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Runoff Volume Reduction from SubBasins in Plaster Creek Watershed, Kent County, MI

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Abstract

Because Plaster Creek Watershed in Kent County, Michigan, receives too much rainwater runoff, restoration efforts are necessary to reduce the amount of runoff reaching the creek. Plaster Creek Stewards, a local environmental restoration initiative through the Calvin College Biology Department, has been involved in efforts to restore the native vegetation and pre-development state of the creek. Part of these efforts involves a hydrologic study of the watershed conducted during the summer of 2015. This study utilized a hydrologic model of Plaster Creek and a geographic informations systems (GIS) model to quantify the effects of proposed stormwater best management practices (BMPs). BMPs do make a quantifiable difference to the state of the creek. Our study results show a delayed and reduced peak discharge and a reduced water volume throughout the entire Plaster Creek Watershed.

Introduction

Plaster Creek is getting too much of a good thing: rainwater. This excess rainwater entering the creek too warm, too fast, and too voluminous causes erosion along the creekbed and often carries pollutants from roads and parking lots. In order to slow down the flow of the creek, certain restoration measures can be taken, such as installing rain gardens in neighborhoods within the watershed or temporarily holding water in a detention pond. These methods are called best management practices (BMPs). While some small-scale BMPs have already been installed in Plaster Creek, too much water still reaches the creek.

In order to understand where this excess water reaches the creek, during the summer of 2015 the Calvin Biology and Engineering Departments began a hydrology study to discover where water flows within the watershed after a rainfall. This study was conducted by Engineering Adjunct Professor Julie Wildschut and her research assistant. Her assistant was Ryan De Groot, a senior civil/environmental engineering student at Calvin College. Michael Ryskamp and his team of research assistants also contributed to this hydrology study. This paper's author, Dena De Kryger, was one of Ryskamp's research assistants. Ryskamp is the Program Coordinator for Plaster Creek Stewards. For this project, we installed instruments, called Leveloggers, to help us better understand how different areas of the watershed contribute to the stormwater "flash" that we see in the creek after a rain event. The data collected was combined with soil and land use data and used to build and calibrate a hydrologic model of the Plaster Creek Watershed. This model shows where rain water flows most intensely. These areas are considered "problem areas" and are the targets of future BMP installments.

We investigated these "problem areas" such as Woodland Mall, and designated areas by Ryskamp, such as the SteelCase "pyramid" as locations for future restoration efforts of Plaster Creek Stewards. Because the most significant issue for Plaster Creek is too much runoff, the goal of this study's research was to model the reduction of water volume that reaches the creek due to future installation of BMPs within the watershed. We consulted the Low Impact Development Plan for Michigan, the hydrology model of Plaster Creek developed during the summer of 2015, and additional appropriate materials. The hydrology model produced in the summer of 2015 allowed us to assess the efficiency of each potential BMP through comparing the total volume of water stored using potential BMPs with the current state without the BMPs. We used the LID document to identify the most appropriate BMPs for specific locations within the Plaster Creek Watershed. The results of this study are specific to Plaster Creek and its watershed through the use of the management plan and the hydrology model.

Methods

To start, we needed to establish which sub-basins needed stormwater runoff management. Using the global summary data from the 2015 hydrology model of Plaster Creek (Wilschut and De Groot, 2015), we established a rating number for each basin by dividing the excess runoff volume from each basin by the contributing area of each basin. These rating numbers gave us a way to compare the runoff contributions of basins despite their various sizes. The rating numbers can be found in Table 1. These rating numbers illuminated six sub-basins (2015 GIS Model) with relatively high volume per area. Plaster Creek Stewards had two suggestions for locations, found in sub-basins 2A and 10B (2015 GIS Model). These rating numbers and the interest shown by Plaster Creek Stewards revealed eight sub-basins that required attention: 6A, 2D, 11B, 4A, 4C, 10B, 9, and 2A (2015 GIS Model). Table 1 provides details on each sub-basin.

2015 GIS Sub-basin	**2016 GIS Sub-basins**	**Contains (landmarks)**	**Rating Number (acre-feet per sq mi)**	**Names used in this study**
2D	2D North, 2D South, 2D Excluded	Steelcase Pyramid	11.538	2D Steelcase, 2D North and South
11B	11B North, 11B South	US131 and Division, GM Powertrain Plant	27.139	11B, 11B Division
6A	6A North, 6A South	Woodland Mall, Centerpoint Mall, Whiskey Creek	19.962	6A_South, Whiskey, Woodland
4A	4A	portions of Gerald R. Ford Airport	9.020	N/A
4C	4C	portions of Gerald R. Ford Airport	11.550	N/A
9	9	Breton Ave and Burton St intersection	11.544	N/A
10B*	10B	Silver Creek, Silver Creek Apartments drain	2.581	N/A
2A*	2A	Leisure Creek Apartments	3.754	N/A

Table 1: Each row details a sub-basin from the 2015 GIS Model with its smaller, updated 2016 GIS Model sub-basins. Each sub-basin also had specific landmarks within its borders. The names used in this study are those which the researchers used to identify each specific sub-basin throughout the study. 2015 GIS Sub-basins with askterisks indicate the two sub-basins initially targeted by Plaster Creek Stewards as being of high interest for BMPs.

After determining the sub-basins (2015 GIS Model) using the rating numbers and adding the sub-basins (2015 GIS Model) targeted by Plaster Creek Stewards, we consulted with Ryskamp again. Ryskamp suggested dismissing sub-basin 10B (2015 GIS Model) because in order to make any impact, Silver Creek, a tributary to Plaster Creek, would have to be daylighted in multiple places; at this point in time, a project of this size is out of Plaster Creek Stewards' capability. Likewise, large-scale projects were not feasible in sub-basin 9 (2015 GIS Model) because of the underground and already meandering character of the stream here. There are already projects in the planning stages for sub-basin 2A (2015 GIS Model).

We also researched in the Low-Impact Development Manual for Michigan, looking for BMPs that would be feasible for Plaster Creek Stewards to retrofit onto specific sites in the sub-basins (2015 GIS Model). Sub-basins 4A and 4C (2015 GIS Model) would require the most retrofitting for the smallest areas on impact; close proximity to the airport limits the amount of restoration activity. After consultation with Ryskamp and the LID Manual, we established three sub-basins (2015 GIS Model) on which we focused for the remainder of our study: 6A, 2D, and 11B. In our study, we considered 6A_North to be managed by Lake Eastbrook, a small lake at the downstream end of the sub-basin (2016 GIS Model). Instead, we worked in 6A_South (2016 GIS Model). We also worked with 2D North and 2D South (2016 GIS Model) because the water from each of these smaller sub-basins combines to flow past our BMP location (2016 GIS Model). There is a portion on 2D (2015 GIS Model) that will bypass our BMP location before leaving sub-basin 2D (2015 GIS Model); the portion that bypasses our BMP was called 2D Excluded (2016 GIS Model) and was not used for runoff calculations. Although we divided 11B (2015 GIS Model) into two smaller sub-basins, we used both 11B North and 11B South in our 11B sub-basins as well (2016 GIS Model).

We used Google Earth to find potential locations for future BMPs. Potential locations were large patches of grass or wooded area along the creek between buildings and parking lots. This kind of area would be a quality location for floodplain recreation or a retention/infiltration basin. Some areas away from the creek path were considered but not explored because the potential BMPs that would fit in these locations have less impact on water volume and at a higher cost in time and money for retrofitting. We added the potential BMP locations to the 2016 GIS Model in the layer called FutureBMPLocations. This layer outlined the area that could be used to capture rainwater from the creek. In order to see an impact of the BMPs in each sub-basin (2015 GIS Model), we broke up the sub-basins in the Subwatershed_model layer (2015 GIS Model) into smaller sub-basins (2016 GIS Model). These smaller sub-basins, in the BMPSub_basins layer (2016 GIS Model), followed the area_20000 sub-basins layer included in the 2015 GIS Model.

We also created routes for the time of concentration for each of the sub-basins (2016 GIS Model). The time of concentration is the amount of time it takes a drop of water to travel from the furthest hydrologic edge of the sub-basin to the discharge point at the downstream end of the sub-basin. De Groot had created a route or two for each of the 2015 sub-basins along the longest route. Some of De Groot's routes (2015 GIS Model) matched up with the smaller sub-basins (2016 GIS Model) that we created for this study. De Groot's routes were verified using his spreadsheet PlasterCreekHydrographData.xlsx. The remaining routes for time of concentration were created using the Topography.shp and World_Imagery basemap (2016 GIS Model). These were the times of concentration used in our study.

In the 2016 GIS Model, we integrated nlcd2011_LandCover.shp, ClippedSoils.shp, and BMPSub_Basins.shp to determine the GridCode values, which were exported to an Excel Spreadsheet for each sub-basin (2016 GIS Model): 2DSteelcaseCNData.xlsx, 6AWoodlandCNData.xlsx, and 11BDivisionCNData.xlsx. The GridCode numbers correspond with land use, land condition, and soil quality to determine the CN value. We converted the GridCode numbers to CN values for the sub-basins (2016 GIS Model) through these Excel spreadsheets. These values were the CN values used in our study.

We printed GIS maps of our FutureBMPLocations (2016 GIS Model) and began to design rough BMPs in each location. An example can be seen in Image 1. On the printed maps, we sketched outlines for the BMPs, then took measurements of length, height, and elevation using GIS (2016 GIS Model). These measurements were used for volume calculations.

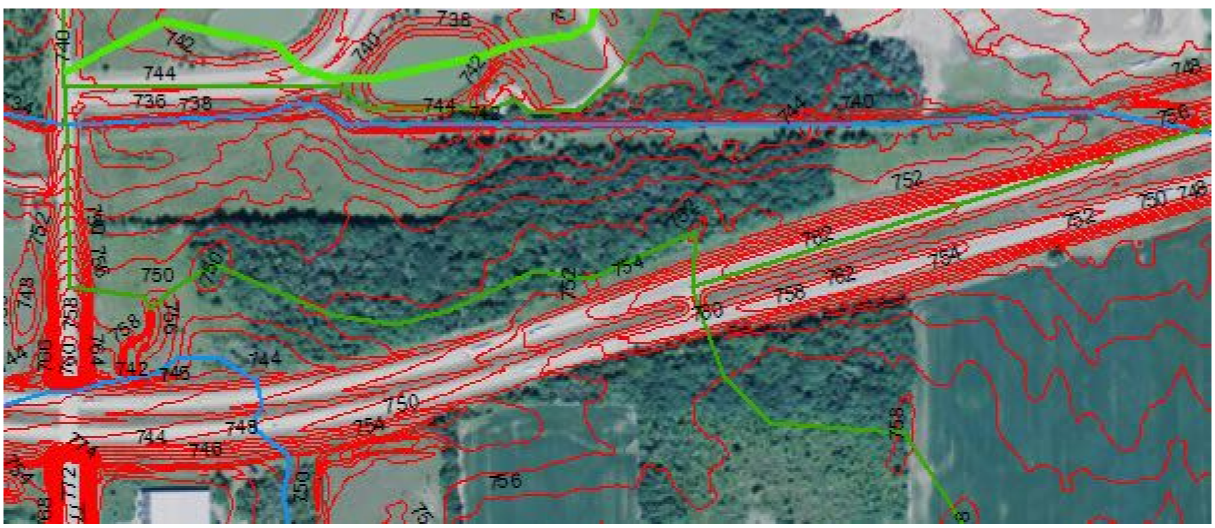

Image 1: Topographic map of a portion of the 2D_North sub-basin (2016 GIS Model) for the 2D Steelcase BMP (FutureBMPLocations, 2016 GIS Model). We used the contours and stream path to sketch the BMPs and GIS to measure distances for volume reduction calculations.

For 11B and 6A_South, we decided to implement floodplain recreation as a BMP. We broke down the FutureBMPLocations (2016 GIS Model) into multiple triangular prisms, or wedges, in order to calculate volume of floodplain storage. The first volume calculated was the CFcurrent (current cubic feet of water flow through the designated area). Using a 3:1 horizontal:vertical slope, new contours were designed, as if combing back the contours. The space where that dirt had been would create water volume storage via floodplain recreation. The calculations were as follows: CFcurrent - CFdirt = ΔCF (where ΔCF is the volume of water removed from the creek by the BMP).

In order to model the additional volume stored in the recreated floodplain (ΔCF), we needed to alter the 2015 hydrologic model. We used three features to do this. First, we changed the cross section of the impacted reaches to show the wider, more open area after implementing the BMP. For sub-basin 6A_South, we split the original reach (2015 Hydrology Model) into two parts: Woodland and Whiskey. Whiskey Creek is a small tributary that runs through sub-basin 6A_South and 6A_North (2016 GIS Model). The "Whiskey" reach in the hydrologic model represents a small reach that includes runoff from Basin 6A from Levelogger #5 (2015 GIS Model) to the confluence with Little Plaster Creek (2016 GIS Model). Woodland was the name of the unaltered stretch of creek that kept the trapezoidal shape of the creek channel just upstream of Whiskey Reach.

Second, we used the diversion tool on HEC-HMS to establish a diversion from the main flow portion of Plaster Creek to the floodplain storage section. This diversion tool allows some of the flow of the creek to remain in the creek while another portion is diverted elsewhere. In this study, the "elsewhere" was to the floodplain banks provided by the BMP. This volume of water was removed from the hydrologic model using a sink tool. This should accurately model how a portion of the runoff would infiltrate into the overbank areas of a newer, wider creek if a BMP of floodplain recreation was installed, while the main portion of the creek would continue to flow downstream. We used a similar model to demonstrate the impact of a BMP in sub-basin 11B. We altered Reach-5 in sub-basin 11B (2015 Hydrology Model) in a similar manner as for Whiskey Reach for this stretch of the creek and added a diversion and a sink as well.

Third, we treated 2D North and South (2016 GIS Model) differently because our chosen location had utility lines running parallel to the creek and the edge of the designated area in FutureBMPLocations (2016 GIS Model). We do not anticipate the ability to add connected floodplain to this section of the creek, Instead, we decided that the BMP for 2D North and South would be an infiltration basin, or back channel, which fills when the creek reaches a certain height. The volume for this retention basin was calculated as a trapezoidal prism the same way as above: CFcurrent - CFdirt = ΔCF (where ΔCF is the volume of water removed from the creek by the BMP). We did not alter the creek's trapezoidal cross-section on the 2016 Hydrology Model for 2D North and South because the channel's integrity and contours would not change after the retention basin construction. This BMP was also modeled using a diversion from the main channel to the infiltration bed and sink tool on HEC-HMS.

After setting up the BMPs into the 2016 hydrologic model, we ran a simulation with a 2-year rain event. A rain event is considered to be a 2-year storm when a rain event of that magnitude has a one in two chance of occurring. In order to model the impact of the BMPs in our three chosen sub-basins (2016 GIS Model), we used the aforementioned sinks for each sub-basin (2016 Hydrology Model). The water entering these sinks would not flow out of the sink but rather be diverted from the main flow of the creek. The total volume storage was added up for each sub-basin (2016 GIS Model) from all the BMPs in each that sub-basin: 2D North and South, 10 acre-feet; 6A_South, 55 acre-feet; 11B, 18 acre-feet. This volume was set as the maximum capacity for each sink in the HEC-HMS model (2016 Hydrology Model). The general summary data was collected from HEC-HMS from both the 2015 Hydrology Model (the current state of Plaster Creek) and the 2016 Hydrology Model (the potential state of Plaster Creek after implementation of this study's proposed BMPs). This general summary data was exported to Basins6A2D11BHydrographData.xlsx spreadsheet and analyzed.

Results

We used the global summary data from our HEC-HMS model (2016 Hydrology Model) to calculate the percent decrease in peak discharge and in runoff volume. This data was exported to the Excel file Basins6A2D11BHydrographData.xlsx for further calculation. Using HEC-HMS, we generated two hydrographs for each sub-basin (2016 GIS Model) we studied: a "before BMP" and an "after proposed BMP". These hydrographs can be seen in Figures 1 - 3.

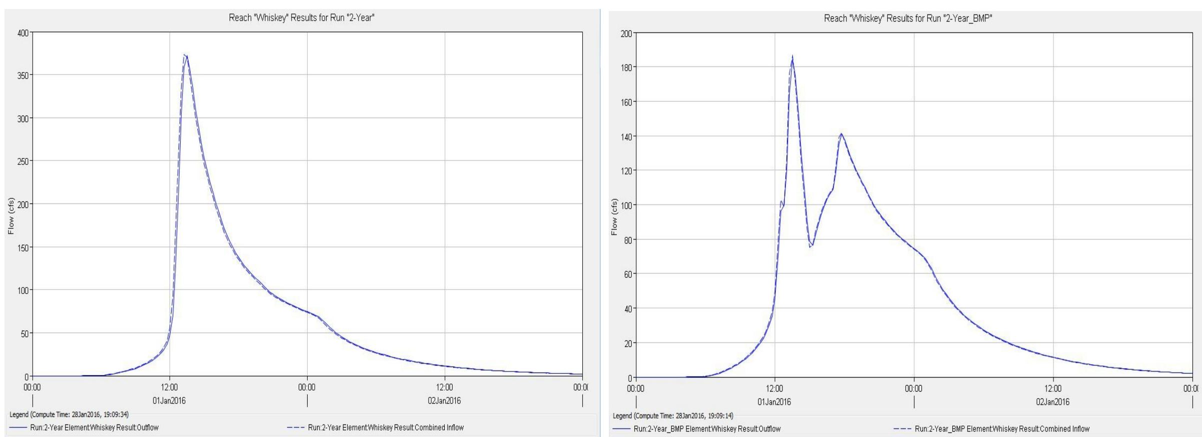

Figure 1: The hydrographs generated by the 2016 Hydrology Model of Whiskey, for sub-basin 6A_South (2016 GIS Model), shows the effect of the proposed BMPs on the volume and discharge of water. The current state of Plaster Creek (left) in 6A had a steep peak discharge and a high volume. The proposed state of Plaster Creek including the BMPS (right) flows with a 50.5% decrease in peak discharge and a 26.9% decrease in volume.

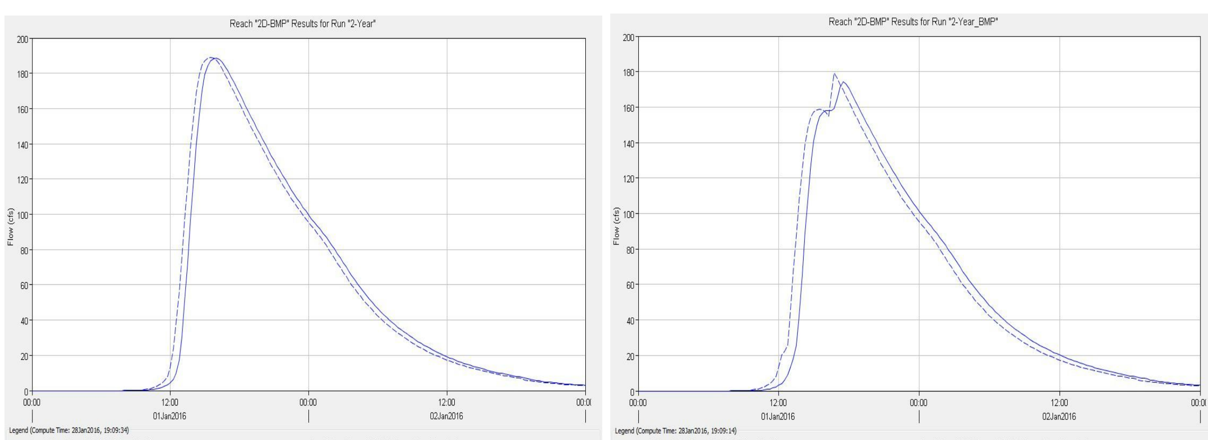

Figure 2: The hydrographs generated by the 2016 Hydrology Model of 2D-BMP, for sub-basin 2D North and South (2016 GIS Model), shows the effect of the proposed BMPs on the volume and discharge of water. The current state

of Plaster Creek (left) in 2D North and South had a high peak discharge and a high volume. The proposed state of Plaster Creek including the BMPS (right) flows with a 7.7% decrease in peak discharge and a 5.3% decrease in volume.

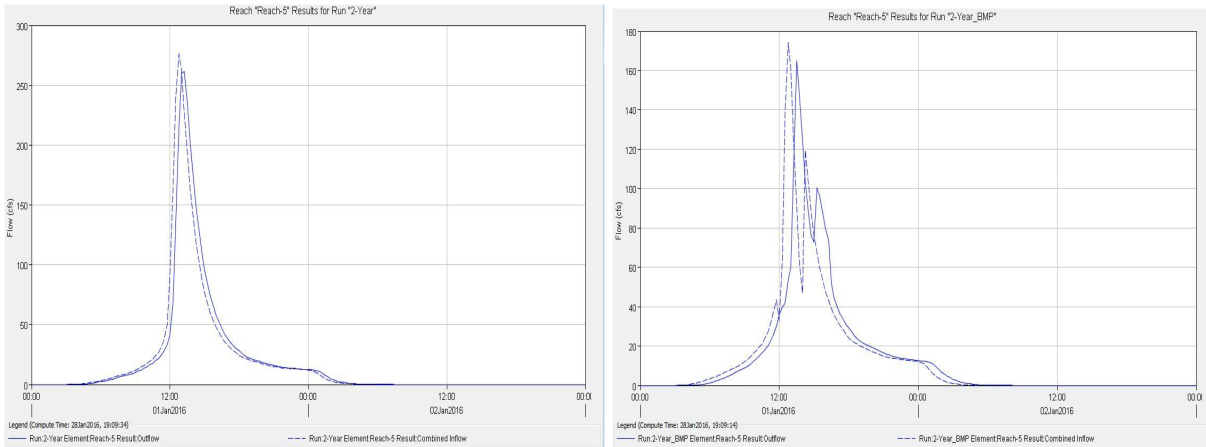

Figure 3: The hydrographs generated by the 2016 Hydrology Model of Reach-5, for sub-basin 11B (2016 GIS Model), shows the effect of the proposed BMPs on the volume and discharge of water. The current state of Plaster Creek (left) in 11B had a sharp peak discharge and a high volume. The proposed state of Plaster Creek including the BMPS (right) flows with a 39.9% decrease in peak discharge and a 24.4% decrease in volume. The two peaks appear in 11B with the BMP as the creek works itself toward equilibrium. Once the floodplain fills with water, there is less water flowing past; yet as the water continues to flow, the volume of water and the discharge increase again.

We used Basins6A2D11BHydrographData.xlsx spreadsheet to compare the current volume of water making its way through the creek without proposed BMPs and the potential volume of water flowing through the creek with the proposed BMPs. We noticed a volume reduction for Whiskey (in 6a_South), Reach-5 (in 11B), and 2D-BMP (in 2D); these are the reach names for the stretches immediately downstream from the BMP locations. In 2D North and South (2016 GIS Model), we saw a reduction of 10 acre-feet (5.3% reduction). In 6A_South (2016 GIS Model), we saw a reduction of 55 acre-feet (26.9% reduction). Finally, in 11B (2016 GIS Model), we saw a reduction of 18 acre-feet (24.4% reduction). The volume of reduction was the same amount of water that each sink could hold. We also saw a delay and decrease in the peak discharge, measured in cubic feet per second, because of each BMP. In 2D North and South (2016 GIS Model), we calculated a 7.7% decrease in peak discharge. In 6A (2016 GIS Model), we calculated a 50.5% decrease in peak discharge. Finally in 11B (2016 GIS Model), we calculated a 36.9% decrease in peak discharge. Table 2 shows the numbers used in our calculations for each sub-basin and for the entire watershed.

Before Proposed BMPs						After Proposed BMPs				
Basin Name	Drainage Area [mi^2]	Peak Discharge [cfs]	Time of Peak	Volume [ac_ft]	Maximum Volume Removed [ac-ft]	Basin Name	Drainage Area [mi^2]	Peak Discharge [cfs]	Time of Peak	Volume [ac_ft]
2D-BMP	2.839	188.6	01Jan2016, 16:00	190.8	10	2D-N+S_Reach _after BMP	2.839	174.1	01Jan2016, 17:30	180.7
Whiskey	3.144	371.4	01Jan2016, 13:30	204.5	55	Whiskey	3.144	183.9	01Jan2016, 13:30	149.5
Reach-5	0.692	261.4	01Jan2016, 13:15	71.3	18	Reach-5	0.692	165	01Jan2016, 13:30	53.9
J-all	57.5616	1809.1	02Jan2016, 01:00	2833.5	N/A	J-all	57.5616	1783.3	02Jan2016, 01:00	2752

Table 2: The information from Basins612D11BHydrologyData.xlsx was used to calculate the percent changes in peak discharge and runoff volume for 2D-BMP, Whiskey, Reach-5, and J-all (2016 Hydrology Model).

The volume reduction upstream was reflected downstream as well. We saw lower flow rates, delayed peak discharges, and lower peak discharges because of the water that the sinks were able to divert from the creek. The 10 acre-feet difference could be seen at each junction downstream; this difference increased to 65 acre-feet when the 55 acre-feet difference from Whiskey joined the 10 acre-feet difference at J-6+5+4,0,1,2; the water volume drops from 1964.1 acre-feet to 1899 acre-feet (Basins612D11BHydrologyData.xlsx). The 18 acre-feet from 11B added to this 75 acre-feet to produce a total water volume reduction of 81.5 acre-feet throughout the entire watershed, as seen in J-all (Basins6A2D11BHydrologyData.xlsx).

At the final junction of the entire watershed, the proposed BMPs make a noticeable difference on the peak discharge and water volume. The discharge volume and timing was measured at the junction of all the sub-basins and reaches, called J-all. From the entire watershed, we saw a reduction in water volume and both a delayed and reduced peak discharge. The graphs in Figure 4 show two peaks for J-all. The first peak is the initial flow of water from the proximal sub-basins (2015 GIS Model, 2015 Hydrology Model), including 11B. The second peak is the water from upstream, included 6A_South and 2D North and South. Over all, the first peak of flow drops from about 1350 cfs to 1300 cfs, showing the diversion of water in 11B (i.e. 18 acre-feet). The second peak of flow drops from about 1810 to 1780, showing the diversion of water in 6A and 2D (i.e. 55 acre-feet and 10 acre-feet respectively). The BMPs create a total reduction of 81.5 acre-feet of water throughout the creek, an overall 2.9% reduction in water volume.

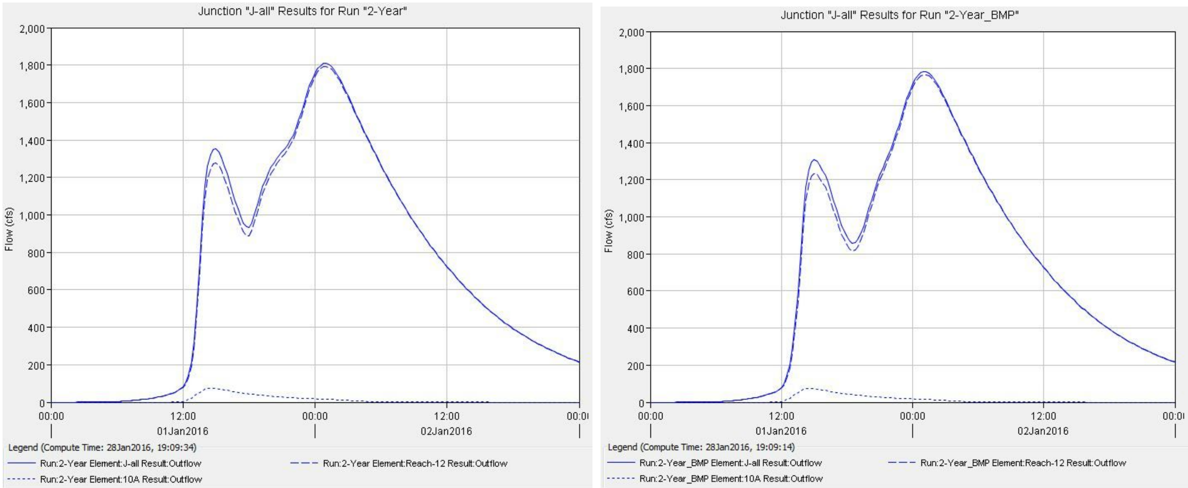

Figure 4: Both peaks decrease in height from the 2-Year to the 2-Year-BMP, showing the before and after implementation of proposed BMPs. The bump seen on 2-Year between 1000-1400 cfs at 1800-2200 on 01Jan2016 also flattens out in 2-Year-BMP. The 2-year storm (left) flows through the final junction of Plaster Creek, J-all, with a total volume of 2833.5 acre-feet of water. The same 2-year storm runs through the 2-Year-BMP 2016 Hydrology Model (right), with the reductions due to the proposed BMPs. The BMPs create a total reduction of 81.5 acre-feet of water throughout the creek, an overall 2.9% reduction in water volume.

Discussion

Impact

Our results show the noticeable impact that three large-scale projects can have on the creek's peak discharge and flow rates. The volume diverted and infiltrated by the proposed BMPs produced a 3% decrease in watershed water volume and a 5.3-26.9% decrease in the sub-basins' runoff contribution. If more BMPs of this scale were installed throughout the watershed, a further decrease in overall runoff volume and in peak discharge could cut down on erosion along the creek, flooding in populated areas, flash flooding during severe rain events, and the need for concrete installations for flood control. The ideal scenario would be to capture enough runoff volume to bring the character of Plaster Creek Watershed back to its pre-development state in which the watershed's land use and soil quality were meadow. However, we can still see how effective the proposed BMPs could be at reducing the volume of water flowing through the creek in its current state.

This process could be used in future BMP planning to model the effects of the planned BMP. We worked with realistic measurement estimates in order to see the possibility of reduction downstream. We did indeed see the 10, 55, and 18 acre-feet reductions all the way down the creek. The fact that we saw the difference continue downstream through HEC-HMS (2016 Hydrology Model) means the BMPs do make a quantifiable difference in the volume of water reaching the creek and the time it takes for the runoff to reach the creek. Future researchers and designers could use the same method we did to model the effects of other future BMPs in Plaster Creek Watershed.

Engineering and Design

Because ours was a preliminary study and produces high-quality estimates, specific design of each BMP location is necessary. However, now we know that BMPs do indeed make a difference in the peak discharge (lower and delayed) and the water volume flowing downstream (decreased). While it is possible that the engineered design plans in the future would not capture exactly the same amount of water that our study proposes (some may capture more, some may capture less), the process we used to model the effect of the BMP could be used to establish a base volume necessary to be removed by any BMP engineered in the future.

Conclusion and Recommendations

The LID Manual that we consulted for our research on structural BMPs also included information on contaminants and which BMPs are effective in filtering specific contaminants. The contaminants included were total suspended solids, total phosphorus, and total nitrogen/nitrate (SEMCOG, 2008). After consultation with Ryskamp, we chose to eliminate the variable of possible contamination because contamination is only a major problem far downstream. Our study was concerned with locations throughout the watershed, and our focus was primarily on water volume.

There was one location that immediately stuck out to us as we searched for BMP locations using Google Earth: an old General Motors power plant located in 11B. The demolition of this Willow Run Powertrain Plant in 2013-2014 left the ground with high contamination of oil and chemicals previously used in the plant. To prevent the pollution of the groundwater, General Motors capped the nearly 70 acre plot with a giant concrete slab (Perkins, 2013). The level of contamination and potential for environmental restoration are tremendous in this location. Since then, General Motors has put the plot up for sale (Perkins, 2013). If Plaster Creek Stewards could purchase a lot on site or capture and filter the runoff just downstream, the contaminants could be contained and filtered out of the groundwater. This project would require collaboration with multiple entities to get a plot on site or downstream, acquire the necessary information on the contaminants, apply for grant funding and possible permits, delegate proper engineering, construction, and installation of BMPs, and provide native vegetation and local expertise.

In 2015 to present, Plaster Creek Stewards has been involved in the installation of rain gardens which provide bioretention along the creek. This project worked with the residents in Alger Heights neighborhood (sub-basin 11C in the 2015 GIS Model) to implement native vegetation into the parkways of their properties. This project was designed to get the community involved in the installation, maintenance, and publicity of restoration efforts along Plaster Creek (Ryskamp, et. al., 2015). Likewise, we propose that apartment complexes in any number of the sub-basins (2015 GIS Model) could be locations for multiple small-scale BMPs, similar to Alger Heights PCS project of 2015-2016.

Using GIS and volume calculations, we were able to design rough BMPs in optimal locations. The volumes from the potential BMPs were modeled using HEC-HMS, showing a difference between the current state of the creek and the potential state of the creek after BMP implementation. This process used in this study quantified the effect of proposed large-scale BMPs, and could be replicated to quantify the effect of any real, future BMPs throughout the Plaster Creek watershed.

Key Terms

BMP: Best Management Practice; restoration measures that handle water runoff and provide stormwater retention on site, occasionally providing filtration of contaminants

2015 Hydrology Model: hydrologic model of Plaster Creek Watershed produced by Wildschut and De Groot during summer 2015; represents current hydrologic state of Plaster Creek Watershed

2016 Hydrology Model: hydrologic model of Plaster Creek Watershed produced by Wildschut and De Kryger during January 2016; represents the potential hydrologic state of Plaster Creek Watershed that includes the proposed BMPs from this study

2015 GIS Model: geographic information system of Plaster Creek Watershed created by Wildschut and De Groot during summer 2015; includes features relevant to this study: the watershed boundaries, sub-basin boundaries, topography, soil quality groups, land uses, world imaging from Google Earth, creek path, CN values, and time of concentration routes.

2016 GIS Model: copied and modified version of the 2015 GIS Model by Wildschut and De Kryger; includes features created during this study: future BMP locations, additional smaller sub-basins, additional time of concentration routes for the smaller sub-basins, and modified CN values for the smaller sub-basins

LID Manual: Low Impact Development Manual for Michigan; provides information on the ground state of Michigan, soil quality maps, and structural and non-structural BMPs; used in the research of BMP specifications for volume calculations in this study

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