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Kawkawlin River Watershed Filter Strip Study

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Date of Report: July 12, 2011
Project I.D. Number 118688SG2010

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DEFINITIONS AND ACRONYMS

Best Management Practices (BMPs): A technique or feature used to mitigate adverse impacts of stormwater runoff on downstream systems. Mitigation can include reduction of stormwater quantity and/or an increase in stormwater quality.

Buffer or Filter Width: The distance that the filter strip extends from the stream bank into the upland areas. This is roughly equivalent to the flow length of stormwater runoff flowing through a filter strip.

Conservation Reserve Program (CRP): Program administered by the US Department of Agriculture which offers rental payments to farmers who install specified preservation practices on erodible farmland.

Conservation Reserve Enhancement Program (CREP): US Department of Agriculture program developed from CRP with a focus on environmentally sensitive areas.

Erosivity Index: Measure of rainfall's ability to erode soil. This varies throughout the year depending on temperature and quantity of precipitation.

MDNRE: Michigan Department of Natural Resources and Environment now split into Department of Environmental Quality (DEQ) and Department of Natural Resources (DNR).

NRCS: Natural Resources Conservation Service

Revised Universal Soil Loss Equation (RUSLE): Version of the Universal Soil Loss Equation updated with more empirical data and designed to be applied to areas where empirical data may be unavailable.

RUSLE2: Computer program which uses the RUSLE equation to calculate sediment yield from agricultural lands. The program includes information tailored to a region's climate, soils, and farming practices.

Universal Soil Loss Equation (USLE): Empirical equation for calculating soil loss which has been specifically developed for use in agricultural areas.

USDA: United States Department of Agriculture

V-ditch: A small V-shaped channel cut through an agricultural field to provide surface water drainage.

Vegetative Filter Strip (VFS): A barrier of grasses, shrubs, trees, or other vegetation placed along a hill slope which is intended to mitigate the impacts of stormwater runoff by settling and/or filtering contaminants (including sediment).

I. INTRODUCTION

The Kawkawlin River Watershed carries stormwater runoff from a large portion of Bay County, Michigan into the Saginaw Bay. Historically, sedimentation has been problematic in the Kawkawlin River and its tributaries due to the flat slopes prevalent in the watershed. The Bay County Drain Commissioner with a grant through the Saginaw Bay Watershed Initiative Network has requested Spicer Group, Inc. perform a study of vegetative filter strips to address sedimentation concerns in County drains located in the Kawkawlin River Watershed. This study started with research into existing data and information available for filter strip design. A computer simulation was then developed to quantify the amount of benefit various types of filter strips can provide in situations typical of those found in the Kawkawlin River Watershed. Based on the computer results, specific recommendations and conclusions were made regarding filter design and effectiveness.

Much of the land in the Kawkawlin River Watershed is cultivated by agricultural producers. Therefore, this study seeks to specifically address the use of filter strips adjacent to farmland. Numerous factors affecting filter strip effectiveness were evaluated using the RUSLE2 computer model produced by the U. S. Department of Agriculture. With the aid of this model, agricultural fields were compared with varying upland characteristics including slope, length of slope, soil type, and agricultural practices. RUSLE2 was then used to evaluate the ability of filter strips, with varying widths and types of vegetation, to reduce sediment loads to receiving waterways.

Based on the evaluation in the RUSLE2 model, specific recommendations were made in an effort to address the widest possible array of conditions commonly found in the Kawkawlin River Watershed. The results of the RUSLE2 analysis coupled with historical data of drain improvement projects and anecdotal information indicated 10 foot switchgrass filter strips could reduce average sediment inflow from an estimated 6.0 ft^3/ac/yr of sediment to about 3.0 ft^3/ac/yr. This reduction in sediment yield would suggest that if the recommended grass filter strips were implemented on all drains throughout a sub-watershed, the rate of sediment accumulation would be roughly halved. However, it was noted that certain environmental factors can allow sediment-laden stormwater runoff to circumvent filter strips and subsequently reduce overall effectiveness. In particular, runoff that becomes concentrated, either due to the development of preferential overland flow paths or by manually cut drainage paths, tends to have higher velocities than runoff occurring as sheet flow. When this occurs, fast-moving water cannot be sufficiently slowed by filter strips to induce settling of entrained particles. Therefore, other methods of sediment removal must be considered.

Spicer Group recommends that vegetative filter strips be supplemented by the use of sedimentation basins in the treatment regimen to address sediment inflows from concentrated flow paths. It is recommended that basins be sized to settle particles of large aggregate and sand. This will make the anticipated level of treatment consistent with that expected from vegetative filter strips. Additionally, this target size allows for relatively small basins capable of removing a large percentage of incoming sediment. If smaller particles were targeted, the size of the basin would need to be substantially larger.

In addition to the study described in this report, Spicer Group recommends additional work be done to address sediment impacts in the Kawkawlin River Watershed. A field-scale model of filter strips and sedimentation basins should be developed to refine estimates generated by computer models. This would allow sediment inflow and treatment rates to better reflect field conditions. Also, any implementation of filter strips and sedimentation basins in agricultural areas will need to be accompanied by an information and education program (I&E) which explains proper design and highlights the benefits of these practices.

II. BACKGROUND

The Kawkawlin Watershed is located in Bay County, Michigan and drains approximately 225 square miles. The watershed is characterized by relatively flat slopes and somewhat poorly drained soils. A map of the Kawkawlin Watershed is shown below in Figure 1.

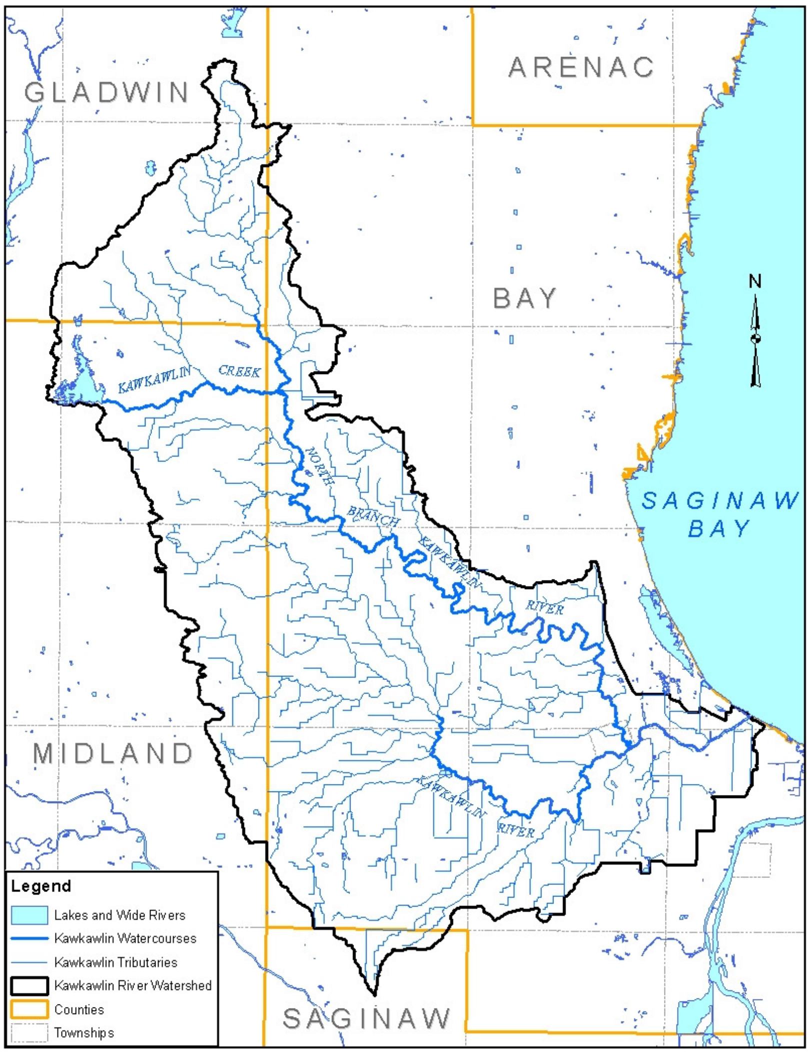

Figure 1: Location Map of the Kawkawlin River Watershed.

Local economy in the Kawkawlin River Watershed relies heavily on agricultural production. As such, open channels have been excavated to convey stormwater runoff and sub surface groundwater from agricultural lands to the Kawkawlin River and ultimately into the Saginaw

Bay. Many of these open channels have been established as county drains. This drainage often carries with it nutrients and soil particles from agricultural fields. Because the Kawkawlin River Watershed is in a low-lying area with minimal slope, sediment and nutrients entrained in stormwater runoff tend to settle out in the slow-moving waters of the Kawkawlin River and in the drains that contribute flow to the river. Settling, particularly of sediment, has been observed to create impediments to flow of stormwater and reduce channel capacity. This can cause flooding of large areas of land adjacent to the drain or river. Therefore, county drains must be dredged and maintained to ensure proper flow capacity is maintained.

The office of the Bay County Drain Commissioner has requested Spicer Group, Inc. (SGI) perform an evaluation of methods to reduce the amount of sediment introduced by agricultural runoff to drains in the Kawkawlin River Watershed. Substantial reductions in maintenance costs may be realized if best management practices (BMPs) are implemented to reduce the quantity of sediment being deposited in county drains. A study was performed to quantify the impacts of sediment loading to county drains and assess the use of BMPs to mitigate these effects. Specifically, vegetative filter strips (also referred to as "buffer strips") were assessed for their ability to filter and settle out sediment particles entrained in stormwater runoff.

A. Study Outline

SGI first reviewed relevant literature that has been published regarding BMPs intended to reduce sediment loads in stormwater. Particular emphasis was placed on techniques relevant to agricultural areas, as this is likely the primary source of sediment, in the Kawkawlin River system. In conjunction with this background information, research was conducted on the use of computerized models to quantify sediment loads under various conditions and to determine the effectiveness of sediment-reducing BMPs. Ultimately, the Revised Universal Soil Loss Equation, Version 2 (RUSLE2) was selected. This program is published by the United States Department of Agriculture (USDA) and is applicable to agricultural land use. The program can be customized to reflect conditions specific to a given area of the United States.

RUSLE2 was used to simulate various agricultural practices, soil types, and natural sediment filtration BMPs. Through this analysis, specific conclusions were drawn which quantify sediment load reductions for the selected BMPs. These results were then applied to typical county drains in the Kawkawlin River Watershed. This allowed for recommendations to be made with regard to filter strip design. Furthermore, the analysis provided estimates for the increase in time between drain cleanouts.

Research on filter strips was supplemented with information on sedimentation basin design. In areas where flow is concentrated, sedimentation basins may be more effective than filtration BMPs. By addressing concentrated flow paths, sedimentation basins provided a second method of sediment reduction. This allowed for a larger portion of sediment loads to be addressed.

Finally, a cost-benefit analysis was performed to assess the financial impact of filter strips. This analysis was based on the cost of removing sediment from drains relative to the amount of sediment reduction produced by BMPs. In this way, cost savings produced by BMPs could be compared to the expense of BMP implementation and maintenance.

III. LITERATURE REVIEW

Research for sediment reduction techniques in the Kawkawlin River Watershed can be broken into two primary categories. First, assessments were performed regarding the type and width of vegetative filter strips (VFS) needed to effectively treat stormwater runoff from agricultural lands. This research was done to determine an appropriate approach for quantifying sediment discharge to receiving water bodies. Secondly, settling BMPs were assessed for application in situations where concentrated flows would make filter strips ineffective. Finally, land rental rate data were used to assess the cost of BMP implementation.

A. Vegetative Filter Strip Design

There have been several studies done to assess the ability of VFS to reduce sediment yield from agricultural lands. These studies utilized several different designs for filter strips and had varying recommendations for filter widths. Typically, studies suggested the use of several different "zones" of vegetation (Schultz et al., 1997; USDA, 1997; Clermont County, 2006). An example of such a design is shown below in Figure 2.

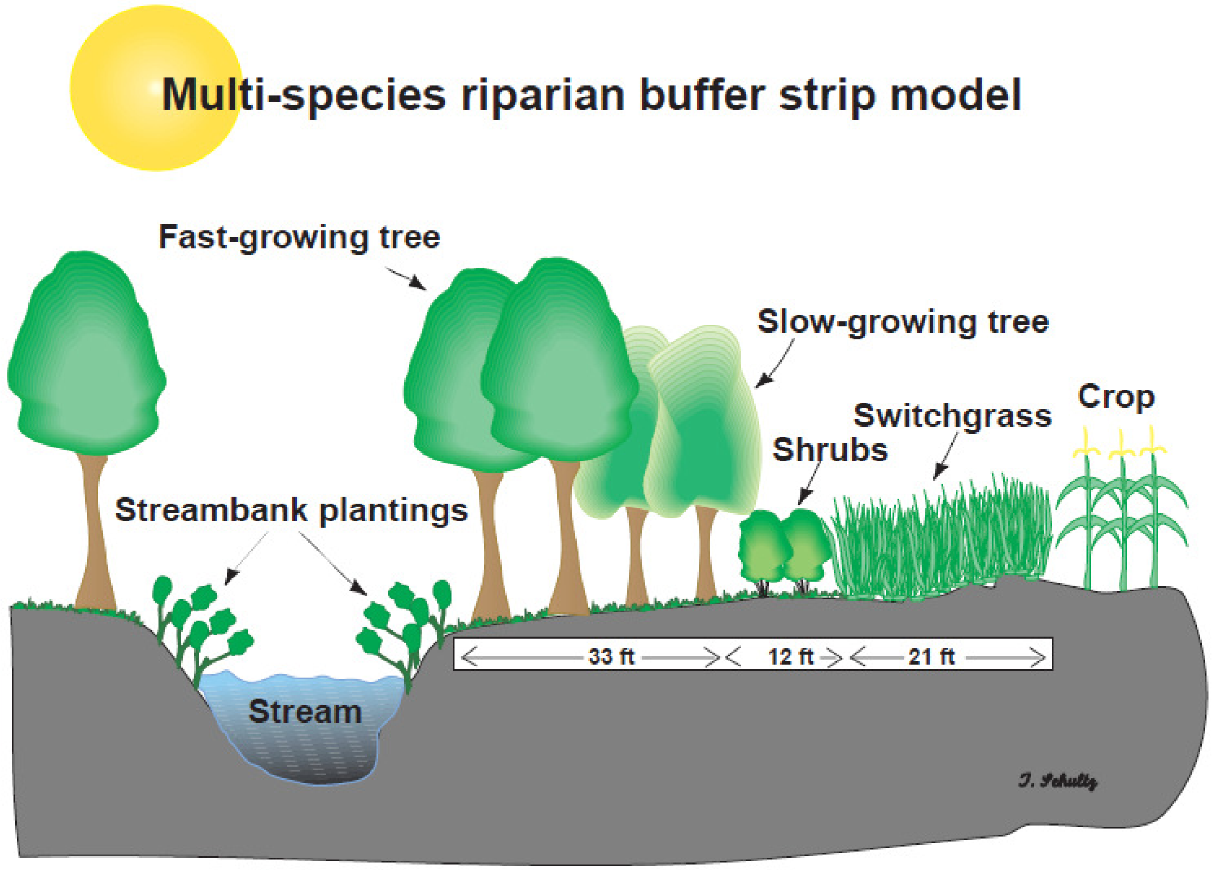

Figure 2: The natural benefits of a riparian (or river) zone can be recreated by planting strips of trees, shrubs, and grasses, and stabilizing streambanks, shown above, as well as constructing small wetlands to capture tile flow from nearby fields. (Source: Shultz et al., 1997)

These zones are designed not only to promote settling and filtration of sediment particles but to encourage uptake of nutrients such as nitrogen and phosphorus (Schultz et al., 1997; NRCS, 2000; Reed & Carpenter, 2002; NRCS 2008). Furthermore, wooded streamside corridor areas can create wildlife habitat, increase air quality through carbon sequestration, and improve stream aesthetics (NRCS, 2008).

Studies have also been done to assess simpler buffer strips than shown above. Such studies typically focus on the use of simple grass or otherwise densely vegetated barriers located adjacent to receiving waters (NRCS, 2000; Minnesota BMP, 2001; NRCS 2008). The primary advantage to this sort of design is that it is relatively simple and inexpensive to implement. Thick stands of grass promote settling of sediment particles and prevent sediment from entering the receiving watercourse (NRCS, 2000). However, these types of filter strips do not create the same level of habitat and aesthetic improvement that multi-zoned filter strips provide.

B. Filter Width

The effectiveness of vegetative filter strips varies with the length of the stormwater flow path through the strip (NRCS, 2008). Increased flow length causes stormwater to flow more slowly through the filter strip and provides sediment entrained in the filter strip a greater distance in which to settle out. Furthermore, increased flow length provides more area for stormwater infiltration and thus reduces total runoff volume (NRCS, 2000; UMRSHNC, 2008). Studies also indicated that larger buffer widths were necessary if nutrients were of concern (Schultz et al., 1997; NRCS, 2008).

Other factors affecting VFS effectiveness included vegetation density, stiffness of vegetation, land use of upland contributing area, area of buffer strip relative to contributing area, soil types, and land slopes (Bren, 1998; NRCS, 2007; NRCS, 2008; UMRSHNC, 2008). Therefore, the needed width of a VFS to treat stormwater varied substantially among studies. Table 1 shows the wide disparity between different studies resulting in different design criteria.

Table 1: Comparison of recommendations for vegetated filter widths for various studies and sources.

Source	Year	Filter Zones	Recommended Filter Width: Sediment (ft) Min.	Sediment (ft) Max.	Chemicals (ft) Min.	Chemicals (ft) Max.	Description
Schultz et al.	1997	Multiple	50	50	66	300	Iowa State University: "Stewards of out Streams"
USDA	1997	Multiple	50	50	n/a	n/a	Agroforestry Notes: "A Riparian Buffer Design for Cropland"
NRCS	2000	Single	50	n/a	50	150	Michigan, CREP-CP21: "Filter Strips"
Minnesota BMP	2001	Single	15	100	15	100	Minnesota Metropolitan Council BMP Manual: "Filter Strips"
NRCS	2008	Single	20	n/a	30	n/a	Standard Practice 393: "Filter Strip"
Nebraska Dept. of Agriculture	2009	Single	100	n/a	100	n/a	"Buffer Strip Act" - NE Admin. Code Title 25, Ch 4., Sect. 2-5101 to 2-5111
Minnesota Statute	2010	Single	16.5	n/a	16.5	n/a	103E.021 - Requires perennial vegetation on "ditches"
Ohio Code	1999	Single	4	15	n/a	n/a	6131.14 - Single County Ditches; County Engineer's Duties

**Other sources use variable width buffers (Bren 1998)*

Due to the inherent variability of field conditions, it is unlikely there is a "one-size-fits-all" optimum VFS width. Instead, filter strips must be applied based on local conditions. For instance, a study by Bren (1998) sought to size filter strips based on upland contributing area. It was reasoned that portions of a channel receiving a disproportionately high percentage of total stormwater runoff should have larger filter strips. Conversely, areas receiving little runoff would need much smaller filter strips.

In Michigan, the Natural Resources Conservation Service (NRCS) Standard Practice 393 (NRCS, 2008) has been modified slightly to include specific information on plantings that may be used in VFS implementation (NRCS, 2009). This entire document is included in Appendix A. As the focus of this report is on sediment load reduction, only those grasses capable of sediment removal should be considered.

C. Filter Strip Implementation

The difficulty with sizing filter strips on a site-by-site basis is that large scale implementation would be cumbersome and inefficient. Therefore, standards are used for particular types of filter strips which are then applied over large areas or jurisdictions. Government programs such as the Conservation Reserve Program (CRP) or Conservation Reserve Enhancement Program (CREP), operated by the United States Department of Agriculture (USDA), offer subsidies to agricultural producers to implement VFS along drainage ways. These programs require a 10 to 15-year commitment from land owners and are intended to protect natural resources along waterways (USDA, 2010). Similarly, the Nebraska Department of Agriculture provides financial incentives to farmers willing to implement VFS (Nebraska Buffer Strip Act, 2004). The state of Illinois provides incentives for VFS by offering tax breaks to agricultural producers who install such practices (IL Admin. Code 35ILCS 200/10-152). However, all of these programs are voluntary and rely on financial incentive to entice farmers to implement BMPs. Some government agencies have also begun to require the use of VFS in the form of statutes and laws. Minnesota Statute 103E.021 titled "Ditches Must be Planted with Perennial Vegetation" requires that drainage ways be buffered on either side by a 16.5 foot wide vegetative barrier. Another regulatory practice in place in Ohio is the Codes of Ohio (ORC) Chapter 6131 – Single County Ditches, under Section 6131.14 County Engineer's Duties states that specifications "*shall provide for the establishment of a sod or seeded strip not fewer than four feet nor more than fifteen feet wide, measured at right angles to the ditch bank. The sod or seeded strips established and maintained in excess of four feet* *shall be compensated for they their removal from the taxable valuation of the property of which they are a part*" (Ohio Revised Code, 1999).

D. Computer Modeling

Under ideal conditions, all VFS designs and alternatives would be evaluated based on investigative results of actual fields and on results observed from physical models or test sites. However, this sort of analysis is expensive and impractical when a wide array of alternatives are being considered. In such instances, computer models can be used to help simplify, analyze, and compare multiple conditions.

Sediment transport modeling is a difficult and inexact process. Two computer models were considered for this analysis. The first is VFSMOD-W (a.k.a. - Vegetative Filter Strips Modeling System) produced by North Carolina State University and the University of Florida. This program uses a one-dimensional kinematic wave model to predict sediment yield through a vegetative filter strip. It relies on user input rainfall hyetographs to perform event-based analysis. Soil erosion rates are based on a modified form of the Universal Soil Loss Equation (USLE) which is shown below.

$$A = R \cdot K \cdot LS \cdot C \cdot P$$

Where:
A = Average soil loss
R = Rainfall and runoff erosivity factor
K = Soil erodibility factor
LS = Topographic factor based on upland length and slope
C = Watershed cover factor
P = Factor for conservation practices

(Source: Muñoz-Carpena & Parsons , 2010)

Another program that can be used to calculate sediment yield through vegetative filter strips is RUSLE2 which was developed for the USDA. This program also uses a form of the USLE to calculate soil loss, however, it includes a database of local climate, soil erosion, and agricultural practices. Rather than using event-based rainfall and runoff inputs, RUSLE2 uses long-term average rainfall and climate data to determine typical daily rainfall and erosion parameters. They are then aggregated to produce average annual sediment loadings. Filter strips can then be added to create deposition.

E. Sedimentation Basin Design

Sedimentation basins rely on gravity to cause particles entrained in stormwater runoff to settle out. Mihelcic (1999) provides equations for such a settling process which is typically used for wastewater treatment plants. The equation states that settling of a given particle will occur if:

$$v_s \geq \frac{Q}{A_{top}}$$

Where:
v_s = Particle settling velocity
Q = Water flow rate
A_{top} = Surface area of the top of the basin

Note that this equation is solely a function of flow rate and surface area. Therefore, depth of the basin has no bearing on the effectiveness of a sedimentation basin. Depth is only necessary to provide storage for settled particles. This type of basin functions as water flows in, on the upstream end, and out, via an overflow, at the downstream end of the basin. For basins to be effective, the length to width ratio should be at least 4 to 1 (MDNRE, 2010).

Other sedimentation basin designs can also be used. Dane County, Wisconsin uses a design with a vertical stand pipe as the primary outlet as shown below in Figure 3.

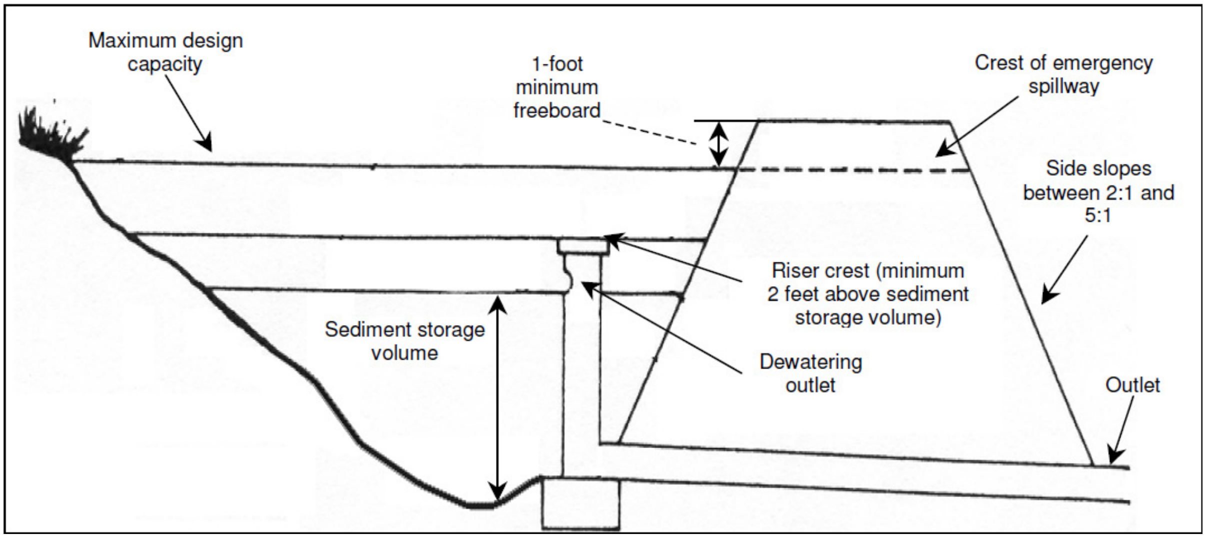

Figure 3: An Example of a Sediment Basin (Source: Dane County, 2007)

Though such a design can be effective, on small-scale basins such as those needed to treat runoff from agricultural fields, stand pipes can lead to increased cost. Therefore, simpler designs without a vertical riser may be more cost-effective and will allow the BMP to be repositioned as needed.

F. Cost Benefit of BMPs

The value of benefit derived by a BMP is equivalent to the decreased cost incurred by the person(s) responsible for maintenance of the receiving water body. Therefore, this is solely a function of the cost of maintenance and the amount of pollutant (in this case, sediment) removed. For BMPs to be cost effective however, the cost savings they produce must be greater than or equal to the cost to implement them.

The primary cost to agricultural producers who implement filter strips and sedimentation basins in the Kawkawlin River Watershed, or any watershed, is the removal of the land used to implement the BMP from production. This opportunity cost should be reflected by the typical rental rate agricultural producers charge for land. The USDA's National Agricultural Statistics Service maintains data on rental rates of agricultural land. Table 2 shows average rental rates reported for farmers in Bay County from 2008 through 2010.

Table 2: National Agricultural Statistics Service average rental rates for non-irrigated cropland in Bay County, MI.

Average Rental Rates in Bay County	
Year	**Rent Price per Acre**
2008	$102.00
2009	$98.50
2010	$95.00

Based on the most recent rental information, for BMPs to be cost effective in the Kawkawlin River Watershed, each acre of land covered by BMPs must produce at least $95 of benefit per acre and must also compensate for the cost of BMP implementation (e.g. - excavating a sedimentation basin or planting a filter strip). A survey of farmers in East Central Michigan conducted in 2010 found rental rates to be slightly higher as shown in Table 3 (MSU, 2010). The results reported from this survey are based on data obtained from 38 survey respondents from an area of Michigan which includes Arenac, Bay, Huron, Saginaw, Sanilac, and Tuscola Counties.

Table 3: Average land rental rate in 2010 for East Central Michigan counties.

Average Rental Rates in for 2010	
Rent Price per Acre	**Description**
$142.00	Field Crop, Tiled
$103.00	Field Crop, Non-Tiled
$165.00	Sugar Beet
$178.00	Irrigated

The USDA's Farm Service Agency breaks down soil rental rates based on soil type. Information collected for Bay County, Michigan is presented in Table 4 and indicates rental rates are in-line with those presented in Table 2 and Table 3.

Table 4: Farm Service Agency average soil rental rates for Bay County, Michigan.

Bay County Soil Rental Rates			
Soil Type	**Cost/acre**	**Soil Type**	**Cost/acre**
12	$99	50	$82
13	$82	57A	$99
16	$70	58A	$130
17A	$82	59	$45
23	$130	61	$82
25A	$45	62A	$130
31	$99	63A	$107
35A	$45	64B	$130
37B	$45	65B	$130
43A	$130	66A	$45
49A	$130	67	$45

IV. STUDY DEVELOPMENT

This study of agricultural BMPs focuses on three main areas pertaining to drain maintenance. First, vegetative filter strips are analyzed to assess their potential for sediment removal from overland runoff. This type of BMP addresses sediment entrained in sheet flow, however, such BMPs do not perform as well when overland flow leaving an agricultural field becomes concentrated in natural or constructed channels. Therefore, sediment reduction in concentrated flows is addressed through the use of small-scale sedimentation basins. Finally, a cost analysis is done to ensure these agricultural BMPs are economical. Costs to landowners must be counteracted by a corresponding reduction of drain cleanout costs assessed to a drainage district.

A. Vegetative Filter Strips

For this study, RUSLE2 was selected to model VFS effectiveness. It was chosen for a number of reasons which are listed below:

- RUSLE2 does not use an event-based rainfall component and instead uses long-term averages computed from actual rainfall data. The advantage of this approach is that the model is applicable to runoff in a typical year rather than to a specific design storm. Unlike stormwater detention, which is designed to mitigate large, relatively infrequent storms, filter strips should be designed to reduce sediment in small, frequent storms. It is acknowledged that large storms such as the 10, 25, 50, or 100-year event may cause substantial erosion; however, filter strips should be designed for "typical" rainfall situations.

- Databases within RUSLE2 provide easy access to typical soil and agricultural practice data for a given area. These databases simplify input and allow the user to easily compare multiple alternatives.
- The RUSLE2 program is used by the USDA and is an accepted method of computing sediment yield from agricultural lands.

Once an appropriate computer model was selected, the next step was to set up the model to describe VFS effectiveness in the Kawkawlin River Watershed. As described previously, there are vast arrays of variables which impact the effectiveness of a VFS. Appropriate design of a VFS requires agricultural practices, soil conditions, topographic variables, and climactic characteristics to be considered. If such a design is to be widely utilized, it must have broad applicability over a wide array of circumstances. Therefore, emphasis was placed on situations that were common to the Kawkawlin River Watershed.

1. Soil Types

The first step in developing a sediment transport model for the Kawkawlin Watershed is to determine general soil characteristics. Initially, a soil map of Bay County, Michigan was used to identify those soil types most common in the area. Eight soil types were identified as being common in the watershed which are shown below in Table 5.

Table 5: Common soils found in the Kawkawlin River Watershed.

Code	Name	Slope	Description
17A	Wixom Loamy Sand	0-3%	Wixom loamy sand 90%
23	Tappan Loam	n/a	Tappan loam 85%
43A	Londo Loam	0-1%	Londo loam 85%
49A	Londo-Poseyville Complex	0-3%	Londo loam 50%
49A	Londo-Poseyville Complex	0-3%	Poseyville loamy sand 30%
57A	Poseyville Loamy Sand	0-3%	Poseyville loamy sand 90%
58A	Tappan-Poseyville Complex	0-3%	Poseyville loamy sand 27%
58A	Tappan-Poseyville Complex	0-3%	Tappan loam 55%

These soil types were then grouped by their erosion characteristics used in RUSLE2. Erosion is primarily a function of sediment size distributions. By referring to the database in RUSLE2, the eight identified soils were separated into three groups with similar sediment particle distributions. These groupings are shown below in Table 6 with associated particle size distributions in Table 7. By categorizing soil types, the number of soil types that had to be modeled could be reduced from eight to three.

Table 6: Soil groupings based on RUSLE2 soil characteristics.

Group #	Code	Name	Slope	Description
1	17A	Wixom Loamy Sand	0-3%	Wixom loamy sand 90%
	49A	Londo-Poseyville Complex	0-3%	Poseyville loamy sand 30%
	57A	Poseyville Loamy Sand	0-3%	Poseyville loamy sand 90%
	58A	Tappan-Poseyville Complex	0-3%	Poseyville loamy sand 27%
2	23	Tappan Loam	n/a	Tappan loam 85%
	58A	Tappan-Poseyville Complex	0-3%	Tappan loam 55%
3	43A	Londo Loam	0-1%	Londo loam 85%
	49A	Londo-Poseyville Complex	0-3%	Londo loam 50%

Table 7: RUSLE2 soil particle size distributions.

	Percent of Particles		
	Group 1	Group 2	Group 3
Sand (0.05-2mm)	84%	42%	45%
Silt (0.002-0.05mm)	9%	38%	41%
Clay (<0.002 mm)	7%	20%	14%

2. *Agricultural Practices*

Sediment yield from a VFS depends greatly on the amount of sediment entering the filter. Therefore, the land use in upland areas contributing to the filter strip plays a key role in filter effectiveness. In a temperate climate such as Michigan, seasonal changes can affect both the filter strip vegetation and agricultural land use. Only a limited number of crops can be planted in the winter months due to frequent cold temperatures and snow. Additionally, many grasses go dormant during these times. Therefore, it is difficult to determine a "typical" crop/VFS combination that applies broadly throughout the year.

The RUSLE2 model was used to predict sediment transport for a range of different agricultural practices selected from the database, all of which are specific to the Kawkawlin Watershed area.

3. Climate Data

Another important model characteristic which influences sediment yield is local climate. As mentioned previously, climate data were obtained from the RUSLE2 database. The data, based on actual climate records, contained typical annual rainfall and temperature information. This could be broken down and compared by month, half-month, or daily increments. RUSLE2 calculates rainfall erosivity based on an "erosivity index" which is defined as an "Index of average annual rainfall erosivity at a location; closely related to rainfall amount and intensity; monthly erosivity is average sum of individual storm values in month, annual erosivity is average sum of values in year; storm rainfall amount must be ½ inch or more to be included in sum" (USDA-ARS, 2008; p 18).

In calculating rainfall erosivity, RUSLE2 accounts for seasonal changes by reducing erosion to near zero when average temperatures fall below 30^{o}F (USDA-ARS, 2008; p 126). In this way, it effectively eliminates erosion when precipitation changes from rain to snow. However, upon temperatures increasing, RUSLE2 does not account for erosion resulting from snowmelt.

4. Upland Slope

Slope also plays a pivotal role in calculating sediment yield from agricultural lands. Steeper slopes produce faster flowing runoff than do shallower slopes. This higher velocity tends to increase sediment particle detachment and therefore produce more sediment yield. Unlike many of the other parameters modeled in this analysis, slopes in the Kawkawlin River Watershed are fairly consistent. Based on geospatial topographic information provided by the State of Michigan, slopes in the watershed are typically less than 1.0%. Though other slopes were modeled for comparative purposes, slopes of between 0.5 and 1.0% were found to be typical of agricultural lands in the Kawkawlin River Watershed.

5. Slope Length

Slope length is used by RUSLE2 as a measure of contributing area to a receiving water body. This is the length over which runoff flows before entering the outlet. The RUSLE2 User Guide (USDA-ARS, 2003) recommends a maximum overall slope length of 1,000 feet. Distances longer than this will likely result in flows becoming concentrated. Equations used in RUSLE2 are designed to estimate sheet, rill, and inter-rill erosion. Once flow becomes concentrated in channels, the sediment transport equations in RUSLE2 no longer apply.

6. Filter Strip Design

Design of vegetative filter strips requires the identification of two key parameters, vegetation type, and filter width. RUSLE2 was used to compare various types of vegetation to determine relative treatment performance. Though the literature review found several sources that used filter strips with various zones of trees, grasses, and shrubs, this study only analyzed grass filter strips. One reason why only grass strips were used is because they tend to be narrower than multi-zoned strips. This reduces the amount of agricultural land that must be removed from production and minimizes the financial impact on landowners. Furthermore, the focus of zoned filter strips includes improvement of wildlife habitat and uptake of chemical pollutants (Schultz et al., 1997). Though these are positive effects, the focus of this study is on sediment reduction. Therefore, the grass filtration zone is likely the most important component of a zoned system. It should be noted the grass filter may not be large enough to promote chemical uptake of nutrients, however, those nutrients attached to sediment particles may still be removed.

The other primary component of filter strip effectiveness is filter width. This width is the length of hill slope covered by VFS measured perpendicular to the receiving channel. Logically, larger filter widths should have higher levels of filtration and thus, lower sediment yields. However, the other factors described above complicate this relationship. As sediment supply and runoff velocity change, the effectiveness of the filter is altered. Furthermore, optimum filter width may vary seasonally. During times of the year when fields are bare and large rainfall events occur, more filtration is needed than during frozen winter months or when fields are densely covered with crops. Therefore, a standard design time and rainfall condition is needed for which filter strips are designed.

B. Sedimentation Basins

Concentrated flows require a different treatment sequence than sheet flow runoff. Instead of filtration BMPs such as VFS, gravity settling BMPs can be used to slow water and allow sediment to settle out. Though RUSLE2 has some capability to model impoundments, it does not provide a sufficient number of options to actually design a settling basin at the end of a concentrated flow path. However, despite this limitation, RUSLE2 does provide information regarding the distribution of detached particles. This particle size distribution can be used in conjunction with settling basin equations to design basins with a particular rate of sediment removal.

C. Cost Analysis

Information on drain maintenance in the Kawkawlin River Watershed can be used to assign a cost to sediment. Through the use of BMPs such as filter strips and sedimentation basins, sediment loads in receiving water bodies may be reduced. Therefore, drainage ways will accrue sediment more slowly and require less frequent cleanouts and maintenance. This increase in time between cleanouts is the financial benefit of sediment removal. For these sediment removal BMPs to be cost-effective, the benefit derived by increasing the time between cleanouts must be greater or equivalent to the cost of BMP implementation.

V. RESULTS

Various scenarios were modeled in RUSLE2 to compare the relative influence of each of the identified parameters influencing VFS effectiveness. Over 600 different combinations of soil types, agricultural practices, upland slope, slope length, and filter strip design were analyzed in the RUSLE2 model. Sensitivity of each of these characteristics was assessed so analysis could be limited to only those characteristics which strongly impact filter strip effectiveness. Additionally, results of the sedimentation basin analysis were determined based on sediment characteristics used in RUSLE2. Finally, a cost analysis model was created to measure the benefit derived from BMP implementation.

A. RUSLE2 Filter Strips

1. Soil Types

A soil map of Bay County, Michigan was used to determine eight (8) of the most common soil types in the Kawkawlin River Watershed. Data in RUSLE2 were compared for each soil type. Of the eight (8) soil types, RUSLE2 showed they could be grouped into three (3) distinct categories based on particle size distributions. These groupings were shown previously Table 6.

2. Agricultural Practices

Agricultural practices vary throughout the Kawkawlin River Watershed. Examples of crops prevalent in the area include wheat, corn, soybeans, and sugar beets. Additionally, erosion under bare ground conditions is also important. In Figure 4, several different agricultural practices are compared for each of the soil categories shown in Table 6.

These values were produced using a 1,000 foot upland slope length and standard slope of 1.0 percent.

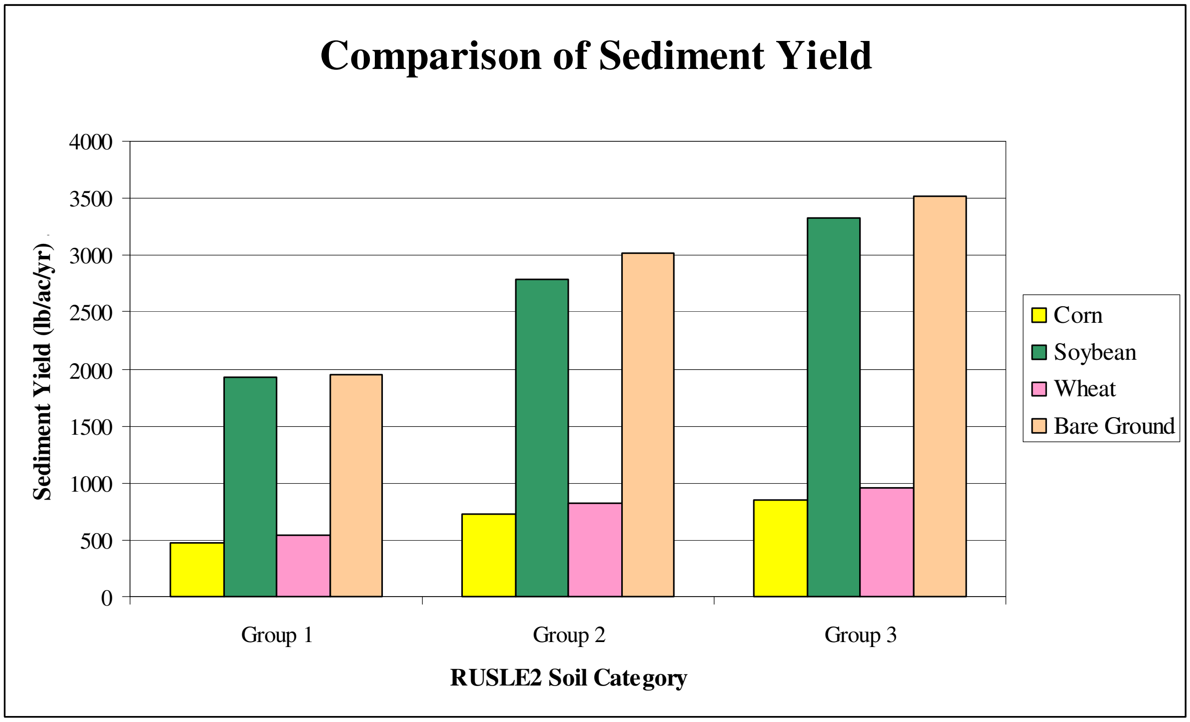

Figure 4: Comparison of agricultural practices on each soil classification in RUSLE2.

As shown in the above figure, soils have the greatest propensity for erosion when vegetative cover has not been established. Also of importance is the sediment yield disparity between various vegetation types. In all cases, average annual sediment yield from a field planted with soybeans is more than three (3) times that experienced by a field planted with corn or wheat. To establish a standard for determining VFS effectiveness and design criteria, a standard design condition was needed. The "Bare Ground" scenario was selected as a baseline for this filter strip study. This was done because it simulates a worst-case scenario and is indicative of conditions when runoff can cause the most severe erosion. In the Kawkawlin River Watershed, bare ground exists in the early spring when the ground has thawed and crops have either not been planted or are not established to sufficiently provide ground cover. Such conditions may also exist in the fall after crops have been harvested.

3. Upland Slope

Another key factor affecting erosion rate is the slope of upland areas contributing runoff to a filter strip. Various slopes were modeled using the RUSLE2 computer model which included 0.5, 1.0, and 2.0 percent slopes. A fourth scenario was modeled which was comprised of a 1.0 percent slope for most of the upland area and a steeper 5.0 percent slope for the final 100 feet adjacent to the drain. Figure 5 shows the relative average annual sediment yield produced by each of the varying slopes. From the graph, it appears that doubling the upland slope roughly doubles the sediment yield from the agricultural land. For the purposes of this study, an average slope of 0.5 percent was selected. This decision was based on available topographic and geospatial information for the Kawkawlin River Watershed.

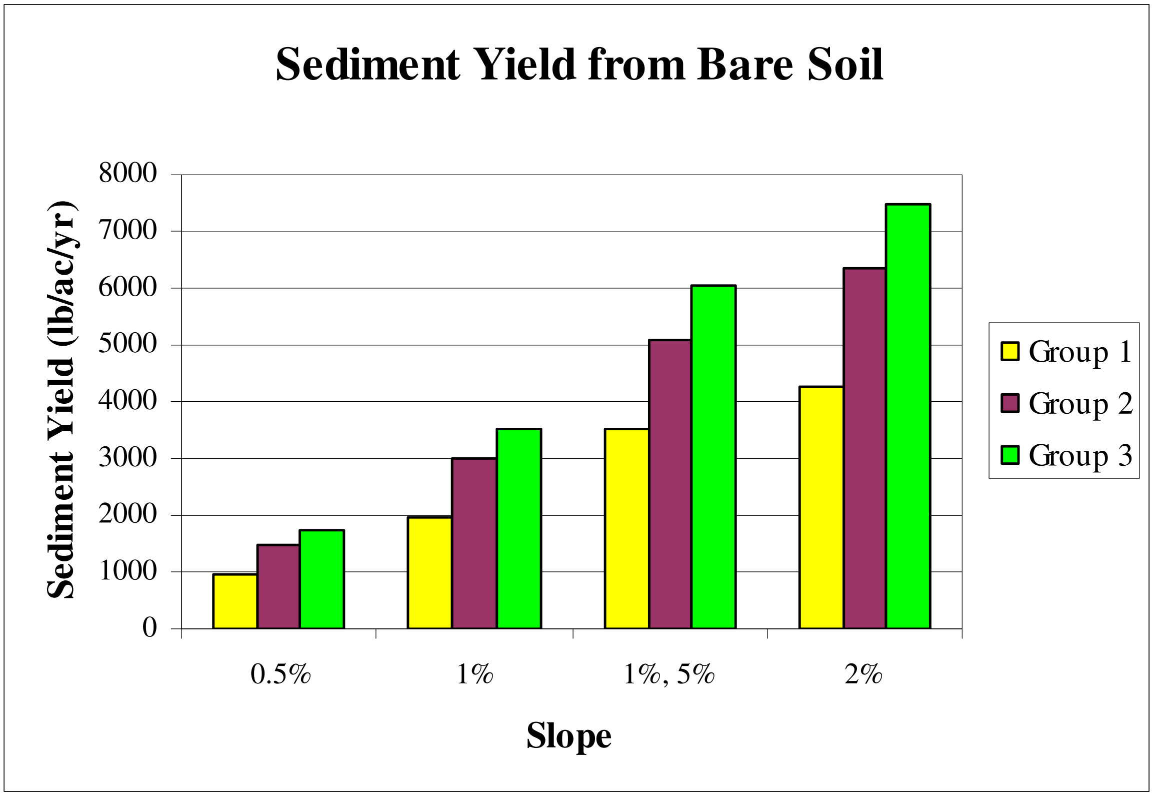

Figure 5: Sediment yield from bare soil for each RUSLE2 soil group using 1,000 ft of upland slope.

4. Slope Length

In addition to slope, the length over which runoff flows before reaching a filter strip or receiving water body affects the quantity of sediment that will be delivered. RUSLE2 was used to model the effect of various upland slope lengths on overall sediment delivery. Here, bare soil was used with the 0.5 percent slope identified in the previous section. The results of this analysis are shown below in Figure 6.

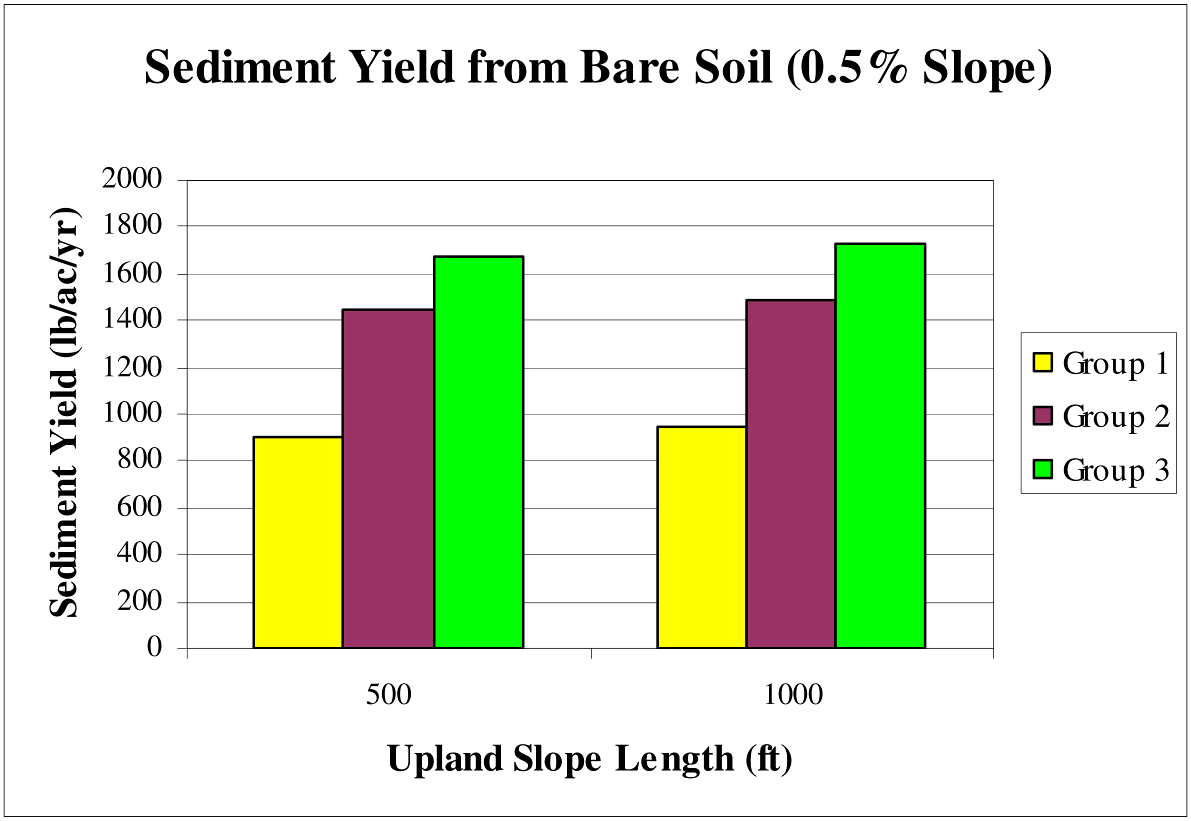

Figure 6: Rate of sediment yield from bare soil on 0.5% slope for each RUSLE2 soil group for varying upland slope lengths.

Note the similarity in erosion rates for each slope length. This does not indicate that the total sediment quantity coming off each simulated field is similar. Instead it indicates that the rate of sediment yield is similar on a per-acre basis. Therefore, the model simulating a 1,000 foot slope length would produce roughly twice the volume of sediment as would be produced by a 500 foot slope because it contains twice the ground area. This can be demonstrated by showing a comparison of sediment volume per mile of length along the drainage way as was done in Figure 7. The mass of sediment was converted to a volume using the specific gravity of each soil type in the RUSLE2 program (2.27, 1.97, & 2.09 for Group #1, 2, & 3 respectively).

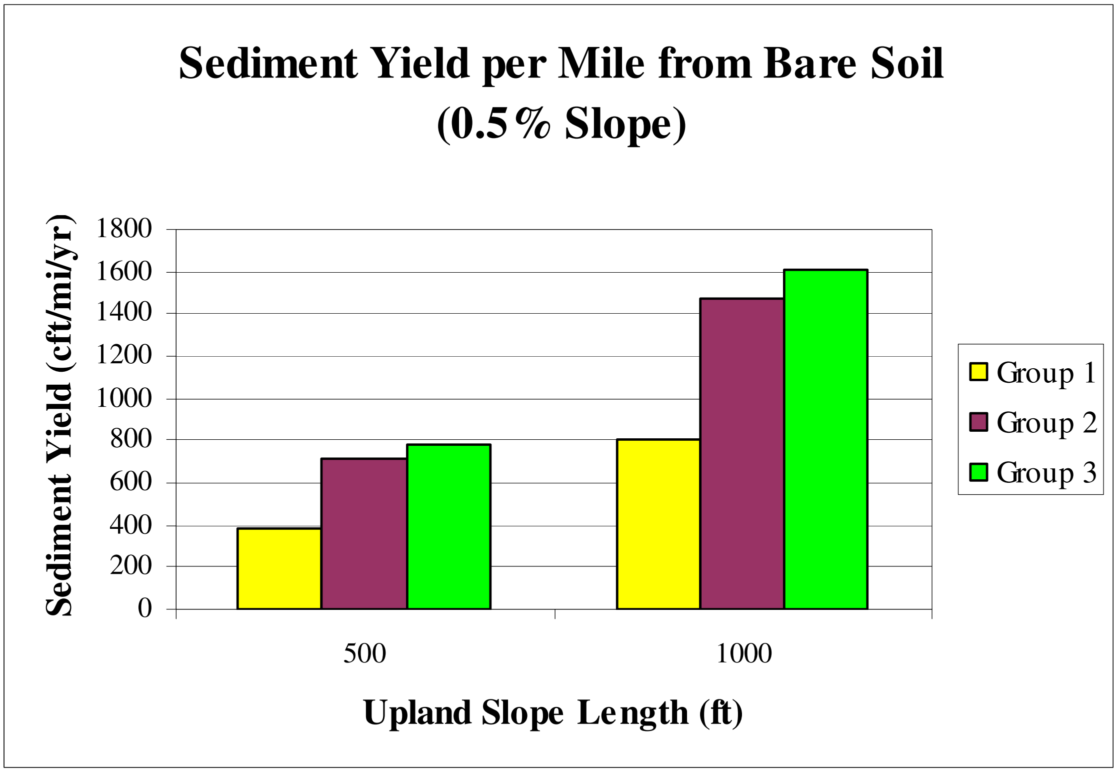

Figure 7: Sediment yield from bare soil at 0.5% slope for different upland slope lengths. Yield is quantified on a volume per length basis.

Notice that the sediment yield per length of drain for the 1,000 foot slope is roughly double that of the 500 foot slope. This result was expected as the contributing area for the 1,000 foot slope is double that of the 500 foot.

5. Filter Strip Design

Filter strip design can be broken down into two primary factors which affect VFS effectiveness: vegetation type and filter width. Each of these factors were analyzed independently in RUSLE2. First, filter strip widths of 10, 20, 30, 40, 50, and 70 feet were modeled. A typical switchgrass filter strip was used to treat runoff from a 1,000 foot long section of bare soil at an average grade of 0.5 percent. This was done for each of the three soil groupings prevalent in the Kawkawlin River Watershed as shown in Figure 8.

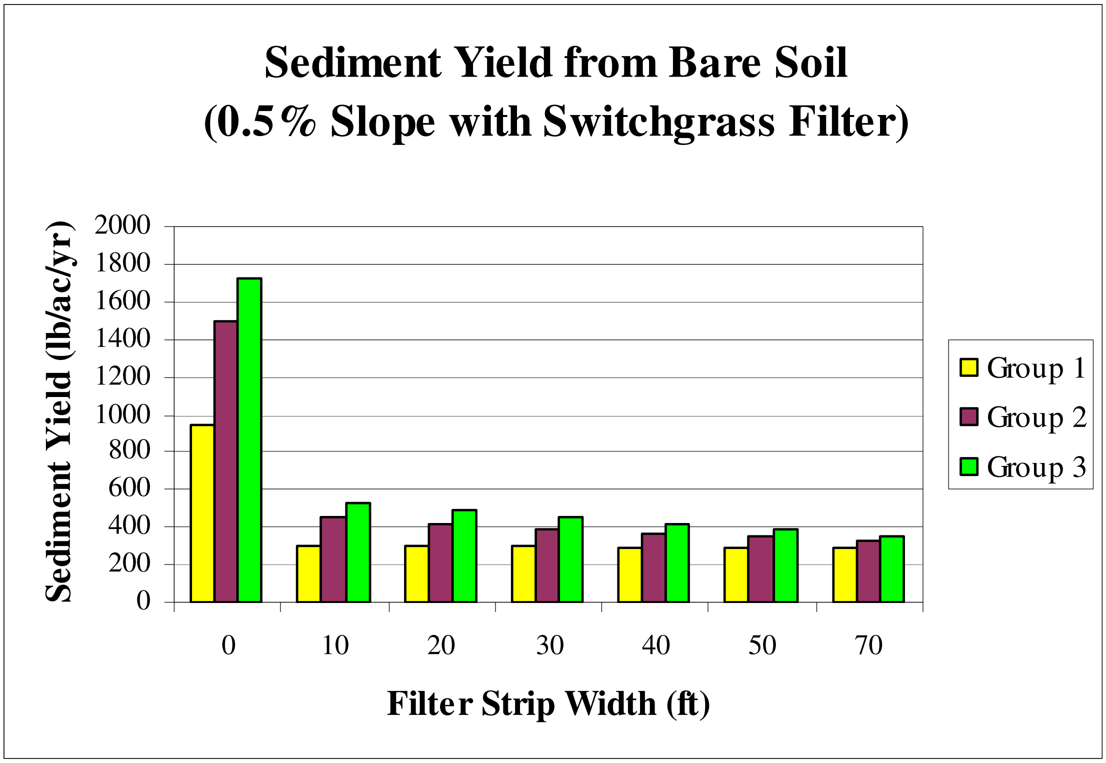

Figure 8: Comparison of filter strip effectiveness modeled in RUSLE2 for each soil grouping.

Of particular interest in the above figure is the sharp decrease in sediment yield when a small 10 foot strip is implemented. Additional filter length shows some further decrease in the amount of sediment leaving the field however the decrease is less substantial than that modeled between no filter and a 10 foot strip.

Next, several different common vegetative barriers were assessed using the RUSLE2 program. These included switchgrass, Kentucky Bluegrass, and Bermuda grass. This comparison is shown below in Figure 9. Again a 1,000 foot slope length was used on a 0.5% slope. For the purposes of comparison, Figure 9 shows each grass being used on soils from Group #2.

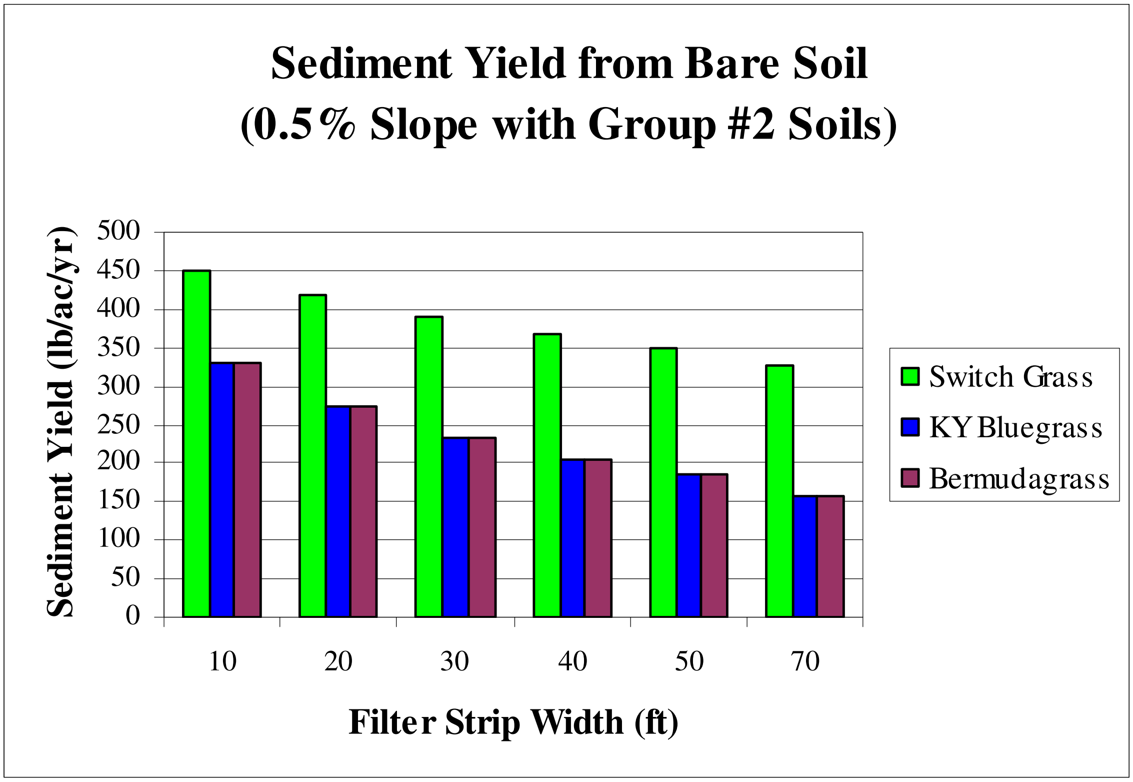

Figure 9: Analysis of filter strip effectiveness for various grasses. Analysis was performed using soils from Group #2.

The above figure shows that RUSLE2 predicts lower levels of sediment passing through Kentucky Bluegrass and Bermudagrass filter strips than switchgrass. However, this does not account for how robust a particular grass type is throughout the season. For instance, switchgrass is typically stiffer than either Kentucky Bluegrass or Bermudagrass. Therefore, it may be less susceptible to heavy snow loads or high winds than would other grasses.

B. Sedimentation Basin Design

Using a residence time settling calculation (Mihelcic, 1999, p189) with average settling velocities and sediment classifications from RUSLE2, Table 8 was produced. This table assumes an inflow rate of 2.10 ft^3/s, based on a V-shaped channel flowing full, that is 1.0 feet deep, 2.0 feet wide at the ground surface, on a 0.5 percent slope, and with a Manning's "n" of 0.025. The Manning's value was selected based on a winding earthen channel without vegetation (Sturm, 2001, p117).

Table 8: Required settling basin surface area to settle out various soil particle sizes at the end of a V-ditch carrying 2.10 cfs.

Soil Classification	Residence Time (sec)	Settling Velocity (ft/sec)	Settling Velocity (mm/sec)	Surface Area (ft^2)
clay	196,675	0.000010	0.003	207,000
silt	7,620	0.0003	0.080	8,000
small agg.	1,604	0.0012	0.380	1,700
large agg.	34	0.0591	18.000	36
sand	27	0.0755	23.000	28

The distribution of the particles shown in Table 8 was then analyzed for each of the three soil groups identified in Table 6. Each soil group was assessed based on its particle distribution. Table 9 shows the relative proportions of detached particles estimated in RUSLE2 for each of the identified soil groups.

Table 9: Portion of detached particles calculated in RUSLE2 for each of three soil groupings.

	Portion of Detached Particles		
	Group 1	Group 2	Group 3
clay	1.8%	5.2%	3.6%
silt	0.0%	9.8%	16.0%
small aggregate	9.2%	28.1%	25.2%
large aggregate	30.7%	43.1%	34.1%
sand	58.3%	13.8%	21.1%

Based on Table 8, a settling basin with surface area of 36 ft^2 will allow large aggregate and sand to settle out of stormwater runoff conveyed by a V-ditch with a flow rate of 2.1 cfs. If all large aggregate and sand were settled from each of the soil groups, 89, 57, and 55 percent of total sediment load could be removed from runoff over soils in Group #1, 2, and 3 respectively. The next step was to compare the sedimentation basin design needed for varying size V-ditches. Table 10 shows the basin surface area needed to settle various particle sizes for flows up to 15 cfs. 15 cfs equates to a full-flowing V-ditch that is on a 0.5%

slope, a Manning's "n" of 0.025, a depth of 2.0 feet, and a top width of 4.5 feet. Note, the depth of the sedimentation basin will determine the quantity of sediment that may be accumulated before maintenance becomes necessary, however, it does not impact the size of particle that can be settled.

Table 10: Requisite surface area to settle particles of varying sizes for various inflow rates.

Surface Area to Settle Specified Particle Size					
Discharge (cfs)	Clay (sft)	Silt (sft)	Small Aggregate (sft)	Large Aggregate (sft)	Sand (sft)
1	98,323	3,810	802	17	13
2	196,645	7,620	1,604	34	27
3	294,968	11,430	2,406	51	40
4	393,290	15,240	3,208	68	53
5	491,613	19,050	4,011	85	66
6	589,935	22,860	4,813	102	80
7	688,258	26,670	5,615	119	93
8	786,581	30,480	6,417	135	106
9	884,903	34,290	7,219	152	119
10	983,226	38,100	8,021	169	133
11	1,081,548	41,910	8,823	186	146
12	1,179,871	45,720	9,625	203	159
13	1,278,194	49,530	10,427	220	172
14	1,376,516	53,340	11,229	237	186
15	1,474,839	57,150	12,032	254	199

C. Cost Analysis Model

A cost analysis model was developed to quantify the impact of BMPs on sediment. This model was developed in such a way as to maximize its applicability to various drains. The model was designed to incorporate key features of drains which may impact the rate of sediment accumulation, cleanout frequency, and cleanout cost. The final model output provided an annual value of BMPs at a field-scale. Specific results of the model depend on assumptions made for sediment yield rates produced from agricultural fields. Therefore, these results are contingent upon the conclusions made in the filter strip and sedimentation basin analyses.

VI. ANALYSIS AND DISCUSSION

The purpose of this study has been to determine a standard method of quantifying the impact of vegetative filter strips on sediment entrained in stormwater runoff entering drains in the Kawkawlin River Watershed. To accomplish this, standards had to be determined for filter width and treatment effectiveness. Additionally, estimates had to be made for sediment settling in drains and the impact this has on drain maintenance.

A. Standard Design of Upland Areas

Several characteristics of upland areas affect the amount of sediment reaching and subsequently passing through a VFS. As discussed in the Results section, soil type, agricultural practices, upland slope, and slope length all play important roles in determining the quantity and character of sediment reaching a VFS. Also, the type and width of the VFS itself has a substantial impact on the amount of sediment finally reaching the receiving drainage way.

1. Soil Type

In comparing the soil types analyzed with RUSLE2, soils in Group #2 were consistently between those in Groups #1 and 3. Additionally, soils identified in Group #2 make up over one-third of the soils found in Bay County (USDA, 1980; p 86). Therefore, typical erosion rates will be based off of soil in Group #2.

2. Agricultural Practices

The RUSLE2 analysis showed vast inconsistencies in sediment yield among farming practices in the Kawkawlin River Watershed. As an additional step beyond the analysis results from RUSLE2, daily erosivity was considered. These values were taken from the climatic data used in RUSLE2. By performing a weighted average of daily values and summing the result for each month, Table 11 was produced which shows the distribution of rainfall erosivity as it varies throughout the year.

Table 11: Distribution of erosivity index used in RUSLE2 for Bay County, MI.

Bay County, MI Relative Erosivity	
January	0.75%
February	0.78%
March	2.62%
April	5.01%
May	8.43%
June	15.74%
July	16.92%
August	21.18%
September	17.05%
October	6.31%
November	3.50%
December	1.71%
TOTAL	**100.00%**

Notice that the greatest potential for erosion occurs in the summer months when crops are on the fields. Only about 23 percent of the annual erosivity occurs in the period from November through May when fields are bare or have little growth. It should be noted, however, that snowmelt is not incorporated into the RUSLE2 model. This, coupled with anecdotal information, shows that erosion during winter and spring months is typically not due to rainfall but due to snowmelt. Based on this assessment, in conjunction with the variability shown among crop types, filter strips should be designed for the bare soil condition. This condition is indicative of conditions when soil is most prone to erosive forces.

3. Slope Characteristics

As explained in Part 4 of the Results section, slope length can be effectively negated if erosion is measured in terms of volume (or weight) per acre. The rate of sediment yield per acre remains relatively constant regardless of the size of the overall contributing area. Changes in slope however cause substantial differences in total sediment yield. As a result, a standard slope of 0.5 percent was selected based on typical land slopes in the Kawkawlin River Watershed.

4. Filter Strip Design

In Part 5 of the Results section, various filter strip grasses and widths were analyzed. From Figure 8, use of only a 10 foot filter strip was shown to reduce sediment yield by roughly 70 percent for a switchgrass filter on soils from Group #2. Increasing the filter width to 20 feet showed a reduction of about 72 percent as compared to bare soils. If the filter were extended out to 70 feet, the modeled load reduction would be about 78 percent. These results indicate the vast majority of sediment is removed in the first 10 feet of a VFS. Additional width beyond 10 feet may increase filter longevity, however, the amount of added benefit is minimal. Therefore, a filter width of 10 feet, measured from the top of the receiving waterway bank, is recommended. It is also important to note that percent reduction as a sediment removal metric will depend on the character and quantity of sediment entering the VFS. Percent reduction will decrease if excessively large or small quantities of sediment are supplied to the filter strip. Large amounts of sediment may overwhelm the filter, thereby reducing efficiency. Since the filter strip functions by settling sediment, very small amounts of sediment may be unaffected by the filter strip, particularly if the sediment consists of small particles.

Grass type was also assessed in RUSLE2 models. Figure 9 showed Kentucky Bluegrass and Bermudagrass to be slightly more effective than switchgrass. However, as noted previously, the added strength of switchgrass under snow loads and during high flows makes it the recommended filter grass.

B. Sediment Accumulation

Rate of sediment accumulation in a receiving watercourse depends on the quantity and character of sediment leaving upland areas. Also, the width of the receiving drain will impact the rate at which sediment depth increases. Based on identified standard design criteria of Group #2 soils, bare ground condition, and 0.5 percent slope, net sediment yield calculated by RUSLE2 is roughly 12 ft^3/ac/yr. With a 10 foot switchgrass VFS, sediment yield was shown to decrease to roughly 3.5 ft^3/ac/yr.

If it is assumed all sediment settles out of the water and deposits in the drain, a volume of sediment entering the drain may be calculated. Though it is unlikely this will occur in the reach of drain immediately adjacent to a given property, it is likely the majority of sediment will settle out somewhere downstream in the drain. The precise location of sediment deposition depends largely on water velocity and the size of sediment particles passing through the VFS. A comparison of model results to historical drain maintenance information is needed to confirm the findings of the RUSLE2 model and calibrate it to field conditions.

C. Drain Maintenance

Drain maintenance is necessary when sediment has accumulated in a drain to the point that flow capacity is reduced, drainage is impaired, and flooding occurs. Based on the reduction of sediment from 12 to 3.5 ft^3/ac/yr, the time between drain cleanouts would increase by roughly 3.4 times. This would seem to indicate that if drains are typically cleaned every 30 years, the time between cleanouts could be increased to 100 years with complete coverage of VFS. However, this result does not account for other extraneous environmental factors which may impact VFS effectiveness. First, wind erosion may contribute sediment to drainage ways which is unaccounted for in the RUSLE2 model. Secondly, tributary flows contributed by drainage ways, which are not established county drains may still contribute sediment at historic rates. Additionally, the RUSLE2 model can only calculate sheet flow erosion, rill erosion, and inter-rill erosion. If preferential flow paths develop through a filter strip, higher than predicted erosion rates may occur. Prevalent farming practices such as small v-shaped surface channels ("V-ditches") cut through fields to provide surface drainage and concentrate flow, making filter strips less effective. In such instances, other treatment methods such as settling basins would be needed to help reduce sediment inflows. Also, sediment may be contributed to filter strips by parcels not immediately adjacent to the drainage way. In these cases, overland flow may come from a neighboring parcel and create higher concentrations of sediment in the drain than would be expected if only the parcels immediately adjacent to the drain were considered. Finally, some agricultural producers in the Kawkawlin River watershed do not presently farm right to the edge of drainage ways. In such instances, any vegetation left between farmed land and the drain could act as a filter strip and reduce total sediment load.

Because of the number of variables affecting filter strip effectiveness and sediment yield from farmland, historical drain cleanout information was used to establish typical patterns of drain maintenance in the Kawkawlin River Watershed. Information was collected from the Bay County Drain Office which included plans and cleanout records from six (6) drains which met the following criteria:

- Located in the Kawkawlin River Watershed
- Have had a cleanout in the past 25 years
- Have been cleaned out regularly since being established
- Drain primarily agricultural lands
- Do not abut roads for long reaches

The drains meeting the aforementioned criteria are shown below in Table 12. The table shows general characteristics of the most recent cleanouts on each drain. Figure 10 highlights each of these drains on a map of the Kawkawlin River Watershed.

Table 12: Historical drain cleanout data in Kawkawlin River Watershed.

Drain Name	Year Cleaned	Prior Cleanout	Time Between (yrs)	Drainage Area (ac)	Length Cleaned (mi)	Approx. Sed. Removed (cyd)	Rate (cft/ac/yr)
Crump	1993	1963	30	3,400	8.4	20,600	5.5
Hembling	1993	1970	23	4,500	10.6	13,500	3.5
Popp	1998	1970	28	1,310	5.2	9,500	7.0
Bradford	1989	1952	37	2,760	8.3	23,800	6.3
Hildebrandt-Anderson	1998	1972	26	2,240	6.2	7,800	3.6
Goss (Bedell)	1998	1955	43	422	1.8	2,600	3.9
AVERAGES			**31.2**	**2,440**	**6.8**	**13,000**	**4.6**

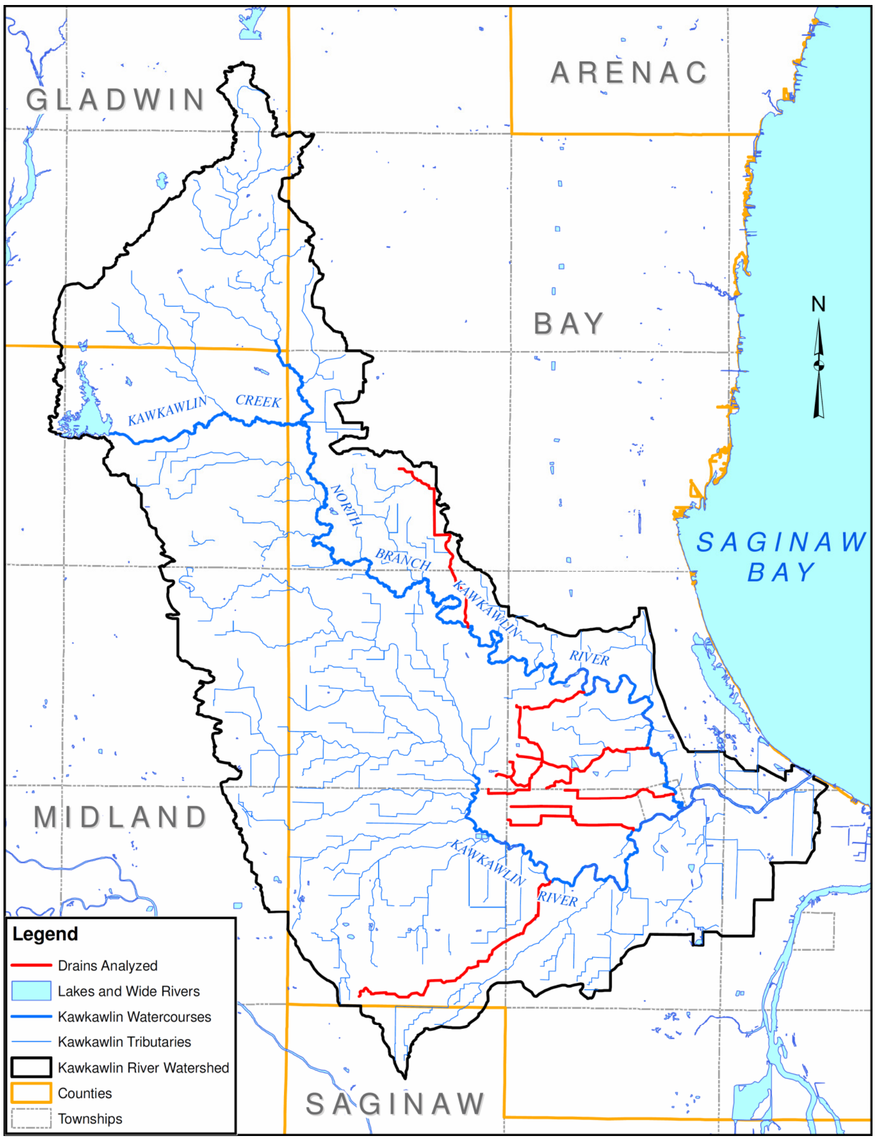

Figure 10: Map of Kawkawlin River Watershed highlighting (red) those drains analyzed which have historical drain cleanout information.

From the data in Figure 10, an average rate of sedimentation of 4.6 ft^3/ac/yr was found. This value is substantially lower than the modeled value of 12 ft^3/ac/yr calculated in the RUSLE2 model. However, it is important to consider that the RUSLE model was used for bare soil conditions which are typically present for the period of November through May. During this period, the erosivity accounts for roughly 23 percent of the annual total as shown in Table 11. Therefore, it can be presumed that about 3 ft^3/ac/yr occurs during periods where bare ground conditions exist. Depending on the type of crop planted, erosion rates for the remainder of the year may be significantly reduced. Furthermore, RUSLE2 calculates the volume of sediment entering a receiving water body. It is possible that some of the smallest particles entering the drainage way do not settle out. An adjusted value of sediment yield is needed to account for differences between the model and observed conditions. Additionally, sediment contributions from concentrated flow paths, such as V-ditches are not accounted for in the RUSLE2 assessment of filter strip effectiveness.

D. Concentrated Flows

As demonstrated in Table 10, there is a sharp increase in required area to settle particles when size decreases from small aggregate to silt. A similar increase was shown when size decreases from large aggregate to small aggregate. Additionally, it was previously noted from Table 9 that at least 50 percent of total detached particles modeled with RUSLE2 are either sand or large aggregate. For the maximum flow rate modeled of 15 cfs, an area of only 254 ft^2 (0.006 acres) was necessary to settle these larger particles. If small aggregate is also targeted, the area needed increases to over 12,000 ft^2 (0.28 acres). The optimum design will require a balance between land use and benefit to the drainage district.

E. Cost Assessment

The information in Table 12 provided actual information with respect to time between drain cleanouts, drain length, sediment accumulation, and watershed area. This information may be used in conjunction with estimated RUSLE2 data to corroborate sediment accumulation rates shown by the RUSLE2 model. By adding a cost per foot of drain, the cost benefit derived from filter strip implementation can be found. This assessment will be made based on conclusions made in the following section.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. Vegetative Filter Strips

RUSLE2 results coupled with historical drain cleanout data have lead to specific conclusions regarding the effectiveness of vegetative filters. Limited historical data have indicated an average sediment yield rate of roughly 4.6 ft^3/ac/yr. Considering all of the drainage areas contributing to the analyzed drains are not likely to be comprised exclusively of agricultural land and all agricultural areas are not tilled right to the edge of drains, this number is likely lower than the value expected from a given field. For farmed regions without filter strips, a value of 6.0 ft^3/ac/yr is recommended. This equates to roughly 38 tons per year from a 100 acre field.

The results of the RUSLE2 analysis have also indicated that a filter strip as narrow as 10 feet (measured from the top of bank) can remove the majority of sediment produced by runoff from agricultural fields in the Kawkawlin River Watershed. Also, though switchgrass is often less dense than other grasses, its sturdiness makes it a suitable type of vegetation for use in grass filter strips. Therefore, a standard 10 foot switchgrass filter strip is recommended along agricultural lands which drain via sheet flow to water bodies. Noting that filter strips implemented under field conditions will likely experience imperfect sheet flow and subsequently will develop preferential flow paths, filters will be less effective than demonstrated by the RUSLE2 model. Additionally, when crops are planted on agricultural fields, large sediment will be unlikely to reach the VFS. Instead, sediment entrained in runoff will consist of predominantly small particles. These particles are typically less likely to settle out in filter strips. This phenomenon generally decreases the effectiveness of a VFS as measured by "percent removal." Therefore, though the design sediment inflow for a filter strip has been adjusted from 12 to 6.0 ft^3/ac/yr, the amount of sediment passing the filter strip should remain largely unchanged. A rate of sediment inflow of 3.0 ft^3/ac/yr is recommended for those lands utilizing the recommended VFS design. This is equivalent to about 19 tons of sediment per year from a 100 acre field.

Through dimensional analysis, a simple equation can be formulated to convert sediment yield into an equivalent depth of accumulation in a receiving drain. The following equation may be used in conjunction with the estimated sediment yield values to calculate the rate of sediment accumulation in a drain.

$$R = 12 \cdot \frac{Y_T \cdot A}{W_B \cdot L}$$

Where:
R = Rate of sediment accumulation in drain (in/yr)
Y_T = Total sediment yield from upland area (6.0 ft^3/ac/yr no VFS; 3.0 ft^3/ac/yr with VFS)
A = Area of agricultural land contributing water and sediment to filter strip (acres)
W_B = Typical bottom width of receiving drain (ft)
L = Length of drain along contributing field (ft) *

**Note: If the field being considered is on both sides of the drain, the length should be doubled as filter strips will be needed along each bank.*

From the above analysis, the rate of sediment accumulation from agricultural land without a filter strip is estimated as double that of the same land with a filter strip. Therefore, it is estimated if filter strips were implemented along all waterways contributing to a given drain, the time between needed drain cleanouts would roughly double. This does not, however, account for maintenance needed for other reasons such as bank erosion, clogging, culvert replacement, etc. Also, other sources of sediment including in-stream erosion and sediment contributions from V-ditches are not considered. Therefore, the results of the V-ditch sedimentation basin assessment must be considered separately.

B. V-Ditch Sedimentation Basins

The Analysis and Discussion section identified the sharp increase in surface area needed to settle particles smaller than the "large aggregate" RUSLE2 classification. Additionally, at least 50 percent of sediment can be removed if particles of large aggregate and larger are targeted. This level of removal is consistent with that estimated for filter strips and again a reduction from 6.0 ft^3/ac/yr to 3.0 ft^3/ac/yr is estimated. Therefore, SGI recommends that sedimentation basins be designed to target large aggregate particles. Table 13 shows the area necessary to address V-ditch flows of varying sizes. As before, a channel slope of 0.5 percent and Manning's n of 0.025 is assumed with each V-ditch configuration flowing full.

Table 13: Sedimentation basin design for varying V-ditch sizes.

Surface Area Needed to Settle Large Aggregate			
Depth (ft)	Top Width (ft)	Discharge (cfs)	Surface Area (sft)
0.50	1.00	0.33	6
0.75	1.50	0.98	17
1.00	2.00	2.10	36
1.25	2.50	3.81	65
1.50	3.00	6.20	105
1.75	3.50	9.35	158
2.00	4.00	13.34	226
2.25	4.50	18.27	309

Though sedimentation basins function independently of depth, shallower basins will need to be cleaned more frequently than deeper basins. Therefore, the reduction of sediment load from 6.0 to 3.0 ft^3/ac/yr means that an estimated 3.0 ft^3/ac/yr of sediment is trapped in a given basin. This information may be used on a field-by-field basis to estimate the needed volume of storage below the invert of a given V-ditch.

It is important to note that proper design of sedimentation basins is important for maximum sediment settling to be achieved. Ideally, basins should be oblong with inlets and outlets located at opposite ends. The Michigan Department of Environmental Quality (MDEQ) recommends that a length to width ratio of 4 to 1 be used for sedimentation basins (MDEQ, 2010). Though some resources indicate that perforated riser pipes can be used, clogging can be problematic. Furthermore, if perforations are below the level of storage, sediment may leave the basin through the riser. If a riser pipe is used, Spicer Group suggests that there not be holes below the top of the incoming V-ditch.

Along some drains in the Kawkawlin River Watershed, spoil piles left from prior drain cleanouts may be present along the banks. These spoil piles may be used as the overflow for a sedimentation basin. If a spoil pile is not present, a riprap check dam or proprietary check dam alternative (e.g. - EnviroBerm) may be necessary to detain water in the sedimentation basin. In either instance, overflow locations must be properly reinforced to minimize erosion. If it is undesirable to have ponded water in sediment basins for extended periods of time, infiltration may be increased through the use of an underdrain. Typical details for sedimentation basins are included in Appendix B.

C. Cost Savings Analysis

Benefit derived from BMP implementation for a given drain was assessed based on sediment inflow and typical cleanout costs. The Sedimentation Prediction and Incurred Cost Estimation Resource (SPICER) model was developed to assess the benefit of sediment reduction at both the sub-watershed and field-scale. SPICER is a simple spreadsheet model developed to use drain characteristics to determine the reduction in cleanout cost expected when BMPs are implemented. This model was used in conjunction with field data for six county drains located within the Kawkawlin River Watershed. Using the suggested sedimentation rates of 3.0 ft^3/ac/yr and 6.0 ft^3/ac/yr for drains with and without BMPs respectively, the estimated time between drain cleanouts was determined. Based on historical records, drains were assumed to be cleaned once sediment had accumulated to a depth of 2.0 feet. Table 14 compares these cleanout times with data collected on historical drain cleanouts.

Table 14: Comparison of modeled and historic drain cleanout intervals.

Drain Name	Drainage Area (ac)	Length Cleaned (ft)	Average Drain Width (ft)	Actual Cleanout Interval (yrs)	Modeled Cleanout Interval without BMPs (yrs)	Modeled Cleanout Interval with BMPs (yrs)
Crump	3,400	44,578	8.0	30	35.0	69.9
Hembling	4,500	55,848	6.6	23	27.3	54.6
Popp	1,310	26,409	6.9	28	46.4	92.7
Bradford	2,760	43,600	7.6	37	40.0	80.0
Hildebrandt-Anderson	2,240	28,341	6.1	26	25.7	51.5
Goss (Bedell)	422	9,731	4.0	43	30.7	61.5

The SPICER model was run using a typical drain cleanout cost of $5/foot. Spreading this cost over the entire period between cleanouts, an annual benefit was determined for BMP implementation. Table 15 shows the estimated value each acre of filter strips provides to a drainage district using the sedimentation rates suggested in this report. SPICER output spreadsheets are included in Appendix C which show all parameters used in this calculation.

Table 15: Benefit derived for each acre of filter strip for six drains in the Kawkawlin River Watershed.

Drain Name	Drainage Area (ac)	Length Cleaned (ft)	Average Drain Width (ft)	Benefit to District ($/ac/yr of VFS)
Crump	3,400	44,578	8.0	$155.74
Hembling	4,500	55,848	6.6	$199.43
Popp	1,310	26,409	6.9	$117.43
Bradford	2,760	43,600	7.6	$136.06
Hildebrandt-Anderson	2,240	28,341	6.1	$211.65
Goss (Bedell)	422	9,731	4.0	$177.10

Data shown in Table 2, Table 3, and Table 4 for rental rates of agricultural lands in Bay County are comparable or slightly lower than the estimated benefit from VFS implementation. Therefore, the benefit from implementation of the suggested BMPs is generally equal to or greater than the opportunity cost of agricultural land which would be lost. The following section outlines further work which may aid in reducing sediment loads in the Kawkawlin River Watershed.

VIII. FUTURE WORK

This report assesses the impact of vegetative filter strips on sediment laden runoff from agricultural lands in the Kawkawlin River Watershed. To fully target sediment inflows from agricultural lands, other sediment sources must be addressed. Specifically, sediment stilling basins at the end of V-ditches should be analyzed. Some preliminary work has been done with such a design.

It is recommended that field data be gathered in the Kawkawlin River Watershed on actual filter strips. The rate of sediment accumulation in a filter strip could help calibrate the RUSLE2 model results to actual conditions. This would refine information provided in this report to more closely reflect all variables impacting filter strip effectiveness in agricultural applications. Of particular interest in such a field test would be the use of seed mixes in filter strips. The RUSLE2 model used to produce the results in this report has a set of predefined filter strip grasses and does not allow for grass mixes to be explicitly assessed. It is possible that a combination of various grasses might be more effective than any single grass type. Some information regarding seeding of filter strips in Michigan is included in Appendix A.

Lastly, public education programs will be essential in outlining the need for VFS along drainage ways in the Kawkawlin River Watershed. One public outreach tool which some landowners may find informative is the "RUSLE On-line Soil Erosion Assessment Tool" published by the Michigan State University Institute of Water Research in cooperation with the USDA. The tool may be found at http://www.iwr.msu.edu/rusle/.

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APPENDIX A

Michigan Design Guidelines

Filter Strip (Ac.) 393

DEFINITION

A strip or area of herbaceous vegetation that removes contaminants from overland flow is a filter strip.

PURPOSE

- Reduce suspended solids and associated contaminants in runoff.
- Reduce dissolved contaminant loadings in runoff.

CONDITIONS WHERE PRACTICE APPLIES

Filter strips are established where environmentally-sensitive areas need to be protected from sediment, other suspended solids, and dissolved contaminants in runoff.

CRITERIA

General Criteria Applicable to All Purposes

Overland flow entering the filter strip shall be uniform sheet flow.

Concentrated flow shall be dispersed before it enters the filter strip.

The maximum gradient along the leading edge of the filter strip shall not exceed one-half of the up-and-down hill slope percent, immediately upslope from the filter strip, up to a maximum of 5%.

State-listed noxious plants will not be established in the filter strip. Filter strips shall not be used as a travel lane for equipment or livestock.

Additional Criteria to Reduce Suspended Solids and Associated Contaminants in Runoff

The filter strip will be designed to have a 10-year life span, following the procedure in the *Michigan Agronomy Tech Note #40. The Michigan Filter Strip Design Tech Note is based on the NRCS National* Agronomy Technical Note No. 2 (Using RUSLE2 for the Design and Predicted Effectiveness of Vegetative Filter Strips (VFS) for Sediment). Filter Strip design width is based on the sediment delivery in RUSLE2 to the upper edge of the filter strip and ratio of the filter strip flow length to the length of the flow path from the contributing area. The minimum flow length through the filter strip shall be 20 feet.

The filter strip shall be located immediately downslope from the source area of contaminants.

The drainage area above the filter strip shall have a slope of 1% or greater.

Vegetation

The filter strip shall be established to permanent herbaceous vegetation

Species selected shall be:

- able to withstand partial burial from sediment deposition; and
- tolerant of herbicides used on the area that contributes runoff to the filter strip.

Species selected shall have stiff stems and a high stem density near the ground surface.

Species selected for seeding or planting shall be suited to current site conditions and intended uses. Selected species will have the capacity to achieve adequate density and vigor within an appropriate period to stabilize the site sufficiently to permit suited uses with ordinary management activities.

Species, rates of seeding or planting, minimum quality of planting stock, such as PLS or stem caliper, and method of establishment shall be specified before application. Only viable, high quality seed or planting stock will be used.

Site preparation and seeding or planting shall be done at a time and in a manner that best ensures survival and growth of the selected species. What constitutes successful establishment, e.g. minimum percent ground/canopy cover, percent survival, stand density, etc. shall be specified before application.

Planting dates shall be scheduled during periods when soil moisture is adequate for germination and/or establishment.

The minimum seeding and stem density shall be equivalent to a high quality grass hay seeding rate for the climate area or the density of vegetation selected in RUSLE2 to determine trapping efficiency, whichever is the higher seeding rate. *The recommended vegetation will be selected from Table 1, Planting Table for Grasses and Legumes.*

Deleted Additional Criteria for Irrigation Tail water

Additional Criteria to Reduce Dissolved Contaminants in Runoff

The criteria given in **"Additional criteria to reduce suspended solids and associated contaminants in runoff"** for location, drainage area and vegetation characteristics also apply to this purpose.

The minimum flow length for this purpose shall be 30 feet.

CONSIDERATIONS

General - Filter strip width (flow length) can be increased as necessary to accommodate harvest and maintenance equipment.

Filters strips with the leading edge on the contour will function better than those with a gradient along the leading edge.

Seeding rates that establish a higher stem density than the normal density for a high quality grass hay crop will be more effective in trapping and treating contaminants.

Reducing Suspended Solids and Associated Contaminants in Runoff. Increasing the width of the filter strip beyond the minimum required will increase the potential for capturing contaminants in runoff.

Creating, Restoring or Enhancing Herbaceous Habitat for Wildlife and Beneficial Insects - Filter strips are often the only break in the monotony of intensively-cropped areas. The wildlife benefits of this herbaceous cover can be enhanced by:

- Increasing the width beyond the minimum required, and planting this additional area to species that can provide food and cover for wildlife. This additional width should be added on the downslope side of the filter strip.
- Adding herbaceous plant species to the filter strip seeding mix that are beneficial to wildlife and compatible for one of the listed purposes. Changing the seeding mix should not detract from the purpose for which the filter strip was established.

Select vegetation species that are compliment the desired wildlife species. See NRCS MI eFOTG Section IV Standard 645, Wildlife Upland Habitat Management & associated Conservation Management Sheet Biology 645 Wildflower Plantings

Maintain or Enhance Watershed Functions and Values - Filter strips can:

- enhance connectivity of corridors and non-cultivated patches of vegetation within the watershed;
- enhance the aesthetics of a watershed; and
- be strategically located to reduce runoff, and increase infiltration and ground water recharge throughout the watershed.

Air Quality - Increasing the width of a filter strip beyond the minimum required will increase the potential for carbon sequestration.

PLANS AND SPECIFICATIONS

Plans and specifications shall be prepared for each field site where a filter strip will be installed. A plan includes information about the location, construction sequence, vegetation establishment, and management and maintenance requirements.

As a minimum, the plans shall include:

a) Length, width (flow path), and slope of the filter strip to accomplish the planned purpose (width refers to flow length through the filter strip).

b) Species selection and seeding or sprigging rates to accomplish the planned purpose

c) Planting dates, care and handling of the seed to ensure that planted materials have an acceptable rate of survival

d) A statement that only viable, high quality and regionally adapted seed will be used

e) Site preparation sufficient to establish and grow selected species

OPERATION AND MAINTENANCE

For the purposes of filtering contaminants, permanent filter strip vegetative plantings shall be harvested as appropriate to encourage dense growth, maintain an upright growth habit and remove nutrients and other contaminants that are contained in the plant tissue.

Control undesired weed species, especially state-listed noxious weeds.

If prescribed burning is used to manage and maintain the filter strip, an approved burn plan must be developed.

Inspect the filter strip after storm events and repair any gullies that have formed, remove unevenly deposited sediment accumulation that will disrupt sheet flow, reseed disturbed areas and take other measures to prevent concentrated flow through the filter strip.

Apply supplemental nutrients as needed to maintain the desired species composition and stand density of the filter strip.

Periodically re-grade and re-establish the filter strip area when sediment deposition at the filter strip-field interface jeopardizes its function. Reestablish the filter strip vegetation in these regraded areas, if needed.

If grazing is used to harvest vegetation from the filter strip, the grazing plan must insure that the integrity and function of the filter strip is not adversely affected.

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TABLE 1 - Planting Table for Grasses and Legumes

Recommended species of grasses, legumes, and other forbes. (Select one of the species or seeding mixes below.)

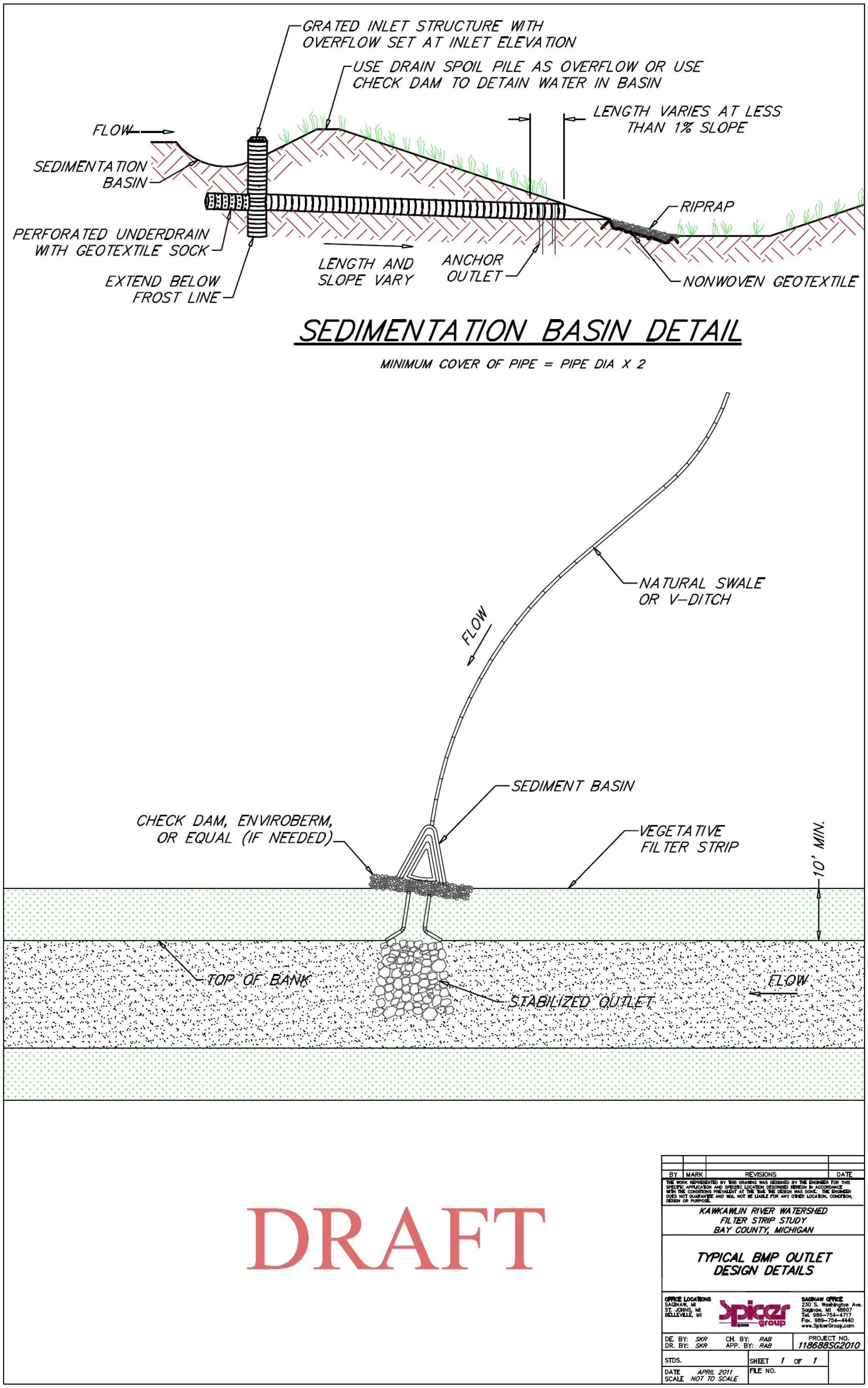
Species or Seeding Mixture	Cool/ Warm Season	Seeding Rate (Lb./Acre)	Established Density (Stems/Ft^2)	Minimum Mowing Height (In.)	Sediment Trapping	Nutrient Trapping	Wildlife Value
Single Grass Species							
Smooth Bromegrass	Cool	15-30	50	4	Y		
Garrison Creeping Foxtail	Cool	6-10	70	4		Y	
Orchardgrass	Cool	10-15	70	4	Y	Y	Y
Reed Canarygrass	Cool	10	50	4	Y	Y	
Tall Fescue **	Cool	15-25	60	4	Y		
Tall Wheatgrass ***	Cool	8-12		6	Y		Y
Introduced Plant Mixtures							
Timothy	Cool	5-10	60	4	Y	Y	Y
Alfalfa		6-10					
Bromegrass	Cool	6-12	60	4	Y	Y	Y
Alfalfa		6-10					
Orchardgrass	Cool	2-5	60	4	Y	Y	Y
Alfalfa		6-10					

Orchardgrass		2.5	70	4			
Timothy		2.5					
Red Clover		3					
Alfalfa		3					
Orchardgrass		2.5	70	4			
Redtop		1					
Alsike Clover		3					
White Dutch Clover		3					
Prairie Grasses							
Intermediate Wheatgrass	Cool	8-12	60	4	Y		Y
Big Bluestem	Warm	10-20	40-50	10-12		Y	Y
Eastern Gamagrass	Warm	8*	40	10-12	Y	Y	Y
Indiangrass	Warm	10-15*	40-50	12		Y	Y
Native Plants							
Switchgrass	Warm	5-10*	50	12	Y		Y
Big Blue Stem		2 *	50	12			
Indiangrass		2					
Little Blue Stem		2					
Wildflower Mixture		0.5					

* Pounds of PLS - Pure Live Seed.
** Use Endophyte - free tall fescue if area is planned for grazing or forage.
*** Do not include tall wheatgrass with filter strips for forestland applications

APPENDIX B

Typical Details for Sedimentation Basins


GRATED INLET STRUCTURE WITH
OVERFLOW SET AT INLET ELEVATION
USE DRAIN SPOIL PILE AS OVERFLOW OR USE
CHECK DAM TO DETAIN WATER IN BASIN
LENGTH VARIES AT LESS
THAN 1% SLOPE
FLOW
SEDIMENTATION
BASIN
RIPRAP
PERFORATED UNDERDRAIN
WITH GEOTEXTILE SOCK
LENGTH AND
SLOPE VARY
ANCHOR
OUTLET
EXTEND BELOW
FROST LINE
NONWOVEN GEOTEXTILE
SEDIMENTATION BASIN DETAIL
MINIMUM COVER OF PIPE = PIPE DIA X 2
NATURAL SWALE
OR V-DITCH
FLOW
SEDIMENT BASIN
CHECK DAM, ENVIROBERM,
OR EQUAL (IF NEEDED)
VEGETATIVE
FILTER STRIP
10' MIN.
TOP OF BANK
STABILIZED OUTLET
FLOW
DRAFT
BY
MARK
REVISIONS
DATE
THE WORK REPRESENTED BY THIS DRAWING WAS DESIGNED BY THE ENGINEER FOR THIS SPECIFIC APPLICATION AND SPECIFIC LOCATION DESCRIBED HEREON IN ACCORDANCE WITH THE CONDITIONS PREVALENT AT THE TIME THE DESIGN WAS DONE. THE ENGINEER DOES NOT GUARANTEE AND WILL NOT BE LIABLE FOR ANY OTHER LOCATION, CONDITION, DESIGN OR PURPOSE.
KAWKAWLIN RIVER WATERSHED
FILTER STRIP STUDY
BAY COUNTY, MICHIGAN
TYPICAL BMP OUTLET
DESIGN DETAILS
OFFICE LOCATIONS
SAGINAW, MI
ST. JOHNS, MI
BELLEVILLE, MI
SAGINAW OFFICE
230 S. Washington Ave.
Saginaw, MI 48607
Tel. 989-754-4717
Fax. 989-754-4440
www.SpicerGroup.com
DE. BY: SKR
DR. BY: SKR
CH. BY: RAB
APP. BY: RAB
PROJECT NO.
118688SG2010
STDS.
SHEET 1 OF 1
DATE APRIL 2011
SCALE NOT TO SCALE
FILE NO.

APPENDIX C

Cost Estimation Information from SPICER Model

Sedimentation Prediction & Incurred Cost Estimation Resource

"SPICER" *Version 1.1*

Drainage District Evaluation Parameters

Drain Name: Bradford Drain

Drain Cleanout Cost
$5.00 /lin. ft.

Rate of Sedimentation
Without Treatment 6.0 cft/ac/yr
With BMP 3.0 cft/ac/yr

Sediment Depth at Cleanout
2.00 ft

BMP Width
10 ft

Watershed Area Covered by BMPs
20 acres

Total Length of Drain
43,600 lin. ft.

Average Bottom Width
7.6 ft

Watershed Area
2,760 acres

Rate of Sedimentation
Without Treatment 0.60 in/yr
With BMP 0.30 in/yr

Estimated Time between Cleanouts
Without Treatment 40.0 years
With BMP 80.0 years

Total Cost Savings
With BMP $109,000.00

Total Value of Treatment
$1.25 /ft on each side of drain

Total Cleanout Cost
$218,000.00

Benefit from Land Covered by BMP $5,445.00 /ac
$136.06 /ac/yr

Annual Cleanout Cost
Without Treatment $5,447.37 /year
With BMP $2,723.68 /year

Annual Cost Savings
$0.00 /year
$2,723.68 /year

Annual Value of Treatment
$0.00 /ft/yr on each side of drain
$0.03 /ft/yr on each side of drain

Field Assessment Calculator

Owner Name Joe Farmer

Parcel ID 00-000-0000-00

Area of Field
160 acres

Length Along Drain
4,356 ft

# of Sides of Drain
1

Area Needed for BMP
1.00 acres

Benefit to Drainage District $136.06 /yr

Sedimentation Prediction & Incurred Cost Estimation Resource

"SPICER" Version 1.1

Drainage District Evaluation Parameters

Drain Name: Crump Drain

Drain Cleanout Cost
$5.00 /lin. ft.

Rate of Sedimentation
Without Treatment 6.0 cft/ac/yr
With BMP 3.0 cft/ac/yr

Sediment Depth at Cleanout
2.00 ft

BMP Width
10 ft

Watershed Area Covered by BMPs
20 acres

Total Length of Drain
44,578 lin. ft.

Average Bottom Width
8 ft

Watershed Area
3,400 acres

Rate of Sedimentation
Without Treatment 0.69 in/yr
With BMP 0.34 in/yr

Estimated Time between Cleanouts
Without Treatment 35.0 years
With BMP 69.9 years

Total Cost Savings
With BMP $111,445.00

Total Value of Treatment
$1.25 /ft on each side of drain

Total Cleanout Cost
$222,890.00

Benefit from Land Covered by BMP $5,445.00 /ac
$155.74 /ac/yr

	Annual Cleanout Cost	Annual Cost Savings	Annual Value of Treatment
Without Treatment	$6,375.00 /year	$0.00 /year	$0.00 /ft/yr on each side of drain
With BMP	$3,187.50 /year	$3,187.50 /year	$0.04 /ft/yr on each side of drain

Field Assessment Calculator

Owner Name Joe Farmer **Parcel ID** 00-000-0000-00

Area of Field	Length Along Drain	# of Sides of Drain	Area Needed for BMP
160 acres	4,356 ft	1	1.00 acres

Benefit to Drainage District $155.74 /yr

Sedimentation Prediction & Incurred Cost Estimation Resource

"SPICER" Version 1.1

Drainage District Evaluation Parameters

Drain Name: Goss Drain (a.k.a. - Bedell)

Drain Cleanout Cost
$5.00 /lin. ft.

Rate of Sedimentation
Without Treatment 6.0 cft/ac/yr
With BMP 3.0 cft/ac/yr

Sediment Depth at Cleanout
2.00 ft

BMP Width
10 ft

Watershed Area Covered by BMPs
4 acres

Total Length of Drain
9,731 lin. ft.

Average Bottom Width
4 ft

Watershed Area
422 acres

Rate of Sedimentation
Without Treatment 0.78 in/yr
With BMP 0.39 in/yr

Estimated Time between Cleanouts
Without Treatment 30.7 years
With BMP 61.5 years

Total Cost Savings
With BMP $24,327.50

Total Value of Treatment
$1.25 /ft on each side of drain

Total Cleanout Cost
$48,655.00

Benefit from Land Covered by BMP $5,445.00 /ac
$177.10 /ac/yr

Annual Cleanout Cost
Without Treatment $1,582.50 /year
With BMP $791.25 /year

Annual Cost Savings
$0.00 /year
$791.25 /year

Annual Value of Treatment
$0.00 /ft/yr on each side of drain
$0.04 /ft/yr on each side of drain

Field Assessment Calculator

Owner Name Joe Farmer

Parcel ID 00-000-0000-00

Area of Field
160 acres

Length Along Drain
4,356 ft

# of Sides of Drain
1

Area Needed for BMP
1.00 acres

Benefit to Drainage District $177.10 /yr

BAY COUNTY MICHIGAN • 1857

DEQ

Spicer group
ENGINEERS • SURVEYORS • PLANNERS

Sedimentation Prediction & Incurred Cost Estimation Resource

"SPICER" Version 1.1

Drainage District Evaluation Parameters

Drain Name: Hembling Drain

Drain Cleanout Cost
$5.00 /lin. ft.

Rate of Sedimentation
Without Treatment 6.0 cft/ac/yr
With BMP 3.0 cft/ac/yr

Sediment Depth at Cleanout
2.00 ft

BMP Width
10 ft

Watershed Area Covered by BMPs
26 acres

Total Length of Drain
55,848 lin. ft.

Average Bottom Width
6.6 ft

Watershed Area
4,500 acres

Rate of Sedimentation
Without Treatment 0.88 in/yr
With BMP 0.44 in/yr

Estimated Time between Cleanouts
Without Treatment 27.3 years
With BMP 54.6 years

Total Cost Savings
With BMP $139,620.00

Total Value of Treatment
$1.25 /ft on each side of drain

Total Cleanout Cost
$279,240.00

Benefit from Land Covered by BMP $5,445.00 /ac
$199.43 /ac/yr

Annual Cleanout Cost
Without Treatment $10,227.27 /year
With BMP $5,113.64 /year

Annual Cost Savings
$0.00 /year
$5,113.64 /year

Annual Value of Treatment
$0.00 /ft/yr on each side of drain
$0.05 /ft/yr on each side of drain

Field Assessment Calculator

Owner Name Joe Farmer

Parcel ID 00-000-0000-00

Area of Field
160 acres

Length Along Drain
4,356 ft

# of Sides of Drain
1

Area Needed for BMP
1.00 acres

Benefit to Drainage District $199.43 /yr

Sedimentation Prediction & Incurred Cost Estimation Resource

"SPICER" Version 1.1

Drainage District Evaluation Parameters

Drain Name: Hildebrandt-Anderson Drain

Drain Cleanout Cost
$5.00 /lin. ft.

Rate of Sedimentation
Without Treatment 6.0 cft/ac/yr
With BMP 3.0 cft/ac/yr

Sediment Depth at Cleanout
2.00 ft

BMP Width
10 ft

Watershed Area Covered by BMPs
13 acres

Total Length of Drain
28,341 lin. ft.

Average Bottom Width
6.1 ft

Watershed Area
2,240 acres

Rate of Sedimentation
Without Treatment 0.93 in/yr
With BMP 0.47 in/yr

Estimated Time between Cleanouts
Without Treatment 25.7 years
With BMP 51.5 years

Total Cost Savings
With BMP $70,852.50

Total Value of Treatment
$1.25 /ft on each side of drain

Total Cleanout Cost
$141,705.00

Benefit from Land Covered by BMP $5,445.00 /ac
$211.65 /ac/yr

Annual Cleanout Cost
Without Treatment $5,508.20 /year
With BMP $2,754.10 /year

Annual Cost Savings
$0.00 /year
$2,754.10 /year

Annual Value of Treatment
$0.00 /ft/yr on each side of drain
$0.05 /ft/yr on each side of drain

Field Assessment Calculator

Owner Name Joe Farmer

Parcel ID 00-000-0000-00

Area of Field
160 acres

Length Along Drain
4,356 ft

# of Sides of Drain
1

Area Needed for BMP
1.00 acres

Benefit to Drainage District $211.65 /yr

Sedimentation Prediction & Incurred Cost Estimation Resource

"SPICER" Version 1.1

Drainage District Evaluation Parameters

Drain Name: Popp Drain

Drain Cleanout Cost
$5.00 /lin. ft.

Rate of Sedimentation
Without Treatment 6.0 cft/ac/yr
With BMP 3.0 cft/ac/yr

Sediment Depth at Cleanout
2.00 ft

BMP Width
10 ft

Watershed Area Covered by BMPs
12 acres

Total Length of Drain
26,409 lin. ft.

Average Bottom Width
6.9 ft

Watershed Area
1,310 acres

Rate of Sedimentation
Without Treatment 0.52 in/yr
With BMP 0.26 in/yr

Estimated Time between Cleanouts
Without Treatment 46.4 years
With BMP 92.7 years

Total Cost Savings
With BMP $66,022.50

Total Value of Treatment
$1.25 /ft on each side of drain

Total Cleanout Cost
$132,045.00

Benefit from Land Covered by BMP $5,445.00 /ac
$117.43 /ac/yr

Annual Cleanout Cost
Without Treatment $2,847.83 /year
With BMP $1,423.91 /year

Annual Cost Savings
$0.00 /year
$1,423.91 /year

Annual Value of Treatment
$0.00 /ft/yr on each side of drain
$0.03 /ft/yr on each side of drain

Field Assessment Calculator

Owner Name Joe Farmer

Parcel ID 00-000-0000-00

Area of Field	Length Along Drain	# of Sides of Drain	Area Needed for BMP
160 acres	4,356 ft	1	1.00 acres

Benefit to Drainage District $117.43 /yr