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# UTILIZING SWMM AND GIS TO IDENTIFY TOTAL SUSPENDED SOLIDS HOTSPOTS TO IMPLEMENT GREEN INFRASTRUCTURE IN LUCAS COUNTY, OH

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**ABSTRACT**

This research demonstrates that modeling approaches can be used to identify priority areas to implement green stormwater infrastructure (GSI) resulting in improved water quality outcomes. The total suspended solids (TSS) washoff loading from watersheds in Lucas County, Ohio due the municipal separate storm sewer system (MS4) was reported based on 2015 rain data. The highest TSS loading was experienced in the winter season in 80% of the watersheds. Subcatchments with the highest predicted TSS washoff loadings were identified as priority areas or hotspots. In subsequent simulations, GSI implementation in hotspots improved water quality by more than 2-fold as compared to indiscriminate implementation of GSI. These hotspot maps are being used by regional stormwater stakeholders to focus their urban water quality efforts and to identify site characteristics that may be used to inform environmental policy.


**NOVELTY**

We report on an approach for identifying stormwater contaminant hotspots in watersheds using hydrologic water quality modeling and GIS. The results are currently being used by regional clean water stakeholders to direct GSI site implementation and to identify patterns that may be used to inform future policies on development and stormwater management.


**KEYWORDS**

Urban Runoff, Stormwater Modeling, SWMM, Total Suspended Solids, Green Stormwater Infrastructure

## INTRODUCTION

Urbanization accompanied by increased surface imperviousness result in negative effects on the hydrology and water quality of receiving water bodies [1-5]. Increased runoff volume and velocity contribute to downstream erosion, thereby degrading stream ecosystems, scouring structures (e.g., bridge foundations, catch basins), and decreasing water quality as the water contains suspended eroded solids and sediments [6, 7]. The poor water quality in the Western Basin of Lake Erie can be attributed to many causes among them is increased urbanization in the Greater Toledo Area [8]. Extreme or changing precipitation patterns associated with climate change and combined with poor maintenance and undersized stormwater infrastructure exacerbate the negative effects of urbanization [9-11].

To address stormwater management challenges, many communities are designing and implementing green stormwater infrastructure in lieu of or in conjunction with upgrades to existing gray infrastructure. Rain gardens, also known as bioretention cells (BRCs), are vegetated depressions that allow shallow ponding of runoff and gradual infiltration through an engineered soil and storage layer. Bioretention, the most widely applied green stormwater infrastructure in North America, aims to restore some functions of the natural systems, including attenuation, evapotranspiration, and infiltration, present prior to urbanization and to manage stormwater close to its source [12]. BRCs have been determined through direct monitoring to have water quality, hydrologic, and flow attenuation benefits in several previous studies [13-18].

Although promising, the observed benefits from BRCs are predicated on many site-specific conditions including native soils, climate, imperviousness, and quality of construction.

Since vacant land is often scarce and expensive in urban environments, it is important to select preferred sites for green infrastructure installation, where the desired benefits (e.g., water quality improvements) are achievable and may be maximized [19]. Hydrologic modeling and geographic information systems (GIS) analysis of pertinent parcel data can be used for planning and design of urban runoff or proposed abatement options. GIS are commonly used to collect and manage the spatial data required as inputs for hydrologic models such as SWMM5 [20]. The planning and prioritization process of bioretention remediation can benefit from a GIS containing such spatial data. Previous studies have identified land use type and in-situ soil data as the best planning and prioritization parameters for utilization in a GIS format [20-22]. In this research, GIS analysis of available spatial data (e.g., soils, site imperviousness, and land use) was coupled with hydrologic model simulations (EPA Stormwater Management Model or SWMM) to identify "hotspots" where contaminant generation from stormwater runoff was comparatively high and to determine the potential benefits to stormwater of implementation of bioretention cells in varied locations of a watershed.

## MATERIALS AND METHODS

### *Site Description*

Lucas County (596 $mi^2$) located in Northwest Ohio, includes the City of Toledo, the 4th most populous city in Ohio (Est. 287,208 in 2010) and is adjacent to Lake Erie. In Lucas County, 29 twelve-digit hydrologic units (HUC-12) watersheds, defined by their contribution of runoff to local waterways, are included in the municipal separate storm sewer system (MS4) (Figure 1). The largest of these watersheds is Sibley-Creek-Ottawa River (14,000 acres). The watersheds are composed of commercial, industrial, residential, and undefined (roadway) land uses. They range from 0.5 to 41 percent impervious and have a wide range of soil properties (HSG groups A through D).

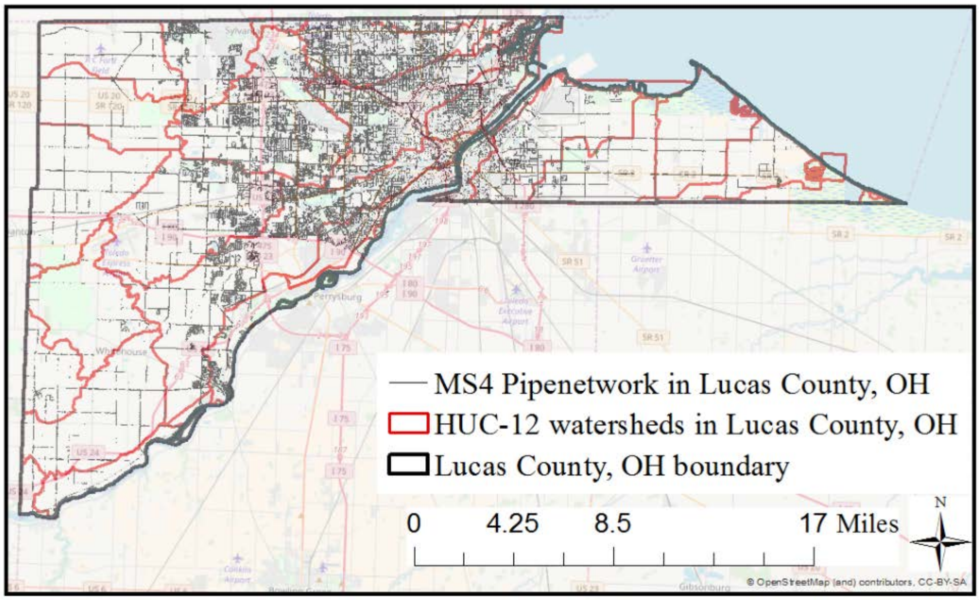


*Figure 1 MS4 Pipe Network in HUC-12 Watersheds in Lucas County*

A hydrology-hydraulic model was built for watersheds in the MS4 in Lucas County using digital elevation models, land characteristics (imperviousness, soil type), and contaminant characteristics (buildup and washoff). Continuous simulations were carried out using rain data collected at a nearby gauge (Figure 2). The HUC-12 watersheds projected to produce the highest TSS loads were identified using hydrologic modeling. In addition, seasonal variations in TSS load were identified. Seasonal variations in TSS load were also investigated in this study. Subsequent investigation focused on the Sibley Creek-Ottawa River watershed.

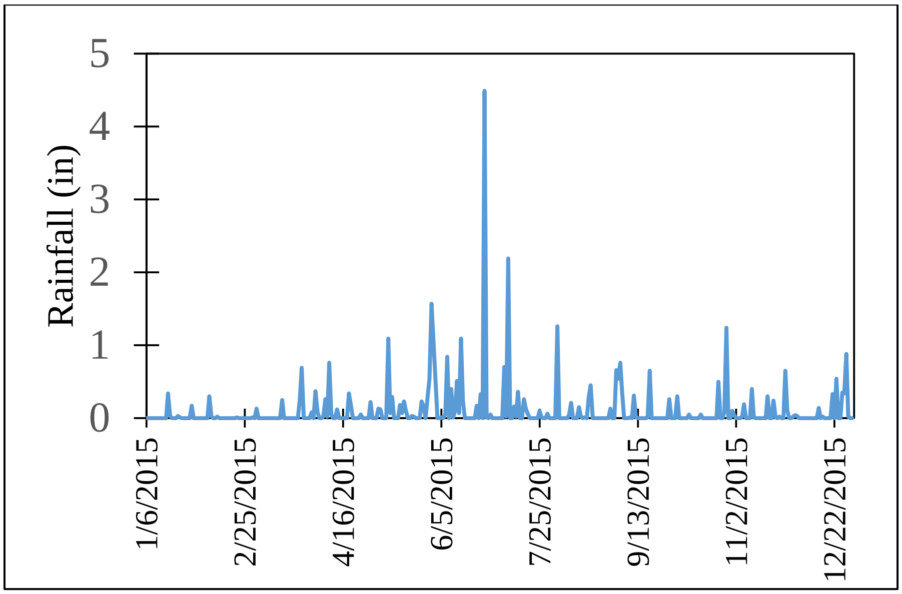


*Figure 2 Continuous 2015 Rain Data from Gauge near the Sibley Creek-Ottawa River Watershed*

***Software***

SWMM is a dynamic rainfall-runoff simulation model used for single event or long-term (continuous) simulation of runoff quantity and quality from primarily urban areas [23]. Subcatchments, described by area, characteristic width and slope, percent imperviousness, and soil properties, receive this rainfall. SWMM uses uniform, kinematic or dynamic routing to model water movement on or into the subcatchments/channels-modeled as conduits. Commercial versions of hydrologic-hydraulic models are available running the SWMM5 engine. These are user-friendly and offer easy compatibility with other software like GIS, AutoCAD, and HECRAS. Of these, PCSWMM was used in this project.

The Imperviousness Surface Analysis Tool (ISAT) in ArcMap, a component of a commercially available GIS software, was used to calculate imperviousness of a surface; ISAT assigns impervious surface coefficients to remotely sensed land cover and population data to determine the total and the percentage of impervious surface area within specified polygons [24]. Shuttle radar topography mission digital elevation model (DEM) data was downloaded from https://earthexplorer.usgs.gov/. The various HUC-12 were used as masks to extract individual HUC-12 DEMs to input into PCSWMM. The extracted DEMs for the HUC-12 were the inputs to delineate watersheds with a target discretization of 10ac. The existing MS4 pipe network in Lucas County was used as the burn in stream layer to describe the path within the pipe system [25, 26].

Area weighted averaging is an arithmetic averaging approach where the relevance of the area covered by an item is considered. A commercial version of PCSWMM's area weighting tool was used to calculate the percent imperviousness, proportion of land use, and proportion of soil types of a subcatchment as read from the parcel data in the GIS [27].

*Water Quality Model Calibration and Sensitivity Analysis*

Many researchers including [28-34] critiqued and summarized methods available for simulation of surface runoff quality and ultimately suggested alternatives considering the constituent and antecendant dry days. SWMM provides three options for buildup and for washoff of surface constituents i.e. power/linear, exponential and Michaelis-Menton for buildup and exponential, rating curve and event mean concentration for washoff [29]. Street cleaning, which is performed in most urban areas for control of solids and trash deposited along street gutters, does not have a significant impact on water quality unless done daily [29, 35, 36].

The initial water quality model was built based on literature values [36, 37] including buildup and washoff parameters for total suspended solids. A buildup function defines the rate at which a contaminant, in our case TSS, accumulates on the surfaces of the watershed. The power equation was selected based on previous research [23, 29, 38].

$$B = min(C_1, C_2 t^{C_3}) \quad (1)$$

Where B is buildup (lb.), $C_1$ is the maximum possible buildup (mass / area), $C_2$ is the buildup rate and $C_3$ is the time exponent. The specific buildup parameters used in this research for the Sibley Creek Ottawa River HUC-12 watershed after model calibration are provided in Table 1.

*Table 1 Buildup parameters for Sibley Creek – Ottawa River Watershed.*

| **Land use** | **Commercial** | **Industrial** | **Residential** | **Roadways** |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| **Function** | Power | Power | Power | Power |
| **Max Buildup rate** | 11.99 | 27.61 | 21.30 | 28.50 |
| **Rate Constant** | 1.10 | 10.80 | 0.66 | 12.00 |

*For all land uses, the power constant was 1, and area was used to normalize the data.

A washoff function defines the rate at which a contaminant, in our case TSS, is washed off or eroded from the surfaces of the watershed to a natural waterway. The exponential function was selected based on previous research [23, 29].

$$W = C_1 q^{C_2} B \quad (2)$$

Where B is the buildup (lb.), W is the washoff (lb.), $C_1$ is the washoff coefficient, $C_2$ is the washoff exponent and q is runoff rate per unit area in/hr or mm/hr. The specific washoff parameters used for the Sibley Creek Watershed after model calibration are included in Table 2.

*Table 2 Washoff parameters for Sibley Creek – Ottawa River Watershed.*

| **Land use** | **Commercial** | **Industrial** | **Residential** | **Roadways** |
|---|---|---|---|---|
| **Function** | Exponential | Exponential | Exponential | Exponential |
| **Coefficient** | 0.14 | 0.69 | 0.04 | 0.75 |

*For all land uses, the washoff exponent ($C_2$) used was 2. And, the cleaning and the BMP efficiency were estimated as 0.

Model calibration was carried out using quarterly field monitoring data by altering water quality parameters (maximum buildup coefficient, washoff coefficient, buildup rate, antecedent dry days (ADD) and washoff exponent). A sensitivity analysis was carried out to determine how responsive the water quality model was to a change in a specific water quality parameter [39].

***SWMM Modeling of Bioretention Cells***

Using the LID editor in the SWMM model of the Sibley Creek Watershed, rain gardens (bioretention cells) were implemented in subcatchments in accordance with three different scenarios: (i) in the highest TSS producing subcatchments; (ii) in subcatchments with adequate land availability (randomized based on pervious land cover); and (iii) in the lowest TSS producing subcatchments. The specific characteristics of the rain gardens implemented in the SWMM model using the LID editor are included in Table 3. TSS reduction was observed as a function of the rain garden areas implemented in all three scenarios. TSS produced per subcatchment was read from the SWMM status report and the TSS/ac produced was calculated.

*Table 3 Rain Garden Characteristics in the Model*

| | | |
|---|---|---|
| Surface Layer | Berm height, in | 12 |
| | Vegetative volume fraction | 0.2 |
| | Surface Roughness (n) | 0.075 |
| | Surface Slope (percent) | 1 |
| Soil Layer | Thickness, in | 30 |
| | Porosity | 0.437 |
| | Field capacity | 0.105 |
| | Wilting point | 0.047 |
| | Conductivity, in/hr | 0.86 |
| | Conductivity slope | 0.01 |
| | Suction head, in (mm) | 2.4 |
| Storage Layer | Thickness, in | 12 |
| | Void Ratio | 0.45 |
| | Seepage rate, in/hr | 0.05 |
| | Clogging factor | 0 |

**RESULTS AND DISCUSSION**

The HUC-12 watersheds in Lucas County, Ohio were studied to determine how stormwater runoff contributes to water quality issues in the Western Basin of Lake Erie. Certain characteristics like imperviousness, land use, and soil type were expected to be important determinants of runoff water quality. Table 1 shows the top ten impervious HUC-12 watersheds. Shantee Creek is the watershed with the highest imperviousness (over 40%) while Sibley Creek-Ottawa River, Detwiler-Ditch-Frontal Lake Erie, Halfway Creek, and Delaware Creek-Maumee River follow closely behind at approximately 38% impervious. Interestingly, in these top five impervious HUC-12 watersheds, residential land use, ranging from 34 to 50%, is higher than other land uses (i.e., industrial, commercial, roadways). Roadways (approx. 100% impervious) were considered a land use type in this study and make up >10% (11 to 28%) of the land use in the top ten TSS producing watersheds.

*Table 4 Watershed Imperviousness and Land Use*

| **HUC-12 Watershed** | **Imperv (%)** | **Land use (%)** | | | |
|---|---|---|---|---|---|
| | | Commercial | Industrial | Residential | Roadways |
| **Shantee Creek** | 40.7 | 20 | 15 | 50 | 16 |
| **Sibley Creek-Ottawa River** | 38.9 | 17 | 20 | 40 | 23 |
| **Detwiler Ditch-Frontal Lake Erie** | 38.8 | 15 | 20 | 38 | 28 |
| **Halfway Creek** | 38.5 | 32 | 22 | 34 | 11 |
| **Delaware Creek-Maumee River** | 37.7 | 16 | 19 | 39 | 26 |
| **Otter Creek-Frontal Lake Erie** | 25.7 | 19 | 37 | 31 | 13 |
| **Heldman Ditch-Ottawa River** | 22.0 | 18 | 9 | 58 | 15 |
| **North Tenmile Creek** | 20.4 | 11 | 6 | 68 | 15 |
| **Tenmile Creek** | 20.2 | 11 | 31 | 47 | 11 |
| **Heilman Ditch-Swan Creek** | 19.8 | 19 | 30 | 38 | 13 |

The SWMM models produced TSS loads per area (lb/acre) delivered to nearby waterways by the stormwater collection system for all of the HUC-12 watersheds in Lucas County. A SWMM simulation based on the 2015 rain data gathered at nearby rain gauges was used to estimate the stormwater TSS loads (Figure 2). The TSS loads produced by the watersheds ranged from near zero lb/acre (green) to over 140 lb/acre (red). The watersheds indicated by red and orange (loading of over 50 lb/acre) might present opportunities to mitigate stormwater pollution by preferentially implementing stormwater management practices in these areas. These watersheds are proximal to the river and tend to be in highly developed areas with significant man-made infrastructure (e.g., buildings, pipes, and roadways).

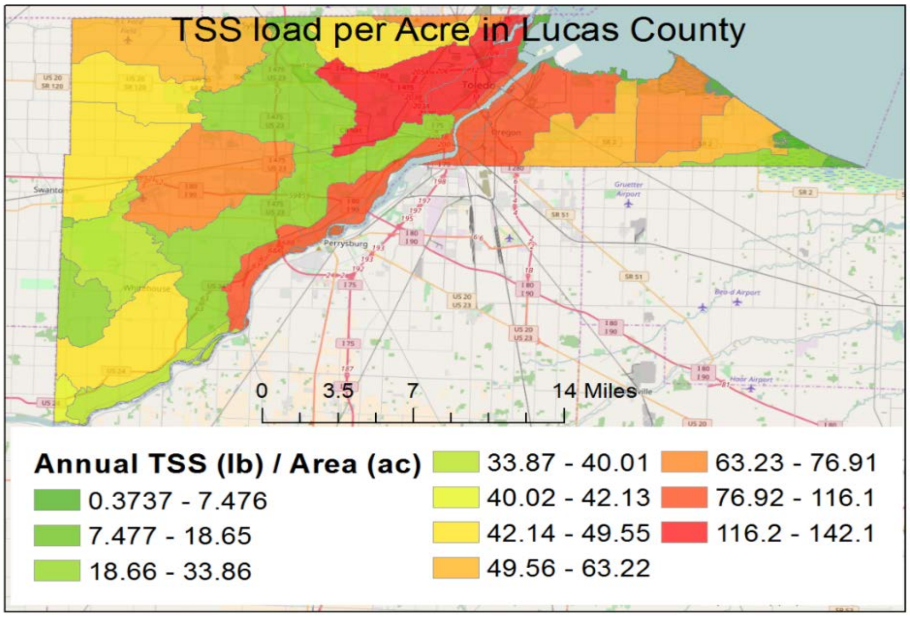


*Figure 3 TSS Loading from HUC-12 Watersheds in Lucas County, OH using 2015 Rain Data*

Figure 4 shows the top five HUC-12 watersheds organized from left to right by TSS load per area (highest to lowest). They range from approximately 80 to 140 lb/acre. Figure 4 also indicates HUC-12 % imperviousness for each watershed. The Sibley Creek-Ottawa River HUC-12 produced the highest load (over 140 lb/acre). There appears to be some relationship between imperviousness (%) and TSS load since some of the HUC-12 watersheds with high imperviousness (up to 40%) also produce the top TSS loads. However, imperviousness does not completely explain the TSS loads because some HUC-12 watersheds with lower imperviousness still have high TSS loads. For example, the Crooked Creek-Maumee River watershed is the 4$^{th}$

highest producer of TSS load (approximately 100 lb/acre), but the watershed is not in the top ten impervious HUC-12 watersheds as it has an imperviousness of just over 15% (Figure 4).

Figure 4 demonstrates the annual TSS load as well as the TSS load by season. The simulation data indicated that the highest TSS loading is produced during the winter (Jan, Feb and Mar) for the majority of the watersheds. Otter Creek-Frontal Lake Erie is the exception. This may be explained by the fact that the number of antecedent dry days in the winter can be greater than other seasons causing solids build up [40]. In addition, winter precipitation and the land surface are often frozen which causes more solids to build up and less infiltration to occur.

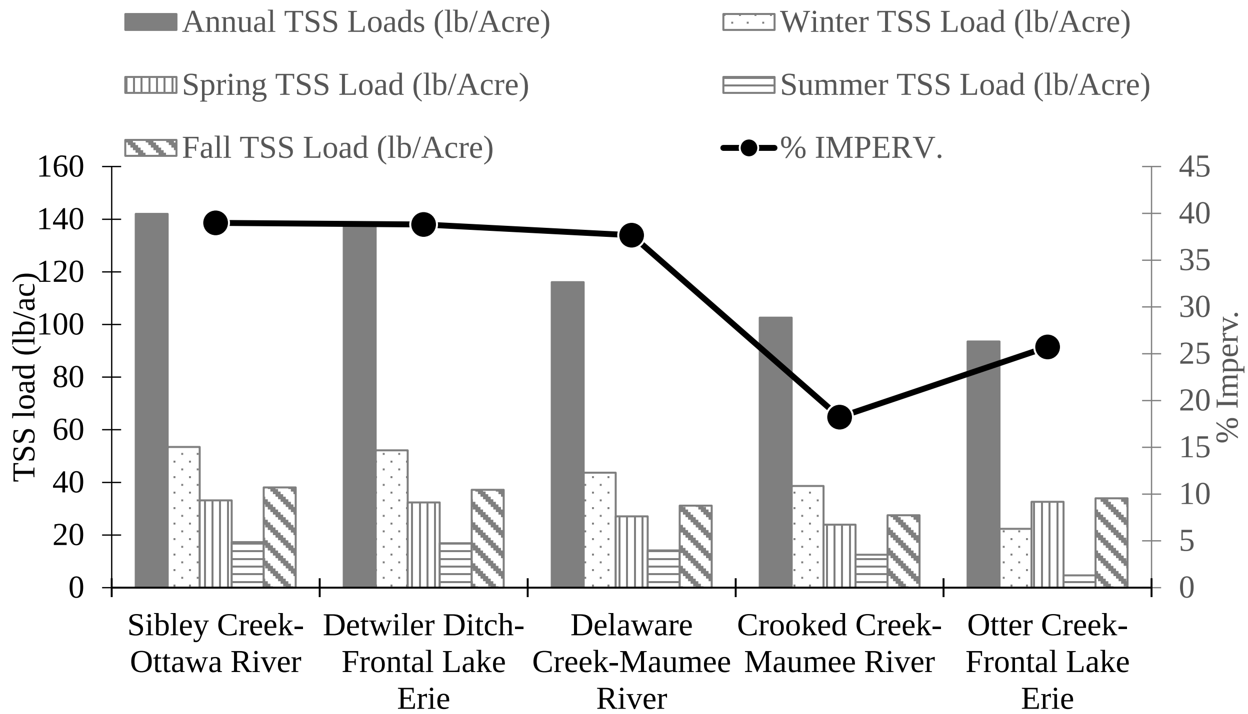


*Figure 4 Seasonal Loading from Top 5 TSS Producing HUC-12 Watersheds in Lucas County, OH for 2015*

In this research, Sibley Creek-Ottawa River HUC-12 watershed (the extent of which is shown in Figure 5) was selected for further study because it was estimated to produce the highest amount of TSS load per acre in Lucas County. It is also the fourth largest HUC-12 watershed (approximately 14,000 acres) in Lucas County. Each of the subwatersheds in Sibley Creek-Ottawa River (from 0.02 to 43 acres) was ranked according to TSS load. The result is a "hotspot" map for the HUC-12 watershed that indicates the subwatersheds that were predicted to contribute the highest annual TSS load. The estimated TSS loads were up to 595 lb/acre. The highest loads were identified on the "hotspot" map and seemed to indicate some patterns associated with land use (Figure 5).

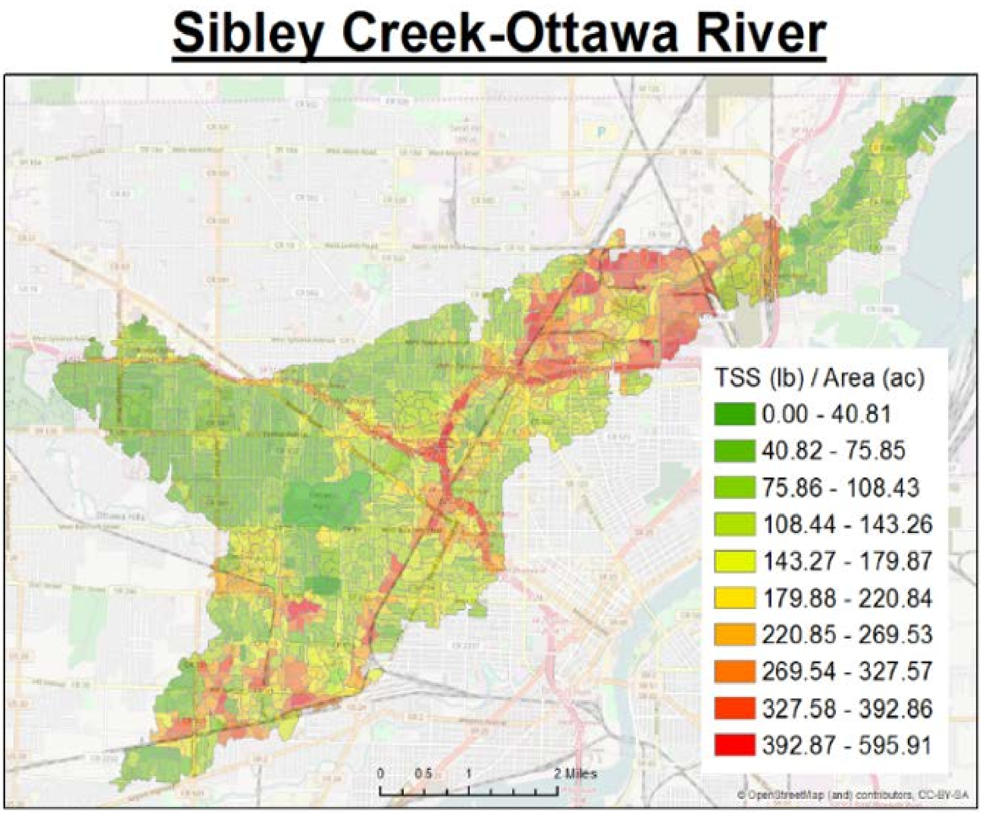


*Figure 5 TSS Hotspots in Sibley Creek Ottawa River HUC-12 Watershed*

Figure 5 shows the subwatersheds in Sibley Creek Ottawa River HUC-12 that produced the highest TSS loads included major roadways such as interstates (I-75). These areas are highly impervious and often include adjacent industrial land. Other subcatchments identified as hotspots are selected industrial and commercial sites. This analysis provided the opportunity to identify specific land parcels for implementing strategies for reducing TSS loads. The results of this analysis did not change when the water quality model simulation was repeated using the annual rain data from 2016. The same geographical areas (subwatersheds) were identified as "hotspots." These hotspot maps provide visual confirmation of the pressing need to focus stormwater mitigation efforts in areas adjacent to roadways and commercial/industrial sites and provide quantification of the differences in the impact of these areas on urban water quality as compared to other urban parcels. In some cases, these parcels produced more than two times the annual load of TSS when compared to adjacent parcels. Subsequent simulations were used to determine if implementing targeted contaminant reduction strategies, specifically green stormwater infrastructure, in the hotspots could significantly improve water quality. Current strategies for implementing green stormwater infrastructure retrofits are often focused on identifying adequate available land for building remediation strategies (e.g., parks, public lands) rather than targeting specific contaminant hotspots.

The implementation of rain gardens in TSS hotspot areas was simulated in the Sibley Creek-Ottawa River Watershed using SWMM. TSS reduction was observed as a function of the rain garden areas implemented in three scenarios including implementation in hotspots, randomized, and the lowest TSS producing subcatchments. In these scenarios, simulations were run, and the results of TSS removal were plotted against the percent of the HUC-12 watershed area used for rain garden implementation. In agreement with previous researchers [28, 41, 42], hyperbolic regression curves were fitted to the plots of TSS removal against the percent of the

HUC-12 watershed area used for rain garden implementation, in the scenarios described above (Figure 6).

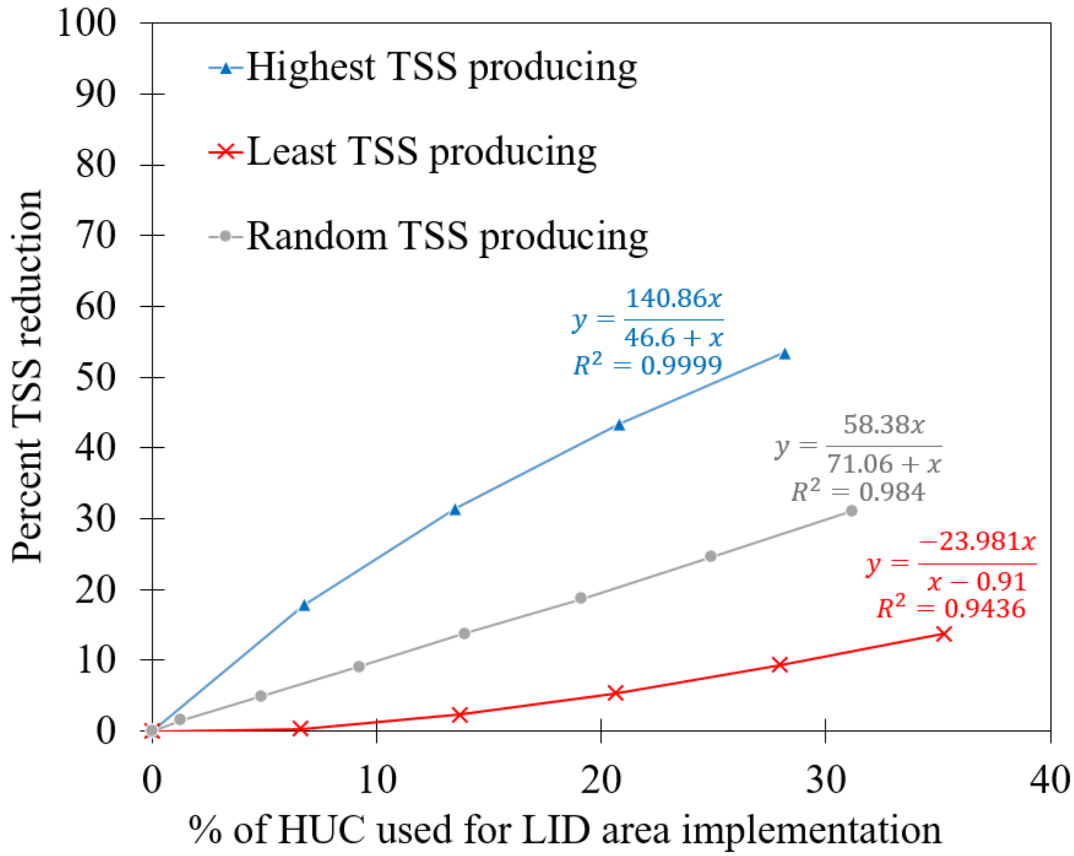


*Figure 6 Percent TSS Reduction as a Function of Percent of Watershed Converted to LID in Sibley Creek Ottawa River HUC-12*

In order to be properly sized to capture a typical event, rain gardens are typically designed to occupy 5 to 10 percent of the area of a contributing watershed [43]. For 10% of the contributing watershed, an annual TSS load reduction of approximately 2.4X was observed when rain gardens are implemented in the hotspot subwatersheds as compared to randomized placement (Table 5). For 20% of the HUC-12 targeted for LID implementation, TSS reduction varied from 42.3% (highest TSS subwatersheds) to approximately 5% (lowest TSS subwatersheds). Randomized targeting of subwatersheds resulted in approximately 20% TSS reduction. Our results indicate that the benefit of placing rain gardens using the simulation is maximized in the range of 5 to 10% of the watershed area. And, the benefit is slightly reduced as the % area of the rain garden increases. The extent of rain garden implementation necessary will depend on the TSS load reduction desired and/or the funding and land available to implement rain gardens. Urbanization leads to decreased water quality, and urban land is more costly and scarce due to its inherent economic value. Therefore, it is important to maximize the use and benefit of the urban land being converted to green stormwater infrastructure.

*Table 5 Percent TSS reduction for selected LID implementation area in an HUC-12*

| | **Percent Area of HUC-12 Occupied by Rain Garden** | | | |
|---|---|---|---|---|
| | **5** | **10** | **15** | **20** |
| Highest TSS | 13.65 | 24.89 | 34.30 | 42.31 |
| Random | 5.61 | 10.39 | 14.53 | 18.13 |
| Lowest TSS | 0.23 | 0.65 | 1.52 | 4.57 |

## CONCLUSION

In this study, hydrologic/water quality simulation was used to generate hotspot maps that identify the watershed and subwatersheds likely to produce the highest contaminant loads. The creation of the water quality models requires significant site data including imperviousness, native soil type, land use, elevation, infrastructure dimensions, and local rain data. In addition, the water quality component of the model requires water quality parameters (i.e. buildup coefficient, washoff coefficient, and buildup exponent), calibration and a sensitivity analysis. Hotspot maps can be useful to visual problem areas and to target those areas for maximizing strategies to reduce runoff pollution. This study suggests that using simulation modeling confers significant benefits to water quality mitigation efforts. The properties that contribute the highest loads can be identified, mitigation strategies can be implemented, and the best outcome can be achieved for the least investment.

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| **Land use** | **Commercial** | **Industrial** | **Residential** | **Roadways** |
|---|---|---|---|---|
| **Function** | Power | Power | Power | Power |
| **Max Buildup rate** | 11.99 | 27.61 | 21.30 | 28.50 |
| **Rate Constant** | 1.10 | 10.80 | 0.66 | 12.00 |

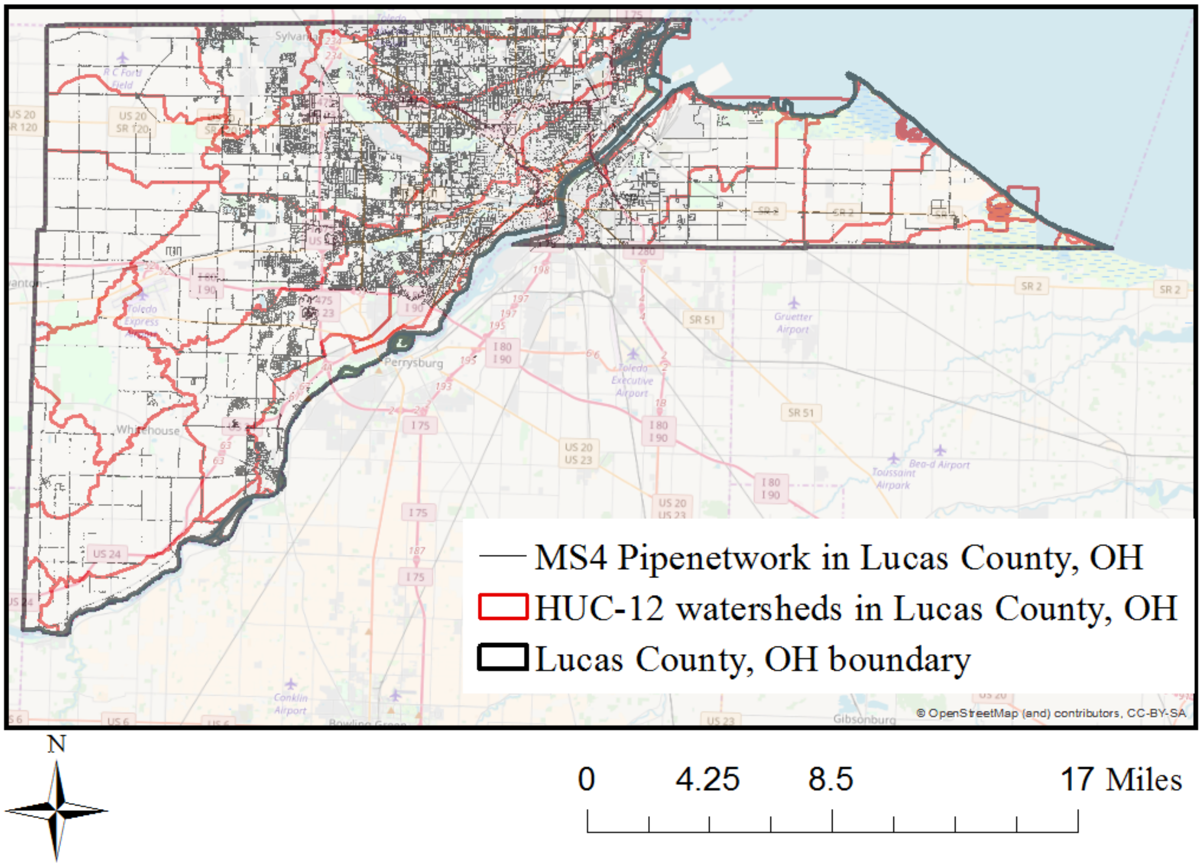
| Land use | Commercial | Industrial | Residential | Roadways |
|---|---|---|---|---|
| **Function** | Exponential | Exponential | Exponential | Exponential |
| **Coefficient** | 0.14 | 0.69 | 0.04 | 0.75 |

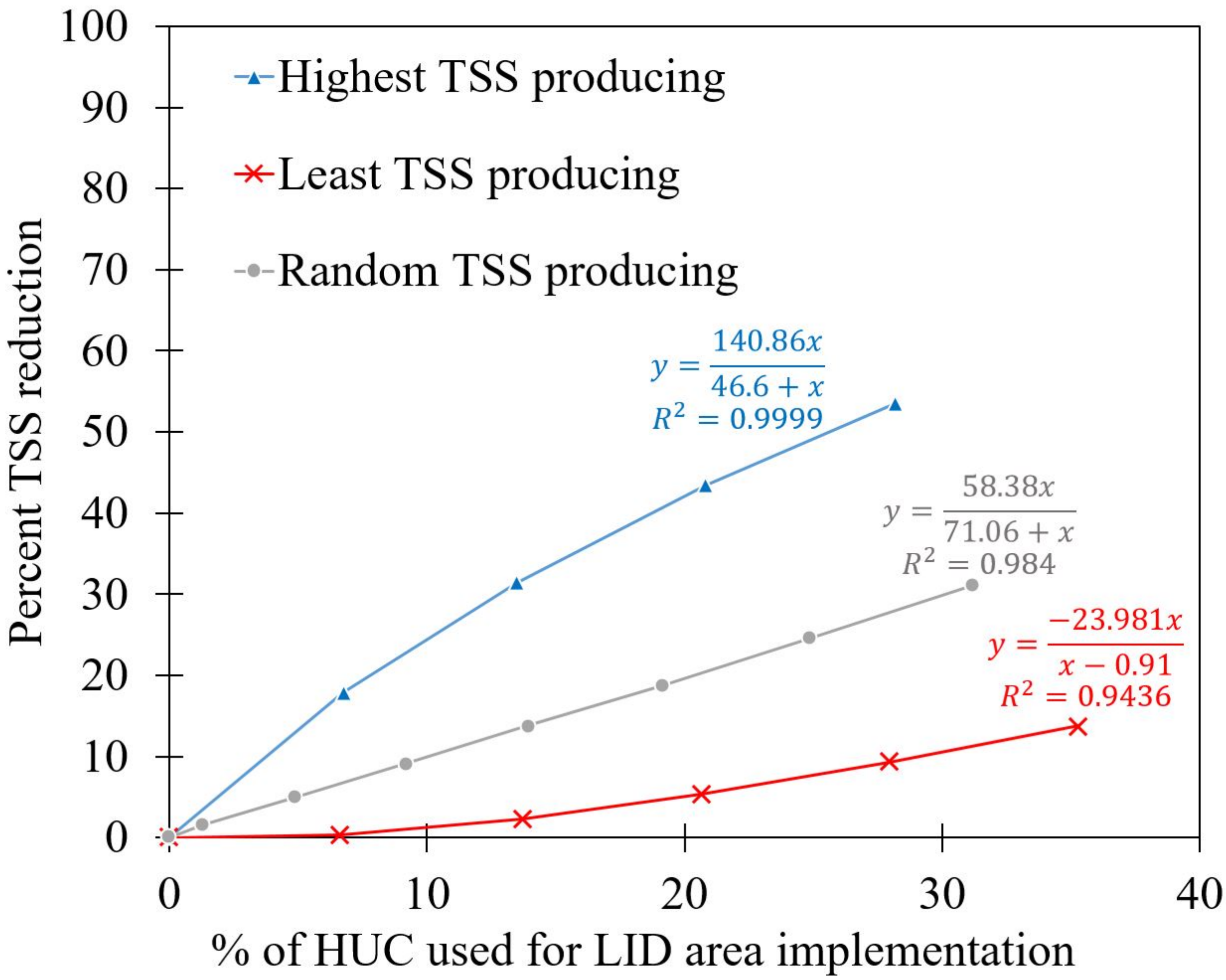
| | | |
|---|---|---|
| Surface Layer | Berm height, in | 12 |
| | Vegetative volume fraction | 0.2 |
| | Surface Roughness (n) | 0.075 |
| | Surface Slope (percent) | 1 |
| Soil Layer | Thickness, in | 30 |
| | Porosity | 0.437 |
| | Field capacity | 0.105 |
| | Wilting point | 0.047 |
| | Conductivity, in/hr | 0.86 |
| | Conductivity slope | 0.01 |
| | Suction head, in (mm) | 2.4 |
| Storage Layer | Thickness, in | 12 |
| | Void Ratio | 0.45 |
| | Seepage rate, in/hr | 0.05 |
| | Clogging factor | 0 |

| HUC-12 Watershed | Imperv (%) | Land use (%) | | | |
|---|---|---|---|---|---|
| | | Commercial | Industrial | Residential | Roadways |
| **Shantee Creek** | 40.7 | 20 | 15 | 50 | 16 |
| **Sibley Creek-Ottawa River** | 38.9 | 17 | 20 | 40 | 23 |
| **Detwiler Ditch-Frontal Lake Erie** | 38.8 | 15 | 20 | 38 | 28 |
| **Halfway Creek** | 38.5 | 32 | 22 | 34 | 11 |
| **Delaware Creek-Maumee River** | 37.7 | 16 | 19 | 39 | 26 |
| **Otter Creek-Frontal Lake Erie** | 25.7 | 19 | 37 | 31 | 13 |
| **Heldman Ditch-Ottawa River** | 22.0 | 18 | 9 | 58 | 15 |
| **North Tenmile Creek** | 20.4 | 11 | 6 | 68 | 15 |
| **Tenmile Creek** | 20.2 | 11 | 31 | 47 | 11 |
| **Heilman Ditch-Swan Creek** | 19.8 | 19 | 30 | 38 | 13 |

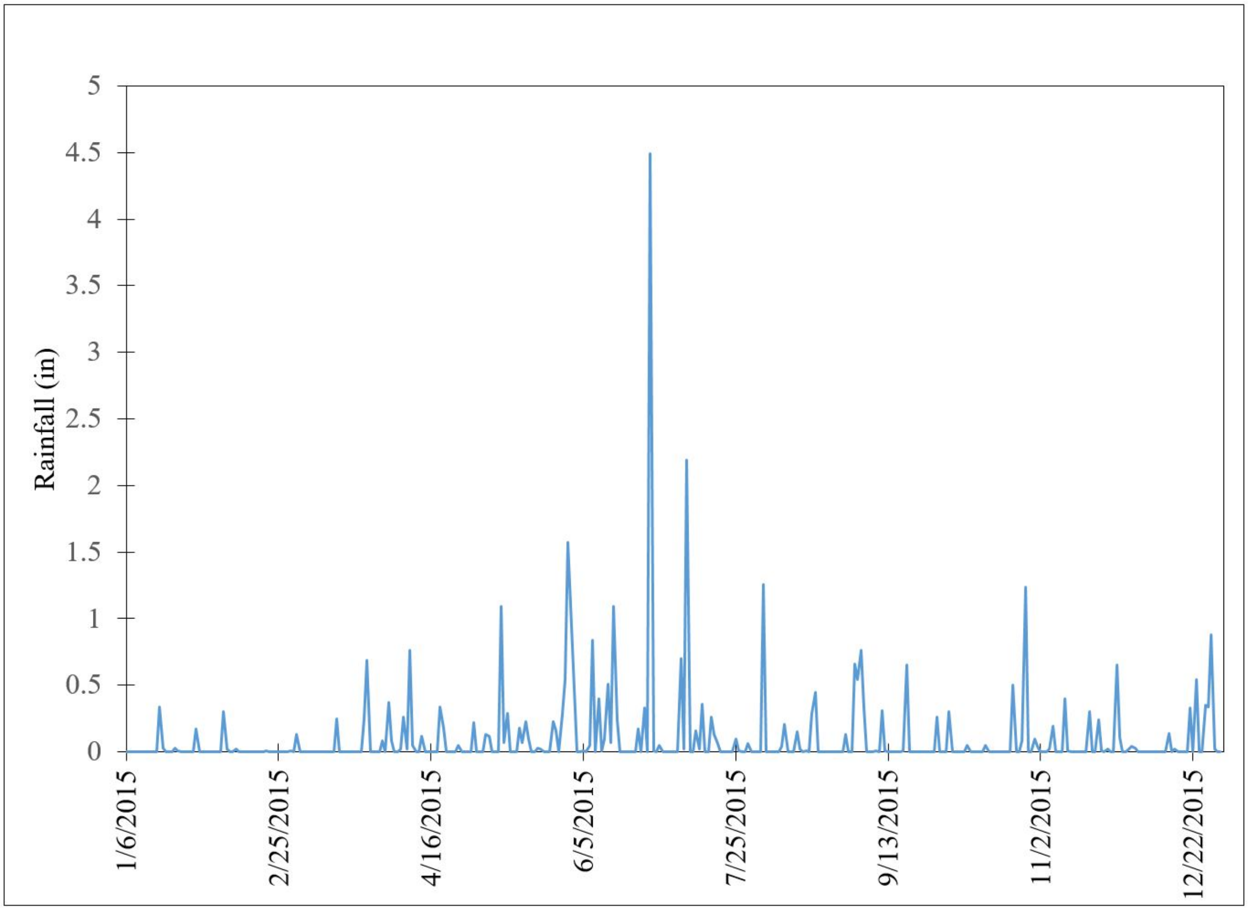
| | Percent Area of HUC-12 Occupied by Rain Garden | | | |
|---|---|---|---|---|
| | **5** | **10** | **15** | **20** |
| Highest TSS | 13.65 | 24.89 | 34.30 | 42.31 |
| Random | 5.61 | 10.39 | 14.53 | 18.13 |
| Lowest TSS | 0.23 | 0.65 | 1.52 | 4.57 |

MS4 pipe network with HUC-12 watersheds in Lucas County

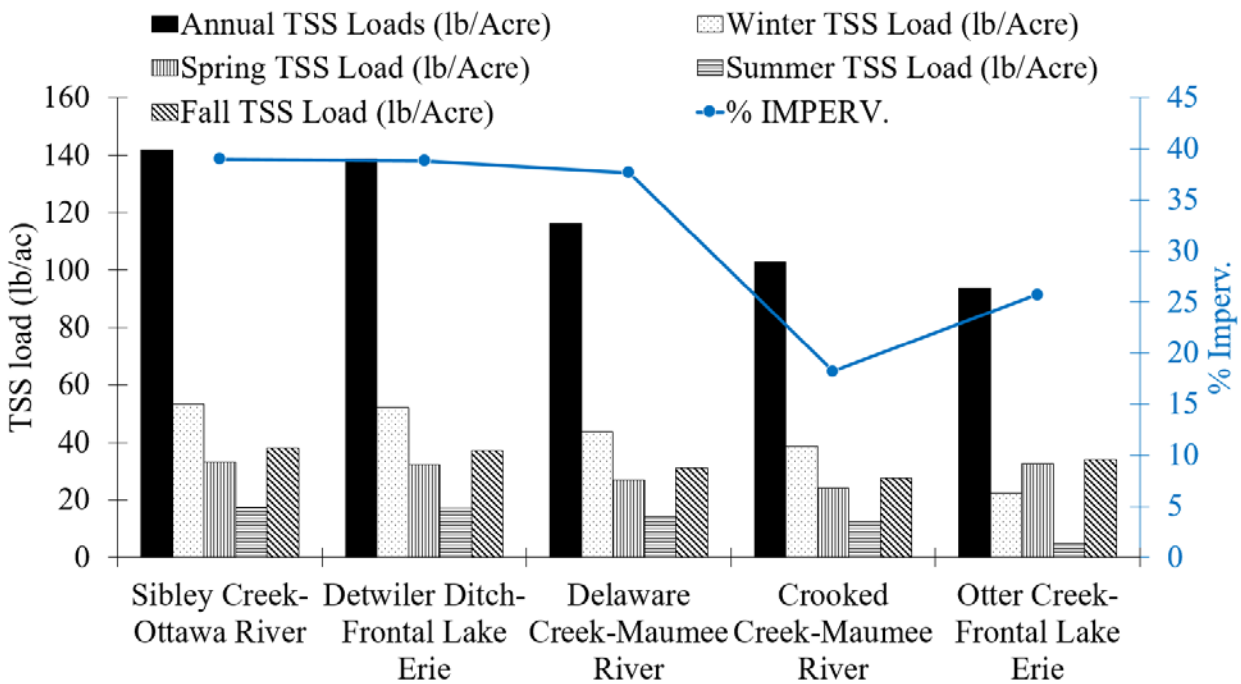


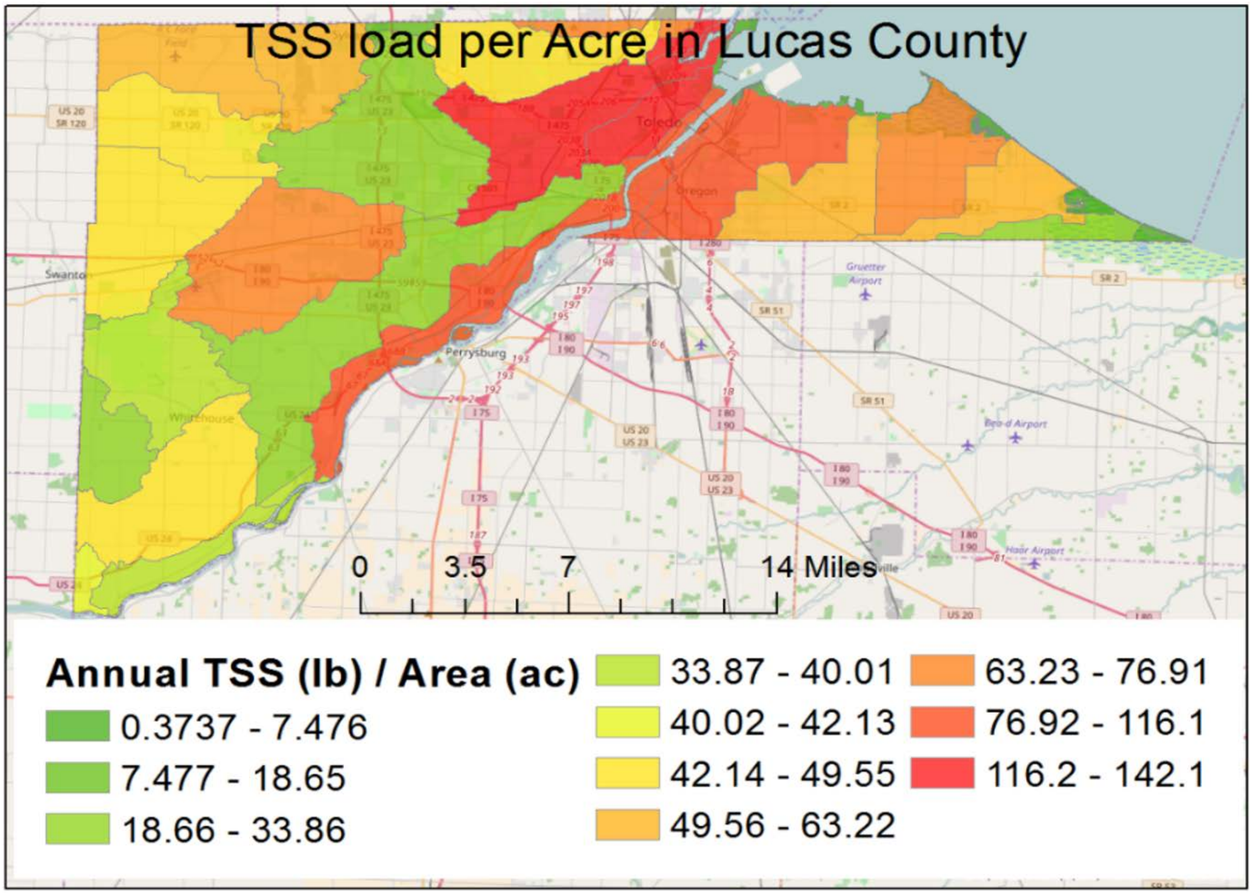


100
90
80
70
60
50
40
30
20
10
0
Percent TSS reduction
Highest TSS producing
Least TSS producing
Random TSS producing
$y = \frac{140.86x}{46.6 + x}$
$R^2 = 0.9999$
$y = \frac{58.38x}{71.06 + x}$
$R^2 = 0.984$
$y = \frac{-23.981x}{x - 0.91}$
$R^2 = 0.9436$
0
10
20
30
40
% of HUC used for LID area implementation



5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Rainfall (in)
1/6/2015
2/25/2015
4/16/2015
6/5/2015
7/25/2015
9/13/2015
11/2/2015
12/22/2015


Annual TSS Loads (lb/Acre)
Winter TSS Load (lb/Acre)
Spring TSS Load (lb/Acre)
Summer TSS Load (lb/Acre)
Fall TSS Load (lb/Acre)
% IMPERV.
TSS load (lb/ac)
% Imperv.
0
20
40
60
80
100
120
140
160
0
5
10
15
20
25
30
35
40
45
Sibley Creek-Ottawa River
Detwiler Ditch-Frontal Lake Erie
Delaware Creek-Maumee River
Crooked Creek-Maumee River
Otter Creek-Frontal Lake Erie


TSS load per Acre in Lucas County
0
3.5
7
14 Miles
Annual TSS (lb) / Area (ac)
0.3737 - 7.476
7.477 - 18.65
18.66 - 33.86
33.87 - 40.01
40.02 - 42.13
42.14 - 49.55
49.56 - 63.22
63.23 - 76.91
76.92 - 116.1
116.2 - 142.1