Title: Identifying Ideal Locations for Stormwater Interception with Curb-cut Rain Gardens in the Oakdale Neighborhood, Grand Rapids, Michigan

Investigators: Kyle Bradshaw, Alicia De Jong

Abstract:

This project estimates the optimal locations for curb-cut rain gardens in the Oakdale Neighborhood in Grand Rapids, Michigan. ArcGIS was used to delineate watersheds for each stormwater catchment basin in the area based on a 2-foot resolution DEM. ERDAS Imagine was used to classify surface permeability of each watershed based on multispectral imagery. The total amount of surface runoff emptying into each stormdrain was calculated for a one-inch rainfall event using the NRDC runoff equasion. Stormdrain watersheds were ranked based on total stormwater runoff in cubic meters. Stormdrains with highest runoff are classified as highest priority for stormwater interception by curb-cut raingardens.

Introduction:

The Plaster Creek watershed in Grand Rapids, Michigan is one of the most polluted watersheds in southwest Michigan. Chemical, bacterial, sedimentary, and thermal pollution can be attributed to runoff from rural and urban surfaces. While permeable surfaces allow water to be filtered into groundwater, paved, urban surfaces channelize polluted water directly into the stream without filtration. One solution to this problem is the diversion of surface runoff into rain gardens—landscaped depressions that allow for infiltration. This study addresses the question: what are the optimal locations for rain gardens in the Oakdale Park Neighborhood of Grand Rapids?

Objectives:

1. Delineate the watershed of each storm drain within our study area using a two-foot resolution DEM in ArcGIS
2. Classify the study area into categories of land cover based on their permeability using ERDAS Imagine remote sensing software
3. Estimate the amount of water entering each storm drain in a 1 inch rain event based on each storm drain watershed and it's percent permeability
4. Rank storm drains based on how much water they receive
5. Determine the best potential locations for curb-cut rain gardens in the study area based on the ranking of storm drain watersheds.

Background:

The Plaster Creek watershed is zoned with a wide variety of land uses most of which are impervious surfaces such as roofs, roads, and parking lots. The impervious surfaces exacerbate the E.coli, toxic metals, and other hazardous chemicals that run off into Plaster Creek and contaminate the watershed. This problem is only made worse after storms when the volume of runoff is greater.

Rain gardens are often used to address pollution in urban environments. These landscaped depressions are used to used to receive stormwater runoff from impervious surfaces. Their permeable surfaces allow rainwater to be filtered into the groundwater system before returning to streams (Emery 2006). Curb cut rain gardens are where a section of curb is removed allowing even more runoff water to leach through the soil instead of enter a storm drain. Curb cut rain gardens are most effectively placed just upstream from the storm drains that receive the most stormwater discharge in rain events.

Plaster Creek Stewards is a non-profit organization located in Grand Rapids that seeks to educate the community about the watershed, research the history and current effects on the stream, and ultimately do on-the-ground work to restore the Plaster Creek watershed. Plaster Creek Stewards recently received a grant from the Michigan Department of Environmental Quality (MDEQ) that includes three large scale projects, a large number of rain gardens, a stormwater capture and bank stabilization at a local church, and a hydrology model for a housing development. Twenty of the rain gardens in the grant are designated for the Oakdale Neighborhood. Currently six curb cuts have been placed in Oakdale (Geelhoed, 2016). This study will help Plaster Creek Stewards by discovering optimal locations for future rain gardens in the neighbhorhood.

This project builds on a study by Betts, Hughey and Boldenow in 2014 that also aided Plaster Creek Stewards by identifying ideal locations for curb-cut rain gardens in the Alger Park Neighborhood. Our study seeks to improve upon limitations found in the Betts, Hughey, Boldenow report. Specifically, the former study was only able to find a DEM resolution of 10 meters which made delineating watersheds on such a small-scale nearly impossible to determine. We were able to access a higher resolution (2 foot) DEM from the City of Grand Rapids GIS database manager; this allowed for more accurate calculations. Remote sensing and GIS technologies provide a way to make more accurate estimates for the amount of water flowing into each stormwater catch basin at a larger scale. This is important because our study area is 6.14 square miles compared to Betts, et al's 2.1 square mile study area. Our project utilizes these technologies to advise rain garden placement.

Methods:

Location

Plaster Creek Stewards was given a grant to begin implementing rain gardens within the Oakdale neighborhood in Grand Rapids (Geelhoed, 2016). Our study area (Figure 1) focuses on Oakdale neighborhood (more specifically within the boundaries of Hall Street, Sylvan Avenue, Burton Street, and Division Avenue).

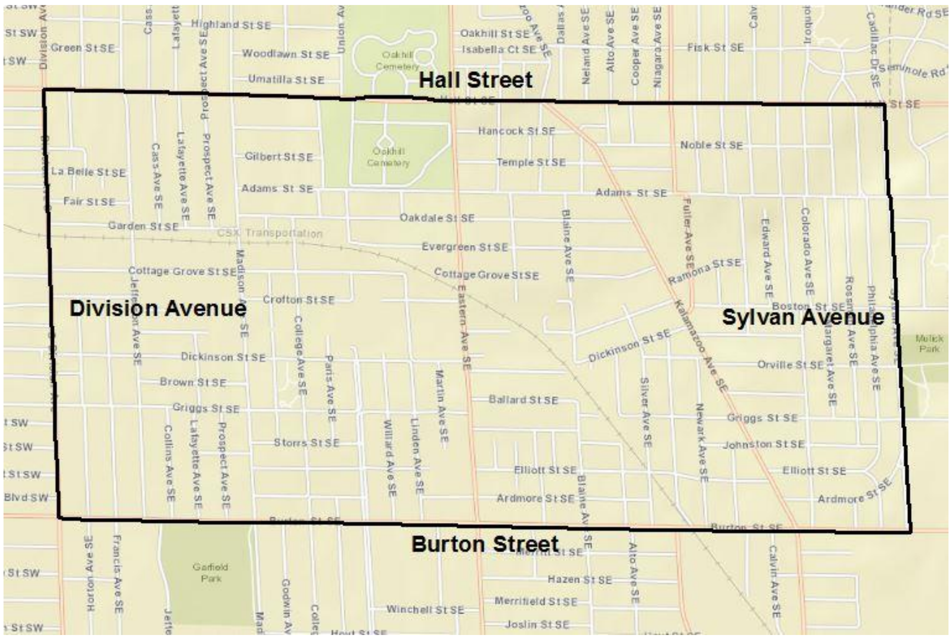

Figure 1 Map of Oakdale neighborhood study area (6.14 square miles)

Watershed Delineation

Previous work by Betts et al. (2014) relied on a combination of city shapefiles of storm drains, storm water pipelines, parcel data, and Google Earth Pro street elevation in order to determine watersheds of each individual storm drain. Unlike its predecessor, this study has access to a 2-foot resolution digital elevation model (DEM) of the city. Hydrology Spatial Analysis tools in ArcGIS were therefore be used to delineate watersheds with greater accuracy. Detailed methods can be found in Appendix 1.

The Flow Direction tool was used to show the direction water will flow between cells according to the DEM. Flow Accumulation then revealed the number of cells that flow into each drainage cell (Chang, 2008). Individual watersheds were then delineated for each point of interest (in this case, storm drains). The resulting raster (see Figure 2) indicates watersheds of each storm drain in the neighborhood that are used in later calculations.

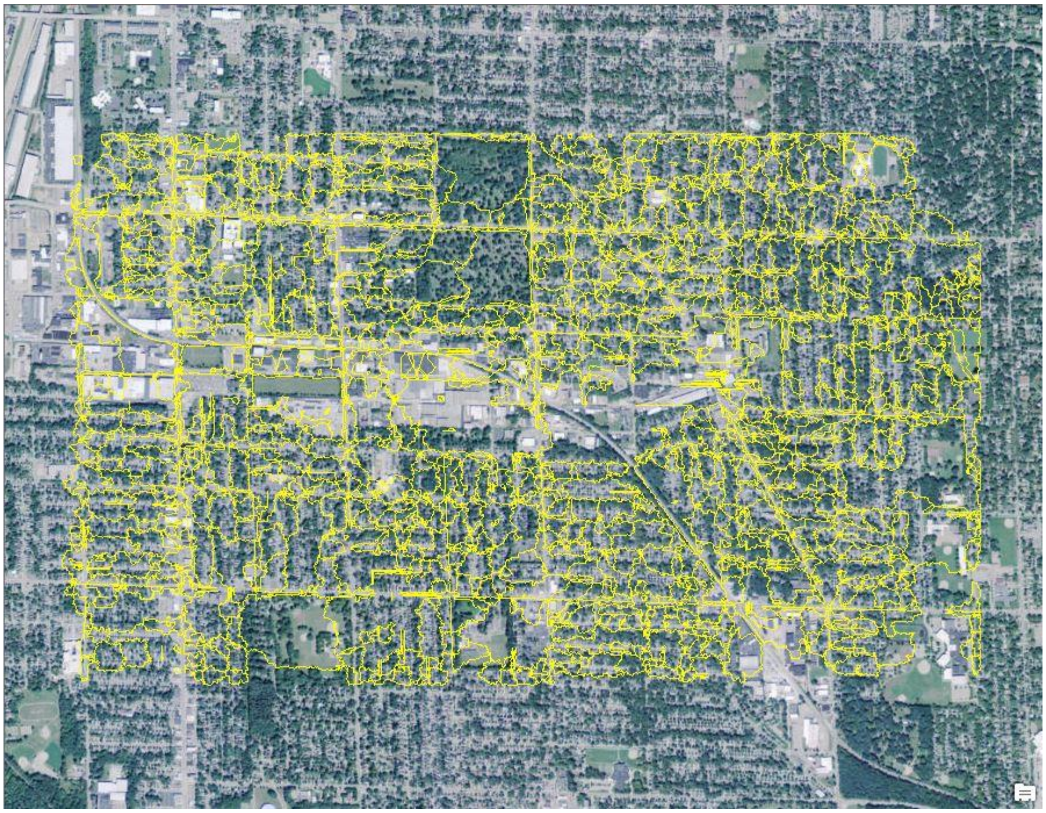

Figure 2 Storm drain watersheds (yellow) in Oakdale neighborhood, Grand Rapids

Permeability Analysis

To maintain consistency, the same method from Betts et al. (2014) was to determine surface permeability in the area. National Agriculture Imagery Program (NAIP) JPEG2000 spatially referenced multispectral aerial imagery was acquired from the USGS Earth Explorer database. A Normalized Difference Vegetation Index (NDVI) of the imagery was then calculated using ERDAS Imagine remote sensing software. An unsupervised classification was performed on the NDVI results to separate imagery into three spatial categories based on permeability: impermeable surfaces (roof and pavement), semi-permeable surfaces (lawn), and highly vegetated surfaces (forest). More detailed methods can be found in Appendix 2. This raster was then exported to ArcGIS and superimposed onto the map of storm drain watersheds (see Figure 3).

Figure 3 Image of the three permeability classes (green) overlaid with the storm drain watershed shapefile (yellow). Data from this combination is used to rank storm drains.

Runoff Calculations and Storm Drain Ranking

To maintain consistency with Betts et al's study (2014), we used the same Natural Resources Defense Council's Curve Number Runoff Equation to estimate discharge of runoff that would flow into each storm drain during a one-inch rainfall event. This takes into account tabulation of each watershed's permeability. Methods for how to produce a data table for calculations are provided in Appendix 3.

The NRDC equation is shown below where Q is the total depth of runoff (in inches) during a rainstorm with a depth of rainfall P (in inches). Ia is the "initial abstraction" (in inches), and is calculated as K*S. K is a constant of 0.2, and S is the maximum potential retention (in inches) of a given surface. S values are calculated based on a curve number, which is surface specific. We used the same curve numbers as Betts et al's study matched with S values under Arc II (average conditions) from chapter 10 of the NRDC Hydrology National Engineering Handbook: impermeable surfaces (S= 0), lawn/lightly vegetated surfaces (S = 2.2), and wooded areas (S = 9.23).

$$Q = \frac{\left(P - I_a\right)^2}{\left(P - I_a\right) + S}$$

Using these S values and a P of 1 (a 1-inch rain event), we calculated Q for each permeability class for each watershed and summed the Q's for each watershed. We converted this final Q from inches to meters (1 inch = 0.0254 meters). We then calculated discharge for each storm drain watershed by adding the Q's of each permeability class in each watershed, which gives a result in m^3. Finally, the storm drains were ranked from highest total runoff to lowest total runoff. Like Betts et al, we assumed that all Q is runoff that would enter into the storm drain at the base of the watershed.

Advised Rain Garden Placement

We processed our results into a table and map similar to the Betts et al (2014) study. Storm drains that received the highest amount of storm water runoff indicate locations with highest potential for storm water interception (ie. the placement of rain gardens). This assumes that rain gardens will be placed uphill of storm drains in order to divert the largest amount of water. The product of this study will be given to the Plaster Creek Stewards for use in prioritization of locations for rain gardens in the Oakdale neighborhood. This has potential to optimize storm water filtration and make their work as effective as possible.

Results:

We produced a map and calculated the area of each storm drain's watershed (Figure 2). We also produced an image of the three permeability classes (impermeable, lawn/semipermeable, and forest) with an overlay of each storm drain watershed (Figure 3). Lastly, we produced a map (Figure 4) to visualize the results after calculating the total runoff for a 1-inch rain event and rank the storm drains (where storm drains receiving the most runoff are ranked with highest priority). The official version of this map that will be given to Plaster Creek Stewards can be found in Appendix 4. See Appendix 5 for table of top 200 storm drain watershed areas, percent permeability, runoff, and rankings.

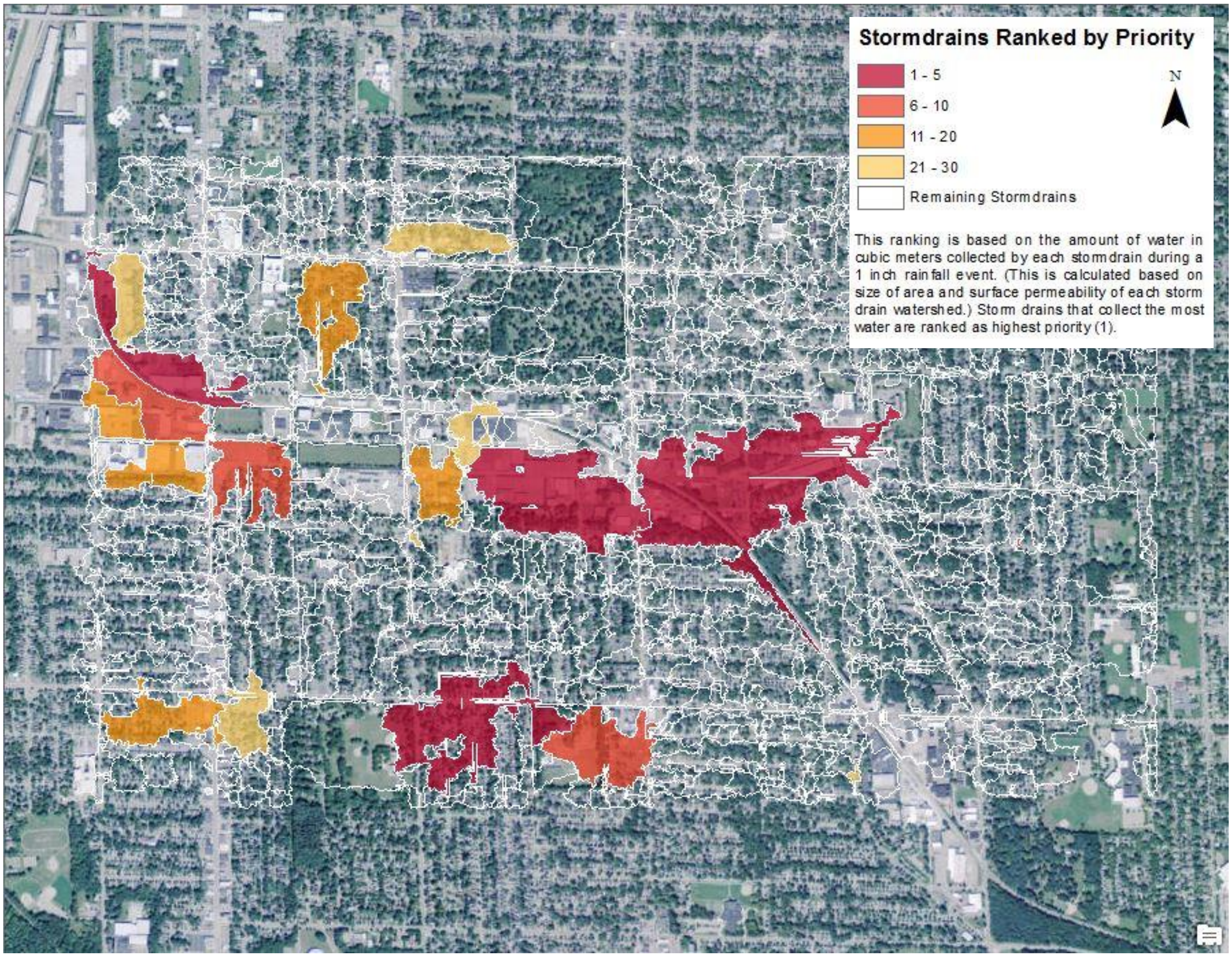

Figure 4 Storm drain watersheds of Oakdale neighborhood ranked by amount of water runoff received during a 1-inch rainfall event

Within the 6.14 square mile study area, 48.28% was impermeable, 23.95% semipermeable/lawn, and 27.76% forested. This area includes 2,135 stormdrains (and an equal number of stormdrain watersheds). Size of the watersheds ranged from 7 to 267,568 square meters; impermeability of these watersheds ranged from as little as 0% to as much as 100%. As noted in the Betts et al.'s study (2014), total runoff was affected by both watershed area and permeability. As visualized in Figure 4, the top five watersheds with most surface runoff have large surface areas (ranging from 68,086 to 267,568 square meters) and are situated in regions with high impermeability. More specifically, these areas include the intersection of Eastern Ave SE and Boston St SE, the intersection of College Ave SE and Crofton St SE, and the intersection of Stevens St SW and Division Ave S. Given that these stormdrain watersheds have the highest runoff, lawn areas just upstream of each stormdrain would be optimal locations for curb-cut rain gardens and ultimately stormwater interception.

Discussion:

The results above successfully answer the research question of: what are optimal locations for Rain Gardens in the Oakdale Park Neighborhood? The map (Figure 4) in the Results section (and

Appendix 4) outlines the five storm drains that have the highest storm water footprint and should therefore be prioritized for raingarden placement. These results advise Plaster Creek Stewards on ideal locations for which to focus resources and raingarden instillation efforts (and make best use of grant funding).

This study also successfully addresses limitations mentioned in the Betts et al (2014) study. Where their study relied upon manual delineation of watersheds based on parcels and other observations, we were able to access and utilize a 2 foot resolution DEM. This increased the accuracy of storm drain watershed delineation in our larger study area. Acknowledging that this study might again be replicated for Plaster Creek Stewards (or elsewhere), we also included detailed methods for our process (see Appendices 1, 2, and 3). That being said, there is still room for improvement. Our methods in ArcGIS and ERDAS Imagine might be made more efficient and our results might be re-visualized to yield different results (such as a map solely highlighting impervious areas throughout the study area or a ranking of watersheds only in residential areas).

Conclusions:

This study achieved the goals it set out for and will provide Plaster Creek with important results in order to aid them in where to place curb-cut rain gardens in the Oakdale Neighborhood. We concluded that there were 2135 watersheds in our study zone. We then ranked these storm drains and concluded that the most run off received ranged between 1244.26 - 4066.72 m^3. The top five areas were all in highly impermeable areas with dominantly commercial land use areas.

Finally, as mentioned in the discussion section, this study produced replicable results that can be transfers in another neighborhood of Grand Rapids or elsewhere. The identified locations will enable Plaster Creek Stewards to be effective in their grant funding and improve stream restoration along Plaster Creek.

Acknowledgements:

We would first like to thank David Zubenko of the City of Grand Rapids for the GIS storm drain and catch basin data. We would also like to thank Joel Betts who did a similar project in 2014, for helping us work through some difficulties we ran into while doing calculations. Deanna Geelhoed, a Plaster Creek Stewards employee who commissioned us for the project was also an invaluable asset answering all our questions about the Plaster Creek watershed and rain gardens. We would finally like to thank Dr. Jason VanHorn and Dr. Mark Bjelland of the Calvin College GEO Department for all their guidance and assistance in everything related to GIS and remote sensing.

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Appendix 1: Methods for Watershed Delineation[1]

1. Open ArcGIS
    2. Add a DEM clip to a blank data frame
    3. Add the catch basins (storm drains) shapefile
4. Under the Spatial Analysis tab select hydrology and select the Flow Direction tool to compute a raster that shows the direction the water is flowing in each cell.
    5. Input DEM clip
6. Select the Sink tool to create a corrected flow direction that shows areas of external drainage called sinks.
    7. Input Flow Direction raster
8. Select the Fill tool which will fill the sinks found in the DEM clip and compute a corrected DEM.
    9. Input Dem clip
10. Select the Flow Direction tool to compute a corrected raster that shows the direction the water is flowing in each cell.
    11. Input the corrected depressionless DEM
12. Select the Flow Accumulation tool to create a raster that calculates the number of cells draining into each cell
    13. Input flow direction raster
14. Select the snap pour point tool to snap the catch basins to the nearest high point as the catch basins may have shifted when creating a depressionless DEM.
    15. Input catch basin shapefile
    16. Input flow accumulation raster
17. Select the Watershed tool to complete watershed delineation.
    18. Input corrected snap pour point file
    19. Input flow direction raster.

[1]For a more detailed description see this detailed Watershed creation outline created at Tufts University (http://sites.tufts.edu/gis/files/2013/11/Watershed-and-Drainage-Delineation-by-Pour-Point.pdf)

Appendix 2: Methods for Permeability Analysis

1. Access USGS Earth Explorer database and enter study area in "Search Criteria."
2. Under "Data Sets," select NAIP JPG2000.
3. From search results, select a recent image that covers the study area (this study involved two images from August 28, 2014).
4. Download and open images in ERDAS Imagine.
5. To calculate a NDVI:
    6. From the Raster tab, click Unsupervised and select NDVI.
    7. Make sure to enter the correct Sensor (to retain the image's projection information) and output before clicking, "OK."
8. To perform an unsupervised classification of NDVI:
    9. In a new view, open the created NDVI.
    10. From the Raster tab, select Unsupervised Classification.
    11. In the dialog box, fill in correct input and output information.
    12. Give the Output Signature Set a similar name (this will be used to identify each category of classification.)
    13. Make sure the "Initialize from Statistics" radio button is checked on.
    14. Set the number of Classes to 3 (you might have a result of 4 – one for unclassified.)
    15. Set Maximum Iterations to 25.
    16. Leave the Convergence Threshold at 0.950.
    17. Click OK.
18. To create a classification overlay:
    19. Open the unsupervised classification results in a new view.
    20. Open the attribute table.
    21. Determine which class number corresponds with each category: "impermeable surfaces" (roof and pavement), "semipermeable surfaces" (lawn), and "highly vegetated surfaces" (forest) and assign appropriate colors (ie. grey, light green, and dark green respectively.)
22. (If multiple images are involved, repeat steps 5-7 for each image.)
23. This classified NDVI can now be opened in ArcGIS for further analysis.

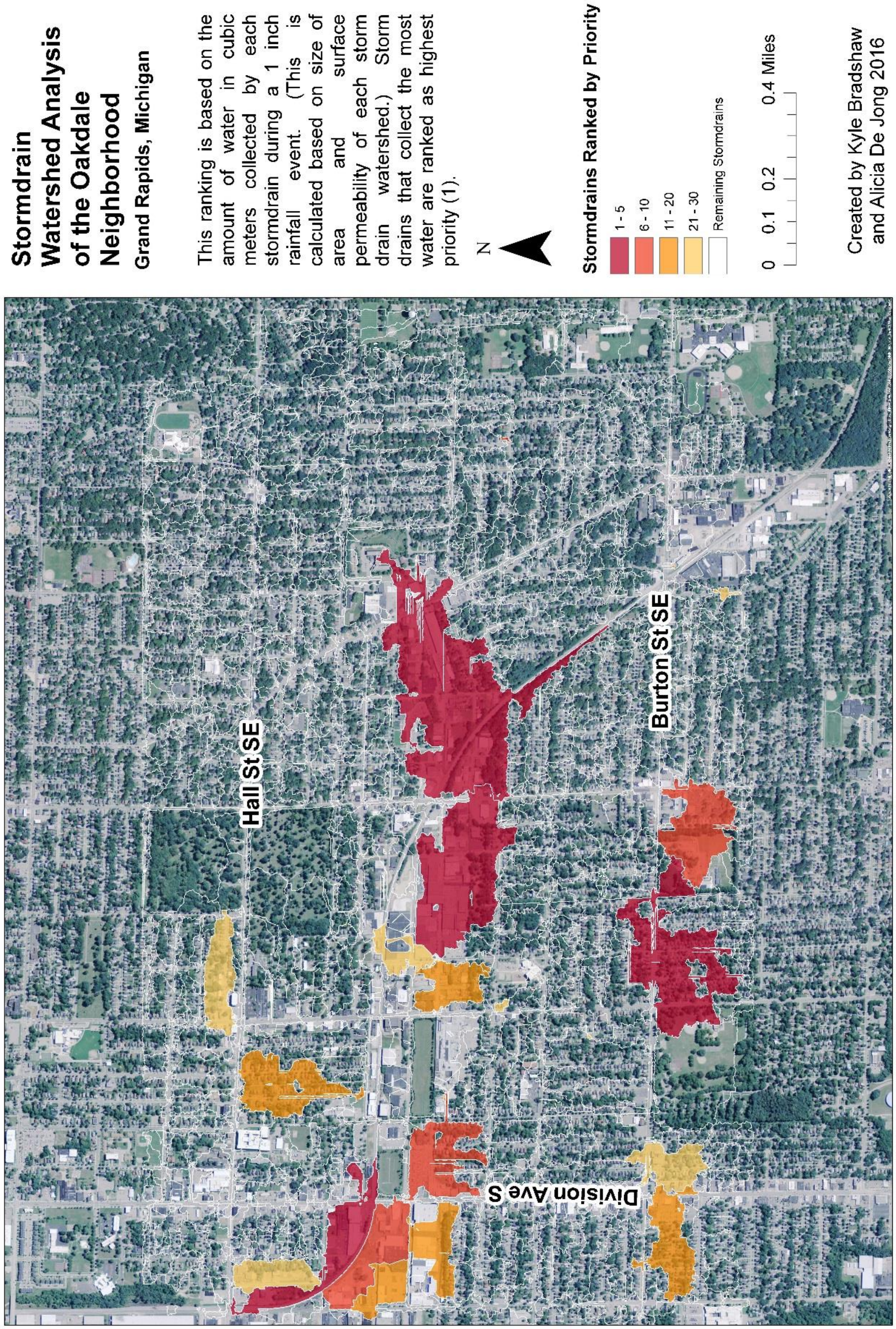
Appendix 3: Methods for Analysis of Watersheds and Permeability Overlay

(If multiple classified NDVI images are being utilized:)

1. Open ArcGIS.
2. Create a new geodatabase in your workspace.
3. Use the Create a Mosaic Dataset tool to create a new mosaic dataset in the created geodatabase.
4. Use the Add Rasters to Mosaic Dataset tool to merge multiple images into one raster.
5. Reclassify this new raster into the three original permeability categories with the Reclassify tool.

1. Open your classified NDVI image and storm drain watershed raster in ArcGIS.
2. Project the storm drain watershed raster to match the NDVI image raster. (It helps if the cell size is 1,1 and the linear units of the Spatial Reference are in meters.)
3. Select the Tabulate Area tool.
    4. Use the re-projected watershed raster as input for “feature zone data” and the NDVI raster as input for the “feature class data.”
5. Save the output table to your workspace.
6. The results from this table will indicate the number of cells of each permeability class within each sub watershed.
7. This table can be exported to Excel for further calculations.

Appendix 4: Final Map for Plaster Creek Stewards



Appendix 5: Table of calculations

	Stormdrain Watershed Area (m^2)				% Permeability Class			Runoff (m^3) for .0254m of Rain				
Stormdrain ID	**Forest**	**Imperm**	**Lawn**	**Total**	**Forest**	**Imperm**	**Lawn**	**Forest**	**Imperm**	**Lawn**	**Total**	**Rank**
31047	69970	148565	49033	267568	26.15%	55.52%	18.33%	151.70	3773.55	141.46	4066.72	1
155282	25954	100570	19688	146212	17.75%	68.78%	13.47%	56.27	2554.48	56.80	2667.55	2
173187	50930	43207	36158	130295	39.09%	33.16%	27.75%	110.42	1097.46	104.32	1312.20	3
6620	69063	39873	34199	143135	48.25%	27.86%	23.89%	149.74	1012.77	98.66	1261.18	4
112025	6528	46747	14811	68086	9.59%	68.66%	21.75%	14.15	1187.37	42.73	1244.26	5
6203	62158	38915	34089	135162	45.99%	28.79%	25.22%	134.77	988.44	98.35	1221.56	6
156909	3123	44624	8365	56112	5.57%	79.53%	14.91%	6.77	1133.45	24.13	1164.35	7
77783	18645	34800	14594	68039	27.40%	51.15%	21.45%	40.42	883.92	42.10	966.45	8
111242	15028	32368	11684	59080	25.44%	54.79%	19.78%	32.58	822.15	33.71	888.44	9
6301	23045	29797	20597	73439	31.38%	40.57%	28.05%	49.96	756.84	59.42	866.23	10
6098	9987	31164	3774	44925	22.23%	69.37%	8.40%	21.65	791.57	10.89	824.11	11
3712	5375	28362	26646	60383	8.90%	46.97%	44.13%	11.65	720.39	76.87	808.92	12
111388	13602	26330	9784	49716	27.36%	52.96%	19.68%	29.49	668.78	28.23	726.50	13
236389	8927	25083	3316	37326	23.92%	67.20%	8.88%	19.35	637.11	9.57	666.03	14
5862	26470	20471	10401	57342	46.16%	35.70%	18.14%	57.39	519.96	30.01	607.36	15
3420	45650	14397	45268	105315	43.35%	13.67%	42.98%	98.98	365.68	130.60	595.26	16
156898	595	22801	2293	25689	2.32%	88.76%	8.93%	1.29	579.15	6.62	587.05	17
134779	21892	18383	21470	61745	35.46%	29.77%	34.77%	47.46	466.93	61.94	576.33	18
192060	7852	20889	6006	34747	22.60%	60.12%	17.28%	17.02	530.58	17.33	564.93	19
3403	19671	18226	11915	49812	39.49%	36.59%	23.92%	42.65	462.94	34.37	539.96	20
3460	18560	16899	9251	44710	41.51%	37.80%	20.69%	40.24	429.23	26.69	496.16	21
3445	9011	17562	6635	33208	27.14%	52.88%	19.98%	19.54	446.07	19.14	484.75	22
162957	8758	17491	7172	33421	26.21%	52.34%	21.46%	18.99	444.27	20.69	483.95	23
6041	2468	18453	2307	23228	10.63%	79.44%	9.93%	5.35	468.71	6.66	480.71	24
155284	236	18624	1030	19890	1.19%	93.63%	5.18%	0.51	473.05	2.97	476.53	25
3277	9958	16317	9542	35817	27.80%	45.56%	26.64%	21.59	414.45	27.53	463.57	26
2994	4175	17103	2585	23863	17.50%	71.67%	10.83%	9.05	434.42	7.46	450.93	27
135093	13685	15216	10258	39159	34.95%	38.86%	26.20%	29.67	386.49	29.59	445.75	28
142201	7138	15771	7744	30653	23.29%	51.45%	25.26%	15.48	400.58	22.34	438.40	29
6550	16578	12992	15310	44880	36.94%	28.95%	34.11%	35.94	330.00	44.17	410.11	30
12329	6620	14650	6054	27324	24.23%	53.62%	22.16%	14.35	372.11	17.47	403.93	31
3707	1014	15406	3422	19842	5.11%	77.64%	17.25%	2.20	391.31	9.87	403.38	32
3409	13878	13167	8461	35506	39.09%	37.08%	23.83%	30.09	334.44	24.41	388.94	33
2996	5968	13837	8499	28304	21.09%	48.89%	30.03%	12.94	351.46	24.52	388.92	34
3789	5074	14044	4926	24044	21.10%	58.41%	20.49%	11.00	356.72	14.21	381.93	35
6487	1681	13886	2604	18171	9.25%	76.42%	14.33%	3.64	352.70	7.51	363.86	36
6479	7667	13030	5389	26086	29.39%	49.95%	20.66%	16.62	330.96	15.55	363.13	37
6743	16936	11605	8928	37469	45.20%	30.97%	23.83%	36.72	294.77	25.76	357.24	38
3658	2938	13400	2479	18817	15.61%	71.21%	13.17%	6.37	340.36	7.15	353.88	39
127108	12770	11783	9176	33729	37.86%	34.93%	27.21%	27.69	299.29	26.47	353.45	40
155301	104	13036	387	13527	0.77%	96.37%	2.86%	0.23	331.11	1.12	332.46	41
6178	13893	11091	7051	32035	43.37%	34.62%	22.01%	30.12	281.71	20.34	332.18	42
156242	33437	5625	39516	78578	42.55%	7.16%	50.29%	72.50	142.88	114.00	329.37	43
73609	11846	11110	6697	29653	39.95%	37.47%	22.58%	25.68	282.19	19.32	327.20	44
127452	3351	11999	4900	20250	16.55%	59.25%	24.20%	7.27	304.77	14.14	326.18	45

3593	11519	10790	7831	30140	38.22%	35.80%	25.98%	24.97	274.07	22.59	321.63	46
3765	64242	4058	25916	94216	68.19%	4.31%	27.51%	139.29	103.07	74.77	317.13	47
3795	4504	11021	4371	19896	22.64%	55.39%	21.97%	9.77	279.93	12.61	302.31	48
125845	1238	11426	2730	15394	8.04%	74.22%	17.73%	2.68	290.22	7.88	300.78	49
5749	5859	10504	6171	22534	26.00%	46.61%	27.39%	12.70	266.80	17.80	297.31	50
3256	4856	10606	3784	19246	25.23%	55.11%	19.66%	10.53	269.39	10.92	290.84	51
146625	2965	10332	4572	17869	16.59%	57.82%	25.59%	6.43	262.43	13.19	282.05	52
6485	3295	9962	6945	20202	16.31%	49.31%	34.38%	7.14	253.03	20.04	280.22	53
146619	3789	10164	3100	17053	22.22%	59.60%	18.18%	8.22	258.17	8.94	275.32	54
5771	10979	9028	6804	26811	40.95%	33.67%	25.38%	23.80	229.31	19.63	272.74	55
6236	6978	9103	8555	24636	28.32%	36.95%	34.73%	15.13	231.22	24.68	271.03	56
3541	6409	9135	5977	21521	29.78%	42.45%	27.77%	13.90	232.03	17.24	263.17	57
12471	1191	10074	1437	12702	9.38%	79.31%	11.31%	2.58	255.88	4.15	262.61	58
52162	4009	9494	3958	17461	22.96%	54.37%	22.67%	8.69	241.15	11.42	261.26	59
208743	5901	8948	5828	20677	28.54%	43.28%	28.19%	12.79	227.28	16.81	256.89	60
6387	13070	8046	8159	29275	44.65%	27.48%	27.87%	28.34	204.37	23.54	256.24	61
3757	1047	9724	1667	12438	8.42%	78.18%	13.40%	2.27	246.99	4.81	254.07	62
6012	14973	7713	6394	29080	51.49%	26.52%	21.99%	32.46	195.91	18.45	246.82	63
6459	5024	8753	3769	17546	28.63%	49.89%	21.48%	10.89	222.33	10.87	244.09	64
3411	2057	9013	2122	13192	15.59%	68.32%	16.09%	4.46	228.93	6.12	239.51	65
12255	5677	8009	4489	18175	31.24%	44.07%	24.70%	12.31	203.43	12.95	228.69	66
1959	1320	8605	2410	12335	10.70%	69.76%	19.54%	2.86	218.57	6.95	228.38	67
235989	231	8803	678	9712	2.38%	90.64%	6.98%	0.50	223.60	1.96	226.05	68
3873	363	8662	1201	10226	3.55%	84.71%	11.74%	0.79	220.01	3.46	224.27	69
31684	3782	7982	4098	15862	23.84%	50.32%	25.84%	8.20	202.74	11.82	222.77	70
127439	258	8469	699	9426	2.74%	89.85%	7.42%	0.56	215.11	2.02	217.69	71
24712	1633	6726	14630	22989	7.10%	29.26%	63.64%	3.54	170.84	42.21	216.59	72
12253	3001	7696	3552	14249	21.06%	54.01%	24.93%	6.51	195.48	10.25	212.23	73
125865	4470	7309	5692	17471	25.59%	41.84%	32.58%	9.69	185.65	16.42	211.76	74
173179	3147	7664	2566	13377	23.53%	57.29%	19.18%	6.82	194.67	7.40	208.89	75
3660	166	8104	579	8849	1.88%	91.58%	6.54%	0.36	205.84	1.67	207.87	76
6170	9560	6916	3839	20315	47.06%	34.04%	18.90%	20.73	175.67	11.08	207.47	77
190463	6366	7009	4999	18374	34.65%	38.15%	27.21%	13.80	178.03	14.42	206.25	78
235986	200	7986	368	8554	2.34%	93.36%	4.30%	0.43	202.84	1.06	204.34	79
3870	1900	7728	1249	10877	17.47%	71.05%	11.48%	4.12	196.29	3.60	204.01	80
146647	5514	7152	3109	15775	34.95%	45.34%	19.71%	11.96	181.66	8.97	202.59	81
167420	4061	7239	3391	14691	27.64%	49.28%	23.08%	8.80	183.87	9.78	202.46	82
12328	5983	6775	3715	16473	36.32%	41.13%	22.55%	12.97	172.09	10.72	195.77	83
6372	2889	6853	4496	14238	20.29%	48.13%	31.58%	6.26	174.07	12.97	193.30	84
3737	22863	3683	16139	42685	53.56%	8.63%	37.81%	49.57	93.55	46.56	189.68	85
3330	4950	6330	5554	16834	29.40%	37.60%	32.99%	10.73	160.78	16.02	187.54	86
5882	5846	6177	5765	17788	32.86%	34.73%	32.41%	12.67	156.90	16.63	186.20	87
3582	7874	5947	4694	18515	42.53%	32.12%	25.35%	17.07	151.05	13.54	181.67	88
3698	283	6963	1329	8575	3.30%	81.20%	15.50%	0.61	176.86	3.83	181.31	89
2988	3176	6380	3943	13499	23.53%	47.26%	29.21%	6.89	162.05	11.38	180.31	90
246802	1473	6579	2044	10096	14.59%	65.16%	20.25%	3.19	167.11	5.90	176.20	91
12313	3339	6264	3156	12759	26.17%	49.09%	24.74%	7.24	159.11	9.11	175.45	92
3574	6247	5773	4855	16875	37.02%	34.21%	28.77%	13.54	146.63	14.01	174.19	93
3270	280	6681	1126	8087	3.46%	82.61%	13.92%	0.61	169.70	3.25	173.55	94
3402	5915	5864	3696	15475	38.22%	37.89%	23.88%	12.82	148.95	10.66	172.43	95

236388	489	6662	509	7660	6.38%	86.97%	6.64%	1.06	169.21	1.47	171.74	96
5877	9666	5109	5836	20611	46.90%	24.79%	28.31%	20.96	129.77	16.84	167.56	97
111293	5284	5969	1550	12803	41.27%	46.62%	12.11%	11.46	151.61	4.47	167.54	98
3872	2179	6220	1585	9984	21.82%	62.30%	15.88%	4.72	157.99	4.57	167.29	99
3695	1193	6278	1777	9248	12.90%	67.88%	19.21%	2.59	159.46	5.13	167.17	100
6657	6109	5564	3642	15315	39.89%	36.33%	23.78%	13.25	141.33	10.51	165.08	101
8486	8508	5330	3826	17664	48.17%	30.17%	21.66%	18.45	135.38	11.04	164.87	102
22755	148	6342	670	7160	2.07%	88.58%	9.36%	0.32	161.09	1.93	163.34	103
6652	2958	5942	1855	10755	27.50%	55.25%	17.25%	6.41	150.93	5.35	162.69	104
127420	0	6398	49	6447	0.00%	99.24%	0.76%	0.00	162.51	0.14	162.65	105
3407	4477	5688	2835	13000	34.44%	43.75%	21.81%	9.71	144.48	8.18	162.36	106
127412	228	6116	2043	8387	2.72%	72.92%	24.36%	0.49	155.35	5.89	161.73	107
6084	4778	5580	2896	13254	36.05%	42.10%	21.85%	10.36	141.73	8.35	160.45	108
127443	1810	5852	2718	10380	17.44%	56.38%	26.18%	3.92	148.64	7.84	160.41	109
111378	161	6245	450	6856	2.35%	91.09%	6.56%	0.35	158.62	1.30	160.27	110
131609	4462	5293	5383	15138	29.48%	34.96%	35.56%	9.67	134.44	15.53	159.65	111
5954	7908	4943	5392	18243	43.35%	27.10%	29.56%	17.15	125.55	15.56	158.25	112
111290	2713	5690	2350	10753	25.23%	52.92%	21.85%	5.88	144.53	6.78	157.19	113
73607	7957	5200	2673	15830	50.27%	32.85%	16.89%	17.25	132.08	7.71	157.04	114
111310	5359	5355	3119	13833	38.74%	38.71%	22.55%	11.62	136.02	9.00	156.63	115
12273	5743	5167	4377	15287	37.57%	33.80%	28.63%	12.45	131.24	12.63	156.32	116
116238	2121	5435	2225	9781	21.68%	55.57%	22.75%	4.60	138.05	6.42	149.07	117
155280	3938	5351	1569	10858	36.27%	49.28%	14.45%	8.54	135.92	4.53	148.98	118
3609	1559	5466	2128	9153	17.03%	59.72%	23.25%	3.38	138.84	6.14	148.36	119
6486	5708	4801	4640	15149	37.68%	31.69%	30.63%	12.38	121.95	13.39	147.71	120
3594	4097	5032	3081	12210	33.55%	41.21%	25.23%	8.88	127.81	8.89	145.58	121
35844	10533	4148	5949	20630	51.06%	20.11%	28.84%	22.84	105.36	17.16	145.36	122
3383	2820	5245	2054	10119	27.87%	51.83%	20.30%	6.11	133.22	5.93	145.26	123
3398	2573	5251	1961	9785	26.30%	53.66%	20.04%	5.58	133.38	5.66	144.61	124
136068	527	5563	606	6696	7.87%	83.08%	9.05%	1.14	141.30	1.75	144.19	125
131614	2388	5138	2899	10425	22.91%	49.29%	27.81%	5.18	130.51	8.36	144.05	126
174778	6889	4410	4646	15945	43.20%	27.66%	29.14%	14.94	112.01	13.40	140.35	127
175434	2364	5067	2218	9649	24.50%	52.51%	22.99%	5.13	128.70	6.40	140.23	128
3749	235	5448	463	6146	3.82%	88.64%	7.53%	0.51	138.38	1.34	140.22	129
129973	4108	4730	3817	12655	32.46%	37.38%	30.16%	8.91	120.14	11.01	140.06	130
111258	208	5393	716	6317	3.29%	85.37%	11.33%	0.45	136.98	2.07	139.50	131
3733	18081	2279	14614	34974	51.70%	6.52%	41.79%	39.20	57.89	42.16	139.25	132
6678	14599	3727	4232	22558	64.72%	16.52%	18.76%	31.65	94.67	12.21	138.53	133
12440	2505	4855	3378	10738	23.33%	45.21%	31.46%	5.43	123.32	9.75	138.49	134
129971	2384	4931	2604	9919	24.03%	49.71%	26.25%	5.17	125.25	7.51	137.93	135
127438	3494	4817	2389	10700	32.65%	45.02%	22.33%	7.58	122.35	6.89	136.82	136
204738	7147	4274	4217	15638	45.70%	27.33%	26.97%	15.50	108.56	12.17	136.22	137
174799	447	5200	704	6351	7.04%	81.88%	11.08%	0.97	132.08	2.03	135.08	138
6241	4434	4522	3621	12577	35.25%	35.95%	28.79%	9.61	114.86	10.45	134.92	139
6422	2986	4790	2291	10067	29.66%	47.58%	22.76%	6.47	121.67	6.61	134.75	140
5880	4332	4511	3572	12415	34.89%	36.34%	28.77%	9.39	114.58	10.31	134.28	141
156252	1559	4965	1502	8026	19.42%	61.86%	18.71%	3.38	126.11	4.33	133.82	142
3864	877	5099	810	6786	12.92%	75.14%	11.94%	1.90	129.51	2.34	133.75	143
5835	5339	4504	2653	12496	42.73%	36.04%	21.23%	11.58	114.40	7.65	133.63	144
6400	4602	4439	2940	11981	38.41%	37.05%	24.54%	9.98	112.75	8.48	131.21	145

6603	10745	3836	3601	18182	59.10%	21.10%	19.81%	23.30	97.43	10.39	131.12	146
6270	5313	4231	4079	13623	39.00%	31.06%	29.94%	11.52	107.47	11.77	130.75	147
12469	1859	4599	2921	9379	19.82%	49.04%	31.14%	4.03	116.81	8.43	129.27	148
1982	5809	4006	5099	14914	38.95%	26.86%	34.19%	12.59	101.75	14.71	129.06	149
6278	1499	4724	1434	7657	19.58%	61.70%	18.73%	3.25	119.99	4.14	127.38	150
74242	9270	3850	3255	16375	56.61%	23.51%	19.88%	20.10	97.79	9.39	127.28	151
173498	7415	3916	4018	15349	48.31%	25.51%	26.18%	16.08	99.47	11.59	127.14	152
6390	1273	4774	1033	7080	17.98%	67.43%	14.59%	2.76	121.26	2.98	127.00	153
3302	1069	4657	2116	7842	13.63%	59.39%	26.98%	2.32	118.29	6.10	126.71	154
3839	6186	4066	3473	13725	45.07%	29.62%	25.30%	13.41	103.28	10.02	126.71	155
6212	3468	4359	2673	10500	33.03%	41.51%	25.46%	7.52	110.72	7.71	125.95	156
192059	723	4786	968	6477	11.16%	73.89%	14.95%	1.57	121.56	2.79	125.92	157
185024	3052	4233	3853	11138	27.40%	38.01%	34.59%	6.62	107.52	11.12	125.25	158
6200	4327	4165	3019	11511	37.59%	36.18%	26.23%	9.38	105.79	8.71	123.88	159
3004	4245	3923	5208	13376	31.74%	29.33%	38.94%	9.20	99.64	15.03	123.87	160
2999	2233	4413	2359	9005	24.80%	49.01%	26.20%	4.84	112.09	6.81	123.74	161
3265	3280	4232	3114	10626	30.87%	39.83%	29.31%	7.11	107.49	8.98	123.59	162
3732	7190	3540	6152	16882	42.59%	20.97%	36.44%	15.59	89.92	17.75	123.25	163
3874	200	4625	931	5756	3.47%	80.35%	16.17%	0.43	117.48	2.69	120.59	164
12311	3634	4136	2395	10165	35.75%	40.69%	23.56%	7.88	105.05	6.91	119.84	165
3008	2689	4188	2591	9468	28.40%	44.23%	27.37%	5.83	106.38	7.48	119.68	166
24674	342	4464	1907	6713	5.09%	66.50%	28.41%	0.74	113.39	5.50	119.63	167
127429	1912	4275	2264	8451	22.62%	50.59%	26.79%	4.15	108.59	6.53	119.26	168
3522	2563	4213	2201	8977	28.55%	46.93%	24.52%	5.56	107.01	6.35	118.92	169
3262	916	4141	3931	8988	10.19%	46.07%	43.74%	1.99	105.18	11.34	118.51	170
6293	2288	4163	2327	8778	26.07%	47.43%	26.51%	4.96	105.74	6.71	117.41	171
5812	3481	4055	2291	9827	35.42%	41.26%	23.31%	7.55	103.00	6.61	117.15	172
6079	1940	4105	2811	8856	21.91%	46.35%	31.74%	4.21	104.27	8.11	116.58	173
146623	8094	3387	4255	15736	51.44%	21.52%	27.04%	17.55	86.03	12.28	115.85	174
5813	2471	4061	2239	8771	28.17%	46.30%	25.53%	5.36	103.15	6.46	114.97	175
5801	3072	3985	2244	9301	33.03%	42.84%	24.13%	6.66	101.22	6.47	114.35	176
2984	3075	3899	2958	9932	30.96%	39.26%	29.78%	6.67	99.03	8.53	114.24	177
6407	2783	4089	1389	8261	33.69%	49.50%	16.81%	6.03	103.86	4.01	113.90	178
3465	3510	3928	2112	9550	36.75%	41.13%	22.12%	7.61	99.77	6.09	113.47	179
111295	5355	3698	2466	11519	46.49%	32.10%	21.41%	11.61	93.93	7.11	112.65	180
3013	69	4350	613	5032	1.37%	86.45%	12.18%	0.15	110.49	1.77	112.41	181
6596	5641	3549	3260	12450	45.31%	28.51%	26.18%	12.23	90.14	9.41	111.78	182
6468	1159	4101	1626	6886	16.83%	59.56%	23.61%	2.51	104.17	4.69	111.37	183
6345	4109	3543	4194	11846	34.69%	29.91%	35.40%	8.91	89.99	12.10	111.00	184
6276	5841	3466	3420	12727	45.89%	27.23%	26.87%	12.66	88.04	9.87	110.57	185
6033	1565	4043	1125	6733	23.24%	60.05%	16.71%	3.39	102.69	3.25	109.33	186
156907	3930	3686	2369	9985	39.36%	36.92%	23.73%	8.52	93.62	6.83	108.98	187
3697	116	4127	1239	5482	2.12%	75.28%	22.60%	0.25	104.83	3.57	108.65	188
12519	519	4152	606	5277	9.84%	78.68%	11.48%	1.13	105.46	1.75	108.33	189
6147	6577	3370	2923	12870	51.10%	26.18%	22.71%	14.26	85.60	8.43	108.29	190
6199	3091	3719	2345	9155	33.76%	40.62%	25.61%	6.70	94.46	6.77	107.93	191
127425	0	4206	155	4361	0.00%	96.45%	3.55%	0.00	106.83	0.45	107.28	192
104034	4328	3509	2993	10830	39.96%	32.40%	27.64%	9.38	89.13	8.63	107.15	193
155294	28	4188	77	4293	0.65%	97.55%	1.79%	0.06	106.38	0.22	106.66	194
6431	3808	3485	3422	10715	35.54%	32.52%	31.94%	8.26	88.52	9.87	106.65	195

125849	1359	3967	978	6304	21.56%	62.93%	15.51%	2.95	100.76	2.82	106.53	196
3578	6591	3213	3622	13426	49.09%	23.93%	26.98%	14.29	81.61	10.45	106.35	197
1964	848	4040	564	5452	15.55%	74.10%	10.34%	1.84	102.62	1.63	106.08	198
6100	1	4147	107	4255	0.02%	97.46%	2.51%	0.00	105.33	0.31	105.64	199
111306	10	4128	130	4268	0.23%	96.72%	3.05%	0.02	104.85	0.38	105.25	200
TOTAL*	**5277362**	**6761591**	**3858673**	**15897626**	**27.76%**	**48.28%**	**23.95%**	**11442.06**	**171744.41**	**11132.27**	**194318.74**	

*Total based on entire study area (table only includes top 200 storm drains)