Canadian Ontario Agreement Mapping

A GIS based Approach to Green Infrastructure

Site Selection for the Application of Agricultural Best Management Practices

Final Report

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1. INTRODUCTION

1.1 Project Overview

The intent of this project was the development of a mapping tool and/or a methodology for identifying potential sites for green infrastructure on agricultural lands, which will provide environmental and economic benefits by increasing resiliency, improving water quality, and optimizing drainage infrastructure.

This project examined potential sites across three Conservation Authorities (Kettle Creek, Catfish Creek, and Long Point Region) with the aim of prescribing the appropriate best management practices (BMPs) to reduce nutrient loading by identifying lands for wetland creation, erosion control and tallgrass prairie plantings.

1.2 Objectives

The objectives for this project were as follows:

1. Conduct a literature review of studies and methodologies to determine the most current trends and practices in agricultural best practices.
2. Once complete, determine the most applicable studies/methodologies using the available data in the project study area.
3. Conduct a proof-of-concept test to determine the validity of the methodologies.
4. Select a test subwatershed and run the same methodologies to see whether they are scalable.
5. Analyze results of subwatershed test against original studies to determine if results are similar
6. Once complete, gain approval of selected methodology and process the remaining extend of the project study area.

1.3 Project Study Area

The project study area encompasses three Conservation Authorities (Kettle Creek/Catfish Creek/Long Point Region) covering 3900 km^2 along the north shore of Lake Erie in six municipalities (Figure 1). The area encompasses 28 major subwatersheds ranging in size from 6.8-749 km^2

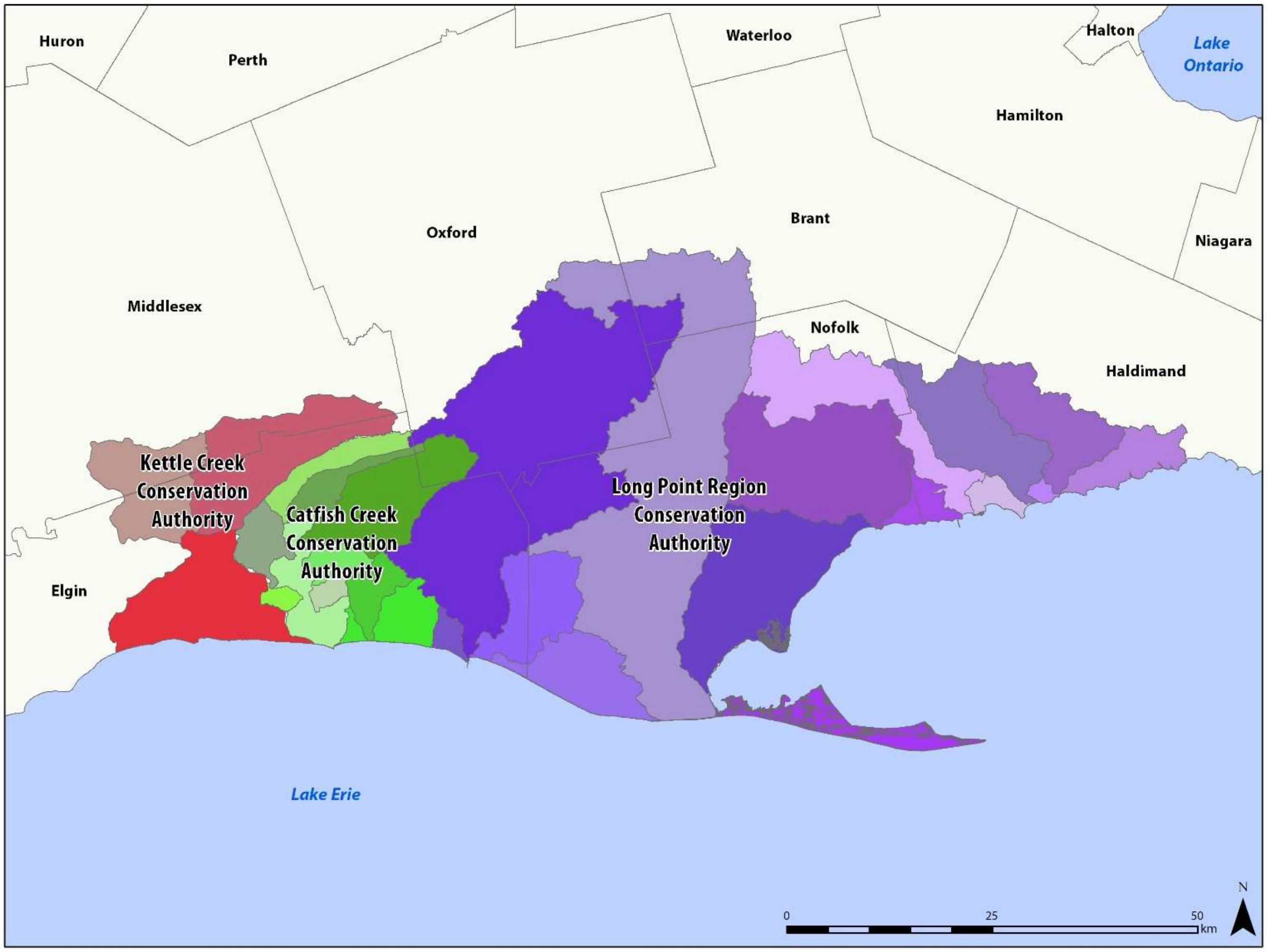

FIGURE 1: PROJECT STUDY AREA & SUBWATERSHEDS BY CONSERVATION AUTHORITY

2. PROJECT STATUS

2.1 Progress

- Reviewed the completed Mapping Datasets document
- Reviewed several case studies, project reports, and dissertations that represent the most recent work in the field and overall best practices.
- A technical review of methodology was conducted to ascertain the best techniques currently utilized for BMP GIS creation. This included numerous online articles, descriptions of GIS tools, and instructional videos on how to create the products to be used in the methodology. Several GIS tools identified in the review were downloaded for potential use.
- Categorized and assembled data for the project
- Selected an area (26 km2) between Port Stanley and Port Bruce) to test methodology. There are five small creeks that flow into Lake Erie surrounded by agricultural fields and forests. Second test area to be selected based on municipal drain layer.
- Began generating data with the OMAFRA Lidar for the test area.
- Acquiring relevant GIS data from various sources (ie. LIO, CAs etc.)
- Completed all processing
- Built a test application using the Dodd Creek data, was reviewed by CA staff, and found to be suitable for the last project objective
- Built the final web application for the project in ArcGIS Online using the completed data
- Sent completed data to each CA

2.2 Processing Areas

Approval of the methodology was given in July 2021 after the successful trial of one watershed (Dodd Creek). The CA's Watershed Boundary data formed the basis for each processing boundary, but some prepossessing had to occur when the watercourse data extended beyond the boundary. Each watershed boundary was adjusted to ensure that its watercourses where wholly contained within.

For Kettle Creek and Catfish Creek, the watershed boundaries were all relatively similar in size ranging from 90-200 km^2. Each was processed with minimal adjustments to the edge areas as previously outlined, and the size was not too onerous for a desktop PC to handle. This could not be continued with Long Point, as the watershed boundaries ranged from 6-750 km^2. The larger areas were too large to be processed, and it was inefficient to process the small areas. Therefore, the watershed boundaries in Long Point Region were merged and/or subdivided into areas no larger than 250 km^2.

All areas that have been processed have been subjected to a QA/QC process to ensure all data is consistent and complete.

3. PROJECT DELIVERABLES AND METRICS

Three separate sets of data were created for each watershed boundary: Riparian Buffer Zone Analysis, Potential for Sheet and Gully Erosion, and Depressions within the RBZ. For detailed methodologies for each please see Appendix 1.

3.1 Riparian Buffer Zones

For this project 8,738.7 km of watercourse was analyzed, producing 98,989.87 acres of riparian buffer zones.

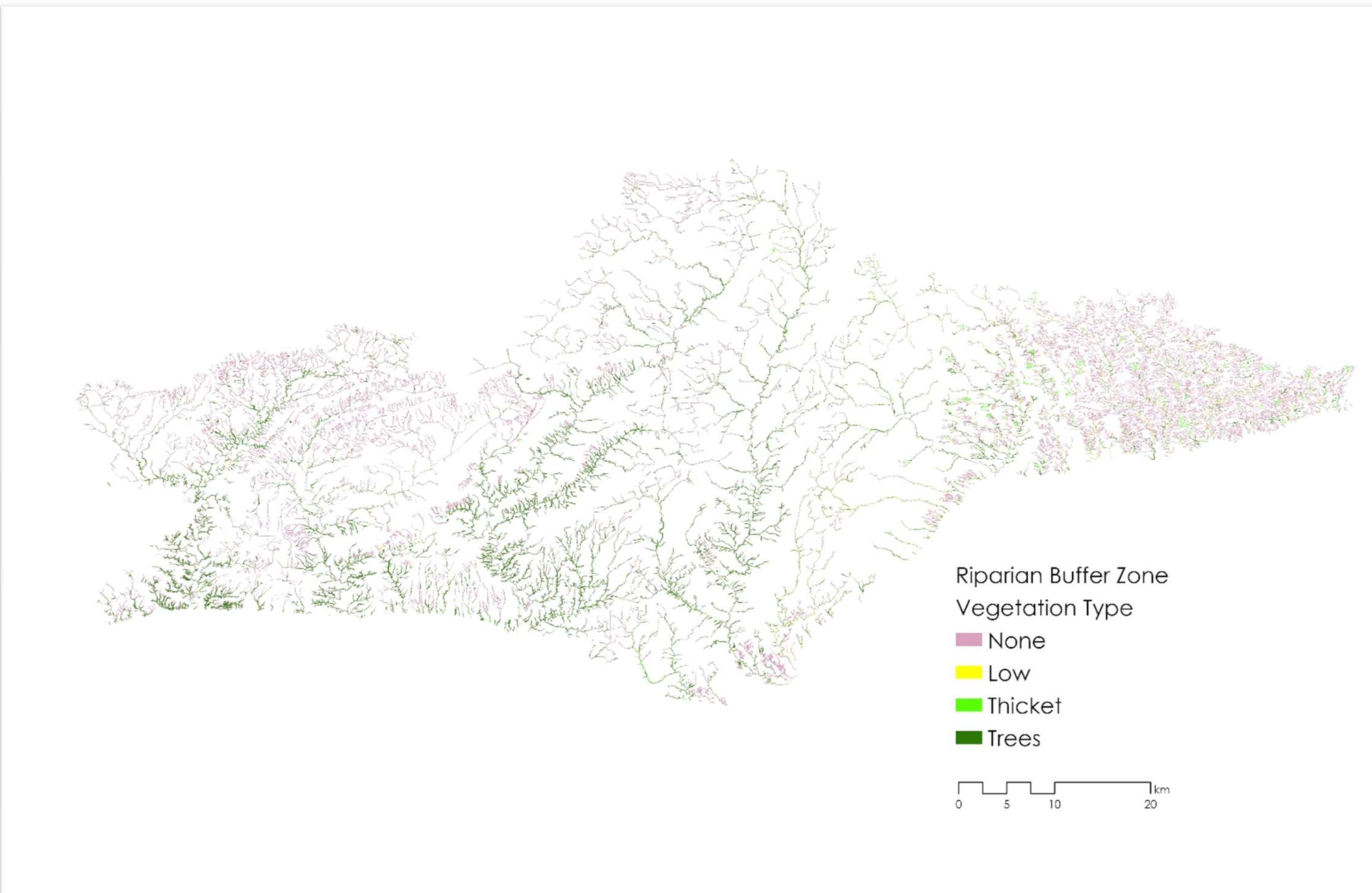

FIGURE 2: RIPARIAN BUFFER ZONE BY VEGETATION TYPE

Each buffer zone was classified by:

1. Vegetation Class (<0.15m, 0.15-1m, 1-5m, >5m)
2. Vegetation Type (None, Low, Thicket, Trees)
3. Watercourse Type (Bridge, Conduit, Ditch, Stream, Virtual Canopy Cover, Virtual Flow)
4. Watercourse Permanency (Ephemeral, Intermittent, Permanent, Unknown)

5. Land Cover (Combination of SOLRIS & LPRCA's data)
6. Municipal Drain Present (yes, no)
7. Depression Present (yes, no)
8. Watershed

Below are some sample tables showing the results of this methodology along with examples of how this data can be used to determine the location of best management practices.

Table 1 Riparian Buffer Zone by Vegetation

Vegetation Class	Vegetation Type	Acres	Percentage
<0.15m	None	57449.0	58.0%
0.15-1m	Low	3591.2	3.6%
1-5m	Thicket	9784.1	9.9%
>5m	Trees	28165.6	28.5%
		98989.9	100%

The analysis shows that most of the buffer zones have no vegetation cover; these are then prime areas for best-management practice applications. Areas with tree or shrub cover are also good indicators of riparian health and can be used to determine overall watershed quality.

Table 2 Buffer Zone by Watercourse Permanency

Watercourse Type	Acres	Percentage
Ephemeral	37402.6	37.78%
Intermittent	9105.0	9.20%
Permanent	45500.9	45.97%
Unknown	6981.4	7.05%
	98989.9	100.00%

Watercourse Permanency is important for prioritizing those buffer areas that have more flow, and more potential for sediment transfer into Lake Erie.

Table 3 Riparian Buffer Zones by Land Cover

Land Cover	Acres	Percentage
Bare Soil Areas	5732.4	5.79%
Barren Areas	119.3	0.12%

Built-Up Area - Impervious	231.4	0.23%
Built-Up Area - Pervious	223.6	0.23%
Commercial/Industrial	2301.3	2.32%
Conifer Treed Forest	865.3	0.87%
Coniferous Forest	9.2	0.01%
Cultivated Crop Lands	37407.7	37.79%
Deciduous Forest	8608.1	8.70%
Deciduous Treed Forest	10055.3	10.16%
Extraction - Aggregate	4.6	0.00%
Forest	3.5	0.00%
Grasslands/Shrubs	128.7	0.13%
Hedge Rows	216.4	0.22%
Marsh	221.3	0.22%
Mixed Forest	66.5	0.07%
Mixed Treed Forest	9932.3	10.03%
Open Water	450.0	0.45%
Open Water Areas	1527.9	1.54%
Plantations – Tree Cultivated	91.3	0.09%
Roads	1834.7	1.85%
Settlement Open Areas	102.1	0.10%
Sparse Treed	933.3	0.94%
Thicket Swamp	166.7	0.17%
Tilled	12097.5	12.22%
Transportation	616.6	0.62%
Treed Swamp	989.6	1.00%
Undifferentiated	3992.0	4.03%
Wetlands	60.9	0.06%
Grand Total	98989.9	100.00%

Agricultural areas represent 56% of the land cover within the riparian buffer zones. This data can also be used for watershed and riparian health indicators.

TABLE 4 VEGETATION IN AGRICULTURAL AREAS

Vegetation Class	<0.15m	0.15-1m	1-5m	>5m	Total
Vegetation Type	**None**	**Low**	**Thicket**	**Trees**	
Bare Soil Areas	5617.3	36.6	28.3	50.3	5732.4
Cultivated Crop Lands	3311.0	1756.8	3311.0	3672.9	12051.6
Tilled	11423.8	94.3	187.6	391.7	12097.5
Grand Total	20352.1	1887.7	3526.9	4114.9	29881.6
Percentage	68.11%	6.32%	11.80%	13.77%	100.00%

This table shows the breakdown of the vegetation types within agricultural areas. This shows the need for BMPs as 68% of the riparian buffer zones along watercourses through farm fields have no vegetation cover.

Additional analysis can be run with the data; these tables showcase the results of the processing and a sample analysis. Each CA can take the data produced through this project and adapt it to several uses, including Best Management Practices but also riparian health, stream naturalization and restoration, and wetland creation.

3.2 Agricultural Field Run-Off Assessment

Both Potential for Sheet and Gully Erosion were processed using the provincial Lot Fabric and scored for low/moderate/high risk by the same watershed data that was used for the Riparian Buffer Analysis. Once all watersheds were processed, the lots were merged together and a combined risk score was assigned based on the following matrix:

TABLE 5 MATRIX TO DETERMINE COMBINED RANK

<table>
<tr><td></td><td colspan="3">Potential for Sheet Erosion (PSE) (K*LS*R)</td></tr>
<tr><td>Stream Power Index (Rank value)</td><td>Highest (3) (> 0.5 SD. above the mean)</td><td>Moderate (2) (0.5 SD. above to -0.5 SD below the mean)</td><td>Low/flat (1) Low (< -0.5 SD below the mean)</td></tr>
<tr><td>Highest (3) (> 0.5 SD dev. above the mean)</td><td>High (6) Combined</td><td>High (5) Combined</td><td>Moderate (4) Combined</td></tr>
<tr><td>Moderate (2) (0.5 SD dev. above to -0.5 below the mean</td><td>High (5) Combined</td><td>Moderate (4) Combined</td><td>Moderate (3) Combined</td></tr>
</table>

Low (1) (< -0.5 below the mean)	Moderate (4) Combined	Moderate (3) Combined	Low (2) Combined

In total 6172 lots were processed.

TABLE 6 BREAKDOWN OF RANKS BY LOT

	Low Risk	Moderate Risk	High Risk
Potential for Sheet Erosion	1680 Lots	3155 Lots	1337 Lots
Potential for Sheet Erosion	2125 Lots	2885 Lots	1162 Lots
Combined Rank	1367 Lots	4312 Lots	493 Lots

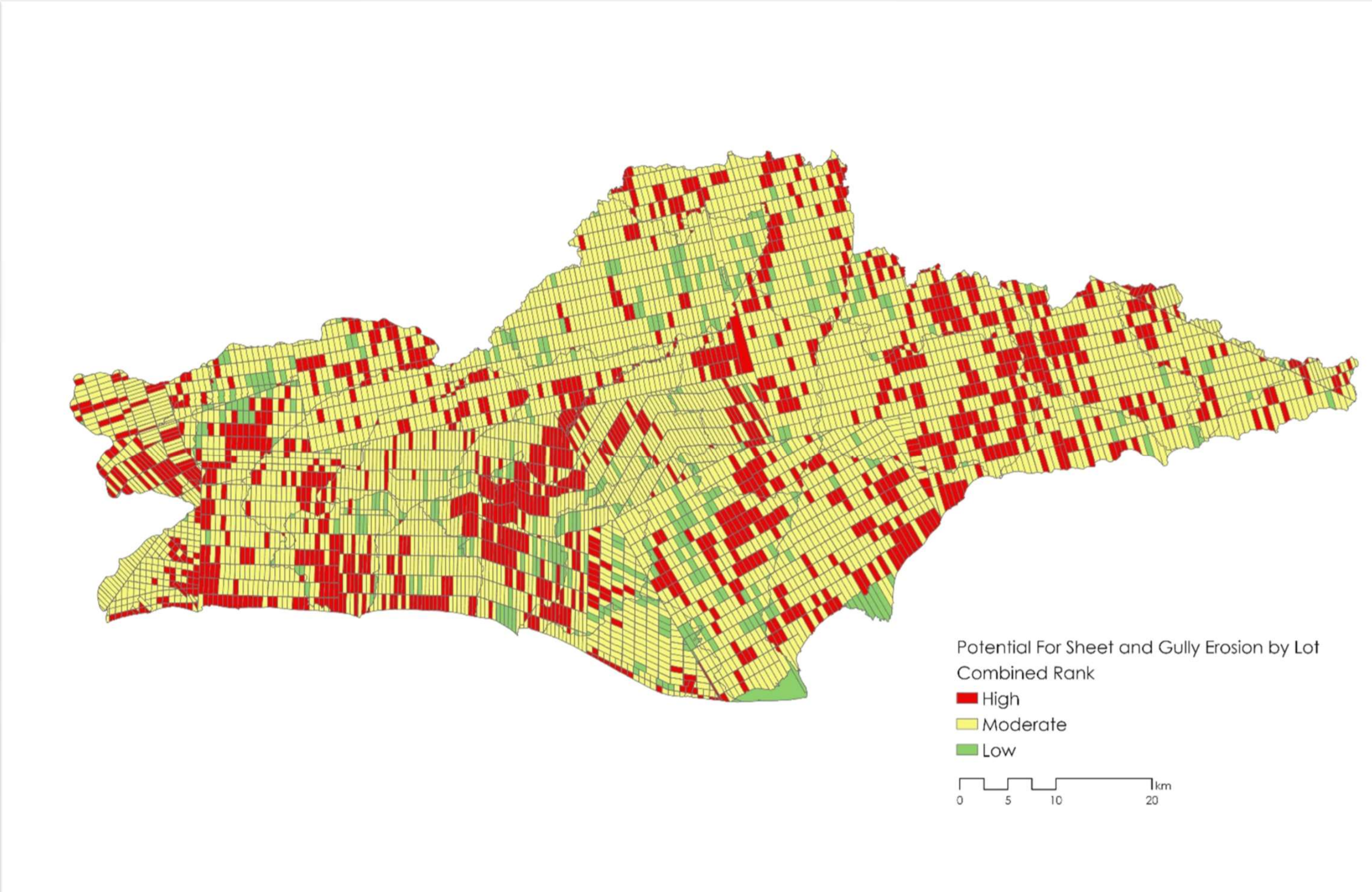

FIGURE 3: LOTS BY COMBINED RANK

3.3 Depressions with the Riparian Buffer Zone

In total 237,155 depressions over 10m^2 were identified with the Riparian Buffer Zones covering 1835.5 acres.

3.4 Web Application

A Web Application that displays the results of the analysis and allows for those without specialized GIS software to view and query the data was demonstrated during the testing phase of the project and subsequently approved. The test application was built on ArcGIS Online, in a collaborative environment were all Conservation Authorities of Ontario have access. In this way the tool can be easily passed over from TRCA to CCCA/KCCA/LPRCA and each CA can add their own data if needed.

FIGURE 4 WEB APPLICATION SCREENSHOT

This tool contains a series of queries which allows the user to pinpoint areas of interest. For instance, if the goal was to build more riparian habitat to capture sediment, the query could identify Riparian Buffer Zones that have no vegetation cover and are adjacent to agricultural fields. This application is also capable of being viewed on mobile devices and could be taken with staff into the field to verify the conditions and have discussions with landowners.

The final web application was built and populated with the completed data, with the same queries. Access has been given to CA staff.

APPENDIX 1: PROJECT METHODOLOGIES

1 Riparian Buffer Zone Analysis

Two methodologies were selected that could be used with the available data. The first was the *Brown Creek Riparian Study* by Seidler et al. This methodology is a vegetation analysis along a watercourse buffer, producing a polyline feature indicating the presence/absence of certain vegetation types along a watercourse. The main drawback with this methodology was the large amount of manual input required. The buffer was determined by the width of the watercourse, data that is not available and would have to be created by either measuring the distance or calculating bankfull width. Furthermore, the methodology states that if the watercourse width is greater than 4 m, both banks would need to be digitized instead of using the available centreline data. The riparian vegetation type along the watercourse buffer was also manually entered by viewing aerial imagery and making a subjective determination if it was meadow/thicket/woodland. The Brown Creek methodology could work well in a small area (the study area was only 155 km^2) where time could spent on a single subwatershed. As the study area for this project is over 3400 km^2 with 8739 km of watercourse, a manual approach would be too time consuming. Furthermore, this methodology does not create an actual riparian buffer zone. It merely identifies the vegetation along a watercourse. It suggests a buffer based on stream width, but the final product is a single line. When looking to create new buffers where vegetation is absent, it merely suggests the location, not the actual width required.

The Akturk et al *Modeling and Monitoring Riparian Buffer Zones using LiDAR data in South Carolina* methodology offers a similar result to Seidler et al but uses Lidar as an input and removes all manual digitization and classification. The methodology creates a riparian buffer zone based on the mean slope found within 30 m of a watercourse segment. This buffer consists of a primary zone of 12 m, plus a secondary zone determined by the mean slope. Steeper slopes contribute more sediment run-off, so a larger buffer zone is required in those areas.

Slope (%)	Width of RBZs on each side (m)		
	Primary	Secondary	Total
< 5%	12	0	**12**
5-20%	12	12	**24**
21-40%	12	24	**26**
> 40%	12	36	**48**

The riparian buffer zone is then used to clip an absolute height raster (Digital Surface Model – Digital Elevation Model) to determine the height of vegetation within the buffer. This methodology uses a vegetation classification of <0.5 m/0.5-5 m/> 5 m which gives a similar output to Seidler et al (meadow/thicket/woodland); Arturk et al call their classes “other/shrub/trees” but stipulates that these classes can be modified based on the required BMP. If this study were to attempt to distinguish between agricultural crops and low riparian vegetation along a watercourse, the classes could be adjusted accordingly. As the Lidar was flown in the spring, the only crops present are those left from the previous year. Corn stalks could be identified and were generally 30 cm high.

The Akturk et al study has the following advantages over Seidler et al:

1. No manual inputs required. The entire process is automated
2. Output is a riparian buffer zone determined by the surrounding slope of the watercourse segment

3. A vegetation analysis is performed based on actual height, not subjective interpretation of aerial imagery

4. Vegetation heights/types can be customized

One additional field in the Brown Creek Study is whether the watercourse is within 30 m of an agricultural field. A similar analysis can be conducted using the SOLRIS/LPRCA land cover data. The province's Agricultural Resource Inventory has very limited coverage in the project area so these two datasets are used in lieu of actual fields.

Furthermore, using the newly created riparian buffer zones, the actual land use *within* the buffer can be added as a field using one of the two Land Cover datasets. In this way the data can be queried to determine which RBZs have no vegetation cover and are within agricultural fields.

Veg Class	Watercourse	Permanency	Land Cover	Shape Area	Watercourse within 30m of Tile Drained Field	Veg Type
0.5-5m	Bridge	Ephemeral	Built-Up Area - Impervious	Area is m2	Yes	Other
<0.5m	Constructed Drain	Intermittent	Built-Up Area - Previous		No	Shrubs
>5m	Culvert	Permanent	Deciduous Forest			Trees
	Ditch	Unknown	Forest			
	Stream		Hedge Rows			
	Virtual Canopy Cover		Marsh			
			Open Water			
			Planations - Tree Cultivated			
			Thicket Swamp			
			Tilled			
			Transportation			
			Treed Swamp			
			Undifferentiated			

The final fields for this analysis area:

1. Vegetation Class: height of vegetation (used three classes but can be customized)

2. Vegetation Type: name of height classes from study

3. Watercourse: types from CA watercourse data

4. Permanency: types of CA watercourse data

5. Land Cover: from SOLRIS/LPRCA landcover

6. Shape Area: area in meters squared

7. Watercourse within 30m of Tile Drained Field: use provincial tile drainage to determine proximity

Upon completion of the test watershed, the methodology was altered from three vegetation classes to four:

1. Vegetation Class (<0.15m, 0.15-1m, 1-5m, >5m)
2. Vegetation Type (None, Low, Thicket, Trees)

The Watershed within 30m of a Tile Drained Field was replaced by the presence or absence of a municipal drain within the buffer zone.

2 Agricultural Field Run-Off Assessment

The methodology selected as most applicable is *The Use of GIS in the Gully Creek Watershed to Identify Suitable Locations for Agricultural Best Management Practices* by McPherson et al. The study identifies two separate types of run-off, sheet & gully erosion, and provides a methodology for identifying each.

Potential for Sheet Erosion

To determine the potential for sheet erosion, a modified Revised Universal Soil Loss Equation is used:

$$PSE = K*LS*R$$

K represents the soil erodibility factor. In McPerson et al, the value was determined by soil samples. As this is impossible for such a large study area, the "KFactor1" field in the provincial soil data was used.

LS represents the length of slope value and can calculated using a slope in percent rise and flow accumulation raster. Both datasets are created from the provincial Lidar digital elevation model.

R represents the terrain roughness factor, which is derived from a land use/cover layer. Two land cover datasets are available for the project area, SOLRIS and LPRCA's, with differing classes. SOLRIS has complete coverage but dates to 2011, whereas the LPRCA only covers that Conservation Authorities boundaries with a small buffer into Catfish Creek but dates to 2017. Both are raster datasets with a gridcode representing a land cover type.

McPerson et al provides an R value for their Land Use type, which was then matched to the SOLRIS/LPRCA grid code according to the following:

R_Factor	Land use	SOLRIS Gridcode
0.36	Agricultural crops	193 Tilled
0.10	Woodlands	90,91,92,93,191,192 (FO,FOC, FOM, FOD, CUP, CUH)
0.03	Farmsteads	250 Undifferentiated
0.042	Rough lands (i.e., pastures, meadows, ditches, grassed waterways)	131,135,160 (SWC, SWM, SWD, SWT, MA)
0	Water, roads	170,201,202,203,204

R_Factor	Land use	LPRCA Landcover Gridcode
0.36	Agricultural crops	1,2 (crop lands, bare soil)
0.10	Woodlands	4,5,6 (forests)
0.03	Farmsteads	
0.042	Rough lands (i.e., pastures, meadows, ditches, grassed waterways)	3,7,10,14 (grasslands, spare treed, barren, settlement open areas)

0	Water, roads	8,9,12,13,15

The LPRCA landcover dataset is superior to SOLRIS in terms of temporal date and quality of capture. Therefore the input for the potential sheet erosion calculation will be a combination of both with SOLRIS clipped to the missing extent of the project area that LPRCA landcover does not encompass (Figure 2).

Once all three inputs are created, they are multiplied together per the formula using the Raster Calculator to create the raster dataset. The final raster uses the largest cell size of the available data, which is SOLRIS at a 15 m resolution.

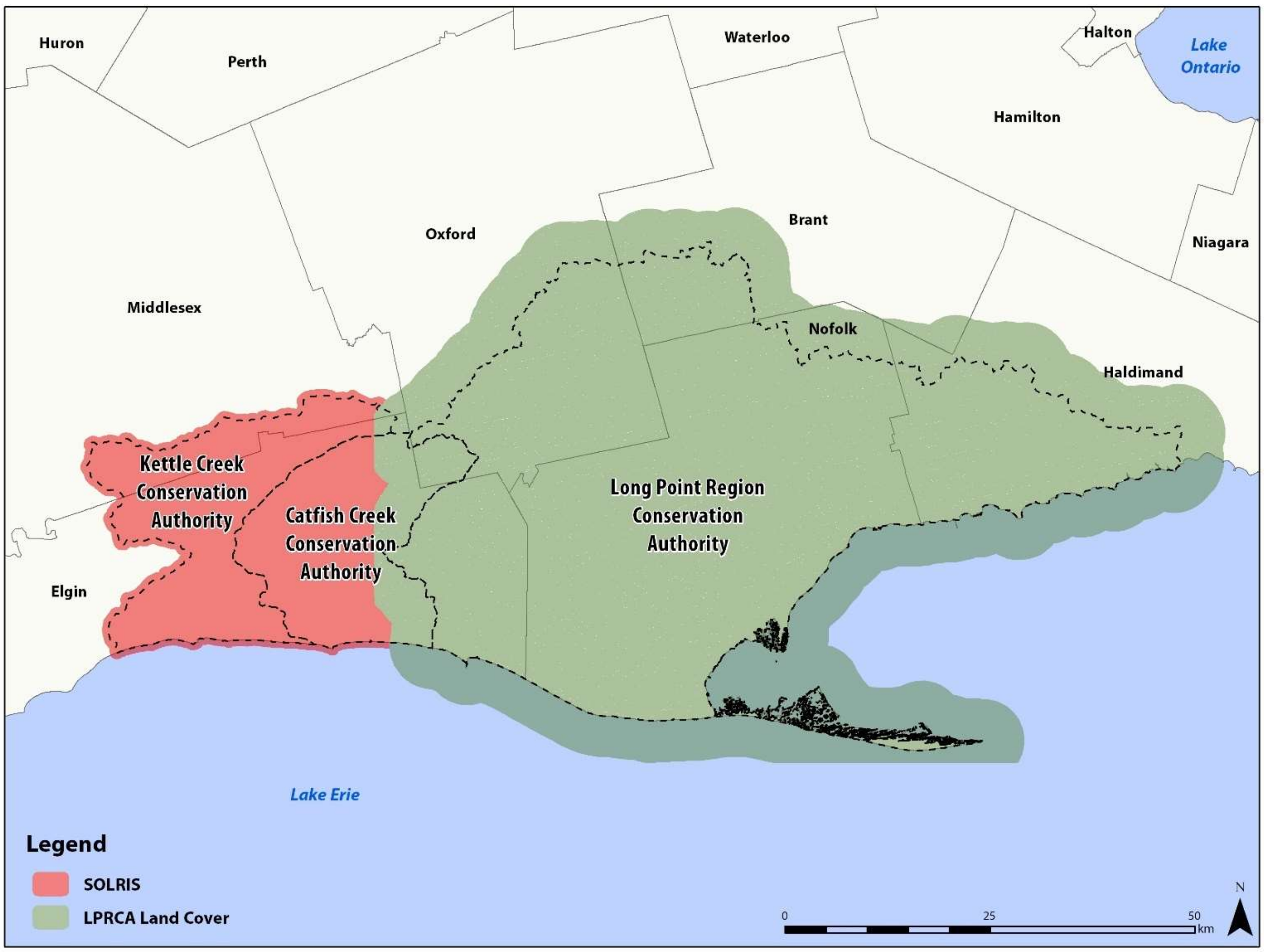

FIGURE 2: LAND COVER DATASET COVERAGE

Potential for Gully Erosion

The potential for gully erosion is calculated through a formula that creates a ***Stream Power Index***. This modeling determines which areas have higher and faster flow and are more likely to create scours in the landscape. This method utilizes a Lidar-derives Slope and Flow Accumulation grid, and is calculated via the following:

SPI= ln(flow_accumulation_dem+0.001)(slope_dem/100)+0.001)*

The two inputs, a flow accumulation and slope raster, are created with the provincial Lidar DEM.

Linking Results with Individual Agricultural Fields

Both the Ootential Sheet and Gully Raster results are a raster that covers the entirety of the subwatershed. This is impracticable to use as a screening layer at a subwatershed level, so in order to more easily determine which individual fields are at risk and to rank them zonal statistics are used to add quantitative measurements to agricultural fields.

The Gully Creek study used the provincial Agricultural Resources Inventory. This dataset is lacking data in most of the Project Area so cannot be used. An option considered was using the land use data (SOLRIS/LPRCA Land Cover) and extracting all agricultural polygons. This was determined to be impracticable as the data was a general land use and all agricultural areas were merged into large polygons with no individual fields present. The tile-drained field data was considered as well, but only contained fields with this drainage feature and not all fields.

The solution was to use the provincial lot fabric as a substitute for individual fields. The rational was:

1. These were the original land grants and many fields still follow this grid
2. They exclude road allowances (modern roads notwithstanding)
3. They are consistently a uniform size (roughly 100 acres)
4. The underlying input criteria includes all features within the lot (forest, wetland, urban areas) so these are reflected in the output
5. They are easy to view at a subwatershed scale
6. If there are any questionable results, the input criteria can be further investigated to understand the output

The PSE and PGE rasters were clipped to the subwatercourse boundary (or a buffer if the watercourses therein extend past the boundary) so the lots can either be clipped to the boundary or selected and exported. Some lots will be bisected by subwatershed boundaries, so there will be instances where two halves of a lot may have differing values.

Using Zonal Statistics, the mean PSE and PGE values within each lot are added to the lot polygon. This data can then be used to rank lots according to their susceptibility to gully and sheet erosion with a high/medium/low classification based on standard deviation. McPherson et al combined the PSE and PGE values into a final ranking, using the matrix below:

	Potential for Sheet Erosion (PSE) (K*LS*R)		
Stream Power Index (Rank value)	Highest (3) (> 0.5 SD. above the mean)	Moderate (2) (0.5 SD. above to -0.5 SD below the mean)	Low/flat (1) Low (< -0.5 SD below the mean)
Highest (3) (> 0.5 SD dev. above the mean)	High (6) Combined	High (5) Combined	Moderate (4) Combined
Moderate (2) (0.5 SD dev. above to -0.5 below the mean	High (5) Combined	Moderate (4) Combined	Moderate (3) Combined
Low (1) (< -0.5 below the mean)	Moderate (4) Combined	Moderate (3) Combined	Low (2) Combined

3 Depressions within the Riparian Buffer Zone

Using hydrological tools, it is possible to located depressions in the landscape with the Lidar DTM. Depressions adjacent to watercourses within an RBZ are prime locations for the construction of wetlands (Figure 9).

This analysis uses already-processed data, so can be run after the RBZs have been delineated, and only in those areas. Depressions for Dodd Creek were run and can be used as an additional screening tool when determining implementing BMPs.

APPENDIX 2: DETAILED METHODOLOGY

RBZ Analysis

1. Create new folder in "Production" in the correct CA for the watershed to be run
2. Use Subwatershed layer to select all watercourses in F:\COA Mapping\Data\KCCA\watercourses\watercourses_kcca_ccca_lprca.shp
3. If some watercourses extend beyond boundary, manually select them. This process relies on watercourse extent, not subwatershed boundary. Export the watercourse layer into "SubwatershedName_watercourse"

4. Buffer watercourses by 30m. This step is to determine the slope surrounding the watercourse and to determine the width of the buffer zone. Call it “WatercourseXX_Buffer_30m”
5. Bring in the “DTM_Mosaic”
6. Use Raster Function on the mosaic to create a Slope by Percent Rise grid
7. Use Zonal Statistics as Table tool using the 30m buffer and the slope grid. Need the mean of slope within the buffer. Use the object ID of both when running tool.
8. Once the tool has run, join the zonal statistics table to “SubwatershedName_watercourse” layer. Create two new fields called “Mean_Slope” and “BufferWidth”. Both are Double.
9. Copy mean slope from the table into Mean_Slope field.
10. The mean slope determine the buffer applied to the watercourse for the Riparian Buffer Zone.
11. For the BufferWidth Field, add the values below based on the Mean_Slope field:
    - Slope <5% = **12**
    - Slope 5-20% = **24**
    - Slope 21-40% = **36**
    - Slope >40% = **48**
12. Use **Create Buffers** tool and use BufferWidth field as input in the Buffer Type area. Dissolve the buffer by the fields “watercourse” and “permanency”.
13. New layer of buffered watercourses “SubwatershedName_watercourse_RBZ” is created. Bigger buffer = more slope around hence greater chance of colluvium entering watercourse.
14. Use “SubwatershedName_watercourse_RBZ” to clip the DSM and DTM mosaics.
15. Subtract the clipped DTM from the DSM using the Raster Calculator to create an Absolute_Height raster. “SubwatershedName_DSM_clip” – “SubwatershedName_DTM_clip” = “SubwatershedName_AbHeight”
16. Symbolize “SubwatershedName_AbHeight”into /0-0.15 m/0.15-1 m/1-5m/>5 m or use the Absolute Height.lyrx
17. Use **Reclassify** to remove <0 m class and convert the other three into integer from floating point. Call it “SubwatershedName_AbHeight_reclassify”
    a. 0-0.15m – **1**
    b. 0.15m-1m – **2**
    c. 1-5m – **3**
    d. >5m – **4**
    e. **There may be additional values if there are hydro lines present. These can be removed like the <0m class. There may be additional gridcodes in the negative range. These are from aggregate pits or other deep depressions. They can be deleted when the layer is dissolbed**
18. Using the **Raster to Polygon** tool, convert “SubwatershedName_AbHeight_reclassify” into a polygon called “SubwatershedName_AbHeight_export”. Simplify the polygon part.

19. Dissolve the exported polygon class by grid code and call it "SubwatershedName_AbHeight_export_dissolve"
20. Add a new string fields called "Veg_Class" (use alias Vegetation Class) and "Veg_Type" (use alias Vegetation Type) to "SubwatershedName_AbHeight_export_dissolve"
21. Select each gridcode in turn, and add the following text in the Vegetation Class and Vegetation Type fields:
    a. Gridcode 1 = 0-**0.15m = None**
    b. Gridcode 2 = **0.15-1m = Low**
    c. **Gridcode 3 = 1-5m = Thicket**
    d. Gridcode 4 = **>5m = Trees**
22. The next step involves combining the RBZ vegetation data with landuse and watercourse data. Using the **Pairwise Intersect** tool, combine "SubwatershedName_AbHeight_export_dissolve" and "SubwatershedName_watercourse_RBZ". Call it SubwatershedName_Vegetation_RBZ
23. Combine "SubwatershedName_Vegeation_RBZ" with "SubwatershedName_Landcover" with the same Pairwise intersect tool.
24. Call the output "WatershedName_Vegetation_RBZ_LandCover"
25. The final step is to determine if the RBZ contains a depression or municipal drain. Add two text fields "Municipal_Drain" (alias Municipal Drain) and "Depression_in_RBZ" (alias Depression in RBZ)
26. Use the **Select by Location** tool. Select all the polygons that intersect a municipal drain or depression. Those will be "yes" in the two fields. Switch the selection and make the rest "no".

Modified RUSLE Analysis

Potential for Sheet Erosion (PSE)

PSE = K*LS*R

R= vegetation/land use

- For this input the provincial SOLRIS data and LPRCA Land Cover data was used
- The R values to be used come from McPherson & Veliz, 2016 and are five broad categories:

Value	Land use	Source or rationale
0.36	Agricultural crops	OMAFRA example (grain corn, spring plow)
0.10	Woodlands	Wall et al. 2002
0.03	Farmsteads	Assumed that had lawns and trees. NOAA 2008
0.042	Rough lands (i.e., pastures, meadows, ditches, grassed waterways)	Institute of Water Research 2002 – Continuous Low Residue Grass
0	Water, roads	

- The SOLRIS and LPRCA data has a much more detailed typology:

Value	Name

11	Open Beach/Bar
21	Open Sand Dune
23	Treed Sand Dune
41	Open Cliff and Talus
43	Treed Cliff and Talus
51	Open Alvar
52	Shrub Alvar
53	Treed Alvar
81	Open Tallgrass Prairie
82	Tallgrass Savannah
83	Tallgrass Woodland
90	Forest
91	Coniferous Forest
92	Mixed Forest
93	Deciduous Forest
131	Treed Swamp
135	Thicket Swamp
140	Fen
150	Bog
160	Marsh
170	Open Water
191	Plantations – Tree Cultivated
192	Hedge Rows
192	Tilled
201	Transportation
202	Built-Up Area - Pervious
203	Built-Up Area - Impervious
204	Extraction - Aggregate
205	Extraction – Peat/Topsoil
250	Undifferentiated

- It is also an integer raster, and the R vales are floating point
- Convert the SOLIR/LPRCA Land Cover raster to a polygon using the **Raster to Polygon** tool
- Call the output “KC_CC_SOLRIS”/”LPRCA_Landcover”
- Dissolve each by Gridcode
- Add a new field (double) to each called R_Factor

- For each gridcode, assign the value in the tables below

R_Factor	Land use	SOLRIS Gridcode
0.36	Agricultural crops	193
0.10	Woodlands	90,91,92,93,191,192
0.03	Farmsteads	250
0.042	Rough lands (i.e., pastures, meadows, ditches, grassed waterways)	131,135,160
0	Water, roads	170,201,202,203,204

R_Factor	Land use	LPRCA Landcover Gridcode
0.36	Agricultural crops	193
0.10	Woodlands	90,91,92,93,191,192
0.03	Farmsteads	250
0.042	Rough lands (i.e., pastures, meadows, ditches, grassed waterways)	131,135,160
0	Water, roads	170,201,202,203,204

- Use the Polygon to Raster tool to convert back to a raster. For the Value use R_Factor, and for cell size use 15 m2 as this was the original raster size.

K= soil erodibility factor

- Provincial Soils data (“Soil_Survey_Complex”)contains a field for K value (K Factor1)
- Clip the “Soil_Survey_Complex” by the Subwatershed Boundary. If on the edge of the CA boundary, see how far any watercourses extend past this. Then use this distance to buffer the Subwatershed boundary before clipping. Call it “SubwatersheName_Soils”
- The K value for urban areas or some valley lands is -9. As the expected K value is between 0-1 this will effect the analysis, so remove those areas from “SubwatersheName_Soils”
- Use the **Polygon to Raster** tool. The Value field is K Factor 1. Cell size is 15m

LS=Slope Steepness and Length of Slope

- LS = [0.065 + 0.0456 (slope) + 0.006541 $(\text{slope})^2$](slope length ÷ $\text{constant})^{NN}$
- https://www.youtube.com/watch?v=-ISuKwQj830
- Ls=(("fac"*30/22.1)^0.5)*(0.065+0.045*"slopprcent"+0.0065*("slopprcent"* "slopprcent"))
- Clip DTM_Mosaic with Subwatershed boundary
- Create Slope grib by percent rise
- Run Fill on clipped DRM
- Flow Direction
- Flow Accumulation
- Raster Calculator for the formula

Potential for Gully Erosion (Stream Power Index)

- ***SPI*= Ln(flow_accumulation_dem+0.001)*(slope_dem/100)+0.001)**
- Use the already created Flow Accumulation and % Slope rasters
- Call the output *SubwatershedName_PGE*

Determining Sheet and Gully Erosion potentiality for Individual Fields

- Run Zonal Statistics as Tool to generate Mean for each field
- Input is the lots, raster is the PGE/SPI raster
- Use OBJECTID as the common link
- In lots, add new double fields PGE_VALUE and PSE_VALUE. Add new text fields PGE_RANK and PSE_RANK
- Join the Zonal Stats table with the lots data
- Copy the Mean data from PGE/PSE into the resulting tables
- For the rank, determine the mean and standard deviation of the _VALUE field
- For the Rank field Low <0.5 SD/ Moderate between -0.5SD and +0.5 SD/High >0.5 SD
- Determine ½ SD, subtract from the mean value, select all values that are <0.5 SD for "Low" in %_RANK
- Determine ½ SD, add to the mean value, select all values that are >0.5 SD for "High" %_RANK
- Select all remaining values (%_VALUE IS NULL) and add "Moderate" for these in %_RANK

Locating Depressional Areas within the RBZ

- Using the DTM clipped to the final RBZ buffer (SubwatershedName_Clip), run the **Fill** tool and call the output *SubwatershedName_Clip_Fill*
- This fill in any areas in the DTM that water does not flow out of
- Using the **Raster Calculator**: "SubwatershedName_Clip_Fill - SubwatershedName_Clip"
- Call the results *SubwatershedName_Depressions*
- Use the Set Null tool to remove all areas that are 0
- Use SubwatershedName_Depressions for both the "Input conditional raster" and "input false raster or constant value" input fields
- In "Expression (optional)" enter "VALUE = 0"
- For the "Output raster" enter *SubwatershedName_Depressions_SetNull*
- This eliminates all areas without depressions, but there are still many areas where the depth may be only 1 mm. It's best to set a minimum depth before exporting to a polygon.
- Classify the raster into two classes. For a minimum depth use at least 2 cm, so the classes would be 0.000001-2cm, and 2-XX cm
- To convert to a polygon, the raster needs to be converted from a floating point to an integer. The class under 2 cm also needs to be removed. Both of these can be performed with one tool

- Use the **Reclassify** tool. For the class under 2cm, reclass it to NoData. Change the second class (2>cm) to a 1. Call the output *SubwatershedName_Depressions_Reclassify*
- Use **Raster to Polygon** to export the new output to a polygon feature class. Call it *SubwatershedName_Depressions_Export*
- This new feature class will have several tens of thousands of polygons. To clean it up and make it more manageable, delete all entries that have a shape area of <1.0 m.

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