

# Sunset Circle Vegetated Swale and Infiltration Basin System Monitoring Report: Rainy Seasons 2012-13 and 2013-14

## Abstract



Site Summary	Project Features	Sunset Circle
Vegetated swales and infiltration basins were constructed at the Sunset Circle parking lot to reduce stormwater flow to adjacent Lake Merced. The green infrastructure was installed in 2006, and from 2012 to 2014 stormwater flow exiting the system was monitored and compared to simulated pre-construction flows under 100% impervious conditions. Results show that the vegetated swales and infiltration basin system is performing well and retains the majority of stormwater runoff from the parking lot.	<b>Year Constructed</b>	2006
	<b>GI Elements</b>	Vegetated Swales and Infiltration Basin
	<b>Drainage Management Area (ft<sup>2</sup>)</b>	92,000
	<b>% of Drainage Area that is GI</b>	16%
	<b>Monitoring Period</b>	2012-14 post-construction



### Hydrologic Improvement Highlights

- **Estimated flow volume reduction**      **96%**
- **Estimated peak flow rate reduction**      **96%**
- **Estimated delay in flow**                      **87 min**
- **Largest storm with no flow**                      **0.6"**

# Sunset Circle Vegetated Swale and Infiltration Basin System Monitoring Report: Rainy Seasons 2012-13 and 2013-14

## Project Overview

The City of San Francisco and the San Francisco Public Utilities Commission (SFPUC) have begun to prioritize green infrastructure (GI) projects as one of many solutions to help detain and retain stormwater runoff and thereby reduce or delay stormwater runoff to the sewer system. Constructed between January 2006 and March 2007, the Sunset Circle parking lot was one of the early GI demonstration projects for San Francisco. The project partners coordinated the GI design with a public art installation provided by the San Francisco Arts Commission. Prior to construction, stormwater runoff from the parking lot flowed untreated directly into the adjacent Lake Merced (Figure 1A). To minimize the impacts of this runoff to the lake, vegetated swales and infiltration basins were constructed on site (Figures 1B and 1C). Two bioretention islands were located in the middle of the lot, which include vegetated swales that convey stormwater towards small infiltration basins within the island bulb-out areas. Additionally, swales were constructed along the u-shape perimeter of the southern and western edge of the parking lot. These swales receive stormwater runoff from the parking lot, detain the flow and direct it toward a larger infiltration basin in the southwestern corner. A public art installation, a statue of Juan Baptista de Anza, was placed within this larger infiltration basin. This placement and the plantings within the infiltration basin help to showcase the statue.

Flows exiting the system were monitored for two rainy seasons (2012-2013 and 2013-2014). Multiple groups were involved in the monitoring and analysis of the site, including SFPUC, Sustainable Watershed Designs, and San Francisco Estuary Institute (SFEI) (referred to hereafter as “the Team”). The Team monitored outflows from the site (Figure 2) which were compared with pre-construction simulated flow conditions in order to estimate changes in stormwater volume, peak flow rates, and delays between rainfall and flow to the Lake associated with the demonstration project.



**Figure 1. A) Aerial view showing location of Sunset Circle vegetated swales and infiltration basin system, with GI features shaded in semi-transparent green along the edge of the u-shape, B) View of vegetated swales lining parking lot, and C) View of large infiltration basin and statue.**



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Figure 2. (A) Flows at Sunset Circle were simulated for the pre-construction conditions using SWMM hydrologic modeling software. (B) Post-construction flows were measured in a catchbasin (at yellow circle) located within the large infiltration basin in the southwestern point of the parking lot. Catchment boundary in both aerials shown as yellow outline.

### Hydrologic Improvement Highlights

	Sunset Circle
<b>Estimated flow Volume Reduction<sup>1</sup>:</b>	96%
<b>Estimated peak Flow Rate Reduction<sup>2</sup>:</b>	96%
<b>Estimated delay in Flow<sup>3</sup>:</b>	87 minutes
<b>Largest Storm with no Flow<sup>4</sup>:</b>	0.6 inches

<sup>1</sup> Flow Volume Reduction Percentage =  $(\text{Volume}_{\text{pre-construction}} - \text{Volume}_{\text{post-construction}}) / \text{Volume}_{\text{pre-construction}} \times 100$

<sup>2</sup> Average peak flow rate reduction measured for all storm events with measurable outflow post-construction.

<sup>3</sup> Change in the median lag time between the start of rainfall and the start of detectable outflow from pre- to post-construction.

<sup>4</sup> Largest storm measured during the monitoring period with complete capture of all runoff volume.

## Project Findings: Rainy Seasons 2012-2013 and 2013-2014

### Was Flow Volume Reduced?

The majority of parking lots across the San Francisco City landscape are highly impervious with little to no stormwater storage or infiltrative function. As a result, any irrigation overflow and most of the rain falling onto City parking lots during storm event runs off into the storm sewer system. GI elements are designed to detain and retain rainfall and runoff, thereby reducing stormwater surface flows, increasing ground water recharge and returning some of the previous function of the watershed. A reduction in storm flow volume is one straightforward and important measure of GI effectiveness at managing stormwater on site. When storm flow volume decreases between pre- and post-GI implementation, the volume reduction represents infiltration or evapotranspiration within the catchment.

The vegetated swales and infiltration basins in the Sunset Circle parking lot are estimated to have substantially reduced flow volumes exiting the system to Lake Merced (Figure 3 and Table 1). Prior to the GI installation, an estimated 84% of total rainfall drained directly to the lake (based on simulated pre-construction conditions and using period of record storm events). Post swale and infiltration basin installation, runoff volume to the lake was estimated to have been reduced by 96% (only 3% of post-construction rainfall onto the catchment area flowed into the lake versus an estimated 84% pre-construction). Assuming similar relative performance<sup>5</sup> during an average rainfall year when approximately 21 inches of rain falls on San Francisco, the vegetated swale and infiltration basin system would retain approximately 130,000 cubic feet (or 0.97 million gallons). On an individual storm basis, the basin retained 91-100% of the stormwater flow volume. During the study period, 29 of 53 storms monitored post-construction at the site produced no measureable stormwater outflow. Storm size with no resulting outflow ranged from 0.01 to as much as 0.6 inches<sup>6</sup>.

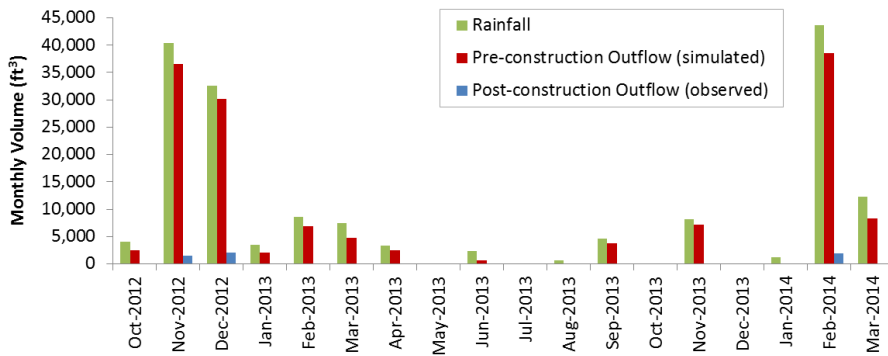


Figure 3. Monthly rainfall and outflow volume measured post-construction at Sunset Circle compared with modeled outflow volumes under pre-construction conditions

Table 1. Total rainfall and outflow volumes pre- and post-construction at Sunset Circle during the monitored storms of Rainy Seasons 2012-13 and 2013-14 and outflow estimates based on an average rainfall year.

Catchment	Monitored Storms			Average Yearly Estimates <sup>7</sup>		
	Total Rainfall <sup>6</sup> (ft <sup>3</sup> )	Outflow (ft <sup>3</sup> )	% of Rainfall Measured as Outflow	Total Rainfall (ft <sup>3</sup> )	Outflow (ft <sup>3</sup> )	Total Volume Diverted from Lake (ft <sup>3</sup> )
Sunset Circle pre-construction (modeled)	172,700	144,400	84%	160,000	135,000	130,000 <sup>8</sup>
Sunset Circle post-construction (measured)		5,800	3%		5,000	

<sup>5</sup> The monitoring data captured 85% of the usable storms and 81% of the usable precipitation data, though the monitored rainy seasons were drier than average; it is unknown how the infiltration basin performance would be affected during a wetter year.

<sup>6</sup> Some storm events smaller than 0.6 inches did produce runoff.

<sup>7</sup> Data are normalized to an average rainfall year (21 inches for this part of San Francisco). The estimated results are a simple scaling based on the monitoring data shown in the left-hand side of Table 1. Variations in rainfall intensity and duration might impact the estimate.

<sup>8</sup> 130,000 ft<sup>3</sup> is equivalent to 0.97 million gallons.

### Were Peak Flow Rates Reduced?

When a catchment’s land cover consists of a high proportion of impervious surfaces such as asphalt or concrete (sidewalks, roads, and parking lots), a large fraction of rainfall quickly becomes runoff and produces higher peak flow rates relative to natural or landscaped areas that retain or infiltrate water. At the local scale, this can result in street surface ponding. Further downstream, when flows from multiple catchment areas combine in a stormwater-sewer system, large peak flow rates can trigger combined sewer discharges. Although runoff from this parking lot flows into Lake Merced rather than the combined sewer system, reduction in peak flow rates is typically an important measure of success for GI projects in urban areas, consistent with the goal of GI implementation to slow and infiltrate stormwater runoff. And because this installation was a demonstration project, it was still very useful to characterize the resulting changes in peak flows from this site.

The vegetated swales and infiltration basin at Sunset Circle are estimated to have substantially reduced peak flow rates exiting the system. Peak outflow rates measured post-construction during storms producing flow exiting the outlet (n=24 range of reduction 88% to 99%; Table 2) were, on average, 96% lower than peak outflows simulated for the site given pre-construction conditions. The swale and infiltration basin system performed comparably well across the range of small and larger storms (Figure 4 and Table 2). However, the greatest storm return interval was less than a 1-yr return for the 3-hour storm and approximately a 0.25-year return for the 24-hr event; therefore, only relatively common, small storms were observed during the monitoring period and used to form the conclusions described here. Data from additional monitoring efforts could be used to assess the effectiveness of Sunset Circle parking lot during larger storm events.

**Table 2. Reduction in peak flow rates for storm events that had 5-minute peak rainfall intensity greater than 0.5 inches per hour.**

Storm Date	Peak 5-minute Rainfall (converted to in/hr)	Storm Return Interval (year; based on 3 hour duration) <sup>9</sup>	Pre-construction Peak Flow Rate (cfs)	Post-construction Peak Flow Rate (cfs)	Peak Flow Rate Reduction	Average Peak Flow Rate Reduction
12/1/2012	1.56	0.5	2.30	0.26	89%	<b>96%</b> <sup>10</sup>
11/28/2012	1.56	< 0.25	2.33	0.12	95%	
9/21/2013	1.2	< 0.25	1.44	0	100%	
11/17/2012	0.96	< 0.25	1.16	0.06	95%	
2/7/2014	0.96	0.25 - 0.5	1.24	0.15	88%	
11/16/2012	0.72	< 0.25	0.84	0.0004	100%	
2/7/2013	0.72	< 0.25	0.28	0	100%	
2/19/2013	0.72	< 0.25	1.06	0	100%	
11/19/2013	0.72	< 0.25	1.14	0.04	96%	
3/5/2014	0.72	< 0.25	0.78	0.003	100%	
11/20/2012	0.6	0.25	0.94	0.05	95%	
12/4/2012	0.6	0.5 - 1	1.13	0.10	91%	
2/26/2014	0.6	< 0.25	1.02	0.09	91%	
3/26/2014	0.6	< 0.25	0.61	0.00003	100%	

<sup>9</sup> A 0.5-yr return interval occurs on average two times in one year; a 0.25-yr return interval occurs on average four times in one year; and a <0.25-yr return interval occurs on average more than four times in one year.

<sup>10</sup> This metric is the average peak flow rate reduction for all observed storms that produced outflow (n=24) and the same for the 14 storms presented in the table.

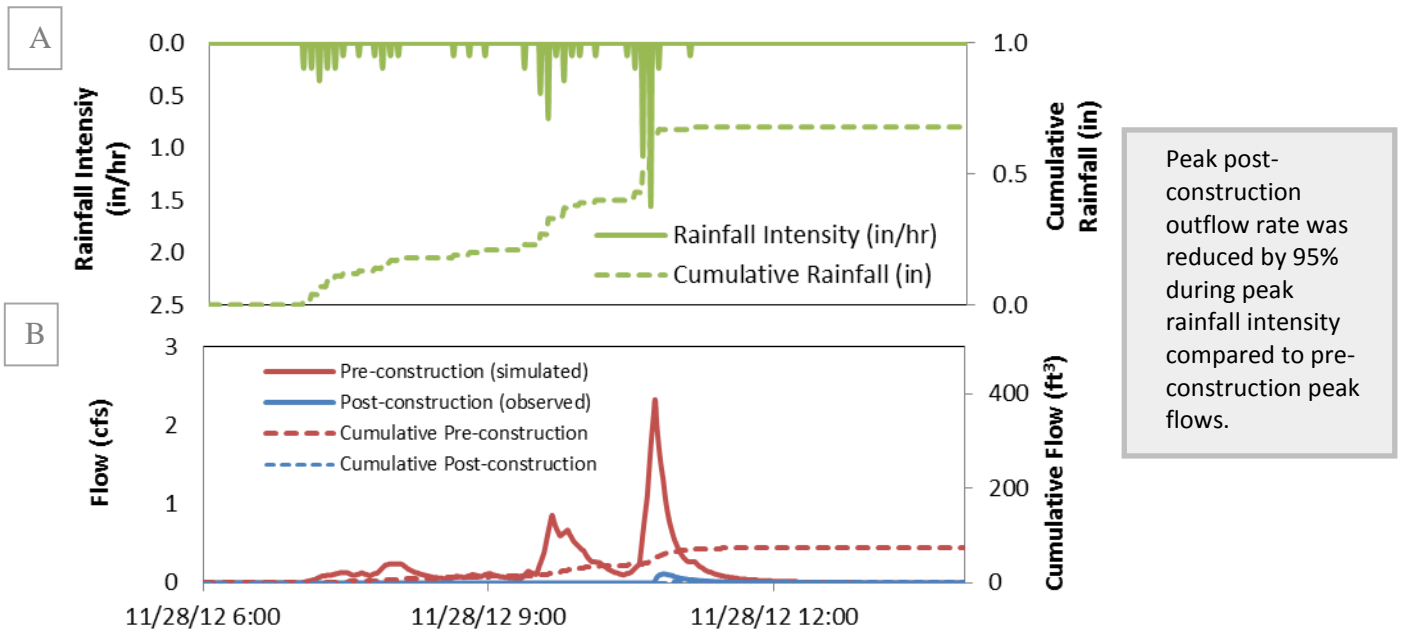


Figure 4. A) Rainfall intensity and cumulative rainfall during one of the highest intensity rainfall events on November 28, 2012. B) Storm hydrograph with pre- and post-construction outflow rates and cumulative flow volumes.

### Were Lag Times Between Rainfall and Flow Increased?

The time delay (or “lag time”) between rainfall and outflow is a measure of catchment responsiveness (flashy versus lagged) to rainfall. Large proportions of impervious area in a catchment rapidly convey runoff to the receiving storm sewer system or waterbody and result in shorter lag times. GI elements help to increase the lag time between rainfall and outflow. In an urban setting with a combined sewer system, implementing GI and delaying flows to the combined sewer system (CSS) in strategic locations can result in reduced likelihood that the CSS becomes locally overwhelmed. Increasing the lag time of runoff into Lake Merced may not have obvious benefits, but because this was a demonstration project, again it is useful to report lag times that could result from such an installation in areas where delaying outflows to the CSS would be more important. Two measures of lag time are reported here: the difference between rainfall and flow start times and the difference between peak rainfall and peak flow times. An increase in either of these measures indicates success; a larger increase in time indicates a higher level of temporary or permanent storage within the catchment area.

Lag times were assessed during the 24 (out of 58) storms where measurable outflow occurred. Lag times between the start of rainfall and the start of flow are estimated to have increased by a median of 87 minutes at the Sunset Circle parking lot (Table 3 and Figure 5) based on modeling and observations. Similarly, the time lag from the peak in rainfall to the peak flow rate was also considerably delayed (median increase in lag time was 37 minutes).

Table 3. Median lag time between start of rainfall to start of flow (Start<sub>r</sub> to Start<sub>f</sub>) and peak of rainfall to the peak of flow (Peak<sub>r</sub> to Peak<sub>f</sub>) at Sunset Circle.

Sunset Circle		
Median Lag Time (minutes)		
	Start <sub>r</sub> to Start <sub>f</sub>	Peak <sub>r</sub> to Peak <sub>f</sub>
Pre-construction estimates	<1	1
Post-construction	88	38
Increased lag due to GI elements	87	37

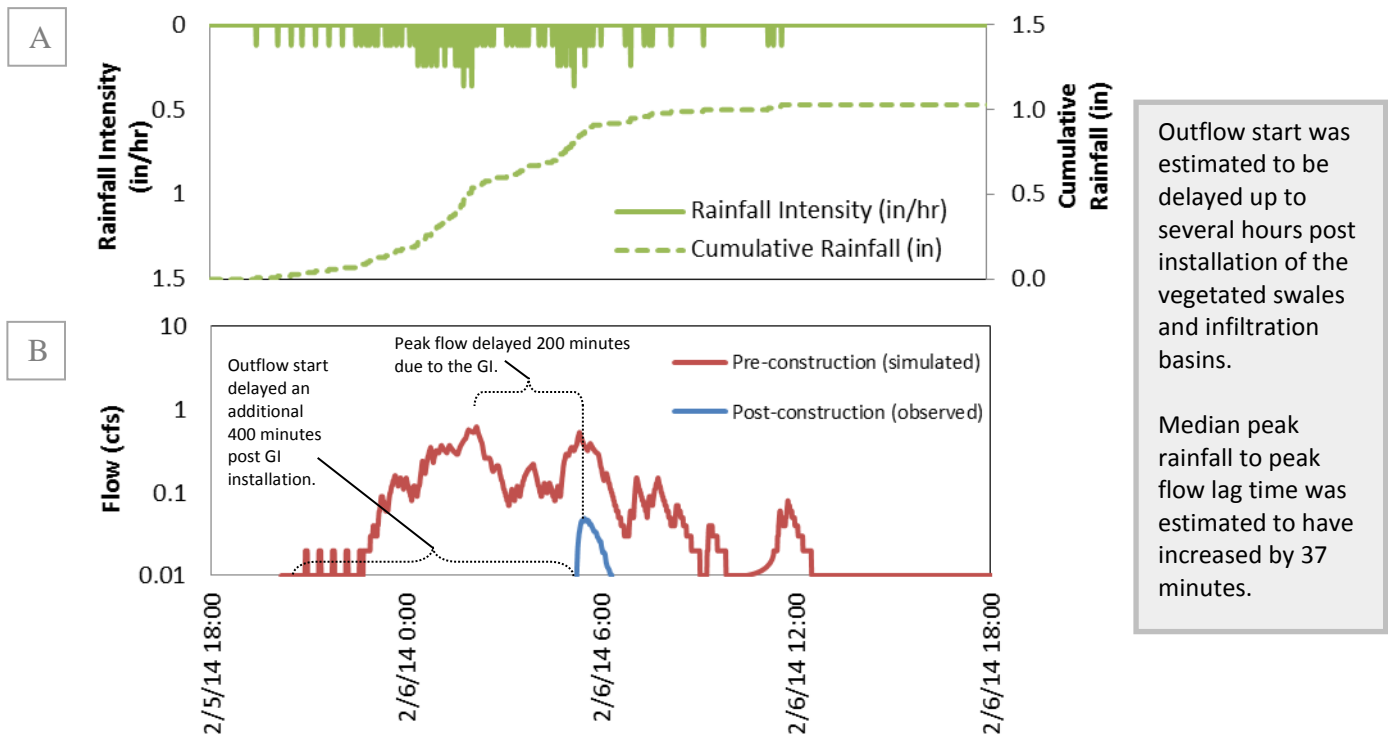


Figure 5. A) Rainfall intensity and cumulative rainfall during a storm event on February 5 and 6, 2014. B) Storm hydrograph showing pre- and post-construction outflows from this site.

## Summary

Interpretation of the data collected at the demonstration project at Sunset Circle parking lot illustrates that GI likely had a substantial positive impact on the catchment's hydrology. In summary,

- GI installation at Sunset Circle resulted in an estimated 96% reduction of total surface flow volume to the lake (total based on modeling simulations and all storms monitored). As a result of the demonstration project, that volume was either evapotranspired or infiltrated into the groundwater where it recharged Lake Merced.
- Approximately one half of the monitored storms had no measureable outflow to the lake post-construction.
- There was an estimated average 96% peak stormwater flow rate reduction for storms with measurable outflow.
- During the study period, Sunset Circle's vegetated swales and infiltration basins diverted an estimated 96% or 130,000 cubic feet (0.97 million gallons) of untreated stormwater from the lake either via infiltration and/or evapotranspiration.
- Outflows to the lake post-construction were estimated to have been delayed up to several hours and median peak outflows were delayed by one half hour relative to pre-construction outflows.

Reduced volume of untreated stormwater runoff to Lake Merced could have positive impacts on the water quality of Lake Merced, an important natural water body in San Francisco. Although reduced peak flow rates and increased lag times are arguably less important for this location since the runoff drains into Lake Merced rather than into the City's combined stormwater sewer system, these metrics are important for other locations in San Francisco and are reported here as a measure of effectiveness for this type of GI and site design. The results indicate that GI has the potential to be an effective mechanism for stormwater management if implemented broadly and strategically throughout the City of San Francisco