Cesar Chavez Streetscape Improvement Project Report: Rainy Season 2014-15

Project Overview

The City of San Francisco and the San Francisco Public Utilities Commission (SFPUC) have prioritized green infrastructure (GI) projects as an important strategy to detain and retain stormwater runoff and thereby reduce runoff to the sewer system. This prioritization is part of the larger Better Streets planning effort which seeks to improve pedestrian environments, reduce stormwater flows, and improve residential quality of life in San Francisco. Completed in March 2014 as a demonstration project for the Better Streets Plan, the Cesar Chavez Streetscape Improvement Project was implemented as a partnership between the SFPUC, Department of Public Works (DPW), and Municipal Transportation Agency (MTA). The project included construction of bioretention planters along more than a half mile of impervious streetscape from Hampshire Street to Guerrero Street in the Mission neighborhood of San Francisco (Figure 1). Additional improvements include traditional landscaping, traffic-calming bulb-outs, and a permanent bike lane. Prior to construction, stormwater runoff from these street and sidewalk areas flowed directly into the sewer system.

This project was completed prior to current SFPUC GI design standards and the development of GI performance metrics. The GI was opportunistically sited where space was most easily available and maximum surface stormwater flows could be captured. The results presented within this report offer a unique opportunity to analyze the performance of opportunistic GI within a dense urban setting.

Figure 1. A) Locations of seven monitored planters within the Cesar Chavez Streetscape Improvement Project. B) View of the Folsom Street SW bioretention planter in dry conditions, and C) under storm conditions.

In total, 18 bioretention planters of various sizes were constructed, seven of which were selected to monitor stormwater ponding depth using piezometers in order to evaluate GI effectiveness (Figure 1 and Table 1). The monitoring occurred during the 2014-15 Rainy Season (a Rainy Season spans from October to the end of September; this project was monitored 10/20/2014 – 3/11/2015). Monitoring and analysis of the site included SFPUC, Lotus Water, and San Francisco Estuary Institute (SFEI) (collectively referred to hereafter as "the Team"). Monitoring data and specific characteristics of the bioretention planters and the drainage management areas (DMAs) were then used to develop a US EPA Storm Water Management Model (SWMM). The model was used to simulate flows at each of the seven monitored bioretention planters under pre-construction and post-construction conditions. These simulations compared stormwater runoff volumes and peak flow rate reductions for individual storm events. Assuming similar parameters for the additional 11 non-monitored bioretention planters, the model results were extrapolated to estimate the combined stormwater volume reduction for all 18 bioretention planters in the project (individual storm analysis was not completed for these additional sites).

Based on modeling results for the 2014-15 Rainy Season, the 18 Cesar Chavez Streetscape Improvement Project bioretention planters are estimated to have reduced the total volume of stormwater entering the combined sewer system by 53%, which would be equivalent to over 1.5 million gallons for an average year (21 inches of rainfall). Since implementation of GI was opportunistic and installed prior to development of the SFPUC design standards, many of the bioretention planters were not sized for optimum stormwater retention. This analysis, therefore, provided a unique opportunity to assess performance with varying bioretention planter to DMA ratios.

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Table 1. Characteristics of the bioretention planters and Drainage Management Areas for the seven monitored sites at the Cesar Chavez Streetscape Improvement Project.

Metric	Valencia NW	Valencia SE	Mission NE	Folsom SW	Bryant NW	Bryant SW	Hampshire NW
Drainage Management Area (DMA) (ft^2)	24,950	18,238	12,912	16,368	8,554	10,059	9,242
% Imperviousness of DMA pre-construction	100	100	100	95	100	100	100
Area of bioretention planters (ft^2)	120	110	495	325	62	165	98
% of DMA that is GI	0. 5	0. 6	3. 8	2	0. 7	1. 6	1. 1

Project Findings: Rainy Season 2014-2015

Was Stormwater Volume Reduced?

Prior to implementation of the Streetscape Improvement Project, Cesar Chavez Street was a highly impervious streetscape with little to no stormwater storage or infiltrative function. As a result, most of the rain falling onto the street and sidewalk during storm events ran off into the sewer system. GI elements were designed and installed to detain and retain rainfall and runoff, thereby reducing stormwater surface flows, increasing groundwater recharge and returning some of the natural functionality of the watershed.

The bioretention planters received a total of 18.4 inches of rainfall during Rainy Season 2014-2015 (10/20/2014 – 3/11/2015). This rainfall total was slightly below average for San Francisco, which typically receives about 21 inches per year. Most of the rainfall (72%) fell during the first three weeks of December and included large storm events. At the 1-hour duration, which is relevant to street surface flooding in urban areas, the December 2nd-3rd and December 10th storms were both classified as 25-year events, and the December 11th–12th storm was classified as a 10-year event. Therefore, despite the low rainfall year, the 2014-15 Rainy Season includes events that tested the performance of these planters.

For the period modeled, estimated volume reduction at individual sites ranged from 31% (at the most undersized unit, Valencia NW) to 89% (at the bioretention planter near recommended sizing criteria, Mission NE) (Figure 2) and total runoff volume from the seven sites post-construction was reduced by 53%.

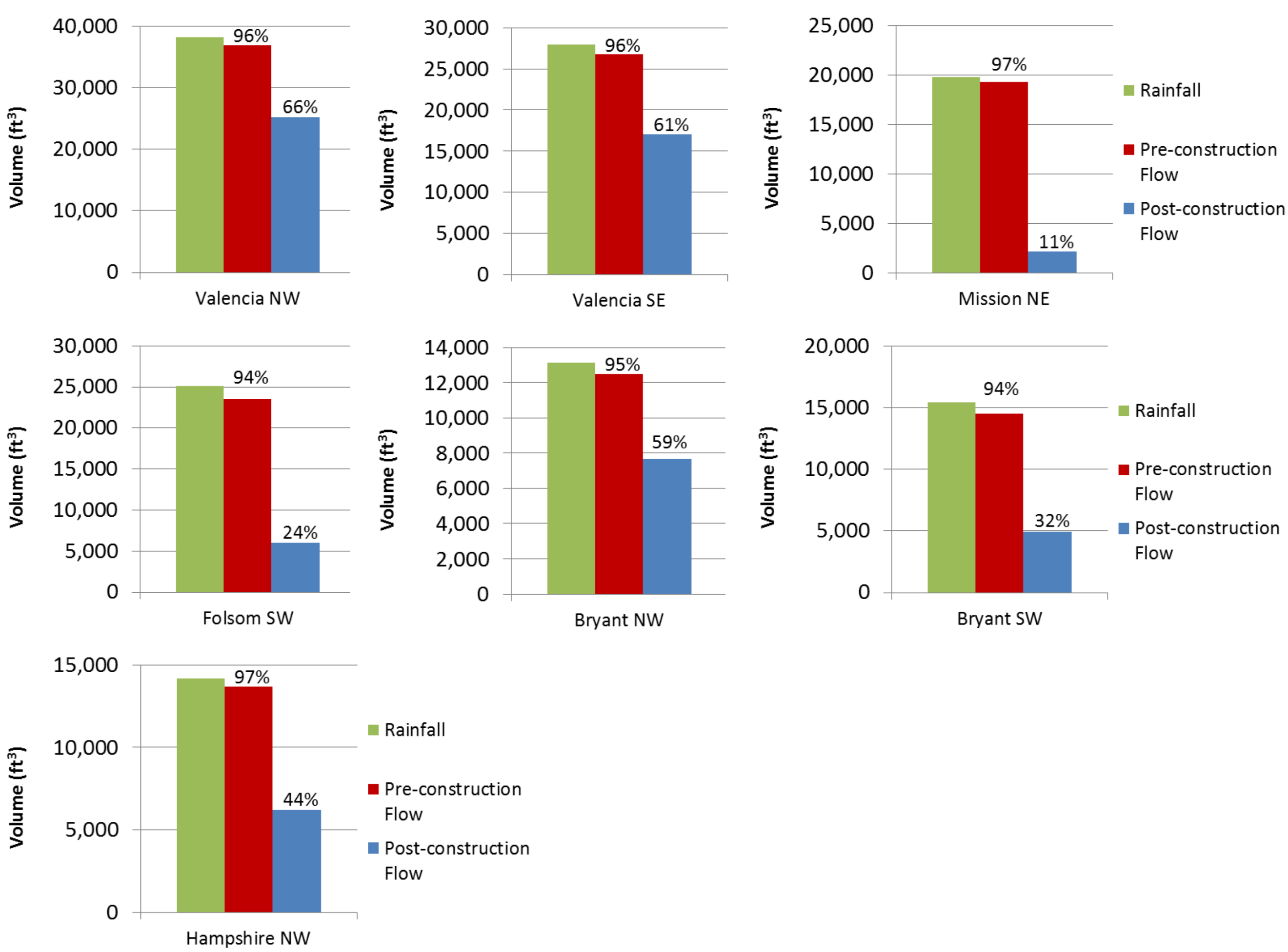

Figure 2. Estimated total flow volume at the seven analyzed bioretention planters under pre- and post-construction conditions as a percentage of the total rainfall volume for the monitoring period.

In total, more than 580,000 gallons of runoff was estimated to be retained by the seven bioretention planters for the modeling period. Extrapolating the model to all 18 planters yielded equivalent overall performance (53% annual volume reduction), which equates to over 1.5 million gallons diverted from the combined sewer system (CSS) during an average Rainy Season. Volume reduction was correlated with the ratio of GI area to the DMA. Planters with higher ratios were estimated to perform better and had higher stormwater retention than planters with lower ratios. This is shown in Table 2, which highlights the total volume and peak flows at the highest- (Mission NE) and lowest- (Valencia NW) performing bioretention planters for a large storm event in December 2014. Relative to its DMA, the Mission NE planter is nearly eight times the size of the Valencia NW planter. This ratio best accounts for the water retention performance differences between the two planters.

As noted previously, many of the Cesar Chavez bioretention planters were undersized relative to the optimum sizing criteria of 4% GI:DMA (Table 1). The smallest bioretention planter relative to its DMA still reduced total runoff volume by an estimated 31% (Table 2).

Table 2. Characteristics of the largest total rainfall storm event (December 11th-12th) at the Mission NE (highest performing) and Valencia NW (lowest performing) locations.

Storm or Flow Characteristic	Valencia NW	Mission NE
% of DMA that is GI	0.5%	3.8%
Storm Date(s)	December 11-12, 2014	
Storm Total Rainfall (in)	4.19	
Storm Duration (hrs)	24	
Peak 5-minute Rainfall Intensity (in/hr)	3.6	
% of Rainfall Flowing to CSS (pre-construction)	100%	100%
% of Rainfall Flowing to CSS (post-construction)	83%	14%
% Runoff Reduction due to GI	17%	86%
Peak Flow Rate (pre-construction) (cfs)	2.06	1.09
Peak Flow Rate (post-construction) (cfs)	1.43	0.69
% Peak Flow Reduction due to GI	31%	37%

Were Peak Flow Rates Reduced?

When the DMA's land cover has a high proportion of impervious surfaces such as sidewalks, roads, and parking lots, a large fraction of rainfall quickly becomes runoff and produces higher peak flow rates than more natural or vegetated areas that are more likely to retain or infiltrate water. At the local scale, this can result in street surface ponding. Further downstream, when flows from multiple DMAs converge in the sewer system, large peak flow rates can trigger unwanted combined sewer discharges. Reduction in peak flow rates is an important measure of success for GI projects in urban areas, consistent with the goal of GI implementation to slow and infiltrate stormwater runoff.

A total of 31 discrete storm events were identified during the 2014-15 monitoring period, and the hydrographs for each modeled event at the seven bioretention planters were characterized. Not all storm events produced outflow at each individual bioretention planter (Table 3). Predictions based on model outputs for Mission NE showed the fewest number of outflow producing events (n=4). There were eight storm events that were estimated to produce no outflow from any of the seven planters, with the largest of these eight events having a rainfall total of 0.18 inches. At the best performing bioretention planter (Mission NE), 27 storm events were predicted to have no outflow, the largest being a 1.52-inch rainfall event. For storms in which no outflow occurred, there was 100% stormwater retention and 100% peak flow reduction. For the storm events in which outflow did occur, the peak flow rate reduction varied between the seven sites, with the largest estimated reductions at sites with a higher GI:DMA ratio (Mission NE and Folsom SW). The average estimated peak flow reduction at each site (when considering only storms with outflow) varied between 35% and 50% and was closely associated with the rain intensity of each storm event. Even during the most intense storm event, when the bioretention planters are more likely to become overwhelmed by the magnitude of surface runoff over a short time period, the bioretention planter sized closest to the 4% sizing criteria (Mission NE) still reduced peak flow to the CSS by 26%.

Table 3. Estimated peak flow reduction characteristics for the 31 storm events modeled for each bioretention planter, organized from highest to lowest % GI:DMA.

	Storms with Outflow				Storms with No Outflow		
Site	Storm Events	Minimum Peak Reduction	Maximum Peak Reduction	Average Peak Reduction	Storm Events	Largest Storm Event with No Outflow (in)	% GI : DMA
Mission NE	4	26%	97%	47%	27	1.52	3.8%
Folsom SW	10	16%	90%	49%	21	0.49	2.0%
Bryant SW	12	13%	88%	49%	19	0.45	1.6%
Hampshire NW	18	10%	86%	45%	13	0.25	1.1%
Bryant NW	19	5%	60%	35%	12	0.25	0.7%
Valencia SE	22	5%	89%	40%	9	0.18	0.6%
Valencia NW	23	4%	83%	36%	8	0.18	0.5%

What Is the Predicted Hydrologic Response to the Design Storm?

An important measure of GI performance from a planning perspective and for comparison to other projects is the hydrologic response to the design storm. Although this project was designed and built prior to current SFPUC GI design standards, GI projects are often designed to treat particular storm sizes over certain durations and rainfall intensity. The more opportunistic design of the Cesar Chavez Streetscape Improvement Project provided a unique opportunity to evaluate the performance of undersized bioretention planters, which may be the only feasible option in certain construction situations.

Two design storms were simulated at each of the seven bioretention planters; the 1-year 24-hour storm event (total of 2.65 inches) and the 5-year 3-hour storm event (total of 1.14 inches). The estimated performance varied by bioretention planter and flow volume reduction was strongly associated with the ratio of the GI area to the DMA (Figure 3A and 3B). Flow volume reductions varied across the seven planters and ranged from 31% to 93% for the 1-year 24-hour design storm. Across all seven sites combined, the total volume reduction for the 1-year 24-hour storm was 56%. Flow volume reductions for the 5-year 3-hour design storm were less, ranging between 13% and 75% across the seven individual planters. In combination, the total estimated volume reduction was 31%. The lower performance in the 5-year 3-hour storm event is due to the greater intensity of the rainfall during this event.

Peak flow reduction during the simulated design storms was not strongly associated with GI size (Figure 3C and 3D). The reduction in peak flow rates varied less across the seven sites, ranging from 31% to 46% for the 1-year 24-hour storm and 26% to 37% in the 5-year 3-hour storm. The combined peak flow reduction from all seven sites was 35% and 29% for the 1-year 24-hour storm event and the 5-year 3-hour storm event, respectively. When considering the seven bioretention planters' combined impacts, significant reductions in estimated total volume and peak flow rates were attained.

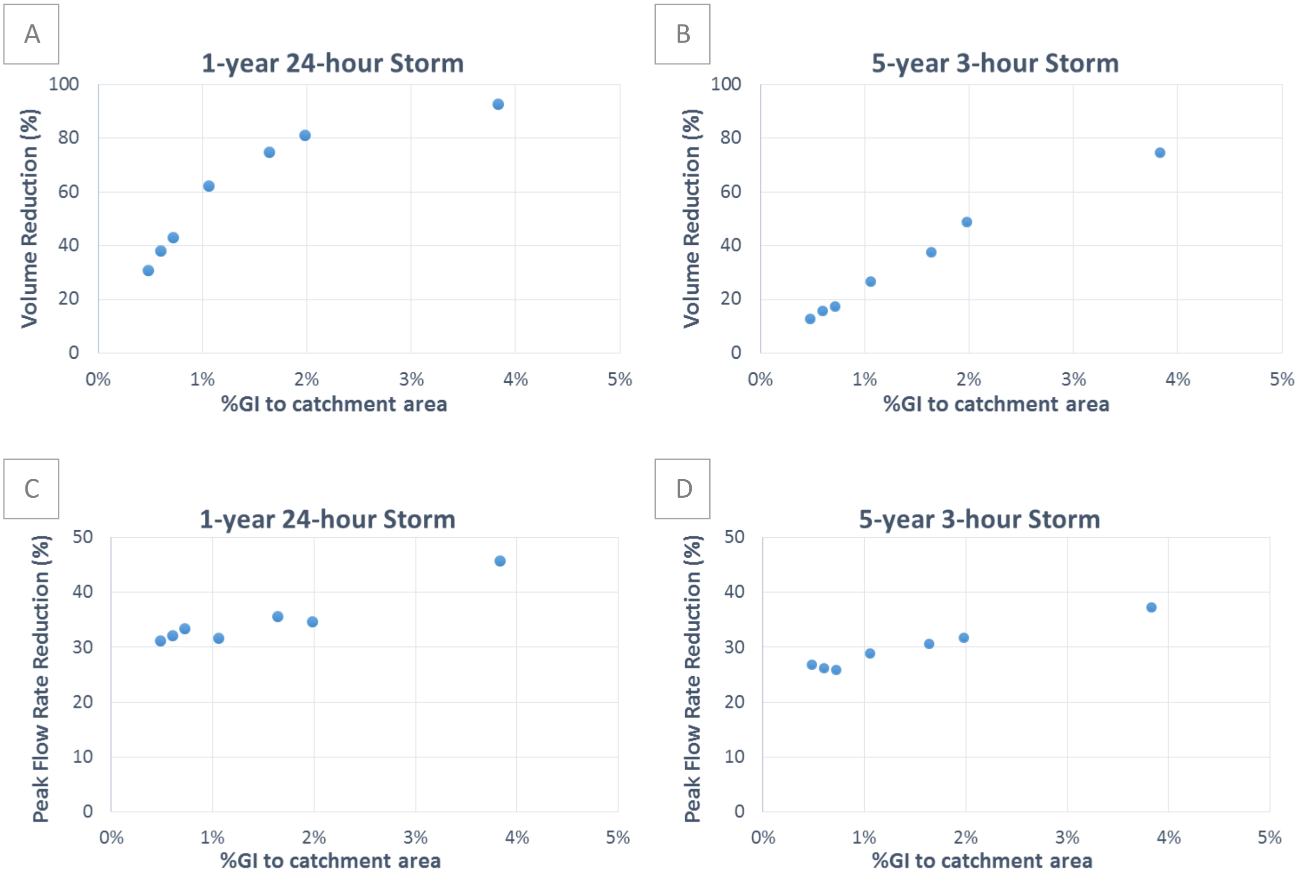

Figure 3. Estimated flow volume reduction in relation to the ratio of GI area to DMA for the A) 1-year 24-hour storm, and B) 5-year 3-hour storm. Estimated peak flow rate reduction in relation to the ratio of GI area to DMA for the C) 1-year 24-hour storm, and D) 5-year 3-hour storm.

Summary

This modeling exercise estimated that 580,000 gallons of stormwater were retained in the seven monitored facilities over the 2014-15 Rainy Season. Extrapolated to all 18 bioretention planters, estimated runoff reduction for the monitoring period was estimated to be 1.3 million gallons. A 1.5 million gallon reduction would be expected during an average rainfall year (21 inches). Performance estimates produced during the planning phase of this project, also via SWMM modeling, predicted a reduction of approximately 0.5 million gallons for the whole project, so this study suggests higher than anticipated volume reduction.

Based on the modeling simulations, the Cesar Chavez Streetscape Improvement Project bioretention planters' individual performance related to site specific design characteristics. Of the design characteristics, the most notable was the sizing ratio between the bioretention planter and the DMA. Planters with larger GI:DMA ratios generally perform better, retaining greater stormwater runoff volume, having fewer storms that produce outflow to the sewer system, and having greater reductions in peak outflow rates. Undersized planters still have significant impacts to peak and total volume reductions, but to a lesser extent during the larger design storms. These findings suggest that sizing criteria are critical to meeting Level of Service performance goals, but where GI implementation space is limited, measurable stormwater retention and peak flow volume reduction can still be attained.