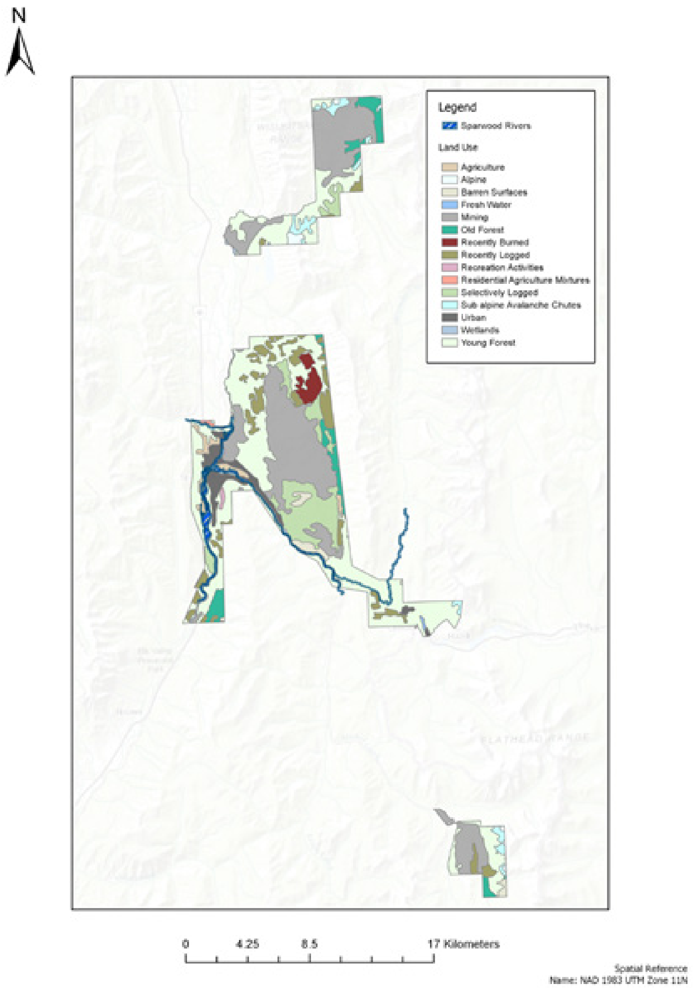


Figure 1 – MNAI project area. Source: Green Analytics

Some areas of the river are regularly impacted by large stormwater flows dumping sediment and other urban runoff into the river. As a result, the river turns brown after heavy rainfall events. This is of particular relevance and concern to the community given the strong emphasis placed on recreation, tourism and fisheries, all of which have important economic benefits in the region.

Figure 2 shows principle outlets where sediment can enter the river. Upstream from these outlets are multiple point sources for erosion and sedimentation. Run-off from these feed into various channels and finally, the outlets. Individually, these point sources are not substantial, but collectively, they may have a substantial effect on water quality.

Figure 2 - Approximate location of outlets into river. Sediment from multiple point sources reaches each outlet, diminishing water quality. Source: Google Earth

Sedimentation may increase given the predicted regional effects of climate change, including more frequent and intense rainfall events. Furthermore, the impact of individual point sources can reasonably be expected to increase in areas that are still being developed, for example, Sparwood Heights. Figure 3 shows a channel and culvert in the Sparwood Heights area. It is an example of one of the many point sources of sediment to the river. The culvert is partially filled with sediment. Erosion and sedimentation from Sparwood Heights will likely increase as development continues.

Figure 3 - Culvert and channel in Sparwood Heights. Source: MNAI

The river also receives selenium leachate from historical and current mining practices. To date, significant data has been compiled associated with understanding potential mining impacts on the community. As part of new coal mine applications, permit conditions require well replacement or abatement. To date, mining activity has only affected one municipal well (#3), which has been shut down. Other wells could potentially be impacted depending on the level of water extraction. Selenium leachate was not selected as a focus for this project. However, the data gathered in respect of mining activities were used as inputs for the Sparwood Project.

An assumption explored in the Sparwood project is that managing, monitoring, rehabilitating and/or building natural assets to reduce erosion and sedimentation at key points throughout an area to provide stormwater control and treatment could improve water quality around the community.

Natural Asset Focus of the Sparwood Project

MNAI defines natural assets as ecosystem features that are nature-based and provide services that would otherwise require the equivalent of engineered infrastructure. For local governments, natural assets can include forests that convey stormwater and recharge aquifers, wetlands that reduce flooding risk, and coastal areas that protect against storm surges and sea level rise, among others. By identifying natural assets at the community level and prioritizing those in municipal asset management portfolios, local governments can secure important budget savings while also delivering vital municipal services. They will also be better prepared to deal with the local effects of climate change (MNAI 2018).

For the Sparwood project, analysis focused on a pond at the storm outlet immediately downstream of the railroad (Figure 4). This area receives runoff from a developed subcatchment. As such, the stormwater runoff discharging through the culvert and into the pool contains sediment. The pool provides temporary attenuation for these flows, meaning that the flow of water is slowed down as it moves through the pool. As a result, some sediment is able to settle out before reaching the Elk River. Other natural assets (e.g. wetland, forest, riparian areas) that provide, or could provide with restoration, filtering and storage services above the principle outlets into the river are also relevant but did not receive the same level of scrutiny in this analysis.

Figure 4 - The pond area at the storm outlet; the key natural asset of interest to the project. Source: Google Earth

Approach

This section describes MNAI's overall approach, and its use in the Sparwood project.

MNAI Approach

MNAI's natural asset methodology is rooted in modern, structured asset management processes. The methodology generally follows the standard asset management assess, plan and implement steps, highlighting novel considerations required for local natural assets and associated services.

MNAI has a range of tools, including templates and guidelines, that are configured for use according to local government needs. The methodology and tools are delivered through ongoing support from the MNAI technical team over the project life. The levels and details of this support are described in a Memorandum of Understanding that MNAI signs with local government partners.

Asset management strategies require a multi-disciplinary approach. The MNAI process begins with an initial engagement session with community representatives from across a range of disciplines. This includes, for example, Parks, Public Works, Geographic Information Systems (GIS), Engineering, Planning, Water and Wastewater, and Finance. During the initial engagement session, plans and priorities of the community are discussed, key natural assets within the jurisdictional boundaries of the community are identified along with the important services those assets provide. Site visits to areas containing important natural assets may be undertaken and key geospatial features observed and documented. The objectives of this initial engagement session are to identify:

- natural asset/s that will be the focus of the natural asset assessment
- geographic boundary/ies of the focus assets
- skillsets and expertise of relevance to the natural asset assessment
- community personnel that will engage in the assessment process
- data needs of the assessment and the sources for the relevant data

The initial community engagement session for the Sparwood project took place on June 13, 2018. It was attended by representatives from numerous departments including Operations, Finance, Parks, and Planning. Appendix A contains the agenda for the session along with a list of participants. At the completion of the session, the focus on the role of natural assets in supporting improved water quality in the Elk River was established.

Following the initial community engagement session, the MNAI team works with the target community to complete a natural asset assessment. The assessment generally involves the following steps:

1. Defining the scope of natural asset
2. Inventorying the natural assets by collecting and organizing existing information about the asset
3. Conducting a condition assessment of the assets
4. Conducting a risk assessment of the assets
5. Quantifying existing service levels from the assets
6. Developing scenarios to explore alternative management plans and future implications to existing service levels
7. Quantifying services levels under alternative scenarios
8. Developing operation and management plans based on existing conditions, risks, and desired service level trajectories

The steps above were completed for Sparwood with a focus on improving water quality in the Elk River. The scope of the project was determined be weighing the project objectives against data availability and proposed modeling and economic approaches. An assumption made in this and other MNAI projects is that a manageable initial project can, with effective design, be replicated in other areas of relevance to the local government.

The asset inventory was informed by land cover data obtained from the community. The condition and risk assessment were conducted in consultation with community representatives as was defining the alternative management scenarios and future implications to existing service levels.

As described below, four scenarios were assessed for Sparwood. The modelling approach employed to quantify the service levels under the alternative scenarios (step 7 above) is also described.

Modelling Approach for Scenario Analysis

As noted, the natural asset of interest to the Sparwood project is the pond at the outlet of a culvert (Figure 4), and thus the focus of the hydrologic and hydraulic modelling. The modelling approach estimated the overall percent of total suspended solids (TSS) removed from the water flowing into the Elk River by the pond on an average annual basis. The performance of the pond in this regard was evaluated for four scenarios:

- Scenario 1: Existing geometry, based on historic rainfall data,
- Scenario 2: Existing geometry, considering future rainfall with an allowance for climate change,
- Scenario 3: Enhanced geometry, based on historic rainfall data, and
- Scenario 4: Enhanced geometry, considering future rainfall with an allowance for climate change.

The modelling steps required for each scenario are described below.

Scenario 1 – Existing Conditions with Historical Rainfall

For Scenario 1, PCSWMM was employed to model sediment removal by the pond under existing conditions.[1] One year of hourly/daily rainfall data was obtained from the Environment Canada rain gauge located in Sparwood.[2] This data was used to establish a flow exceedance-duration curve that measures the percent of flow that exceed various flow rate thresholds. The rate of sediment removal (given the size of the sediment entering the pond from the upstream catchment area) within the pond was estimated and used to specify removal efficiency rates across a range of flow rates (e.g. at 0.01 m^3/s, the pond removed 95% of total suspended solids). The removal efficiency rates were then applied to the average annual flow exceedance-duration curve to estimate the average annual TSS removal rate of the pond under existing conditions and based on historical rainfall.

Scenario 2 – Existing Conditions with Climate Change

For scenario 2, the historical rainfall data was scaled up to simulate increased frequency and intensity of rainfall events due to climate change. This revised data was used to simulate water outflow into the pond. A flow exceedance-duration curve that measures the percent of flows that exceed various flow rate thresholds was established. The rate of sediment removal (given the size of the sediment entering the pond from the upstream catchment area) within the pond was estimated and, as was done with the baseline conditions, used to specify removal efficiency rates across a range of flow rates. The removal efficiency rates were then applied to the revised annual flow exceedance-duration curve to estimate the average annual TSS removal rate of the pond under existing conditions and based on increased rainfall.

1 https://www.pcswmm.com/

2 We received hourly rainfall data from Environment Canada for the Sparwood Gauge (No. 1157630), for the period of record from 1980 to 2017

Scenario 3 – Enhancement with Historical Rainfall

Under this scenario, an enhancement of the pond was considered in combination with historical rainfall. The enhancement assumed that the existing pond is connected to an old remnant side channel. This enhancement would increase the flow length between the storm outfall and the river, which would increase the retention time. The result would be increased settlement of total suspended solids, which would increase the removal efficiency rates of the natural system. To model this scenario, revised removal efficiency rates were established that reflect the increased settlement resulting from the longer flow area between the storm outfall and the river. The revised efficiency rates were then applied to annual flow exceedance-duration curves (based on historical rainfall levels) and the average annual TSS removal rate of the enhanced pond considering historical rainfall was established.

Scenario 4 – Enhancement with Climate Change

This final scenario examined the impact of enhancing the pond by connecting it to the old remnant side channel combined with increased intensity and frequency of rainfall due to climate change. For this scenario, revised removal efficiency rates (as per Scenario 3) were applied to annual flow exceedance-duration curves that reflect increased rainfall (as per Scenario 2). The average annual total suspended solids removal rates of the enhanced pond were then established taking into consideration increased rainfall.

Natural Asset Assessment

This section presents the results of the assessment of natural assets within the Sparwood area.

Asset Inventory

For the community of Sparwood, a number of avenues were explored to complete a natural asset inventory.

First, land cover data was obtained for the Sparwood area from the BC government[3] and the different land cover types within the project area were identified, grouped and quantified. The data from the BC government is low resolution considering the size of the project area and it was clear that some natural assets within the urban area of Sparwood are not being captured by this data. Thus, other avenues were explored to identify the natural assets in the project area.

Second, an unsupervised classification of landcover types was undertaken. This approach is used when local data/knowledge is lacking. With unsupervised classification, analysts choose a number of classes to divide images of the project area into. Images are then scanned and an algorithm divides the area into the class types that correspond to landcover types (i.e. forest, water, grasslands). The location and area of each landcover type are then quantified. For Sparwood, the unsupervised classification, which is presented in Appendix B, did not differentiate well between built-up areas along the river.

Third, a supervised classification of landcover types was undertaken for the project area. With this approach, local knowledge is used to identify “training sites” for the algorithm. This involves identifying areas of a known land cover type and informing the algorithm of the location and extent of the landcover type. The algorithm then uses that information to identify other areas of the same landcover type. A range of landcover types can be specified in this manner and areas of each specified landcover type can be identified and quantified. The supervised classification was compared with the landcover data obtained from the BC government and a number of discrepancies between the two datasets were identified. The use of supervised classification can be a challenge when applying it to mountainous areas where shadows can mask the landcover types. The results of the supervised classification are provided in Appendix C. In the end, the landcover data obtained from the BC government was deemed the most reliable source of data for informing the asset inventory. The supervised classification may be useful in the future if local knowledge is used to improve the land cover classifications provided in Appendix C.

Table 1 presents a breakdown of land cover types for the area depicted in the figure above. The vast majority of the land (almost 50%) is young forest with a sizable area dedicated to urban as well.

TABLE 1 – LAND COVER TYPES IN THE SPARWOOD AREA

Land Cover Type	Area (hectares)	Portion of Land (%)
Agriculture	295.4	12.9
Mining	8.7	0.4
Forest - Recently Logged	75.7	3.3
Mixed Residential Agriculture	33.6	1.5
Forest - Selectively Logged	61.3	2.7
Urban	518.5	22.6
Wetlands	191.4	8.3
Forest - Young Forest	1,113.6	48.5
TOTAL	**2,333.0**	**100**

3 www.data.gov.bc.ca

Ecosystem Services Overview

The natural assets present in the Sparwood area deliver ecosystem services to the local residents. The most prevalent natural land covers in the area are agriculture and forests but wetlands and mining areas also exist. Collectively, these land cover types deliver a host of ecosystem services to the people living in the area. Table 2 lists key ecosystem services provided by the natural assets in the project area. The pond that is the focus of this project is located within an area classified as forest (young forest in particular).

TABLE 2 – ECOSYSTEM SERVICE PROVISION BY NATURAL ASSET CATEGORY

Natural Asset	Ecosystem Services
Forest	• Water quality • Stormwater management • Water storage • Air quality improvement • Carbon sequestration • Recreation
Agriculture	• Water storage • Crop production • Carbon sequestration
Wetlands	• Water quality • Stormwater management • Water storage • Carbon sequestration • Recreation
Mining	• Coal production

Condition Assessment

The condition of natural assets influences the provision of ecosystem services and the resiliency of assets to threats. A condition assessment examines how well assets function in relation to their ability to provide such services. A baseline condition assessment can be used to model changes in the level of ecosystem service provision that may result from positive interventions that improve the condition of assets or from negative impacts that impoverish the condition of assets.

This pond area, along with the forested area adjacent to the pond and the river provide important water quality management services for the Sparwood community. A condition assessment was completed for these assets taking into consideration the physical condition, functional condition (i.e. the ability of the asset to remove pollutants), and demand condition (i.e. the ability of the asset to meet the current demand from the stormwater outflow). The results of the condition assessment are provided in Table 3 below.

TABLE 3 – SUMMARY OF ASSET CONDITIONS

Natural Riverbank				
Asset component	**Description**	**Physical condition**	**Functional condition**	**Demand condition**
Pond at storm water outlet	Physical dimensions: 7.5 m wide by 19.9 m long	Good	Good	Fair
Forested area	Forested area adjacent to the pond and the river	Good	Good	Excellent

*scale: physical, functional and demand condition - poor, fair, good, excellent

**scale: potential condition improvement – low, medium, high

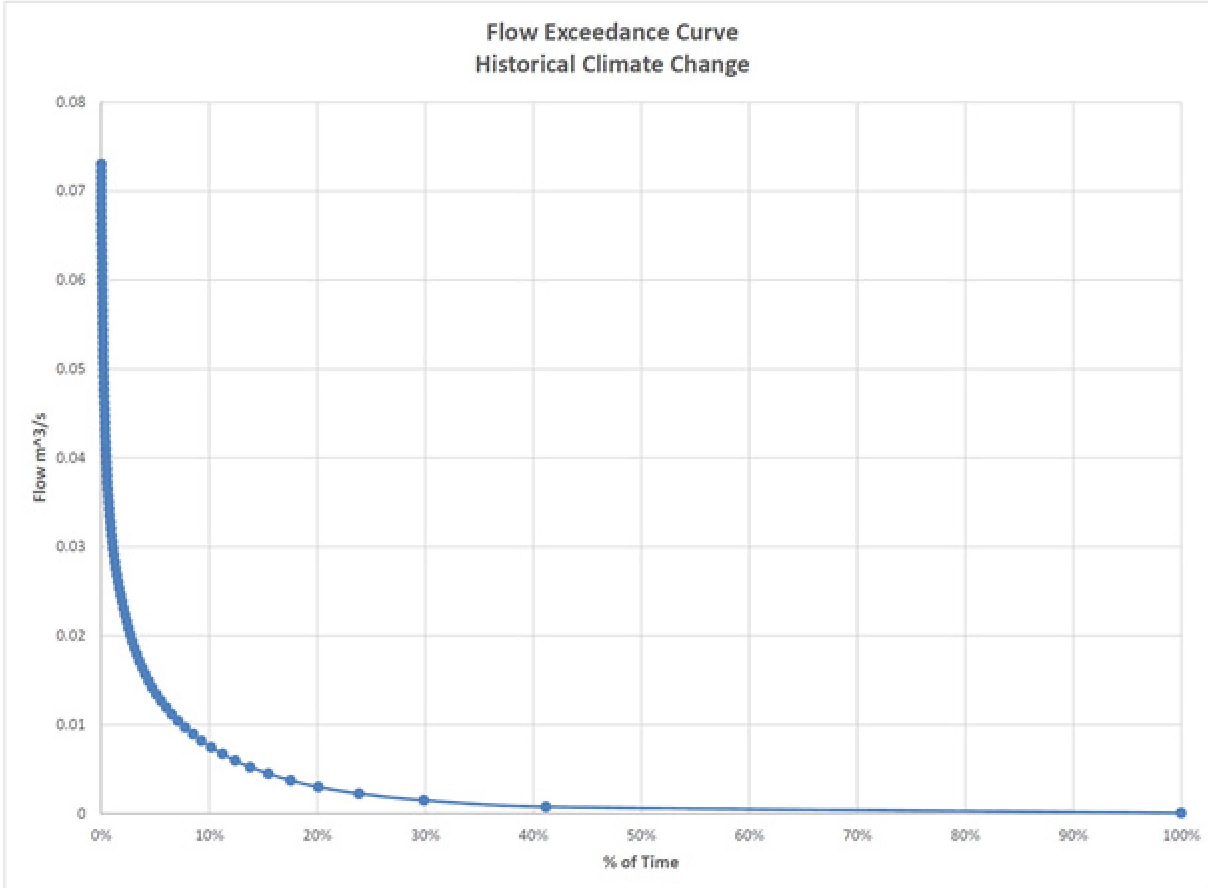
Water Quality Benefits

As the focus of the Sparwood project is on the water quality benefits provided by the pond at the storm outlet downstream of the railroad, such benefits were assessed in detail. The results of the baseline scenario (Scenario 1) are provided here. The District of Sparwood provided an existing PCSWMM model of the area. This model includes both a hydrologic component and a hydraulic component. The hydrologic component of the model simulates rainfall events, and estimates the amount of runoff that is generated based on the sub-catchments. Some of the key parameters that impact the amount of runoff include the sub-catchment areas, the shape of the sub-catchments, the slope of the ground, the type of land cover (i.e. forested, grassed, paved), and soil properties. The hydraulic component of the model includes all of the ditches, channels, culverts and pipes that route the water through the system to the outfall to the Elk River.

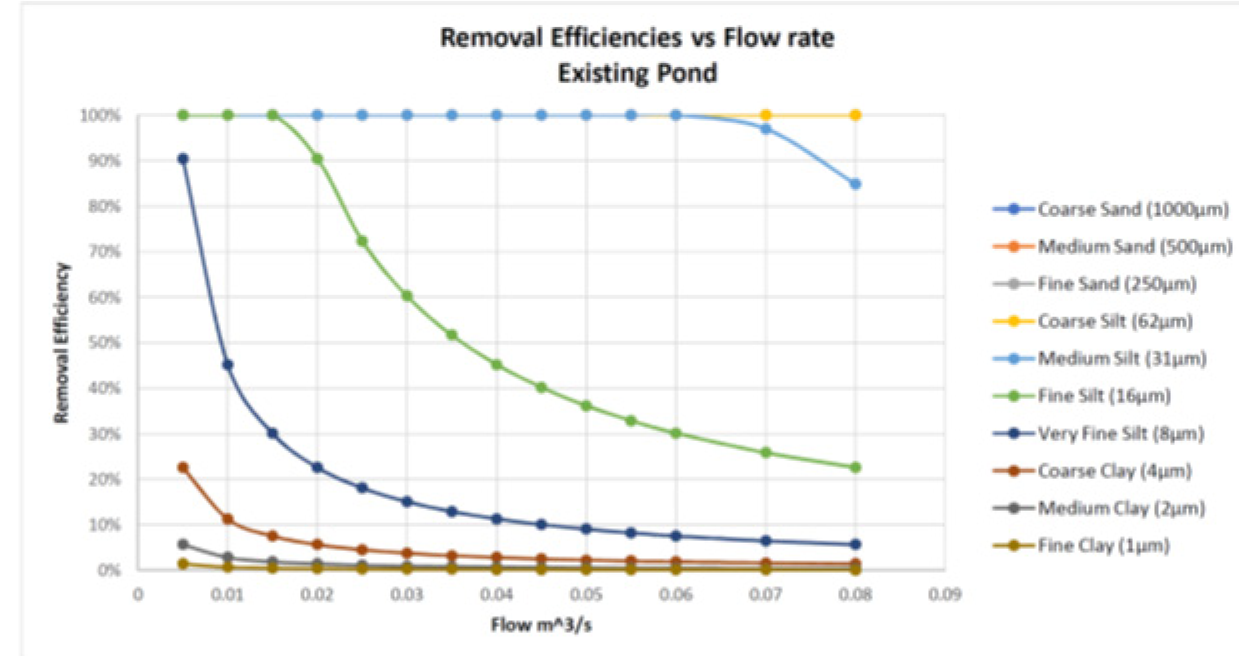
Hourly rainfall data was received from Environment Canada for the Sparwood Gauge (No. 1157630), for the period of record from 1980 to 2017. A cursory review of the data noted that precipitation values were missing from the dataset for all of the winter months.

Using the PCSWMM model provided by the District, hourly rainfall values were entered and a continuous simulation run for the 37 years of data. This is not a complete data set because values are missing in winter months, presumably when the precipitation is falling as snow, and is not detected by the gauge. As such, the model is effectively looking at all of the rainfall events, and not considering the snowfall events.

Upon completion of the continuous simulation, the timeseries for the flow rate entering the pond was extracted. Then, an exceedance curve was developed to illustrate how often various flow rates are exceeded over the duration of the analysis (Figure 5).

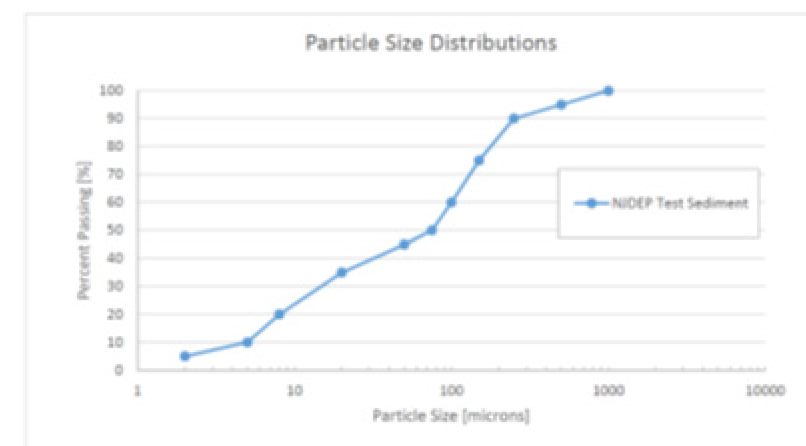


A separate analysis was completed on the pond to estimate the TSS that can be removed from the runoff using the methodology outlined in the Land Development Guidelines for the Protection of Aquatic Habitat (Ministry of Environment). Based on the geometry of the pond, this method estimates the amount of sediment that is removed for a specified flow rate; it gives a different removal percentage for each particle size. This calculation was completed for a range of incrementally increasing flow rates, and developed a treatment rating curve for the existing pond. The rating curve shows the removal efficiency as a function of flow rate, with each line on the curve representing a different particle size (Figure 6). The analysis is based on the existing pond geometry, which has an estimated length of 19.9 m, and an estimated width of 7.5 m.

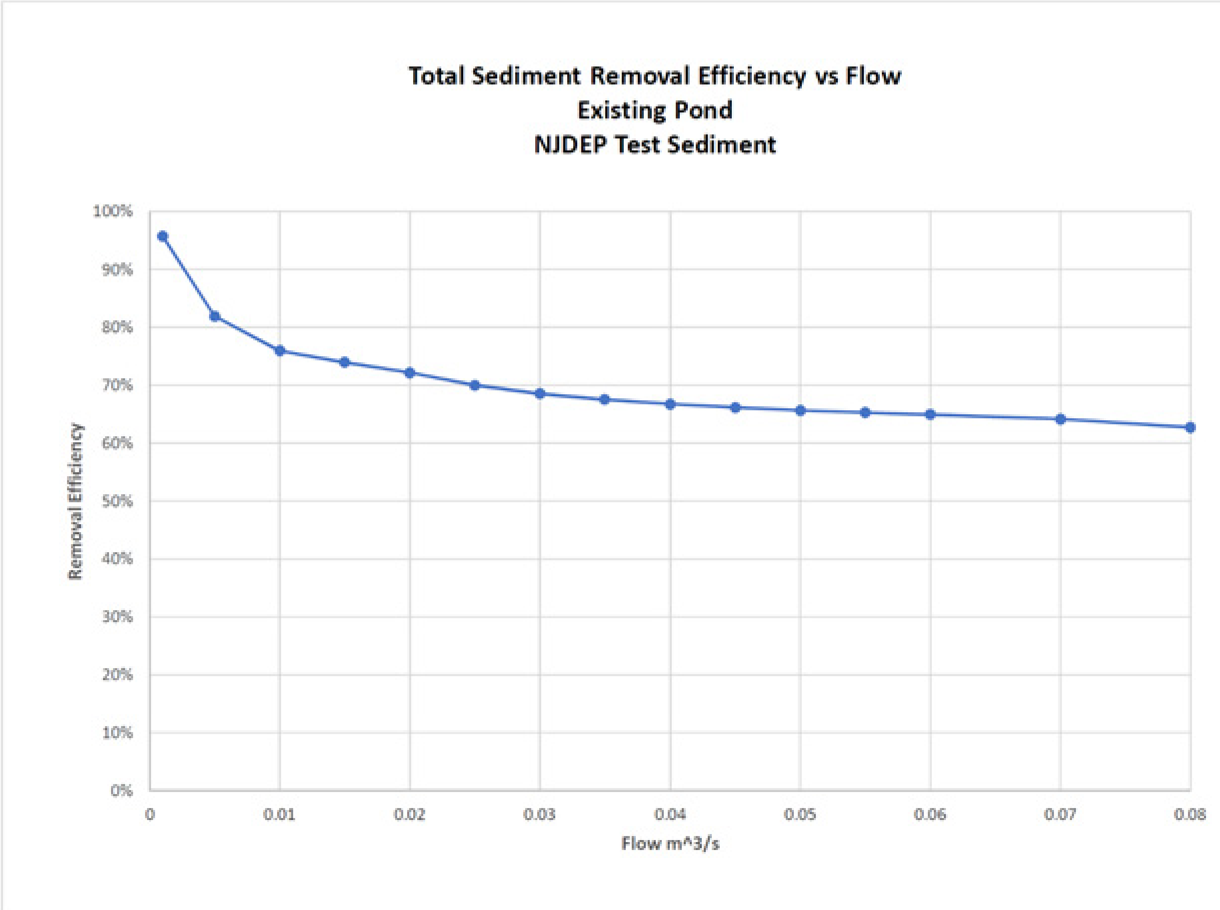


To estimate removal efficiency of the pond based on the simulated flow rates it was necessary to understand the size of the existing sediment. If the sediment in the runoff is very fine-grained ("fines"), less of it is removed by the pond. Conversely, if the sediment is coarse-grained, more of it is removed by the pond. Unfortunately, a detailed particle size distribution is not available for the existing runoff from the site. In the absence of site-specific data, the particle size distribution for the New Jersey Department of Environmental Protection (NJDEP) standard test sediment (Figure 7) was adopted. This is a representative particle size distribution used by NJDEP in the standardized testing of various stormwater treatment devices.

NJDEP Test Sediment	
Size	Percent Passing
[microns]	%
1000	100
500	95
250	90
150	75
100	60
75	50
50	45
20	35
8	20
5	10
2	5



Combining the particle size distribution with the various removal efficiency curves for the pond, we developed an overall treatment rating curve for the pond which shows the estimated TSS removal as a function of flow rate (Figure 8).



This overall treatment rating curve was then combined with the flow exceedance curve from the 37-year continuous simulation model to estimate the average annual removal of total suspended solids by the pond. Using this approach, based on the simulated historic rainfall data, the existing pond is estimated to remove approximately 90.1% of TSS on an annual basis.

This is a relatively high removal efficiency. The catchment area draining to the pond is quite small, so the flow rates through the pond are quite low. Accordingly, the flow velocities through the pond are also quite low. Based on the assumed particle size distribution, the results indicate a high removal efficiency on an annual basis.

Valuation of Water Quality Benefit

Based on the foregoing, it is apparent that the pond provides temporary attenuation of stormwater flows, providing for the reduction of total suspended solids (TSS). The modelling demonstrated an increase in TSS reduction for an enhanced pond. Here we review the economic considerations of an engineered alternative capable of similar reductions. The economic analysis includes an assessment of (1) the upfront, or capital costs of three infrastructure alternatives – the existing pond, the enhanced pond, and the grey infrastructure alternative, (2) the monitoring, operations and maintenance (O&M) costs of each of the three aforementioned alternatives, and (3) a lifecycle analysis of the three alternatives.

Capital valuation of infrastructure alternatives

An engineered alternative to the pond was identified through consultations with the District.[4] A range of structural treatment devices were proposed, including Vortechs Separators, Stormceptors and CDS units. The decision to proceed with Stormceptors for the purpose of an economic analysis was agreed upon as the District already has one in use and is familiar with the operations and maintenance requirements.

Suppliers of Stormceptors were contacted to obtain a quote for options that provide treatment of 90% to 95% TSS removal for a catchment of 8.035 hectares with 60.8% impervious areas. Due to the large area and the water quality targets, the suppliers recommended a treatment train consisting of a Stormceptor in line with a Jellyfish Filter. The upstream Stormceptor would reduce the size of the Jellyfish Filter required as the Stormceptor pre-treats the coarse particles, reducing the maintenance load on the Jellyfish Filter. Appendices D and E provide Supplier Sizing Reports.

The treatment train would consist of the following:

1. Stormceptor EFO10 – Removes 52% TSS for the particle size distribution
2. Jellyfish JF8-10-2 – Completes removal of up to 80% TSS for the particle size distribution

This combination of engineered infrastructure components do not meet the same reduction levels of TSS as the focus natural asset. Treatment up to 90 – 95% would require additional treatment measures such as infiltration or bioretention.

Table 4 provides a comparison of the capital costs for the three infrastructure options – the existing pond, the enhanced pond, and the grey infrastructure alternative. The pond in its current state has no capital costs, whereas the enhanced pond will require extending the channel length by 60.1 meters. We obtained an estimate for this from the Canadian Nursery Landscape Association for an enhanced grass swale.[5] The cost was estimated at $61.12/m^2. The enhanced pond stipulates an increase of 450.75m^2 (7.5m x 60.1m), which amounts to $27,549.84.

The engineered alternative costs were provided by suppliers. Installation was estimated at 35% of purchase costs. The capital costs for the engineered alternative does not include taxes and freight and as such, should be considered a lower-bound estimate. Given these considerations, the upfront cost of the engineered alternative is $200,070.00.

TABLE 4 – COMPARISON OF CAPITAL COSTS FOR INFRASTRUCTURE OPTIONS

Costing Components	Natural asset - current	Enhanced natural asset	Engineered alternative	
			Stormceptor	Jellyfish Filter
Purchase cost	n/a	n/a	$57,000.00	$91,200.00
Taxes & Freight	n/a	n/a	unknown	unknown
Installation	n/a	$27,549.84	$19,950.00	$31,920.00
Total	$0	$27,549.84	$76,950.00	$123,120.00
			$200,070.00	

* Total cost excludes taxes and freight

Monitoring, operating and maintenance costs for infrastructure alternatives

An assessment of monitoring, operating and maintenance costs was completed for the current pond, the enhanced pond and the engineered alternative (i.e. Stormceptor + Jellyfish Filter).

4 Personal communications with Tyler Madsen, Director of Operations and Development for Sparwood.

5 Canadian Nursery Landscape Association (no date). Available on line: https://cnla.ca/learn/life-cycle-cost-analysis-of-stormwater-management-methods.

The natural asset of focus in this project - the current pond - only requires trimming of vegetation, which has been completed by students in the Sparwood region and has no or insignificant associated cost.[6]

The enhanced natural asset – the elongated pond – would require vegetative planting, which would assist in capturing sediments. The annual maintenance cost of $2,128 is adapted from the Canadian Nursery Landscape Association and represents the annualized maintenance cost at 25 years for a naturalized stormwater pond, which includes planting, weeding, waterfowl deterrence and cleaning of the inlet and outlet pipes. We determined this to be a close approximation of the maintenance requirements for the enhanced natural asset.

The engineered alternative – the Stormceptor unit and Jellyfish Filter unit – will require flushing and vacuuming annually, as well as replacement filters every 2-5 years. The cost of flushing and vacuuming was estimated by the City, who owns its own flush trucks. The estimate is based on the rental fee ($100/hour), operator salaries (2 operators at $50/hour) and inspection and cleaning time (8 hours), for a total of $1,600/year. The cost of replacement filters was obtained from the suppliers. We assumed regular maintenance practices and extended the replacement timing to the maximum of every 5 years.

While not a regulatory requirement, monitoring of water quality to assess the effectiveness of the natural asset over time is recommended. As this cost is common to all, the amount was not included in this analysis.

TABLE 5 – MONITORING, OPERATING AND MAINTENANCE COSTS FOR INFRASTRUCTURE OPTIONS

Maintenance categories	Frequency	Natural asset - current	Enhanced natural asset	Engineered alternative
Planting & weeding of vegetation; cleaning of inlet and outlet pipes		n/a	$2,128.00	n/a
Trimming of vegetation		nil	nil	nil
Inspection, flushing and vacuuming	Annually			$1,600
Filter replacement	Every 5 years			$10,000

* does not include water quality monitoring, which is common to all options

Lifecycle Cost Comparisons (over 25 years)

Table 6 combines the information above into a lifecycle cost comparison. A timeframe of 25 years was used as this reflects a reasonable long-term planning horizon for municipal stormwater infrastructure.

A discount rate was chosen to assess the economic costs of investments across time as a net present cost (NPC). A rate of 5% was chosen, given that civil infrastructure projects generally use a discount rate of 3 – 5%.

End-of-life comparisons were not included as they occurred outside of the 25-year timeframe for each alternative. The pond does not have an end of life, nor does the enhanced pond. The engineered alternative's concrete components last 100+ years, where its fiberglass components last 50+ years. Its filters, however, last only 5 years. As such, the replacement costs for the filters were included in this analysis.[7]

With the considerations outlined above, we found the current-day costs of each option as follows:

6 Personal communications with Tyler Madsen, Director of Operations and Development for Sparwood.

7 https://www.codot.gov/programs/research/pdfs/2006/discountrate.pdf; http://www.wisconcrete.org/wp-content/uploads/2016/02/5b-Wathne-LCCA-Fundamentals.pdf

- The natural pond in its current state has a 25-year cost of $0
- The enhanced pond has a 25-year cost of approximately $64,000
- The engineered alternative has a 25-year cost of approximately $248,000.

TABLE 6 – LIFECYCLE COST COMPARISONS

Year	Natural asset - current	Enhanced natural asset	Engineered alternative
0	$0	$27,549.84	$200,070
1	$0	$2,128.00	$1,600
2	$0	$2,128.00	$1,600
3	$0	$2,128.00	$1,600
4	$0	$2,128.00	$1,600
5	$0	$2,128.00	$11,600
6	$0	$2,128.00	$1,600
7	$0	$2,128.00	$1,600
8	$0	$2,128.00	$1,600
9	$0	$2,128.00	$1,600
10	$0	$2,128.00	$11,600
11	$0	$2,128.00	$1,600
12	$0	$2,128.00	$1,600
13	$0	$2,128.00	$1,600
14	$0	$2,128.00	$1,600
15	$0	$2,128.00	$11,600
16	$0	$2,128.00	$1,600
17	$0	$2,128.00	$1,600
18	$0	$2,128.00	$1,600
19	$0	$2,128.00	$1,600
20	$0	$2,128.00	$11,600
21	$0	$2,128.00	$1,600
22	$0	$2,128.00	$1,600
23	$0	$2,128.00	$1,600
24	$0	$2,128.00	$1,600
25	$0	$2,128.00	$11,600
Net present cost	$0	$63,792.98	$248,126.80

Natural Asset Co-benefits

The Sparwood natural asset assessment focusses narrowly on the value of water quality improvements resulting from the of the pond at the storm outlet, as is evident in Table 2. However, the pond and other natural assets in the Sparwood area have functions that provide important co-benefits including:

1. Improved water quality for downstream communities
2. Improved stream health/biodiversity
3. Improved recreational, specifically fishing, opportunities

For example, forests and wetlands in and around Sparwood provide water filtration services that contribute to improved water quality for the residents of Sparwood and downstream communities including Fernie (population 5,249), Hosmer (population 115) and Elko (population 163). Water quality is a particular concern for this area given current and historical selenium concentrations in the surface waters of the Elk River. Such concentrations have been increasing since the 1990s as a result of open-pit coal mining activities in the area.[8] Selenium is found in coal rich deposits like those underlying much of the Elk Valley, where Teck Resources owns and operates five metallurgical coal mines. While selenium is a naturally occurring element and is essential to human health in very small doses, it can become toxic at higher levels and it is harmful to aquatic life and other egg-laying creatures, even at low levels.[9] Selenium persists and bioaccumulates and can be transferred through the food chain, thus having the potential to cause long-term damage to the environment, particularly near areas where continuous emissions occur.[10] To safeguard aquatic life, B.C.'s water quality guidelines recommend selenium levels not exceed 2 parts per billion.[11] Those same guidelines limit selenium in drinking water to 10 parts per billion.

Selenium will remain a concern in the area for the foreseeable future. Teck is planning an $88.5 million expansion at its existing Fording River mine. The Swift project will produce an additional 170 tonnes of coal over 25 years, according to a B.C. government news release.[12] Over the next 5 years, Teck expects to invest between $850 and $900 million in water treatment facilities. The company is experimenting with 'saturated rock fill' methods in an attempt to reduce the amount of selenium entering the environment via waste rock piles. Despite this, a 2014 water quality plan focuses on attempting to stabilize selenium levels in the water until 2023. B.C. does not anticipate that Teck will begin the work of lowering selenium levels in the watershed until the 2030s.

Notwithstanding this, it is important to note that many natural assets in the Sparwood area filter toxins and prevent them from entering the Elk River. Downstream communities benefit from this, and will continue to do so provided the natural assets remain intact and functional.

Benefits of selenium filtering services include maintaining aquatic biodiversity, including habitat for the westslope cutthroat trout (Oncorhynchus clarkii lewisi or "Cutties"), an indicator of ecosystem health. In 2014, an expert report prepared for Environment Canada warned that selenium pollution from mining in the Elk Valley was negatively impacting fish. The report warned that increases in selenium pollution would inevitably lead to "a total population collapse of sensitive species like the westslope cutthroat trout.".[13] These fish are thought to be one of the first species to populate B.C. after the last ice age, but are now found in only in a small fragment of its historic habitat. The oxbows of the Upper Fording, a tributary of the Elk River, have created unique conditions for a particular population of westslope cutthroat trout that have remained genetically distinct, not having bred or 'hybridized' with other nearby populations. Pacific populations of this species are currently listed by the federal government as a species of special concern.

8 Lemly, 2014

9 Linnitt, 2018

10 Ibid

11 B.C. Ministry of Environment & Climate Change Strategy, 2019a

12 Ibid

13 Lemly, D., 2014, p.4

Beneficiaries of aquatic biodiversity include both local populations (the population of the Elk Valley is 15,000) and visitors to Elk Valley. The latter includes anglers pursuing fishing opportunities on the Elk River and contributes to the region's economic base.

Indeed, the Kootenay Rockies region in which the Elk Valley is located, is a popular tourist destination. The area received 18.9 million overnight tourist visits in 2014, and generated $9.2 billion in related spending.[14] A majority of the tourists (> 75%) visiting the Kootenay Rockies region are from Alberta and other parts of B.C. Sparwood received close to 55,000 visitors in 2013, with the vast majority visiting between July-September when fishing is at a peak. Anglers fish westslope cutthroat trout and bull trout. Local highways and forest service roads run parallel to the Elk River from Elko to Elkford and its tributaries throughout the valley. The Elk River fishery is one of seven deemed "classified waters" in southeastern B.C. Classified waters are regulated and have a specific number of angler days assigned to guides, of which there are approximately 20 offering services in the Elk Valley. Non-guided anglers also make extensive use of the river, with an estimated 9,000 non-guided angler days used during each season. Total room revenue in 2012 for the Kootenay Rockies region was $81 million.[15] A portion of this value would be attributable to angling in the Sparwood region.

14 Destination BC, 2017

15 Penfold & Meyer, 2015

In addition to the existing pond under historic rainfall conditions (Scenario 1), the pond was evaluated under a climate change scenario (Scenarios 2 and 4), as well as upgraded pond scenarios (Scenarios 3 and 4). The results of the modelling of these scenarios follow.

Scenario 2: Existing Pond Geometry with Climate Change Allowance

To estimate the potential future impacts of climate change on the design rainfall data, we reviewed the Plan2Adapt information provided by the Pacific Climate Impacts Consortium (PCIC).[16] Based on this tool, the average annual precipitation in the East Kootenay Region is expected to increase by 12% by the 2080's (based on the 90th percentile of the various Global Circulation Models).

To account for this predicted impact, we increased the rainfall by 12% at each hourly timestep in the historic rainfall file. We then reran the 37-year continuous simulation with the PCSWMM model, and extracted the timeseries for flows entering the pond to develop a new exceedance curve (Figure 9).

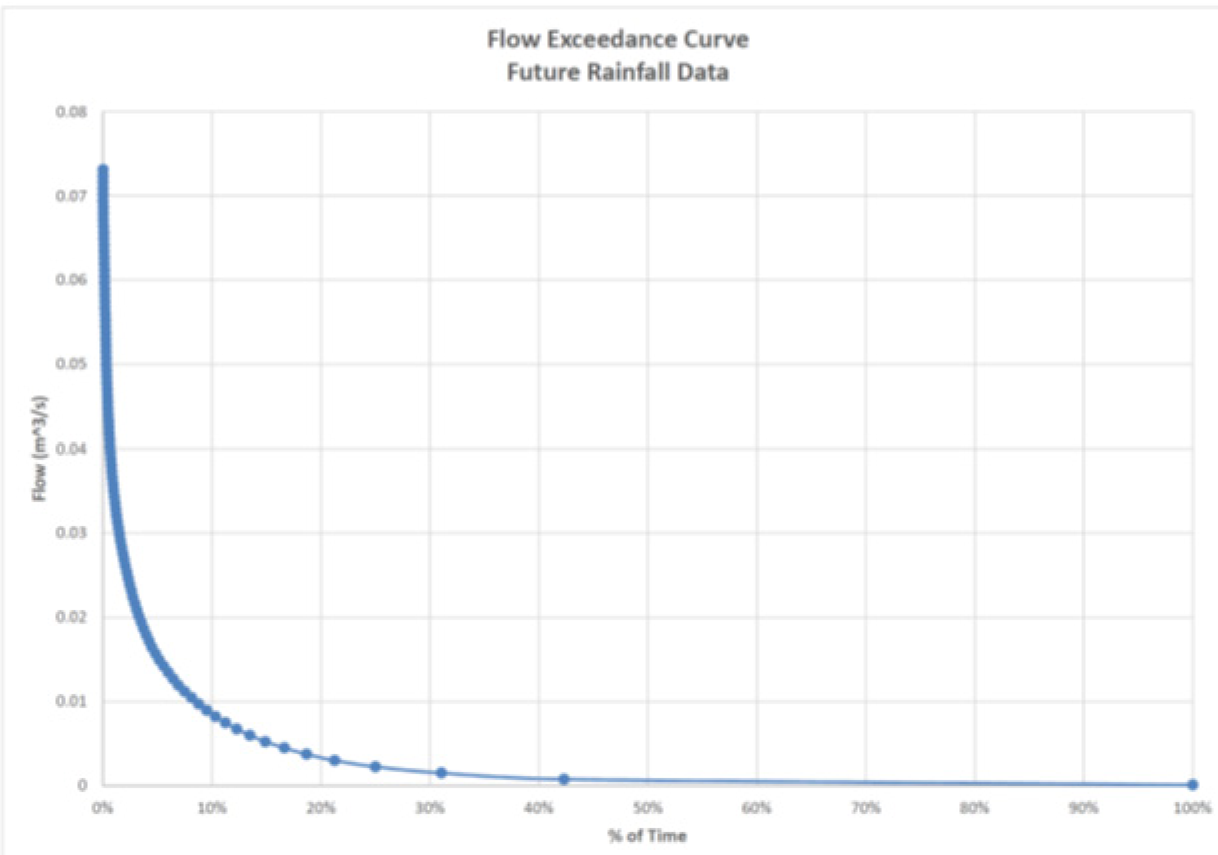


Figure 9 – Flow exceedance curve for climate change data set

We used the same approach outlined for the existing condition scenario to estimate the overall removal efficiency of the pond. Under a future climate change scenario with a 12% increase in average annual precipitation, the existing pond is estimated to remove approximately 89.8% of TSS on an annual basis.

The estimated removal efficiency is slightly lower under the climate change scenario because flow rates are expected to increase, which will increase velocities through the pond. As velocities through the pond increase, retention time is reduced, so less sediment is able to settle out. The reduction in the average annual removal efficiency of the pond is quite low because at the upper end of the range, larger particles are 100% removed at the flows seen in the pond. Even with a 12% increase in rainfall, and the corresponding increase in runoff, the larger particles still experience 100% removal for most of the flow spectrum.

16 PCIC, 2013.

Scenario 3: Enhanced Pond Geometry with Historic Rainfall Data

Recognizing that removal efficiency of the pond is based on the pond geometry, additional analysis was completed to evaluate the potential benefits of increasing pond dimensions. For this potential enhanced pond scenario, the pond width was kept at 7.5 m, but the length increased from 19.9 m to 80 m. By increasing the length of the pond, the retention time is increased, providing more opportunity for sediment to settle.

Using the same methodology from MoE outlined above, new removal efficiencies curves for various particle sizes for the enhanced pond (Figure 10) were established. This information was combined with the assumed particle size distribution to develop an updated overall removal efficiency rating curve for the enhanced pond (Figure 11).

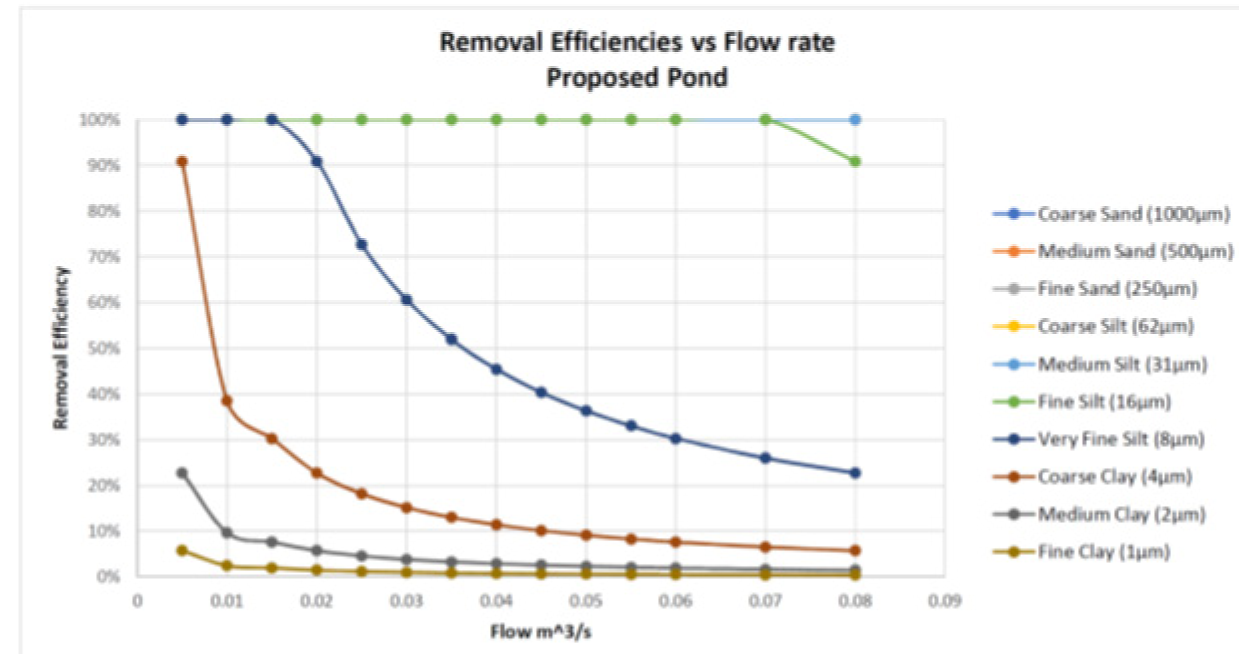


Figure 10 - Removal Efficiency Curves for Various Particle Sizes – Enhanced Pond

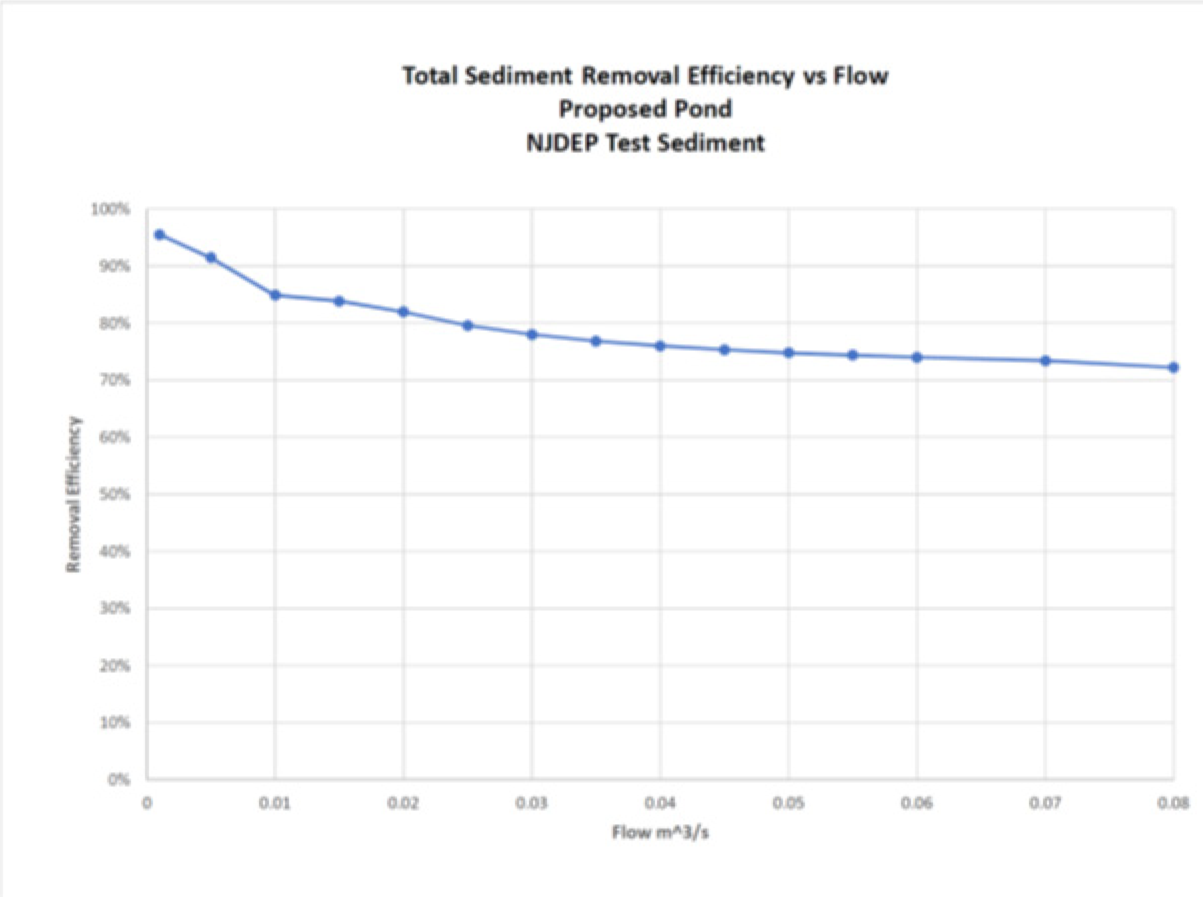


Figure 11 - Overall removal efficiency rating curve for the enhanced pond

Based on the simulated historic rainfall data (without any allowance for climate change), the enhanced pond is estimated to remove 94.1% of TSS annually. This is an increase compared to the existing pond geometry, and reflects the additional treatment achieved as a result of increased retention time.

Scenario 4: Enhance Pond Geometry with Climate Change Allowance

The performance of the enhanced pond using the simulated flow rate information from the climate change scenario was then assessed.

Under a future climate change scenario, the enhanced pond is estimated to remove approximately 93.9% of TSS on an annual basis. As with the existing pond geometry, the enhanced pond is expected to experience a slight reduction in average annual removal rates as a result of climate change.

Modelling Limitations

This assessment does not consider the potential for re-suspension of sediment during periods when the pond is subject to high flows which could cause turbulence.

Furthermore, the removal efficiency of the pond is highly dependent on the actual particle size distribution of the sediment in the runoff. As noted, in the absence of site-specific data, the particle size distribution for the New Jersey Department of Environmental Protection (NJDEP) standard test sediment was adopted. If the actual sediment within the runoff has a higher fines content, then removal efficiencies would be lower.

Implementation of Natural Asset Plan

By inventorying and assigning service levels, value and O&M costs to the pond and developing an understanding of climate scenarios, the District now has a basis for evidence-based actions to manage the project site and expand the work to other areas. Following are initial elements for a natural asset management plan that can be refined and elaborated in Sparwood to translate the results into core management and financial processes.

1. **Consider developing a natural asset policy**

A nature asset-management policy can formalize commitments to integrating nature into asset management at the strategic level in local governments but it is not a prerequisite for starting to incorporate natural assets into asset management.

An asset-management policy sets out the local government will do in terms of asset management and is generally council-endorsed.

The policy describes principles that the local government will follow when implementing asset-management practices to meet its strategic objectives; who will be responsible for ensuring the policy will be implemented; and the scope of assets and services covered by the policy.

An example of principles included in a good practice asset-management policy from the Federation of Canadian Municipalities Leadership in Asset Management Program include:

- **Service delivery to customers,** which centres decision-making on delivering defined levels of service that reflect customer expectations while balancing risk and affordability.
- **Long-term sustainability and resilience,** which requires that services and infrastructure assets be socio-culturally, environmentally and economically sustainable over the long term. This involves long-term planning that manages risks, incorporates triple bottom line (socio-cultural, environmental, economic) considerations, climate change awareness and development of resilience.
- **Holistic and integrated approach,** where decisions are made collaboratively across departments and disciplines.
- **Fiscal responsibility,** which requires robust asset-management decision-making processes to make the best use of available funds to deliver services to communities.
- **Innovation and continual improvement,** which recognizes that asset management is an ongoing process and that a culture of continual improvement will enable the local government to deliver services to the community and stakeholders more effectively and efficiently.

Natural assets can be included in the scope of the asset-management policy. Consideration of natural asset ownership is critical at this stage, as in some cases management and monitoring of the asset is possible without ownership (such as the management of Gibsons' aquifer), whereas in other cases negotiation with senior government is required to identify roles and responsibilities (such as watershed management). In situations where regulations are required for protection of an asset, the presence of conflicting needs may make management for local services difficult or impossible (such as the use of a provincial forest for local stormwater conveyance when the forest has an active harvesting licence). In these latter cases, a local government may wish to build a business case for further discussions with senior government officials.

A good-practice asset management policy usually starts with the policy's intent, describes how the policy will help support the achievement of the local government's strategic objectives, and lists strategic documents that it is aligned with. Strategic documents related to conservation, protection or management of natural assets such as a climate adaptation strategy, urban forest management plans, and/or source water protection plans can be included.

Example:

The City of Edmonton, AB adopted an asset management policy in 2018 that includes natural assets in its definition of infrastructure assets covered by the policy:

(City of Edmonton Asset Management Strategy)

Natural asset policy template:

The City/Town of _____ recognizes the importance of natural assets in providing vital services to the community and will include these in its inventories and asset-management practices. Examples include water bodies, wetlands and wildlife corridors.

2. **Develop a natural asset management road map**

An asset management road map is a plan to help guide local governments in implementing their strategy. It includes a path for implementing the range of improvement initiatives identified in their strategy or as a result of doing a maturity assessment. Local governments may have more than one road map. For example, one might focus on defining further engagement with stakeholders while another focuses on improving risk management decision-making.

Asset Management British Columbia developed a generic Asset Management Roadmap[17] to support local governments in developing basic asset-management practices. The road map is organized around a number of modules that break out the core components of asset management into tasks or activities that can be individually actioned. Local governments can use the road map to get started and make progress over time.

3. **Identify areas in which the project can be replicated**

- Sparwood may wish to complete the process for other sub-catchments and/or expand upon the existing analysis. In Sparwood, expanding the project to Cypress Drive is recommended as a near-term action.

To the extent that it is impractical for Sparwood to build a complete SWMM model for an entire watershed, the District also has options to link sub-catchment assessments. In this situation, users should identify a priority sub-watershed area and construct a SWMM model for that portion of the larger watershed. Inflows from upstream can be added manually to the sub-watershed model by specifying a constant or time-varied inflow value at a junction. These estimates can be refined as resources become available for in-depth analysis. Similarly, the outflow time series from a sub-watershed can serve as input to a further downstream sub-watershed. This allows for a step-by-step natural asset valuation for a large watershed.

Workflow considerations are based on open-source EPA SWMM 5.1.010 software to develop the biophysical model. However, there are several proprietary software suites, such as PCSWMM and XPSWMM, that can be added to the engine to strengthen analysis.

PCSWMM and XPSWMM integrate GIS capabilities with SWMM and make it easier to calculate sub-catchment and stream network properties. These software suites also allow for 2-dimensional flood analysis to determine the lateral extent of flooding along stream channels.

17 https://www.assetmanagementbc.ca/wp-content/uploads/Guide_for_using_the_Roadmap20-AMBC-Sept_23_2011.pdf

4. **Recognize interdependencies within natural asset management**

As local governments improve coordination and integration of decision-making regarding infrastructure and asset management, they gain an ability to understand the interdependencies of different services provided to the community, and the role natural assets can play in supporting service delivery and building resilience.

Below are a few examples:

- **Broader understanding of value.** The Buttertubs Marsh in the City of Nanaimo, B.C., was once valued only for aesthetic and recreational services. The City recently analyzed the stormwater-related services it provides and determined that it provides stormwater storage for the one-in-100-year storm and was resilient under climate change scenarios. As a result, the Marsh has been valued at $4.6 million and the analysis enables the city to allocate resources to ensure services are maintained.
- **Integration of transportation planning and stormwater management:** Where staff responsible for transportation services and stormwater management historically worked in their own silos with little coordination, there are now examples of how collaboration can lead to new approaches that integrate natural assets (or green infrastructure) more explicitly into infrastructure design. For example, traffic islands, which are typically unattractive tracts of concrete or ashphalt, can contribute to urban heat island effect and force stormwater runoff into sewers and pipes, where it needs treatment. Some cities are transforming these spaces into rain gardens that provide benefits including: capturing and filtering stormwater on-site, reducing the urban heat island effect, protecting biodiversity, and providing aesthetic value to the community.
- **Integration of parks and recreation and stormwater management**: Some cities are recognizing the important role that parks can play in mitigating flooding. For example, a park in Corktown Commons, a neighbourhood in Toronto, Ontario, has been designed to flood when the Don River runs high.
- **Land use and transportation**: Some cities are recognizing the long-term impacts of land-use decisions and are designing their built environments to protect the natural environment and biodiversity. For example, the City of Edmonton, Alberta, won an award for incorporating wildlife passages that enable wildlife to move safely between natural areas in the city.

Appendix A: Launch workshop agenda

Municipal Natural Assets Initiative (MNAI) – Cohort 1 Launch Workshop

For Sparwood

June 13 2018 - 0800-1700

Location:

Draft Annotated Agenda

Meeting purpose

Launch MNAI project.

Objectives

1. Ensure common understanding of: MNAI method, process & milestones; project details; roles, responsibilities and expectations
2. Develop detailed roadmap towards Milestone 1, including understanding of roles and responsibilities

Anticipated outputs

1. Final project document (although some details may continue to evolve)
2. Roadmap towards Milestone 1* including specific dates and times for regular check-ins and product deadlines.
3. Description of next steps

Meeting documents (available at https://tinyurl.com/y8ynjjvu)

- Signed MOU
- Project document
- MNAI introductory presentation
- MNAI presentation on data needs and collection
- Enlarged maps of site (provided by local government)
- Workplan template (to fill out at end of meeting)
- MNAI guidance document
- MNAI Communications plan
- ***Note on Milestone 1**
- Milestone 1 needs to be reached by Week 1 of September 2018.
- The Milestone is: Creating foundation: biophysical characteristics and condition of municipal natural assets are understood and documented, all data is gathered.
- Milestone 1 webinar will occur in first 2 weeks of September with objective of extracting and sharing key lessons or findings from data gathering (e.g. are there particular challenges or opportunities in terms of finding good data, and lessons that can be shared.
- MNAI team will provide help desk support between launch workshop and Milestone 1 webinar to make sure Milestone is reached.

AGENDA			
Time	**Item**	**Lead**	**Outcome & Comments**
Part 1: Creating a common understanding			
0800-0815	Welcome and introductions	Local government	
0815-0900	Overview of MNAI process: how we got here and what to expect	Roy	Objective: ensure participants understand have shared understanding of MNAI and what to expect
0900-1030	Overview of project document: goals, objectives, outputs of project	Local government with Michelle and Jeff	Objective: ensure common understanding of project
1030-1230	Visit site	Local government	Objective: gather additional information/ context on site
1230-1330	Working Lunch	All	Discussion: did the site visit change anyone's understanding of the project? Lunch provided by local government
Part 2: Roles, responsibilities and actions			
1330-1430	Introduction to goals, objectives and activities towards Milestone 1	Michelle & Jeff	Objective: ensure common understanding of what is required for effective data gathering to meet project goals
1430-1530	Discussion on roles and responsibilities towards Milestone 1	Michelle & Jeff with support from Roy	
15h30-16h30	Conclusions, next steps	Roy, Michelle, Jeff	[This part can be shortened or used to cover additional issues raised during the day]

List of Participants:

Tyler Madsen - Director of Operations, District of Sparwood

Kristi Bilodeau - Director of Finance, District of Sparwood

Terry Melcer - Chief Executive Officer, District of Sparwood

Darrell Kaisner - Roads and Parks Foreman, District of Sparwood

Nelson Wight - Manager of Planning, District of Sparwood

Nic Milligan – Manager of Social Responsibility, Teck Resources Limited

Meredith Hamstead, Climate Action Program Coordinator, Columbia Basin Trust

Roy Brooke – Executive Director, MNAI

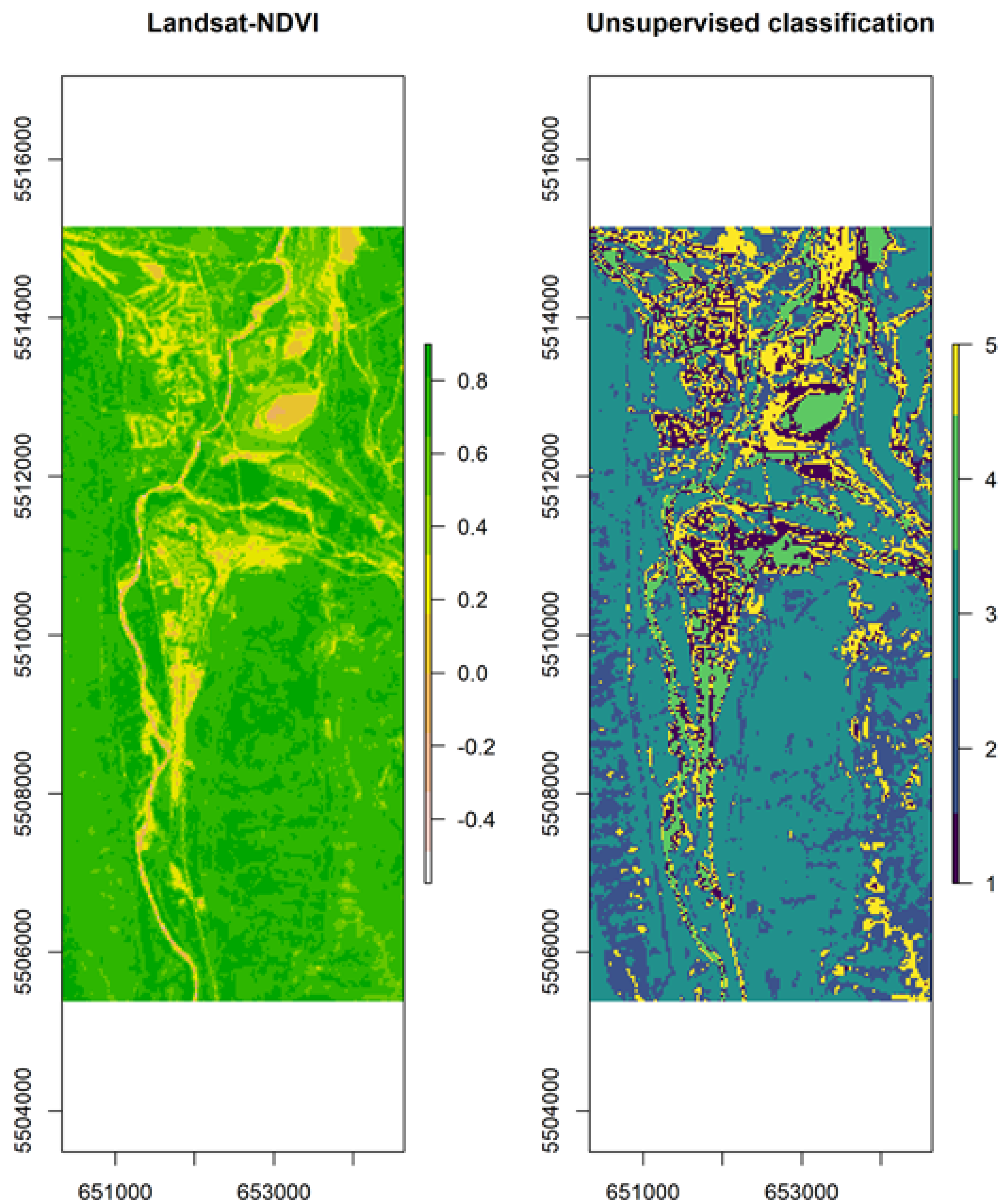
Michelle Molnar – Technical Director, MNAI

Jeff Wilson – Technical Support, MNAI

Josh Thiessen – Technical Support, MNAI

Appendix B: Asset Inventory Unsupervised Classification

Unsupervised classification used k-means clustering to establish 5 classes from the NDVI data. Results are shown below.



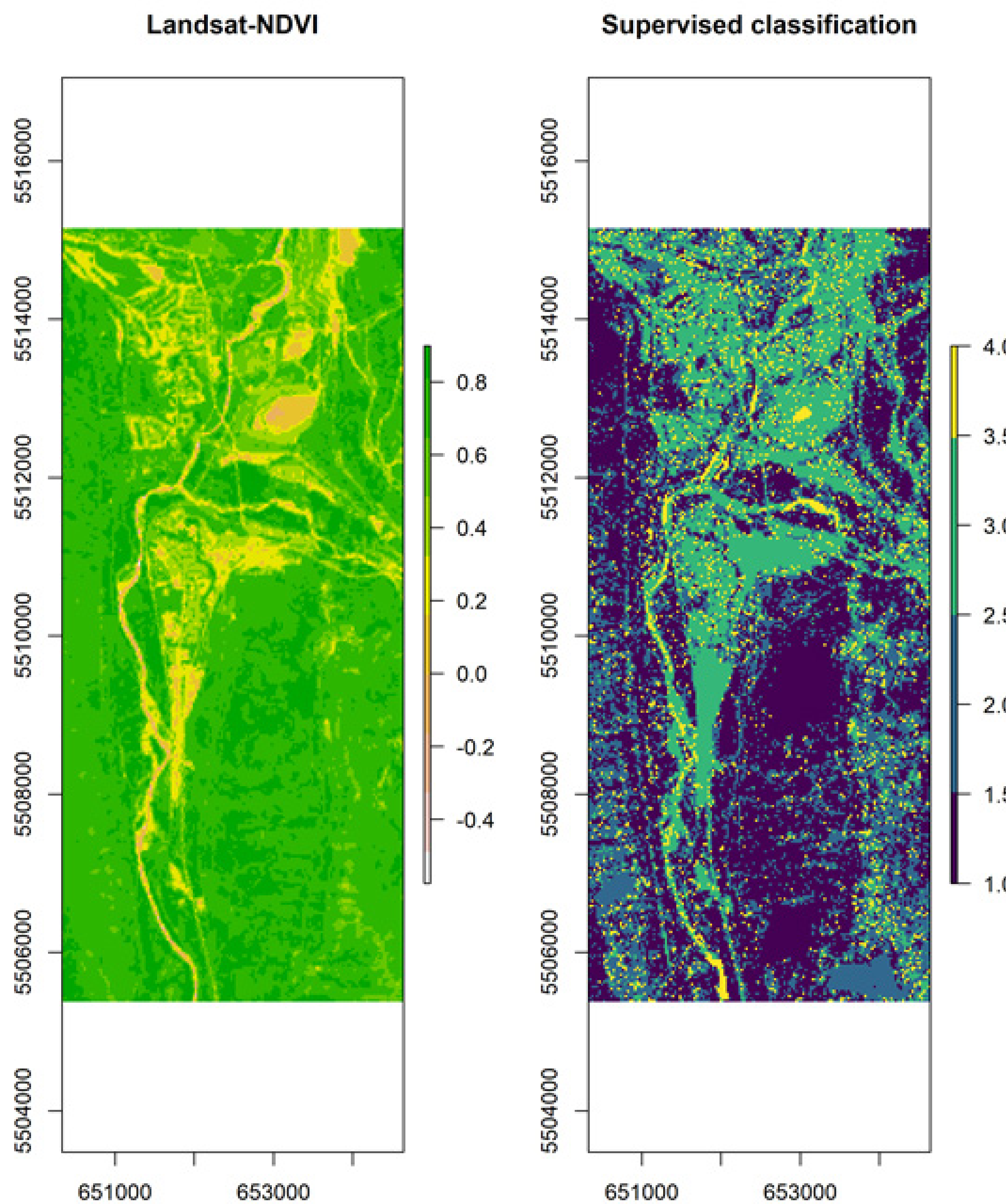
Appendix C: Asset Inventory Supervised Classification

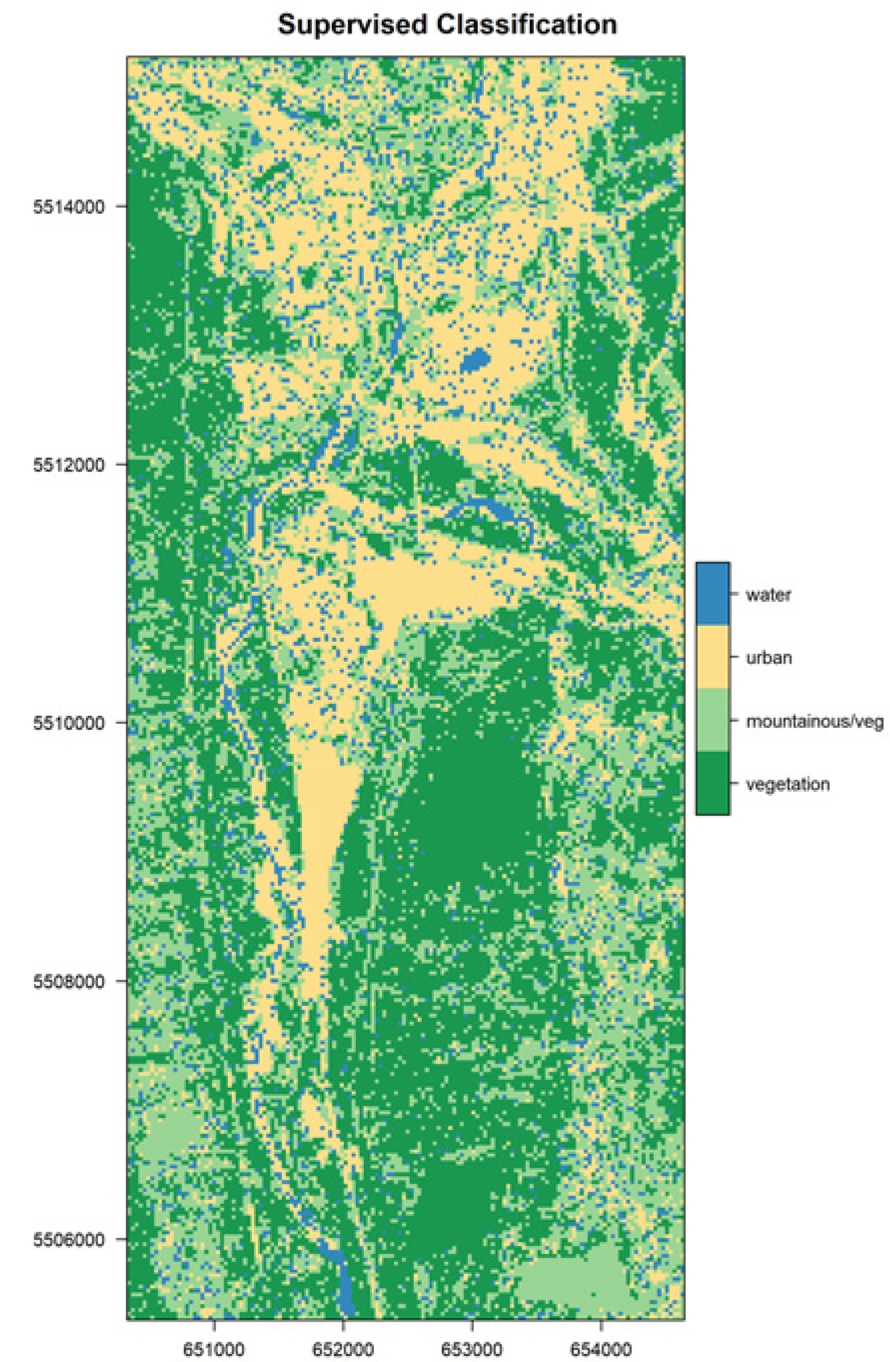
Four classes were developed from visual inspection of Landsat images and NDVI. These classes were then used as training sites for a supervised classification using Random Forests.

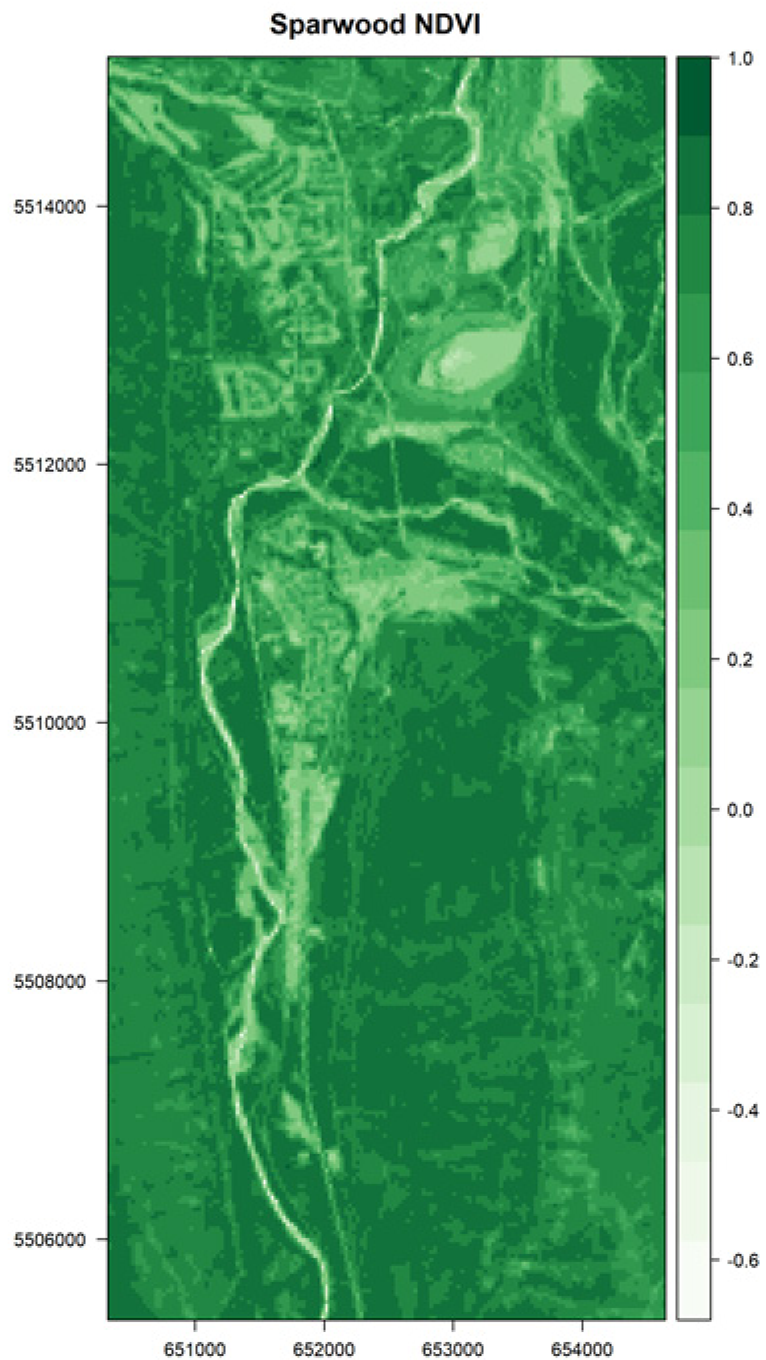
These classes aim to summarize the general land classes of Sparwood:

- Vegetated
- Mountainous vegetated
- Urban
- Water

In both supervised and unsupervised, there is difficulty with accurately differentiating between areas where urban and water mix (e.g. along the river).


Landsat-NDVI
Supervised classification
5516000
5514000
5512000
5510000
5508000
5506000
5504000
651000
653000
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4


Supervised Classification
5514000
5512000
5510000
5508000
5506000
651000
652000
653000
654000
water
urban
mountainous/veg
vegetation



Appendix D: Stormceptor Sizing Report

Stormceptor®

The Langley Concrete Group

Stormceptor® EF Sizing Report

ESTIMATED NET ANNNUAL SEDIMENT (TSS) LOAD REDUCTION STORMCEPTOR®

Province :	British Columbia
City :	Sparwood
Nearest Rainfall Station :	CRANBROOK AP
NCDC Rainfall Station Id :	0115
Years Of Rainfall Data :	12
Site Name :	Associated Sizing (Sparwood)
Drainage Area (ha) :	8.035
% Imperviousness :	60.80
Runoff Coefficient 'c' :	0.66
Partical Size Distribution :	CA ETV
Target TSS Removal (%) :	50.0
Require Hydrocarbon Spill Capture?	Yes
Upstream Flow Control?	No
Required Water Quality Runoff Volume Capture (%) :	
Peak Conveyance (maximum) Flow Rate (L/s) :	
Site Sediment Transport Rate (kg/ha/yr) :	

Project Name :	Associated Sizing
Project Number :	20017
Designer Name :	Joel Shimozawa
Designer Company :	The Langley Concrete Group
Designer Email/Phone :	jshimozawa@langleyconcretegroup.com
EOR Name :	
EOR Company :	
EOR Email/Phone :	

Net Annual Sediment (TSS) Load Reduction Sizing Summary

Stormceptor Model	TSS Removal Provided (%)
EFO4	31
EFO6	40
EFO8	47
EFO10	52
EFO12	56

Recommended Stormceptor EFO Model : EFO10

Estimated Net Annual Sediment (TSS) Load Reduction (%) : 52

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info@imbriumsystems.com **Page 1** **www.imbriumsystems.com**

THIRD-PARTY TESTING AND VERIFICATION

► **Stormceptor® EF and Stormceptor® EFO** are the latest evolutions in the Stormceptor® oil-grit separator (OGS) technology series, and are designed to remove a wide variety of pollutants from stormwater and snowmelt runoff. These technologies have been third-party tested in accordance with the Canadian ETV **Procedure for Laboratory Testing of Oil-Grit Separators** and performance has been third-party verified in accordance with the **ISO 14034 Environmental Technology Verification (ETV)** protocol.

PERFORMANCE

► **Stormceptor® EF and EFO** remove stormwater pollutants through gravity separation and floatation, and feature a patent-pending design that generates positive removal of total suspended solids (TSS) throughout each storm event, including high-intensity storms. Captured pollutants include sediment, free oils, and sediment-bound pollutants such as nutrients, heavy metals, and petroleum hydrocarbons. Stormceptor is sized to remove a high level of TSS fromthe frequent rainfall events that contribute the vast majority of annualrunoff volume and pollutant load. The technology incorporates an internal bypass to convey excessive stormwater flows from high-intensity storms through the device without resuspension and washout (scour) of previously captured pollutants. Proper routine maintenance ensures high pollutant removal performance and protection of downstream waterways.

PARTICAL SIZE DISTRIBUTION (PSD)

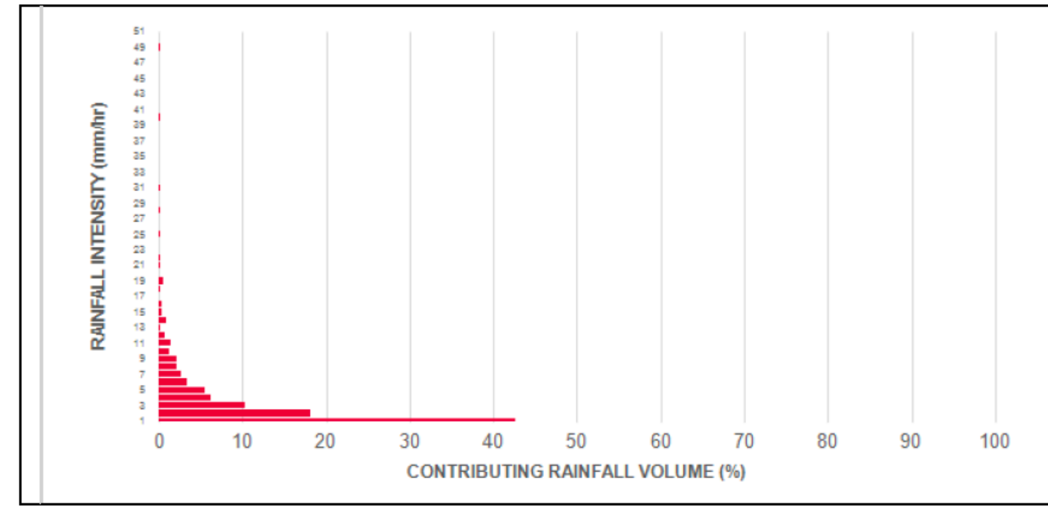
► The **Canadian ETV PSD** shown in the table below was used, or in part, for this sizing. This is the identical PSD that is referenced in the Canadian ETV ***Procedure for Laboratory Testing of Oil-Grit Separators*** for both sediment removal testing and scour testing. The Canadian ETV PSD contains a wide range of particle sizes in the sand and silt fractions, and is considered reasonably representative of the particle size fractions found in typical urban stormwater runoff.

Particle Size (µm)	Percent Less Than	Particle Size Fraction (µm)	Percent
1000	100	500-1000	5
500	95	250-500	5
250	90	150-250	15
150	75	100-150	15
100	60	75-100	10
75	50	50-75	5
50	45	20-50	10
20	35	8-20	15
8	20	5-8	10
5	10	2-5	5
2	5	<2	5

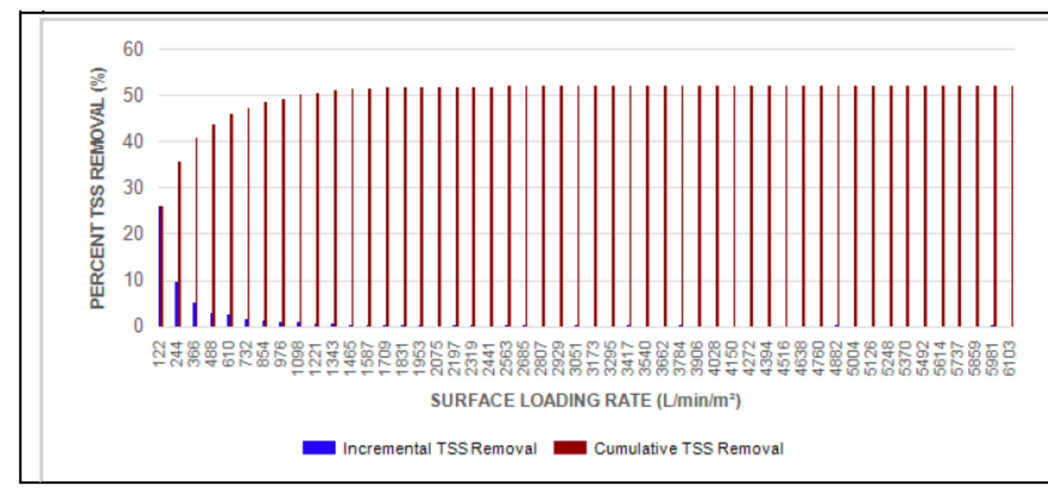
RainFall Intensity (mm / hr)	Percent Rainfall Volume (%)	Cumulative Rainfall Volume (%)	Flow Rate (L/s)	Flow Rate (L/min)	Surface Loading Rate (L/min/m²)	Removal Efficiency (%)	Incremental Removal (%)	Cumulative Removal (%)
1	42.7	42.7	14.85	891.0	122.0	61	25.9	25.9
2	18.2	60.9	29.70	1782.0	244.0	53	9.6	35.5
3	10.4	71.3	44.55	2673.0	366.0	49	5.1	40.6
4	6.3	77.6	59.40	3564.0	488.0	46	2.9	43.5
5	5.6	83.2	74.25	4455.0	610.0	42	2.3	45.9
6	3.3	86.5	89.10	5346.0	732.0	41	1.4	47.2
7	2.7	89.2	103.95	6237.0	854.0	41	1.1	48.3
8	2.1	91.3	118.80	7128.0	976.0	40	0.8	49.2
9	2.1	93.4	133.65	8019.0	1098.0	39	0.8	50.0
10	1.3	94.7	148.50	8910.0	1221.0	37	0.5	50.4
11	1.5	96.2	163.35	9801.0	1343.0	35	0.5	51.0
12	0.8	97.0	178.20	10692.0	1465.0	33	0.3	51.2
13	0.2	97.2	193.05	11583.0	1587.0	30	0.1	51.3
14	0.9	98.1	207.90	12474.0	1709.0	28	0.3	51.5
15	0.3	98.4	222.75	13365.0	1831.0	26	0.1	51.6
16	0.3	98.7	237.60	14256.0	1953.0	24	0.1	51.7
17	0.0	98.7	252.45	15147.0	2075.0	23	0.0	51.7
18	0.2	98.9	267.30	16038.0	2197.0	22	0.0	51.7
19	0.5	99.4	282.15	16929.0	2319.0	21	0.1	51.8
20	0.0	99.4	297.00	17820.0	2441.0	20	0.0	51.8
21	0.1	99.5	311.85	18711.0	2563.0	19	0.0	51.9
22	0.1	99.6	326.70	19602.0	2685.0	18	0.0	51.9
23	0.0	99.6	341.55	20493.0	2807.0	18	0.0	51.9
24	0.0	99.6	356.40	21384.0	2929.0	18	0.0	51.9
25	0.1	99.7	371.25	22275.0	3051.0	18	0.0	51.9

RainFall Intensity (mm / hr)	Percent Rainfall Volume (%)	Cumulative Rainfall Volume (%)	Flow Rate (L/s)	Flow Rate (L/min)	Surface Loading Rate (L/min/m²)	Removal Efficiency (%)	Incremental Removal (%)	Cumulative Removal (%)
26	0.0	99.7	386.10	23166.0	3173.0	18	0.0	51.9
27	0.0	99.7	400.95	24057.0	3295.0	18	0.0	51.9
28	0.2	99.9	415.80	24948.0	3417.0	18	0.0	51.9
29	0.0	99.9	430.65	25839.0	3540.0	18	0.0	51.9
30	0.0	99.9	445.50	26730.0	3662.0	18	0.0	51.9
31	0.2	100.1	460.34	27621.0	3784.0	18	0.0	52.0
32	0.0	100.1	475.19	28512.0	3906.0	18	0.0	52.0
33	0.0	100.1	490.04	29403.0	4028.0	18	0.0	52.0
34	0.0	100.1	504.89	30294.0	4150.0	18	0.0	52.0
35	0.0	100.1	519.74	31185.0	4272.0	18	0.0	52.0
36	0.0	100.1	534.59	32076.0	4394.0	18	0.0	52.0
37	0.0	100.1	549.44	32967.0	4516.0	18	0.0	52.0
38	0.0	100.1	564.29	33858.0	4638.0	18	0.0	52.0
39	0.0	100.1	579.14	34749.0	4760.0	18	0.0	52.0
40	0.1	100.2	593.99	35640.0	4882.0	18	0.0	52.0
41	0.0	100.2	608.84	36531.0	5004.0	18	0.0	52.0
42	0.0	100.2	623.69	37422.0	5126.0	18	0.0	52.0
43	0.0	100.2	638.54	38313.0	5248.0	18	0.0	52.0
44	0.0	100.2	653.39	39204.0	5370.0	18	0.0	52.0
45	0.0	100.2	668.24	40095.0	5492.0	18	0.0	52.0
46	0.0	100.2	683.09	40986.0	5614.0	18	0.0	52.0
47	0.0	100.2	697.94	41877.0	5737.0	18	0.0	52.0
48	0.0	100.2	712.79	42768.0	5859.0	18	0.0	52.0
49	0.1	100.3	727.64	43659.0	5981.0	18	0.0	52.0
50	0.0	100.3	742.49	44550.0	6103.0	18	0.0	52.0
							Estimated Net Annual Sediment (TSS) Load Reduction =	52 %

RAINFALL DATA FROM CRANBROOK AP RAINFALL STATION



INCREMENTAL AND CUMULATIVE TSS REMOVAL FOR THE RECOMMENDED STORMCEPTOR® MODEL



Stormceptor® EF Sizing Report

Maximum Pipe Diameter / Peak Conveyance

Stormceptor EF / EFO	Model Diameter (m)	Model Diameter (ft)	Min Angle Inlet / Outlet Pipes	Max Inlet Pipe Diameter (mm)	Max Inlet Pipe Diameter (in)	Max Outlet Pipe Diameter (mm)	Max Outlet Pipe Diameter (in)	Peak Conveyance Flow Rate (L/s)	Peak Conveyance Flow Rate (cfs)
EF4 / EFO4	1.2	4	90	609	24	609	24	425	15
EF6 / EFO6	1.8	6	90	914	36	914	36	990	35
EF8 / EFO8	2.4	8	90	1219	48	1219	48	1700	60
EF10 / EFO10	3.0	10	90	1828	72	1828	72	2830	100
EF12 / EFO12	3.6	12	90	1828	72	1828	72	2830	100

SCOUR PREVENTION AND ONLINE CONFIGURATION

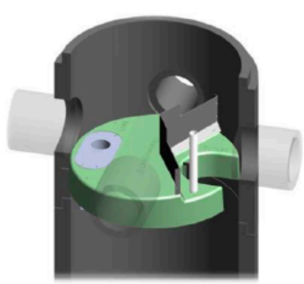
► **Stormceptor® EF and EFO** feature an internal bypass and superior scour prevention technology that have been demonstrated in third-party testing according to the scour testing provisions of the Canadian ETV **Procedure for Laboratory Testing of Oil-Grit Separators**, and the exceptional scour test performance has been third-party verified in accordance with the ISO 14034 ETV protocol. As a result, Stormceptor EF and EFO are approved for online installation, eliminating the need for costly additional bypass structures, piping, and installation expense.

DESIGN FLEXIBILITY

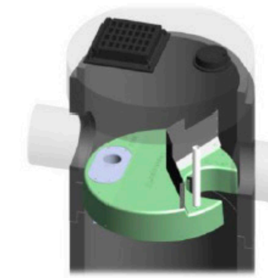
► **Stormceptor® EF** and **EFO** offers design flexibility in one simplified platform, accepting stormwater flow from a single inlet pipe or multiple inlet pipes, and/or surface runoff through an inlet grate. The device can also serve as a junction structure, accommodate a 90-degree inlet-to-outlet bend angle, and can be modified to ensure performance in submerged conditions.

OIL CAPTURE AND RETENTION

► While Stormceptor® EF will capture and retain oil from dry weather spills and low intensity runoff, **Stormceptor® EFO** has demonstrated superior oil capture and greater than 99% oil retention in third-party testing according to the light liquid re-entrainment testing provisions of the Canadian ETV **Procedure for Laboratory Testing of Oil-Grit Separators**. Stormceptor EFO is recommended for sites where oil capture and retention is a requirement.



Stormceptor® EF Sizing Report



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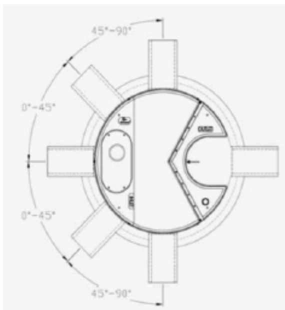
Stormceptor® EF Sizing Report



INLET-TO-OUTLET DROP

Elevation differential between inlet and outlet pipe inverts is dictated by the angle at which the inlet pipe(s) enters the unit.
0(degree)-45(degree):The inlet pipe is 1-inch (25mm) higher than the outlet pipe.
45(degree)-90(degree):The inlet pipe is 2-inches (50mm) higher than the outlet pipe.

HEAD LOSS

The head loss through Stormceptor EF is similar to that of a 60-degree bend structure. The applicable K value for calculating minor losses through the unit is 1.1. For submerged conditions the applicable K value is 3.0.

Pollutant Capacity

Stormceptor EF / EFO	Model Diameter		Depth (Outlet Pipe Invert to Sump Floor)		Oil Volume		Recommended Sediment Maintenance Depth *		Maximum Sediment Volume *		Maximum Sediment Mass **	
	(m)	(ft)	(m)	(ft)	(L)	(Gal)	(mm)	(in)	(L)	(ft^3)	(kg)	(lb)
EF4 / EFO4	1.2	4	1.52	5.0	197	52	203	8	1190	42	1904	5250
EF6 / EFO6	1.8	6	1.93	6.3	348	92	305	12	3470	123	5552	15375
EF8 / EFO8	2.4	8	2.59	8.5	545	144	610	24	8780	310	14048	38750
EF10 / EFO10	3.0	10	3.25	10.7	874	231	610	24	17790	628	28464	78500
EF12 / EFO12	3.6	12	3.89	12.8	1219	322	610	24	31220	1103	49952	137875

*Increased sump depth may be added to increase sediment storage capacity
** Average density of wet packed sediment in sump = 1.6 kg/L (100 lb/ft^3)

Feature	Benefit	Feature Appeals To
Patent-pending enhanced flow treatment and scour prevention technology	Superior, verified third-party performance	Regulator, Specifying & Design Engineer
Third-party verified light liquid capture and retention for EFO version	Proven performance for fuel/oil hotspot locations	Regulator, Specifying & Design Engineer, Site Owner
Functions as bend, junction or inlet structure	Design flexibility	Specifying & Design Engineer
Minimal drop between inlet and outlet	Site installation ease	Contractor
Large diameter outlet riser for inspection and maintenance	Easy maintenance access from grade	Maintenance Contractor & Site Owner

STANDARD STORMCEPTOR EF/EFO DRAWINGS

For standard details, please visit http://www.imbriumsystems.com/stormwater-treatment-solutions/stormceptor-ef

STANDARD STORMCEPTOR EF/EFO SPECIFICATION

For specifications, please visit http://www.imbriumsystems.com/stormwater-treatment-solutions/stormceptor-ef

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Stormceptor® EF Sizing Report

Table of TSS Removal vs Surface Loading Rate Based on Third-Party Test Results
Stormceptor® EFO

SLR (L/min/m²)	TSS % REMOVAL	SLR (L/min/m²)	TSS % REMOVAL	SLR (L/min/m²)	TSS % REMOVAL	SLR (L/min/m²)	TSS % REMOVAL
1	70	660	46	1320	48	1980	35
30	70	690	46	1350	48	2010	34
60	67	720	45	1380	49	2040	34
90	63	750	45	1410	49	2070	33
120	61	780	45	1440	48	2100	33
150	58	810	45	1470	47	2130	32
180	56	840	45	1500	46	2160	32
210	54	870	45	1530	45	2190	31
240	53	900	45	1560	44	2220	31
270	52	930	44	1590	43	2250	30
300	51	960	44	1620	42	2280	30
330	50	990	44	1650	42	2310	30
360	49	1020	44	1680	41	2340	29
390	48	1050	45	1710	40	2370	29
420	48	1080	45	1740	39	2400	29
450	48	1110	45	1770	39	2430	28
480	47	1140	46	1800	38	2460	28
510	47	1170	46	1830	37	2490	28
540	47	1200	47	1860	37	2520	27
570	46	1230	47	1890	36	2550	27
600	46	1260	47	1920	36	2580	27
630	46	1290	48	1950	35		

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Appendix E: Jellyfish Filter Sizing Report

Jellyfish® Filter Sizing Report

Green cells require user input / selection
Grey cells indicate optional user input
Yellow cells indicate sizing results

Date: 10/4/2019

Project Name:	
Project Number:	
Designer Company:	AE
Designer Name:	Josh Theissen
Designer Email / Phone:	604-293-1411

Drainage Area (ha):	8.035
% Imperviousness:	60.8
Runoff Coefficient 'c': 0.6648	
Licensee Name:	Langley
Manhole or Vault style:	Manhole
Cartridge Length:	54

Province:	British Columbia
City:	Sparwood
Nearest Rainfall Station:	CRANBROOK AP
NCDC Rainfall Station ID:	BC115 Years of Rainfall Data: 12

Is the Jellyfish Filter **OFF- LINE** of the Drainage System?	Yes
Required Water Quality Runoff Volume Capture (%):	70
	42.7
Average Annual Rainfall Depth (mm)*:	385
Influent TSS Concentration Rate (mg/L):	Medium Sediment Rate
Upstream Pre-treatment?	Yes
Enter Credit (%):	50
Estimated Average Annual Sediment Load (kg/yr):	617

*Source: Environment Canada

Jellyfish Filter Recommendation

Jellyfish Filter Model:	JF8-10-2
Manhole Diameter (m):	2.4
# of Hi-Flo Cartridges:	10
# of Draindown Cartridges:	2
Required Treatment Flow Rate (L/s):	42.7
Treatment Flow Rate Provided (L/s):	50.5
Required Sediment Capacity (kg/yr):	617
Sediment Capacity Provided (kg/yr):	627

Recommended Off-line Jellyfish Filter Model: JF8-10-2

JELLYFISH FILTER SIZING OVERVIEW

The Jellyfish Filter model JF8-10-2 is recommended to meet the water quality objective of removing 80% TSS by treating a flow rate of 50.5 L/s, which meets or exceeds treatment of 70% of the average annual rainfall based on 12 years of CRANBROOK AP rainfall data. The Jellyfish Filter model has a sediment capacity of 627 kg, which meets or exceeds the estimated average annual sediment load for the site.

Regular scheduled maintenance is necessary to assure proper functioning of the Jellyfish Filter. The maintenance inverval is designed to be approximately every 12 months, but this may vary significantly with site loading conditions and upstream pretreatment measures. Biannual inspections, as well as inspection after storms of unusually high intensity or long duration, are recommended.

THIRD-PARTY TESTING AND VERIFICATION

- ► Third-party field tested in accordance with TARP Tier II Protocol
- ► Third-party verified in accordance with ISO 14034 Environmental Technology Verification (ETV)
- ► Third-party verification by New Jersey Corporation for Advanced Technology (NJCAT)

POLLUTANT REMOVAL PERFORMANCE

- ►Total Suspended Solids (TSS) 83% - 90%
- ►Total Nitrogen (TN) 31% - 55%
- ►Total Zinc (TZn) 39% - 75%

Source: ISO 14034 ETV Verification Statement

- ►Total Trash 99%

Source: Monteco Research and Development Centre Floatables Testing

- ►Total Phosphorus (TP) 43% - 60%
- ►Total Copper (TCu) 75% - 99%
- ►Oil & Grease 43% - 100%

This report provides information for the sizing and specification of the Jellyfish Filter. When designed properly in accordance to the guidelines detailed in the Jellyfish Filter Technical Manual, the Jellyfish Filter will exceed the performance and longevity of conventional horizontal bed and granular media filters. Please see www.ImbriumSystems.com for more information.

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Jellyfish® Filter Sizing Report

JELLYFISH FILTER SYSTEM OVERVIEW

The Jellyfish Filter is a patented stormwater quality treatment technology featuring high flow pretreatment and membrane filtration in a compact stand-alone system. Jellyfish Filter removes floatables, trash, oil, debris, TSS, fine silt-sized particles, and a high percentage of particulate-bound pollutants; including phosphorus, nitrogen, metals and hydrocarbons. The high surface area membrane cartridges, combined with up-flow hydraulics, frequent passive backwashing, and rinseable / reusable cartridges ensure long-lasting performance.

JELLYFISH FILTER OPERATION

► Stormwater enters the Jellyfish Filter through the inlet pipe or inlet grate, builds driving head, and traps floating pollutants behind the maintenance access wall and below the cartridge deck.
► Water is pushed down below the cartridge deck where a separation skirt around the cartridges directs oil, trash and debris outside the filtration zone, allowing sand-sized particles to settle in the sump.
► Water is directed to the filtration zone, enters the membranes, and exits through the top of the cartridges into the backwash pool. Once the treated water has filled the backwash pool, treated water overflows the weir and exits via the outlet pipe.
► The membrane filters provide a very high surface area to effectively remove fine sand and silt-sized particles, and a high percentage of particulate-bound pollutants such as nitrogen, phosphorus, metals and hydrocarbons, while ensuring long-lasting treatment.
► After every storm peak, the filtered water in the backwash pool flows back through the hi-flo membrane cartridges into the lower chamber. This passive backwash, coupled with vibrational pulses and gravity, extends cartridge service life for future storm events.
► The draindown cartridge(s) located outside the backwash pool enables water levels to balance.

The Jellyfish Filter and components are depicted in Figure 2 below

FIGURE 2 **Jellyfish Filter Components**

Note: Separator Skirt not shown

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Jellyfish® Filter Sizing Report

JELLYFISH FILTER STANDARD DESIGN

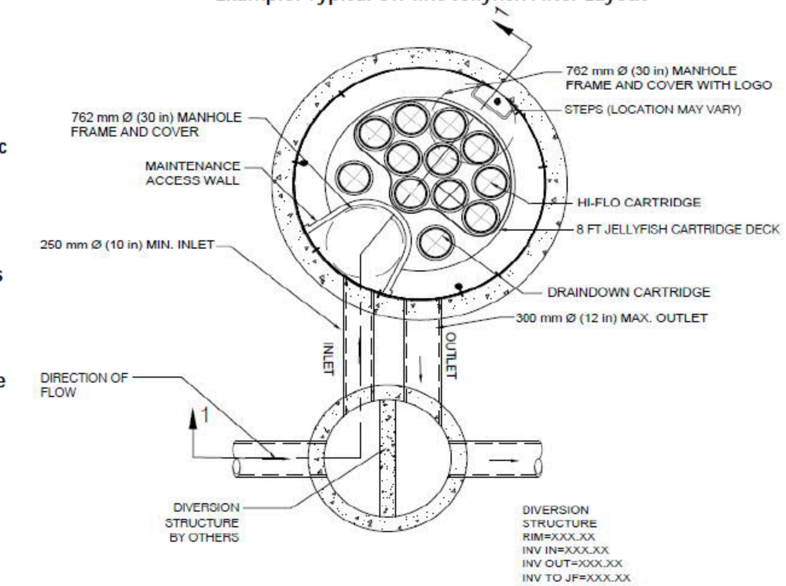
► Typically, the Jellyfish Filter is designed in an off-line configuration, as all stormwater filter systems will perform for a longer duration between required maintenance services when designed and applied in off-line configurations. Depending on the design parameters, an optional internal bypass may be incorporated into the Jellyfish Filter, however, the inspection and maintenance frequency will be increased as compared to an off-line system.

► Typically, 18 inches (457 mm) of driving head is designed into the system, calculated as the difference in elevation between the top of the diversion structure weir and the invert of the Jellyfish Filter outlet pipe. Design driving head can range from 12 to 24 inches (305 to 610mm) depending on specific site requirements, and requires additional sizing and design assistance.

► Typically, the Jellyfish Filter is designed with the inlet pipe invert configured 6 inches (150 mm) above the outlet pipe invert elevation. However, depending on site parameters, this can vary to an optional configuration with the inlet pipe entering the unit below the outlet invert elevation. Outlet pipe invert is always set at the Jellyfish Filter deck elevation.

► The Jellyfish Filter can accommodate multiple inlet / outlet pipes within certain restrictions.

Example: Typical Off-line Jellyfish Filter Layout



► While the optional below deck inlet pipe configuration offers 0 to 360 degree flexibility between the inlet and outlet pipe, typical systems conform to the following:

Model Name	Model Diameter		Minimum Angle Between Inlet / Outlet Pipes	Minimum Inlet Pipe Diameter		Minimum Outlet Pipe Diameter	
	(m)	(ft)		(mm)	(in)	(mm)	(in)
JF4	1.22	4	62°	150	6	200	8
JF6	1.83	6	59°	200	8	250	10
JF8	2.44	8	52°	250	10	300	12
JF10	3.05	10	48°	300	12	450	18
JF12	3.66	12	40°	300	12	450	18

► The Jellyfish Filter can be built at all depths of cover generally associated with conventional stormwater conveyance systems. For sites that require minimal depth of cover for the stormwater infrastructure, the Jellyfish Filter can be applied in a shallow application using a hatch cover. The general <u>minimum</u> depth of cover using a hatch is 36 inches (915 mm) from the bottom side of the top slab to the outlet pipe invert.

► The Jellyfish Filter will function effectively under submerged conditions, however, maintenance and cartridge cleaning may be more frequent. Please contact your local representative for submerged Jellyfish Filter applications.

► Jellyfish Filter systems may incorporate grated inlets depending on system configuration.

► For sites with water quality treatment flow rates or sediment mass loadings that exceed the design rates of the largest standard Jellyfish Filter models, systems can be designed that hydraulically connect multiple Jellyfish Filters in parallel.

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SIZING FOR THE STORMWATER QUALITY EVENT

► The Jellyfish Filter is sized to meet both an estimated annual sediment load and a water quality flow rate. The water quality flow rate is typically determined as the flow rate associated with the 90th percentile average annual rainfall event. The Jellyfish Filter sizing program uses a local rainfall dataset based on a minimum of seven (7) years of historic rainfall information from the National Climate Data Center or Environment Canada. Most rainfall events are much smaller than design storms used for urban drainage models. In any given area, most frequently recurrent rainfall events are of low intensity and depth.

RAINFALL DATA FROM THE CRANBROOK AP RAINFALL STATION

Rainfall Intensity (mm/hr)	Percent Rainfall Volume	Cumulative Rainfall Volume	Flow Rate (L/s)
1.0	42.7%	42.7%	14.85
2.0	18.2%	60.9%	29.70
3.0	10.4%	71.3%	44.55
4.0	6.3%	77.6%	59.40
5.0	5.6%	83.2%	74.25
6.0	3.3%	86.5%	89.10
7.0	2.7%	89.2%	103.95
8.0	2.1%	91.3%	118.80
9.0	2.1%	93.4%	133.65
10.0	1.3%	94.7%	148.50
11.0	1.5%	96.2%	163.35
12.0	0.8%	97.0%	178.20
13.0	0.2%	97.2%	193.05
14.0	0.9%	98.1%	207.90
15.0	0.3%	98.4%	222.75
16.0	0.3%	98.7%	237.60
17.0	0.0%	98.7%	252.45
18.0	0.2%	98.9%	267.30
19.0	0.5%	99.4%	282.15
20.0	0.0%	99.4%	297.00
21.0	0.1%	99.5%	311.85
22.0	0.1%	99.6%	326.70
23.0	0.0%	99.6%	341.55
24.0	0.0%	99.6%	356.40
25.0	0.1%	99.7%	371.25

Rainfall Intensity (mm/hr)	Percent Rainfall Volume	Cumulative Rainfall Volume	Flow Rate (L/s)
26.0	0.0%	99.7%	386.10
27.0	0.0%	99.7%	400.95
28.0	0.2%	99.9%	415.80
29.0	0.0%	99.9%	430.65
30.0	0.0%	99.9%	445.50
31.0	0.2%	100.1%	460.34
32.0	0.0%	100.1%	475.19
33.0	0.0%	100.1%	490.04
34.0	0.0%	100.1%	504.89
35.0	0.0%	100.1%	519.74
36.0	0.0%	100.1%	534.59
37.0	0.0%	100.1%	549.44
38.0	0.0%	100.1%	564.29
39.0	0.0%	100.1%	579.14
40.0	0.1%	100.2%	593.99
41.0	0.0%	100.2%	608.84
42.0	0.0%	100.2%	623.69
43.0	0.0%	100.2%	638.54
44.0	0.0%	100.2%	653.39
45.0	0.0%	100.2%	668.24
46.0	0.0%	100.2%	683.09
47.0	0.0%	100.2%	697.94
48.0	0.0%	100.2%	712.79
49.0	0.1%	100.3%	727.64
50.0	0.0%	100.3%	742.49

NCDC Rainfall Station ID: BC115 Years of Rainfall Data: 12

JELLYFISH FILTER MODEL NAMING CONVENTION

OFF- LINE Manhole Configuration

Example (1): JF6-6-1

- Manhole Diameter (ft)
- # of Hi-Flo Cartridges
- # of Draindown Cartridges

Example (2): JF4-2-1-27C

- Cartridge Length (in)

ON- LINE Manhole Configuration

Example (1): JF8-10-2-L1

Model is online and requires the internal by-pass and one extra foot of sump depth

Example (2): JF8-10-2-L0

Model is online, but does not require the internal by-pass or extra foot of sump depth

ON- LINE / OFF- LINE Vault Configuration

Example (1): JFVLAN-III-6-3-27C

- Vault Precaster ID
- Vault Style
- Cartridge Length (in)

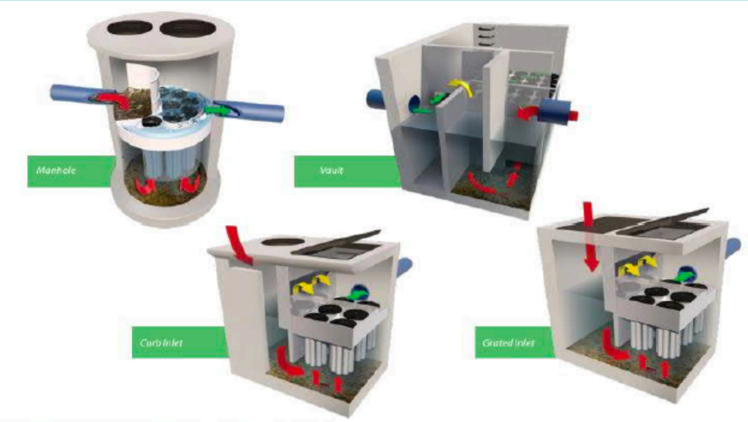
Example (2): JFVLEC-V-30-6-54C

- # of Hi-Flo Cartridges
- # of Draindown Cartridges

***Note**: Standard manhole cartridge length is 54 inches (1372 mm). Cartridge length is only included in the model name if it is not the standard 54 inch (1372 mm) length.*

JELLYFISH FILTER CONFIGURATIONS

The Jellyfish Filter can be designed in a variety of configurations: manhole, catch basin, vault, fiberglass tank, or custom configuration. Typically, 18 inches (457 mm) of driving head is designed into the system. Please contact Imbrium Systems at (800) 565-4801 or by email at info@imbriumsystems.com to inquire about custom configurations.



Jellyfish Filter cartridges are available in various lengths as depicted in Table 1 below:

Table 1 – Cartridge Lengths / Weights and Cartridge Lid Orifice Diameters

Cartridge Lengths	Dry Weight	Hi-Flo Orifice Diameter	Draindown Orifice Diameter
15 inches (381 mm)	10 lbs (4.5 kg)	35 mm	20 mm
27 inches (686 mm)	14.5 lbs (6.6 kg)	45 mm	25 mm
40 inches (1,016 mm)	19.5 lbs (8.9 kg)	55 mm	30 mm
54 inches (1,372 mm)	25 lbs (11.4 kg)	70 mm	35 mm

Jellyfish® Filter Sizing Report

INSPECTION & MAINTENANCE

The primary purpose of the Jellyfish Filter is to capture and remove pollutants from stormwater runoff. As with any filtration system, captured pollutants must be removed to maintain the filter's maximum treatment performance. Regular inspection and maintenance are required to insure proper functioning of the system. Maintenance frequencies and requirements are site specific and vary depending on pollutant loading. Maintenance activities may be required in the event of an upstream chemical spill or due to excessive sediment loading from site erosion or extreme runoff events. It is a good practice to inspect the system after major storm events.

Inspection activities are typically conducted from surface observations and include:

- Observe if standing water is present
- Observe if there is any physical damage to the deck or cartridge lids
- Observe the amount of debris in the Maintenance Access Wall (MAW)

Maintenance activities typically include:

- Removal of oil, floatable trash and debris
- Removal of collected sediments from manhole sump
- Rinsing and re-installing the filter cartridges
- Replace filter cartridge tentacles, as needed.

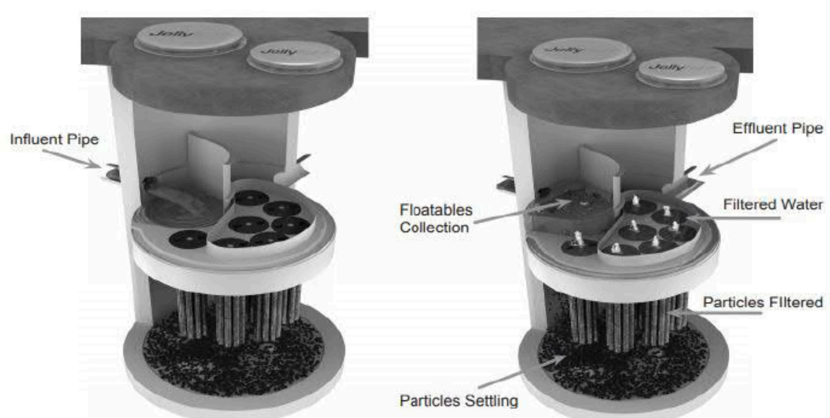
It is recommended that Jellyfish Filter inspection and maintenance be performed by professionally trained individuals, with experience in stormwater maintenance and disposal services. Maintenance procedures may require manned entry into the Jellyfish structure. Only professional maintenance service providers trained in confined space entry procedures should enter the vessel. Procedures, safety and damage prevention precautions, and other information, included in the Jellyfish Filter Owner's Manual, should be reviewed and observed prior to all inspection and maintenance activities.

FIGURE 1

Jellyfish Filter Treatment Functions

Membrane Filtration

Section View with Maintenance Access Wall (MAW) Cutaway



STANDARD JELLYFISH FILTER DRAWINGS

For standard details, please visit http://www.imbriumsystems.com/stormwater-treatment-solutions/jellyfish-filter

STANDARD JELLYFISH FILTER SPECIFICATION

For specifications, please visit http://www.imbriumsystems.com/stormwater-treatment-solutions/jellyfish-filter

imbrium

STANDARD SPECIFICATION
STORMWATER QUALITY – MEMBRANE FILTRATION TREATMENT DEVICE

PART 1 – GENERAL

1.1 WORK INCLUDED

Specifies requirements for construction and performance of an underground stormwater quality membrane filtration treatment device that removes pollutants from stormwater runoff through the unit operations of sedimentation, floatation, and membrane filtration.

1.2 REFERENCE STANDARDS

ASTM C 891: Specification for Installation of Underground Precast Concrete Utility Structures
ASTM C 478: Specification for Precast Reinforced Concrete Manhole Sections
ASTM C 443: Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets
ASTM D 4101: Specification for Copolymer steps construction

CAN/CSA-A257.4-M92
Joints for Circular Concrete Sewer and Culvert Pipe, Manhole Sections and Fittings Using Rubber Gaskets

CAN/CSA-A257.4-M92
Precast Reinforced Circular Concrete Manhole Sections, Catch Basins and Fittings

Canadian Highway Bridge Design Code

1.3 SHOP DRAWINGS

Shop drawings for the structure and performance are to be submitted with each order to the contractor. Contractor shall forward shop drawing submittal to the consulting engineer for approval. Shop drawings are to detail the structure's precast concrete and call out or note the fiberglass (FRP) internals/components.

1.4 PRODUCT SUBSTITUTIONS

No product substitutions shall be accepted unless submitted 10 days prior to project bid date, or as directed by the engineer of record. Submissions for substitutions require review and approval by the Engineer of Record, for hydraulic performance, impact to project designs, equivalent treatment performance, and any required project plan and report (hydrology/hydraulic, water quality, stormwater pollution) modifications that would be required by the approving jurisdictions/agencies. Contractor to coordinate with the Engineer of Record any applicable modifications to the project estimates of cost, bonding amount determinations, plan check fees for changes to approved documents, and/or any other regulatory requirements resulting from the product substitution.

1.5 HANDLING AND STORAGE

Prevent damage to materials during storage and handling.

PART 2 – PRODUCTS

2.1 GENERAL

2.1.1 The device shall be a cylindrical or rectangular, all concrete structure (including risers), constructed from precast concrete riser and slab components or monolithic precast structure(s), installed to conform to ASTM C 891 and to any required state highway, municipal or local specifications; whichever is more stringent. The device shall be watertight.

2.1.2 Cartridge Deck The cylindrical concrete device shall include a fiberglass deck. The rectangular concrete device shall include a coated aluminum deck. In either instance, the insert shall be bolted and sealed watertight inside the precast concrete chamber. The deck shall serve as: (a) a horizontal divider between the lower treatment zone and the upper treated effluent zone; (b) a deck for attachment of filter cartridges such that the membrane filter elements of each cartridge extend into the lower treatment zone; (c) a platform for maintenance workers to service the filter cartridges (maximum manned weight = 450 pounds (204 kg)); (d) a conduit for conveyance of treated water to the effluent pipe.

2.1.3 Membrane Filter Cartridges Filter cartridges shall be comprised of reusable cylindrical membrane filter elements connected to a perforated head plate. The number of membrane filter elements per cartridge shall be a minimum of eleven 2.75-inch (70-mm) diameter elements. The length of each filter element shall be a minimum 15 inches (381 mm). Each cartridge shall be fitted into the cartridge deck by insertion into a cartridge receptacle that is permanently mounted into the cartridge deck. Each cartridge shall be secured by a cartridge lid that is threaded onto the receptacle, or similar mechanism to secure the cartridge into the deck. The maximum treatment flow rate of a filter cartridge shall be controlled by an orifice in the cartridge lid, or on the individual cartridge itself, and based on a design flux rate (surface loading rate) determined by the maximum treatment flow rate per unit of filtration membrane surface area. The maximum design flux rate shall be 0.21 gpm/ft^2 (0.142 lps/m^2).

Each membrane filter cartridge shall allow for manual installation and removal. Each filter cartridge shall have filtration membrane surface area and dry installation weight as follows (if length of filter cartridge is between those listed below, the surface area and weight shall be proportionate to the next length shorter and next length longer as shown below):

Filter Cartridge Length (in / mm)	Minimum Filtration Membrane Surface Area (ft2 / m2)	Maximum Filter Cartridge Dry Weight (lbs / kg)
15	106 / 9.8	10.5 / 4.8
27	190 / 17.7	15.0 / 6.8
40	282 / 26.2	20.5 / 9.3
54	381 / 35.4	25.5 / 11.6

2.1.4 Backwashing Cartridges The filter device shall have a weir extending above the cartridge deck, or other mechanism, that encloses the high flow rate filter cartridges when placed in their respective cartridge receptacles within the cartridge deck. The weir, or other mechanism, shall collect a pool of filtered water during inflow events that backwashes the high flow rate cartridges when the inflow event subsides. All filter cartridges and membranes shall be reusable and allow

for the use of filtration membrane rinsing procedures to restore flow capacity and sediment capacity; extending cartridge service life.

2.1.5 Maintenance Access to Captured Pollutants The filter device shall contain an opening(s) that provides maintenance access for removal of accumulated floatable pollutants and sediment, removal of and replacement of filter cartridges, cleaning of the sump, and rinsing of the deck. Access shall have a minimum clear vertical clear space over all of the filter cartridges. Filter cartridges shall be able to be lifted straight vertically out of the receptacles and deck for the entire length of the cartridge.

2.1.6 Bend Structure The device shall be able to be used as a bend structure with minimum angles between inlet and outlet pipes of 90-degrees or less in the stormwater conveyance system.

2.1.7 Double-Wall Containment of Hydrocarbons The cylindrical precast concrete device shall provide double-wall containment for hydrocarbon spill capture by a combined means of an inner wall of fiberglass, to a minimum depth of 12 inches (305 mm) below the cartridge deck, and the precast vessel wall.

2.1.8 Baffle The filter device shall provide a baffle that extends from the underside of the cartridge deck to a minimum length equal to the length of the membrane filter elements. The baffle shall serve to protect the membrane filter elements from contamination by floatables and coarse sediment. The baffle shall be flexible and continuous in cylindrical configurations, and shall be a straight concrete or aluminum wall in rectangular configurations.

2.1.9 Sump The device shall include a minimum 24 inches (610 mm) of sump below the bottom of the cartridges for sediment accumulation, unless otherwise specified by the design engineer. Depths less than 24 inches may have an impact on the total performance and/or longevity between cartridge maintenance/replacement of the device.

2.2 PRECAST CONCRETE SECTIONS

All precast concrete components shall be manufactured to a minimum live load of HS-20 truck loading or greater based on local regulatory specifications, unless otherwise modified or specified by the design engineer, and shall be watertight.

2.3 JOINTS All precast concrete manhole configuration joints shall use nitrile rubber gaskets and shall meet the requirements of ASTM C443, Specification C1619, Class D or engineer approved equal to ensure oil resistance. Mastic sealants or butyl tape are not an acceptable alternative.

2.4 GASKETS Only profile neoprene or nitrile rubber gaskets in accordance to CSA A257.3-M92 will be accepted. Mastic sealants, butyl tape or Conseal CS-101 are not acceptable gasket materials.

2.5 FRAME AND COVER Frame and covers must be manufactured from cast-iron or other composite material tested to withstand H-20 or greater design loads, and as approved by the local regulatory body. Frames and covers must be embossed with the name of the device manufacturer or the device brand name.

2.6 DOORS AND HATCHES If provided shall meet designated loading requirements or at a minimum for incidental vehicular traffic.

2.7 CONCRETE All concrete components shall be manufactured according to local specifications and shall meet the requirements of ASTM C 478.

2.8 FIBERGLASS The fiberglass portion of the filter device shall be constructed in accordance with the following standard: ASTM D-4097: Contact Molded Glass Fiber Reinforced Chemical Resistant Tanks.

2.9 STEPS Steps shall be constructed according to ASTM D4101 of copolymer polypropylene, and be driven into preformed or pre-drilled holes after the concrete has cured, installed to conform to applicable sections of state, provincial and municipal building codes, highway, municipal or local specifications for the construction of such devices.

2.10 INSPECTION All precast concrete sections shall be inspected to ensure that dimensions, appearance and quality of the product meet local municipal specifications and ASTM C 478.

PART 3 – PERFORMANCE

3.1 GENERAL

3.1.1 Verification – The stormwater quality filter treatment device shall have been field tested in accordance with either TARP Tier II Protocol (TARP, 2003) and New Jersey Tier II Stormwater Test Requirements – Amendments to TARP Tier II Protocol (NJDEP, 2009) or Washington State Technology Assessment Protocol – Ecology (TAPE), 2011 or later version. The field test shall have been verified in accordance with ISO 14034:2016 Environmental Management – Environmental Technology Verification (ETV). See Section 3.2 of this specification for field test performance requirements.

3.1.2 Function - The stormwater quality filter treatment device shall function to remove pollutants by the following unit treatment processes; sedimentation, floatation, and membrane filtration.

3.1.3 Pollutants - The stormwater quality filter treatment device shall be ISO 14034 ETV verified to remove oil/grease, suspended solids, metals and nutrients from stormwater runoff.

3.1.4 Bypass - The stormwater quality filter treatment device shall typically utilize an external bypass to divert excessive flows. Internal bypass systems shall be equipped with a floatables baffle, and must avoid passage through the sump and/or cartridge filtration zone.

3.1.5 Treatment Flux Rate (Surface Loading Rate) – The stormwater quality filter treatment device shall treat 100% of the required water quality treatment flow based on a maximum design treatment flux rate (surface loading rate) across the membrane filter cartridges of 0.21 gpm/ft^2 (0.142 lps/m^2).

3.2 FIELD TEST PERFORMANCE

At a minimum, the stormwater quality filter treatment device shall have been field tested in accordance with either TARP Tier II Protocol (TARP, 2003) and New Jersey Tier II Stormwater Test Requirements – Amendments to TARP Tier II Protocol (NJDEP, 2009) or Washington State Technology Assessment Protocol – Ecology (TAPE), 2011 or later version. The field test shall have been verified in accordance with ISO 14034:2016 Environmental Management – Environmental Technology Verification (ETV). The field test shall have monitored a minimum of twenty (20) TARP or TAPE qualifying storm events.

3.2.1 Suspended Solids Removal - The stormwater quality filter treatment device shall have ISO 14034 ETV verified load based median TSS removal efficiency of at least 85% and load based median SSC removal efficiency of at least 98%.

3.2.2 Runoff Volume – The stormwater quality filter treatment device shall be engineered, designed, and sized to treat a minimum of 90 percent of the annual runoff volume determined from use of a minimum 15-year rainfall data set.

3.2.3 Fine Particle Removal - The stormwater quality filter treatment device shall have demonstrated the ability to capture fine particles as indicated by a minimum median removal efficiency of 75% for the particle fraction less than 25 microns, and an effluent d_{50} of 15 microns or lower for all monitored storm events.

3.2.4 Turbidity Reduction - The stormwater quality filter treatment device shall have demonstrated the ability to reduce turbidity such that effluent turbidity is 15 NTU or lower.

3.2.5 Nutrients:

3.2.5.1 Total Phosphorus (TP) Removal - The stormwater quality filter treatment device shall have ISO 14034 ETV verified load based median TP removal efficiency of at least 49%.

3.2.5.2 Total Nitrogen (TN) Removal - The stormwater quality filter treatment device shall have ISO 14034 ETV verified load based median TN removal efficiency of at least 39%.

3.2.6 Metals:

3.2.6.1 Total Zinc (Zn) Removal - The stormwater quality filter treatment device shall have ISO 14034 ETV verified load based median Zn removal efficiency of at least 69%.

3.2.6.2 Total Copper (Cu) Removal - The stormwater quality filter treatment device shall have ISO 14034 ETV verified load based median Cu removal efficiency of at least 91%.

3.3 INSPECTION and MAINTENANCE

The stormwater quality filter device shall have the following features:

3.3.1 Durability of membranes are subject to good handling practices during inspection and maintenance (removal, rinsing, and reinsertion) events, and site specific conditions that may have heavier or lighter loading onto the cartridges, and pollutant variability that may impact the membrane structural integrity. Membrane maintenance and replacement shall be in accordance with manufacturer's recommendations.

3.3.2 Inspection which includes trash and floatables collection, sediment depth determination, and visible determination of backwash pool depth shall be easily conducted from grade (outside the structure).

3.3.3 Manual rinsing of the reusable filter cartridges shall promote restoration of the flow capacity and sediment capacity of the filter cartridges, extending cartridge service life.

3.3.4 The filter device shall have a minimum 12 inches (305 mm) of sediment storage depth, and a minimum of 12 inches between the top of the sediment storage and bottom of the filter cartridge tentacles, unless otherwise specified by the design engineer. Variances may have an impact on the total performance and/or longevity between cartridge maintenance/replacement of the device.

3.3.5 Sediment removal from the filter treatment device shall be able to be conducted using a standard maintenance truck and vacuum apparatus, and a minimum one point of entry to the sump that is unobstructed by filter cartridges.

3.3.6 Maintenance access shall have a minimum clear height that provides suitable vertical clear space over all of the filter cartridges. Filter cartridges shall be able to be lifted straight vertically out of the receptacles and deck for the entire length of the cartridge.

3.3.7 Filter cartridges shall be able to be maintained without the requirement of additional lifting equipment.

PART 4 – EXECUTION

4.1 INSTALLATION

4.1.1 PRECAST DEVICE CONSTRUCTION SEQUENCE

The installation of a watertight precast concrete device should conform to ASTM C 891 and to any state highway, municipal or local specifications for the construction of manholes, whichever is more stringent. Selected sections of a general specification that are applicable are summarized below.

4.1.1.1 The watertight precast concrete device is installed in sections in the following sequence:

- aggregate base
- base slab
- treatment chamber and cartridge deck riser section(s)
- bypass section
- connect inlet and outlet pipes
- concrete riser section(s) and/or transition slab (if required)
- maintenance riser section(s) (if required)
- frame and access cover

4.1.2 The precast base should be placed level at the specified grade. The entire base should be in contact with the underlying compacted granular material. Subsequent sections, complete with joint seals, should be installed in accordance with the precast concrete manufacturer's recommendations.

4.1.3 Adjustment of the stormwater quality treatment device can be performed by lifting the upper sections free of the excavated area, re-leveling the base, and re-installing the sections. Damaged sections and gaskets should be repaired or replaced as necessary to restore original condition and watertight seals. Once the stormwater quality treatment device has been constructed, any/all lift holes must be plugged watertight with mortar or non-shrink grout.

4.1.4 Inlet and Outlet Pipes Inlet and outlet pipes should be securely set into the device using approved pipe seals (flexible boot connections, where applicable) so that the structure is watertight, and such that any pipe intrusion into the device does not impact the device functionality.

4.1.5 Frame and Cover Installation Adjustment units (e.g. grade rings) should be installed to set the frame and cover at the required elevation. The adjustment units should be laid in a full bed of mortar with successive units being joined using sealant recommended by the manufacturer. Frames for the cover should be set in a full bed of mortar at the elevation specified.

4.2 MAINTENANCE ACCESS WALL

In some instances the Maintenance Access Wall, if provided, shall require an extension attachment and sealing to the precast wall and cartridge deck at the job site, rather than at the precast facility. In this instance, installation of these components shall be performed according to instructions provided by the manufacturer.

4.3 FILTER CARTRIDGE INSTALLATION Filter cartridges shall be installed in the cartridge deck only after the construction site is fully stabilized and in accordance with the manufacturer's guidelines and recommendations. Contractor to contact the manufacturer to schedule cartridge delivery and review procedures/requirements to be completed to the device prior to installation of the cartridges and activation of the system.

PART 5 – QUALITY ASSURANCE

5.1 FILTER CARTRIDGE INSTALLATION Manufacturer shall coordinate delivery of filter cartridges and other internal components with contractor. Filter cartridges shall be delivered and installed complete after site is stabilized and unit is ready to accept cartridges. Unit is ready to accept cartridges after is has been cleaned out and any standing water, debris, and other materials have been removed. Contractor shall take appropriate action to protect the filter cartridge receptacles and filter cartridges from damage during construction, and in accordance with the manufacturer's recommendations and guidance. For systems with cartridges installed prior to full site stabilization and prior to system activation, the contractor can plug inlet and outlet pipes to prevent stormwater and other influent from entering the device. Plugs must be removed during the activation process.

5.2 INSPECTION AND MAINTENANCE

5.2.1 The manufacturer shall provide an Owner's Manual upon request.

5.2.2 After construction and installation, and during operation, the device shall be inspected and cleaned as necessary based on the manufacturer's recommended inspection and maintenance guidelines and the local regulatory agency/body.

5.3 REPLACEMENT FILTER CARTRIDGES When replacement membrane filter elements and/or other parts are required, only membrane filter elements and parts approved by the manufacturer for use with the stormwater quality filter device shall be installed.

END OF SECTION

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