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THE EFFECT OF GREEN STRUCTURES ON HYDROLOGY IN URBAN AREAS OF AKRON, OHIO

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University of Akron – Honors Research Project

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ABSTRACT

Stormwater runoff is a major environmental concern in dense urban areas. Runoff in these areas contributes to flooding as well as water quality problems in the streams, lakes, and reservoirs downstream. The Cuyahoga River is the receiving waterbody for the City of Akron’s stormwater runoff. Currently, combined sewer overflow (CSO) from the city's outdated sewer system is the overriding reason for poor water quality in the Cuyahoga River.

Implementation of green infrastructure is one way to mitigate problems associated with stormwater runoff from urban areas. In this study, hydrologic modeling of the Little Cuyahoga watershed was conducted to determine how different levels of implementation of green infrastructure may cause different hydrological responses, such as a decrease in total stormwater runoff.

In this study, the reduction in peak discharge at the outlet of the sub-watershed was evaluated by adjusting the curve number for each subbasin based on a level of implementation of green infrastructure. The HEC-HMS modeling simulation results concluded that moderately high levels of green infrastructure implementation would be required to reduce the outflow of the study area by a significant amount, solely based on the re-classification of land use for medium- and high-intensity urban areas. Although they are outside the scope of this study, there are added benefits to the implementation of green infrastructure, such as improvements in water quality.

The cumulative benefits of both reduction in water volume and improvement of water quality make green infrastructure an excellent choice for the rehabilitation of a watershed. These improvements directly correlate to a significant reduction of construction and maintenance costs for hydrologic infrastructure of any major city.

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INTRODUCTION

As a branch of science, hydrology studies properties of the water on the earth, especially its movement in relation to land. Surface water hydrology relates to hydrologic processes that operate at or near the Earth's surface [1]. This paper will discuss green infrastructure implementation as a means of stormwater management, and its potential effects on the hydrology of Akron, Ohio.

Healthy urban streams are vital to our communities as well as the natural environment. Most of Akron lies within the Cuyahoga River Watershed. The Cuyahoga River is famous for being heavily polluted. The 1969 Cuyahoga River fire event provoked public outcry and led to the Clean Water Act passed by Congress in 1972, with the ultimate goal of protecting all waterways from pollution and destruction. The City of Akron is working to restore its waterways, but the river is still far from healthy.

Downtown Akron lies within the Little Cuyahoga River watershed. The Little Cuyahoga River is a 17.4-mile long tributary to the Cuyahoga River. [2] It is located in southeast Summit County and southwest Portage County, with a watershed area of 61.7 square miles in total. According to the Ohio EPA, the Little Cuyahoga River does not meet current standards for biological and recreational uses [2]. Though there are many reasons for its poor water quality, the leading cause of pollutants in the river is the combined sewer overflow (CSO) from the City of Akron.

“There are currently 29 CSO outlets in the Little Cuyahoga River annually discharging hundreds or thousands of gallons of combined sewage and storm water. Without controlling Akron’s combined sewer discharges, Ohio EPA believes the Little Cuyahoga River will not reach state water quality standards for biological and recreational uses.” [2]

The most direct way to reduce CSOs is to reduce the amount of stormwater runoff that enters the city's wastewater system. Strategically reducing stormwater runoff would decrease the volume of water in the city's storm sewers, and rarefy combined sewer discharges. If this goal could be accomplished, most small storms could wash through the city's pipes without overwhelming the system.

One way to work toward the goal of reducing stormwater runoff is the use of green infrastructure. When nature is harnessed by people and used as an infrastructural system it is called "green infrastructure" [3]. This concept highlights the importance of the natural environment in urban planning and stormwater management. A sustainable and multifunctional urban environment that does not pollute its valuable waterways can be achieved through efficient use of green infrastructure.

TYPES OF GREEN INFRASTRUCTURE

GREEN ROOFS

Green infrastructure is most commonly associated with buildings, or the engineered roofing systems that are built on top of them. There are two types of engineered roofing systems that affect the hydrology of a building site: green roofs and blue roofs. Green roofs contain vegetation that increase infiltration on the roof and reduce total runoff volume. Blue roofs have no vegetation but detain water and release it gradually to mimic a natural flow curve.

Green roof systems come in the following three major types: vegetated mat systems, built-in-place systems, and modular tray systems, as shown in Figure 1 (obtained from the NYC Green Roof Study) [4]. The Department of Civil Engineering and Mechanics at Columbia University in New York conducted a study to evaluate the effectiveness of these three different types of green roofs. In their study, each type was installed on a different commercial or residential building, and its effectiveness was recorded with the use of instrumentation and observation. Using precipitation records from 1971 to 2010 for Central Park, the model estimated total rainfall retention to be 45%, 53%, and 58% for the vegetated mat, built-in-place, and modular tray green roofs respectively [4]. The modular tray system yielded the highest percentage for rainfall retention.

Among the three major types, the vegetated mat systems are the most common form of green roofs. A vegetated mat consists of a layer of plant material rooted into a layer of soil and mesh and underlain by a protective barrier between the roof and mat. The mat is delivered to the site with the plant material already rooted and growing, so the system is immediately effective. For example, the system used in Columbia University’s study included a 32mm-thick pre-planted substrate mat underlain by two 6mm thick water retention fleeces made of synthetic fibers, a 19mm non-woven polymer drainage mat, and a 0.5mm synthetic root barrier. The NYC Green Roof study conducted by Columbia University found that vegetated mat systems performed rather well in small storms, with a retention rate of 85% for storm sizes under 10 mm or approximately half an inch of total rainfall [4].

Modular tray systems are constructed by placing rows of lightweight metal or synthetic trays on the roof, then placing pre-planted rectangular mats within the trays. Due to the use of pre-planted mats, they also are immediately effective. The NYC Green Roof study found that modular tray systems performed better than the other two types in large storms. The modular tray system reached a retention rate of approximately 52% for storm sizes over 30 mm, compared to a retention rate of 30% for both the vegetated mat system and the built-in-place system in large storms [4].

Built-in-place systems are green roofs that are constructed new on-site. They consist of a barrier or tray between the soil medium and roof, where sedum is planted within the medium and are generally specified to reach 80 to 90% coverage within 2 years. The built-in-place systems are generally thicker and more robust than both vegetated mats and modular tray systems. Furthermore, compared to the other 2 systems, it is more critical to properly consider the structural loads of the building. Built-in-place systems showed the best performance in small storms among all three systems analyzed in the Columbia University study. The built-in-place system had a retention rate of 93% for storm sizes under 10 mm, compared to a retention rate of 83% for the vegetated mat system and a rate of 68% for the modular tray system [4].

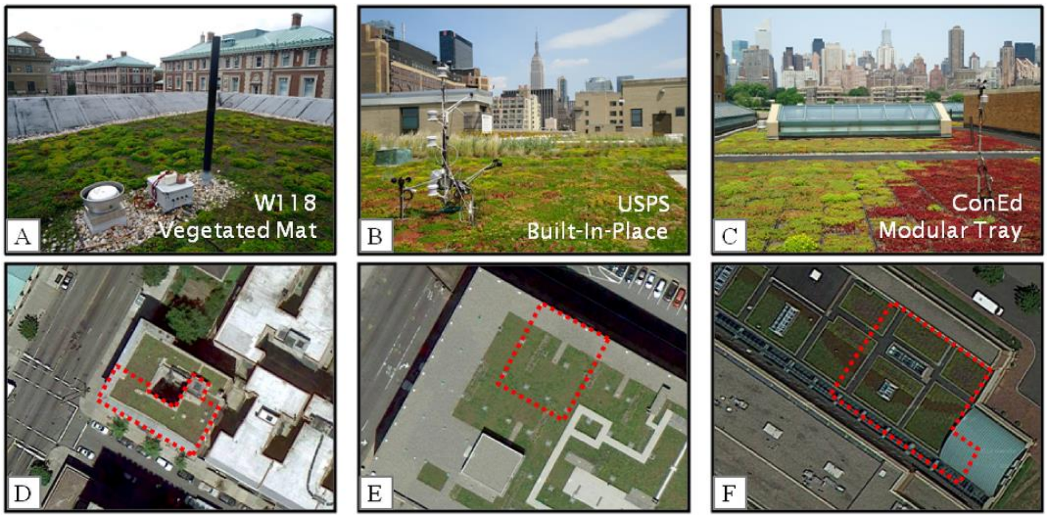


Figure 1*: (a)–(c) Rooftop view of the W118, USPS, and ConEd green roofs, respectively. (d)–(f) Aerial view of the W118, USPS, and ConEd green roofs, respectively (scale: 1 cm = 20 m). The monitored drainage area for each roof is indicated by the dotted line. Panels (d) and (f) c Bluesky, DigitalGlobe, Sanborn, USDA Farm Service Agency, Map data c 2013 Google. Panel (e) c Bluesky, DigitalGlobe, Sanborn, Map data c 2013 Google, Sanborn. [4]*

BIORETENTION AREAS

Bioretention is another type of green infrastructure. The goal of bioretention is to create an area that will intercept storm runoff and infiltrate a required amount of water per storm event. Some examples of bioretention include bioswales, green streets, rain gardens, constructed wetlands, or even simple solutions such as trees and vegetation. This type of green infrastructure is generally constructed to achieve zero outflow for a certain design precipitation amount. For example, a rain garden could be designed to intercept 1 inch of rainfall and have 100 percent infiltration. This design would create zero outflow for any 1-inch event over the catchment area serviced by the bioretention facility.

Bioswales (also known as vegetated swales) are a type of bioretention installation that include planted areas and engineered soils that collect, slow down, infiltrate, and filtrate runoff [5]. The vegetation used in these areas are specifically designated to match the native vegetation of the area, and have been tested to have properties beneficial to high levels of infiltration. The vegetation is planted in engineered soils to increase the time of concentration and to allow for more infiltration [5]. Bioswales are placed in locations that can collect the surface runoff from gutters and curbs and are generally more prevalent in commercial applications. Any additional runoff that is unable to be infiltrated passes the bioswale and enters the storm sewer system [5]. Figure 2 shows an example of a typical roadside bioswale.

Green streets utilize green stormwater infrastructure similarly to bioswales, but in a different location. Green streets refer specifically to roads which have bioretention areas on the curb or in the median of a roadway to intercept flow along curb gutters. These areas are sometimes called berm swales.

Figure 2: An example of a roadside bioswale [6].

Rain gardens are similar to bioswales, but smaller and more commonly used in residential applications. For this reason, they can be installed and maintained by landscapers and homeowners without high levels of assistance or guidance. Rain gardens are placed depression areas that collect runoff from a small property. The native soil can be used unless it is unsuitable for infiltration [4]. They are designed for use during both heavy rainfall and drought, allowing the vegetation to thrive even with little rainfall.

Another simple type of green infrastructure is efficient use of trees and vegetation. Plants naturally increase infiltration by their need for rainwater for growth and nourishment. Trees and vegetation are particularly easy to implement due to the low cost and fast implementation.

Table 1 summarizes the performance that can be expected from a typical bioretention facility using the reduction percentage in outflow. The reduction percentage is obtained from a collection of 20 different installations [7].

Table 1: Percent reduction of outflow achieved by bioretention facilities during storm events of precipitation ≤ 1 inch [7].

# of Studies	25th Percentile	Median	75th Percentile	Average
20	42%	66%	98%	66%

PERMEABLE PAVEMENT

Permeable pavement is another excellent form of green infrastructure. Permeable pavement is perfect for driveways or other paved areas that do not require a high strength surface and do not have high traffic volume. The goal of permeable pavement is to infiltrate water that comes in contact with the pavement, instead of conveying the water to another location. Since there is typically no way for the water to flow completely across a permeable pavement, the performance of permeable pavement is generally measured using the infiltration rate rather than percent infiltration. Some examples of permeable pavement include porous concrete or asphalt and permeable pavers such as brick or stone. Figure 3 shows an example of permeable concrete pavement.

***Figure 3**: An example of a permeable pavement installation [6]*

DETENTION

In situations where above-ground infrastructure is not possible, a subsurface detention system can be an alternative. These systems are underground installations that typically consist of perforated pipe above a gravel bed [6]. If a large volume of detention is desired, a storage tank can be included that will detain water until it is able to fully infiltrate into the gravel bed. Other methods of rainwater detention include the use of cisterns and rain barrels. These are watertight containers that catch and store stormwater runoff from roofs or other impervious surfaces [6]. Cisterns are the larger of the two and are usually placed underground. As the result, the cisterns are used more often in commercial or industrial applications. Rain barrels are smaller than cisterns and are used more commonly on smaller commercial properties or for residential use. Rain barrels are connected to the downspout of a roof and used for watering or landscaping. Figure 4 below shows an example of a rain barrel with a hose connection at a release valve.

***Figure 4**: A rain barrel with a gardening hose connection [6]*

Some roofing systems aim to detain and release stormwater gradually over time instead of infiltrating runoff. This type of roof system is known as a blue roof. Blue roofs do not consist of layers of vegetation and soil, but they are constructed through the use of a collection system and a storage area. These systems collect rainwater during a storm event and release water as runoff after the storm has passed. There is no infiltration taking place in these systems, so the percent reduction of outflow is 0%. The goal of this type of system is to flatten the outflow hydrograph of a storm by reducing the peak flows entering the storm sewer. Although blue roofs do not increase infiltration in a catchment area, they are still highly beneficial to the hydrology of a watershed as a whole. Figure 5 shows an example of a blue roof installation.

***Figure 5**: A modular blue roof installation [6]*

PERFORMANCE OF GREEN INFRASTRUCTURE

Each installation of green infrastructure is designed differently and thus has different performance curves and values. Most green infrastructure is designed to infiltrate a specified percentage of rainfall for a certain design storm. There have been several studies that can be found in educational, industrial, and federal sources on the performance of the types of green infrastructure. The US EPA has created a website with links to the most useful conglomerations of data that provide various information on the benefits to reduce runoff volume and to improve water quality with the implementation of green infrastructure [8]. Due to the nature of this report, only volume reduction data was used.

Table 2 shows volume reduction measurements for different types of green infrastructure, including Conventional Treatments and Low Impact Development. The average annual peak flow reductions reported in this table are based on specific installations with controlled variables. As such, higher percent reductions could be achieved.

***Table 2**: Performance of Various Stormwater Management Practices [9]*

Stormwater Management Practice	*Average Annual Peak Flow Reduction (%)*
Retention Pond	86%
Detention Pond	93%
Stone (rip-rap) Swale	6%
Vegetated Swale	52%
Berm Swale	16%
Surface Sand Filter	69%
Bioretention - 48" depth	75%
Bioretention - 30" Depth	79%
Bioretention - 30" Depth	84%
Bioretention - 37" Depth	95%
Subsurface Gravel Wetlands	92%
Porous Asphalt	82%
Pervious Concrete	93%
Permeable Concrete Pavement	99%
Tree Filter	31%

Table 3 reports similar results from a study done by the Illinois EPA. [10] The following reductions of peak flow and runoff volume were taken from a multitude of green infrastructure installments. This table gives a better representation of the expected performance of green infrastructure.

***Table 3**: Percent Reduction in Peak Flow and Runoff Volume for different types of green infrastructure*

Green Infrastructure Type	*Peak Flow*	*Runoff Volume*
Permeable Pavement	70%	65%
Infiltration/ Bioretention	50%	85%
Green Roofs	65%	60%

PRACTICAL IMPLEMENTATION OF GREEN INFRASTRUCTURE

Green infrastructure offers many benefits to a wide variety of projects and applications. These benefits can open doors to a variety of diverse funding sources. The EPA website can be useful in discovering many different funding opportunities for green infrastructure projects [11].

Four proven ways to reduce the cost of green infrastructure projects are to (1) integrate with planned projects, (2) seek economies of scale, (3) use incentive programs, and (4) consider maintenance in new ways [12]. Some of the most cost-effective green infrastructure projects are those that are organized into repeatable programs that have similar contracting and implementation mechanisms. Considering economy-of-scale and increasing the amount of impervious area managed is another way to reduce construction cost per unit area. Incentive programs encourage private sector participation and can often eliminate maintenance costs while achieving stormwater goals more quickly.

The first step in implementing green infrastructure is to be able to design and model the benefits of green infrastructure installments. The scope of this study does not include the modeling of water quality benefits of green infrastructure and focuses completely on the reduction of stormwater runoff due to green infrastructure. The following analysis outlines the process of applying a curve number adjustment to a watershed based on a percentage implementation of green infrastructure.

METHODS OF ANALYSIS

WATERSHED DESCRIPTION

The Little Cuyahoga River is a 17.4-mile long tributary to the Cuyahoga River [2]. It is located in southeast Summit County and southwest Portage County. Its watershed is 61.7 square miles covering portions of the City of Akron, City of Tallmadge, Springfield Township, Village of Lakemore, Village of Mogadore, Brimfield Township, Suffield Township, and Randolph Township. There are six primary tributaries for Little Cuyahoga River: Ohio Erie Canal, Camp Brook, Springfield Lake Outlet, Roosevelt Ditch, Union Oil Tributary, and Wingfoot Lake Outlet.

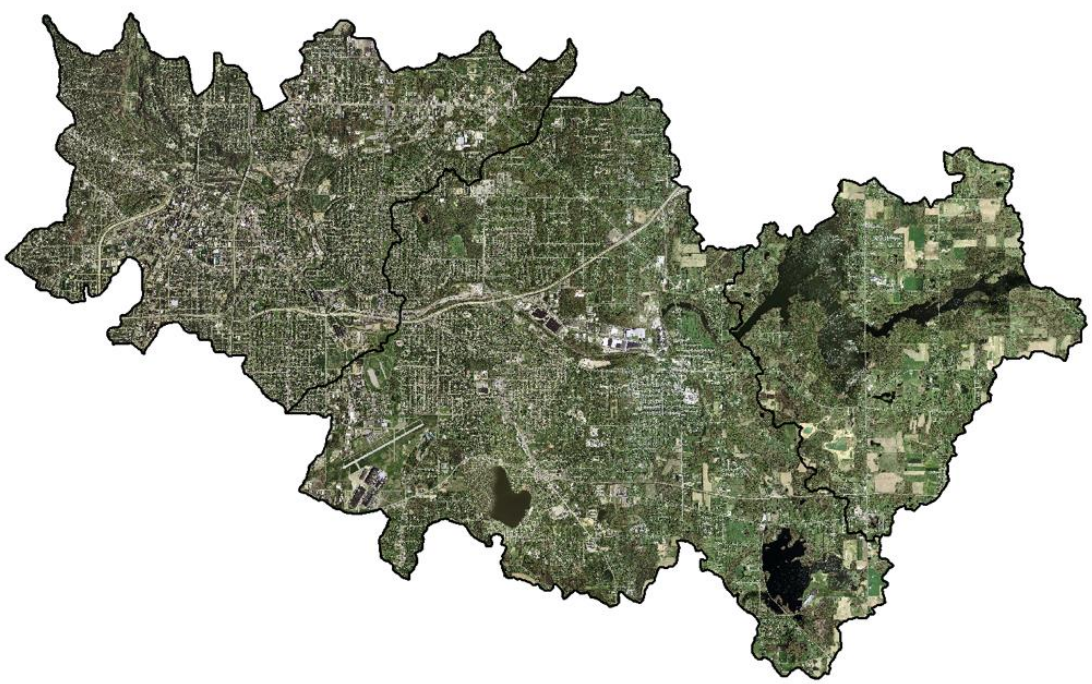


Figure 6: *Aerial View of Little Cuyahoga Watershed*

The Little Cuyahoga watershed may be delineated into 3 main sub-watersheds representing the most upstream reach, the middle reach, and the most downstream reach. The sub-watershed for the most downstream reach was chosen for analysis. The UGCI identifier for this sub-watershed is HUC041100020304. This sub-watershed was chosen because it contains the outlet of the Little Cuyahoga River, its confluence point with the Cuyahoga River, which is the point of interest for this analysis.

The study area was further delineated into 5 sub-watersheds, based on river reaches and tributaries. These sub-watersheds, named as W200, W210, W220, W221, and W222, were applied for watershed modeling and analysis. Each sub-watershed is discussed in detail below.

W222 is the most upstream sub-watershed chosen for analysis. This sub-watershed contains a portion of the Little Cuyahoga River, and covers East Akron, Middlebury, Ellet, and the southern part of Goodyear Heights. The area of W222 is 4.53 square miles.

W221 is the portion of the watershed that drains into Camp Brook, which is a tributary of the Little Cuyahoga River. W221 has an area of 5.58 square miles covering a portion of Tallmadge, including Tallmadge Circle, as well as portions of the Goodyear Heights and Chapel Hill neighborhoods of Akron.

W220 is the central sub-watershed. It contains a portion of the Little Cuyahoga River, Elizabeth Park Valley, and part of North Hill. The area of this sub-watershed is 2.34 square miles.

W210 contains the Ohio Erie Canal and its watershed. W210 has an area of 4.15 square miles, covering Summit Lake, as well as most of downtown Akron and West Akron.

W200 is the most downstream sub-watershed for the analysis. W200 has an area of 2.33 square miles, covering Highland Square, Wallhaven, Northwest Akron, and some of Merriman Valley.

Figures 7 and 8 below show the Little Cuyahoga Watershed Land Use categories and quantities. As shown in Figure 7, the Little Cuyahoga Watershed is heavily developed with the two most predominant land use categories of Developed, Medium Intensity and Developed, High Intensity.

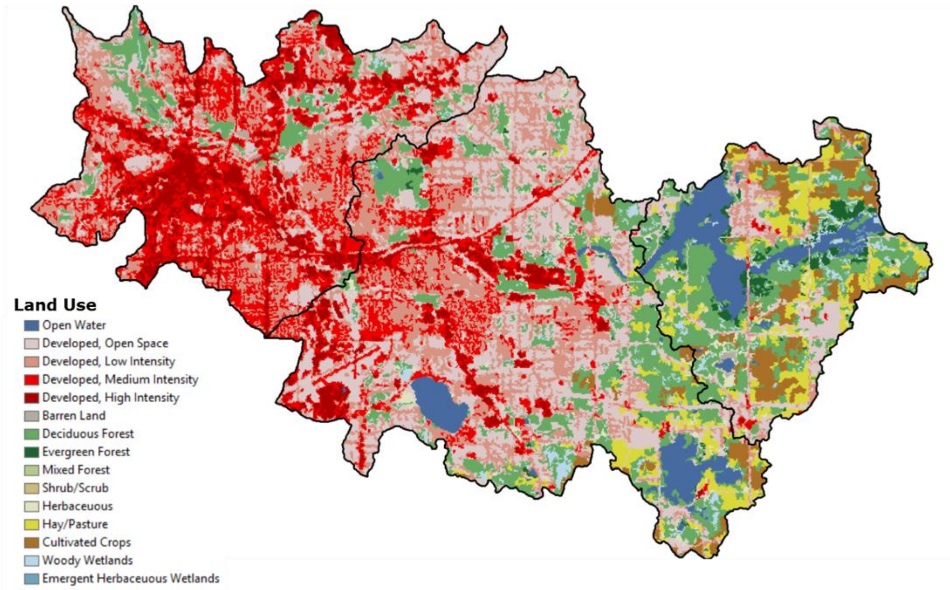


Figure 7: *Little Cuyahoga Watershed- Land Use*

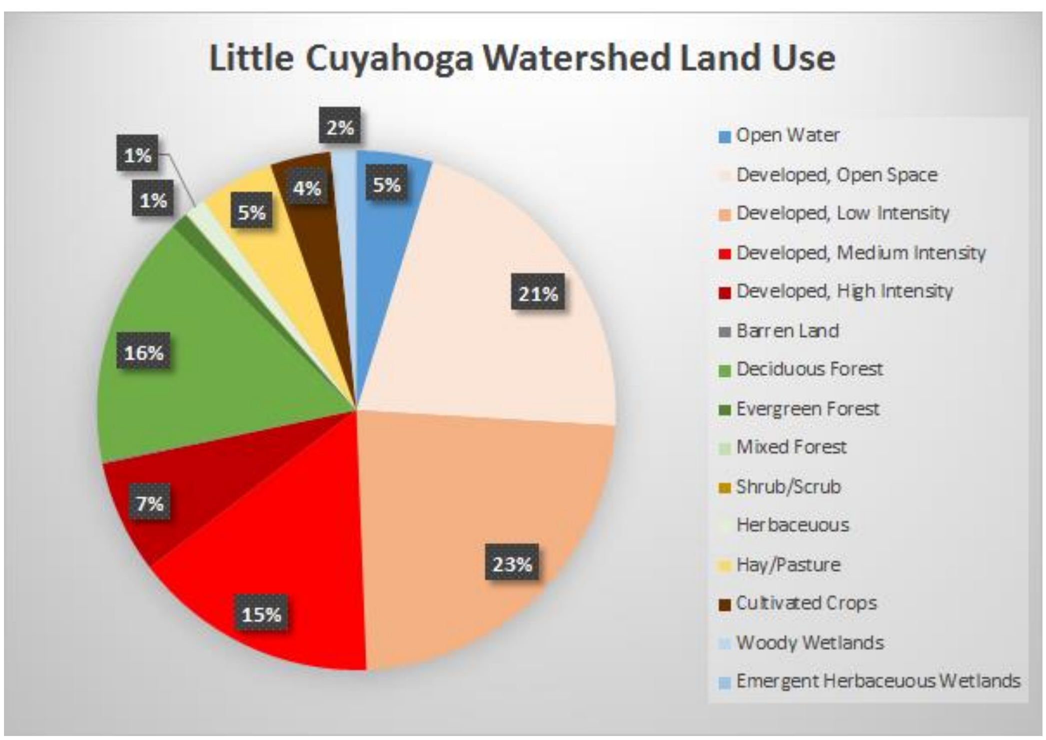


Figure 8: *Little Cuyahoga Watershed- Land Use Pie Chart*

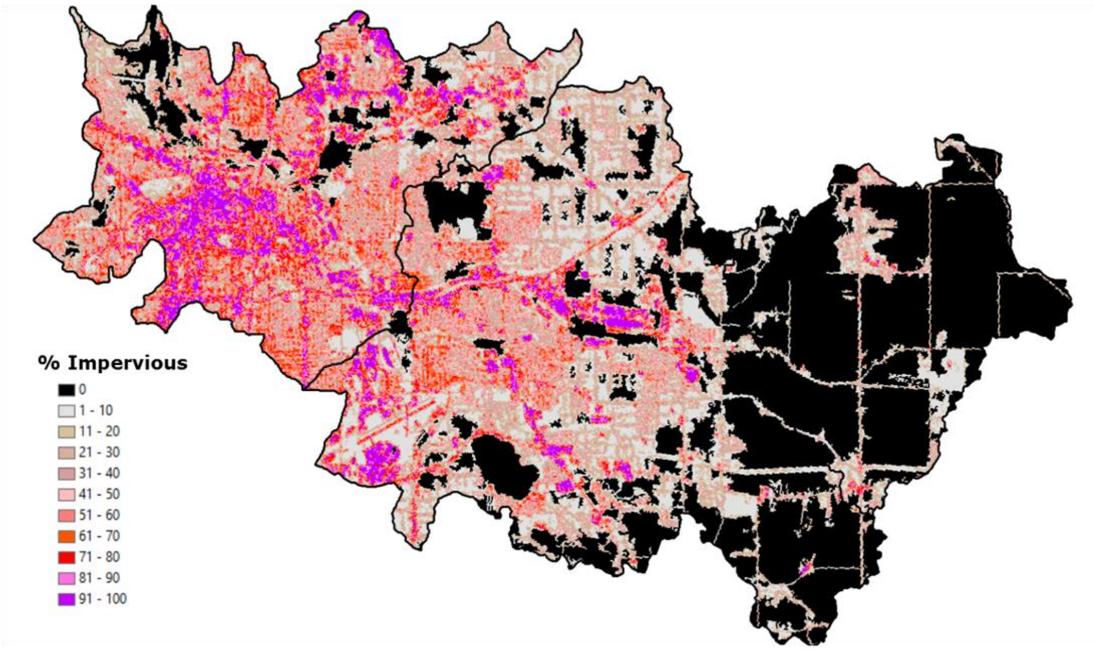


Figure 9: *Little Cuyahoga Watershed- Percent Impervious*

Figure 9 shows the perviousness and imperviousness of the Little Cuyahoga Watershed. Figures 7-9 clearly indicate that the largest area of concern in the watershed is Downtown Akron. The land use of downtown Akron is classified as Developed, High Intensity. Furthermore, the area has the highest concentration of imperviousness. There are few wetland areas around downtown, and no riparian setback along the river. Riparian areas are naturally vegetated land along rivers and streams that are used to trap pollutants as well as reduce erosion. All of these factors contribute to very slow infiltration rates, causing significant stormwater runoff during storm events.

WATERSHED MODELING

In order to analyze the effects of green infrastructure on hydrology in Akron, OH, a watershed model was constructed for the study area, which includes the portion of the Little Cuyahoga Watershed just downstream of USGS Station No. 04204500, Little Cuyahoga River at Massillon Road in Akron, Ohio. This stream gage was used to define outflow from the portion of the Little Cuyahoga watershed upstream of the study area, which serves as the inflow source. An overview of the study area including the delineated subbasins and aerial imagery is shown below in Figure 10. The aerial imagery was obtained from the Ohio Geographically Referenced Information Program's (OGRIP) OSIP I [13]. This model was used as the existing-condition hydrological model with 0% implementation of green infrastructure.

The software packages required for the model construction include ArcMap 2.2.0 and its extension toolboxes of ArcHydro, Hec-GeoHMS, and HEC-HMS. ArcMap 2.2.0, ArcHydro, and Hec-GeoHMS were applied to develop the necessary geospatially-referenced dataset and maps for the study area. HEC-HMS was applied for watershed analysis. The data required to successfully perform the watershed analysis includes:(i) basin characteristics that can be processed within ArcMap (e.g., soil survey information, time of concentration, Land-use and Land Cover, percent imperviousness, and stream networks); (ii) available precipitation and discharge gauging information (e.g., observed storm event or design storm and inflow/outflow data); and (iii) storage area information if existing. A flow chart of this process is included in **Appendix A**, attached to this report. The detailed information is provided in what follows.

The first part of the process involved identifying the project area and obtaining flowlines from National Hydrography Dataset (NHD). The Northeast Ohio Four County Regional Planning and Development Organization (NEFCO) provided a personal geodatabase with NHD data, land cover raster datasets, and watershed boundary shapefiles [14]. Before further processing, all components of the geodatabase were confirmed or re-projected to the

Projected Coordinate System, i.e., Ohio North StatePlane (US survey feet). This projected coordinate system was carried throughout the analysis for consistency. The NHD data and watershed shapefiles were used to identify the study area for the Little Cuyahoga Watershed. The re-projected NHD flowlines were imported into the basemap and clipped to the study area, which would later be used as an AGREE stream polyline in the HEC-GeoHMS preprocessing. The Summit County Mosaic ESRI GRID DEM was downloaded from the OSIP I database on the website [13]. The surface raster and DEM were also imported into the ArcMap basemap and clipped to the boundary of the watershed. The default cell size of 2.5m x 2.5m was used to ensure the file sizes were small enough to work with.

***Figure 10**: The delineated subbasins within the study area with an Aerial imagery overlay obtained from the OGRIP website.*

The second part of the process involved the use of the HEC-GeoHMS extension within ArcMap. The AGREE stream was burned into the DEM using the DEM Reconditioning tool. DEM reconditioning has two main purposes. First, it makes deep elevation cuts into the surface raster to tell the program where to accumulate water. Second, it prevents the program from considering other channel-like depressions like highways or railroads as river systems. After DEM reconditioning, the "fill sinks" process was used to ensure that water would never pool and always flow in some direction when conducting the analysis. Then, a flow direction grid was created. The flow direction grid tells which direction a drop of water will flow when it hits any given point on the reconditioned surface raster. The flow direction grid was the input for the flow accumulation process to determine quantity of water that may accumulate within the AGREE streams burned into the DEM. The stream may be defined with the use of the stream definition tool after processing the flow accumulation layer. The stream definition tool defines a stream based on the drainage area that has accumulated in the flow accumulation grid. The streams output by the stream definition process were inspected visually to see how they matched to the NHD flowlines imported previously. The drainage area threshold was increased until the stream definition closely matched the NHD flowlines. After the stream definition was calibrated, the stream link tool was used to depict downstream connections within the stream network.

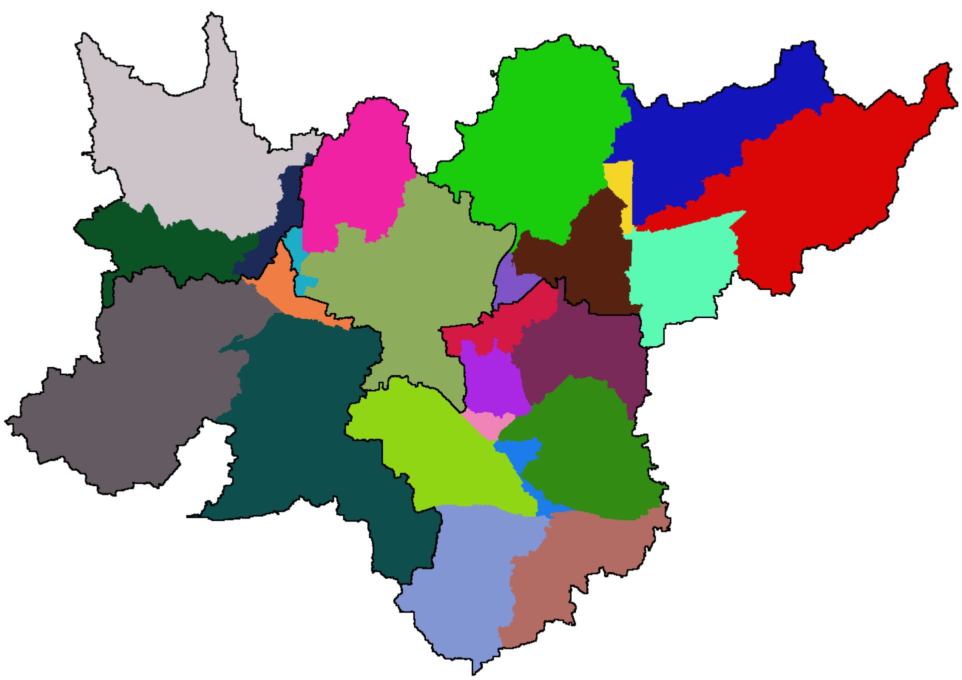


***Figure 11**: The delineated catchments within the study area. A solid black boundary line represents the major subbasins used in analysis.*

The stream definition grid is used to create a catchment grid, which shows the size and location of each major subbasin in relation to the stream definitions. Figure 11 depicts the catchment grid created for the study area within the Little Cuyahoga Watershed. The drainage line tool was used to get a simple polyline of the delineated streams, and the catchment polygon tool was used to get simple polygons of each major subbasin. To complete the terrain preprocessing, the adjoint catchment tool was used to combine the major subbasins into a single watershed. After the completion of terrain preprocessing, basin processing was commenced. This process completed the preliminary data processing for the watershed delineation in ArcMap. In order to move forward with HEC-HMS modeling, a HEC-HMS project was generated using the HEC-GeoHMS software package.

With the use of HEC-GeoHMS, the required characteristics were added to the river, basin, and HEC-HMS model. The "basin merge" command in the basin processing toolbox was used to merge the subbasins that should have been included as one larger subbasin. The basin characteristics tool was used to assign river length, river slope, basin slope, longest flow path, basin centroid, centroid elevation, and centroidal longest flow path to the river and subbasin shapefiles. These parameters were used to calculate TR55 time of concentrations as well as to assign geographical information to each subbasin. The SCS loss method, SCS transform method, recession baseflow method, and Muskingum-Cunge river routing method were then designated by selecting “HMS processes” in the hydrologic parameters toolbox. The TR55 flow path segments, TR55 flow segment parameters, and TR55 Export to Excel tools were used to automatically create a TR55 analysis spreadsheet in Excel based on the previously analyzed longest flow paths and river slopes. This spreadsheet was used later to calculate the time of concentration for each major subbasin. The TR 55 spreadsheet calculations are included in **Appendix B**.

Several major components from the ArcMap model include a curve number grid, percent imperviousness grid, and land use grid. The curve number grid was created using the United States Department of Agriculture Natural Resources Conservation Service (USDA NRCS) Soil Data Viewer extension in

ArcMap. A soil survey database was downloaded for Summit County from the United States Geological Survey Soil Survey Geographic Database (USGS SSURGO) website [15]. This database includes a multitude of soil parameters for each type of soil within Summit County, both in spatial and tabular format. The Soil Data Viewer extension is able to incorporate the soil information into the project area. In addition, hydrologic soil group and soil survey polygon layers were added to the basemap to depict the different types of soils and their corresponding hydrologic soil groups on the map.

The 2011 Summit County land use raster and 2011 Summit County percent impervious raster were downloaded from the USGS land cover website and added to ArcMap [16]. The land use raster was then clipped to the delineated watershed and classified to show land types and the area of each land type present in the watershed. In order to create a curve number grid, the land use raster was converted to a polygon and then merged with the soil survey polygon using "Union" in the ArcMap spatial analyst tool. Additional data fields were added to the curve number union polygon to allow the program to be able to calculate the curve number automatically. Finally, the "generate CN grid" tool was used to compute the weighted curve numbers of each major subbasin. The program generated a raster dataset of curve number (CN) based on the output from the aforementioned tool, which can be seen in Figure 12. To apply the curve numbers and percent imperviousness to each subbasin, the "assign subbasin parameters from raster" tool was used in the hydrologic parameters menu to compute the values for each major subbasin. Table 4 summarizes CN and percent imperviousness for each major subbasin.

Table 4: A summary of basin CN and % Imperviousness for each subbasin

Subbasin	*% Imperviousness*	*Weighted CN*
W200	27.50	79.67
W210	55.95	86.4
W220	49.87	85.9
W221	36.04	80.6
W222	50.72	85.6

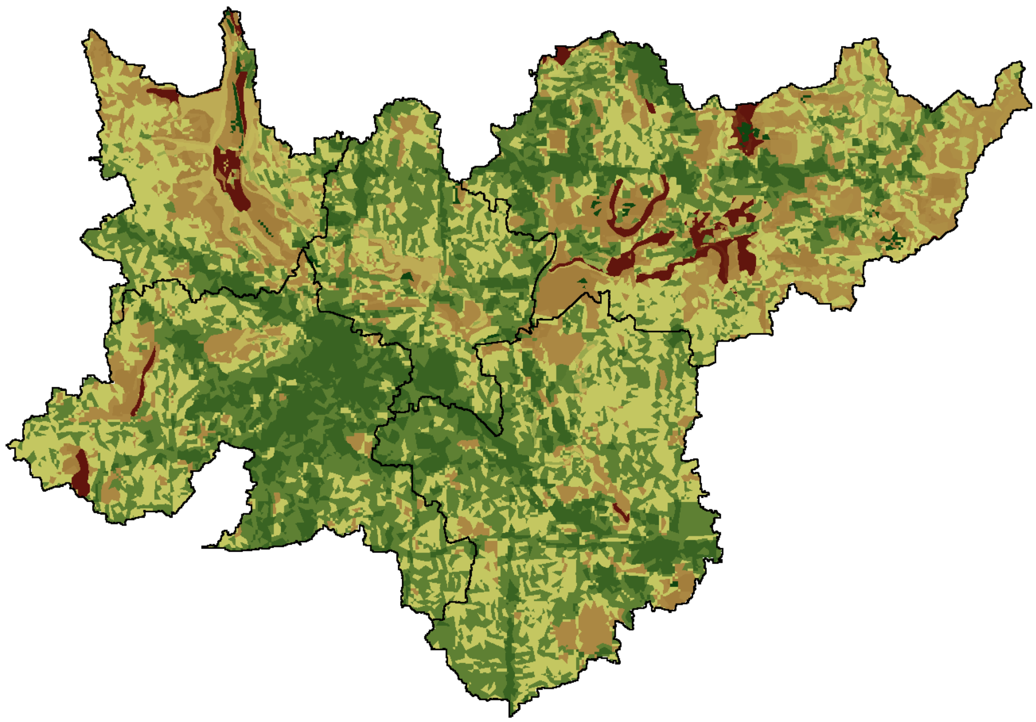


Figure 12*: The CN grid overlay for the study area. A darker green color represents a higher curve number.*

Finally, the basemap was converted to HMS units using the "HMS" menu in the HEC-GeoHMS toolbar. In this step, the HMS schematic and the data prepared in ArcMap was exported to HEC-HMS. Additionally, background map files were created for the river and subbasin for visual clarity in the HEC-HMS model. At this point, all the required pre-processing in ArcMap had been completed and the basin model was ready to be imported into a HEC-HMS model for hydrological analysis.

ANALYSIS

HEC-HMS v.4.0 was applied for the hydrological analysis for this study. The basin model was imported into HEC-HMS from ArcMap. All parameters were checked to ensure that all the data was exported correctly from ArcMap. Figure 13 shows an overview of the HEC-HMS model for the study area. Given the limitation of the pre-processing, the following parameters were input manually: centroid, latitude and longitude, areas, curve numbers, and percent impervious values for each subbasin. These values were taken directly from the ArcMap model described above.

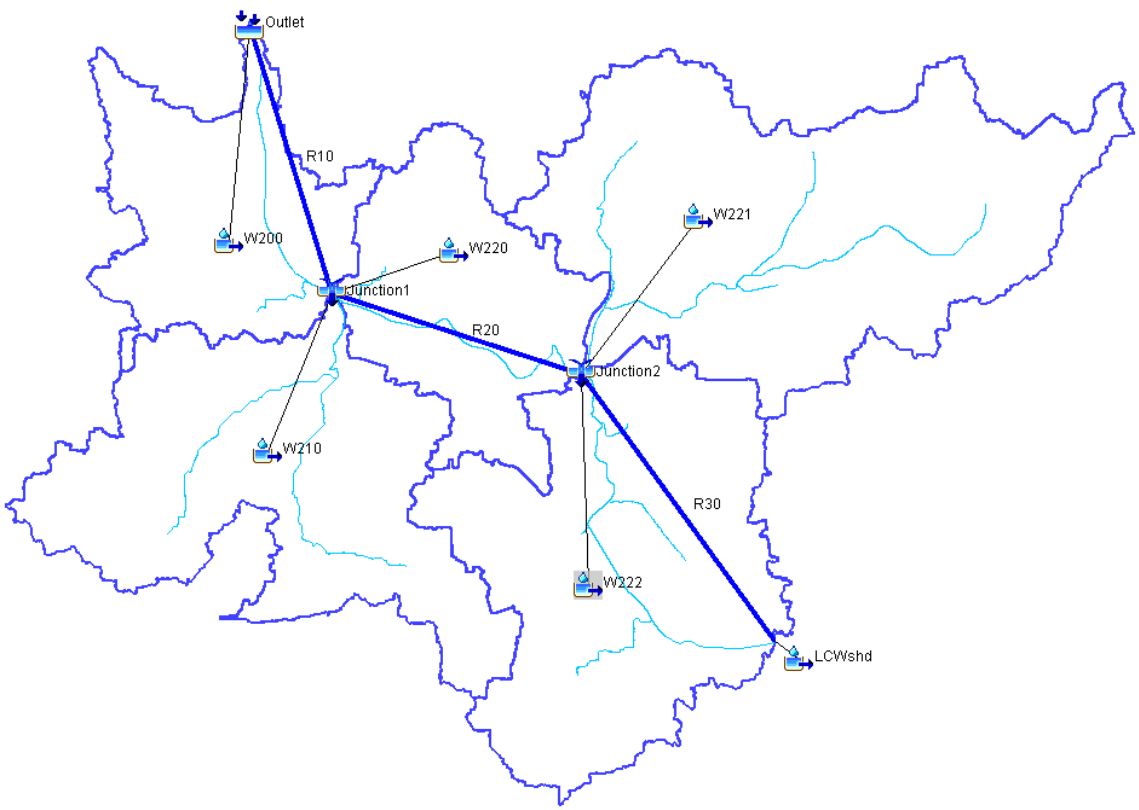


***Figure 13**: The HEC-HMS Basin Model for the study area.*

For each subbasin in HEC-HMS, the lag time was entered based on the TR55 Time of Concentration Excel spreadsheet. In order to compute the lag times using TR55, several assumptions were made. One assumption was that the sheet flow occurred in short grass pasture, using a Manning's *n* value of 0.025 [17]. Type II, 2-year, 24-hr rainfall depth of 2.44 inches was obtained from the NOAA Precipitation Frequency Data Server (PFDS) for the

Akron/Canton area [18]. This NOAA PFDS data is provided in **Appendix C**. The shallow concentrated flow was determined to occur within unpaved areas for each subbasin. FEMA FIS Report Volumes 1 thru 3 for Summit County, Ohio were used to assign river channel characteristics, including cross sectional area, channel width, and manning's roughness coefficient to each subbasin for time of concentration analysis [19]. The wetted perimeter was calculated from these values.

The baseflow parameter for each subbasin in the HEC-HMS basin model was determined using StreamStats ungaged site flow statistics reports in combination with gaged site flow at nearby available discharge gages [20]. The average annual flow (QA) statistic from StreamStats was used as baseflow for each subbasin with a recession constant of 1 and a threshold discharge equal to the baseflow. **Appendix D** contains all the stream gage and StreamStats data used to establish baseflow for each subbasin. Finally, the Muskingum-Cunge method was adopted for flow routing in the river channels. The corresponding routing parameters for each river were used per the TR55 spreadsheet. Length and slope were determined from ArcMap shape files.

For simulation purposes, the 2-year, 2-hour storm was applied as the baseline storm. The rainfall depth of 1.40 inches was obtained from the NOAA PFDS table for the Akron/Canton area for this 2-year, 2-hour Type II storm event. The simulation was run for 48 hours to allow the water to be fully routed through the watershed for the existing condition. Additional simulations were also performed for Type II 10-year and 25-year 2-hour storm events. This completed watershed analysis for the existing conditions.

To evaluate change of the hydrological response to the green infrastructure, five basin models were constructed in which each model represents a different level of green infrastructure implementation. Since the focus of this project is the urban areas of Akron, implementation was only considered in Developed, Medium Intensity and Developed, High Intensity land use areas. These five basin models were constructed to to reflect the estimated impact of 5% implementation, 10% implementation, 20% implementation, 50%

implementation, and 100% implementation of green infrastructure. These percentages represent the portion of medium- to high-intensity area to be modeled as green infrastructure, based on a weighted green infrastructure curve number.

To model the implementation of green infrastructure, two parameters were adjusted for each subbasin in each basin model: curve number and percent imperviousness. First, the detailed hydrological soil groups (A, B, C, or D) were obtained from the soil survey database from USGS SSURGO. These values were reported by percentage for each subbasin. Table 5 lists the curve number for different green infrastructure and different hydrological groups. Using the curve numbers listed in Table 5, a weighted curve number was then computed for green infrastructure implementation areas in each subbasin.

Once weighted curve numbers were calculated for all land use categories, including green infrastructure implementation, they were used to determine the overall weighted curve number for the subbasin. This process was repeated for each of the five basin models to represent different levels of green infrastructure implementation.

***Table 5**: Curve Number Table for various types of Green Infrastructure based on Hydrologic Soil Group [21]*

	Hydrologic Soil Group			
Land Cover	**A**	**B**	**C**	**D**
Green Roof	75	75	75	75
Rain Garden	35	51	63	70
Native Vegetation	35	51	63	70
Vegetated Filter Strips	39	61	74	80
Vegetated Swale	35	51	63	70
Trees	32	58	72	79

Adjusted parameters for each subbasin are shown in Table 6 thru Table 10.

For the project condition (i.e., percent implementation of green infrastructure), the three simulation discussed above were run for each adjusted basin model. The results included hydrographs for each subbasin and river reach based on 2-year, 10-year and 25-year 2-hour storm events. Results from these simulations include hydrographs and peak flow values for each event analyzed.

***Table 6**: Basin Model Adjustment Summary Tables: W200*

W200					
% Implementation	Original CN	New CN	% Reduction	Original % Impervious	New % Impervious
100%	79.67	74.42	7.1%	27.5%	25.6%
50%	79.67	76.81	3.7%	27.5%	26.5%
20%	79.67	78.24	1.8%	27.5%	27.0%
10%	79.67	78.72	1.2%	27.5%	27.2%
5%	79.67	79.63	0.1%	27.5%	27.5%

***Table 7**: Basin Model Adjustment Summary Tables: W210*

W210					
% Implementation	Original CN	New CN	% Reduction	Original % Impervious	New % Impervious
100%	86.4	71.97	20.1%	56.0%	44.7%
50%	86.4	79.16	9.1%	56.0%	50.8%
20%	86.4	83.48	3.5%	56.0%	54.0%
10%	86.4	84.91	1.8%	56.0%	55.0%
5%	86.4	85.63	0.9%	56.0%	55.4%

***Table 8**: Basin Model Adjustment Summary Tables: W220*

W220					
% Implementation	Original CN	New CN	% Reduction	Original % Impervious	New % Impervious
100%	85.9	73.51	16.9%	49.9%	41.5%
50%	85.9	79.66	7.8%	49.9%	46.0%
20%	85.9	83.36	3.0%	49.9%	48.4%
10%	85.9	84.6	1.5%	49.9%	49.1%
5%	85.9	85.21	0.8%	49.9%	49.5%

***Table 9**: Basin Model Adjustment Summary Tables: W221*

W221					
% Implementation	Original CN	New CN	% Reduction	Original % Impervious	New % Impervious
100%	80.6	72.6	11.0%	36.0%	32.1%
50%	80.6	76.4	5.5%	36.0%	34.1%
20%	80.6	78.8	2.3%	36.0%	35.2%
10%	80.6	79.5	1.4%	36.0%	35.5%
5%	80.6	79.9	0.9%	36.0%	35.7%

***Table 10**: Basin Model Adjustment Summary Tables: W222*

W222					
% Implementation	Original CN	New CN	% Reduction	Original % Impervious	New % Impervious
100%	86.4	73.56	17.5%	50.7%	41.9%
50%	86.4	79.6	8.5%	50.7%	46.4%
20%	86.4	83.22	3.8%	50.7%	48.8%
10%	86.4	84.43	2.3%	50.7%	49.5%
5%	86.4	85.04	1.6%	50.7%	49.9%

Complete data sheets for the proposed curve number adjustment are included in **Appendix E**.

RESULTS AND CONCLUSIONS

The focus of this watershed analysis was the reduction of peak discharge at the outlet of the study area. The reduction in peak discharge was calculated by analyzing how implementation of green infrastructure can lower the curve number for each subbasin. Adjusted curve numbers and the percent reduction for each curve number are shown in Tables 11 and 12, respectively.

***Table 11**: Adjusted Curve Numbers for each subbasin based on level of green infrastructure implementation*

	Subbasin				
% Implementation	**W200**	**W210**	**W220**	**W221**	**W222**
100%	74.42	71.97	73.51	72.6	73.56
50%	76.81	79.16	79.66	76.4	79.6
20%	78.24	83.48	83.36	78.8	83.22
10%	78.72	84.91	84.6	79.5	84.43
5%	79.63	85.63	85.21	79.9	85.04
Existing	79.67	86.40	85.9	80.6	86.40

***Table 12**: Percent reduction in curve number for each subbasin based on level of green infrastructure implementation*

	Subbasin				
% Implementation	**W200**	**W210**	**W220**	**W221**	**W222**
100%	7%	20%	17%	11%	17%
50%	4%	9%	8%	5%	9%
20%	2%	3%	3%	2%	4%
10%	1%	2%	2%	1%	2%
5%	0%	1%	1%	1%	2%

These adjusted parameters were incorporated into HEC-HMS basin models for each level of green infrastructure implementation as the project conditions. Comparing the model simulation results for existing conditions with those for project conditions, Tables 13-14 show that the higher levels of green infrastructure implementation yield higher reductions of peak discharge at the outlet.

***Table 13**: Outlet Peak Discharges in cfs for different storm events in each basin model*

Storm → / % Imp. ↓	2 year, 2 hour	10 year, 2 hour	25 year, 2 hour
100%	1556.3	2577.6	3362.3
50%	1798.7	3021.6	3921
20%	1971.6	3313.2	4265.2
10%	2030.3	3402.2	4371.9
5%	2066.5	3461	4439
EXISTING	2107.7	3524.9	4512.6

All results for subbasins within each basin model are included in **Appendix F**.

__Table 14__: Percent Reduction in outlet peak discharges for different storm events in each basin model

Storm → / **% Imp. ↓**	**2 year, 2 hour**	**10 year, 2 hour**	**25 year, 2 hour**
100%	26.2%	26.9%	25.5%
50%	14.7%	14.3%	13.1%
20%	6.5%	6.0%	5.5%
10%	3.7%	3.5%	3.1%
5%	2.0%	1.8%	1.6%

Overall, the study suggests that proper implementation of green infrastructure may significantly reduce runoff and peak discharge values during substantial storm events, as expected. Reduction of peak discharge may greatly reduce volumes of combined sewer overflows, and thus aid in the continued restoration of the watersheds, streams, rivers, and receiving water bodies that have been affected by urbanization and poor stormwater management practices.

REFERENCES

[1] USGS. (n.d.). The USGS Water Science School. Retrieved April 18, 2016, from http://water.usgs.gov/edu/hydrology.html

[2] Northeast Ohio Four County Regional Planning and Development Organization. (2010, October). *Little Cuyahoga River Action Plan - Phase I Preliminary Report* (Rep.). Retrieved March 15, 2016, from Ohio EPA website: http://www.nefcoplanning.org/publications/little_cuy/Little_Cuyahoga_River-Phase_1.pdf

[3] Benedict, Mark A. & McMahon, Edward T. (2006). Green Infrastructure: linking landscapes and communities

[4] Carson, T. B., Marasco, D. E., Culligan, P. J., & McGillis, W. R. (2013). Hydrological Performance of extensive green roofs in New York City. *Environmental Research Letters, 8*, 2nd ser., 1-14. Retrieved April 10, 2016, from http://iopscience.iop.org/article/10.1088/1748-9326/8/2/024036/pdf

[5] Soil Science Society of America. (n.d.). Rain Gardens and Bioswales. Retrieved April 10, 2016, from https://www.soils.org/discover-soils/soils-in-the-city/green-infrastructure/important-terms/rain-gardens-bioswales

[6] NYC Environmental Protection. (n.d.). Types of Green Infrastructure. Retrieved April 10, 2016, from http://www.nyc.gov/html/dep/html/stormwater/combined_sewer_overflow_bmps.shtml

[7] Geosyntec Consultants & Wright Water Engineers, Inc. (2012). Expanded Analysis of Volume Reduction in Bioretention BMPs. *International Stormwater Best Management Practices (BMP) Database, 1*, 1-48. Retrieved April 8, 2016, from http://www.bmpdatabase.org/Docs/Bioretention Volume Reduction Addendum 5 31 12.pdf

[8] US EPA. (2016, February 23). Performance of Green Infrastructure. Retrieved April 15, 2016, from https://www.epa.gov/green-infrastructure/performance-green-infrastructure

[9] University of New Hampshire (2012). *2012 Biannual Report* (pp. 1-36, Publication). Retrieved April 8, 2016, from http://www.unh.edu/unhsc/sites/unh.edu.unhsc/files/docs/UNHSC.2012Report.10.10.12.pdf

[10] Jaffe, M, et al. (2010). *The Illinois Green Infrastructure Study* (Rep.). IL: The Illinois EPA. Retrieved April 8, 2016, from http://www.epa.state.il.us/green-infrastructure/docs/draft-final-report.pdf

[11] EPA. (2015, December 7). Green Infrastructure Funding Opportunities. Retrieved April 8, 2016, from https://www.epa.gov/green-infrastructure/green-infrastructure-funding-opportunities

[12] Water Environment Federation. (2015, December 2). The Real Cost of Green Infrastructure. *Stormwater Report*. Retrieved April 8, 2016, from http://stormwater.wef.org/2015/12/real-cost-green-infrastructure/

[13] OGRIP. (n.d.). Ohio Geographically Referenced Information System (OGRIP). Retrieved March 25, 2016, from http://ogrip.oit.ohio.gov/ProjectsInitiatives/OSIPDataDownloads.aspx

[14] NEFCO Planning. (2016, March 15). *Little Cuyahoga Watershed Geodatabase* [GDB]. Akron, OH: NEFCO Planning.

[15] USDA NRCS. (n.d.). Web Soil Survey. Retrieved April 1, 2016, from http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

[16] USGS. (n.d.). The USGS Land Cover Institute (LCI). Retrieved April 1, 2016, from http://landcover.usgs.gov/

[17] Corvallis Forestry Research Community. (2006). Manning's n Values. Retrieved April 1, 2016, from http://www.fsl.orst.edu/geowater/FX3/help/8_Hydraulic_Reference/Mannings_n_Tables.htm

[18] NOAA's National Weather Service. (n.d.). PF Data Server Home - HDSC/OHD/NWS/NOAA. Retrieved April 1, 2016, from http://hdsc.nws.noaa.gov/hdsc/pfds/

[19] FEMA. (2009, July 20). *Flood Insurance Study - Summit County, Ohio* (Rep. No. 39153CV002A). Retrieved April 1, 2016, from FEMA website: http://www.fema.gov/flood-insurance-study

[20] USGS. (2015, January 26). StreamStats version 3.0: Ohio. Retrieved April 1, 2016, from http://streamstatsags.cr.usgs.gov/v3_beta/viewer.htm?stabbr=OH

[21] Center for Neighborhood Technology. (n.d.). Green Values National Stormwater Management Calculator. Retrieved April 8, 2016, from http://greenvalues.cnt.org/ national/calculator.php

APPENDICES

APPENDIX A

ArcMap Process Flow Chart

ArcMap Watershed Analysis Flow Chart Process:

1. Little Cuyahoga Watershed Subwatersheds and NHD flowlines (from NEFCO Planning) were brought in and a rough boundary was defined.

2. The Summit County Mosaic ESRI GRID DEM was added as a layer and clipped to the rough boundary. The DEM was projected to the Ohio North State Plane coordinate system and the NHD flowlines were burned into the DEM. The sinks were filled to generate the HydroDEM to be used later in the process.

3. A flow direction grid was created using the HydroDEM.

4. A flow accumulation grid was created using the Flow Direction grid.

5. The stream definition tool was used to define the threshold drainage area required to define a stream. The stream link tool was used to link the stream segments together.

6. A catchment grid was created based on the flow direction and stream link grids.

7. A slope grid was created using ArcHydro to be used later on in assigning basin and river characteristics to each subbasin.

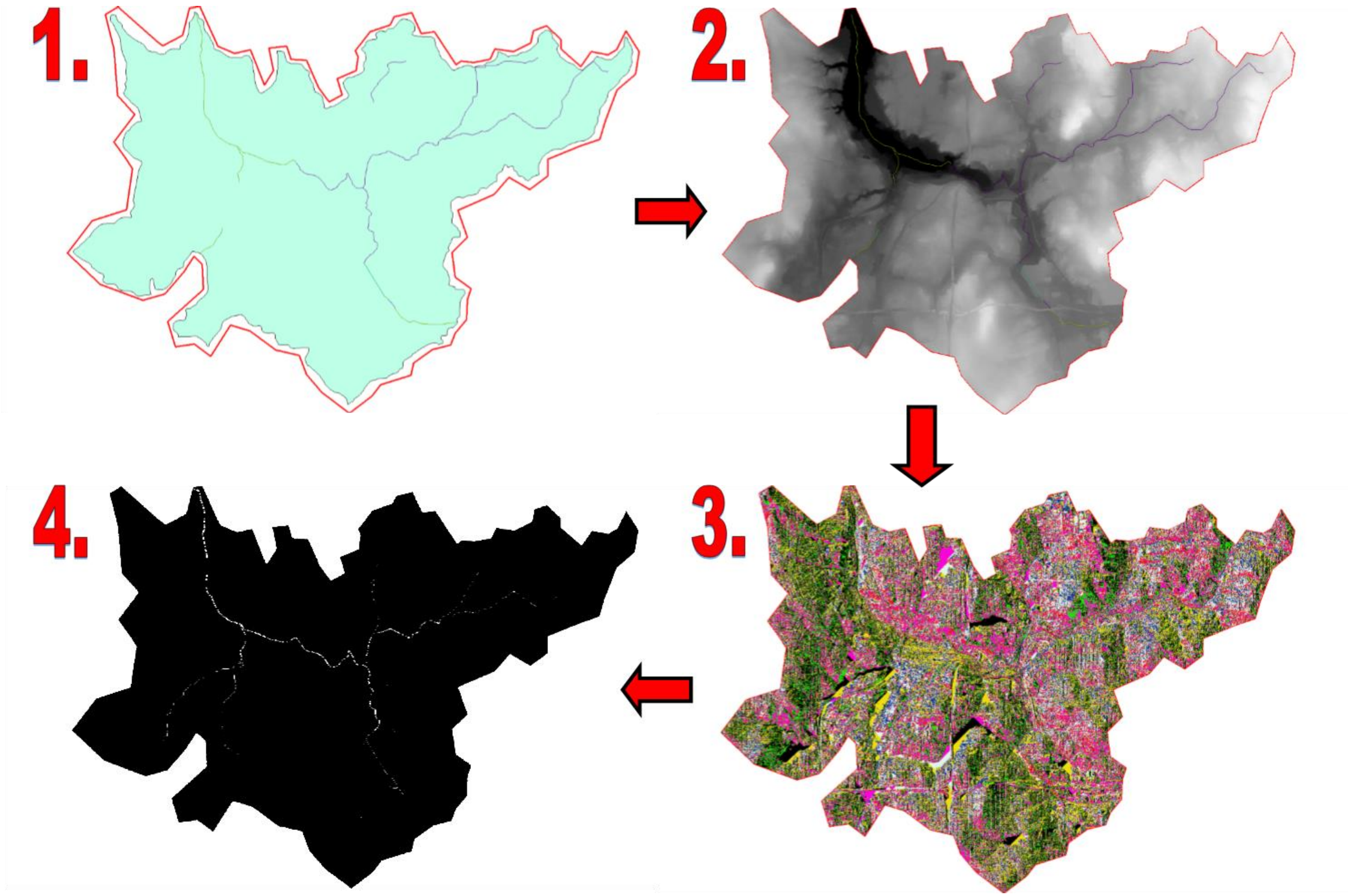
8. The basin characteristics tools were run including longest flow path, basin centroid, centroid elevation, and centroidal longest flow path.

9. A hydrologic soil group map was created using the NRCS Soil Data Viewer.

10. The 2011 Land Use raster dataset was imported from the USGS national land cover database.

11. The 2011 Imperviousness raster dataset was imported from the USGS national land cover database.

12. A Curve Number grid was created using the hydrologic soil group polygons, Soil Survey polygons, and land use raster.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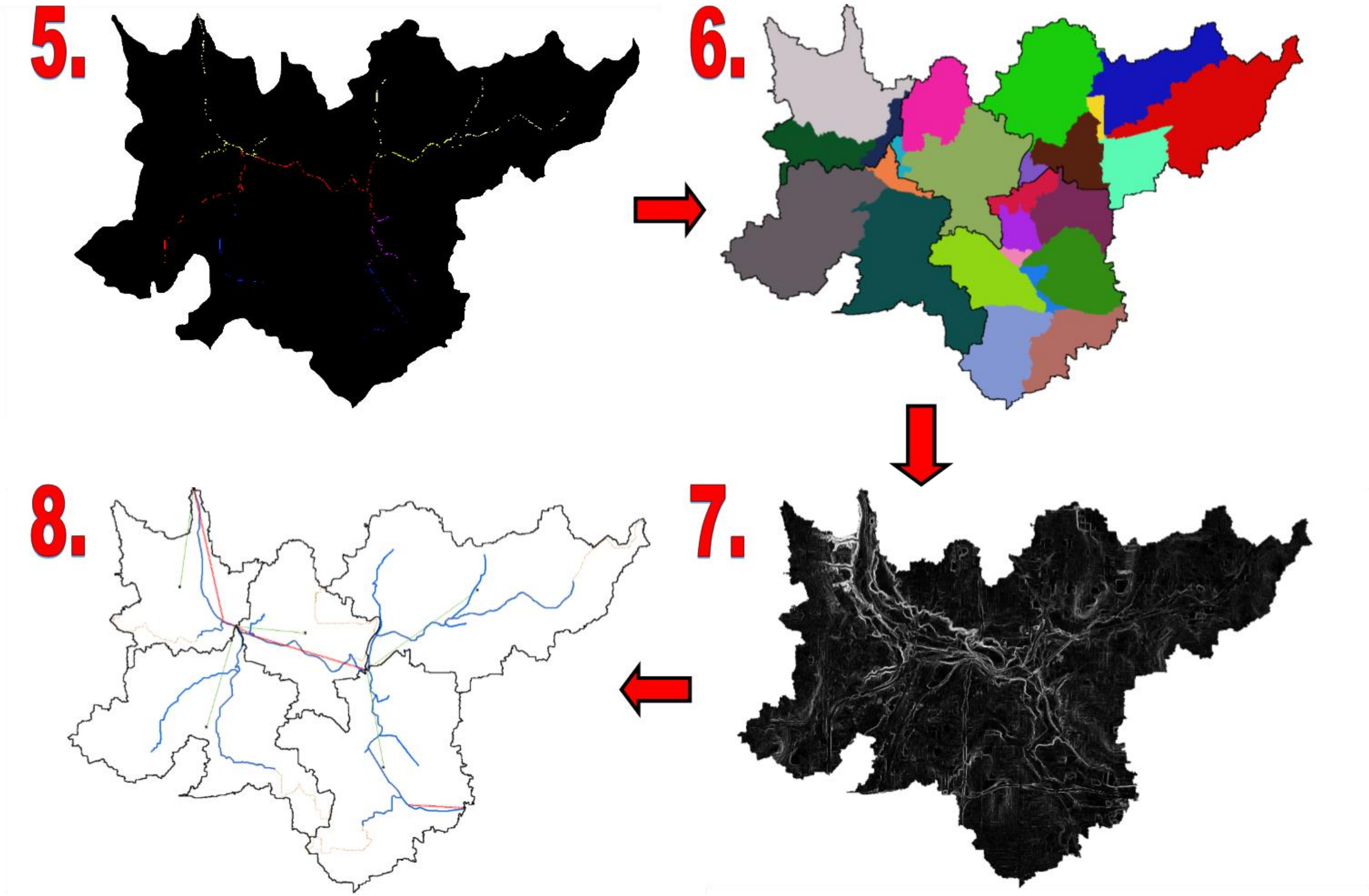
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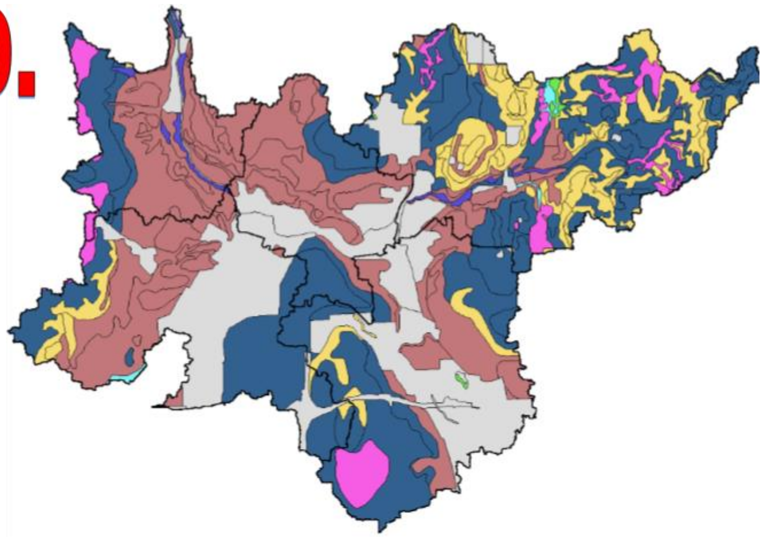
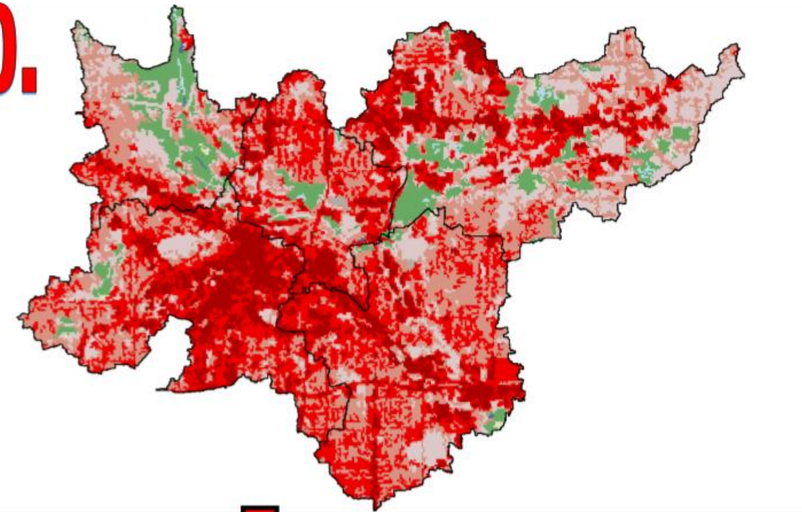


10.



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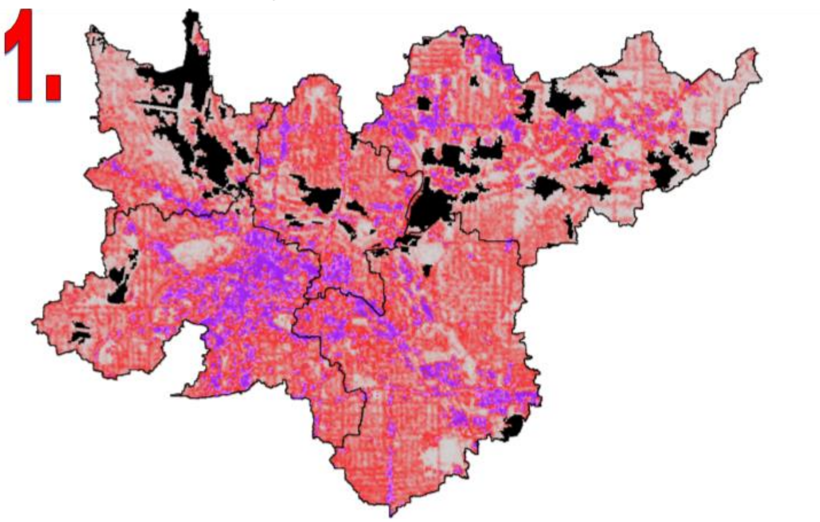

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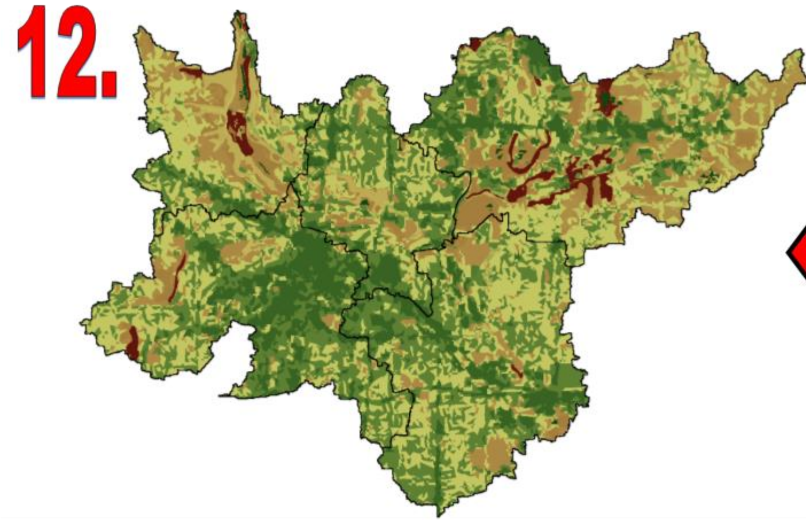

APPENDIX B

TR55 Time of Concentration

Worksheet for computation of time of travel according to TR-55 methodology

Blue - GIS defined, Green - user specified, White and yellow - calculated, Red - final result

Watershed Name	**W220**	**W200**	**W221**	**W210**	**W222**	**Inlet**
Watershed ID	**30**	**33**	**35**	**40**	**46**	
Sheet Flow Characteristics						
Manning's Roughness Coefficient	0.025	0.025	0.025	0.025	0.025	
Flow Length (ft)	100	100	100	100	100	
Two-Year 24-hour Rainfall (in)	2.43	2.43	2.43	2.43	2.43	
Land Slope (ft/ft)	0.0126	0.026	0.0202	0.0376	0.0292	
Sheet Flow Tt (hr)	0.05	0.04	0.04	0.03	0.04	
Shallow Concentrated Flow Characteristics						
Surface Description (1 - unpaved, 2 - paved)	2	2	2	2	2	
Flow Length (ft)	12322	9507	9248	9383	9340	
Watercourse Slope (ft/ft)	0.0124	0.0175	0.0111	0.0161	0.0061	
Average Velocity - computed (ft/s)	2.26	2.69	2.14	2.58	1.59	
Shallow Concentrated Flow Tt (hr)	1.51	0.98	1.20	1.01	1.63	
Channel Flow Characterisitics						
Cross-sectional Flow Area (ft2)	240	200	75	50	150	
Wetted Perimeter (ft)	60	58	35	42.5	40	
Hydraulic Radius - computed (ft)	4.00	3.45	2.14	1.18	3.75	
Channel Slope (ft/ft)	0.0091	0.0148	0.0081	0.0143	0.0078	
Manning's Roughness Coefficient	0.04	0.04	0.03	0.03	0.04	
Average Velocity - computed (ft/s)	8.95	10.34	7.43	6.62	7.94	
Flow Length (ft)	12522	13246	21596	15629	18565	
Channel Flow Tt (hr)	0.39	0.36	0.81	0.66	0.65	
Watershed Time of travel (hr)	**1.95**	**1.38**	**2.05**	**1.70**	**2.32**	**11.31**
Watershed Time of travel (min)	**117.26**	**82.68**	**123.08**	**102.07**	**139.32**	**678.53**
Number of watersheds	5					
MXD Path	HUC20304.mxd					
Stored workbook						
$AVHOME directory						
Name of the table to store the results of the calculation	Subbasin64					
Workspace path	D:\ArcMap\HEC_HMS\HUC20304\HUC20304.gdb					
Initial Discharge (cfs) (from StreamStats OH 4.0)	**55.5**	**89.9**	**5.55**	**19.2**	**34.2**	**27.6**
Links	PDF	http://streams	Pdf (BAH)	http://streams	http://streams	http://streamst

APPENDIX C

NOAA PFDS Precipitation Depth for Akron/Canton

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 2, Version 3

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.322** (0.295-0.352)	**0.384** (0.352-0.419)	**0.465** (0.425-0.507)	**0.527** (0.480-0.574)	**0.606** (0.550-0.659)	**0.666** (0.602-0.723)	**0.724** (0.653-0.786)	**0.783** (0.702-0.850)	**0.862** (0.768-0.934)	**0.919** (0.815-0.997)
10-min	**0.500** (0.458-0.546)	**0.600** (0.550-0.655)	**0.723** (0.660-0.788)	**0.813** (0.742-0.886)	**0.926** (0.842-1.01)	**1.01** (0.913-1.10)	**1.09** (0.982-1.18)	**1.17** (1.05-1.27)	**1.27** (1.13-1.37)	**1.34** (1.19-1.45)
15-min	**0.613** (0.561-0.670)	**0.734** (0.672-0.801)	**0.888** (0.811-0.968)	**1.00** (0.912-1.09)	**1.14** (1.04-1.25)	**1.25** (1.13-1.36)	**1.35** (1.22-1.47)	**1.45** (1.30-1.58)	**1.58** (1.41-1.71)	**1.67** (1.48-1.81)
30-min	**0.811** (0.743-0.886)	**0.982** (0.900-1.07)	**1.22** (1.11-1.32)	**1.39** (1.27-1.51)	**1.62** (1.47-1.76)	**1.78** (1.61-1.94)	**1.96** (1.76-2.12)	**2.12** (1.90-2.30)	**2.34** (2.09-2.54)	**2.51** (2.22-2.72)
60-min	**0.990** (0.907-1.08)	**1.21** (1.10-1.31)	**1.52** (1.39-1.66)	**1.77** (1.61-1.93)	**2.10** (1.90-2.28)	**2.35** (2.13-2.56)	**2.61** (2.36-2.84)	**2.88** (2.58-3.12)	**3.24** (2.89-3.51)	**3.52** (3.12-3.82)
2-hr	**1.15** (1.05-1.26)	**1.40** (1.28-1.54)	**1.79** (1.63-1.96)	**2.10** (1.91-2.30)	**2.55** (2.31-2.78)	**2.92** (2.63-3.18)	**3.31** (2.97-3.60)	**3.73** (3.33-4.05)	**4.32** (3.83-4.69)	**4.82** (4.24-5.23)
3-hr	**1.23** (1.12-1.34)	**1.49** (1.36-1.63)	**1.90** (1.73-2.08)	**2.23** (2.03-2.44)	**2.71** (2.46-2.96)	**3.11** (2.80-3.38)	**3.54** (3.17-3.85)	**4.01** (3.57-4.34)	**4.67** (4.13-5.06)	**5.23** (4.59-5.66)
6-hr	**1.48** (1.35-1.62)	**1.78** (1.63-1.96)	**2.25** (2.06-2.47)	**2.65** (2.41-2.90)	**3.22** (2.92-3.52)	**3.71** (3.34-4.04)	**4.23** (3.78-4.60)	**4.81** (4.27-5.22)	**5.65** (4.96-6.12)	**6.36** (5.53-6.88)
12-hr	**1.74** (1.59-1.92)	**2.09** (1.91-2.31)	**2.61** (2.38-2.89)	**3.06** (2.78-3.38)	**3.72** (3.36-4.09)	**4.29** (3.84-4.70)	**4.90** (4.37-5.36)	**5.58** (4.93-6.09)	**6.58** (5.76-7.17)	**7.43** (6.44-8.09)
24-hr	**2.03** (1.87-2.23)	**2.43** (2.23-2.67)	**3.03** (2.77-3.32)	**3.53** (3.22-3.86)	**4.28** (3.88-4.67)	**4.91** (4.43-5.36)	**5.61** (5.01-6.12)	**6.38** (5.64-6.96)	**7.51** (6.55-8.19)	**8.48** (7.31-9.26)
2-day	**2.35** (2.16-2.57)	**2.81** (2.58-3.08)	**3.46** (3.18-3.78)	**4.00** (3.66-4.38)	**4.80** (4.37-5.25)	**5.48** (4.95-5.98)	**6.21** (5.57-6.78)	**7.00** (6.21-7.66)	**8.16** (7.13-8.93)	**9.14** (7.88-10.0)
3-day	**2.51** (2.31-2.74)	**2.99** (2.75-3.27)	**3.66** (3.37-4.00)	**4.22** (3.87-4.61)	**5.04** (4.59-5.49)	**5.71** (5.18-6.23)	**6.44** (5.79-7.03)	**7.22** (6.44-7.89)	**8.36** (7.36-9.15)	**9.33** (8.12-10.3)
4-day	**2.67** (2.46-2.91)	**3.17** (2.93-3.46)	**3.87** (3.56-4.22)	**4.44** (4.08-4.84)	**5.27** (4.81-5.74)	**5.95** (5.40-6.47)	**6.67** (6.02-7.27)	**7.44** (6.67-8.13)	**8.55** (7.59-9.36)	**9.53** (8.36-10.5)
7-day	**3.19** (2.96-3.44)	**3.79** (3.52-4.09)	**4.57** (4.24-4.95)	**5.22** (4.84-5.64)	**6.15** (5.66-6.64)	**6.91** (6.33-7.46)	**7.71** (7.03-8.34)	**8.56** (7.75-9.27)	**9.75** (8.73-10.6)	**10.7** (9.51-11.7)
10-day	**3.67** (3.43-3.93)	**4.35** (4.07-4.66)	**5.20** (4.86-5.58)	**5.89** (5.49-6.31)	**6.84** (6.36-7.33)	**7.61** (7.04-8.15)	**8.39** (7.73-9.00)	**9.20** (8.44-9.89)	**10.3** (9.38-11.1)	**11.2** (10.1-12.1)
20-day	**5.10** (4.81-5.42)	**6.02** (5.68-6.41)	**7.10** (6.68-7.55)	**7.93** (7.46-8.44)	**9.05** (8.48-9.62)	**9.90** (9.27-10.5)	**10.7** (10.0-11.4)	**11.6** (10.8-12.4)	**12.7** (11.7-13.6)	**13.5** (12.4-14.5)
30-day	**6.40** (6.05-6.77)	**7.54** (7.14-7.97)	**8.78** (8.31-9.29)	**9.73** (9.20-10.3)	**11.0** (10.3-11.6)	**11.9** (11.2-12.6)	**12.8** (12.0-13.5)	**13.7** (12.8-14.5)	**14.8** (13.8-15.7)	**15.7** (14.5-16.7)
45-day	**8.20** (7.79-8.63)	**9.62** (9.14-10.1)	**11.0** (10.5-11.6)	**12.1** (11.5-12.7)	**13.5** (12.8-14.2)	**14.5** (13.7-15.3)	**15.5** (14.6-16.3)	**16.4** (15.4-17.2)	**17.5** (16.4-18.5)	**18.3** (17.1-19.4)
60-day	**9.91** (9.44-10.4)	**11.6** (11.1-12.2)	**13.2** (12.6-13.9)	**14.4** (13.7-15.1)	**15.9** (15.1-16.7)	**17.0** (16.1-17.9)	**18.0** (17.1-18.9)	**18.9** (17.9-19.9)	**20.1** (18.9-21.2)	**20.8** (19.6-22.0)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

APPENDIX D

StreamStats Reports for Major Subbasins

StreamStats Data-Collection Station Report

USGS Station Number	**04205700**
Station Name	**Little Cuyahoga R bl OH & Erie Canal at Akron OH**

Click here to link to available data on NWIS-Web for this site.

Descriptive Information

Station Type	Streamgage, continuous record
Location	
Gage	
Regulation and Diversions	
Regulated?	True
Period of Record	
Remarks	
Latitude (degrees NAD83)	41.0945
Longitude (degrees NAD83)	-81.52151
Hydrologic unit code	04110002
County	153-Summit
HCDN2009	No

Physical Characteristics

Characteristic Name	Value	Units	Citation Number
Descriptive Information			
Datum_of_Latitude_Longitude	NAD83	dimensionless	30
District_Code	39	dimensionless	30
Begin_date_of_record	10/1/1973	days	41
End_date_of_record	11/20/1979	days	41
Number_of_days_of_record	2242	days	41
Number_of_days_GT_0	2242	days	41
Basin Dimensional Characteristics			
Drainage_Area	59.2	square miles	30

Streamflow Statistics

Statistic Name	Value	Units	Citation Number	Preferred?	Years of Record	Standard Error, percent	Variance log-10	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Start Date	End Date	Remarks
Flow-Duration Statistics												
10_Percent_Duration	153.3	cubic feet per second	41	Y	6							
20_Percent_Duration	115.1	cubic feet per second	41	Y	6							
25_Percent_Duration	105	cubic feet per second	41	Y	6							
30_Percent_Duration	98	cubic feet per second	41	Y	6							
40_Percent_Duration	84	cubic feet per	41	Y	6							

		second			
50_Percent_Duration	73	cubic feet per second	41	Y	6
60_Percent_Duration	63	cubic feet per second	41	Y	6
70_Percent_Duration	55	cubic feet per second	41	Y	6
75_Percent_Duration	51	cubic feet per second	41	Y	6
80_Percent_Duration	47	cubic feet per second	41	Y	6
90_Percent_Duration	33	cubic feet per second	41	Y	6
95_Percent_Duration	29	cubic feet per second	41	Y	6
99_Percent_Duration	10	cubic feet per second	41	Y	6
General Flow Statistics					
Minimum_daily_flow	8.5	cubic feet per second	41	Y	6
Maximum_daily_flow	2000	cubic feet per second	41	Y	6
Std_Dev_of_daily_flows	79.656	cubic feet per second	41	Y	6
Average_daily_streamflow	89.877	cubic feet per second	41	Y	6
Base Flow Statistics					
Number_of_years_to_compute_BFI	6	years	42	Y	6
Average_BFI_value	0.588	dimensionless	42	Y	6
Std_dev_of_annual_BFI_values	0.067	dimensionless	42	Y	6

Citations

Citation Number	*Citation Name and URL*
30	Imported from NWIS file
41	Wolock, D.M., 2003, Flow characteristics at U.S. Geological Survey streamgages in the conterminous United States: U.S. Geological Survey Open-File Report 03-146, digital data set
42	Wolock, D.M., 2003, Base-flow index grid for the conterminous United States: U.S. Geological Survey Open-File Report 03-263, digital data set

StreamStats Data-Collection Station Report

USGS Station Number	**410433081312500**
Station Name	**Lock 1 Outlet O&E Canal**

Click here to link to available data on NWIS-Web for this site.

Descriptive Information

Station Type	Streamgage, continuous record
Location	
Gage	
Regulation and Diversions	
Regulated?	True
Period of Record	
Remarks	
Latitude (degrees NAD83)	41.07589
Longitude (degrees NAD83)	-81.52345
Hydrologic unit code	05040001
County	153-Summit
HCDN2009	No

Physical Characteristics

Characteristic Name	Value	Units	Citation Number
Descriptive Information			
Datum_of_Latitude_Longitude	NAD83	dimensionless	30
District_Code	39	dimensionless	30
Begin_date_of_record	6/1/1998	days	41
End_date_of_record	9/30/2003	days	41
Number_of_days_of_record	1948	days	41
Number_of_days_GT_0	1948	days	41

Streamflow Statistics

Statistic Name	Value	Units	Citation Number	Preferred?	Years of Record	Standard Error, percent	Variance log-10	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Start Date	End Date	Remarks
Flow-Duration Statistics												
10_Percent_Duration	32	cubic feet per second	41	Y								
20_Percent_Duration	25	cubic	41	Y								

		feet per second		
25_Percent_Duration	22	cubic feet per second	41	Y
30_Percent_Duration	20	cubic feet per second	41	Y
40_Percent_Duration	18	cubic feet per second	41	Y
50_Percent_Duration	16	cubic feet per second	41	Y
60_Percent_Duration	14	cubic feet per second	41	Y
70_Percent_Duration	13	cubic feet per second	41	Y
75_Percent_Duration	12	cubic feet per second	41	Y
80_Percent_Duration	11	cubic feet per second	41	Y
90_Percent_Duration	8.4	cubic feet per second	41	Y
95_Percent_Duration	5.6	cubic feet per second	41	Y
99_Percent_Duration	2	cubic feet per second	41	Y
General Flow Statistics				
Minimum_daily_flow	0.7	cubic feet per second	41	Y
Maximum_daily_flow	214	cubic feet per second	41	Y
Std_Dev_of_daily_flows	14.529	cubic feet	41	Y

		per second		
Average_daily_streamflow	19.233	cubic feet per second	41	Y

Citations

Citation Number	*Citation Name and URL*
41	Wolock, D.M., 2003, Flow characteristics at U.S. Geological Survey streamgages in the conterminous United States: U.S. Geological Survey Open-File Report 03-146, digital data set

W220

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Wed Apr 13, 2016 11:39:49 PM GMT-4
Study Area: Ohio
NAD 1983 Latitude: 41.0923 (41 05 32)
NAD 1983 Longitude: -81.5164 (-81 30 59)
Drainage Area: 55.8 mi2

Peak Flows Basin Characteristics			
100% Peak Flow Full Model (55.8 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	55.8	0.01	7422
Ohio Region C Indicator 1 if in C else 0 (dimensionless)	0	0	1
Ohio Region A Indicator 1 if in A else 0 (dimensionless)	1	0	1
Stream Slope 10 and 85 Longest Flow Path (feet per mi)	12.2	1.53	674
Percent Storage from NLCD1992 (percent)	10.7	0	25.8

Low Flows Basin Characteristics			
99% Low Flow Region A 2012 5138 (55.5 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	55.8	1	1250
Streamflow Variability Index from Grid (dimensionless)	0.57	0.24	1.12
1% Low Flow Region B 2012 5138 (0.34 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	55.8	1	1250
Streamflow Variability Index from Grid (dimensionless)	0.57	0.24	1.12

Probability of Zero Flow Basin Characteristics			
100% P zero Flow 2012 5138 (55.8 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	55.8	1	1250
Streamflow Variability Index from Grid (dimensionless)	0.57	0.24	1.12

Mean and Percentile Basin Characteristics			
Y coordinate (latitude) of the centroid_ in decimal degrees=41.0575			
100% Low Flow LatLE 41.2 wri02 4068 (55.8 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	55.8	0.12	7422

Percent Forest (percent)	22.7	0	99.1
Percent Storage from NLCD1992 (percent)	10.7	0	19
Mean Annual Precipitation (inches)	36	34	43.2
Streamflow Variability Index from Grid (dimensionless)	0.57	0.25	1.13
Latitude of Basin Centroid (decimal degrees)	41.0575	38.68	41.2
Longitude of Basin Centroid (decimal degrees)	81.4111	80.53	84.6

Peak Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	1420	ft3/s	37	2.1	746	2710
PK5	2080	ft3/s	35	3.3	1130	3820
PK10	2530	ft3/s	34	4.4	1370	4650
PK25	3080	ft3/s	35	5.9	1640	5770
PK50	3480	ft3/s	37	6.8	1820	6670
PK100	3900	ft3/s	38	7.5	1980	7660
PK500	4810	ft3/s	42	8.6	2280	10200

http://pubs.usgs.gov/sir/2006/5312/ (http://pubs.usgs.gov/sir/2006/5312/)
Koltun_ G.F._ Kula_ S.P._ and Puskas_ B.M._ 2006_ A Streamflow Statistics (StreamStats) Web Application for Ohio: U.S. Geological Survey Scientific Investigations Report 2006-5312_ 62 p.

Low Flows Statistics Area-Averaged						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
M1D10Y	0.66	ft3/s	53			
M7D10Y	0.86	ft3/s	40			
M30D10Y	1.36	ft3/s	36			
M90D10Y	2.2	ft3/s	30			
D80	4.75	ft3/s	29			

Low Flows Statistics Low_Flow_Region_A_2012_5138						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
M1D10Y	0.66	ft3/s	53			
M7D10Y	0.86	ft3/s	40			
M30D10Y	1.36	ft3/s	36			
M90D10Y	2.2	ft3/s	30			
D80	4.74	ft3/s	29			

Low Flows Statistics Low_Flow_Region_B_2012_5138						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
M1D10Y	0.66	ft3/s	53			

M7D10Y	0.86	ft3/s	40			
M30D10Y	1.36	ft3/s	36			
M90D10Y	2.92	ft3/s	30			
D80	6.72	ft3/s	29			

Koltun_ G.F._ and Kula_ S.P._ 2013_ Methods for estimating selected low-flow statistics and development of annual flow-duration statistics for Ohio: U.S. Geological Survey Scientific Investigations Report 2012-5138_ 195 p.

Probability of Zero Flow Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PROB 1DAY	0.0283	dim				
PROB 7DAY	0.0127	dim				
PROB 30DAY	0.000731	dim				

#http://pubs.usgs.gov/sir/2012/5138/#
Koltun_ G.F._ and Kula_ S.P._ 2013_ Methods for estimating selected low-flow statistics and development of annual flow-duration statistics for Ohio: U.S. Geological Survey Scientific Investigations Report 2012-5138_ 195 p.

Mean and Percentile Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
Q1	89.5	ft3/s	17			
Q2	85.9	ft3/s	12			
Q3	104	ft3/s	14			
Q4	89.5	ft3/s	11			
Q5	57.6	ft3/s	20			
Q6	39.9	ft3/s	27			
Q7	22.1	ft3/s	28			
Q8	14.9	ft3/s	37			
Q9	10.2	ft3/s	44			
QA	55.5	ft3/s	11			
Q10	12.5	ft3/s	51			
Q11	28.1	ft3/s	38			
Q12	54.6	ft3/s	22			
QAH	13	ft3/s	66			
FPS25	11	ft3/s	29			
FPS50	28	ft3/s	40			
FPS75	74	ft3/s	48			

http://oh.water.usgs.gov/reports/wrir/wrir02-4068.pdf (http://oh.water.usgs.gov/reports/wrir/wrir02-4068.pdf)
Koltun_ G. F._ and Whitehead_ M. T._ 2002_ Techniques for Estimating Selected Streamflow Characteristics of Rural_ Unregulated Streams in Ohio: U. S. Geological Survey Water-Resources Investigations Report 02-4068_ 50 p

W221

StreamStats Version 3.0

Flow Statistics Ungaged Site Report

Date: Wed Apr 13, 2016 11:13:49 PM GMT-4
Study Area: Ohio
NAD 1983 Latitude: 41.0857 (41 05 08)
NAD 1983 Longitude: -81.4872 (-81 29 14)
Drainage Area: 5.37 mi2

Peak Flows Basin Characteristics

100% Peak Flow Full Model (5.37 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	5.37	0.01	7422
Ohio Region C Indicator 1 if in C else 0 (dimensionless)	0	0	1
Ohio Region A Indicator 1 if in A else 0 (dimensionless)	1	0	1
Stream Slope 10 and 85 Longest Flow Path (feet per mi)	44.3	1.53	674
Percent Storage from NLCD1992 (percent)	2.06	0	25.8

Low Flows Basin Characteristics

100% Low Flow Region A 2012 5138 (5.37 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	5.37	1	1250
Streamflow Variability Index from Grid (dimensionless)	0.57	0.24	1.12

Probability of Zero Flow Basin Characteristics

100% P zero Flow 2012 5138 (5.37 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	5.37	1	1250
Streamflow Variability Index from Grid (dimensionless)	0.57	0.24	1.12

Mean and Percentile Basin Characteristics

Y coordinate (latitude) of the centroid_ in decimal degrees=41.0989

100% Low Flow LatLE 41.2 wri02 4068 (5.37 mi2)

Parameter	Value	Regression Equation Valid Range	
		Min	Max
Drainage Area (square miles)	5.37	0.12	7422
Percent Forest (percent)	20.8	0	99.1
Percent Storage from NLCD1992 (percent)	2.06	0	19
Mean Annual Precipitation (inches)	36.9	34	43.2
Streamflow Variability Index from Grid (dimensionless)	0.57	0.25	1.13
Latitude of Basin Centroid (decimal degrees)	41.0989	38.68	41.2

Longitude of Basin Centroid (decimal degrees)	81.4627	80.53	84.6

Peak Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PK2	350	ft3/s	37	2.1	176	696
PK5	590	ft3/s	35	3.3	307	1130
PK10	764	ft3/s	34	4.4	397	1470
PK25	989	ft3/s	35	5.9	502	1950
PK50	1160	ft3/s	37	6.8	573	2330
PK100	1330	ft3/s	38	7.5	638	2760
PK500	1730	ft3/s	42	8.6	768	3880

http://pubs.usgs.gov/sir/2006/5312/ (http://pubs.usgs.gov/sir/2006/5312/)
Koltun_ G.F._ Kula_ S.P._ and Puskas_ B.M._ 2006_ A Streamflow Statistics (StreamStats) Web Application for Ohio: U.S. Geological Survey Scientific Investigations Report 2006-5312_ 62 p.

Low Flows Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
M1D10Y	0.0636	ft3/s	53			
M7D10Y	0.0825	ft3/s	40			
M30D10Y	0.13	ft3/s	36			
M90D10Y	0.21	ft3/s	30			
D80	0.46	ft3/s	29			

#http://pubs.usgs.gov/sir/2012/5138/#
Koltun_ G.F._ and Kula_ S.P._ 2013_ Methods for estimating selected low-flow statistics and development of annual flow-duration statistics for Ohio: U.S. Geological Survey Scientific Investigations Report 2012-5138_ 195 p.

Probability of Zero Flow Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
PROB 1DAY	0.0373	dim				
PROB 7DAY	0.0163	dim				
PROB 30DAY	0.000731	dim				

#http://pubs.usgs.gov/sir/2012/5138/#
Koltun_ G.F._ and Kula_ S.P._ 2013_ Methods for estimating selected low-flow statistics and development of annual flow-duration statistics for Ohio: U.S. Geological Survey Scientific Investigations Report 2012-5138_ 195 p.

Mean and Percentile Statistics						
Statistic	Value	Unit	Prediction Error (percent)	Equivalent years of record	90-Percent Prediction Interval	
					Min	Max
Q1	7.76	ft3/s	17			

Q2	9.06	ft3/s	12				
Q3	10.3	ft3/s	14				
Q4	9.39	ft3/s	11				
Q5	5.48	ft3/s	20				
Q6	3.74	ft3/s	27				
Q7	2.29	ft3/s	28				
Q8	1.54	ft3/s	37				
Q9	0.99	ft3/s	44				
QA	5.55	ft3/s	11				
Q10	1.1	ft3/s	51				
Q11	2.55	ft3/s	38				
Q12	5.3	ft3/s	22				
QAH	0.63	ft3/s	66				
FPS25	0.84	ft3/s	29				
FPS50	2.28	ft3/s	40				
FPS75	5.52	ft3/s	48				

http://oh.water.usgs.gov/reports/wrir/wrir02-4068.pdf (http://oh.water.usgs.gov/reports/wrir/wrir02-4068.pdf)
Koltun_ G. F._ and Whitehead_ M. T._ 2002_ Techniques for Estimating Selected Streamflow Characteristics of Rural_ Unregulated Streams in Ohio: U. S. Geological Survey Water-Resources Investigations Report 02-4068_ 50 p

StreamStats Data-Collection Station Report

USGS Station Number	**04205500**
Station Name	**Little Cuyahoga River at Akron OH**

Click here to link to available data on NWIS-Web for this site.

Descriptive Information

Station Type	Streamgage, continuous record
Location	
Gage	
Regulation and Diversions	
Regulated?	True
Period of Record	
Remarks	
Latitude (degrees NAD83)	41.0595
Longitude (degrees NAD83)	-81.4754
Hydrologic unit code	04110002
County	153-Summit
HCDN2009	No

Physical Characteristics

Characteristic Name	Value	Units	Citation Number
Descriptive Information			
Datum_of_Latitude_Longitude	NAD83	dimensionless	30
District_Code	39	dimensionless	30
Begin_date_of_record	7/10/1920	days	41
End_date_of_record	4/30/1934	days	41
Number_of_days_of_record	2487	days	41
Number_of_days_GT_0	2487	days	41
Basin Dimensional Characteristics			
Drainage_Area	44.4	square miles	30

Streamflow Statistics

Statistic Name	Value	Units	Citation Number	Preferred?	Years of Record	Standard Error, percent	Variance log-10	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Start Date	End Date	Remarks
Flow-Duration Statistics												
10_Percent_Duration	69	cubic feet per second	41	Y	6							
20_Percent_Duration	45	cubic feet per second	41	Y	6							
25_Percent_Duration	38	cubic feet per second	41	Y	6							
30_Percent_Duration	34	cubic feet per second	41	Y	6							
40_Percent_Duration	26	cubic feet per	41	Y	6							

		second			
50_Percent_Duration	22	cubic feet per second	41	Y	6
60_Percent_Duration	18	cubic feet per second	41	Y	6
70_Percent_Duration	14	cubic feet per second	41	Y	6
75_Percent_Duration	13	cubic feet per second	41	Y	6
80_Percent_Duration	12	cubic feet per second	41	Y	6
90_Percent_Duration	10	cubic feet per second	41	Y	6
95_Percent_Duration	9.2	cubic feet per second	41	Y	6
99_Percent_Duration	6.2	cubic feet per second	41	Y	6
General Flow Statistics					
Minimum_daily_flow	3.8	cubic feet per second	41	Y	6
Maximum_daily_flow	838	cubic feet per second	41	Y	6
Std_Dev_of_daily_flows	43.485	cubic feet per second	41	Y	6
Average_daily_streamflow	34.222	cubic feet per second	41	Y	6
Base Flow Statistics					
Number_of_years_to_compute_BFI	6	years	42	Y	6
Average_BFI_value	0.544	dimensionless	42	Y	6
Std_dev_of_annual_BFI_values	0.038	dimensionless	42	Y	6

Citations

Citation Number	*Citation Name and URL*
30	Imported from NWIS file
41	Wolock, D.M., 2003, Flow characteristics at U.S. Geological Survey streamgages in the conterminous United States: U.S. Geological Survey Open-File Report 03-146, digital data set
42	Wolock, D.M., 2003, Base-flow index grid for the conterminous United States: U.S. Geological Survey Open-File Report 03-263, digital data set

StreamStats Data-Collection Station Report

USGS Station Number	**04204500**
Station Name	**Little Cuyahoga River at Massillon Rd Akron OH**

Click here to link to available data on NWIS-Web for this site.

Descriptive Information

Station Type	Streamgage, continuous record
Location	
Gage	
Regulation and Diversions	
Regulated?	True
Period of Record	
Remarks	
Latitude (degrees NAD83)	41.06
Longitude (degrees NAD83)	-81.46
Hydrologic unit code	04110002
County	153-Summit
HCDN2009	No

Physical Characteristics

Characteristic Name	Value	Units	Citation Number
Descriptive Information			
Datum_of_Latitude_Longitude	NAD83	dimensionless	30
District_Code	39	dimensionless	30
Begin_date_of_record	11/14/1945	days	41
End_date_of_record	9/30/1974	days	41
Number_of_days_of_record	10471	days	41
Number_of_days_GT_0	10471	days	41
Ohio_Physiographic_Sections	4	dimensionless	60
Precipitation Statistics			
Mean_Annual_Precip_at_Basin_Centroid	36	inches	60
Land Cover Characteristics			
Percent_Forest	27.9	percent	60
Percent_Storage_from_NLCD1992	14.2	percent	60
Basin Dimensional Characteristics			
Drainage_Area	31.6	square miles	60

Streamflow Statistics

Statistic Name	Value	Units	Citation Number	Preferred?	Years of Record	Standard Error, percent	Variance log-10	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Start Date	End Date	Ren
Low-Flow Statistics												
1_Day_2_Year_Low_Flow	5.7	cubic feet per second	61	Y								
1_Day_5_Year_Low_Flow	4.1	cubic feet per second	61	Y								

1_Day_10_Year_Low_Flow	3.5	cubic feet per second	61	Y	
1_Day_20_Year_Low_Flow	3.1	cubic feet per second	61	Y	
7_Day_2_Year_Low_Flow	6.3	cubic feet per second	61	Y	
7_Day_5_Year_Low_Flow	4.6	cubic feet per second	61	Y	
7_Day_10_Year_Low_Flow	3.9	cubic feet per second	61	Y	
7_Day_20_Year_Low_Flow	3.4	cubic feet per second	61	Y	
30_Day_2_Year_Low_Flow	8	cubic feet per second	61	Y	
30_Day_5_Year_Low_Flow	5.8	cubic feet per second	61	Y	
30_Day_10_Year_Low_Flow	4.9	cubic feet per second	61	Y	
30_Day_20_Year_Low_Flow	4.3	cubic feet per second	61	Y	
90_Day_2_Year_Low_Flow	11	cubic feet per second	61	Y	
90_Day_5_Year_Low_Flow	7.7	cubic feet per second	61	Y	
90_Day_10_Year_Low_Flow	6.5	cubic feet per second	61	Y	
90_Day_20_Year_Low_Flow	5.7	cubic feet per second	61	Y	
7_Day_50_Year_Low_Flow	2.9	cubic feet per second	61	Y	
1_Day_50_Year_Low_Flow	2.7	dimensionless	61	Y	
30_Day_50_Year_Low_Flow	3.7	cubic feet per second	61	Y	
90_Day_50_Year_Low_Flow	4.9	cubic feet per second	61	Y	
Flow-Duration Statistics					
10_Percent_Duration	57	cubic feet per second	41	Y	28
20_Percent_Duration	41	cubic feet per second	41	Y	28
25_Percent_Duration	35	cubic feet per second	41	Y	28
30_Percent_Duration	30	cubic feet per second	41	Y	28
40_Percent_Duration	24	cubic feet per second	41	Y	28
50_Percent_Duration	19	cubic feet per second	41	Y	28
60_Percent_Duration	16	cubic feet per second	41	Y	28
70_Percent_Duration	13	cubic feet per second	41	Y	28
75_Percent_Duration	11	cubic feet per second	41	Y	28
80_Percent_Duration	10	cubic feet per second	41	Y	28
90_Percent_Duration	7	cubic feet per second	41	Y	28
95_Percent_Duration	5.7	cubic feet per second	41	Y	28
99_Percent_Duration	4.1	cubic feet per second	41	Y	28
Annual Flow Statistics					

Mean_Annual_Flow	27.6	cubic feet per second	60	Y
Seasonal Flow Statistics				
1_Day_2_Year_lowflow_May_to_Nov	5.7	cubic feet per second	61	Y
1_Day_5_Year_lowflow_May_to_Nov	4.1	cubic feet per second	61	Y
1_Day_10_Year_lowflow_May_to_Nov	3.5	cubic feet per second	61	Y
1_Day_20_Year_lowflow_May_to_Nov	3.1	cubic feet per second	61	Y
1_Day_50_Year_lowflow_May_to_Nov	2.7	cubic feet per second	61	Y
7_Day_2_Year_lowflow_May_to_Nov	6.4	cubic feet per second	61	Y
7_Day_5_Year_lowflow_May_to_Nov	4.6	cubic feet per second	61	Y
7_Day_10_Year_lowflow_May_to_Nov	3.9	cubic feet per second	61	Y
7_Day_20_Year_lowflow_May_to_Nov	3.5	cubic feet per second	61	Y
7_Day_50_Year_lowflow_May_to_Nov	3	cubic feet per second	61	Y
30_Day_2_Year_lowflow_May_to_Nov	8	cubic feet per second	61	Y
30_Day_5_Year_lowflow_May_to_Nov	5.8	cubic feet per second	61	Y
30_Day_10_Year_lowflow_May_to_Nov	5	cubic feet per second	61	Y
30_Day_20_Year_lowflow_May_to_Nov	4.4	cubic feet per second	61	Y
30_Day_50_Year_lowflow_May_to_Nov	3.8	cubic feet per second	61	Y
90_Day_2_Year_lowflow_May_to_Nov	11	cubic feet per second	61	Y
90_Day_5_Year_lowflow_May_to_Nov	7.7	cubic feet per second	61	Y
90_Day_10_Year_lowflow_May_to_Nov	6.5	cubic feet per second	61	Y
90_Day_20_Year_lowflow_May_to_Nov	5.7	cubic feet per second	61	Y
90_Day_50_Year_lowflow_May_to_Nov	4.9	cubic feet per second	61	Y
1_Day_2_Year_lowflow_Dec_to_Feb	11	cubic feet per second	61	Y
1_Day_5_Year_lowflow_Dec_to_Feb	7.3	cubic feet per second	61	Y
1_Day_10_Year_lowflow_Dec_to_Feb	5.8	cubic feet per second	61	Y
1_Day_20_Year_lowflow_Dec_to_Feb	4.7	cubic feet per second	61	Y
1_Day_50_Year_lowflow_Dec_to_Feb	3.7	cubic feet per second	61	Y
7_Day_2_Year_lowflow_Dec_to_Feb	13	cubic feet per second	61	Y
7_Day_5_Year_lowflow_Dec_to_Feb	8.5	cubic feet per second	61	Y
7_Day_10_Year_lowflow_Dec_to_Feb	6.7	cubic feet per second	61	Y
7_Day_20_Year_lowflow_Dec_to_Feb	5.4	cubic feet per second	61	Y
7_Day_50_Year_lowflow_Dec_to_Feb	4.2	cubic feet per second	61	Y

30_Day_2_Year_lowflow_Dec_to_Feb	18	cubic feet per second	61	Y
30_Day_5_Year_lowflow_Dec_to_Feb	11	cubic feet per second	61	Y
30_Day_10_Year_lowflow_Dec_to_Feb	8.5	cubic feet per second	61	Y
30_Day_20_Year_lowflow_Dec_to_Feb	6.9	cubic feet per second	61	Y
30_Day_50_Year_lowflow_Dec_to_Feb	5.4	cubic feet per second	61	Y
90_Day_2_Year_lowflow_Dec_to_Feb	30	cubic feet per second	61	Y
90_Day_5_Year_lowflow_Dec_to_Feb	18	cubic feet per second	61	Y
90_Day_10_Year_lowflow_Dec_to_Feb	14	cubic feet per second	61	Y
90_Day_20_Year_lowflow_Dec_to_Feb	10	cubic feet per second	61	Y
90_Day_50_Year_lowflow_Dec_to_Feb	7.5	cubic feet per second	61	Y
1_Day_2_Year_lowflow_Sep_to_Nov	6	cubic feet per second	61	Y
1_Day_5_Year_lowflow_Sep_to_Nov	4.4	cubic feet per second	61	Y
1_Day_10_Year_lowflow_Sep_to_Nov	3.8	cubic feet per second	61	Y
1_Day_20_Year_lowflow_Sep_to_Nov	3.4	cubic feet per second	61	Y
1_Day_50_Year_lowflow_Sep_to_Nov	2.9	cubic feet per second	61	Y
7_Day_2_Year_lowflow_Sep_to_Nov	6.8	cubic feet per second	61	Y
7_Day_5_Year_lowflow_Sep_to_Nov	5	cubic feet per second	61	Y
7_Day_10_Year_lowflow_Sep_to_Nov	4.2	cubic feet per second	61	Y
7_Day_20_Year_lowflow_Sep_to_Nov	3.7	cubic feet per second	61	Y
7_Day_50_Year_lowflow_Sep_to_Nov	3.2	cubic feet per second	61	Y
30_Day_2_Year_lowflow_Sep_to_Nov	8.8	cubic feet per second	61	Y
30_Day_5_Year_lowflow_Sep_to_Nov	6.4	cubic feet per second	61	Y
30_Day_10_Year_lowflow_Sep_to_Nov	5.5	cubic feet per second	61	Y
30_Day_20_Year_lowflow_Sep_to_Nov	4.9	cubic feet per second	61	Y
30_Day_50_Year_lowflow_Sep_to_Nov	4.4	cubic feet per second	61	Y
90_Day_2_Year_lowflow_Sep_to_Nov	14	cubic feet per second	61	Y
90_Day_5_Year_lowflow_Sep_to_Nov	9.7	cubic feet per second	61	Y
90_Day_10_Year_lowflow_Sep_to_Nov	8	cubic feet per second	61	Y
90_Day_20_Year_lowflow_Sep_to_Nov	6.8	cubic feet per second	61	Y
90_Day_50_Year_lowflow_Sep_to_Nov	5.7	cubic feet per second	61	Y
98_Percent_Duration_APR_MAR	4.6	cubic feet per second	61	Y
95_Percent_Duration_APR_MAR	5.8	cubic feet per	61	Y

		second		
90_Percent_Duration_APR_MAR	7	cubic feet per second	61	Y
85_Percent_Duration_APR_MAR	8.5	cubic feet per second	61	Y
80_Percent_Duration_APR_MAR	10	cubic feet per second	61	Y
75_Percent_Duration_APR_MAR	12	cubic feet per second	61	Y
70_Percent_Duration_APR_MAR	13	cubic feet per second	61	Y
60_Percent_Duration_APR_MAR	16	cubic feet per second	61	Y
50_Percent_Duration_APR_MAR	19	cubic feet per second	61	Y
40_Percent_Duration_APR_MAR	24	cubic feet per second	61	Y
30_Percent_Duration_APR_MAR	30	cubic feet per second	61	Y
20_Percent_Duration_APR_MAR	41	cubic feet per second	61	Y
10_Percent_Duration_APR_MAR	57	cubic feet per second	61	Y
98_Percent_Duration_MAY_NOV	4.4	cubic feet per second	61	Y
95_Percent_Duration_MAY_NOV	5.2	cubic feet per second	61	Y
90_Percent_Duration_MAY_NOV	6.1	cubic feet per second	61	Y
85_Percent_Duration_MAY_NOV	7	cubic feet per second	61	Y
80_Percent_Duration_MAY_NOV	8	cubic feet per second	61	Y
75_Percent_Duration_MAY_NOV	9	cubic feet per second	61	Y
70_Percent_Duration_MAY_NOV	10	cubic feet per second	61	Y
60_Percent_Duration_MAY_NOV	12	cubic feet per second	61	Y
50_Percent_Duration_MAY_NOV	15	cubic feet per second	61	Y
40_Percent_Duration_MAY_NOV	17	cubic feet per second	61	Y
30_Percent_Duration_MAY_NOV	21	cubic feet per second	61	Y
20_Percent_Duration_MAY_NOV	27	cubic feet per second	61	Y
10_Percent_Duration_MAY_NOV	40	cubic feet per second	61	Y
98_Percent_Duration_DEC_FEB	5.5	cubic feet per second	61	Y
95_Percent_Duration_DEC_FEB	7.5	cubic feet per second	61	Y
90_Percent_Duration_DEC_FEB	9.9	cubic feet per second	61	Y
85_Percent_Duration_DEC_FEB	12	cubic feet per second	61	Y
80_Percent_Duration_DEC_FEB	14	cubic feet per second	61	Y
75_Percent_Duration_December_to_February	15	cubic feet per second	61	Y
70_Percent_Duration_DEC_FEB	16	cubic feet per second	61	Y

60_Percent_Duration_DEC_FEB	20	cubic feet per second	61	Y	
50_Percent_Duration_December_to_February	23	cubic feet per second	61	Y	
40_Percent_Duration_DEC_FEB	28	cubic feet per second	61	Y	
30_Percent_Duration_DEC_FEB	35	cubic feet per second	61	Y	
20_Percent_Duration_DEC_FEB	45	cubic feet per second	61	Y	
10_Percent_Duration_DEC_FEB	64	cubic feet per second	61	Y	
98_Percent_Duration_SEP_NOV	4.3	cubic feet per second	61	Y	
95_Percent_Duration_SEP_NOV	5	cubic feet per second	61	Y	
90_Percent_Duration_SEP_NOV	5.7	cubic feet per second	61	Y	
85_Percent_Duration_SEP_NOV	6.3	cubic feet per second	61	Y	
80_Percent_Duration_SEP_NOV	6.9	cubic feet per second	61	Y	
75_Percent_Duration_SEP_NOV	7.6	cubic feet per second	61	Y	
70_Percent_Duration_SEP_NOV	8.5	cubic feet per second	61	Y	
60_Percent_Duration_SEP_NOV	10	cubic feet per second	61	Y	
50_Percent_Duration_SEP_NOV	12	cubic feet per second	61	Y	
40_Percent_Duration_SEP_NOV	14	cubic feet per second	61	Y	
30_Percent_Duration_SEP_NOV	16	cubic feet per second	61	Y	
20_Percent_Duration_SEP_NOV	20	cubic feet per second	61	Y	
10_Percent_Duration_SEP_NOV	27	cubic feet per second	61	Y	
General Flow Statistics					
Minimum_daily_flow	3.1	cubic feet per second	41	Y	28
Maximum_daily_flow	592	cubic feet per second	41	Y	28
Std_Dev_of_daily_flows	27.306	cubic feet per second	41	Y	28
Average_daily_streamflow	27.561	cubic feet per second	41	Y	28
Streamflow_Variability_Index_At_Site	0.54	dimensionless	60	Y	
Base Flow Statistics					
Number_of_years_to_compute_BFI	28	years	42	Y	28
Average_BFI_value	0.64	dimensionless	42	Y	28
Std_dev_of_annual_BFI_values	0.059	dimensionless	42	Y	28

Citations

Citation Number	*Citation Name and URL*
41	Wolock, D.M., 2003, Flow characteristics at U.S. Geological Survey streamgages in the conterminous United States: U.S. Geological Survey Open-File Report 03-146, digital data set
42	Wolock, D.M., 2003, Base-flow index grid for the conterminous United States: U.S. Geological Survey Open-File Report 03-263, digital data set

60	Koltun, G. F., and Whitehead, M. T., 2002, Techniques for Estimating Selected Streamflow Characteristics of Rural, Unregulated Streams in Ohio: U. S. Geological Survey Water-Resources Investigations Report 02-4068, 50 p
61	Straub, D. E., 2001, Low-Flow Characteristics of Streams in Ohio through Water Year 1997: U. S. Geological Survey Water-Resources Investigations Report 01-4140, 416 p.

APPENDIX E

Proposed Curve Number and Percent Impervious Adjustments

Proposed Adjustment Summary Tables: W200 through W222

W200					
Percent Implementation	Original CN	New CN	% Reduction	Original % Imp	New % imp
100%	79.67	74.42	7.1%	27.5%	25.6%
50%	79.67	76.81	3.7%	27.5%	26.5%
20%	79.67	78.24	1.8%	27.5%	27.0%
10%	79.67	78.72	1.2%	27.5%	27.2%
5%	79.67	79.63	0.1%	27.5%	27.5%

W210					
Percent Implementation	Original CN	New CN	% Reduction	Original % Imp	New % imp
100%	86.4	71.97	20.1%	56.0%	44.7%
50%	86.4	79.16	9.1%	56.0%	50.8%
20%	86.4	83.48	3.5%	56.0%	54.0%
10%	86.4	84.91	1.8%	56.0%	55.0%
5%	86.4	85.63	0.9%	56.0%	55.4%

W220					
Percent Implementation	Original CN	New CN	% Reduction	Original % Imp	New % imp
100%	85.9	73.51	16.9%	49.9%	41.5%
50%	85.9	79.66	7.8%	49.9%	46.0%
20%	85.9	83.36	3.0%	49.9%	48.4%
10%	85.9	84.6	1.5%	49.9%	49.1%
5%	85.9	85.21	0.8%	49.9%	49.5%

W221					
Percent Implementation	Original CN	New CN	% Reduction	Original % Imp	New % imp
100%	80.6	72.6	11.0%	36.0%	32.1%
50%	80.6	76.4	5.5%	36.0%	34.1%
20%	80.6	78.8	2.3%	36.0%	35.2%
10%	80.6	79.5	1.4%	36.0%	35.5%
5%	80.6	79.9	0.9%	36.0%	35.7%

W222					
Percent Implementation	Original CN	New CN	% Reduction	Original % Imp	New % imp
100%	86.4	73.56	17.5%	50.7%	41.9%
50%	86.4	79.6	8.5%	50.7%	46.4%
20%	86.4	83.22	3.8%	50.7%	48.8%
10%	86.4	84.43	2.3%	50.7%	49.5%
5%	86.4	85.04	1.6%	50.7%	49.9%

Curve Number Adjustment - W200

3	23	1061	Developed, Medium Intensity	89.6	Original Curve Number
4	24	341	Developed, High Intensity	93.9	**79.67**

100 PERCENT IMPLEMENTATION

0	11	23	Open Water	99	2277
1	21	1475	Developed, Open Space	73	107675
2	22	2224	Developed, Low Intensity	80.4	178809.6
5	31	24	Barren Land	90.7	2176.8
6	41	1521	Deciduous Forest	71.9	109359.9
3	42	5	Evergreen Forest	71.9	359.5
7	71	15	Herbaceuous	73.9	1108.5
8	90	46	Woody Wetlands	99	4554
9	23	1061	Developed, Medium Intensity, Green	67.7	71829.7
10	23	341	Developed, High Intensity, Green	67.7	23085.7
11	24	0	Developed, Medium Intensity, Gray	89.6	0
12	24	0	Developed, High Intensity, Gray	93.9	0
		6735			**74.42252**
				CN Reduction	5.247476
				% Reduction	7%

50 PERCENT IMPLEMENTATION

0	11	23	Open Water	99	2277
1	21	1475	Developed, Open Space	73	107675
2	22	2224	Developed, Low Intensity	80.4	178809.6
5	31	24	Barren Land	90.7	2176.8
6	41	1521	Deciduous Forest	71.9	109359.9
3	42	5	Evergreen Forest	71.9	359.5
7	71	15	Herbaceuous	73.9	1108.5
8	90	46	Woody Wetlands	99	4554
9	23	531	Developed, Medium Intensity, Green	67.7	35914.85
10	23	171	Developed, High Intensity, Green	67.7	11542.85
11	24	531	Developed, Medium Intensity, Gray	89.6	47532.8
12	24	171	Developed, High Intensity, Gray	93.9	16009.95
		6735			**76.8108**
				CN Reduction	2.859198
				% Reduction	3.6%

20 PERCENT IMPLEMENTATION

0	11	23	Open Water	99	2277
1	21	1475	Developed, Open Space	73	107675
2	22	2224	Developed, Low Intensity	80.4	178809.6
5	31	24	Barren Land	90.7	2176.8
6	41	1521	Deciduous Forest	71.9	109359.9
3	42	5	Evergreen Forest	71.9	359.5
7	71	15	Herbaceuous	73.9	1108.5
8	90	46	Woody Wetlands	99	4554
9	23	212	Developed, Medium Intensity, Green	67.7	14365.94
10	23	68	Developed, High Intensity, Green	67.7	4617.14
11	24	849	Developed, Medium Intensity, Gray	89.6	76052.48
12	24	273	Developed, High Intensity, Gray	93.9	25615.92
		6735			**78.24377**
				CN Reduction	1.426232
				% Reduction	1.8%

10 PERCENT IMPLEMENTATION

0	11	23	Open Water	99	2277
1	21	1475	Developed, Open Space	73	107675
2	22	2224	Developed, Low Intensity	80.4	178809.6
5	31	24	Barren Land	90.7	2176.8
6	41	1521	Deciduous Forest	71.9	109359.9
3	42	5	Evergreen Forest	71.9	359.5
7	71	15	Herbaceuous	73.9	1108.5
8	90	46	Woody Wetlands	99	4554
9	23	106	Developed, Medium Intensity, Green	67.7	7182.97
10	23	34	Developed, High Intensity, Green	67.7	2308.57
11	24	955	Developed, Medium Intensity, Gray	89.6	85559.04
12	24	307	Developed, High Intensity, Gray	93.9	28817.91
		6735			**78.72142**
				CN Reduction	0.948576
				% Reduction	1.2%

5 PERCENT IMPLEMENTATION

0	11	23	Open Water	99	2277
1	21	1475	Developed, Open Space	74	109150
2	22	2224	Developed, Low Intensity	81	180144
5	31	24	Barren Land	91	2184
6	41	1521	Deciduous Forest	73	111033
3	42	5	Evergreen Forest	73	365
7	71	15	Herbaceuous	74	1110
8	90	46	Woody Wetlands	99	4554
9	23	53	Developed, Medium Intensity, Green	67.7	3591.485
10	23	17	Developed, High Intensity, Green	67.7	1154.285
11	24	1008	Developed, Medium Intensity, Gray	89.6	90312.32
12	24	324	Developed, High Intensity, Gray	93.9	30418.91
		6735			**79.62791**
				CN Reduction	0.042087
				% Reduction	0.1%

Totals

PctA	PctB	PctC	PctD	All
2700	3100	66970	8930	81700
3	4	82	11	
3%	4%	82%	11%	

Curve Number Table

99	99	99	99	Open Water
39	61	74	80	Developed, Open Space
57	72	81	86	Developed, Low Intensity
77	85	90	92	Developed, Medium Intensity
89	92	94	95	Developed, High Intensity
77	86	91	94	Barren Land
36	60	73	79	Deciduous Forest
36	60	73	79	Evergreen Forest
36	48	57	63	Shrub/Scrub
48	62	74	85	Herbaceous
99	99	99	99	Woody Wetlands

Computed Curve Number

Weight	Weight	Weight	Weight	Adj. CN	
3.272	3.756	81.151	10.821	99.0	Open Water
1.289	2.315	60.658	8.744	73.0	Developed, Open Space
1.884	2.732	66.396	9.400	80.4	Developed, Low Intensity
2.545	3.225	73.774	10.056	89.6	Developed, Medium Intensity
2.941	3.491	77.052	10.384	93.9	Developed, High Intensity
2.545	3.263	74.593	10.274	90.7	Barren Land
1.190	2.277	59.839	8.635	71.9	Deciduous Forest
1.190	2.277	59.839	8.635	71.9	Evergreen Forest
1.190	1.821	46.723	6.886	56.6	Shrub/Scrub
1.586	2.353	60.658	9.291	73.9	Herbaceous
3.272	3.756	81.151	10.821	99.0	Woody Wetlands

Green Infrastructure Curve Number

75	75	75	75	Green Roof	**67.7**	Average
35	51	63	70	Rain Garden		
35	51	63	70	Native Veg		
39	61	74	80	Veg Filter Strip		
35	51	63	70	Veg Swale		
32	58	72	79	Trees		

Weight	Weight	Weight	Weight	Adj. CN	
2.479	2.846	61.478	8.198	75.0	Green Roof
1.157	1.935	51.641	7.651	62.4	Rain Garden
1.157	1.935	51.641	7.651	62.4	Native Veg
1.289	2.315	60.658	8.744	73.0	Veg Filter Strip
1.157	1.935	51.641	7.651	62.4	Veg Swale
1.058	2.201	59.019	8.635	70.9	Trees

Curve Number Adjustment - W210

2	23	4366	Developed, Medium Intensity	89.7	Original Curve Number
3	24	2913	Developed, High Intensity	93.9	**86.4**

100 PERCENT IMPLEMENTATION

Rowid	VALUE	COUNT	LAND_COVER	CN	
0	21	1064	Developed, Open Space	73.3	78001.74
1	22	3351	Developed, Low Intensity	80.5	269912.2
4	41	236	Deciduous Forest	72.3	17062.8
5	71	14	Herbaceuous	73.6	1030.4
6	90	3	Woody Wetlands	99	297
7	23	4366	Developed, Medium Intensity, Green	67.8	296014.8
8	23	2913	Developed, High Intensity, Green	67.8	197501.4
9	24	0	Developed, Medium Intensity, Gray	89.7	0
10	24	0	Developed, High Intensity, Gray	93.9	0
		11947			**71.96956**
				CN Reduction	14.43044
				% Reduction	17%

50 PERCENT IMPLEMENTATION

Rowid	VALUE	COUNT	LAND_COVER	CN	
0	21	1064	Developed, Open Space	73.3	78001.74
1	22	3351	Developed, Low Intensity	80.5	269912.2
4	41	236	Deciduous Forest	72.3	17062.8
5	71	14	Herbaceuous	73.6	1030.4
6	90	3	Woody Wetlands	99	297
7	23	2183	Developed, Medium Intensity, Green	67.8	148007.4
8	23	1457	Developed, High Intensity, Green	67.8	98750.7
9	24	2183	Developed, Medium Intensity, Gray	89.7	195899.2
10	24	1457	Developed, High Intensity, Gray	93.9	136772.1
		11947			**79.16076**
				CN Reduction	7.239241
				% Reduction	8%

20 PERCENT IMPLEMENTATION

Rowid	VALUE	COUNT	LAND_COVER	CN	
0	21	1064	Developed, Open Space	73.3	78001.74
1	22	3351	Developed, Low Intensity	80.5	269912.2
4	41	236	Deciduous Forest	72.3	17062.8
5	71	14	Herbaceuous	73.6	1030.4
6	90	3	Woody Wetlands	99	297
7	23	873	Developed, Medium Intensity, Green	67.8	59202.96
8	23	583	Developed, High Intensity, Green	67.8	39500.28
9	24	3493	Developed, Medium Intensity, Gray	89.7	313438.7
10	24	2330	Developed, High Intensity, Gray	93.9	218835.4
		11947			**83.47548**
				CN Reduction	2.924524
				% Reduction	3%

10 PERCENT IMPLEMENTATION

Rowid	VALUE	COUNT	LAND_COVER	CN	
0	21	1064	Developed, Open Space	73.3	78001.74
1	22	3351	Developed, Low Intensity	80.5	269912.2
4	41	236	Deciduous Forest	72.3	17062.8
5	71	14	Herbaceuous	73.6	1030.4
6	90	3	Woody Wetlands	99	297
7	23	437	Developed, Medium Intensity, Green	67.8	29601.48
8	23	291	Developed, High Intensity, Green	67.8	19750.14
9	24	3929	Developed, Medium Intensity, Gray	89.7	352618.5
10	24	2622	Developed, High Intensity, Gray	93.9	246189.8
		11947			**84.91371**
				CN Reduction	1.486285
				% Reduction	2%

5 PERCENT IMPLEMENTATION

Rowid	VALUE	COUNT	LAND_COVER	CN	
0	21	1064	Developed, Open Space	73.3	78001.74
1	22	3351	Developed, Low Intensity	80.5	269912.2
4	41	236	Deciduous Forest	72.3	17062.8
5	71	14	Herbaceuous	73.6	1030.4
6	90	3	Woody Wetlands	99	297
7	23	218	Developed, Medium Intensity, Green	67.8	14800.74
8	23	146	Developed, High Intensity, Green	67.8	9875.07
9	24	4148	Developed, Medium Intensity, Gray	89.7	372208.5
10	24	2767	Developed, High Intensity, Gray	93.9	259867
		11947			**85.63283**
				CN Reduction	0.767166
				% Reduction	0.9%

Totals

PctA	PctB	PctC	PctD	All
3000	0	121330	2870	127200
2%	0%	95%	2%	

Curve Number Table

99	99	99	99	Open Water
39	61	74	80	Developed, Open Space
57	72	81	86	Developed, Low Intensity
77	85	90	92	Developed, Medium Intensity
89	92	94	95	Developed, High Intensity
77	86	91	94	Barren Land
36	60	73	79	Deciduous Forest
36	60	73	79	Evergreen Forest
36	48	57	63	Shrub/Scrub
48	62	74	85	Herbaceous
99	99	99	99	Woody Wetlands

Computed Curve Number

Weight	Weight	Weight	Weight	Adj. CN	
2.335	0.000	94.431	2.234	99.0	Open Water
0.920	0.000	70.585	1.805	73.3	Developed, Open Space
1.344	0.000	77.262	1.940	80.5	Developed, Low Intensity
1.816	0.000	85.847	2.076	89.7	Developed, Medium Intensity
2.099	0.000	89.662	2.143	93.9	Developed, High Intensity
1.816	0.000	86.801	2.121	90.7	Barren Land
0.849	0.000	69.631	1.782	72.3	Deciduous Forest
0.849	0.000	69.631	1.782	72.3	Evergreen Forest
0.849	0.000	54.370	1.421	56.6	Shrub/Scrub
1.132	0.000	70.585	1.918	73.6	Herbaceous
2.335	0.000	94.431	2.234	99.0	Woody Wetlands

Green Infrastructure Curve Number

75	75	75	75	Green Roof	**67.83619**	Average
35	51	63	70	Rain Garden		
35	51	63	70	Native Veg		
39	61	74	80	Veg Filter Strip		
35	51	63	70	Veg Swale		
32	58	72	79	Trees		

Weight	Weight	Weight	Weight	Adj. CN	
1.769	0.000	71.539	1.692	75.0	Green Roof
0.825	0.000	60.093	1.579	62.5	Rain Garden
0.825	0.000	60.093	1.579	62.5	Native Veg
0.920	0.000	70.585	1.805	73.3	Veg Filter Strip
0.825	0.000	60.093	1.579	62.5	Veg Swale
0.755	0.000	68.677	1.782	71.2	Trees

Curve Number Adjustment - W220

3	23	2628	Developed, Medium Intensity	90.1	Original Curve Number
4	24	1041	Developed, High Intensity	94.1	**85.9**

100 PERCENT IMPLEMENTATION

0	11	7	Open Water	99	693
1	21	636	Developed, Open Space	74.3	47254.8
2	22	2021	Developed, Low Intensity	81.3	164307.3
5	31	47	Barren Land	91.2	4286.4
6	41	329	Deciduous Forest	73.3	24115.7
8	90	32	Woody Wetlands	99	3168
9	23	2628	Developed, Medium Intensity, Green	68.6	180280.8
10	23	1041	Developed, High Intensity, Green	68.6	71412.6
11	24	0	Developed, Medium Intensity, Gray	90.1	0
12	24	0	Developed, High Intensity, Gray	94.1	0
		6741			**73.50817**
				CN Reduction	12.39183
				% Reduction	14%

50 PERCENT IMPLEMENTATION

0	11	7	Open Water	99	693
1	21	636	Developed, Open Space	74.3	47254.8
2	22	2021	Developed, Low Intensity	81.3	164307.3
5	31	47	Barren Land	91.2	4286.4
6	41	329	Deciduous Forest	73.3	24115.7
8	90	32	Woody Wetlands	99	3168
9	23	1314	Developed, Medium Intensity, Green	68.6	90140.4
10	23	521	Developed, High Intensity, Green	68.6	35706.3
11	24	1314	Developed, Medium Intensity, Gray	90.1	118391.4
12	24	521	Developed, High Intensity, Gray	94.1	48979.05
		6741			**79.66805**
				CN Reduction	6.231946
				% Reduction	7.3%

20 PERCENT IMPLEMENTATION

0	11	7	Open Water	99	693
1	21	636	Developed, Open Space	74.3	47254.8
2	22	2021	Developed, Low Intensity	81.3	164307.3
5	31	47	Barren Land	91.2	4286.4
6	41	329	Deciduous Forest	73.3	24115.7
8	90	32	Woody Wetlands	99	3168
9	23	526	Developed, Medium Intensity, Green	68.6	36056.16
10	23	208	Developed, High Intensity, Green	68.6	14282.52
11	24	2102	Developed, Medium Intensity, Gray	90.1	189426.2
12	24	833	Developed, High Intensity, Gray	94.1	78366.48
		6741			**83.36398**
				CN Reduction	2.536018
				% Reduction	3.0%

10 PERCENT IMPLEMENTATION

0	11	7	Open Water	99	693
1	21	636	Developed, Open Space	74.3	47254.8
2	22	2021	Developed, Low Intensity	81.3	164307.3
5	31	47	Barren Land	91.2	4286.4
6	41	329	Deciduous Forest	73.3	24115.7
8	90	32	Woody Wetlands	99	3168
9	23	263	Developed, Medium Intensity, Green	68.6	18028.08
10	23	104	Developed, High Intensity, Green	68.6	7141.26
11	24	2365	Developed, Medium Intensity, Gray	90.1	213104.5
12	24	937	Developed, High Intensity, Gray	94.1	88162.29
		6741			**84.59596**
				CN Reduction	1.304042
				% Reduction	1.5%

5 PERCENT IMPLEMENTATION

0	11	7	Open Water	99	693
1	21	636	Developed, Open Space	74.3	47254.8
2	22	2021	Developed, Low Intensity	81.3	164307.3
5	31	47	Barren Land	91.2	4286.4
6	41	329	Deciduous Forest	73.3	24115.7
8	90	32	Woody Wetlands	99	3168
9	23	131	Developed, Medium Intensity, Green	68.6	9014.04
10	23	52	Developed, High Intensity, Green	68.6	3570.63
11	24	2497	Developed, Medium Intensity, Gray	90.1	224943.7
12	24	989	Developed, High Intensity, Gray	94.1	93060.2
		6741			**85.21195**
				CN Reduction	0.688054
				% Reduction	0.8%

Totals

PctA	PctB	PctC	PctD	All
0	0	81940	4760	86700
0%	0%	95%	5%	

Curve Number Table

99	99	99	99	Open Water
39	61	74	80	Developed, Open Space
57	72	81	86	Developed, Low Intensity
77	85	90	92	Developed, Medium Intensity
89	92	94	95	Developed, High Intensity
77	86	91	94	Barren Land
36	60	73	79	Deciduous Forest
36	60	73	79	Evergreen Forest
36	48	57	63	Shrub/Scrub
48	62	74	85	Herbaceous
99	99	99	99	Woody Wetlands

Computed Curve Number

Weight	Weight	Weight	Weight	Adj. CN	
0.000	0.000	93.565	5.435	99.0	Open Water
0.000	0.000	69.937	4.392	74.3	Developed, Open Space
0.000	0.000	76.553	4.722	81.3	Developed, Low Intensity
0.000	0.000	85.059	5.051	90.1	Developed, Medium Intensity
0.000	0.000	88.839	5.216	94.1	Developed, High Intensity
0.000	0.000	86.004	5.161	91.2	Barren Land
0.000	0.000	68.992	4.337	73.3	Deciduous Forest
0.000	0.000	68.992	4.337	73.3	Evergreen Forest
0.000	0.000	53.871	3.459	57.3	Shrub/Scrub
0.000	0.000	69.937	4.667	74.6	Herbaceous
0.000	0.000	93.565	5.435	99.0	Woody Wetlands

Green Infrastructure Curve Number

75	75	75	75	Green Roof	**68.64444** Average
35	51	63	70	Rain Garden	
35	51	63	70	Native Veg	
39	61	74	80	Veg Filter Strip	
35	51	63	70	Veg Swale	
32	58	72	79	Trees	

Weight	Weight	Weight	Weight	Adj. CN	
0.000	0.000	70.882	4.118	75.0	Green Roof
0.000	0.000	59.541	3.843	63.4	Rain Garden
0.000	0.000	59.541	3.843	63.4	Native Veg
0.000	0.000	69.937	4.392	74.3	Veg Filter Strip
0.000	0.000	59.541	3.843	63.4	Veg Swale
0.000	0.000	68.047	4.337	72.4	Trees

Curve Number Adjustment - W221

3	23	3306	Developed, Medium Intensity	89.1	Original Curve Number
4	24	1863	Developed, High Intensity	93.7	**80.6**

100 PERCENT IMPLEMENTATION

1	21	3968	Developed, Open Space	71.7	284505.6
2	22	4960	Developed, Low Intensity	79.5	394320
6	41	1784	Deciduous Forest	70.6	125950.4
3	42	3	Evergreen Forest	70.6	211.8
7	71	69	Herbaceuous	72.9	5030.1
8	90	116	Woody Wetlands	99	11484
9	23	3306	Developed, Medium Intensity, Green	66.7	220510.2
10	23	1863	Developed, High Intensity, Green	66.7	124262.1
11	24	0	Developed, Medium Intensity, Gray	89.1	0
12	24	0	Developed, High Intensity, Gray	93.7	0
		16069			**72.57914**
				CN Reduction	8.02086
				% Reduction	10%

50 PERCENT IMPLEMENTATION

1	21	3968	Developed, Open Space	71.7	284505.6
2	22	4960	Developed, Low Intensity	79.5	394320
6	41	1784	Deciduous Forest	70.6	125950.4
3	42	3	Evergreen Forest	70.6	211.8
7	71	69	Herbaceuous	72.9	5030.1
8	90	116	Woody Wetlands	99	11484
9	23	1653	Developed, Medium Intensity, Green	66.7	110255.1
10	23	932	Developed, High Intensity, Green	66.7	62131.05
11	24	1653	Developed, Medium Intensity, Gray	89.1	147282.3
12	24	932	Developed, High Intensity, Gray	93.7	87281.55
		16069			**76.44856**
				CN Reduction	4.151441
				% Reduction	5.2%

20 PERCENT IMPLEMENTATION

1	21	3968	Developed, Open Space	71.7	284505.6
2	22	4960	Developed, Low Intensity	79.5	394320
6	41	1784	Deciduous Forest	70.6	125950.4
3	42	3	Evergreen Forest	70.6	211.8
7	71	69	Herbaceuous	72.9	5030.1
8	90	116	Woody Wetlands	99	11484
9	23	661	Developed, Medium Intensity, Green	66.7	44102.04
10	23	373	Developed, High Intensity, Green	66.7	24852.42
11	24	2645	Developed, Medium Intensity, Gray	89.1	235651.7
12	24	1490	Developed, High Intensity, Gray	93.7	139650.5
		16069			**78.77021**
				CN Reduction	1.829789
				% Reduction	2.3%

10 PERCENT IMPLEMENTATION

1	21	3968	Developed, Open Space	71.7	284505.6
2	22	4960	Developed, Low Intensity	79.5	394320
6	41	1784	Deciduous Forest	70.6	125950.4
3	42	3	Evergreen Forest	70.6	211.8
7	71	69	Herbaceuous	72.9	5030.1
8	90	116	Woody Wetlands	99	11484
9	23	331	Developed, Medium Intensity, Green	66.7	22051.02
10	23	186	Developed, High Intensity, Green	66.7	12426.21
11	24	2975	Developed, Medium Intensity, Gray	89.1	265108.1
12	24	1677	Developed, High Intensity, Gray	93.7	157106.8
		16069			**79.54409**
				CN Reduction	1.055905
				% Reduction	1.3%

5 PERCENT IMPLEMENTATION

1	21	3968	Developed, Open Space	71.7	284505.6
2	22	4960	Developed, Low Intensity	79.5	394320
6	41	1784	Deciduous Forest	70.6	125950.4
3	42	3	Evergreen Forest	70.6	211.8
7	71	69	Herbaceuous	72.9	5030.1
8	90	116	Woody Wetlands	99	11484
9	23	165	Developed, Medium Intensity, Green	66.7	11025.51
10	23	93	Developed, High Intensity, Green	66.7	6213.105
11	24	3141	Developed, Medium Intensity, Gray	89.1	279836.4
12	24	1770	Developed, High Intensity, Gray	93.7	165834.9
		16069			**79.93104**
				CN Reduction	0.668963
				% Reduction	0.8%

Totals

PctA	PctB	PctC	PctD	
18890	4925	212915	22970	259700
7%	2%	82%	9%	

Curve Number Table

99	99	99	99	Open Water
39	61	74	80	Developed, Open Space
57	72	81	86	Developed, Low Intensity
77	85	90	92	Developed, Medium Intensity
89	92	94	95	Developed, High Intensity
77	86	91	94	Barren Land
36	60	73	79	Deciduous Forest
36	60	73	79	Evergreen Forest
36	48	57	63	Shrub/Scrub
48	62	74	85	Herbaceous
99	99	99	99	Woody Wetlands

Computed Curve Number

Weight	Weight	Weight	Weight	Adj. CN	
7.201	1.877	81.165	8.756	99.0	Open Water
2.837	1.157	60.669	7.076	71.7	Developed, Open Space
4.146	1.365	66.408	7.607	79.5	Developed, Low Intensity
5.601	1.612	73.786	8.137	89.1	Developed, Medium Intensity
6.474	1.745	77.066	8.403	93.7	Developed, High Intensity
5.601	1.631	74.606	8.314	90.2	Barren Land
2.619	1.138	59.849	6.987	70.6	Deciduous Forest
2.619	1.138	59.849	6.987	70.6	Evergreen Forest
2.619	0.910	46.731	5.572	55.8	Shrub/Scrub
3.491	1.176	60.669	7.518	72.9	Herbaceous
7.201	1.877	81.165	8.756	99.0	Woody Wetlands

Green Infrastructure Curve Number

75	75	75	75	Green Roof	**66.70786**	Average
35	51	63	70	Rain Garden		
35	51	63	70	Native Veg		
39	61	74	80	Veg Filter Strip		
35	51	63	70	Veg Swale		
32	58	72	79	Trees		

Weight	Weight	Weight	Weight	Adj. CN	
5.455	1.422	61.489	6.634	75.0	Green Roof
2.546	0.967	51.651	6.191	61.4	Rain Garden
2.546	0.967	51.651	6.191	61.4	Native Veg
2.837	1.157	60.669	7.076	71.7	Veg Filter Strip
2.546	0.967	51.651	6.191	61.4	Veg Swale
2.328	1.100	59.029	6.987	69.4	Trees

Curve Number Adjustment - W222

3	23	5066	Developed, Medium Intensity	90	Original Curve Number
4	24	1912	Developed, High Intensity	94	**86.4**

100 PERCENT IMPLEMENTATION

0	11	5	Open Water	99	495
1	21	1328	Developed, Open Space	74.1	98404.8
2	22	4515	Developed, Low Intensity	81.1	366166.5
5	31	23	Barren Land	91.1	2095.3
6	41	176	Deciduous Forest	73.1	12865.6
7	71	24	Herbaceuous	74.3	1783.2
8	90	2	Woody Wetlands	99	198
9	23	5066	Developed, Medium Intensity, Green	68.5	347021
10	23	1912	Developed, High Intensity, Green	68.5	130972
11	24	0	Developed, Medium Intensity, Gray	90	0
12	24	0	Developed, High Intensity, Gray	94	0
		13051			**73.55769**
				CN Reduction	12.84231
				% Reduction	15%

50 PERCENT IMPLEMENTATION

0	11	5	Open Water	99	495
1	21	1328	Developed, Open Space	74.1	98404.8
2	22	4515	Developed, Low Intensity	81.1	366166.5
5	31	23	Barren Land	91.1	2095.3
6	41	176	Deciduous Forest	73.1	12865.6
7	71	24	Herbaceuous	74.3	1783.2
8	90	2	Woody Wetlands	99	198
9	23	2533	Developed, Medium Intensity, Green	68.5	173510.5
10	23	956	Developed, High Intensity, Green	68.5	65486
11	24	2533	Developed, Medium Intensity, Gray	90	227970
12	24	956	Developed, High Intensity, Gray	94	89864
		13051			**79.59841**
				CN Reduction	6.801586
				% Reduction	7.9%

20 PERCENT IMPLEMENTATION

0	11	5	Open Water	99	495
1	21	1328	Developed, Open Space	74.1	98404.8
2	22	4515	Developed, Low Intensity	81.1	366166.5
5	31	23	Barren Land	91.1	2095.3
6	41	176	Deciduous Forest	73.1	12865.6
7	71	24	Herbaceuous	74.3	1783.2
8	90	2	Woody Wetlands	99	198
9	23	1013	Developed, Medium Intensity, Green	68.5	69404.2
10	23	382	Developed, High Intensity, Green	68.5	26194.4
11	24	4053	Developed, Medium Intensity, Gray	90	364752
12	24	1530	Developed, High Intensity, Gray	94	143782.4
		13051			**83.22285**
				CN Reduction	3.177151
				% Reduction	3.7%

10 PERCENT IMPLEMENTATION

0	11	5	Open Water	99	495
1	21	1328	Developed, Open Space	74.1	98404.8
2	22	4515	Developed, Low Intensity	81.1	366166.5
5	31	23	Barren Land	91.1	2095.3
6	41	176	Deciduous Forest	73.1	12865.6
7	71	24	Herbaceuous	74.3	1783.2
8	90	2	Woody Wetlands	99	198
9	23	507	Developed, Medium Intensity, Green	68.5	34702.1
10	23	191	Developed, High Intensity, Green	68.5	13097.2
11	24	4559	Developed, Medium Intensity, Gray	90	410346
12	24	1721	Developed, High Intensity, Gray	94	161755.2
		13051			**84.43099**
				CN Reduction	1.969006
				% Reduction	2.3%

5 PERCENT IMPLEMENTATION

0	11	5	Open Water	99	495
1	21	1328	Developed, Open Space	74.1	98404.8
2	22	4515	Developed, Low Intensity	81.1	366166.5
5	31	23	Barren Land	91.1	2095.3
6	41	176	Deciduous Forest	73.1	12865.6
7	71	24	Herbaceuous	74.3	1783.2
8	90	2	Woody Wetlands	99	198
9	23	253	Developed, Medium Intensity, Green	68.5	17351.05
10	23	96	Developed, High Intensity, Green	68.5	6548.6
11	24	4813	Developed, Medium Intensity, Gray	90	433143
12	24	1816	Developed, High Intensity, Gray	94	170741.6
		13051			**85.03507**
				CN Reduction	1.364934
				% Reduction	1.6%

Totals

PctA	PctB	PctC	PctD	All
180	0	127360	3660	131200
0%	0%	97%	3%	

Curve Number Table

99	99	99	99	Open Water
39	61	74	80	Developed, Open Space
57	72	81	86	Developed, Low Intensity
77	85	90	92	Developed, Medium Intensity
89	92	94	95	Developed, High Intensity
77	86	91	94	Barren Land
36	60	73	79	Deciduous Forest
36	60	73	79	Evergreen Forest
36	48	57	63	Shrub/Scrub
48	62	74	85	Herbaceous
99	99	99	99	Woody Wetlands

Computed Curve Number

Weight	Weight	Weight	Weight	Adj. CN	
0.136	0.000	96.102	2.762	99.0	Open Water
0.054	0.000	71.834	2.232	74.1	Developed, Open Space
0.078	0.000	78.629	2.399	81.1	Developed, Low Intensity
0.106	0.000	87.366	2.566	90.0	Developed, Medium Intensity
0.122	0.000	91.249	2.650	94.0	Developed, High Intensity
0.106	0.000	88.337	2.622	91.1	Barren Land
0.049	0.000	70.863	2.204	73.1	Deciduous Forest
0.049	0.000	70.863	2.204	73.1	Evergreen Forest
0.049	0.000	55.332	1.757	57.1	Shrub/Scrub
0.066	0.000	71.834	2.371	74.3	Herbaceous
0.136	0.000	96.102	2.762	99.0	Woody Wetlands

Green Infrastructure Curve Number

75	75	75	75	Green Roof	**68.45506**	Average
35	51	63	70	Rain Garden		
35	51	63	70	Native Veg		
39	61	74	80	Veg Filter Strip		
35	51	63	70	Veg Swale		
32	58	72	79	Trees		

Weight	Weight	Weight	Weight	Adj. CN	
0.103	0.000	72.805	2.092	75.0	Green Roof
0.048	0.000	61.156	1.953	63.2	Rain Garden
0.048	0.000	61.156	1.953	63.2	Native Veg
0.054	0.000	71.834	2.232	74.1	Veg Filter Strip
0.048	0.000	61.156	1.953	63.2	Veg Swale
0.044	0.000	69.893	2.204	72.1	Trees

APPENDIX F

HEC-HMS Tabular Output for Existing and 5-, 10-, 20-, 50-, and 100- Percent Reduced Basins

EX 2 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	706.6	0.48
R30	44.4	706.3	0.48
W221	5.58	452.1	0.74
W222	4.53	505.7	1.47
Junction2	54.51	1070.1	0.59
R20	54.51	1066.2	0.59
W210	4.15	596.8	1.32
W220	2.34	330.2	2.67
Junction1	61	1892	0.72
R10	61	1888.4	0.71
W200	2.33	287.4	3.42
Outlet	63.33	**2107.7**	0.81

EX 10 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1412.9	0.91
R30	44.4	1412.6	0.9
W221	5.58	820.9	1.25
W222	4.53	832.5	2.07
Junction2	54.51	1830.8	1.04
R20	54.51	1826.8	1.03
W210	4.15	979.4	1.94
W220	2.34	522	3.27
Junction1	61	3171.1	1.18
R10	61	3170.2	1.18
W200	2.33	476.6	3.89
Outlet	63.33	**3524.9**	1.28

EX 25 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1941.1	1.22
R30	44.4	1940.8	1.22
W221	5.58	1089	1.6
W222	4.53	1055.1	2.47
Junction2	54.51	2371	1.36
R20	54.51	2367.6	1.36
W210	4.15	1236.5	2.35
W220	2.34	652.2	3.68
Junction1	61	4067.1	1.51
R10	61	4064.4	1.51
W200	2.33	619	4.23
Outlet	63.33	**4512.6**	1.61

5PCT 2 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	706.6	0.48
R30	44.4	706.3	0.48
W221	5.58	440.1	0.73
W222	4.53	494.8	1.46
Junction2	54.51	1047.3	0.58
R20	54.51	1043.4	0.58
W210	4.15	583.8	1.3
W220	2.34	324.1	2.66
Junction1	61	1852	0.71
R10	61	1850.8	0.71
W200	2.33	287.1	3.42
Outlet	63.33	**2066.5**	0.81

5Pct 10 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1412.9	0.91
R30	44.4	1412.6	0.9
W221	5.58	800.2	1.22
W222	4.53	817.4	2.05
Junction2	54.51	1795.4	1.03
R20	54.51	1792.3	1.03
W210	4.15	961.3	1.91
W220	2.34	513.3	3.25
Junction1	61	3108.2	1.17
R10	61	3106.7	1.17
W200	2.33	476	3.89
Outlet	63.33	**3461**	1.27

5Pct 25 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1941.1	1.22
R30	44.4	1940.8	1.22
W221	5.58	1063.8	1.57
W222	4.53	1038.1	2.45
Junction2	54.51	2329.6	1.36
R20	54.51	2327.5	1.35
W210	4.15	1216.2	2.32
W220	2.34	642.3	3.65
Junction1	61	3993.6	1.51
R10	61	3991.3	1.5
W200	2.33	618.3	4.23
Outlet	63.33	**4439**	1.6

10PCT 2 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	706.6	0.48
R30	44.4	706.3	0.48
W221	5.58	433.4	0.72
W222	4.53	485.8	1.44
Junction2	54.51	1031.6	0.58
R20	54.51	1027.7	0.58
W210	4.15	572.6	1.29
W220	2.34	318.7	2.64
Junction1	61	1821.5	0.71
R10	61	1820.3	0.71
W200	2.33	278.8	3.4
Outlet	63.33	**2030.3**	0.81

10Pct 10 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1412.9	0.91
R30	44.4	1412.6	0.9
W221	5.58	788.5	1.21
W222	4.53	804	2.02
Junction2	54.51	1770.6	1.03
R20	54.51	1769	1.02
W210	4.15	945.3	1.89
W220	2.34	505.4	3.23
Junction1	61	3061.1	1.17
R10	61	3057.5	1.17
W200	2.33	460.6	3.86
Outlet	63.33	**3402.2**	1.26

10Pct 25 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1941.1	1.22
R30	44.4	1940.8	1.22
W221	5.58	1049.5	1.56
W222	4.53	1022.8	2.42
Junction2	54.51	2300.3	1.35
R20	54.51	2295.5	1.35
W210	4.15	1198	2.29
W220	2.34	633.4	3.62
Junction1	61	3938.5	1.5
R10	61	3935.7	1.5
W200	2.33	599.3	4.19
Outlet	63.33	**4371.9**	1.6

20PCT 2 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	706.6	0.48
R30	44.4	706.3	0.48
W221	5.58	422.5	0.7
W222	4.53	469.2	1.41
Junction2	54.51	1004	0.58
R20	54.51	1000.1	0.58
W210	4.15	550.1	1.26
W220	2.34	308.6	2.61
Junction1	61	1764.8	0.7
R10	61	1762	0.7
W200	2.33	274.5	3.39
Outlet	63.33	**1971.6**	0.8

20Pct 10 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1412.9	0.91
R30	44.4	1412.6	0.9
W221	5.58	768.9	1.18
W222	4.53	778.5	1.98
Junction2	54.51	1725.9	1.02
R20	54.51	1721.7	1.02
W210	4.15	912.4	1.84
W220	2.34	490.1	3.18
Junction1	61	2973.8	1.16
R10	61	2973.7	1.16
W200	2.33	452.5	3.84
Outlet	63.33	**3313.2**	1.25

20Pct 25 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1941.1	1.22
R30	44.4	1940.8	1.22
W221	5.58	1025.4	1.53
W222	4.53	993.2	2.37
Junction2	54.51	2247.2	1.35
R20	54.51	2244.1	1.34
W210	4.15	1160.5	2.24
W220	2.34	615.7	3.57
Junction1	61	3836.7	1.49
R10	61	3835.1	1.49
W200	2.33	589.1	4.17
Outlet	63.33	**4265.2**	1.58

50PCT 2 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	706.6	0.48
R30	44.4	706.3	0.48
W221	5.58	388.1	0.66
W222	4.53	423	1.33
Junction2	54.51	923.3	0.57
R20	54.51	919.3	0.57
W210	4.15	488	1.16
W220	2.34	280.5	2.53
Junction1	61	1603.3	0.68
R10	61	1600.9	0.68
W200	2.33	263	3.36
Outlet	63.33	**1798.7**	0.78

50Pct 10 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1412.9	0.91
R30	44.4	1412.6	0.9
W221	5.58	704.9	1.11
W222	4.53	703.8	1.86
Junction2	54.51	1588	1
R20	54.51	1583.9	1
W210	4.15	814.7	1.7
W220	2.34	445.2	3.06
Junction1	61	2707.5	1.13
R10	61	2700.6	1.12
W200	2.33	429.9	3.79
Outlet	63.33	**3021.6**	1.22

50Pct 25 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1941.1	1.22
R30	44.4	1940.8	1.22
W221	5.58	944.7	1.43
W222	4.53	904.5	2.23
Junction2	54.51	2140.9	1.32
R20	54.51	2140.4	1.32
W210	4.15	1046	2.07
W220	2.34	562.8	3.43
Junction1	61	3513	1.45
R10	61	3508.5	1.45
W200	2.33	560.4	4.11
Outlet	63.33	**3921**	1.55

100PCT 2 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	706.6	0.48
R30	44.4	706.3	0.48
W221	5.58	341.3	0.59
W222	4.53	357.6	1.21
Junction2	54.51	810.8	0.55
R20	54.51	807.2	0.55
W210	4.15	400.5	1.02
W220	2.34	241.4	2.41
Junction1	61	1375.9	0.65
R10	61	1374.1	0.65
W200	2.33	246.2	3.32
Outlet	63.33	**1556.3**	0.75

100Pct 10 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1412.9	0.91
R30	44.4	1412.6	0.9
W221	5.58	611.6	0.99
W222	4.53	588.3	1.66
Junction2	54.51	1561.6	0.97
R20	54.51	1561	0.97
W210	4.15	659.5	1.47
W220	2.34	375.9	2.86
Junction1	61	2295.1	1.08
R10	61	2289.6	1.08
W200	2.33	394.8	3.71
Outlet	63.33	**2577.6**	1.17

100Pct 25 YR

Hydrologic Element	Drainage Area (Sq. mi.)	Peak Discharge (cfs)	Volume (in.)
LCWshd	44.4	1941.1	1.22
R30	44.4	1940.8	1.22
W221	5.58	823.7	1.29
W222	4.53	760.5	1.99
Junction2	54.51	2125.3	1.29
R20	54.51	2124.7	1.29
W210	4.15	853.6	1.79
W220	2.34	476.7	3.18
Junction1	61	2997.3	1.39
R10	61	2989.9	1.39
W200	2.33	514.6	4.01
Outlet	63.33	**3362.3**	1.49