Plaster Creek Hydrology Study

Calvin College, MDEQ 319 Grant, 2014-0019

1 Project Summary

From spring 2015 to winter 2016, faculty and students from Calvin College worked together to create a hydrologic model of the Plaster Creek watershed using the United States Army Corps of Engineers software, "Hydrologic Engineering Center Hydrologic Modeling System" (HEC-HMS), as part of a 319 Grant from the Michigan Department of Environmental Quality (MDEQ). Professor Robert Hoeksema, PhD, Professor Julie Wildschut, P.E., and student research assistant Ryan De Groot comprised the hydrology team for this project. The purpose of this project was to create a model that would highlight the trouble areas of the watershed, those that contribute excessive amounts of runoff to the creek, and to help Plaster Creek Stewards plan where Best Management Practices (BMPs) could be installed to help improve the quality of the water in Plaster Creek. The model will also allow users to estimate the changes within the watershed due to the installation of various BMPs.

2 Creating the Model

Quantifying the hydrology of a watershed depends on many variables such as land use, soil type, topography, existing storm sewer and roadways, and the hydrograph for the area. This section of the report lists the sources from which data was retrieved in order to initially set up the HEC-HMS model. Much of the information used was organized by shape files and used in GIS. In addition, this section briefly describes the methods used for calculations in HEC-HMS.

Information Type	Location of Data	Source
Hydrologic Soil Group	Data is stored in a GIS shapeflie: SURGO_Soils\Soils.shp	Soil Survey Geographic Database (SSURGO database) contains information about soil as collected by the National Cooperative soil Survey over the course of a century and obtained at the United States Department of Agriculture (USDA) National Resources Conservation Service (NRCS) website.
Land use	Nlcd2001_KentCounty.shp	Kent County
Topography	2-ft contours created from 1m DEM	City of Grand Rapids
Map	World_Imagery	Http://goto.arcgisonline.com/maps/World_Imagery (provides 1 meter or better satellite and aerial imagery)
Drainage Basins	GIS	Plaster Creek Stewards
Infrastructure and boundaries including Storm Drain Districts	Various shapefiles in GIS, KentCoStormwater, GRCITYStormwater.gbd, KentFramework	City of Grand Rapids, Kent County, Drain Commissioner

Topographic Map (to determine waterways)	KENT_drg24k.tif	United States Geologic Survey (USGS) Topographic Map

2.1 Sub-basins

For previous projects, Professor Jason Van Horn created various drainage basin delineations using GIS, at different scales, based on the 10-meter National Elevation Dataset (DEM). These drainage basins were thus based solely on topography. The hydrology team selected the one of these delineation sets that balanced a relatively high level of detail with the number of leveloggers available for calibration and the time frame and budget given to complete the project. This resulted in 24 sub-basins ranging in size from 614 acres to 4327 acres. In addition, the team updated these sub-basin delineations based on existing roadway and stormwater infrastructure and existing drain district basins. The sub-basins were named based on the Plaster Creek Watershed Management Plan (FTCH 2008).

2.2 HEC-HMS Basin Model Parameters

When setting up the hydrologic model in HEC-HMS, there are several variables that need to be established which are based on the chosen method for calculations. The chosen Loss Method was the SCS Curve Number and the Transform Method was Clark Unit Hydrograph. In order to use these methods, the following variables are needed: Basin area, Initial Abstraction, Curve Number (CN), Impervious %, Time of Concentration (Tc), and Storage Coefficient (R). For all basins, the Initial Abstraction was entered as zero, which sets the initial abstraction to the standard value of 0.25 inches. The impervious % was left 0 because the imperviousness of the land was accounted for in the CN number. The CN value is a combination of the soil type and land use so it was derived from GIS. The Tc is the length of time that it will take water to travel from the hydraulically most distant point in the basin to the outlet of the basin and is a combination of overland, tributary, waterway, and pipe flow travel times. The method for defining these various travel segments and calculating them is defined in the Michigan Department of Natural Resources and Environment Land and Water Management Division document entitled, Computing Flood Discharges for Small Ungaged Watersheds (Sorrell 2010). Using this method, the Tc for flow in sewers was based on 2 feet per second velocity. The USGS Topo on GIS was used to determine the overland flow, tributary flow, and waterway flow. In addition, the infrastructure shapefiles on GIS were helpful in determining pipe flow. Sub-basin areas were recorded from the created GIS shapefile. At the start of the model, the Storage Coefficient was set equal to the Time of Concentration.

2.3 Other HEC-HMS Model Parameters

In addition to a basin model, HEC-HMS needs a meteorologic model and control specifications. The meteorologic model describes the rainfall distribution used for the model while the control specifications defines the time period for calculations. For calibrating purposes, a user specified hyetograph was entered based on National Weather Service gage data for a large storm event that occurred on August 2, 2015. A standard SCS Storm was also set up to run a 2-year and 10-year storm with the basin model. The control specifications are somewhat arbitrary for the standard SCS storms, but are set up to run the calculations for a long enough time so that the hydrographs for various basins return to baseflow. For the specific storms from 2015, actual dates and times for the storm were used in the model.

Time-series data and paired data was added to the model as needed during the calibration process and when modeling possible future BMPs.

3 Calibrating the Model

Calibrating a hydrologic model helps improve its accuracy. In order to do this, actual data from the creek was retrieved and compared to the results from the HEC-HMS model. Then the variables such as the CN values, time of concentration, and storage coefficient were adjusted for the basins so that the model more closely matched the data. There were several steps and calculations performed through this process.

At the beginning of the summer 2015, faculty and students strategically installed 16 leveloggers throughout the watershed, mostly in streams upstream of culverts. These locations were selected due to their close proximity to a sub-basin outlet and their accessibility in order to install the leveloggers and later, collect data. Leveloggers are installed at the thalweg of the creek and log the pressure observed. As the depth of flow changes, so does the pressure at the levelogger. This pressure is converted to a flowrate using a known barometric pressure, as collected on a barologger, located at the Calvin College Green House on Lake Drive, and a rating curve for the stream. A rating curve is a table of data that lists the flow rate in the stream at various depths of flow. Each Levelogger has its own rating curve based on the configuration of the stream and culvert. The rating curves were determined using HY-8, a culvert analysis program designed by the Federal Highway Administration (FHWA). Using the rating curve, the hydrology team converted the levelogger data into a hydrograph for each location. This data was added to the HEC-HMS model as set of time-series data called "discharge gage."

In addition to observed flow rates in the stream, actual precipitation data is needed to complete the calibration. For this process, data was retrieved from the Internet from the MesoWest website which provides the precipitation data as recorded by the National Weather Service at the Gerald R. Ford International Airport in Kent County, Michigan at station KGRR. This data was added to the model as a set of time-series data called "precipitation gage." The selected storm used for calibration occurred on August 2, 2015 with a total rainfall of 0.79 inches.

Using Excel, the hydrology team set up a spreadsheet that graphed the hydrograph during the selected storm for each level logger location. The volume under this hydrograph represents the volume of stormwater runoff. Therefore, comparing this volume to the volume calculated by the SCS method is a good way to check the accuracy of the CN value. In some instances, the estimated CN value based on GIS soil and land use data was adjusted so that the observed hydrograph and the calculated runoff volume were similar. This was the first step in calibrating the model.

The HEC-HMS model is able to compare the calculated hydrographs to the observed hydrographs at each of the levelogger locations throughout the watershed and optimize the parameters of the model. Sometimes these hydrographs were similar, but sometimes they were vastly different. Usually, the Peak-weighted RMS method for calibration was used. This gave the peak of the hydrograph a little more weight than the volume and time, but still took all three factors into account. After the program made recommendations for the best values for the parameters, engineering judgement was used to determine which parameters in the model (CN values, time of concentration, and storage coefficient) to adjust to make the hydrographs match, making sure that any changes made were reasonable and still represented the model accurately. In most cases, the CN values were increased a little. Often, the peak of the runoff as shown from the levelogger data hydrographs was quicker than the peak from the model so the values for time of concentration were reduced. In many places upstream in the watershed, there are a lot of wetlands or flat areas where water ponds. These are modeled by the storage coefficient and as expected, this coefficient was often increased in the upstream basins during calibration.

In some cases, it was obvious that the calculated data could not ever match the observed data. There are several possible reasons that could explain this. One reason may be that the rain event for the calibration process did not fall evenly throughout the watershed. In some cases downstream, in the more urbanized areas, the observed hydrographs went very high, very quickly. This could be explained by the amount of impervious pavement. One possible improvement for future use would be to decrease the size of the basins. This would require additional time, but would improve the accuracy for the model. A third reason for the hydrograph discontinuities could be an error in the rating curve for the streams at some of the Levelogger locations. Better survey data of the cross sections where the leveloggers are located could improve these calculations.

4 Future Use

This model is intended to help plan locations for future Best Management Practices (BMPs) and quantify the potential impacts on the downstream hydrograph. There are several tools built into HEC-HMS that could be used to model BMPs. The diversion tool could be set up in the model to simulate diverting a portion of the flow to an infiltration bed, or sink. Additionally, the detention pond tool could show the impacts of detaining the flow and releasing it slowly into the creek. Sometimes, in order to add these tools to the model, it is beneficial to add sub-basins or adjust the existing ones. Future users will need to continue using the standards established in this document when making changes to the basin models. Adding additional sub-basins to the model could increase the accuracy of the model.

It is likely that after several BMPs are installed the watershed, another round of calibration would benefit the model and also help to show the actual benefit received by the BMPs instead of modeling the anticipated improvements.

In the winter of 2016, research assistant Dena Dekryger spent time identifying potential locations for future BMPs and modeling their impacts. She summarized her process and results in a paper called, “Runoff Volume Reduction from Sub-Basins in Plaster Creek Watershed, Kent County, MI.”

The following table lists the various useful “runs” set up on HEC-HMS. At this time, there is not a basin model that accurately depicts the historic scenario for the watershed. A rough estimate of the historic scenario has been started in the model, but it should be adjusted at a later time for design and planning purposes if that will be helpful. All of these listed runs use the 2-Year SCS Storm because that is often the storm that engineers use for planning BMPs and by using the same storm, one can easily see the improvements expected by BMPs.

Run Name	Basin Model	Meteorologic Model	Control Specifications

2-Year GIS	PCW_Initial_GIS, uses all basin information calculated directly from GIS before any calibration	2-Year SCS Storm, depth = 2.37 inches	Time, 01 Jan 2016 @ 00:00 to 08 Jan 2016 @ 00:00
2-Year Historic	HistoricPlasterCreek, adjusts PCW_Initial_GIS to estimated historic values by changing CN values and time of concentration (Note: this is not completed)	2-Year SCE Storm, depth = 2.37 inches	Time, 01 Jan 2016 @ 00:00 to 08 Jan 2016 @ 00:00
2-Year Cal_Aug2	Cal_Aug2, PCW_Initial_GIS basin model calibrated to rainfall on August 2, 2015	2-Year SCS Storm, depth = 2.37 inches	Time, 01 Jan 2016 @ 00:00 to 08 Jan 2016 @ 00:00
2-Year BMP	Cal_Aug2_wBMPs	2-Year SCS Storm, depth = 2.37 inches	Time, 01 Jan 2016 @ 00:00 to 08 Jan 2016 @ 00:00

5 Summary

The Plaster Creek Hydrology study was useful in gaining a more complete understanding of the various components of the watershed and organizing them into a working, calibrated model. This model will be a useful tool for planning future BMPs to help optimize watershed improvements.