Standish Ericsson Alleyway Retrofit

Monitoring Report

By: Metro Blooms

Prepared for

Minnehaha Creek Watershed District

and

Hennepin County

December 2018

The goal of this monitoring study is to measure and report the effectiveness of a PaveDrain permeable pavement system installed in a typical Minneapolis alleyway by comparing the stormwater runoff flowing to a trench drain in pre- and post- permeable pavement installation conditions.

Abstract:
In May of 2017 a trench drain, flow-rate measurement device, and rain gauge were installed in a private Minneapolis alleyway with a history of flooding, to capture a year of precipitation and runoff data. In May 2018 the alley pavement was replaced with PaveDrain permeable pavement system and a second year of data was captured. It was assumed that permeable pavers are effective at reducing runoff, but it was not clear exactly how effective they might be.

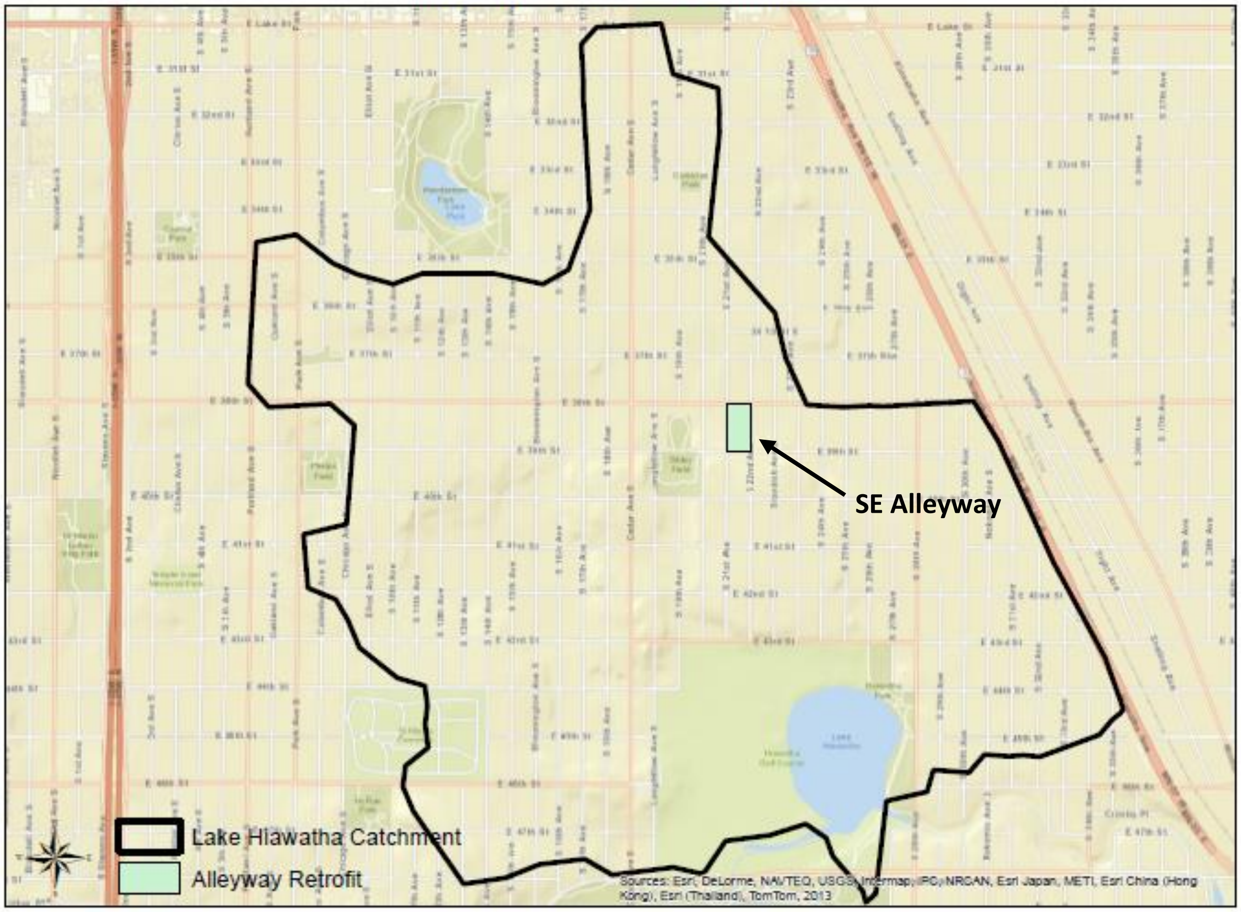
The permeable pavers were able to reduce the studied catchment area's runoff coefficient from an average of .205 per event in 2017 to .029 per event in 2018, a reduction of 85.7%.

Limitations in the study lead us to believe the paver's actual success rate was even higher than measured. In 2018, 185 ft^2 of impervious surface continued to drain directly to the trench drain without any mediation by the pavers, inflating the measured runoff of every event. Stormwater modeling of this impervious area suggests the pavers may have reduced up to 94% of the alleyshed's runoff. Furthermore, no surface flooding was observed in 2018.

Project Location:

3837, 3841, 3845, 3849, 3853 21st Ave South, Minneapolis, MN 55411

Standish Ericsson Alleyway Retrofit



Project Background:

In partnership with Minnehaha Creek Watershed District (MCWD), Hennepin County, alley residents, and the Standish Ericsson Neighborhood Association, a permeable pavement and monitoring system was installed in a privately-owned Minneapolis alleyway in 2017-18. The alleyway, located in the Hiawatha subwatershed (see map), spans 10 residential properties. The alleyway ends 5 houses into the block, and is privately owned by the 5 residences adjacent to the alleyway on the west side of the block. Condition prior to 2018 caused severe flooding of garages, driveways, and backyards. A permeable alleyway solves flooding issues, serves as a pilot study and demonstration, and addresses the approved Total Maximum Daily Loads (TMDLs) for Lake Hiawatha and Minnehaha Creek.

Development of this project began in 2014 when Metro Blooms met alley resident Lori Fewer at the Monarch Festival at Lake Nokomis. Lori informed us that her alleyway was in need of repair due to environmental, aesthetic, and practical reasons. We discussed our Blooming Alleys program with her and began to explore a potential project to retrofit her alleyway with permeable pavement. In 2015, we met with the 4 other neighbors who own the alley, as well as MCWD and the City of Minneapolis on site to discuss project feasibility. Metro Blooms took three 4-foot deep soil auger core samples along the alleyway to ensure viability of permeable pavers; soils were predominantly sandy silt loam 12-36” down. We also began discussing a potential monitoring component with Andy Erickson of the University of Minnesota St. Anthony Falls Laboratory (SAFL).

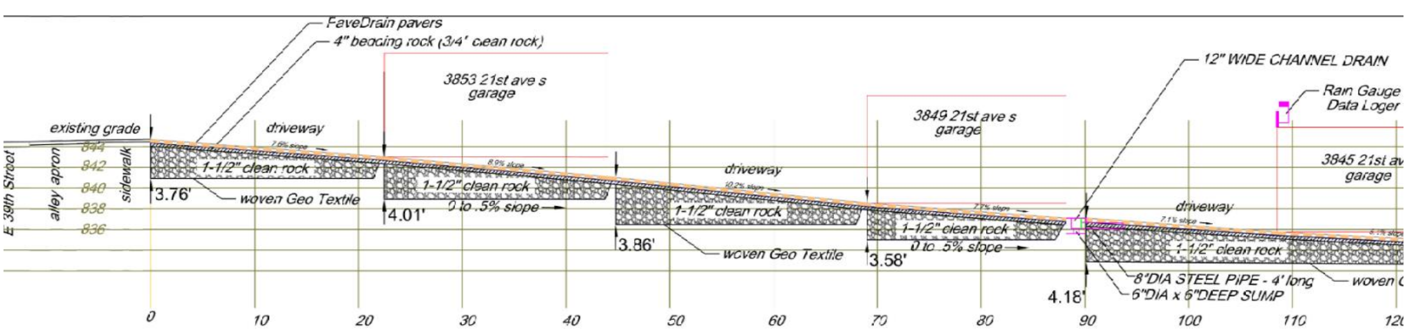
In the fall of 2015, Lori and her neighbors applied for a grant from Hennepin County for the project, and were awarded $40,000 to install a permeable pavement system. That grant funded the monitoring reported here, in addition to potential stormwater management practices on adjacent properties to capture runoff not flowing directly to the alleyway. At this point, we recognized that the scope and scale of the project required additional time and funding for development. In 2016, the property owners hired Metro Blooms to develop construction and bid documents for the project, as well as a detailed plan for stormwater monitoring within the alleyway (see attached). We sent the project to bid on September 6th, 2016 and received three bids in return. The final project was awarded to general contractor J.L. Theis, Inc . On September 26th, 2016 Metro Blooms applied for a $40,000 MCWD cost share grant. On December 15th, 2016 Metro Blooms presented the project to the MCWD Board of Managers, and were awarded the MCWD cost share grant on March 13th, 2017.

Pre 2017 Alley

As outlined in the As-Built drawings, a PaveDrain system was installed along the entire length of the alleyway. This type of system has been used in an alleyway in Columbia Heights, MN, at the Columbia Heights library, and in the parking lot at Ramsey Washington Metro Watershed District, but no stormwater runoff monitoring of these practices had been performed to our knowledge. PaveDrain pavers are highly durable, have a built-in arch system to increase storage capacity, and don't require aggregate between joints, leading to easier maintenance. The alley is sloped, requiring a terraced PaveDrain system design (see cross section below).

In Minneapolis, nearly all alleyways are publically-owned, and presently the City is not interested in pursuing permeable alleyways due to questions of feasibility, maintenance, and equity. This project offers a unique opportunity to not only install a permeable alleyway in the City of Minneapolis, but to monitor the effectiveness of doing so.

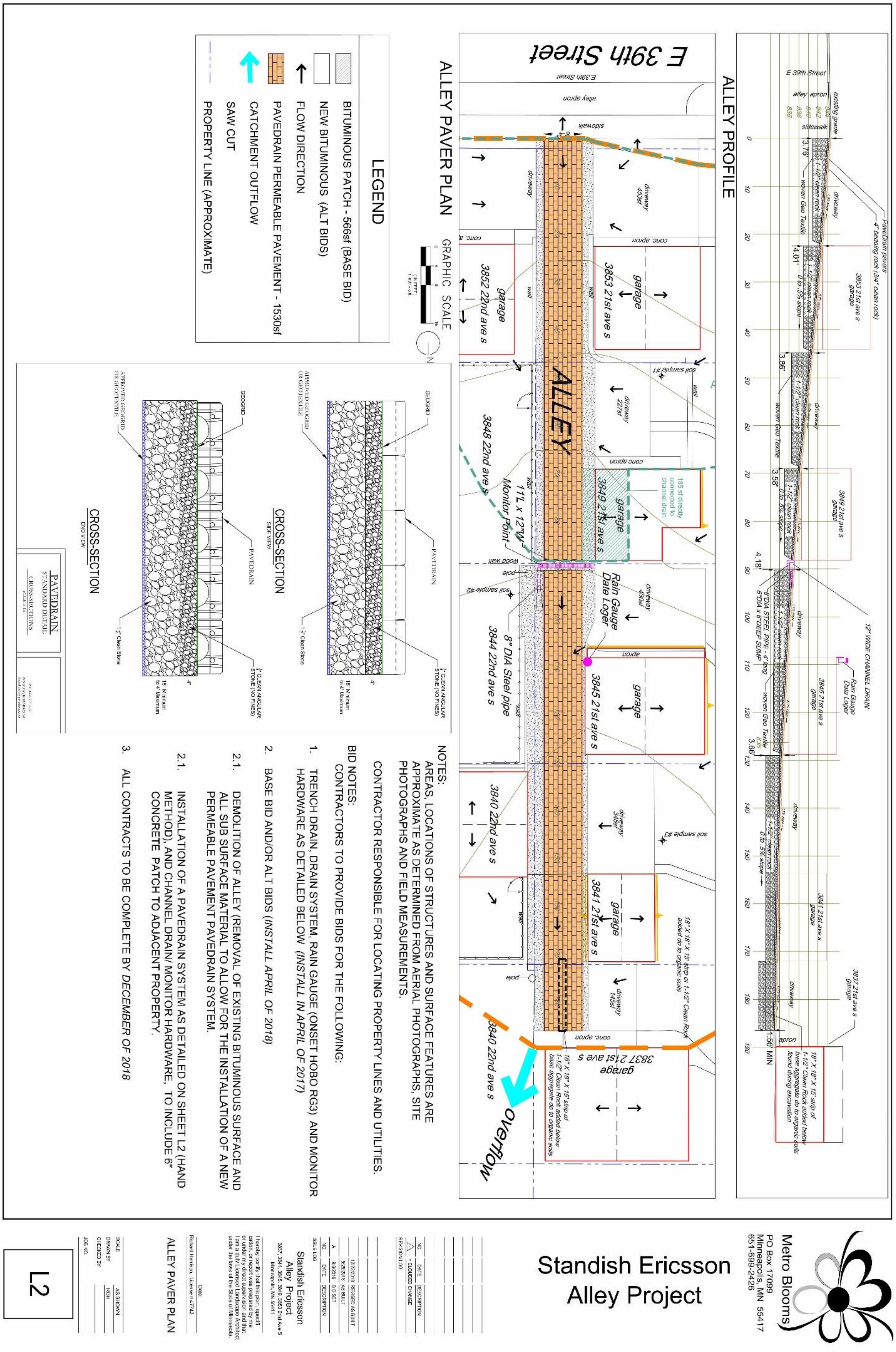
PaveDrain permeable pavers, distributed by Brock White



Longitudinal section showing the individual benches along the sloped alley. Note the flat bottom of each section to allow for efficient infiltration of stormwater.

2017 As Built Plan

2018 As Built Plan



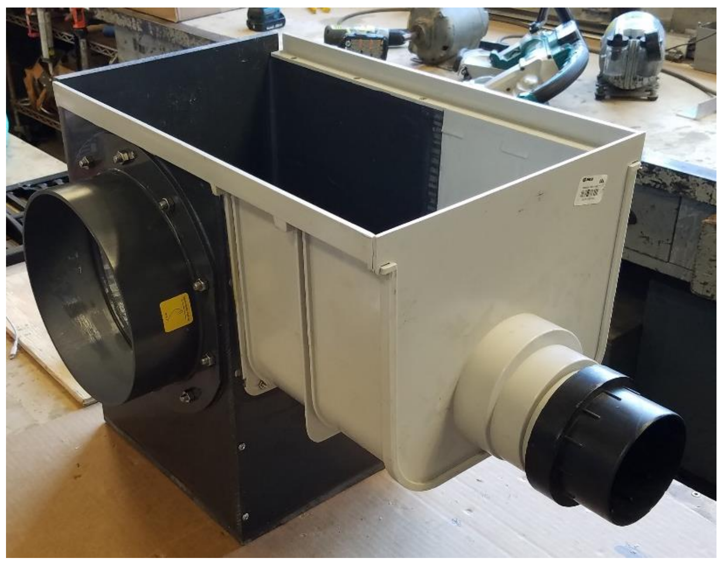
Monitoring Methodology:

The plan to monitor runoff quantity before and after implementation of the permeable pavement alleyway was developed with SAFL, who provided technical assistance, calibration of the equipment, and oversite of monitoring throughout the project period.

Monitoring equipment include:

- NDS 12-Inch Pro Series trench drain across the alley, modified with a PVC sump box. A connected 8-inch steel pipe daylights into a concrete swale draining back to the permeable alley below.
- Pressure Transducer (Onset HOBO MX2001-0x Water Level Logger)
- V-notched weir mounted inside the drain pipe (THEL-MAR 8" PIPE, LLC 90-degree-V-notched compound weir) See http://stormwaterbook.safl.umn.edu/water-budget-measurement/open-channel-flow
- Tip Bucket Rain Gauge (Onset HOBO Data Logging RG3 Rain Gauge)
- HOBO Waterproof Shuttle (U-DTW-1)

V-notched weir



Modified trench drain section with Sump

The pressure transducer mounted at the bottom of the sump box measures the water depth every minute. Using water depth data with the geometry of the weir, it is possible to determine the volume of water passing through the device over time measured in Cubic Feet per Second (CFS).

Pressure transducer mounted in bottom a sump box in a modified trench drain

Tip bucket rain gauge mounted on garage

Tip bucket rain gauge and HOBO waterproof shuttle

V-notched weir mounted inside 8-inch steel drain pipe

The rain gauge measures precipitation over time (intensity) in hundredths of an inch. It was installed at the southeast corner of the 3845 21st Ave S garage at a location clear of trees or other overhead obstruction.

The trench drain and rain gauge were installed in early May 2017. Monitoring of control runoff conditions began in late May and continued through 2017 until the first freeze in October. The PaveDrain permeable pavement system was installed in May 2018. Monitoring and data collection continued through October 2018.

Trench drain with 8-inch steel drain pipe and flow data logger, 2017

Concrete pour and trench drain / 8-inch steel drain pipe and re-installation in same location as 2017

Complete PaveDrain alley, May 2018   Construction by JL Theis. Inc.

Data Collection

The flow data logger collected water depth data at one-minute intervals, resulting in massive data sets of 1,440 data points every day. This level of resolution was recommended by SAFL to accurately capture rapid changes in runoff volumes that are characteristic of an urban setting.

Metro Blooms downloaded data every two to three weeks from the rain gauge monitoring device via the HOBO Waterproof Shuttle, and then uploaded to HOBOware software on a laptop. The flow data logger was uploaded via Bluetooth through a HOBO mobile app. All the data was then uploaded to a Google Drive folder shared with SAFL.

Data Analysis:
The following methods were used to ensure quality data[1]:

- Year-long monitoring: Variables within the catchment area that affect the amount of runoff include percentage of impervious surface, topography, soil composition and vegetative cover. Precipitation events vary greatly through their duration as well as between events in their intensity, or the rate of rainfall (amount of rain over a period of time). Each storm event is unique, which makes comparisons between pre- and post-installation of the permeable pavement challenging. However, by monitoring precipitation and stormwater runoff over a two-year period within the Standish Ericsson Alley, patterns have immerged.

- Insignificant data was flagged: In our comparisons between 2017 and 2018 we gathered data for 19 rain events for each year. We only used precipitation events that produced at least one twentieth of an inch (.05") in 24 hours. This helped normalize the runoff based on the catchment draining to the BMP.

- Suspect data was flagged and removed: Quality Control of the data analysis removed outlier events that were clearly outside other observations due to possible monitoring anomalies, as well as events that were captured by one device but not the other. Measured storm events were randomly spot-checked with wunderground.com's weather archive, which includes multiple weather stations in the Standish neighborhood.

[1] The nature and relationship between precipitation and stormwater runoff is complicated. This is outlined in the Minnesota Stormwater Manual: Overview of basic stormwater concepts https://stormwater.pca.state.mn.us

Monitoring Results

Figure 1. Trend Analysis

Watershed Runoff Depth, measured in inches, represents the average amount of runoff generated by every unit of area in the watershed, using the measured runoff through the weir as the basis of the estimation. Because Precipitation (also measured in inches) is the measured amount of rainfall on one unit of the watershed's area (and extrapolated to full area of the watershed), comparing Precipitation and Watershed Runoff Depth is a way to see how much of the rain falling onto a watershed ends up running off of it. Linear trend analysis is the best method to measure the relationship between these two variables, which are very significantly related. As displayed below: The **2018 data shows an 88% reduction in trend slope compared to 2017**. In other words, a 1-inch rain event in 2017 generated approximately 0.3 inches of Watershed Runoff Depth in 2017, and only 0.04 inches in 2018.

Figure 1. Trend Analysis

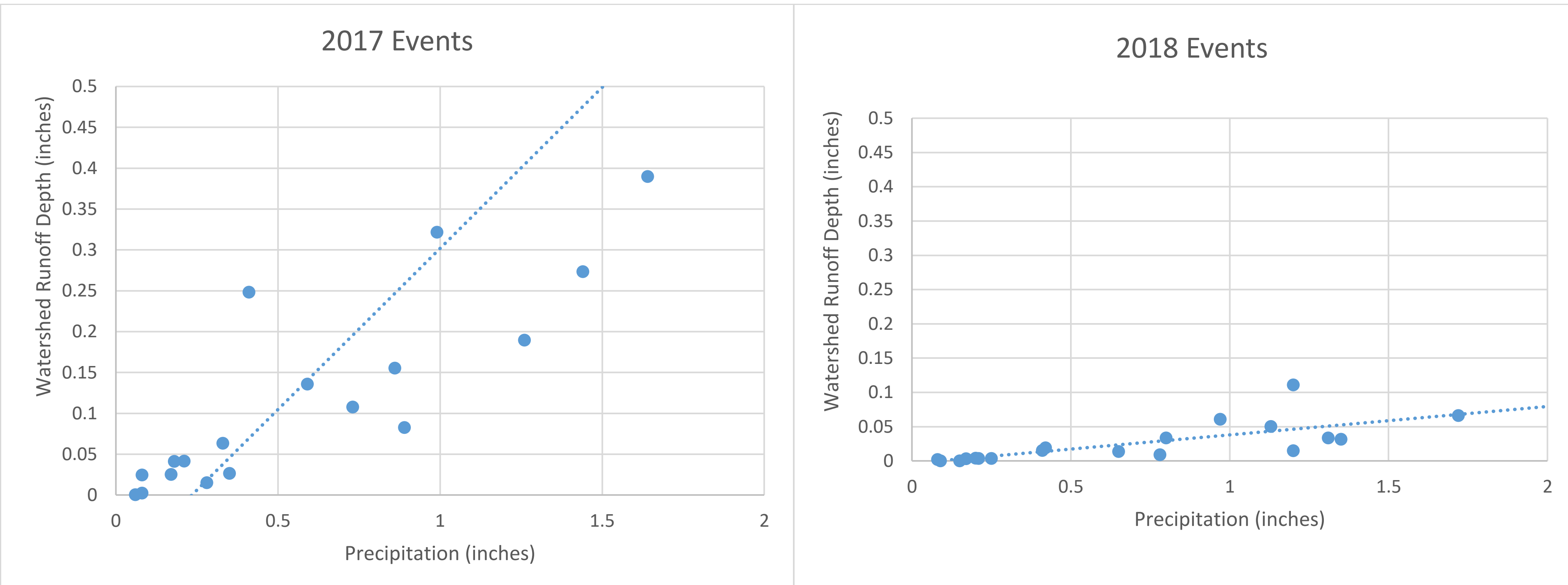


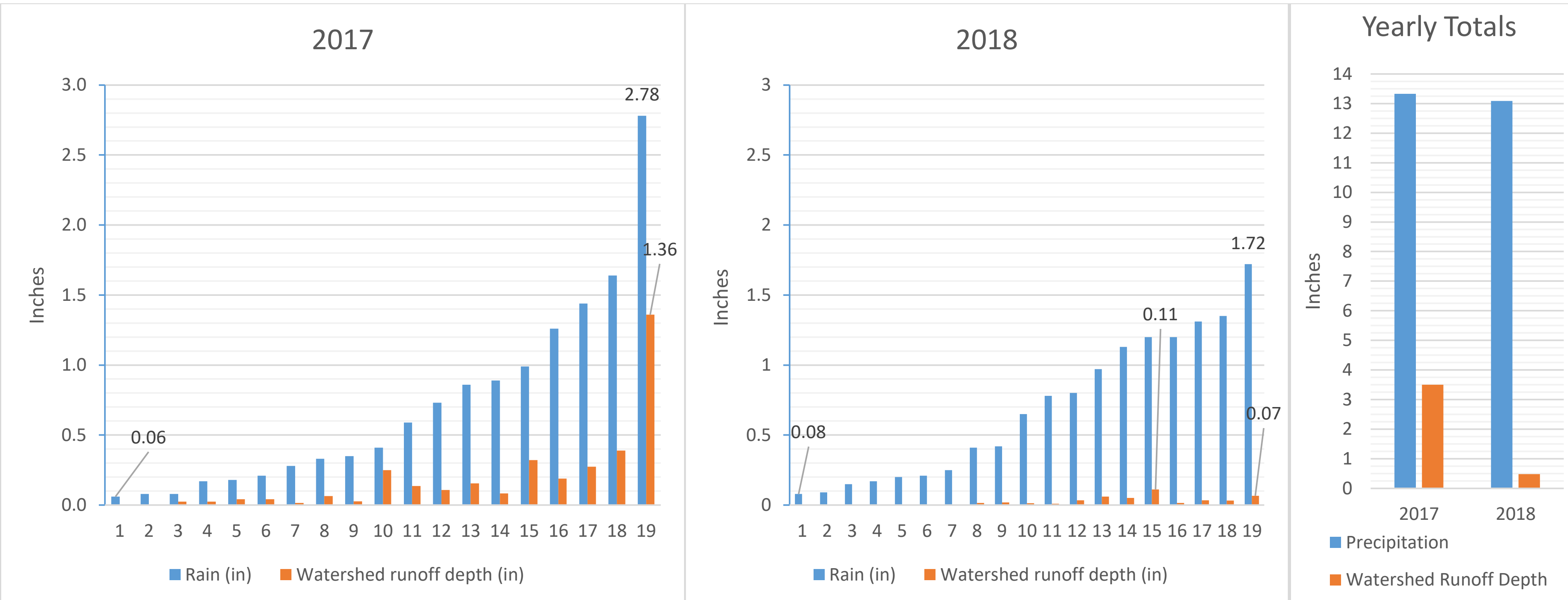
Figure 2. Precipitation and Watershed Runoff Depth (Runoff Coefficients)

Figure 2, below, displays precipitation and watershed runoff depth for each captured significant event in 2017 and 2018, arranged from smallest rainfall to largest in each year. The third chart displays the combined annual precipitation and watershed runoff depths from every event captured in each year. A Runoff Coefficient is another way to measure the permeability of an area, and is determined by dividing the amount of runoff from the area by the precipitation the area received.

- **2017 Runoff Coefficient** = The total annual Watershed Runoff Depth (3.5 inches) / total annual Precipitation (13.33 inches) **= .2626**
- **2018 Runoff Coefficient** = The total annual Watershed Runoff Depth (0.48 inches) / total annual Precipitation (13.09 inches) **= .0367**

<u>**2018's Runoff Coefficient is markedly smaller—by this measure, the amount of rain the area converted into runoff was reduced by 86% in 2018.**</u>

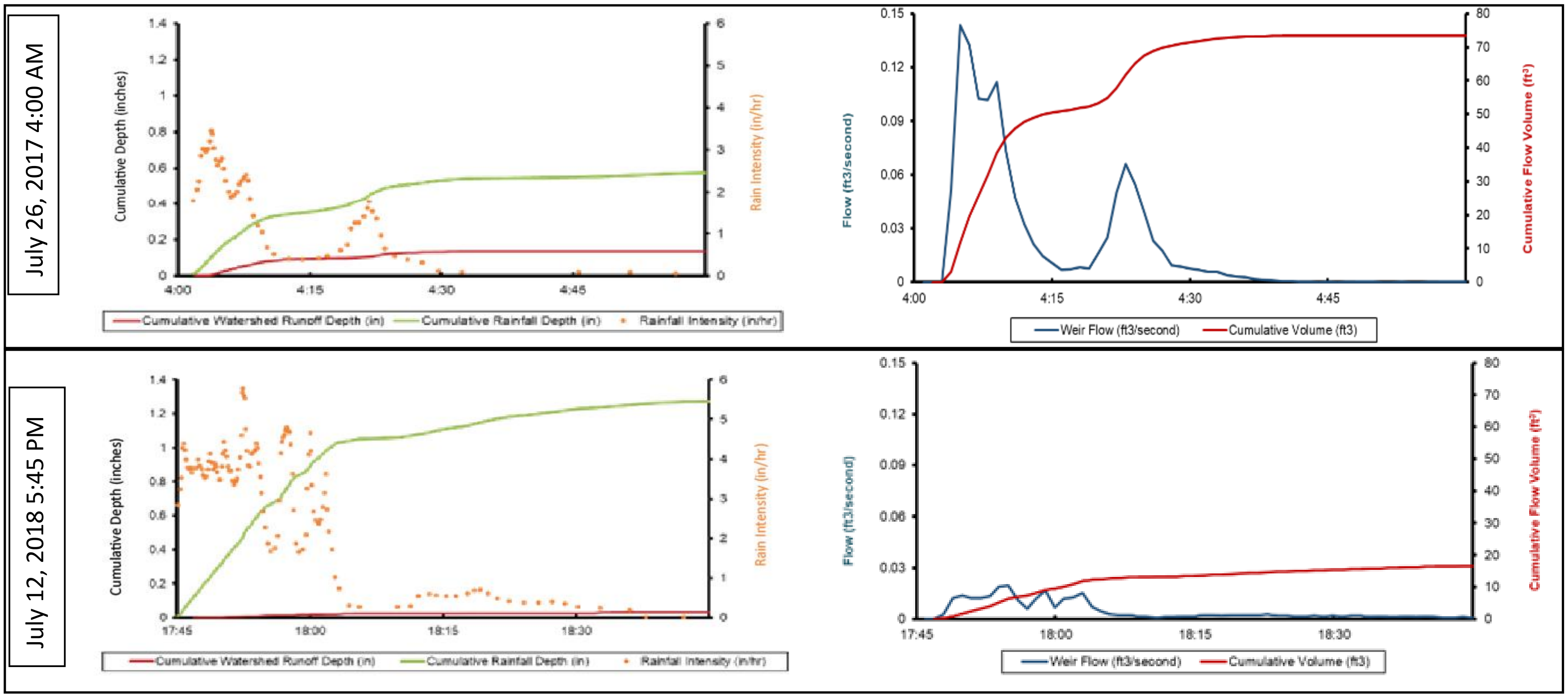
Figure 2. Precipitation vs. Watershed Runoff Depth (Pre- & Post-Installation)



Note: Watershed runoff depth (inch) = cumulative runoff (ft^3) / watershed area (ft^2) x 12

Figure 3. Storm to Storm Comparison 1

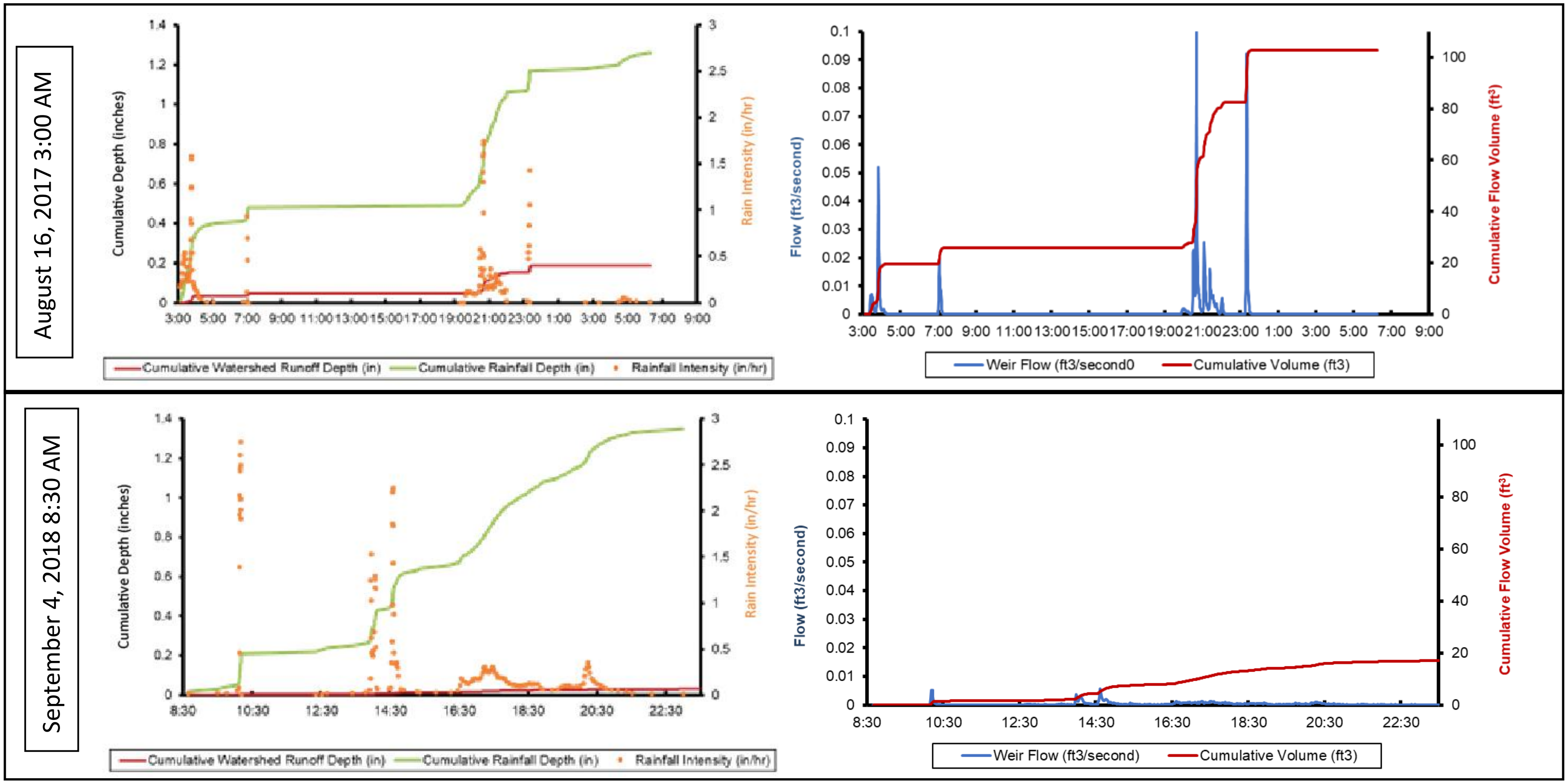
These events were compared for two compelling reasons. First, they share a similar “shape”, typical of a late-summer downpour, with an intense opening event that quickly tapered down. Second, the 2018 event produced over twice the amount of rain in the same amount of time; we were interested to see how the permeable pavers performed. In an urban residential setting, it is no surprise to see 2017’s hydrograph (plot of runoff, or weir flow over time, represented by the blue line on the charts to the right) so closely mirror its hyetograph (plot of intensity of precipitation over time, represented by the orange dots on the charts to the left), with runoff peaking just a couple minutes after peak rainfall. In contrast, the “shape” of the 2018 storm’s hydrograph is considerably more muted than its hyetograph, as well as delayed by a few more minutes. The 2018 also generated much less runoff—approximately 2.57% of the storm’s precipitation, as opposed to the 23% of precipitation from the 2017 storm that became runoff. **<u>This is a reduction in the ratio of generated runoff of 90.3%, in an event that was twice as large.</u>**



Storm Start Time	Storm End Time	Precipitation (in)	Duration (hr:min)	Intensity (in/hr)	Runoff (CF)	Watershed runoff depth (in)	Precipitation: Runoff
7/26/17 4:01	7/26/17 5:24	0.59	1:22	0.43	73.49	0.1356738	23.00%
7/12/18 17:45	7/12/18 20:14	1.31	2:29	0.53	18.23	0.0336554	2.57%

Figure 4. Storm to Storm Comparison 2

These two storms were compared because of their similarities in total precipitation (~1.3 inches) and the similar combination of multiple events happening over the span of hours. Notably, the 2017 storm spans about twice the time of the 2018 storm (27 hours vs. 14 hours). As with the previous example, the more intense storm is in 2018. If that is a handicap against the permeable pavers, they hide it well. **<u>With the same amount of water running over them in half the time, the pavers still only generated 15% of the runoff that the 2017 storm did.</u>**



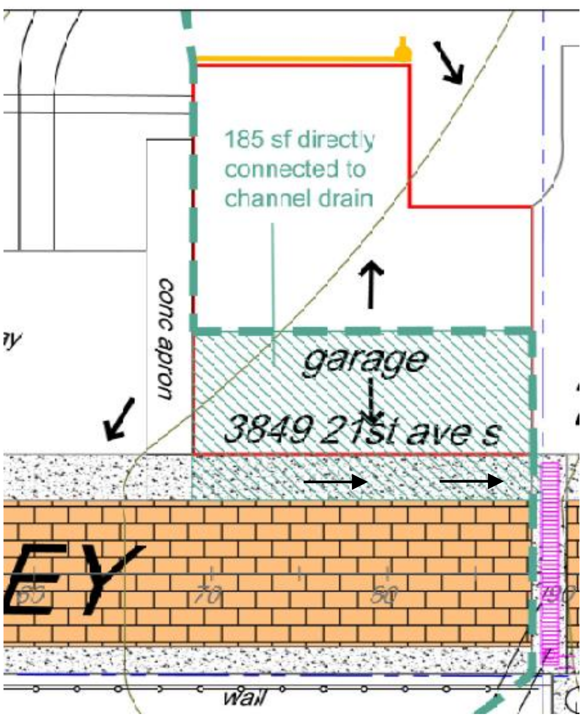
Storm Start Time	Storm End Time	Precipitation (in)	Duration (hr:min)	Intensity (in/hr)	Runoff (CF)	Watershed runoff depth (in)	Precipitation: Runoff
8/16/17 3:07	8/17/17 6:17	1.26	27:09	0.05	102.69	0.1895815	15.05%
9/4/18 8:39	9/4/18 23:00	1.35	14:20	0.09	17	0.0313846	2.32%

Limitations:

After construction of the permeable pavement, it was observed that the concrete ribbon strip between the pavers and garage at 3849 21st St S was not cross-sloped toward the pavers as anticipated. This caused runoff to flow directly downhill, perpendicular to the trench drain. This resulted in approximately 185 square feet of impervious surface (1/2 the garage roof and concrete) still draining directly to the channel drain after the permeable pavement was installed. This untreated runoff skewed the results, lowering the measured effectiveness of the pavers.

WinSLAMM models the runoff this surface generates from a 1.1"/24hr storm at about 12.67 cubic feet of runoff. This would account for a significant amount of runoff measured by the flow data logger in the 2018 post-permeable paver installation data set.

In light of this finding, it could be reasonably assumed the effectiveness of the PaveDrain system is greater than reported. Instead of just capturing the measured ~86% of runoff, rudimental calculations accounting for the runoff such a surface theoretically generates suggest the system may capture closer to 95%.



Field test showing runoff draining directly to the trench drain

Drainpipe from trench drain flows back to the permeable pavers below

Additionally, the monitoring point is at the midway point and any remaining runoff from the 8-inch drainpipe flows back to the permeable pavement system downstream. Of course, additional runoff from the adjacent alleyshed is also being captured by this portion of PaveDrain system.

Total Alleyshed vs Alleyshed to Monitor Point:

Delineating an alleyshed, or subcatchment area is tricky, especially when there is no topographical survey to work with. The alleysheds used in this study were determined based on Hennepin County GIS topographic data at 2-foot intervals and site observation.

The total alleyshed was estimated to be 37,072 ft^2. The alleyshed to the monitor point was estimated to be 8,100 ft^2, approximately 22% of the total alleyshed. The catchment area used in the SAFL spreadsheet to determine Watershed Depth in inches was 6,500 ft^2**.**

Neighbors on the finished alley
Photo by: Star Tribune

Significant Captured Storm Events from 2017 and 2018

Storm Start Time	Storm End Time	Precipitation (in)	Duration (hr:min)	Intensity (in/hr)	Runoff (CF)	Watershed runoff depth (in)	Precipitation : Runoff
5/20/17 9:00	5/20/17 17:11	0.99	8:10	0.12	174.24	0.322	32.49%
5/29/17 13:07	5/29/17 15:06	0.08	1:59	0.04	1.22	0.002	2.82%
6/12/17 14:50	6/12/17 17:25	0.28	2:35	0.11	8.21	0.015	5.41%
6/14/17 0:40	6/14/17 2:19	0.21	1:38	0.13	22.49	0.042	19.77%
6/17/17 20:35	6/18/17 1:41	0.35	5:05	0.07	14.36	0.027	7.57%
7/9/17 21:19	7/9/17 23:48	0.08	2:28	0.03	13.37	0.025	30.85%
7/17/17 22:21	7/18/17 2:56	0.73	4:35	0.16	58.42	0.108	14.77%
7/19/17 15:42	7/19/17 22:51	0.33	7:08	0.05	34.34	0.063	19.21%
7/25/17 17:56	7/25/17 21:03	0.86	3:06	0.28	84.13	0.155	18.06%
7/26/17 4:01	7/26/17 5:24	0.59	1:22	0.43	73.49	0.1356738	23.00%
8/9/17 11:54	8/10/17 1:10	0.89	13:16	0.07	44.67	0.0824677	9.27%
8/10/17 14:55	8/10/17 16:07	0.06	1:11	0.05	0.31	0.0005723	0.95%
8/13/17 19:00	8/14/17 0:59	1.64	5:59	0.27	211.05	0.3896308	23.76%
8/16/17 3:07	8/17/17 6:17	1.26	27:09	0.05	102.69	0.1895815	15.05%
8/25/17 22:42	8/26/17 5:11	1.44	6:29	0.22	148.02	0.2732677	18.98%
8/27/17 16:48	8/27/17 18:01	0.18	1:13	0.15	22.34	0.0412431	22.91%
9/4/17 16:40	9/4/17 19:10	0.17	2:29	0.07	13.7	0.0252923	14.88%
10/1/17 3:26	10/3/17 10:04	2.78	54:38	0.05	736.59	1.3598585	48.92%
10/21/17 7:01	10/21/17 10:18	0.41	3:16	0.13	134.49	0.2482892	60.56%
5/29/18 15:09	5/30/18 12:28	0.97	21:18	0.05	32.88	0.0607015	6.26%
6/2/18 10:59	6/2/18 14:15	0.15	3:15	0.05	0.12	0.0002215	0.15%
6/6/18 5:33	6/6/18 8:30	0.2	2:57	0.07	2.19	0.0040431	2.02%
6/9/18 11:12	6/9/18 15:24	0.21	4:12	0.05	2.03	0.0037477	1.78%
6/16/18 5:57	6/16/18 13:15	1.72	7:17	0.24	35.89	0.0662585	3.85%
6/17/18 22:46	6/19/18 12:29	1.2	37:42	0.03	59.96	0.1106954	9.22%
6/24/18 15:34	6/24/18 15:49	0.09	0:15	0.35	0.07	0.0001292	0.14%
6/26/18 1:49	6/26/18 6:01	0.65	4:11	0.15	7.42	0.0136985	2.11%
7/1/18 8:39	7/1/18 12:35	1.2	3:55	0.31	7.97	0.0147138	1.23%
7/4/18 9:41	7/4/18 14:45	0.42	5:04	0.08	10.31	0.0190338	4.53%
7/12/18 17:45	7/12/18 20:14	1.31	2:29	0.53	18.23	0.0336554	2.57%
8/24/18 5:20	8/24/18 16:12	0.78	10:52	0.07	4.826	0.0089095	1.14%
8/27/18 17:29	8/27/18 18:13	0.08	0:43	0.11	1.2	0.0022154	2.77%
9/2/18 9:07	9/2/18 10:01	0.25	0:54	0.28	1.91	0.0035262	1.41%
9/4/18 8:39	9/4/18 23:00	1.35	14:20	0.09	17	0.0313846	2.32%
10/1/18 11:52	10/1/18 14:06	0.41	2:13	0.18	8.33	0.0153785	3.75%
10/3/18 13:31	10/3/18 17:53	0.8	4:22	0.18	18.18	0.0335631	4.20%
10/4/18 21:04	10/5/18 2:12	0.17	5:07	0.03	1.69	0.00312	1.84%
10/8/18 7:03	10/10/18 1:49	1.13	42:45	0.03	27.12	0.0500677	4.43%

Acknowledgements

Project design and monitoring data collection:
Rich Harrison, Landscape Architect
Metro Blooms

Data Analysis:
John Bly and Jun Tang
Metro Blooms

Water Quantity Study Consultants:
Andy Erickson and Matt Hernick
University of Minnesota St. Anthony Fall Laboratory

In Partnership With:
Standish Ericsson Neighborhood Organization
Minnehaha Creek Watershed District
Hennepin County