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.

Based on the modeling results, the 18 bioretention planters are estimated to have reduced the total volume of stormwater entering the combined sewer system by 53%.

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%.

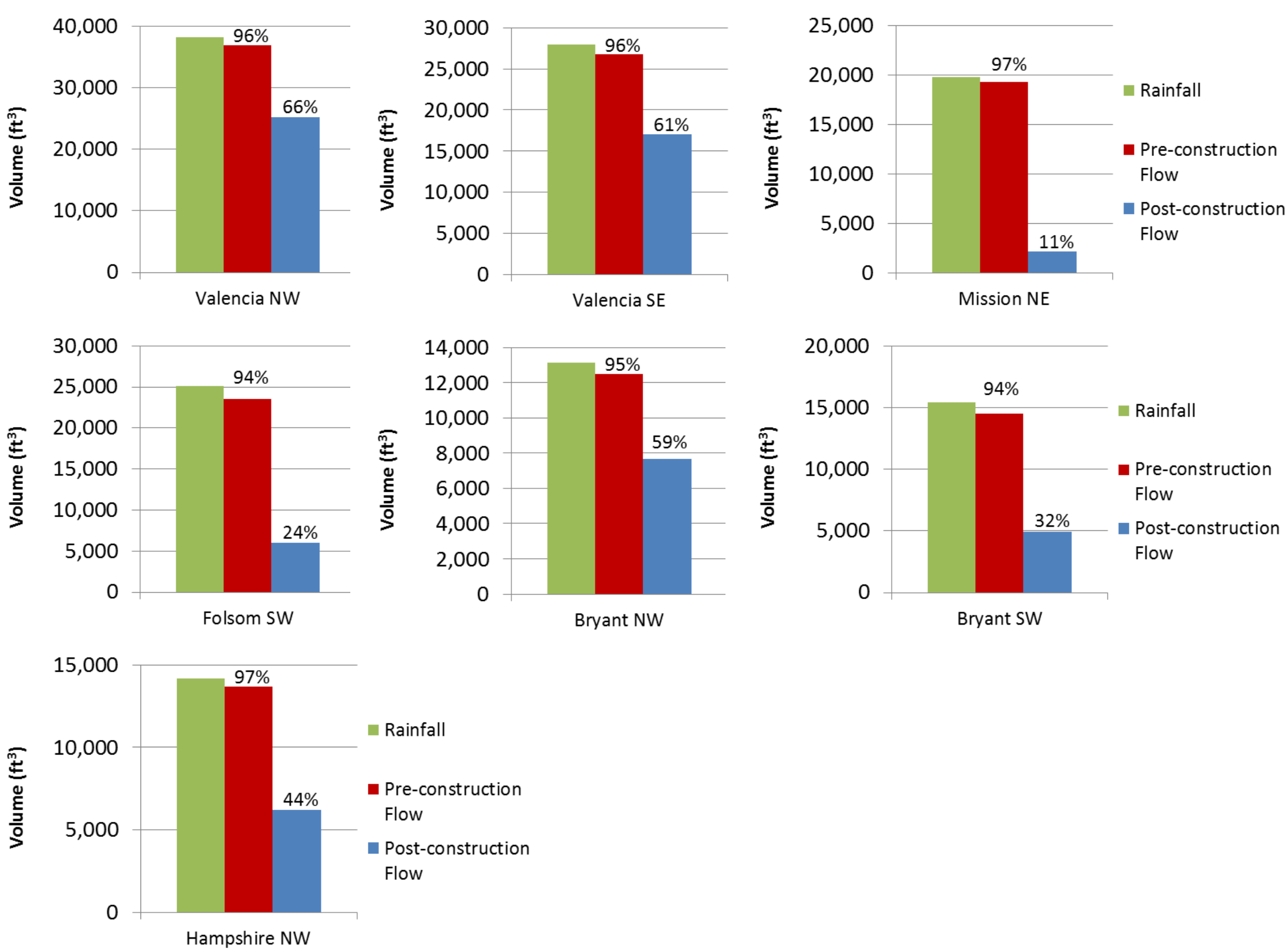


Figure 2. Estimated total flow volume at the seven analyzed bioretention planters under pre- and post-construction conditions as a percentage of the total rainfall volume for the monitoring period.

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.

Site	Storms with Outflow				Storms with No Outflow		% GI : DMA
	Storm Events	Minimum Peak Reduction	Maximum Peak Reduction	Average Peak Reduction	Storm Events	Largest Storm Event with No Outflow (in)	
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.

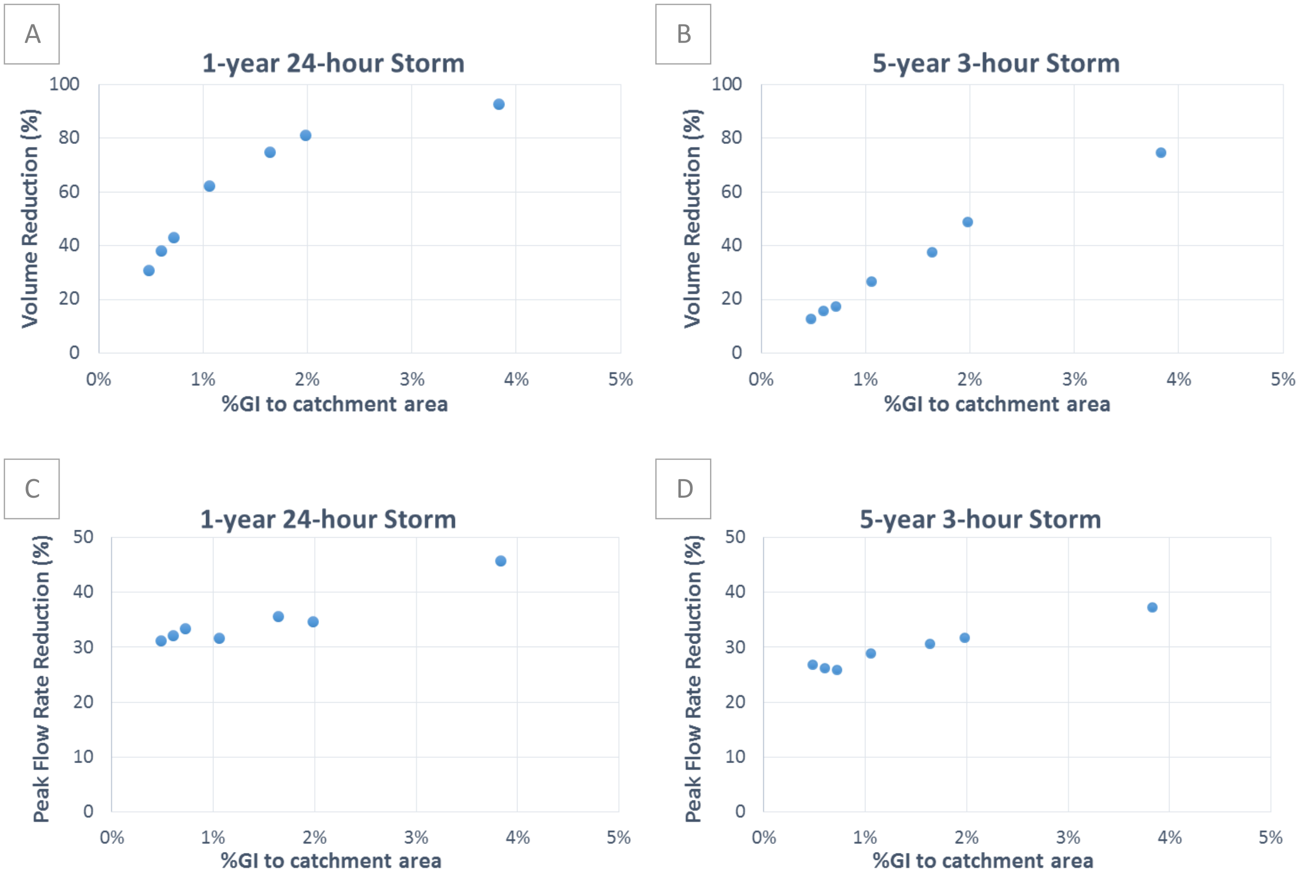


Figure 3. Estimated flow volume reduction in relation to the ratio of GI area to DMA for the A) 1-year 24-hour storm, and B) 5-year 3-hour storm. Estimated peak flow rate reduction in relation to the ratio of GI area to DMA for the C) 1-year 24-hour storm, and D) 5-year 3-hour storm.

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.

Cesar Chavez Streetscape Improvement Project: Technical Appendix

This appendix complements the Cesar Chavez site report by providing technical detail on the modeling and analysis methods, data quality and results, as well as providing suggested improvements for future GI monitoring by the Team.

Project Characteristics

The Cesar Chavez Streetscape Improvement project created a multi-featured street that included permeable pavement, bioretention planters, street trees, and de-paving parts of the existing street which was replaced with drought-tolerant landscaping. This project 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. Prior to implementing this Streetscape Improvement Project, the landscape surface was highly impervious with all stormwater draining to the combined sewer system (CSS). The hydrologic goals of the project were to increase stormwater retention and infiltration via green infrastructure (GI) features and to provide increased rain interception via greater tree canopy. The Streetscape Improvement Project includes 18 bioretention planters that extend from Hampshire Street to Guerrero Street in the Mission neighborhood of San Francisco (Figure 1). Of these 18 units, seven were selected to monitor ponding depth using piezometers in order to evaluate effectiveness. The focus of this technical appendix is to assess the impact of the seven bioretention units on stormwater runoff volume and peak flows.

The bioretention planters are each located immediately upstream of a stormdrain catch basin, and were designed to intercept flows from the drainage management area (DMA) to those catch basins. No underdrains were installed in any of the seven monitored planters in order to maximize stormwater infiltration. Four of the seven planters had three inches of ponding depth, three inches of stone/cobble mulch, 18 inches of engineered soil filter media, and six inches of scarified native soil at the bottom. Infiltration test results indicated that the other three planters had native soils with poor infiltration rates, which led the PUC to adaptively alter the design of these planters to include 15 inches of drain rock underlying the soil filter mix to allow for additional storage and help offset the poorer infiltration rates of the underlying soils.

The total DMAs to the bioretention planters ranged between 8,500 and 25,000 ft^2, and the individual bioretention planters ranged in size themselves between 62 and 495 ft^2 (Table 1). The ratio between the surface area of the GI unit and the DMA (or the % of the DMA that is GI) along with the infiltration rates of the GI soil and underlying native soils are the primary factors which determine how much stormwater a bioretention planter can retain. A common GI sizing criteria in the Bay Area is a minimum 4% of the DMA. When a GI unit sized at 4% has soils with infiltration rates of 5 in/hr, the unit should be capable of infiltrating all the stormwater runoff from the DMA. Relative to the 4% ratio recommendation, the Cesar Chavez units are undersized ranging between 0.5% and 3.8% of the DMA, as they were designed and constructed before the SFPUC had developed its current design and performance standards.

Figure 1. A) Locations of the seven monitored Cesar Chavez bioretention planters, B) view of the Folsom Street SW planter during storm conditions and C) during dry conditions

Table 1. Characteristics of the Drainage Management Area 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 (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

Methods

The performance of each monitored bioretention planter was evaluated using US EPA's Stormwater Management Model (SWMM). Flow characteristics from pre-construction and post-construction conditions were simulated and compared to estimate the effectiveness of the bioretention planters. Simulation was required since limited pre- and post-construction flow monitoring was performed at the bioretention planters due to site and budget constraints. SWMM was chosen because it is primarily designed for urban watersheds, with the ability to simulate hydrologic performance of five GI types including bioretention cells.

The pre-construction simulation was built using data that described the characteristics of the DMA of each planter. Key input parameters included DMA area, width, slope and percent imperviousness. Although measured flows were not available to calibrate the model, the pre-construction simulation was considered to have good certainty because all DMAs were nearly 100% impervious with high runoff coefficients. The post-construction simulation involved adding model parameters that describe the bioretention planter specifications, including size, characteristics of the surface storage layer, the soil filter layer, and the storage area layer (where applicable).

The performance of each bioretention planter was evaluated for a portion of the empirical Rainy Season 2014-2015 (October 2014 – September 2015; actual monitoring period was 10/20/2014 – 3/11/2015) and two design storms (1-year 24-hour and 5-year 3-hour events). The Rainy Season 2014-2015 simulation used the rainfall record collected from SFPUC Rain Gage 25 which was located approximately 1 mile (1.6 km) to the southwest (37.742051, -122.431483) in a location with similar precipitation frequency estimates to those at the project site. At the project site and Rain Gage 25, the 1-yr 24-hr estimate is 1.85 inches and 1.91 inches, respectively, and the 5-yr 3-hr estimates are 1.24 inches and 1.26 inches, respectively. This rainfall record spanned the monitoring period and was collected at 5-minute intervals. Piezometer data collected during the same period of record at each of the seven bioretention units was reviewed to aid in calibrating the infiltration rates of the soil filter media as well as the native soil at each bioretention planter. The time step of model simulation was 5 minutes, to be consistent with rainfall data.

Individual storm events were isolated from the continuous simulation of Rainy Season 2014-2015 and a suite of flow characteristics (flow duration, total flow volume, peak flow rate, and storm runoff coefficient) under both pre-construction and post-construction conditions were estimated for the seven bioretention planters. Reductions of peak flow and total volume at each bioretention planter were primarily used to assess the effectiveness of each unit, both for the empirical Rainy Season 2014-2015 storms as well as the design storms.

This report primarily focuses on the modeling and analysis results for the seven monitored bioretention planters, sometimes focusing on just two planters to highlight the range of performance across the seven sites. The model was further expanded to include the additional 11 unmonitored bioretention planters, which were analyzed only for changes in total runoff volume under pre- and post-construction conditions. For this expanded model, assumptions about infiltration rates for the bioretention planters and underlying native soils were held consistent with the rates assigned to the seven monitored locations.

Data Quality

Table 2 below summarizes each dataset or parameter used in the model and an assessment of its quality. Where quality is only moderate, a suggestion for improving the data quality is provided. In summary, the data quality is high or moderately high for most parameters/datasets.

Table 2. Assessment of data quality for each dataset or parameter used in the model.

Dataset/Parameter	Quality Rank	Quality Description
Parameters for Draiange Areas		
Rainfall data for Rain Gage 25 provided by the SFPUC	High	The rainfall data record is evaluated by SFPUC and the records of gages in timing and magnitude of rainfall events.
Drainage Area	Moderate-High	The drainage area was delinated during dry weather conditions in a team effort between SFEI and Lotus Water. Although the delineation seemed clear in the field, it may be improved by observation and verification during storm conditions.
Slope of catchment	High	Slope was determined using a 1 meter DEM developed through the ARRA Golden Gate LiDAR Project.
% Imperviousness	High	The degree of imperviousness was assessed in the field; although most DMAs included at least small street trees, all DMAs except Folsom SW were overwhelmingly dominated by impervious land cover and the Team decided to parameterize the DMAs as 100% impervious. Only Folsom SW had significant canopy cover yet the land cover of the DMA was still dominantly impervious.
Mannings N values for pervious and impervious areas, depression storage	Moderate-High	The values used in this analysis for thes parameters are average recommended values.
Parameters for Bioinfiltration Units		
Surface Storage Depth	Moderate-High	Surface storage depths were qualitatively observed during a field excursion and, in lieu of a field survey, the SFPUC provided specs as to the average ponding depth for all the units.
Soil Filter Mix Specs (thickness, porosity, field capacity, wilting point, conductivity, suction head)	Moderate	The specs used were consistent with soil properties for loamy sand which decently characterizes the general properties desired for bioinfiltrating units. Knowledge of the properties of the engineered soils in the as-built planters could be improved with testing and verification.
Infiltration Rate of Soil Filter Mix and Native Soil underlying each unit	Moderate	The range of acceptable infiltration rates for the soil filter mix were clearly detailed in the project manual. Infiltration rates of the native soil were tested after the excavation of each unit. Piezometer data for one unit (Mission NE) was used to help calibrate these infiltration rates (the model was highly sensitive to the infiltration rates used), which were then applied to the model for each of the seven sites. A future model run at this or other LID sites to evaluate performance could be improved if data collected on the infiltration rates of native soils were improved with further testing or if better quality piezometer data were to become available.
Storage Layer Specs (for the three units which have a storage layer)	Moderate-High	The change order to add the 15 inch drain rock layer to the bottom of three bioinfiltration clearly detailed the specifications.

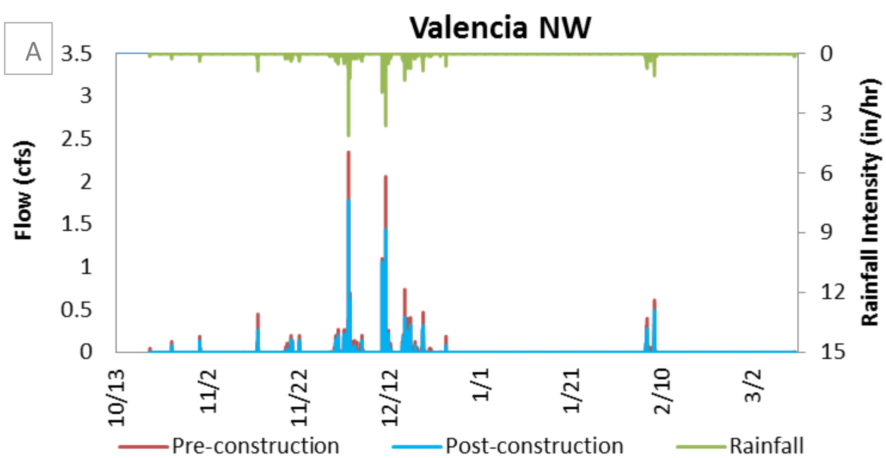
Results for Simulation of Rainy Season 2014-15

Based on the model runs, there is reasonable evidence that the Cesar Chavez Street bioretention planters reduced the total volume flowing to the combined sewer system as well as reduced peak flow rates. The bioretention planters ranged in volume and peak flow reduction performance, with high correlation to the ratio of the GI to its DMA. The details of the results of are discussed below, first in relation to the Rainy Season 2014-15 rainfall record, and then in relation to performance of the units for the Level of Service (LOS) storm events including the 1-year, 24-hour event and the 5-year 3-hour event.

Flow Volume Reduction for Rainy Season 2014-2015

The Cesar Chavez bioretention planters received a total estimated rainfall of 18.4 inches during the modeled period for Rainy Season 2014-2015 (10/20/2014 – 3/11/2015), assuming the rainfall record measured at Rain Gage 25 is representative of the Cesar Chavez study site. The season was slightly below average for San Francisco (which typically receives about 21 inches/yr), where 72% of the rain fell during the first three weeks of December. Three notable December storms occurred on the 2^{nd}-3^{rd} (3.69 inches), the 10^{th} (1.06 inches), and the 11^{th}-12^{th} (4.34 inches). Based on the 3 hour duration, the December 2nd-3rd and Dec 11^{th}-12^{th} storms had an estimated return frequency of 10 years, and the Dec 10^{th} storm was a 2-year event. At the 1 hour duration, the December 2^{nd}-3^{rd} and December 10^{th} storms were 25-year events and the December 11^{th}-12^{th} storm was a 10-year event. Therefore, despite the low rainfall year, the 2015-15 Rainy Season includes events that tested the planters during large storm events.

The seasonal hydrograph for two of the bioretention planters (Valencia NW and Mission NE) are plotted in Figure 2 and show the estimated changes to stormwater flows to the CSS before and after construction. These bioretention planters have the smallest (Valencia NW) and the largest (Mission NE) ratio of GI to DMA, and together represent the range of performance for all of the planters. For both bioretention planters, simulated flows assuming pre-construction conditions were highly correlated with rainfall and occurred in response to almost all storm events. Flows simulated for these DMAs, post-construction of the bioretention units, varied more between the two bioretention planters in response to rainfall. Although the bioretention unit at Valencia NW reduced storm flow volume and peak flow rates, these reductions were the lowest in the study and outflows occurred in all but the smallest rainfall events (largest storm event with no outflow was 0.18 inches with a maximum hourly rainfall of 0.5 inches). Conversely, flows to the CSS from Mission NE were estimated to occur on only four occasions during the Rainy Season, three of which were the large storm events previously described, and the fourth storm resulted in negligible outflow of <1%. Overall, the bioretention units are estimated to have substantially reduced the total stormwater runoff volume draining to the CSS. For the period modeled, total runoff volume exiting the seven bioretention planters post-construction was reduced by an estimated 49%; at individual bioretention planters the estimated runoff volume reduction ranged from 31% (at the most undersized unit, Valencia NW) to 89% (at the bioretention planter near recommended sizing criteria, Mission NE) (Figure 3). In total, over 580,000 gallons (or 77,800 cubic feet) of runoff was estimated to be retained by these seven bioretention units for the study period based on the modeling results. Based on the expanded modeling results of all 18 bioretention planters, the Cesar Chavez Streetscape Improvement Project reduced the total volume of stormwater entering the combined sewer system by an estimated 53%, which would be equivalent to over 1.5 million gallons for an average rainfall year (21 inches).



Flow reductions from Valencia NW were the lowest of the entire group due to the small ratio of GI area to DMA (0.5%). Nearly every storm resulted in outflows to the CSS. Nevertheless, this undersized unit still reduced estimated total flow volumes to the CSS by 31% over the course of the modeled season, and the estimated peak flow rate was reduced by 24% down to 1.77 cfs.

Mission NE was the best performing bioretention planter, and also had the greatest ratio of GI area to DMA (3.8%). This site shows how GI would work when a unit is sized as recommended (a typical recommendation is 4%). Most storm events at Mission NE did not result in flow to the CSS post-construction, and overall this bioretention planter reduced the estimated total flow volume for the season by 89%. As is true for GI generally, performance was not as high during the largest events due to lack of time for infiltration. However, even during the very intense event on Dec 2-3, 2014, the estimated peak flow was reduced by 29%.

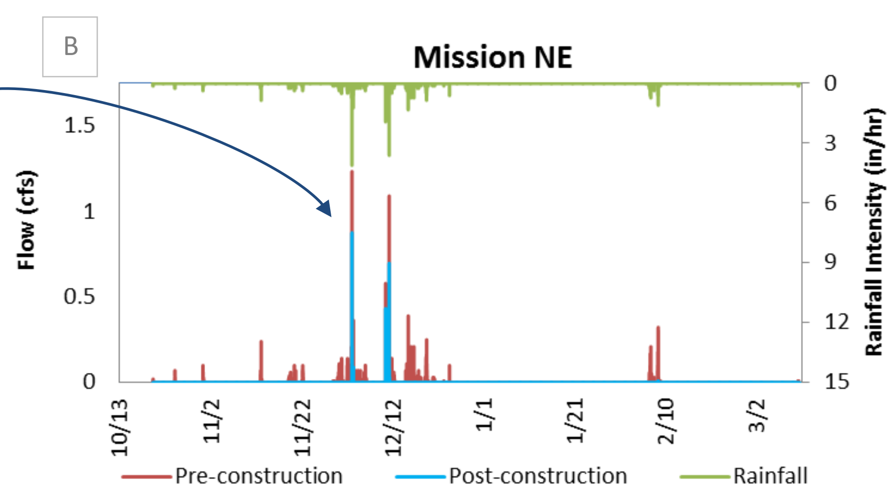


Figure 2. Modeled pre-construction versus post-construction flows and rainfall intensity at Cesar Chavez bioretention sites A) Valencia NW and B) Mission NE for the 2014-2015 rainy season.

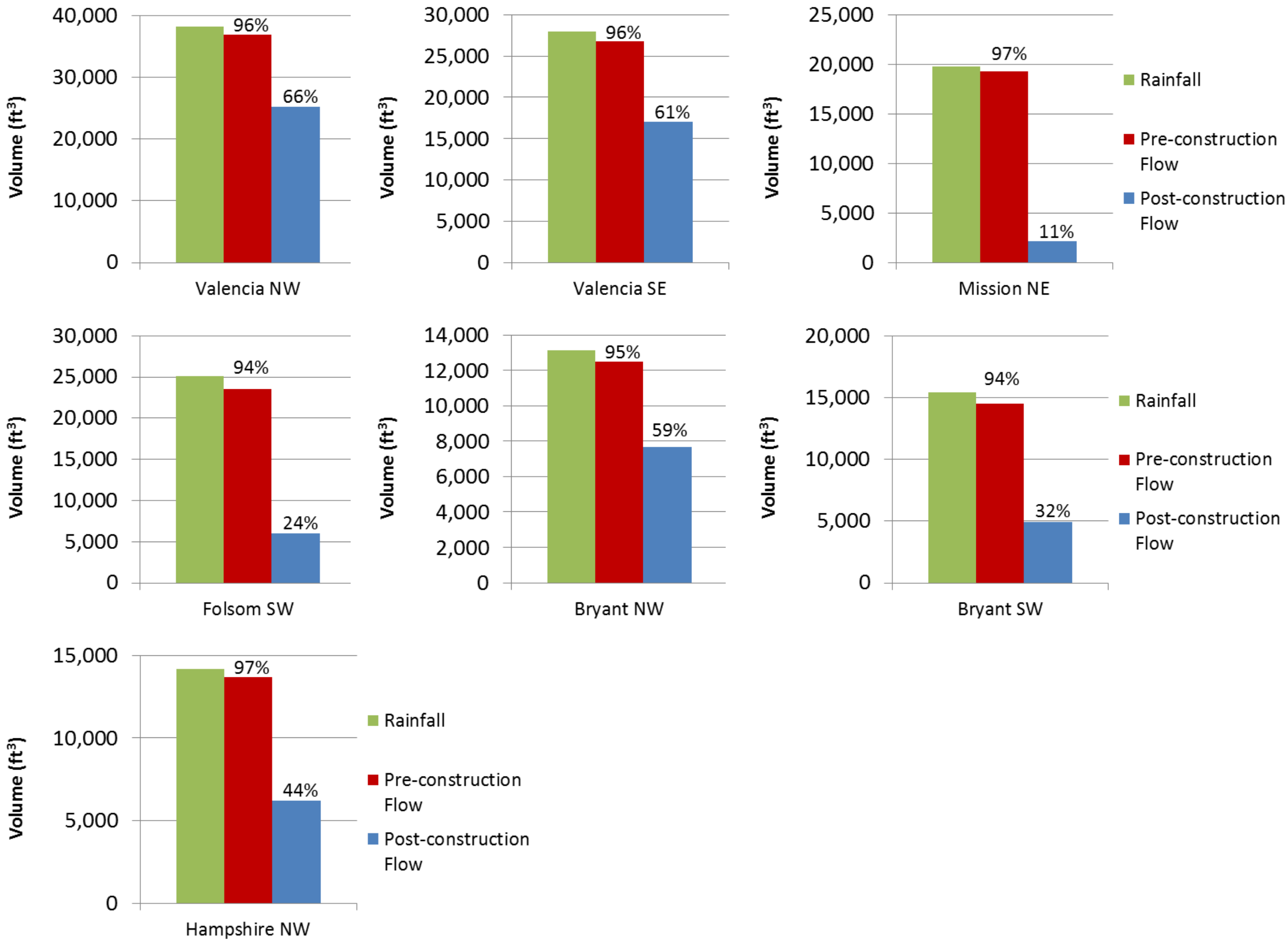


Figure 3. Estimated total flow volume as a percentage of the incident rainfall for the Rainy Season 2014-15 modeled period at each bioretention unit.

Storm hydrographs for Valencia NW and Mission NE during the December 11 and December 19, 2014 storm events are shown in Figure 4 and illustrate the likely changes to runoff patterns at each bioretention planter. The patterns shown in these hydrographs follow typical modifications to hydrology due to GI installations which are undersized (Valencia NW) and sized near 4% (Mission NE). Conceptually, after GI is implemented, we would expect to see fewer storms resulting in outflow and both a reduction in volume and flattening of the peak hydrograph. As seen in Figure 4, these improvements would be more substantial in a GI unit with more capacity relative to the DMA it serves.

The storm event and resulting hydrographs shown in Figures 4A-C illustrate one of the large storm events measured; based on the three hour duration, this storm had a return frequency of 10 years. During this storm, over four inches of rain fell in about 24 hours. The bioretention unit at Valencia NW reached capacity quickly and outflows were not much different for post-construction conditions than those modeled for pre-construction conditions (total flow was reduced 17%) (Table 3). In contrast, Mission NE had estimated outflow for two of the 31 hours of the storm, and total flow was reduced by 86%. During events smaller than the 10-year event, this bioretention planter would be expected to perform even better in terms of total volume and peak flow rate reductions. These results suggest performance at this location is well in excess of the typical regional hydrologic design objective of treating stormwater runoff from rainfall rates up to 0.2 inches per hour. The storm event and resulting modeled hydrographs shown in Figures 4D-F illustrate a much smaller event (chosen because of how the hydrographs contrast with those from the larger, December 11th event) in which 1.06 inches of rain fell over 14 hours. This represents a much more typical storm event for San Francisco. In this event, the undersized Valencia NW still infiltrated about 30% of the runoff, whereas Mission NE infiltrated all runoff from the storm event (Table 4).

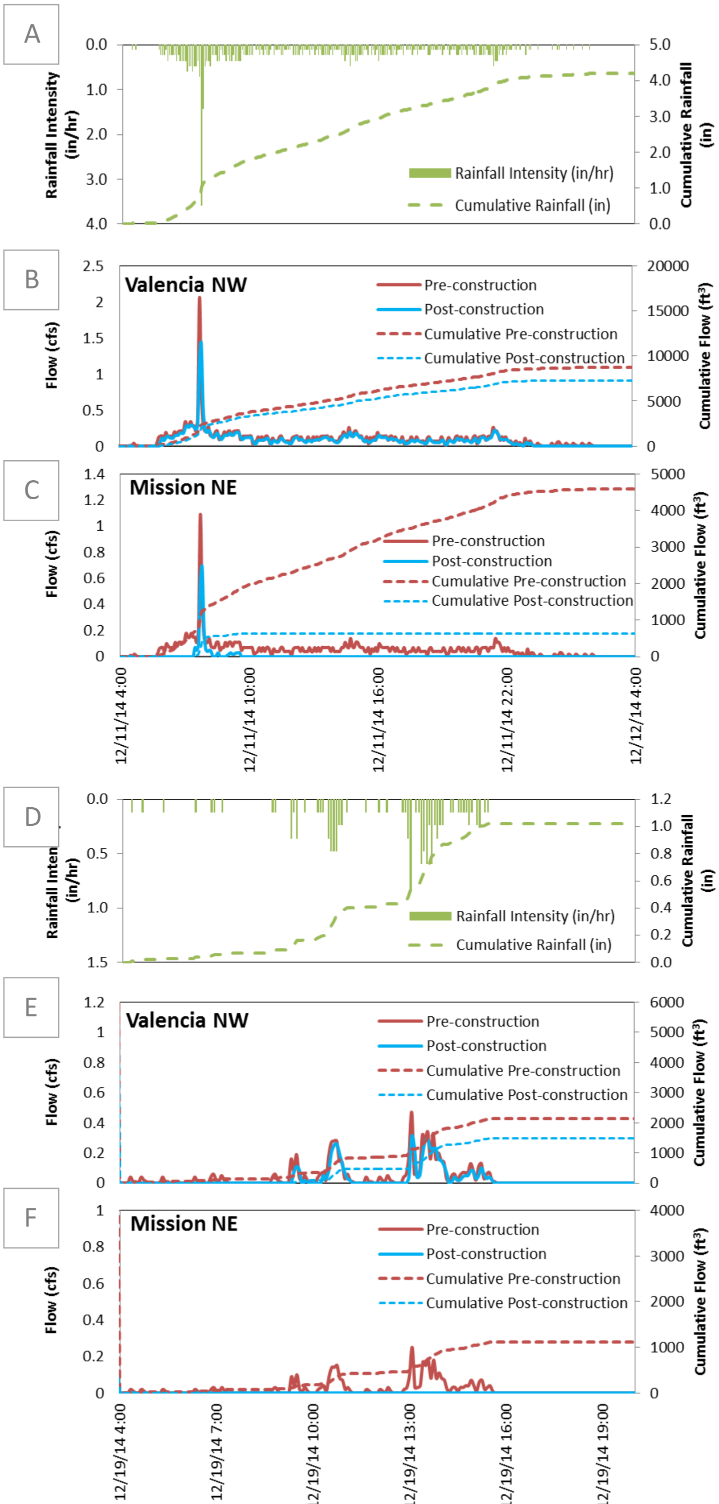


Figure 4. A) Rainfall intensity and cumulative rainfall on December 11, 2014, one of the largest modeled events. Estimated storm hydrographs for post-construction flows for the storm for sites B) Valencia NW and C) Mission NE. D-F) Rainfall and estimated flows for a smaller storm event on December 19, 2014.

Table 3. Storm and estimated flow characteristics for the storm shown in Figure 4 graphs A-C. Note, the storm continued on beyond what is shown and metrics in this table only reflect the period shown.

Storm or Flow Characteristic	Valencia NW	Mission NE
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)	>99%	>99%
% of Rainfall Flowing to CSS (post-construction)	83%	14%
Peak Flow Rate (pre-construction) (cfs)	2.06	1.09
Peak Flow Rate (post-construction) (cfs)	1.43	0.69

Table 4. Storm and estimated flow characteristics for the isolated storm event shown in Figure 4 graphs D-F.

Storm or Flow Characteristic	Valencia NW	Mission NE
Storm Date(s)	December 19, 2014	
Storm Total Rainfall (in)	1.06	
Storm Duration (hrs)	14	
Peak 5-minute Rainfall Intensity (in/hr)	0.84	
% of Rainfall Flowing to CSS (pre-construction)	>99%	97%
% of Rainfall Flowing to CSS (post-construction)	70%	0%
Peak Flow Rate (pre-construction) (cfs)	0.47	0.25
Peak Flow Rate (post-construction) (cfs)	0.31	0

On an individual storm basis, the relationship between rainfall and simulated flow volume for pre-construction conditions had excellent correlation (Figures 5 and 6) since runoff from the nearly 100% impervious watersheds is not affected by some of the more complex factors found in more natural drainage systems such as variation in soil moisture and ground water-slope interactions. The correlation between rainfall and post-construction outflows was less strong (R^2 ranging from 0.68 to 0.98 for each bioretention planter). Stormwater runoff for all seven DMAs, though it is most apparent for the DMAs with the greatest reductions due to GI, one storm resulted in outflows post-construction that were almost as great as the runoff modeled for these areas assuming pre-construction conditions. This point particularly appears to be an outlier for sites Mission NE, Folsom SW, Bryant SW and Hampshire NW in Figures 5 and 6. This storm event represents the very short and very intense event on December 10, 2014 in which 1.06 inches of rain fell in 40 minutes (at the 1-hr duration, this storm was a 25-yr event). As a result of this rainfall intensity, the bioretention units had little time to infiltrate the stormwater runoff, little capacity to store the inflow, and therefore a great majority of that runoff simply bypassed the units and flowed to the CSS. This degree of rainfall intensity is rare, and rare relative to the rest of the storm events during the season, which is why it appears to be an outlier in Figure 5. The magnitude of antecedent rainfall and consequently the saturation condition of a DMA and bioretention planter would be expected to vary the effectiveness of GI in many scenarios. The effect of antecedent conditions (antecedent time periods tested included 1-5 days) was evaluated and found to be negligible, likely due to the imperviousness of the DMAs and the high infiltration rates used to model these units.

Peak Flow Rate Reduction for Rainy Season 2014-2015

Thirty-one (31) storm events from Rainy Season 2014-15 were modeled for each bioretention unit, and post-construction between four and 23 of those storm events produced outflow from the units to the CSS (Table 5). For those storm events producing outflow, reductions in peak flows from pre-construction simulations ranged from 4% to 97% depending on storm characteristics, and averaged between 35 and 49% at all monitored bioretention planters. There were no modeled outflows in numerous storms at each bioretention planter, ranging between eight and 27 events and including storms up to 1.52 inches at the best performing unit (Mission NE). For these storms we predict there was 100% stormwater retention (and 100% peak flow reduction) within the landscape and infiltration units.

Table 5. Peak flow reduction characteristics for the events modeled in each bioretention unit.

Site	Storm Events (Total n)	Storms with Outflow				Storms with No Outflow		% GI : DMA
		Storm Events (n)	Minimum Peak Reduction	Maximum Peak Reduction	Average Peak Reduction	Storm Events (n)	Largest Storm Event with No Outflow (in)	
Valencia NW	31	23	4%	83%	36%	8	0.18	0.5%
Valencia SE	31	22	5%	89%	40%	9	0.18	0.6%
Mission NE	31	4	26%	97%	47%	27	1.52	3.8%
Folsom SW	31	10	16%	90%	49%	21	0.49	2.0%
Bryant NW	31	19	5%	60%	35%	12	0.25	0.7%
Bryant SW	31	12	13%	88%	49%	19	0.45	1.6%
Hampshire NW	31	18	10%	86%	45%	13	0.25	1.1%

Peak flows simulated for the pre- and post-construction conditions had good-to-excellent correlation ($R^2 > 0.77$ in all cases) with all peak rainfall depths tested (5-, 10-, 15-, 20-, 30- and 60-minute peaks) across the range of storms, with generally the strongest correlations at the peak 10-minute rainfall depth (Figure 7 and Reference Table 8). Mission NE had a weaker correlation between peak flow and peak 10-minute rainfall for post-construction conditions because it was the best performing bioretention planter and retained the entire volume for a number of lower intensity storms that dropped <0.2 inches per 10 minutes. Although this bioretention planter entirely captured the volume from many events (primarily due to its larger GI to DMA ratio), during the largest events it still only averaged a peak reduction of around 47%, similar to the other bioretention planters. In summary, based on the model results, it is estimated that a number of smaller storm events were entirely captured by the bioretention units, which would lead to peak flow reductions of 100%. For storms in which outflow did occur, the average peak flow reduction was between 35 and 50%, lower in more intense storm events and for bioretention planters with a lower GI:DMA ratio and higher in less intense storm events and for sites with a higher GI:DMA ratio.

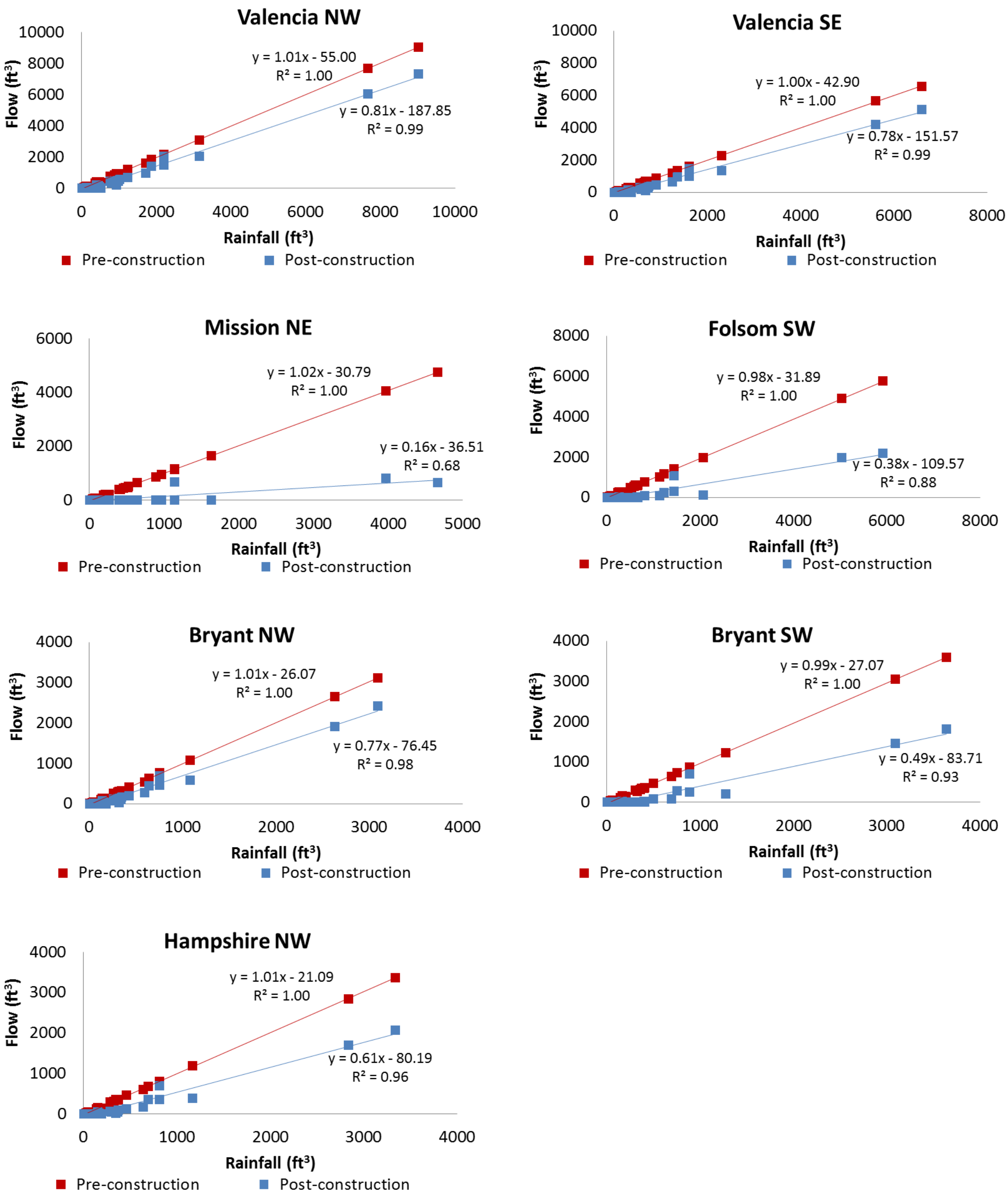


Figure 5. Rainfall and estimated flow volume for all individual storm events during Rainy Season 2014-15 at each bioretention unit based on model results.

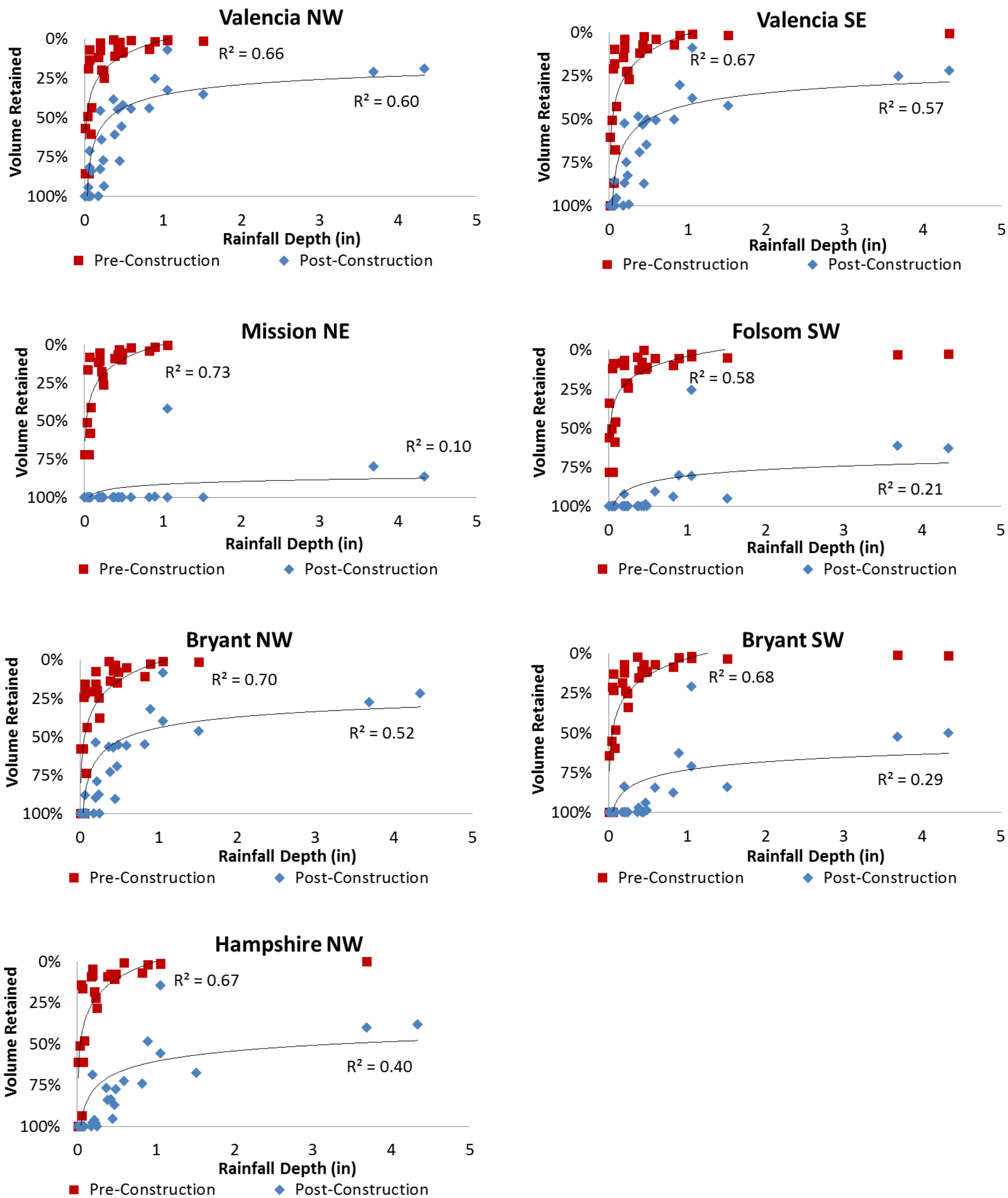


Figure 6. Estimated percentage of rainfall volume retained within each bioretention unit per storm event relative to the storm total rainfall depth based on modeling results.

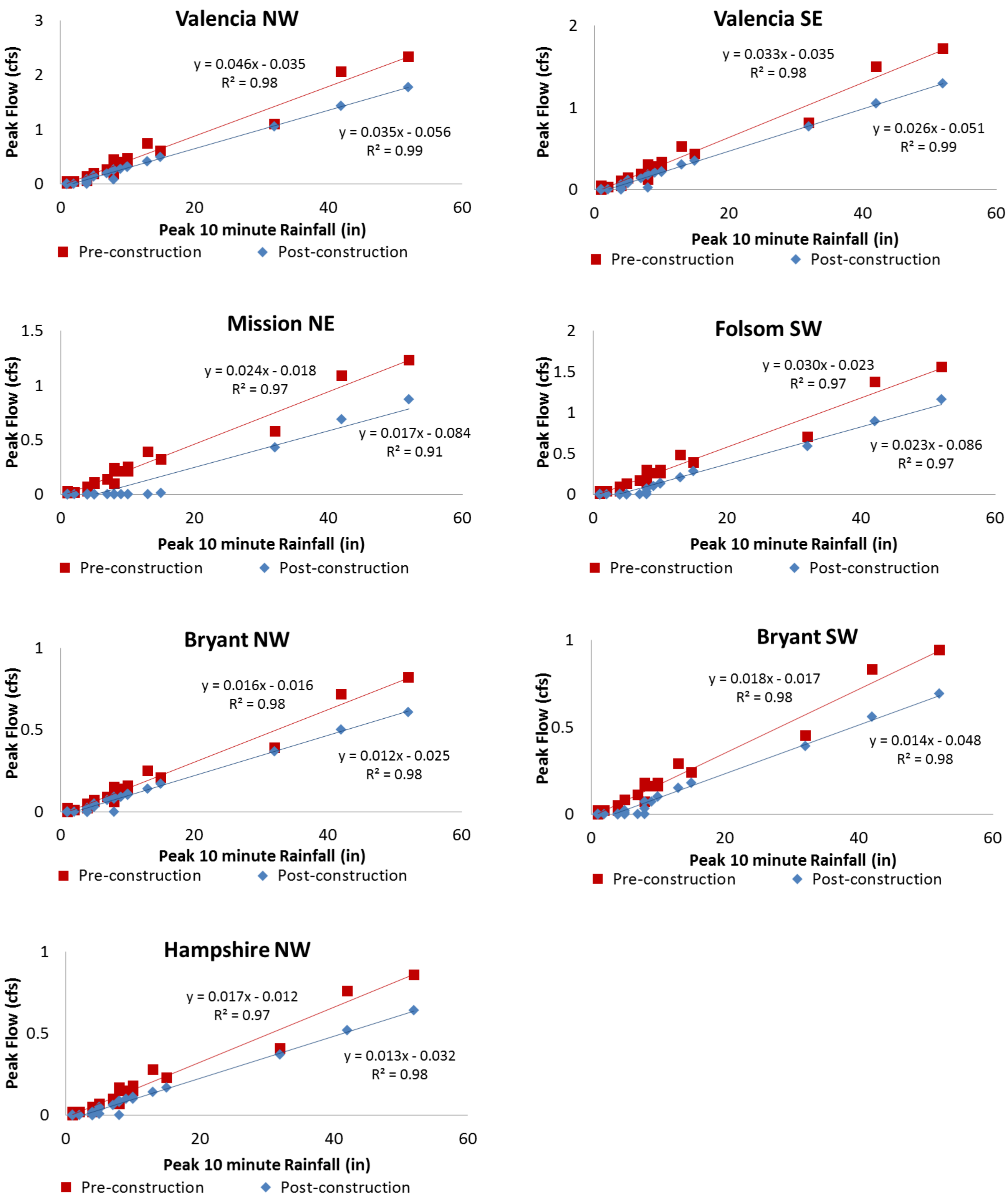


Figure 7. Estimated peak flow for each bioretention unit for pre- and post-construction conditions for corresponding peak 10 minute rainfall depths in each storm event.

Results for Simulation of Design Storms

The performance of each bioretention cell under the design storm conditions was evaluated through the established SWMM model. A 1-year 24-hour design storm of 2.65 inches and a more intense 5-year 3-hour storm of 1.14 inches were tested. The model simulated flow volume and peak volume reductions as well as changes in the hydrograph are discussed below.

Flow Volume Reduction for Design Storms

Under the design storms, the performance of bioretention planters at Cesar Chavez varied by site. The estimated flow volume reduction from pre-construction conditions ranged from 31% to 93% for the 1-year 24-hour storm, with four sites (Mission NE, Folsom SW, Bryant SW, Hampshire NW) having reduced runoff by more than 60% (Table 6). Under the 5-year 3-hour storm, the estimated volume reductions were lower ranging from 13% to 75% (Table 6), with only one bioretention planter (Mission NE) retaining more than 50% runoff. As expected, all bioretention planters were estimated to perform better under the less intense 1-year storm event, as compared to the more intense 5-year storm in which a greater proportion of the stormwater runs off more rapidly than the bioretention planter soil media can infiltrate. This model result confirms the expectation (and is also consistent with the outcomes of the continuous simulation of the 2014-15 Rainy Season) that the planters are more effective at treating longer duration, less intense storm events, and would not perform as well under more intense, shorter duration storms.

Consistent with the modeled results of Rainy Season 2014-2015 and under both design storms, the model runs provide evidence that Mission NE would likely perform the best because it has the biggest sizing ratio of 3.8% among all planters, followed by Folsom SW with the second biggest ratio of 2.0%, while Valencia NW would be the lowest performing bioretention planter because it has the lowest sizing ratio of 0.5%. This again underscores the importance of maximizing the sizing ratio for each individual bioretention planter in order to maximize performance.

Table 6. Estimated flow volume reduction at each bioretention planter under the 1-year 24-hour storm and 5-year 3-hour storm.

Bioretention Site	1-Year 24-hour Storm				5-Year 3-hour Storm			
	Precipitation (gal)	Pre-construction (gal)	Post-construction (gal)	Reduction	Precipitation (gal)	Pre-construction (gal)	Post-construction (gal)	Reduction
Valencia NW	41213	40591	28149	31%	17729	17107	14930	13%
Valencia SE	30126	29671	18417	38%	12960	12505	10573	15%
Mission NE	21328	21007	1529	93%	9175	8853	2254	75%
Folsom SW	27037	25303	4795	81%	11631	10713	5509	49%
Bryant NW	14130	13917	7945	43%	6078	5865	4852	17%
Bryant SW	16616	16365	4138	75%	7148	6897	4326	37%
Hampshire NW	15266	15036	5703	62%	6567	6337	4666	26%

The hydrographs at two selected bioretention planters, Valencia SE[1] and Mission NE, demonstrate the changes to stormwater flow before and after construction of the bioretention planter under both design storms. The Valencia SE was selected to represent the undersized planters with lower relative performance, while Mission NE was selected to represent likely high performance planters with appropriate sizing. The comparison and contrast between them will help highlight the variation in performance for different size planters. At Valencia SE, both volume and peak flow would likely be reduced modestly under the 1-year storm, while the 5-year storm would result in a hydrograph that is largely the same except with about 10 minutes

[1] Note: Earlier in this technical memo, Mission NE is contrasted with Valencia NW, not Valencia SE as is done here. Valencia NW and Valencia SE have similar GI:DMA ratios, 0.5 % and 0.6%, respectively.

lag (Figure 8). In contrast, flows simulated for Mission NE showed significant reductions in both volume and peak flow for the 1-year storm, and similar levels of volume reduction and moderate peak reduction for the 5-year storm (Figure 9). The estimated changes in hydrographs are consistent with the results shown in Table 6.

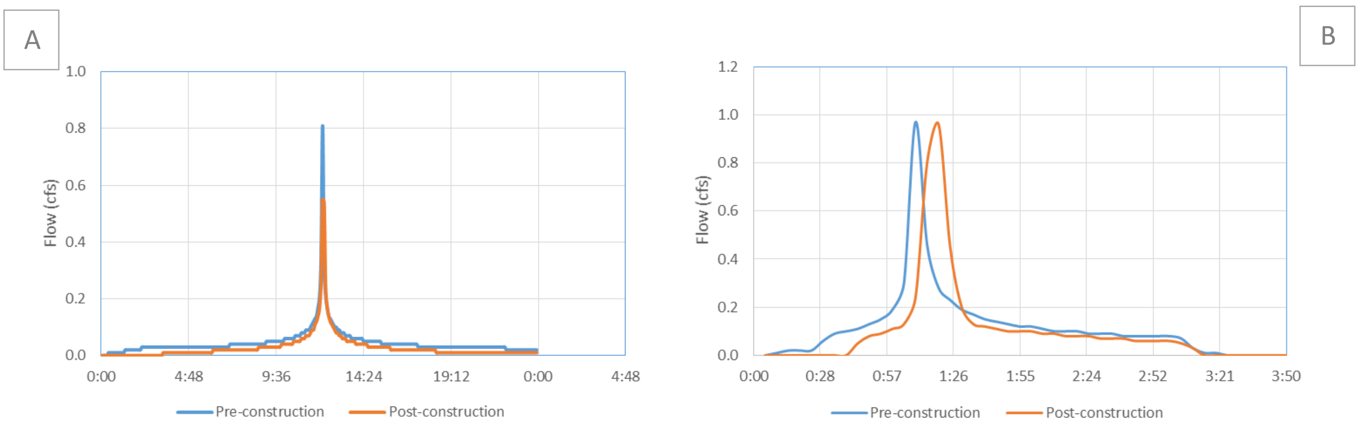


Figure 8. Estimated storm hydrograph for Valencia SE during the simulated: A) 1-year 24-hour storm, and B) 5-year 3-hour storm.

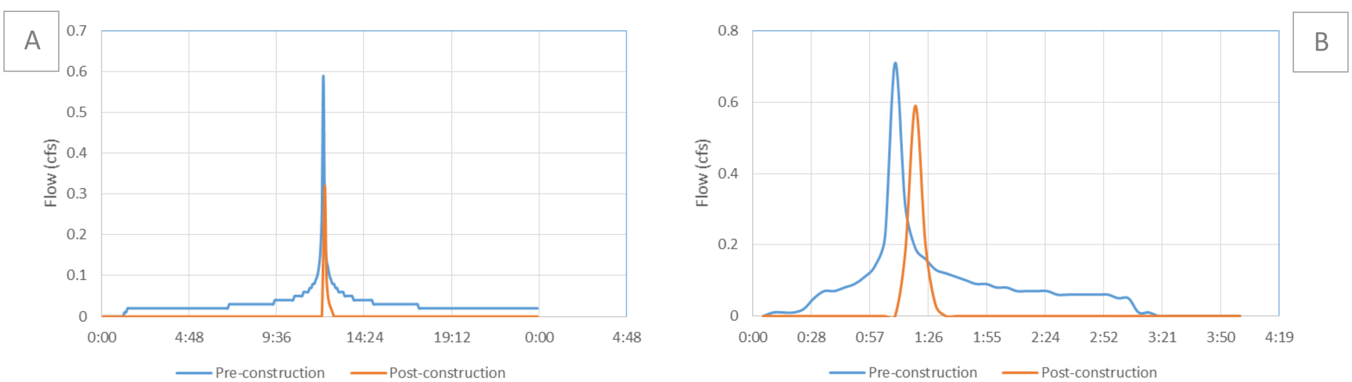


Figure 9. Estimated storm hydrograph for Mission NE during the simulated: A) 1-year 24-hour storm, B) 5-year 3-hour storm.

The relationship between the ratio of GI area to DMA area and volume reduction was investigated to demonstrate the impact of bioretention sizing on performance. The volume reduction is closely correlated to the ratio (Figure 10) in a largely linear relationship. For both design storms, the larger sized planters performed better than the smaller sized planters. The most undersized feature (Valencia NW), which is sized at 0.5% of the DMA area, consistently performed poorly in comparison to the other six bioretention planters. The performance of GI will improve significantly under longer and smaller storms if the size of the bioretention feature is increased to at least 2% of the catchment area (Figure 10 A), and the margin of benefit is smaller but still substantial under the larger 5-year storm (Figure 10 B). Therefore, wherever possible, based on the modeling results, it appears that under the conditions encountered in the Cesar Chavez study area, it is most beneficial to size a GI unit at least as large as 2% of its DMA to ensure desired performance.

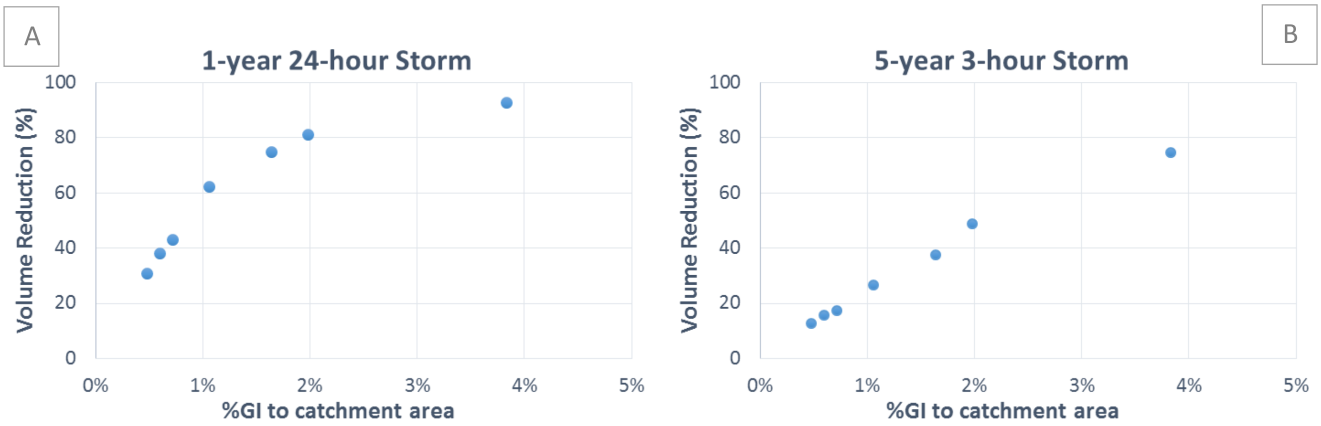


Figure 10. Estimated percentage of flow volume reduction in relation to the ratio of GI area to DMA area: A) 1-year 24-hour storm, B) 5-year 3-hour storm.

Peak Flow Rate Reduction for Design Storms

Peak flow reductions ranged across sites from 31% to 46% for the 1-year storm and 26% to 37% for the 5-year storm (Table 7). This suggests that an average of 25% or better peak flow reduction can be expected long-term at each of the seven bioretention planters during typical LOS storm events. Compared to flow volume, estimated reductions in peak flows from pre-construction simulations were more similar from site to site and across storms, and did not have a strong correlation with the GI:DMA ratio (Figure 11).

Table 7. Estimated peak flow reduction at each bioretention planter under the 1-year 24-hour and 5-year 3-hour storm.

Bioretention Site	1-Year 24-hour Storm			5-Year 3-hour Storm		
	Pre-construction (cfs)	Post-construction (cfs)	Reduction	Pre-construction (cfs)	Post-construction (cfs)	Reduction
Valencia NW	1.12	0.77	31%	1.79	1.31	27%
Valencia SE	0.81	0.55	32%	1.3	0.96	26%
Mission NE	0.59	0.32	46%	0.94	0.59	37%
Folsom SW	0.72	0.47	35%	1.14	0.78	32%
Bryant NW	0.39	0.26	33%	0.62	0.46	26%
Bryant SW	0.45	0.29	36%	0.72	0.5	31%
Hampshire NW	0.41	0.28	32%	0.66	0.47	29%

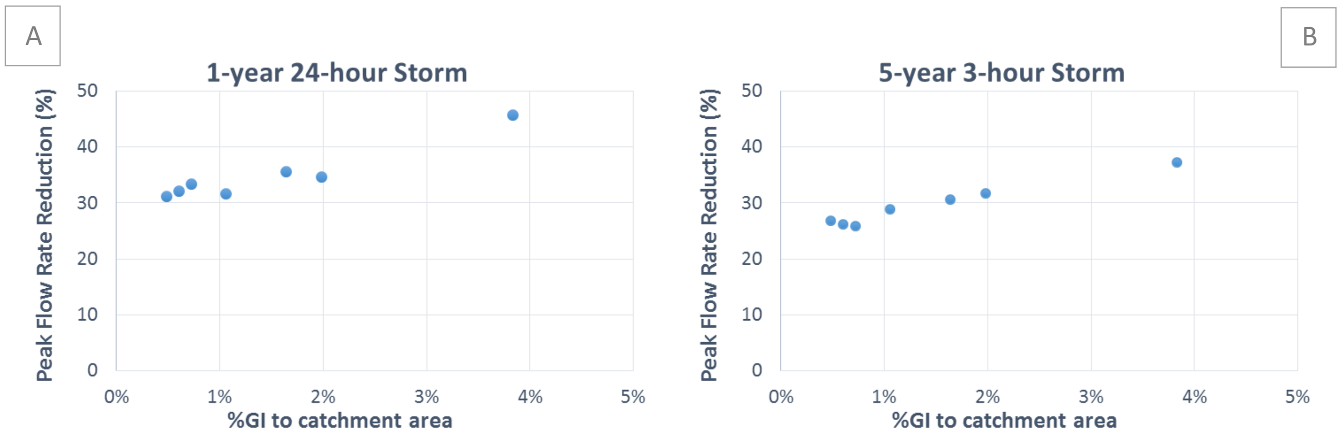


Figure 11. Estimated percentage of flow peak rate reduction in relation to ratio of GI area to DMA area: A) 1-year 24-hour storm, B) 5-year 3-hour storm.

Lessons Learned and Adaptive Management Suggestions

Based on the modeling simulations, the Cesar Chavez bioretention planters likely range in performance for stormwater retention and peak flow rate reduction in relation to site specific design characteristics. Based on the model results, generally, planters with higher ratios of GI area to DMA likely perform better, retain greater stormwater volumes, and likely have fewer storms that produce outflow to the sewer system. In summary:

- For the seven modeled planters, an estimated 580,000 gallons of stormwater was infiltrated. For the full 18 planters, (based on an average rainfall year of 21 inches), it is estimated that over 1.5 million gallons would be retained.
- Implementing green infrastructure in street improvement projects, even where the primary objective does not involve stormwater management, can reduce runoff especially when the improvement project includes features such as corner bulb-outs where GI can be housed.
- A more detailed cost evaluation is pending, but preliminary indications are that stormwater reduction for opportunistically implemented GI can be cost effective and could result in increased GI implementation by collaborating with other municipal improvement projects.

There is a strong correlation between sizing ratio and runoff reduction. Only one of the monitored facilities had a sizing ratio approaching 4%, which is widely used as a minimum threshold (Mission NE at 3.8%), and it was the only facility that effectively reduced peak flows during the majority of larger storm events (>0.5 inches). Facilities with larger sizing ratios have additional advantages over smaller units, such as being less prone to filling with sediment and debris, thus requiring less frequent maintenance. Nevertheless, smaller units can still have cumulatively significant impacts.

Cesar Chavez Streetscape Improvement Project Reference Tables

Reference Table 1. Select individual storm metrics modeled for pre- and post-construction runoff conditions at the Cesar Chavez Streetscape Improvement Project bioretention unit Valencia NW for Rainy Season 2014-15[2].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft^3)	Inlet			Outlet			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft^3)	Volume Retention	Peak Flow (cfs)	Flow (ft^3)	Volume Retention	
12/11/2014 4:25	31.3	4.34	9,024	2.06	9,045	0%	1.43	7299	19%	31%
12/2/2014 1:30	37.8	3.69	7,672	2.34	7,677	0%	1.77	6054	21%	24%
12/14/2014 22:35	17.8	1.52	3,160	0.74	3,108	2%	0.41	2046	35%	45%
12/10/2014 12:25	0.7	1.06	2,204	1.10	2,178	1%	1.06	2043	7%	4%
12/19/2014 2:45	12.7	1.06	2,204	0.47	2,187	1%	0.31	1485	33%	34%
2/8/2015 7:00	6.1	0.90	1,871	0.61	1,833	2%	0.49	1,395	25%	20%
2/6/2015 8:55	15.0	0.83	1,726	0.40	1,608	7%	0.28	966	44%	30%
12/16/2014 15:00	15.3	0.60	1,248	0.41	1,233	1%	0.32	693	44%	22%
11/22/2014 2:20	7.6	0.49	1,019	0.20	936	8%	0.14	588	42%	30%
11/12/2014 23:25	8.5	0.48	998	0.45	906	9%	0.26	444	56%	42%
12/17/2014 13:00	16.6	0.45	936	0.13	915	2%	0.08	210	78%	38%
11/20/2014 9:35	9.3	0.43	894	0.20	837	6%	0.15	492	45%	25%
11/29/2014 22:15	12.8	0.39	811	0.20	720	11%	0.15	318	61%	25%
11/30/2014 17:20	5.4	0.37	769	0.27	762	1%	0.20	474	38%	26%
11/19/2014 4:35	12.3	0.25	520	0.11	390	25%	0.04	33	94%	64%
10/31/2014 9:05	3.8	0.24	499	0.19	396	21%	0.14	114	77%	26%
10/25/2014 4:45	1.7	0.22	457	0.13	366	20%	0.08	165	64%	38%
12/5/2014 13:20	18.6	0.20	416	0.20	384	8%	0.14	72	83%	30%
12/16/2014 1:20	2.6	0.20	416	0.40	405	3%	0.25	225	46%	38%
12/20/2014 20:15	10.7	0.18	374	0.05	330	12%	0.00	0	100%	100%
12/24/2014 13:45	0.2	0.09	187	0.19	105	44%	0.08	30	84%	58%
10/20/2014 9:15	1.4	0.08	166	0.05	66	60%	0.00	0	100%	100%
12/3/2014 22:05	3.7	0.07	146	0.13	126	13%	0.06	27	81%	54%
12/4/2014 8:15	3.2	0.07	146	0.14	135	7%	0.08	42	71%	43%
11/28/2014 23:35	6.8	0.06	125	0.01	18	86%	0.00	0	100%	100%
12/5/2014 0:25	2.3	0.05	104	0.12	84	19%	0.02	6	94%	83%
2/7/2015 13:35	0.1	0.04	83	0.06	42	49%	0.00	0	100%	100%
12/1/2014 6:40	0.0	0.01	21	0.02	9	57%	0.00	0	100%	100%
12/19/2014 23:00	0.0	0.01	21	0.02	9	57%	0.00	0	100%	100%
12/23/2014 7:50	0.0	0.01	21	0.01	3	86%	0.00	0	100%	100%
2/8/2015 22:05	0.0	0.01	21	0.01	3	86%	0.00	0	100%	100%
Total	**264**	**18**	**38,257**		**36,816**			**25,221**	**31%**	
Average	**8.5**	**0.6**	**1,234**	**0.4**	**1,188**		**0.26**	**814**		**53%**
Maximum	**37.8**	**4.3**	**9,024**	**2.3**	**9,045**		**1.77**	**7,299**		**100%**

[2] Outlet volume retention was calculated as the total volume retention divided by the total inlet flow (or, (inlet flow volume – outlet flow volume)/inlet flow volume). “NA” was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.

Reference Table 2. Select individual storm metrics modeled for pre- and post-construction runoff conditions at the Cesar Chavez Streetscape Improvement Project bioretention unit Valencia SE for Rainy Season 2014-15[3].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft³)	Inlet			Outlet			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft³)	Volume Retention	Peak Flow (cfs)	Flow (ft³)	Volume Retention	
12/11/2014 4:25	31.3	4.34	6,596	1.50	6,540	1%	1.05	5139	22%	30%
12/2/2014 1:30	37.8	3.69	5,608	1.72	5,649	-1%	1.29	4182	25%	25%
12/14/2014 22:35	17.8	1.52	2,310	0.52	2265	2%	0.30	1326	43%	42%
12/10/2014 12:25	0.7	1.06	1,611	0.81	1,593	1%	0.77	1464	9%	5%
12/19/2014 2:45	12.7	1.06	1,611	0.33	1,590	1%	0.21	999	38%	36%
2/8/2015 7:00	6.1	0.90	1,368	0.43	1,341	2%	0.35	951	30%	19%
2/6/2015 8:55	15.0	0.83	1,261	0.28	1,170	7%	0.20	627	50%	29%
12/16/2014 15:00	15.3	0.60	912	0.29	873	4%	0.22	450	51%	24%
11/22/2014 2:20	7.6	0.49	745	0.14	675	9%	0.09	369	50%	36%
11/12/2014 23:25	8.5	0.48	730	0.30	660	10%	0.18	255	65%	40%
12/17/2014 13:00	16.6	0.45	684	0.09	666	3%	0.06	87	87%	33%
11/20/2014 9:35	9.3	0.43	654	0.13	606	7%	0.10	306	53%	23%
11/29/2014 22:15	12.8	0.39	593	0.14	522	12%	0.11	183	69%	21%
11/30/2014 17:20	5.4	0.37	562	0.19	564	0%	0.13	288	49%	32%
11/19/2014 4:35	12.3	0.25	380	0.07	276	27%	0.01	3	99%	86%
10/31/2014 9:05	3.8	0.24	365	0.13	282	23%	0.09	63	83%	31%
10/25/2014 4:45	1.7	0.22	334	0.09	258	23%	0.05	84	75%	44%
12/5/2014 13:20	18.6	0.20	304	0.14	276	9%	0.07	39	87%	50%
12/16/2014 1:20	2.6	0.20	304	0.28	291	4%	0.17	144	53%	39%
12/20/2014 20:15	10.7	0.18	274	0.04	234	14%	0.00	0	100%	100%
12/24/2014 13:45	0.2	0.09	137	0.12	78	43%	0.02	6	96%	83%
10/20/2014 9:15	1.4	0.08	122	0.03	39	68%	0.00	0	100%	100%
12/3/2014 22:05	3.7	0.07	106	0.09	87	18%	0.01	3	97%	89%
12/4/2014 8:15	3.2	0.07	106	0.10	96	10%	0.04	15	86%	60%
11/28/2014 23:35	6.8	0.06	91	0.01	12	87%	0.00	0	100%	100%
12/5/2014 0:25	2.3	0.05	76	0.08	60	21%	0.00	0	100%	100%
2/7/2015 13:35	0.1	0.04	61	0.04	30	51%	0.00	0	100%	100%
12/1/2014 6:40	0.0	0.01	15	0.01	6	61%	0.00	0	100%	100%
12/19/2014 23:00	0.0	0.01	15	0.01	6	61%	0.00	0	100%	100%
12/23/2014 7:50	0.0	0.01	15	0.00	0	100%	0.00	0	100%	NA
2/8/2015 22:05	0.0	0.01	15	0.00	0	100%	0.00	0	100%	NA
Total	**264**	**18**	**27,965**		**26,745**			**16,983**	**37%**	
Average	**8.5**	**0.6**	**902**	**0.3**	**863**		**0.18**	**548**		**54%**
Maximum	**37.8**	**4.3**	**6,596**	**1.7**	**6,540**		**1.29**	**5,139**		**100%**

[3] Outlet volume retention was calculated as the total volume retention divided by the total inlet flow (or, (inlet flow volume – outlet flow volume)/inlet flow volume). "NA" was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.

Reference Table 3. Select individual storm metrics modeled for pre- and post-construction runoff conditions at the Cesar Chavez Streetscape Improvement Project bioretention unit Mission NE for Rainy Season 2014-15[4].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft³)	Inlet			Outlet			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft³)	Volume Retention	Peak Flow (cfs)	Flow (ft³)	Volume Retention	
12/11/2014 4:25	31.3	4.34	4,670	1.09	4,746	-2%	0.69	633	86%	37%
12/2/2014 1:30	37.8	3.69	3,970	1.23	4,038	-2%	0.87	801	80%	29%
12/14/2014 22:35	17.8	1.52	1,636	0.39	1644	-1%	0.00	0	100%	100%
12/10/2014 12:25	0.7	1.06	1,141	0.58	1,146	0%	0.43	660	42%	26%
12/19/2014 2:45	12.7	1.06	1,141	0.25	1,137	0%	0.00	0	100%	100%
2/8/2015 7:00	6.1	0.90	968	0.32	954	1%	0.01	3	100%	97%
2/6/2015 8:55	15.0	0.83	893	0.21	855	4%	0.00	0	100%	100%
12/16/2014 15:00	15.3	0.60	646	0.21	633	2%	0.00	0	100%	100%
11/22/2014 2:20	7.6	0.49	527	0.10	498	6%	0.00	0	100%	100%
11/12/2014 23:25	8.5	0.48	516	0.24	465	10%	0.00	0	100%	100%
12/17/2014 13:00	16.6	0.45	484	0.07	468	3%	0.00	0	100%	100%
11/20/2014 9:35	9.3	0.43	463	0.10	432	7%	0.00	0	100%	100%
11/29/2014 22:15	12.8	0.39	420	0.11	381	9%	0.00	0	100%	100%
11/30/2014 17:20	5.4	0.37	398	0.14	399	0%	0.00	0	100%	100%
11/19/2014 4:35	12.3	0.25	269	0.06	198	26%	0.00	0	100%	100%
10/31/2014 9:05	3.8	0.24	258	0.10	204	21%	0.00	0	100%	100%
10/25/2014 4:45	1.7	0.22	237	0.07	195	18%	0.00	0	100%	100%
12/5/2014 13:20	18.6	0.20	215	0.10	192	11%	0.00	0	100%	100%
12/16/2014 1:20	2.6	0.20	215	0.21	204	5%	0.00	0	100%	100%
12/20/2014 20:15	10.7	0.18	194	0.03	171	12%	0.00	0	100%	100%
12/24/2014 13:45	0.2	0.09	97	0.10	57	41%	0.00	0	100%	100%
10/20/2014 9:15	1.4	0.08	86	0.02	36	58%	0.00	0	100%	100%
12/3/2014 22:05	3.7	0.07	75	0.07	69	8%	0.00	0	100%	100%
12/4/2014 8:15	3.2	0.07	75	0.07	69	8%	0.00	0	100%	100%
11/28/2014 23:35	6.8	0.06	65	0.01	18	72%	0.00	0	100%	100%
12/5/2014 0:25	2.3	0.05	54	0.07	45	16%	0.00	0	100%	100%
2/7/2015 13:35	0.1	0.04	43	0.03	21	51%	0.00	0	100%	100%
12/1/2014 6:40	0.0	0.01	11	0.01	3	72%	0.00	0	100%	100%
12/19/2014 23:00	0.0	0.01	11	0.01	3	72%	0.00	0	100%	100%
12/23/2014 7:50	0.0	0.01	11	0.01	3	72%	0.00	0	100%	100%
2/8/2015 22:05	0.0	0.01	11	0.01	3	72%	0.00	0	100%	100%
Total	**264**	**18**	**19,798**		**19,287**			**2,097**	**89%**	
Average	**8.5**	**0.6**	**639**	**0.2**	**622**		**0.06**	**68**		**93%**
Maximum	**37.8**	**4.3**	**4,670**	**1.2**	**4,746**		**0.87**	**801**		**100%**

[4] Outlet volume retention was calculated as the total volume retention divided by the total inlet flow (or, (inlet flow volume – outlet flow volume)/inlet flow volume). "NA" was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.

Reference Table 4. Select individual storm metrics modeled for pre- and post-construction runoff conditions at the Cesar Chavez Streetscape Improvement Project bioretention unit Folsom SW for Rainy Season 2014-15[5].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft^3)	Inlet			Outlet			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft^3)	Volume Retention	Peak Flow (cfs)	Flow (ft^3)	Volume Retention	
12/11/2014 4:25	31.3	4.34	5,920	1.37	5,760	3%	0.89	2190	63%	35%
12/2/2014 1:30	37.8	3.69	5,033	1.56	4,887	3%	1.16	1953	61%	26%
12/14/2014 22:35	17.8	1.52	2,073	0.48	1965	5%	0.21	105	95%	56%
12/10/2014 12:25	0.7	1.06	1,446	0.70	1,407	3%	0.59	1077	26%	16%
12/19/2014 2:45	12.7	1.06	1,446	0.30	1,383	4%	0.14	282	80%	53%
2/8/2015 7:00	6.1	0.90	1,228	0.39	1,161	5%	0.28	243	80%	28%
2/6/2015 8:55	15.0	0.83	1,132	0.26	1,020	10%	0.10	72	94%	62%
12/16/2014 15:00	15.3	0.60	818	0.26	774	5%	0.13	78	90%	50%
11/22/2014 2:20	7.6	0.49	668	0.13	594	11%	0.00	0	100%	100%
11/12/2014 23:25	8.5	0.48	655	0.30	573	12%	0.03	9	99%	90%
12/17/2014 13:00	16.6	0.45	614	0.09	612	0%	0.00	0	100%	100%
11/20/2014 9:35	9.3	0.43	587	0.13	540	8%	0.00	0	100%	100%
11/29/2014 22:15	12.8	0.39	532	0.13	465	13%	0.00	0	100%	100%
11/30/2014 17:20	5.4	0.37	505	0.17	480	5%	0.00	0	100%	100%
11/19/2014 4:35	12.3	0.25	341	0.08	258	24%	0.00	0	100%	100%
10/31/2014 9:05	3.8	0.24	327	0.13	258	21%	0.00	0	100%	100%
10/25/2014 4:45	1.7	0.22	300	0.09	237	21%	0.00	0	100%	100%
12/5/2014 13:20	18.6	0.20	273	0.13	246	10%	0.00	0	100%	100%
12/16/2014 1:20	2.6	0.20	273	0.26	255	7%	0.07	21	92%	73%
12/20/2014 20:15	10.7	0.18	246	0.04	225	8%	0.00	0	100%	100%
12/24/2014 13:45	0.2	0.09	123	0.13	66	46%	0.00	0	100%	100%
10/20/2014 9:15	1.4	0.08	109	0.04	45	59%	0.00	0	100%	100%
12/3/2014 22:05	3.7	0.07	95	0.09	87	9%	0.00	0	100%	100%
12/4/2014 8:15	3.2	0.07	95	0.09	87	9%	0.00	0	100%	100%
11/28/2014 23:35	6.8	0.06	82	0.01	18	78%	0.00	0	100%	100%
12/5/2014 0:25	2.3	0.05	68	0.09	60	12%	0.00	0	100%	100%
2/7/2015 13:35	0.1	0.04	55	0.04	27	51%	0.00	0	100%	100%
12/1/2014 6:40	0.0	0.01	14	0.02	6	56%	0.00	0	100%	100%
12/19/2014 23:00	0.0	0.01	14	0.02	9	34%	0.00	0	100%	100%
12/23/2014 7:50	0.0	0.01	14	0.01	3	78%	0.00	0	100%	100%
2/8/2015 22:05	0.0	0.01	14	0.01	3	78%	0.00	0	100%	100%
Total	**264**	**18**	**25,098**		**23,511**			**6,030**	**74%**	
Average	**8.5**	**0.6**	**810**	**0.2**	**758**		**0.12**	**195**		**84%**
Maximum	**37.8**	**4.3**	**5,920**	**1.6**	**5,760**		**1.16**	**2,190**		**100%**

[5] Outlet volume retention was calculated as the total volume retention divided by the total inlet flow (or, (inlet flow volume – outlet flow volume)/inlet flow volume). "NA" was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.

Reference Table 5. Select individual storm metrics modeled for pre- and post-construction runoff conditions at the Cesar Chavez Streetscape Improvement Project bioretention unit Bryant NW for Rainy Season 2014-15[6].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft^3)	Inlet			Outlet			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft^3)	Volume Retention	Peak Flow (cfs)	Flow (ft^3)	Volume Retention	
12/11/2014 4:25	31.3	4.34	3,094	0.72	3,094	0%	0.50	2418	22%	31%
12/2/2014 1:30	37.8	3.69	2,630	0.82	2,630	0%	0.61	1908	27%	26%
12/14/2014 22:35	17.8	1.52	1,084	0.25	1,084	0%	0.14	579	47%	44%
12/10/2014 12:25	0.7	1.06	756	0.39	756	0%	0.37	693	8%	5%
12/19/2014 2:45	12.7	1.06	756	0.16	747	1%	0.10	453	40%	38%
2/8/2015 7:00	6.1	0.90	642	0.21	624	3%	0.17	435	32%	19%
2/6/2015 8:55	15.0	0.83	592	0.14	528	11%	0.09	267	55%	36%
12/16/2014 15:00	15.3	0.60	428	0.14	405	5%	0.11	189	56%	21%
11/22/2014 2:20	7.6	0.49	349	0.07	321	8%	0.05	156	55%	29%
11/12/2014 23:25	8.5	0.48	342	0.15	291	15%	0.09	105	69%	40%
12/17/2014 13:00	16.6	0.45	321	0.04	309	4%	0.02	30	91%	50%
11/20/2014 9:35	9.3	0.43	307	0.07	285	7%	0.05	132	57%	29%
11/29/2014 22:15	12.8	0.39	278	0.07	240	14%	0.05	75	73%	29%
11/30/2014 17:20	5.4	0.37	264	0.09	261	1%	0.07	114	57%	22%
11/19/2014 4:35	12.3	0.25	178	0.03	111	38%	0.00	0	100%	100%
10/31/2014 9:05	3.8	0.24	171	0.06	129	25%	0.03	21	88%	50%
10/25/2014 4:45	1.7	0.22	157	0.04	126	20%	0.02	33	79%	50%
12/5/2014 13:20	18.6	0.20	143	0.07	120	16%	0.03	15	89%	57%
12/16/2014 1:20	2.6	0.20	143	0.13	132	7%	0.08	66	54%	38%
12/20/2014 20:15	10.7	0.18	128	0.02	102	21%	0.00	0	100%	100%
12/24/2014 13:45	0.2	0.09	64	0.06	36	44%	0.00	0	100%	100%
10/20/2014 9:15	1.4	0.08	57	0.01	15	74%	0.00	0	100%	100%
12/3/2014 22:05	3.7	0.07	50	0.04	39	22%	0.00	0	100%	100%
12/4/2014 8:15	3.2	0.07	50	0.05	42	16%	0.02	6	88%	60%
11/28/2014 23:35	6.8	0.06	43	0.00	0	100%	0.00	0	100%	NA
12/5/2014 0:25	2.3	0.05	36	0.04	27	24%	0.00	0	100%	100%
2/7/2015 13:35	0.1	0.04	29	0.02	12	58%	0.00	0	100%	100%
12/1/2014 6:40	0.0	0.01	7	0.00	0	100%	0.00	0	100%	NA
12/19/2014 23:00	0.0	0.01	7	0.01	3	58%	0.00	0	100%	100%
12/23/2014 7:50	0.0	0.01	7	0.00	0	100%	0.00	0	100%	NA
2/8/2015 22:05	0.0	0.01	7	0.00	0	100%	0.00	0	100%	NA
Total	**264**	**18**	**13,116**		**12,468**			**7,695**	**38%**	
Average	**8.5**	**0.6**	**423**	**0.1**	**402**		**0.08**	**248**		**55%**
Maximum	**37.8**	**4.3**	**3,094**	**0.8**	**3,094**		**0.61**	**2,418**		**100%**

[6] Outlet volume retention was calculated as the total volume retention divided by the total inlet flow (or, (inlet flow volume – outlet flow volume)/inlet flow volume). "NA" was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.

Reference Table 6. Select individual storm metrics modeled for pre- and post-construction runoff conditions at the Cesar Chavez Streetscape Improvement Project bioretention unit Bryant SW for Rainy Season 2014-15[7].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft³)	Inlet			Outlet			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft³)	Volume Retention	Peak Flow (cfs)	Flow (ft³)	Volume Retention	
12/11/2014 4:25	31.3	4.34	3,638	0.83	3,585	1%	0.56	1815	50%	33%
12/2/2014 1:30	37.8	3.69	3,093	0.94	3,057	1%	0.69	1467	53%	27%
12/14/2014 22:35	17.8	1.52	1,274	0.29	1230	3%	0.15	201	84%	48%
12/10/2014 12:25	0.7	1.06	889	0.45	870	2%	0.39	702	21%	13%
12/19/2014 2:45	12.7	1.06	889	0.18	861	3%	0.10	258	71%	44%
2/8/2015 7:00	6.1	0.90	754	0.24	732	3%	0.18	282	63%	25%
2/6/2015 8:55	15.0	0.83	696	0.16	636	9%	0.07	87	87%	56%
12/16/2014 15:00	15.3	0.60	503	0.16	468	7%	0.10	78	84%	38%
11/22/2014 2:20	7.6	0.49	411	0.08	363	12%	0.01	6	99%	88%
11/12/2014 23:25	8.5	0.48	402	0.18	354	12%	0.03	24	94%	83%
12/17/2014 13:00	16.6	0.45	377	0.05	351	7%	0.00	0	100%	100%
11/20/2014 9:35	9.3	0.43	360	0.08	321	11%	0.00	0	100%	100%
11/29/2014 22:15	12.8	0.39	327	0.08	276	16%	0.02	9	97%	75%
11/30/2014 17:20	5.4	0.37	310	0.11	303	2%	0.00	0	100%	100%
11/19/2014 4:35	12.3	0.25	210	0.04	138	34%	0.00	0	100%	100%
10/31/2014 9:05	3.8	0.24	201	0.08	150	25%	0.00	0	100%	100%
10/25/2014 4:45	1.7	0.22	184	0.05	141	24%	0.00	0	100%	100%
12/5/2014 13:20	18.6	0.20	168	0.08	147	12%	0.00	0	100%	100%
12/16/2014 1:20	2.6	0.20	168	0.16	156	7%	0.07	27	84%	56%
12/20/2014 20:15	10.7	0.18	151	0.02	123	18%	0.00	0	100%	100%
12/24/2014 13:45	0.2	0.09	75	0.07	39	48%	0.00	0	100%	100%
10/20/2014 9:15	1.4	0.08	67	0.02	27	60%	0.00	0	100%	100%
12/3/2014 22:05	3.7	0.07	59	0.05	45	23%	0.00	0	100%	100%
12/4/2014 8:15	3.2	0.07	59	0.05	51	13%	0.00	0	100%	100%
11/28/2014 23:35	6.8	0.06	50	0.00	0	100%	0.00	0	100%	NA
12/5/2014 0:25	2.3	0.05	42	0.05	33	21%	0.00	0	100%	100%
2/7/2015 13:35	0.1	0.04	34	0.02	15	55%	0.00	0	100%	100%
12/1/2014 6:40	0.0	0.01	8	0.01	3	64%	0.00	0	100%	100%
12/19/2014 23:00	0.0	0.01	8	0.01	3	64%	0.00	0	100%	100%
12/23/2014 7:50	0.0	0.01	8	0.00	0	100%	0.00	0	100%	NA
2/8/2015 22:05	0.0	0.01	8	0.00	0	100%	0.00	0	100%	NA
Total	**264**	**18**	**15,424**		**14,478**			**4,956**	**66%**	
Average	**8.5**	**0.6**	**498**	**0.1**	**467**		**0.08**	**160**		**78%**
Maximum	**37.8**	**4.3**	**3,638**	**0.9**	**3,585**		**0.69**	**1,815**		**100%**

[7] Outlet volume retention was calculated as the total volume retention divided by the total inlet flow (or, (inlet flow volume – outlet flow volume)/inlet flow volume). "NA" was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.

Reference Table 7. Select individual storm metrics modeled for pre- and post-construction runoff conditions at the Cesar Chavez Streetscape Improvement Project bioretention unit Hampshire NW for Rainy Season 2014-15[8].

Storm Start	Storm Duration (hrs)	Total Rainfall Depth (in)	Total Rainfall Volume (ft³)	Inlet			Outlet			Peak Flow Rate Reduction
				Peak Flow (cfs)	Flow (ft³)	Volume Retention	Peak Flow (cfs)	Flow (ft³)	Volume Retention	
12/11/2014 4:25	31.3	4.34	3,343	0.76	3,343	0%	0.52	2067	38%	32%
12/2/2014 1:30	37.8	3.69	2,842	0.86	2,841	0%	0.64	1698	40%	26%
12/14/2014 22:35	17.8	1.52	1,171	0.28	1,171	0%	0.14	378	68%	50%
12/10/2014 12:25	0.7	1.06	816	0.41	804	2%	0.37	699	14%	10%
12/19/2014 2:45	12.7	1.06	816	0.18	807	1%	0.10	360	56%	44%
2/8/2015 7:00	6.1	0.90	693	0.23	681	2%	0.17	357	48%	26%
2/6/2015 8:55	15.0	0.83	639	0.15	594	7%	0.10	165	74%	33%
12/16/2014 15:00	15.3	0.60	462	0.15	459	1%	0.11	126	73%	27%
11/22/2014 2:20	7.6	0.49	377	0.07	348	8%	0.04	84	78%	43%
11/12/2014 23:25	8.5	0.48	370	0.17	330	11%	0.09	48	87%	47%
12/17/2014 13:00	16.6	0.45	347	0.05	357	-3%	0.02	15	96%	60%
11/20/2014 9:35	9.3	0.43	331	0.07	306	8%	0.04	54	84%	43%
11/29/2014 22:15	12.8	0.39	300	0.07	273	9%	0.05	48	84%	29%
11/30/2014 17:20	5.4	0.37	285	0.10	285	0%	0.06	66	77%	40%
11/19/2014 4:35	12.3	0.25	193	0.04	138	28%	0.00	0	100%	100%
10/31/2014 9:05	3.8	0.24	185	0.07	144	22%	0.01	3	98%	86%
10/25/2014 4:45	1.7	0.22	169	0.05	138	19%	0.01	6	96%	80%
12/5/2014 13:20	18.6	0.20	154	0.07	141	8%	0.01	3	98%	86%
12/16/2014 1:20	2.6	0.20	154	0.15	147	5%	0.08	48	69%	47%
12/20/2014 20:15	10.7	0.18	139	0.02	126	9%	0.00	0	100%	100%
12/24/2014 13:45	0.2	0.09	69	0.07	36	48%	0.00	0	100%	100%
10/20/2014 9:15	1.4	0.08	62	0.02	24	61%	0.00	0	100%	100%
12/3/2014 22:05	3.7	0.07	54	0.05	45	17%	0.00	0	100%	100%
12/4/2014 8:15	3.2	0.07	54	0.05	45	17%	0.00	0	100%	100%
11/28/2014 23:35	6.8	0.06	46	0.01	3	94%	0.00	0	100%	100%
12/5/2014 0:25	2.3	0.05	39	0.05	33	14%	0.00	0	100%	100%
2/7/2015 13:35	0.1	0.04	31	0.02	15	51%	0.00	0	100%	100%
12/1/2014 6:40	0.0	0.01	8	0.01	3	61%	0.00	0	100%	100%
12/19/2014 23:00	0.0	0.01	8	0.01	3	61%	0.00	0	100%	100%
12/23/2014 7:50	0.0	0.01	8	0.00	0	100%	0.00	0	100%	NA
2/8/2015 22:05	0.0	0.01	8	0.00	0	100%	0.00	0	100%	NA
Total	**264**	**18**	**14,171**		**13,639**			**6,225**	**54%**	
Average	**8.5**	**0.6**	**457**	**0.1**	**440**		**0.08**	**201**		**66%**
Maximum	**37.8**	**4.3**	**3,343**	**0.9**	**3,343**		**0.64**	**2,067**		**100%**

[8] Outlet volume retention was calculated as the total volume retention divided by the total inlet flow (or, (inlet flow volume – outlet flow volume)/inlet flow volume). "NA" was assigned in the Peak Flow Rate Reduction column for storms which did not result in flow at the inlet based on the model simulations. These storms were not included in the summary statistics (at the bottom of the table) for this column.

Reference Table 8. Coefficient of determination for peak inlet and outlet flow relative to peak rainfall for each storm event.

Site	Rainfall Depth-Duration	Pre-construction R^2	Post-construction R^2
Valencia NW	5 minute peak rainfall	0.99	0.97
Valencia NW	10 minute peak rainfall	0.97	0.99
Valencia NW	15 minute peak rainfall	0.93	0.98
Valencia NW	20 minute peak rainfall	0.88	0.95
Valencia NW	30 minute peak rainfall	0.8	0.88
Valencia NW	60 minute peak rainfall	0.83	0.9
Valencia SE	5 minute peak rainfall	0.99	0.97
Valencia SE	10 minute peak rainfall	0.98	0.99
Valencia SE	15 minute peak rainfall	0.93	0.97
Valencia SE	20 minute peak rainfall	0.89	0.95
Valencia SE	30 minute peak rainfall	0.8	0.88
Valencia SE	60 minute peak rainfall	0.83	0.9
Mission NE	5 minute peak rainfall	0.99	0.89
Mission NE	10 minute peak rainfall	0.97	0.91
Mission NE	15 minute peak rainfall	0.93	0.88
Mission NE	20 minute peak rainfall	0.88	0.84
Mission NE	30 minute peak rainfall	0.79	0.77
Mission NE	60 minute peak rainfall	0.83	0.78
Folsom SW	5 minute peak rainfall	0.99	0.96
Folsom SW	10 minute peak rainfall	0.97	0.97
Folsom SW	15 minute peak rainfall	0.92	0.94
Folsom SW	20 minute peak rainfall	0.87	0.91
Folsom SW	30 minute peak rainfall	0.78	0.83
Folsom SW	60 minute peak rainfall	0.82	0.85
Bryant NW	5 minute peak rainfall	0.99	0.97
Bryant NW	10 minute peak rainfall	0.98	0.98
Bryant NW	15 minute peak rainfall	0.93	0.97
Bryant NW	20 minute peak rainfall	0.89	0.94
Bryant NW	30 minute peak rainfall	0.8	0.88
Bryant NW	60 minute peak rainfall	0.83	0.9
Bryant SW	5 minute peak rainfall	0.99	0.96
Bryant SW	10 minute peak rainfall	0.98	0.98
Bryant SW	15 minute peak rainfall	0.93	0.95
Bryant SW	20 minute peak rainfall	0.89	0.92
Bryant SW	30 minute peak rainfall	0.8	0.86
Bryant SW	60 minute peak rainfall	0.83	0.87
Hampshire NW	5 minute peak rainfall	0.99	0.97
Hampshire NW	10 minute peak rainfall	0.97	0.98
Hampshire NW	15 minute peak rainfall	0.93	0.96
Hampshire NW	20 minute peak rainfall	0.88	0.94
Hampshire NW	30 minute peak rainfall	0.8	0.87
Hampshire NW	60 minute peak rainfall	0.83	0.89