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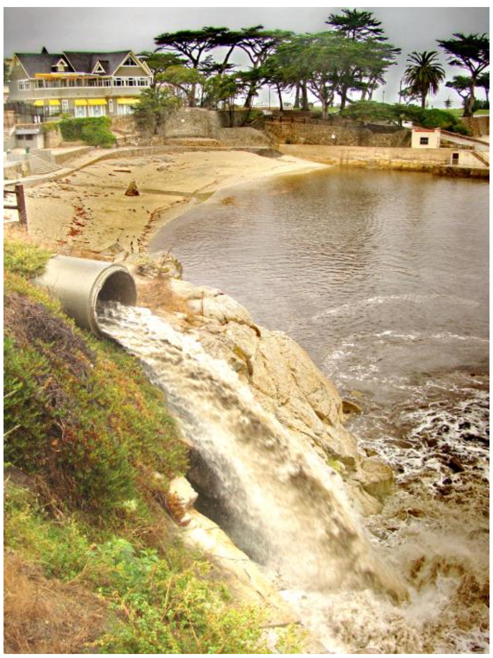

Stormflow monitoring and modelling at Pacific Grove, California, 2012 and 2015

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Table of Contents

1 Overview

This report describes work done by staff and students at the Watershed Institute (CSUMB) for the City of Pacific Grove.

The overall scope of work was to measure stormwater flow in the City of Pacific Grove within diverse watersheds, and to use a data-driven modeling approach to estimate current stormflow and predict future stormflow under specific stormwater control measures (SCMs).

1.1 Background

The work extends previous work done at CSUMB including:

- ENVS 660 (2011) – which included an inventory of outfalls, delineation of watersheds, and GIS characterization of watersheds
- Watson et al. (2012) – which included measurement of stormflow at Greenwood Park during early 2012
- Watson (2013) – low-flow analysis for Greenwood Park
- ENVS 660 (2013) – which included a water balance model for the watersheds that drain into the ASBS, and model-based exploration of future scenarios including general LID expansion and a major diversion and storage project

  The above reports are available at:
  http://ccows.csumb.edu/pubs/proj_pubs/2016/StormwaterProjects/index.htm

1.2 Work done & summary of results

The work done is summarized below. Details appear in the following sections of this report.

- **Section 2 – Study area and weather**
- **Section 3 – Updated flow rating curves for Greenwood Park.** Two new rating curves were designed. These curves enable flow to be estimated from either a staff plate reading or an automatic time series recorded by a logging pressure transducer. The difference from previous curves (Watson et al. 2012) occur at high flows, and were prompted by the observation of water levels following a very high

precipitation event and subsequent high flows leading to substantial backwatering at the Greenwood Park culvert.

- **Section 4 – Additional & updated flow data for Greenwood Park.** Spreadsheets are provided online with an additional winter of flow data (2014-15) for Greenwood Park, and event-based data for 8th St and Pico Ave. These data update and supplement the existing flow data provided for early 2012 by Watson et al. (2012).
- **Section 5 – Watershed stormflow model.** A simple stormflow model is described and calibrated against Greenwood Park flow data. The accuracy of the model is illustrated using hydrographs from 12 storm events of varying sizes.
- **Section 6 – Stormflow data for additional sites using dye-dilution gaging.** A dye-dilution stormflow monitoring technique was developed for use in coastal urban watersheds with outfalls that drop directly into the ocean without any open-channel flow. The technique is portable and intended to be applicable to multiple watersheds without the need for fixed installation of equipment in outfalls, or the risk of fixed equipment leading to blockages in stormwater flow. After a substantial development period, the technique was successfully applied to individual storm events at Greenwood Park, 8th St, and Pico Ave. Pico Ave was shown to have an order of magnitude less flow per unit watershed area than the more urbanized watersheds. This underscores the need to focus stormwater management on the most urbanized watersheds, despite these presenting some of the greatest challenges to management.
- **Section 7 – Design & modeling of a stormwater control measure on Pine Avenue.** An in-street stormwater control measure (SCM) was conceptually designed and located in Pine Ave below a subwatershed with existing drainage that is completely above ground. A model was developed and applied for predicting the performance of the SCM. The model was used to predict that the SCM could substantially reduce the runoff from an 85th percentile storm event, with certain caveats. Further, it was estimated that ten such SCMs could substantially reduce the 85th percentile runoff in the Greenwood Park watershed as a whole.

2 Study area and weather

The study area included three major watersheds within the City of Pacific Grove: the Greenwood Park watershed, the 8th St watershed, and the Pico Ave watershed. Outfall infrastructure for each of these watersheds is shown in Figures 2-1 to 2-3.

Daily precipitation at Lovers Point (a private Wunderground.com station) is summarized in Fig. 2-4. Most of the monitoring for the present report occurred in early 2015, a period in which substantial storms were scarce – despite the wet fall of 2014 and the very large rainfall event of 11 Dec 2014.

Figure 2-1. Greenwood Park – Entrance to culvert that leads to ocean outfall

Figure 2-2. 8th St – ocean outfall

Figure 2-3. Pico Ave – ocean outfall

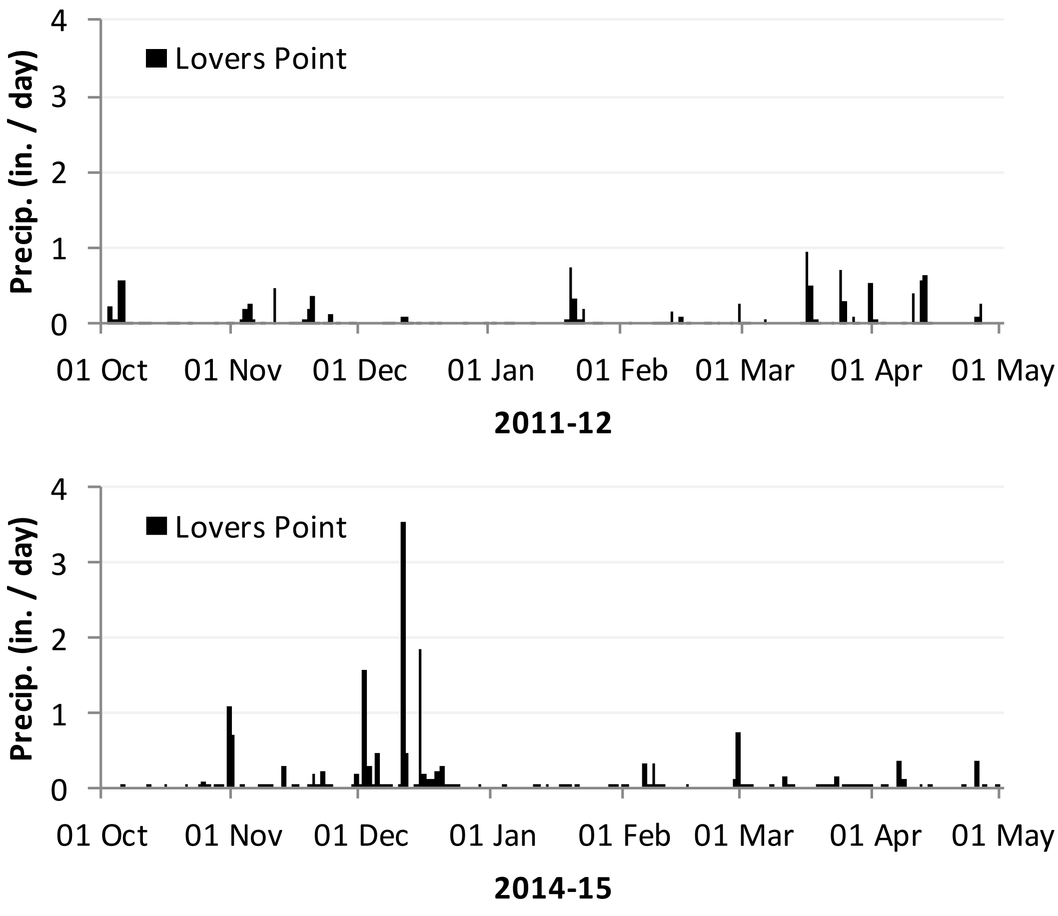

Figure 2-4. Daily precipitation record for "Lovers Point" (a private Wundeground.com station in a residential neighborhood between Lovers Point and Greenwood Park), during the two periods for which Greenwood Park flow data were recorded.

3 Updated flow rating curves for Greenwood Park

A very large rainfall event occurred on 11 Dec 2014, providing an opportunity to revisit and refine the rating curves for Greenwood Park. These rating curves allow estimation of flow rate (CFS) given either a manual staff plate reading (Site C) or an automatic pressure transducer data set (Site D).

The 11-Dec-2014 event involved 3.65 inches of rainfall in a 24-hour period (6:00 AM to 6:00 AM), falling at a maximum rate of 1.92 inches per hour, resulting in an estimated peak stormflow of 177 CFS, from a watershed draining just 256 acres. The water was 8.51 feet deep at peak flow, resulting in the lower portion of Greenwood Park becoming a small pond, backed up behind a rapidly flowing but flooded 4.27-foot culvert.

Flow hydraulics under filled-culvert conditions are readily estimated using established modeling software, and we took advantage of this to simulate a number of additional rating curve points using a simple HEC-HMS model as summarized in Table 4-1. The new points fell lower than expected given the previous rating curve. This was explained by changing the roughness assumptions behind the highest four points of the previous curve, which had been estimated using surface floats and a channel roughness assumption that was apparently too low. The final curve is fit to the same points as the 2012 curve, except that the four highest points are 85% lower, and the new model-derived filled-culvert-flow points are incorporated.

The curve for Site D (pressure transducer) is illustrated in Figure 4-1 and defined by the equation:

$$Q = \begin{Bmatrix} 0.0000275 \times (D-4)^{2.4} & D < 118 \\ 0.37 \times \sqrt{D-75} & D \geq 118 \end{Bmatrix}$$

where Q (m³/s) is flow and D (cm) is water pressure at Site D (atmospherically corrected). The curve for Site C (manual stage) was also updated to match the Site D curve, but an additional accommodation above filled-culvert flow was not made. The equation is:

$$Q = 0.0009 \times (C - 10.7)^{1.6}$$

where C (cm) is stage at Site C.

Table 3-1. HEC-HMS model parameters used to estimate flow rates for filled-culvert-flow at Greenwood Park.

Greenwood "reservoir" for modeling backwater against culvert and headwall

Method	Outflow Structures		
Storage Method	Elevation-Area	Elev-Area Function	
		Elev (ft)	Area (ac)
		0	0.01
		20	0.1
Initial condition	Inflow=Outflow		
Time Step Method	Automatic		
Outlets	1		

"Reservoir" outlet

Method	Culvert Outlet
Solution Method	Inlet Control
Shape	Circular
Chart	Concrete Pipe Culvert
Scale	Square edge entrance with headwall
Length (ft)	80
Diameter (ft)	4.27
Inlet Elevation (ft)	0.25
Entrance Coefficient	0.2
Outlet Elevation (ft)	0
Exit Coefficient	1
Manning's N	0.02

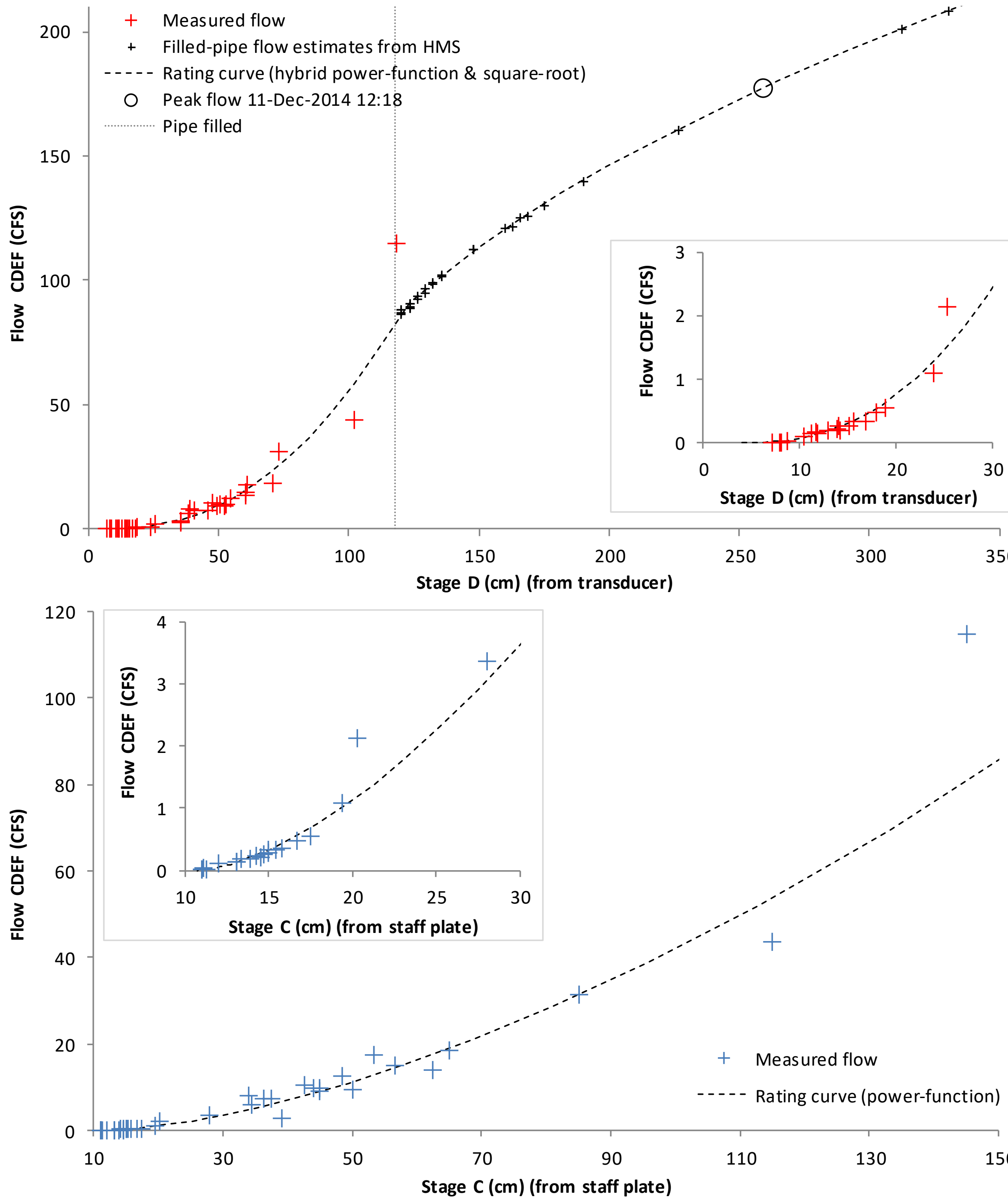

Figure 3-1. Updated rating curves for estimating flow from stage and pressure at Greenwood Park.

4 Additional & updated flow data for Greenwood Park

We deployed pressure transducers at Greenwood Park for 7 months of 2014-15. In combination with the update rating curves for Greenwood Park, this substantially expanded the stormflow record for the City's greatest stormflow-producing watershed. The logging interval was 6-minutes.

The flow data are available at the following URL, and are summarized in Figure 3-1.

http://ccows.csumb.edu/pubs/proj_pubs/2016/CityOfPG_Stormwater/index.htm

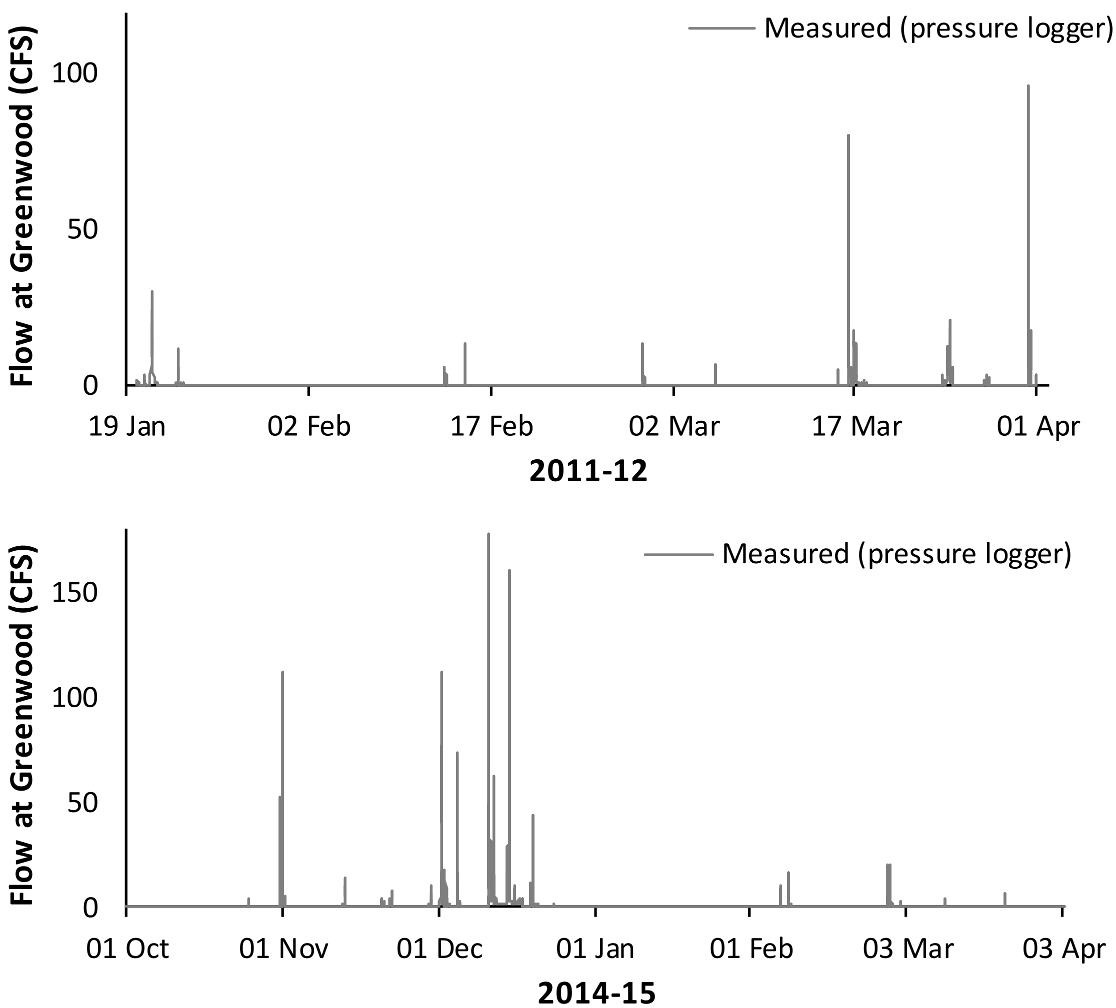

Figure 4-1. Updated and expanded stormflow monitoring record for Greenwood Park.

5 Watershed stormflow model

Given the relative abundance of stormflow data, we found that stormflow within the City can be reasonably predicted by a simple runoff coefficient and lag flow model. (A more-complex model would be required to estimate lower flows such as baseflow and the later parts of stormflow recessions). We implemented such a model using HEC-HMS software (Version 4.1). We utilized the "Impervious %" parameter to express runoff coefficient, and we calibrated the values of this parameter against observed flows (Table 5-1), rather than specifying the values based on mapped impervious cover. For convenience, we implemented this approach within the "Curve Number" (CN) method in HMS, but we set the CN to 1 to completely switch off the generation of runoff via curve numbers. In an alternative approach, curve numbers could be used, but in the present case, we found they were of limited utility when compared to the simplicity of interpretation of a simple runoff coefficient.

Figures 5-1 to 5-9 illustrate the accuracy of the model for 9 representative storms in 2012, 2014, and 2015. In each case, two model runs are shown for 20% and 40% runoff coefficient values, respectively. This illustrates the range of uncertainty of the runoff coefficient ("imperviousness") parameter. Overall, the model is remarkably accurate, given its simplicity. This indicates precipitation at the Lovers Point gage is representative of the watershed as a whole, and that the dominant runoff-producing processes are very direct and simple. Most wet-season flow at the ocean outfall arises from rain falling on impervious surfaces flowing directly through the stormwater system to the outfall. Only a relatively small amount of runoff is generated by indirect means, e.g. by rain percolating into the ground and then re-emerging as throughflow or baseflow. Percolation does occur of course, and probably to a substantial degree; but the fate of most percolated water is apparently something other than eventual discharge at an ocean outfall.

The propensity of the watershed to generate runoff is quantified by the runoff coefficient, which in turn is indirectly measured through the process of matching measured flow and predicted flow corresponding to a particular runoff coefficient. There appears to be a general tendency for the watershed to have a greater propensity to generate runoff (40% runoff coefficient) after a sequence of prior storms (moist antecedent conditions) and/or during the larger rainfall events, and to generate relatively less runoff (20% runoff coefficient) after dry periods (dry antecedent conditions) and/or during the smaller rainfall events (see Figures 5-1 to 5-9).

Table 5-1. HMS model parameters for estimating stormflow in three watersheds in the City of Pacific Grove. See later sections of this report for calibration flows and explanation of the SCM.

Parameter / Option			Current: Greenwood	Current: 8th St	Current: Pico Ave	Hypothetical: Pine above SCM	Hypothetical: Greenwood minus Pine SCM
Area (mi2)			0.40082	0.08651	0.27806	0.01221	0.38861
Model time step		5 minutes					
Loss	Method (nominal)	SCS Curve Number					
	Method (functional)	Rational method					
	Initial abstraction	0					
	Curve Number	1					
	Impervious %		20-40 (low-high)	25	1.8	30	30
Transform	Method (nominal)	SCS Unit Hydrograph					
	Graph Type	Standard (PRF 484)					
	Lag Time (min)		10	8	25	5	10
Canopy	Method	None					
Surface	Method	None					
Baseflow	Method	None					

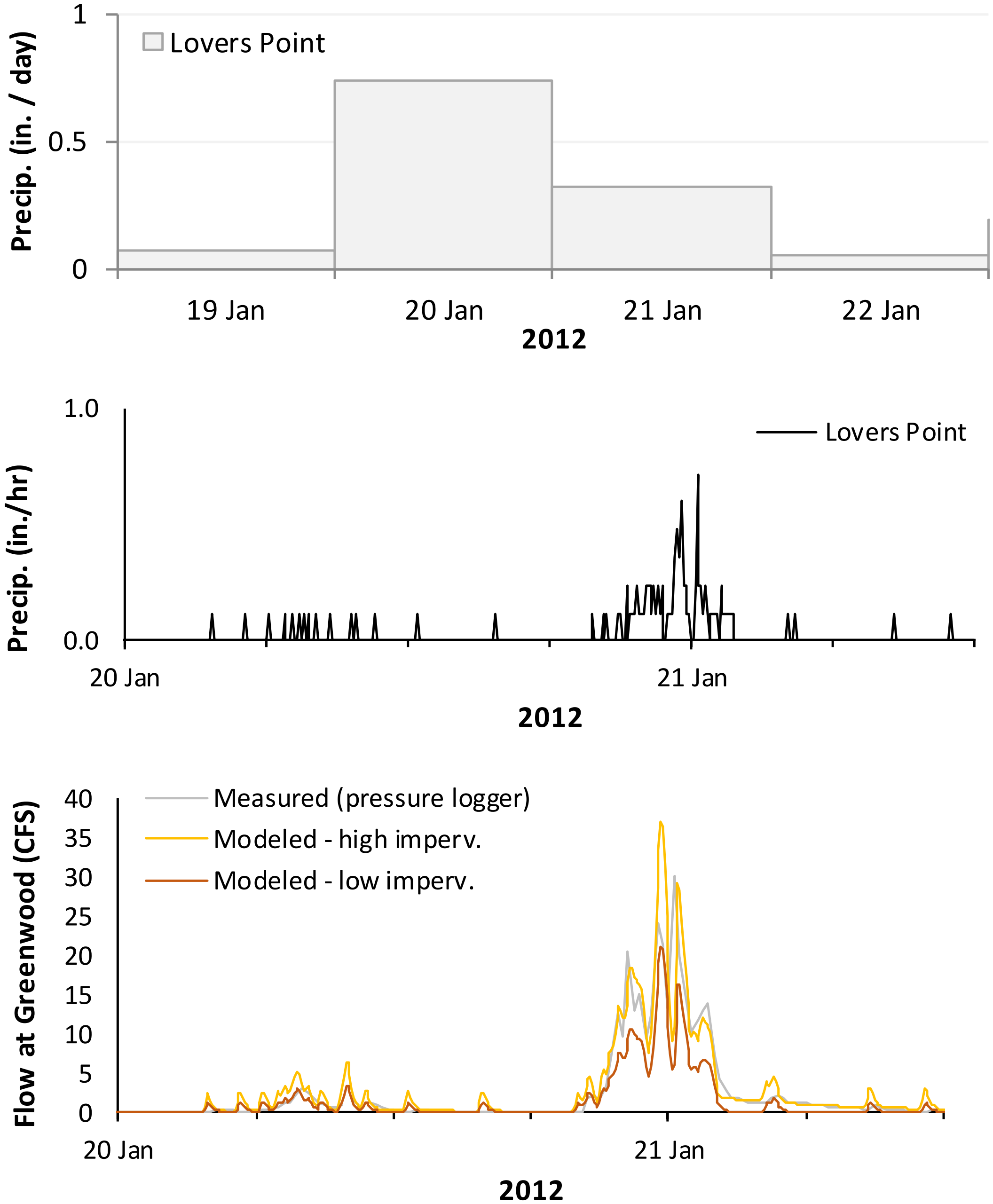

Figure 5-1. Assessment of model accuracy for Greenwood Park during 20-21 Jan 2012 event.

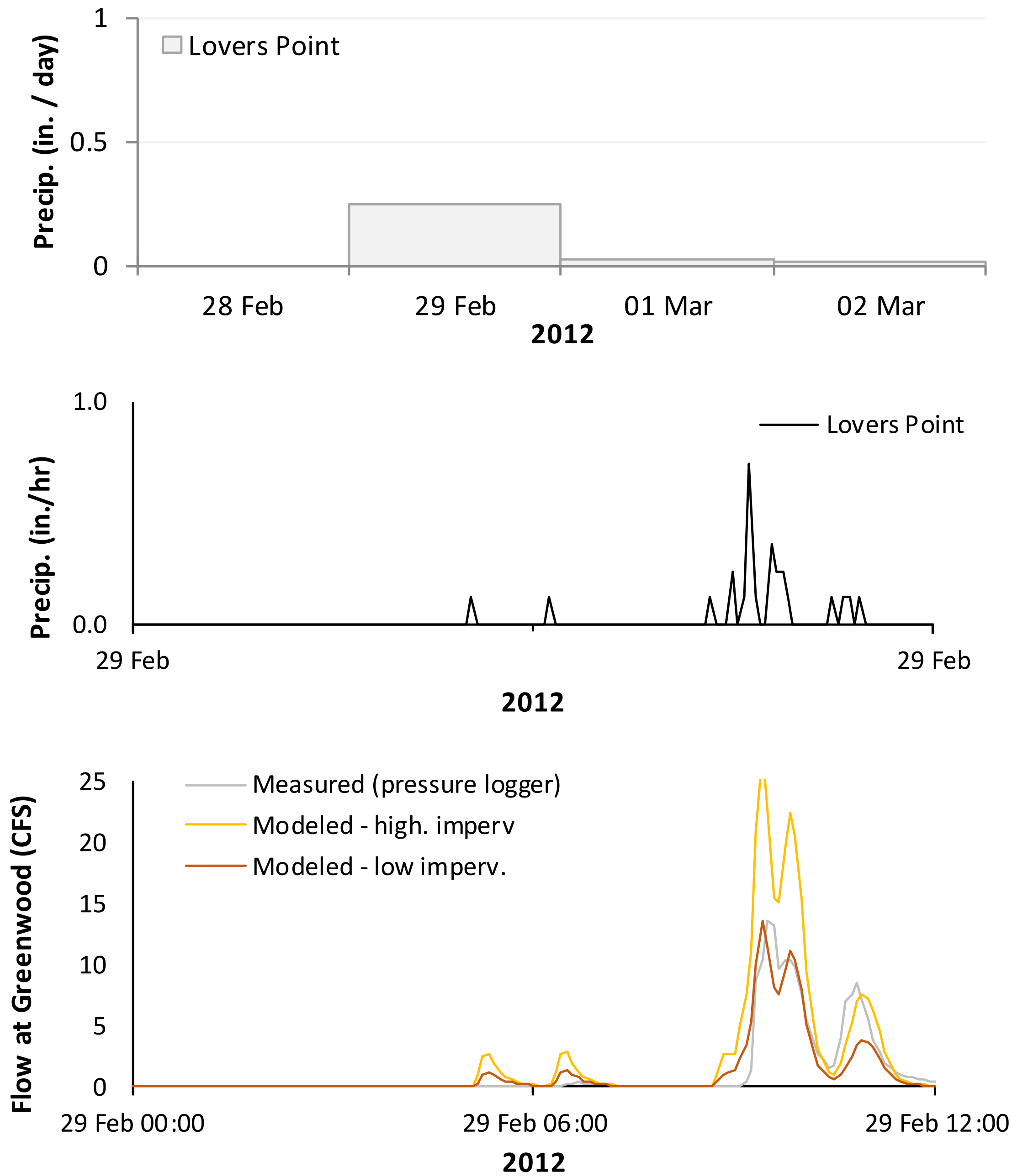

Figure 5-2. Assessment of model accuracy for Greenwood Park during 29 Feb 2012 event.

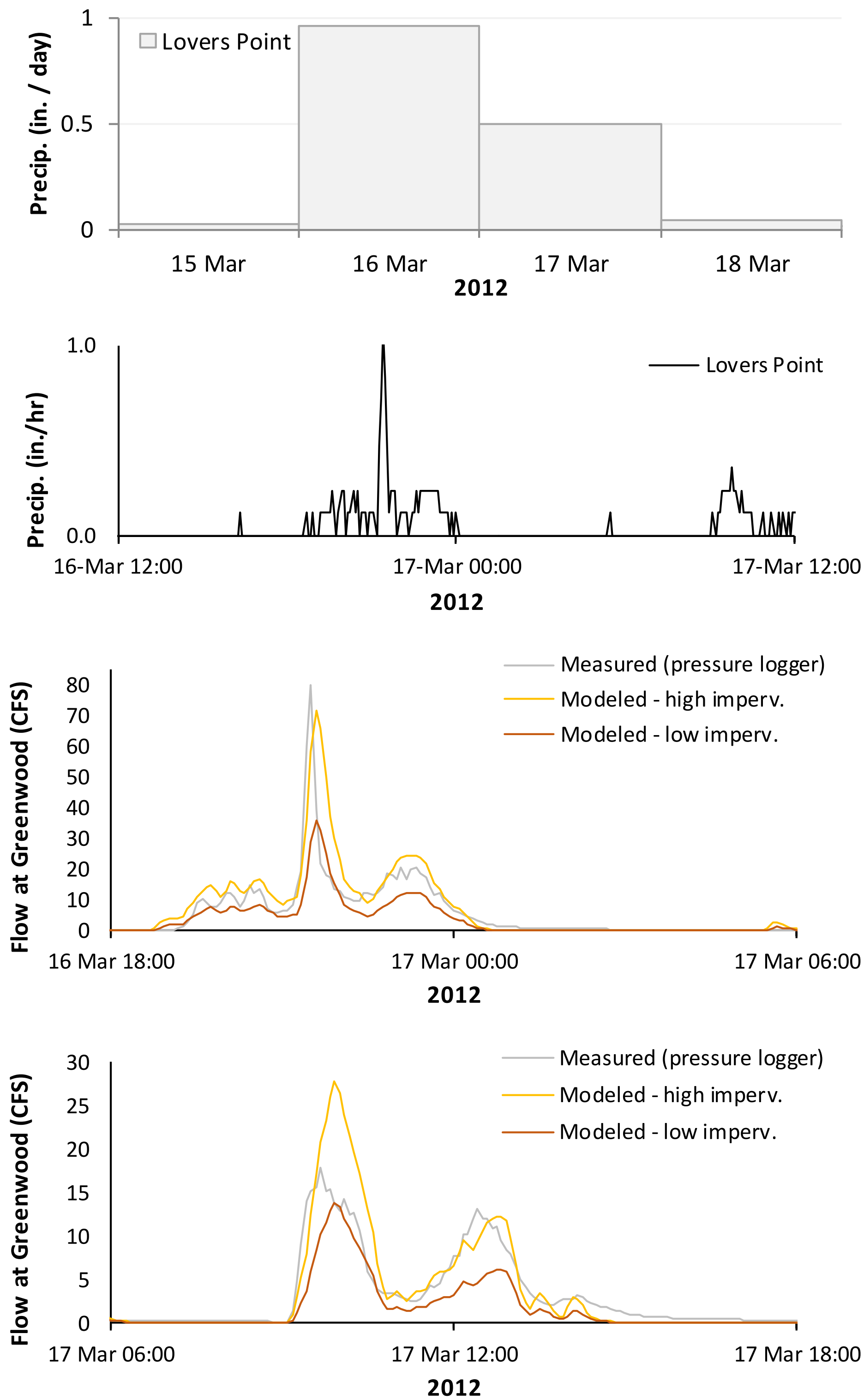

Figure 5-3. Assessment of model accuracy for Greenwood Park during 16 & 17 Mar 2012 events.

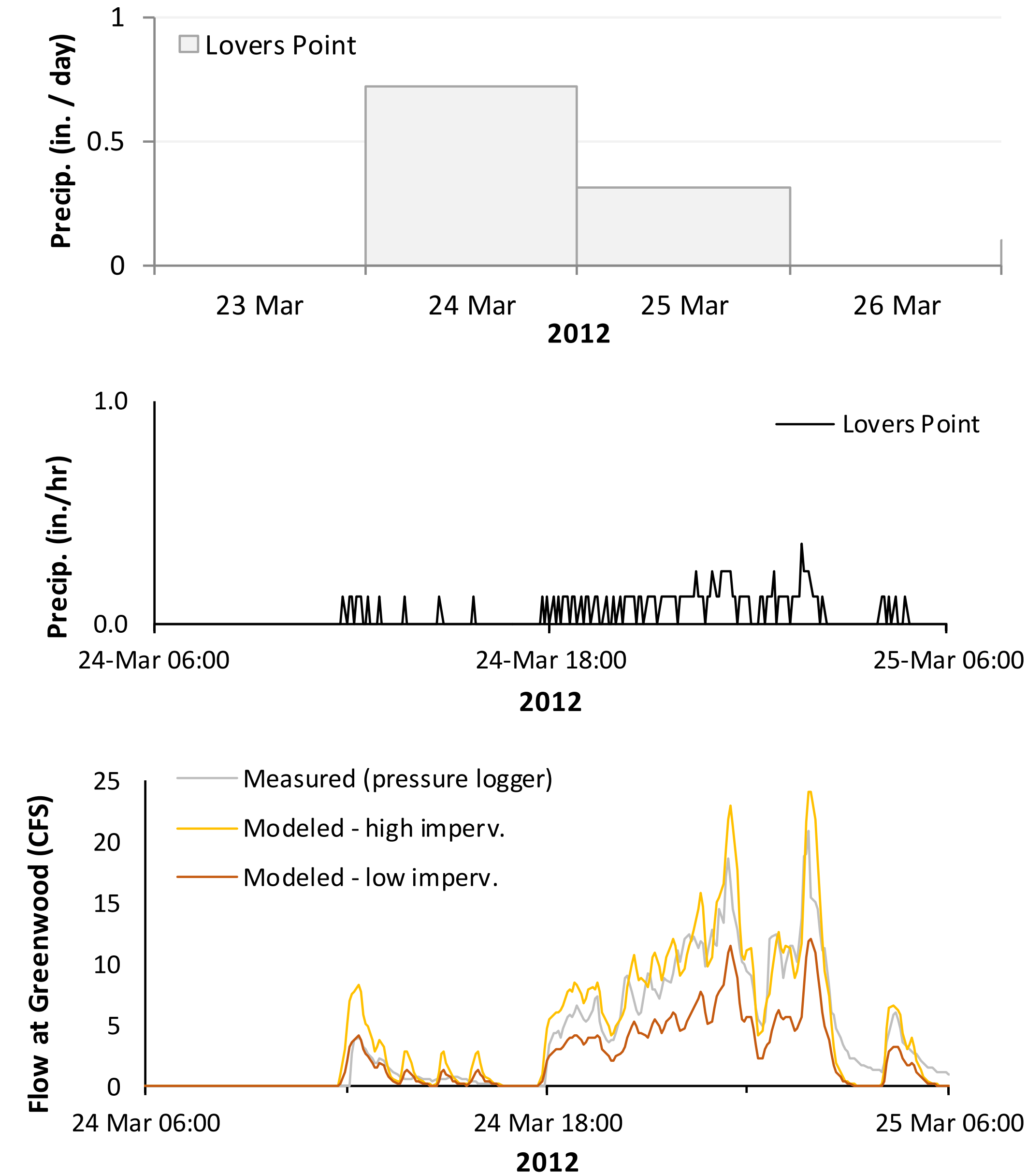

Figure 5-4. Assessment of model accuracy for Greenwood Park during 24 Mar 2012 event.

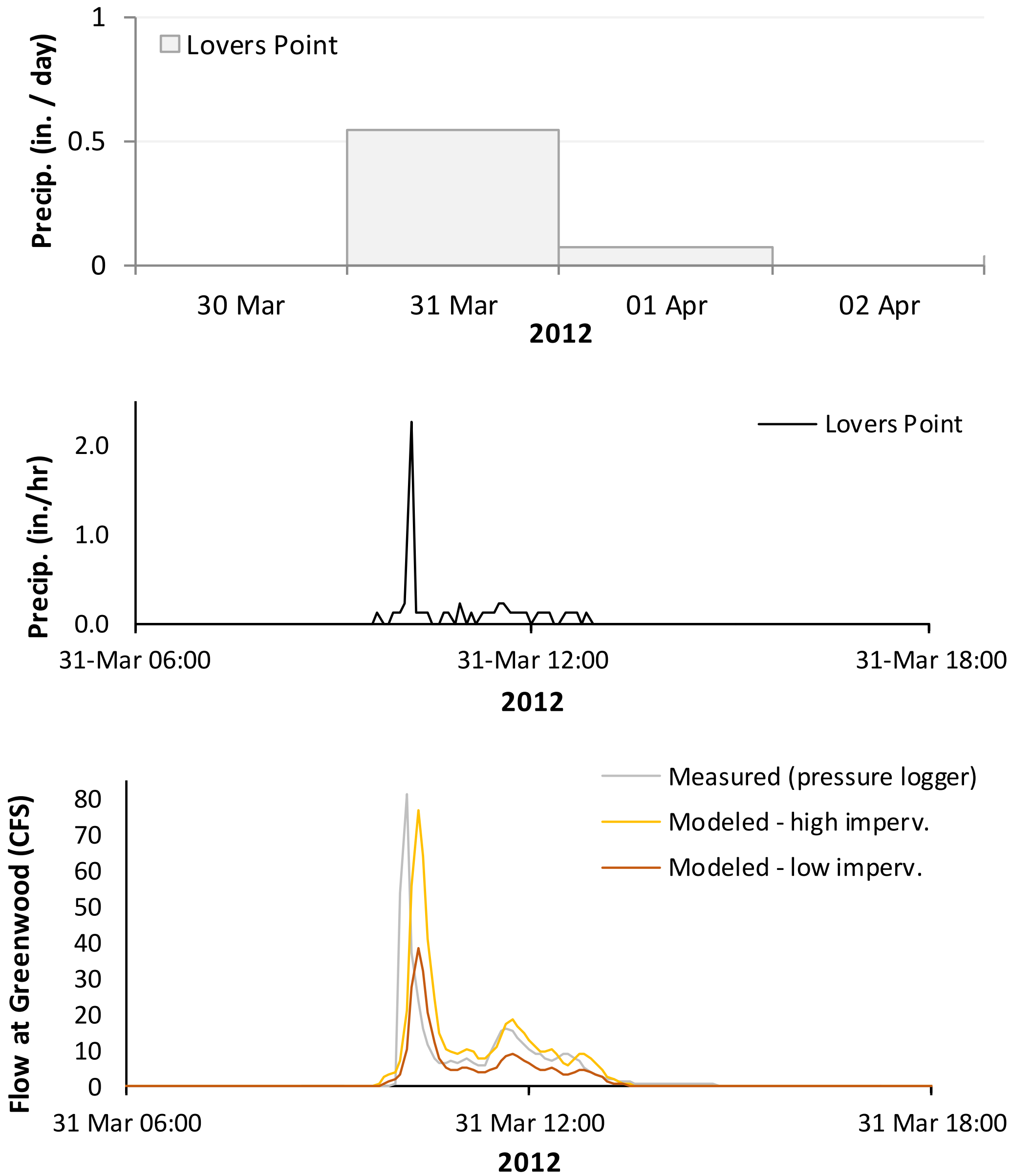

Figure 5-5. Assessment of model accuracy for Greenwood Park during 31 Mar 2012 event.

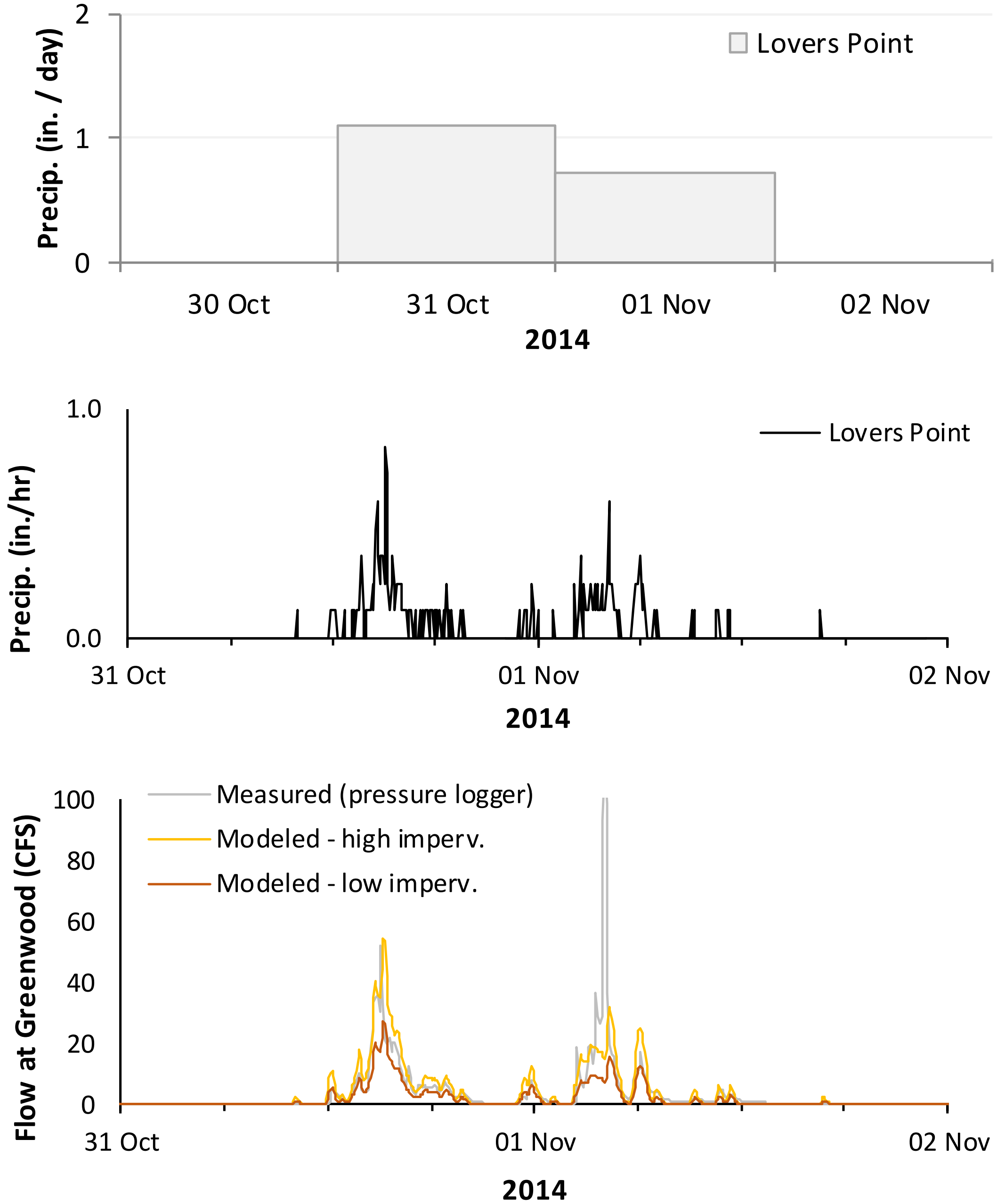

Figure 5-6. Assessment of model accuracy for Greenwood Park during 31 Oct – 1 Nov 2014 events.

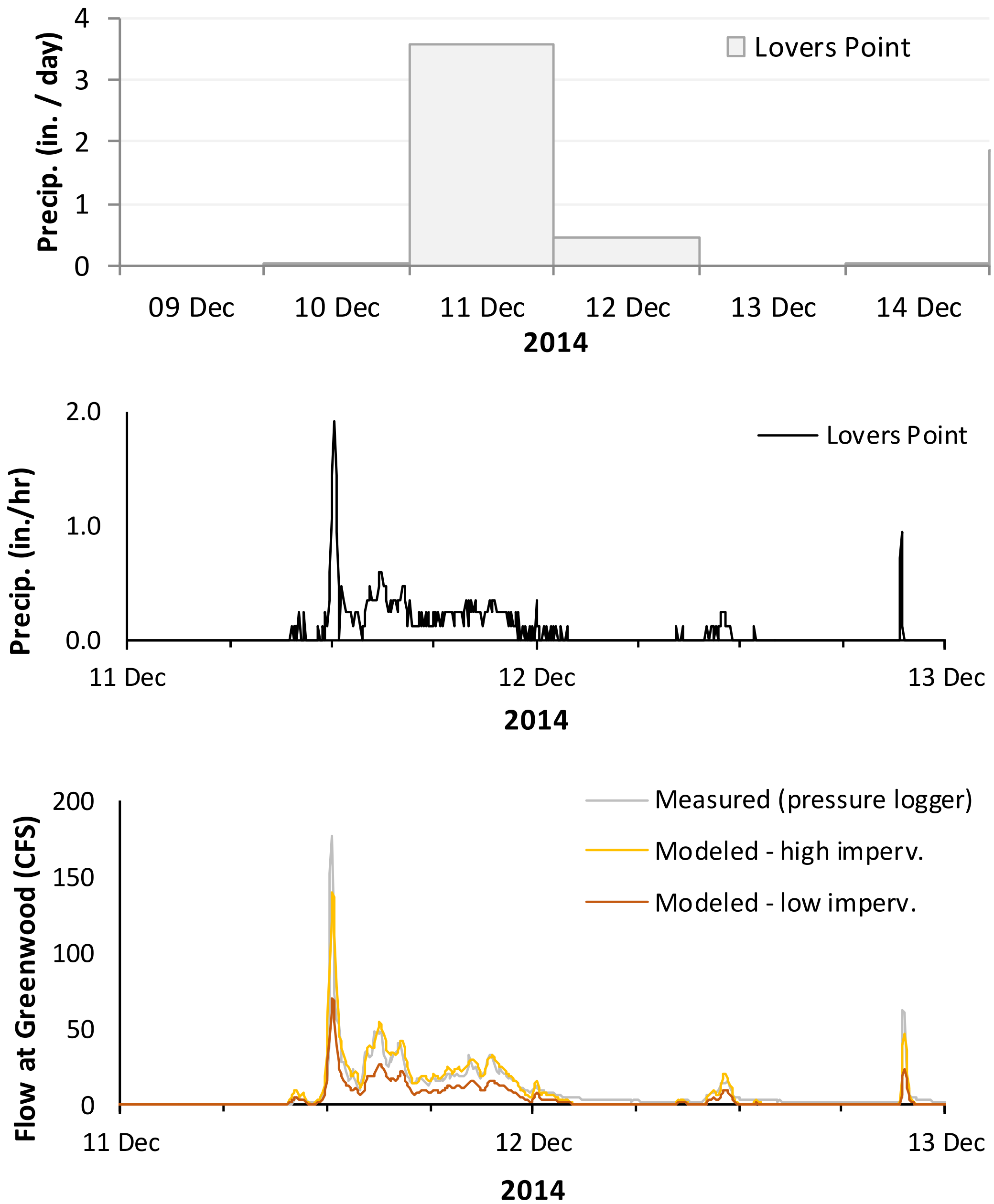

Figure 5-7. Assessment of model accuracy for Greenwood Park during 11-12 Dec 2014 event.

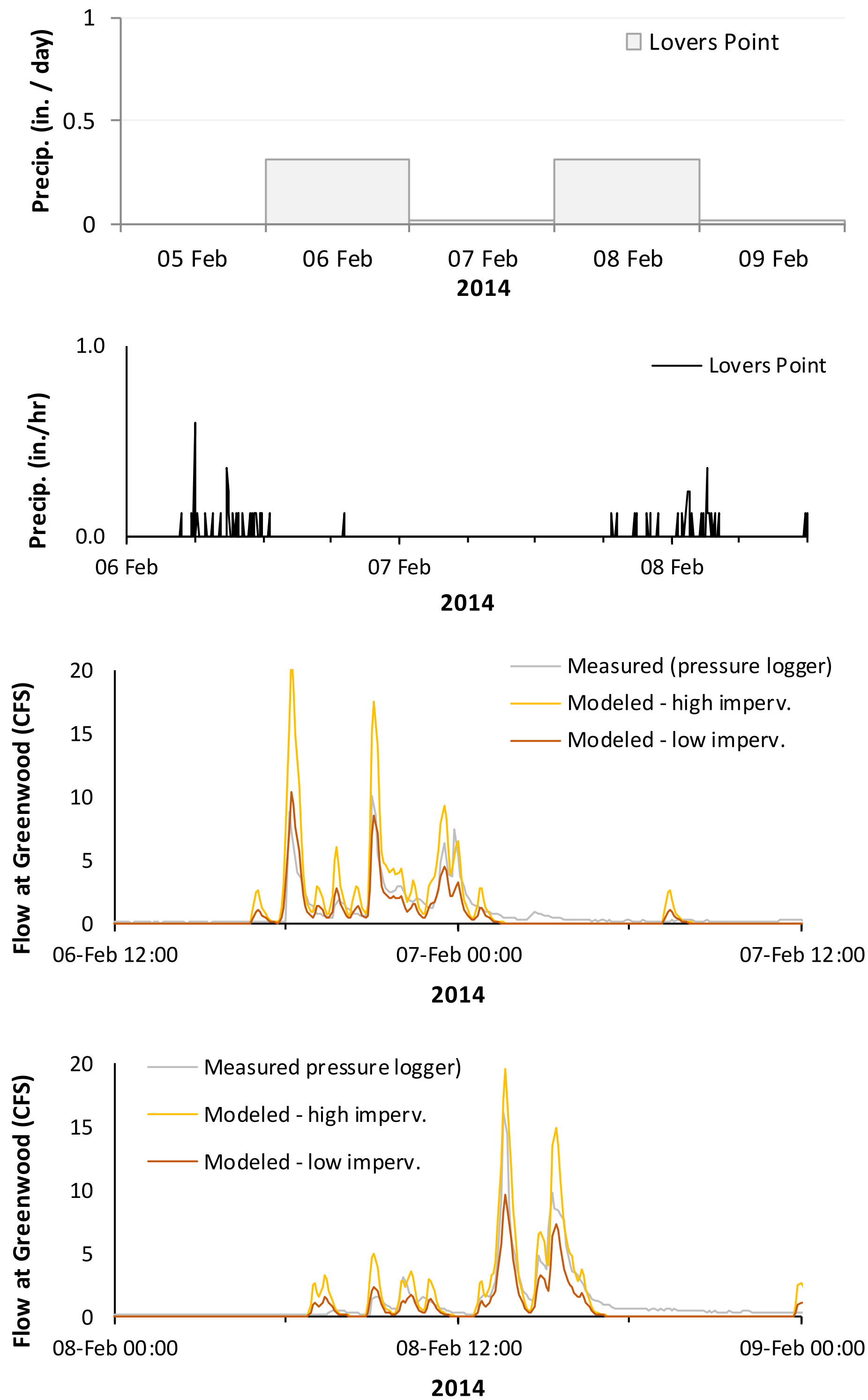

Figure 5-8. Assessment of model accuracy for Greenwood Park during 6-9 Feb 2015 event.

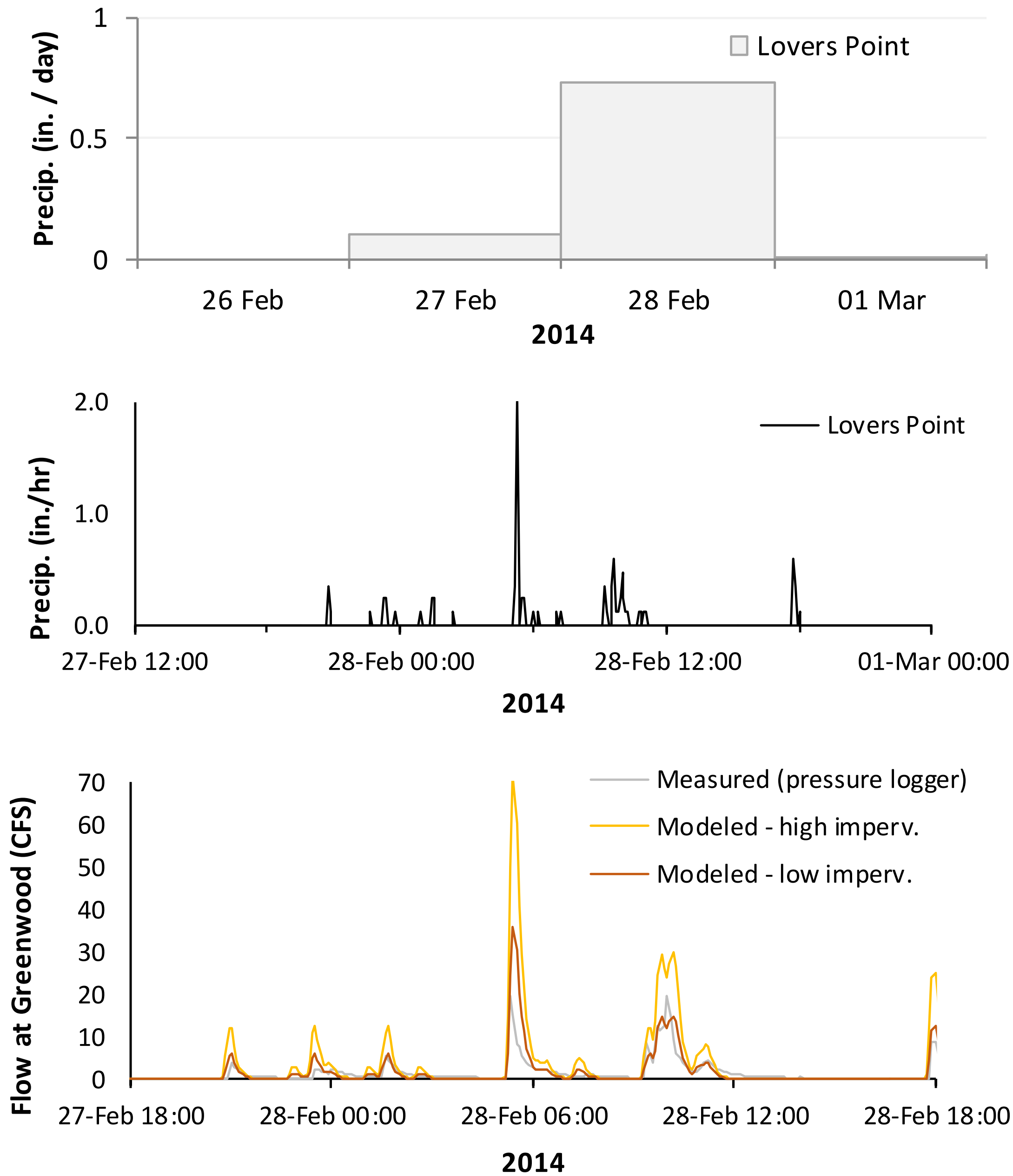

Figure 5-9. Assessment of model accuracy for Greenwood Park during 27-28 Feb 2015 event.

6 Stormflow data for additional sites using dye-dilution gaging

6.1 Dye-dilution development

We developed a variant of the dye-dilution flow measurement technique (Duerk 1983; Kilpatrick & Cobb, 1985; Kilpatrick & Wilson, 1989; Clow & Fleming, 2008) for application to stormflow at coastal outfalls. The essential features of our technique included:

- Dye type: Rhodamine WT
- Dye injection method: Continuous flow maintained using a Mariotte bottle, with periodic manual adjustments to the injection rate to track variations in flow rate and maintain downstream dye concentrations within the target range of dye measurement equipment.
- Dye sampling method: Continuous flow extracted from the stream using a battery-powered pump pulling water through a suction hose terminated by a screened inlet nozzle.
- Dye measurement method: Turner Designs Cylcops Fluorometer connected to a light-excluding through-flow adapter fed by the water pump, and monitored by a Turner Data Bank logger.

We tested a variety of alternate configurations prior to the adoption of the above features. Some ultimately non-adopted design elements included:

- Pulse injection (instead of continuous injection)
- Continuous injection using a peristaltic pump (instead of a Mariotte bottle).
- Direct measurement by placing the fluorometer in the water stream (as opposed to pumping it out of the water stream up to the fluorometer at a separate location)
- Extraction pump systems with either insufficient battery power, or insufficient cooling

Figures 6-1 to 6-8 summarize the field and laboratory trails that led to the eventual successful application of the technique to three different watersheds at Pacific Grove.

(Text is continued after Figure 6-8)

Date	Location	Personnel	Outcome	Dosing	Sampling	Flow
10-Jul-14	Laboratory F	JU, FW	Experience with dye-gaging	P	Direct	Lab
20-Jul-14	Laboratory A	AT, JU	Experience with dye-gaging	P	Direct	Lab
20-Aug-14	Laboratory A?	AT	Experience with dye-gaging	NA	NA	NA
4-Sep-14	Various in PG	AT, JU	Site visits	NA	NA	NA
9-Sep-14	Greenwood Park	AT, JU	Experience with dye-gaging	P	Direct	Low
19-Oct-14	Greenwood Park	AT	Experience with dye-gaging	P	Direct	Low
25-Oct-14	Greenwood Park	AT	Experience with dye-gaging	P	Direct	Storm
27-Oct-14	Salinas Rec Ditch	AT, JU, AB	Experience with dye-gaging	P	Direct	Low
31-Oct-14	Salinas Rec Ditch	AT, SN, AH	Experience with dye-gaging	P	Direct	Storm
31-Oct-14	Greenwood Park	AT	Experience with dye-gaging	P	Direct	Storm
13-Nov-14	Salinas Rec Ditch	AT	Experience with dye-gaging	P	Direct	Post-storm
22-Nov-14	Greenwood Park	AT	Experience with dye-gaging	P	Direct	Post-storm
2-Dec-14	Greenwood Park	AT	Experience with dye-gaging	P	Direct	Storm
11-Dec-14	Greenwood Park	AT	Experience with dye-gaging	P	Direct	Storm
19-Jan-15	Greenwood Park	AT, SN, AB	Experience with dye-gaging	CP	Direct	Low
5-Feb-15	Laboratory F?	AT, FW	Experience with dye-gaging	CM	NA	NA
7-Feb-15	Greenwood Park	AT, SN, AB	Experience with dye-gaging	CM	Direct	Low
8-Feb-15	Laboratory F	FW	Experience with dye-gaging	CM	NA	NA
8-Feb-15	Greenwood Park	AT, SN	Experience with dye-gaging	CM	Direct	Storm
16-Feb-15	Laboratory	AT	Experience with dye-gaging	CM	NA	NA
19-Feb-15	Pico	AT, SN, AB	Experience with dye-gaging. Some steady-flow data.	CM	Pumped & direct	Low
25-Feb-15	8th St	AT, SN	Experience with dye-gaging	CM		
27-Feb-15	8th St	SN, JU, AT	Experience with dye-gaging. Data: low flow.	CM	Pumped & direct	Low
28-Feb-15	8th St	SN, AB, AT	Data: stormflow (8th).	CM	Pumped & direct	Storm
7-Apr-15	Pico & Greenwood	AT, FW	Data: stormflow (GW). Data: low flow (Pico).	CM	Pumped	Storm
25-Apr-15	Pico & Greenwood	AT, JU, SN	Data: stormflow (Pico)	CM	Pumped	Storm

Figure 6-1. Summary of field and laboratory effort during development of the dye-dilution flow gaging technique. (P = Pulse; CP = Continuous peristaltic; CM = Continuous, Mariotte)

Figure 6-2. Continuous dye injection using Mariotte bottle – Pico Ave

Figure 6-3. Measuring dye injection rate – Greenwood Park

Figure 6-4. Remote dye measurement using fluorometer, logger, and a water pumped from stream into flow-through adapter for fluorometer – Pico Ave

Figure 6-5. Remote dye measurement, showing screened suction hose drawing sample water from stream up to sensor – Greenwood Park

Figure 6-6. Heat-vented rain-resistant housing for water pump used to remotely sample stream water

Figure 6-7. Direct dye measurement, with fluorometer inserted directly into stream.
This approach yielded inconsistent readings.

Figure 6-8. Continuous dye injection using a peristaltic pump.
This approach yielded inconsistent injection rates.

6.2 Dye-dilution technique validation

An opportunity to validate the dye-dilution flow measurement technique arose at Greenwood Park on 7-Apr-2015. We obtained concurrent time-series of flow measurements using both the staff-plate/rating-curve technique and the dye-dilution technique. The measurements compared well with each other (Fig. 6-9), and also to model predictions with relatively a low runoff coefficient (as would be expected given the relatively small size of the event, and the dry antecedent conditions – see Fig 2-4 for reference).

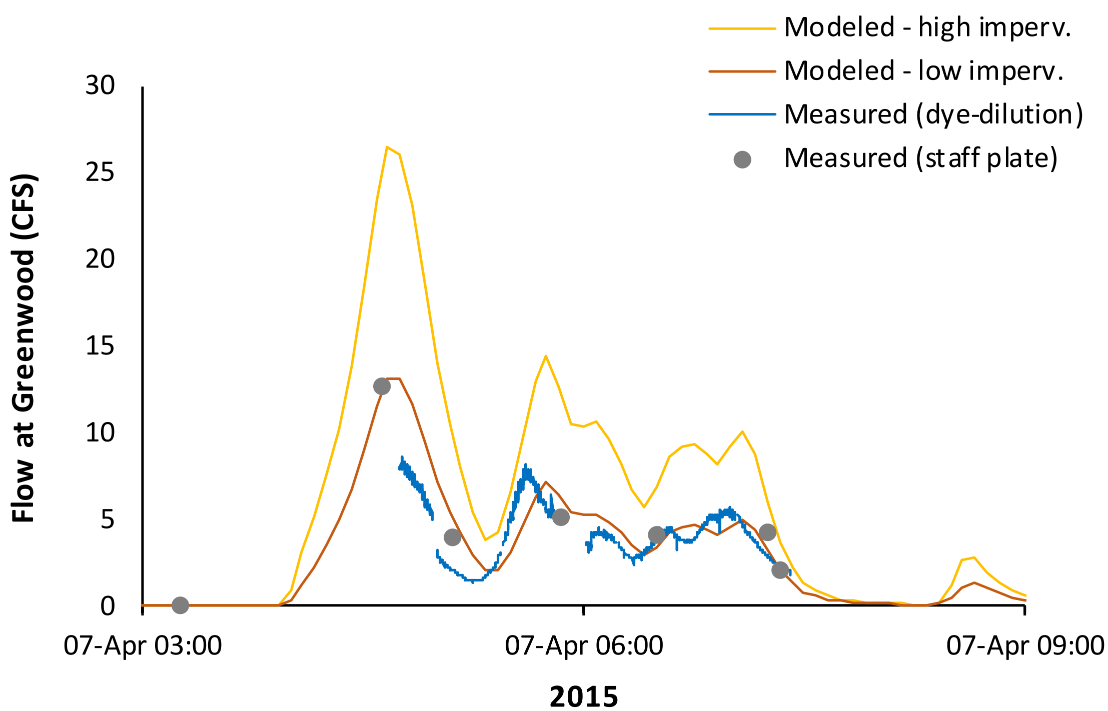

Figure 6-9. Validation of dye-dilution flow measurements against staff-plate/rating-curve flow measurements at Greenwood Park.

6.3 Dye-dilution technique application

The goal of using the dye-dilution technique for flow gaging was to be able to measure storm flow safely without using fixed instrumentation mounted in storm drains or outfalls, in order to obtain support for our postulate that different watersheds in the City of Pacific Grove might yield very different flow rates per unit of watershed area, depending on their watershed characteristics.

In addition to the technique-validation measurements at Greenwood Park, we were able to obtain dye-dilution stormflow measurements at two other watersheds: the 8th St watershed, and the Pico Ave watershed.

Measurements at 8th St were obtained between 25-Feb-2015 and 28-Feb-2015 during two low-flow periods and a storm event. Figure 6-10 illustrates the general context of these measurements, and Figure 6-11 provides a more-detailed examination of flow during the 28-Feb storm event. A good match was observed between the timing of precipitation, measured runoff, and modeled runoff.

The flow measurements imply a 25% runoff coefficient for the watershed during the 28-Feb event, because this was the runoff coefficient required to achieve good match between magnitude of measured and modeled flow (Fig. 6-11). Antecedent conditions were dry (Fig 2-4); the average runoff coefficient for 8th St under non-drought conditions may be higher than 25% e.g. approximately 30%.

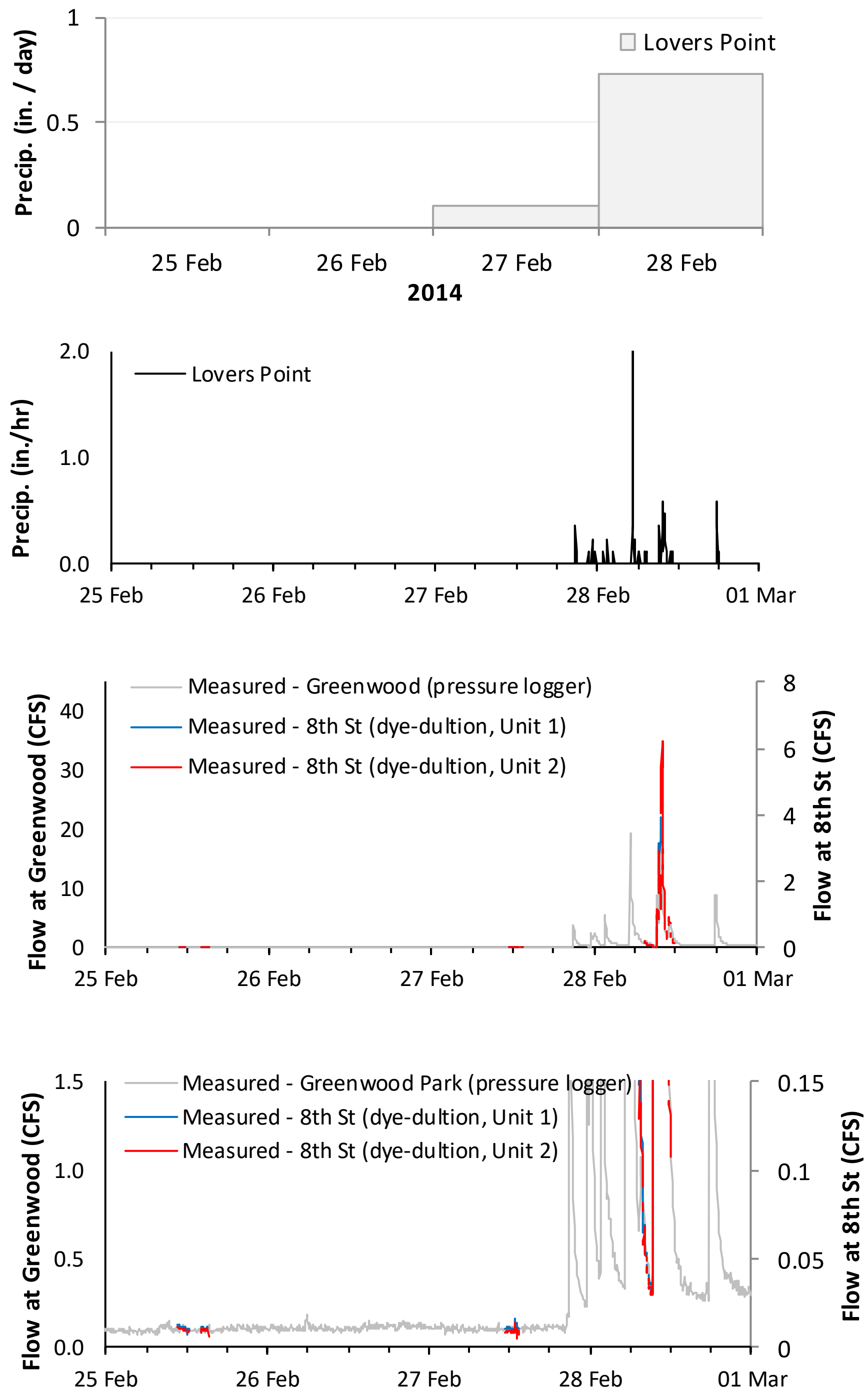

Figure 6-10. Dye-dilution flow measurements at 8th St, with overall context provided by the inclusion of pressure-based data from the adjacent Greenwood Park watershed. Two independent sets of dye-dilution measurements were obtained, using two different fluorometers (“Unit 1” and “Unit 2”). Greenwood Park data are included to clarify low-flow versus storm-event conditions. More detail appears in Figure 6-11.

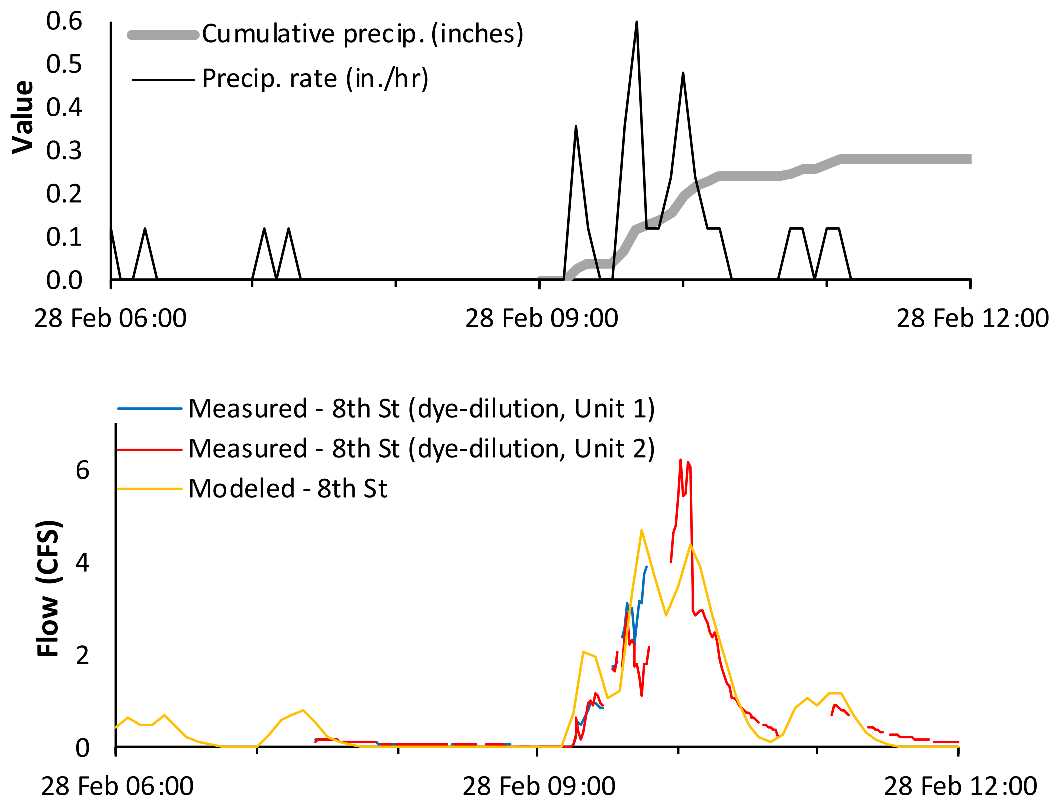

Figure 6-11. Dye-dilution flow measurements at 8th St, and calibration of stormflow model to the dye-dilution measurements.

Dye-dilution flow measurements were obtained for the Pico Ave watershed during low flow before a storm on 7-Apr-2015 and during a storm event on 25-Apr-2015 (Figs 6-12 and 6-13).

A good match was observed in the timing of precipitation, measured runoff, and modeled runoff during the 25-Apr storm event.

The runoff coefficient required to achieve a good match in the magnitude of measured and modeled flow was only 1.8%. The storm was relatively small, and the antecedent conditions were dry; so the average runoff coefficient for the watershed is likely to be higher, but still much less than the runoff coefficients indirectly observed for the more urbanized watersheds like Greenwood Park (20-40%) and 8^{th} St (at least 25%). This supports our initial postulate that some watersheds (like Pico Ave) generate much less runoff (per unit watershed area) than other watersheds in the City.

Several watershed characteristics may lead to lower flow per unit watershed area in watersheds like that of Pico Ave. These include, for example, lower impervious cover, higher tree canopy cover, and higher proportion of sandy soils (derived from sand dunes).

Impervious cover is perhaps the most obvious metric to summarize the runoff-generating propensity of different watersheds within the City. Figure 6-14 briefly explores the relationship between mapped impervious cover (based on satellite remote sensing, ENVS 660 (2011)) and runoff coefficients indirectly measured through calibration of watershed models to measured flows. A positive relationship is evident.

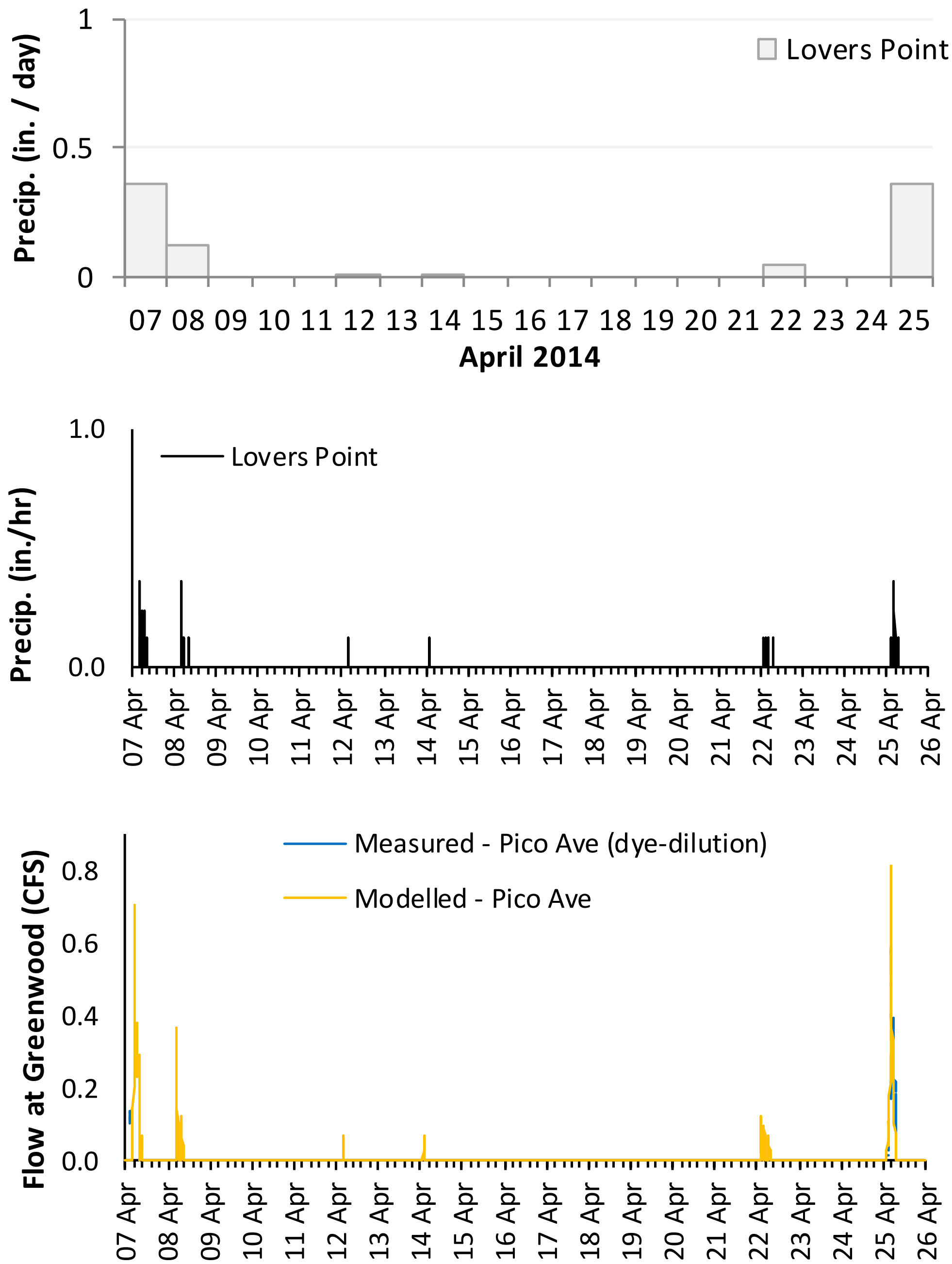

Figure 6-12. Dye-dilution flow measurements at Pico Ave - overall context (more detail in next figure).

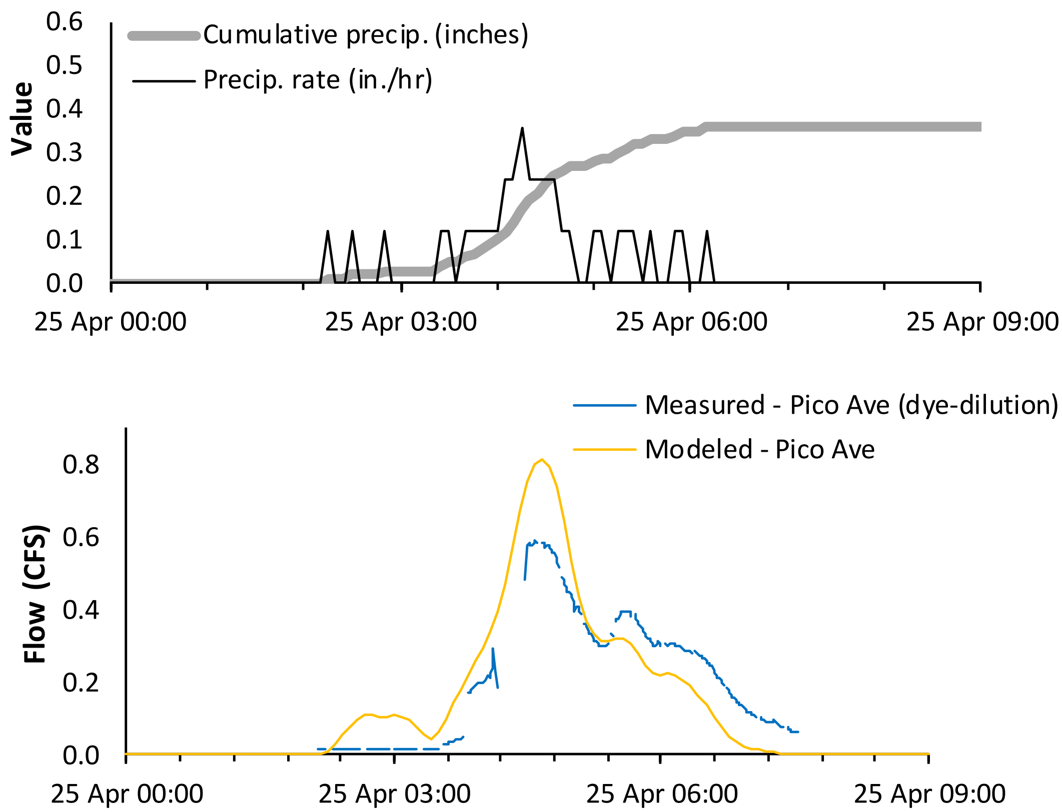

Figure 6-13. Dye-dilution flow measurements at Pico Ave, and calibration of stormflow model to the dye-dilution measurements.

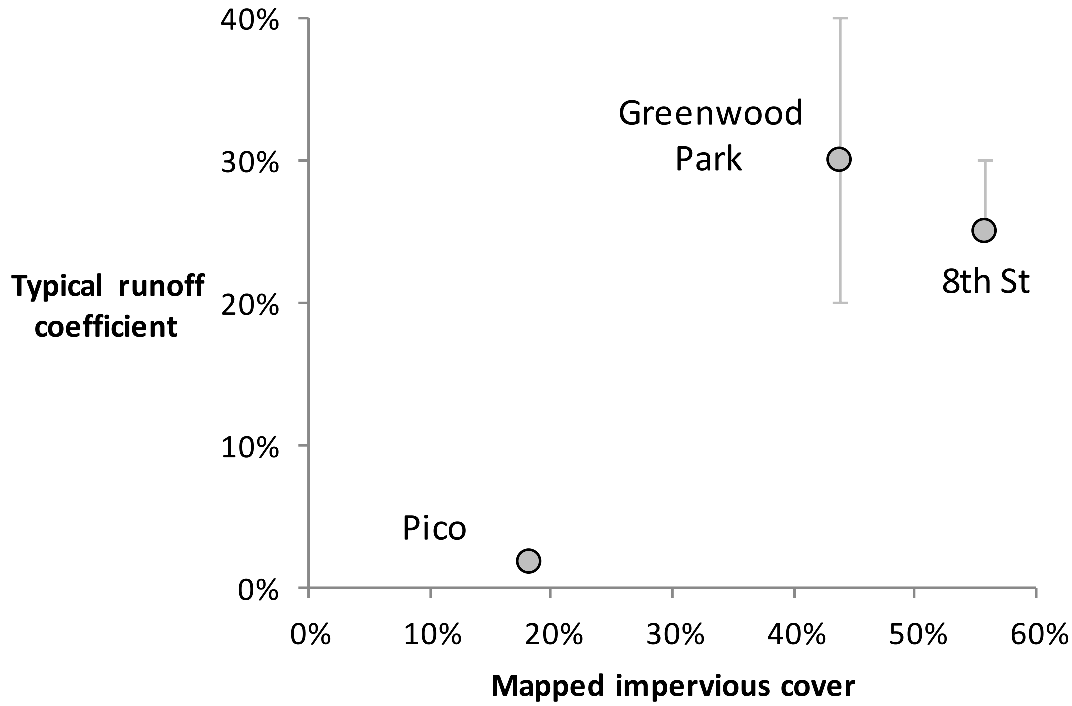

Figure 6-14. Relationship between runoff coefficient (inferred from model calibration to flow measured using dye-dilution gaging) to impervious area (estimated using satellite remote sensing).

7 Design & modeling of a stormwater control measure on Pine Avenue

The City can implement and has implemented a variety of watershed management strategies to reduce runoff, ultimately as a component of reducing pollutant load to managed receiving waters such as the ASBS and the National Marine Sanctuary.

One such strategy is to intercept and detain stormflow once it has entered the street system but before it has entered the subsurface storm drain system. The efficacy of such a strategy requires:

- Identification of relatively large subwatersheds with substantial on-street drainage and no sub-surface drains, ideally within high-priority outfall watersheds like Greenwood Park and 8th Street. This surface-drained criterion is more likely to lead to potential SCM sites where all drainage occurs under gravity without the need to pump water or to re-route subsurface drains to the surface.
- Identification of sites where existing land use can be replaced or supplemented with use as a stormwater interception and detention site, ideally on public land where land use modifications are potentially more feasible and manageable by the City
- Location of such sites in areas with relatively high percolation potential. This requires careful investigation in the geomorphic and geologic setting of Pacific Grove, where bedrock is commonly very close to the surface, but where a sequence of marine terraces and relatively permeable recent sediments also exist (ENVS 660, 2014)

We sought to quantify the potential efficacy of an in-street stormwater interception and detention system (i.e. a stormwater control measure (SCM)), designing and locating this system primarily with reference to the first two requirements above (a suitable subwatershed, and a suitable public site).

We identified a suitable watershed by mapping drainage patterns throughout the entire City and looking for large areas where stormwater drainage was entirely at the surface (e.g. in gutters) and not in subsurface drains (Fig 7-1). The map of drainage patterns was created using the ENVS 660 (2011) approach of "burning" storm drain data into a digital elevation model with 3-meter horizontal resolution. An area just uphill of Pine Avenue between 7th St and Carmel St was revealed as relatively large but without subsurface drainage. Figure 7-1 shows the drainage pathways (in pink shades) and the lack of stormwater infrastructure (storm drains or catch basins) in this area. We confirmed the accuracy of the mapped surface drainage pathways through field observations of water flow in gutters and across streets during rain events.

We located a hypothetical SCM on Pine Ave just downstream of this subwatershed (Fig. 7-1). Pine Ave is a very wide, arguably over-sized street on public land. The SCM concept was based on designs specified by LIDI (2013). It could be described as a "street bioretention facility" approximately 85 feet long and 30 feet wide, excavated at least 4 feet down and filled with permeable gravel and soil. All water that now flows from the above-described watershed down the street along the gutter on the south side of Pine Ave would be routed into the SCM. The nominal dry-weather water table would be at least 4-feet deep. Any water entering the SCM would be allowed to percolate beneath the SCM and laterally into the surrounding subsurface areas (soil, fractured rock, etc.). We assumed a percolation rate of 0.05 inches/hr (1.2 inches/day). Stormwater would typically enter the SCM much faster than could be dispersed through percolation, and so the water level would rise upwards during storms, about twice as fast as if it were surface basin, assuming the gravel and soil of the SCM itself had a porosity of approximately 50%. Once the water level reached the surface, it could exit the SCM via a small spillway 4-feet wide, and thereafter re-enter the gutter, or be directed by a subsurface drain to the nearby stormwater mains. The spillway would be notched into a surrounding confinement (e.g. a curb) to prevent uncontrolled flow out of the SCM.

This hypothetical SCM would reduce net runoff to the downstream stormwater system to a degree that would be controlled by high percolation rates, high SCM volume relative to upstream sub-watershed area, small storm size, and large intervals between successive storms.

To obtain a point of reference along this continuum of multiple influences on SCM efficacy we made some simple assumptions about percolation rate, and simulated the amount of runoff that would be detained during an actual 85th percentile storm (approximately 1-inch) that occurred on 31-Oct-2014. Tables 5-1 and 7-1 detail the relevant HMS parameters. Figure 7-2 describes the dynamics of the event through time series of rainfall, stormflow input, stormflow output, percolation, and depletion of available SCM storage. Table 7-2 summarize the total diversion, and the components of this total.

The SCM was estimated to detain 63% of the stormflow from the target sub-watershed during the simulated event. If this storm were followed by a dry period, the detention could be expected to be permanent, and the efficacy of the SCM could be considered substantial. If the storm was followed quickly by subsequent events, or the percolation rate was lower than assumed, the expected efficacy of the SCM would be reduced accordingly.

Scaling up, Figure 7-3 illustrates the effect that ten similar SCMs might have on the overall Greenwood Park hydrograph, assuming it was possible to identify a sufficient number of candidate subwatersheds above suitable SCM sites. Again, the potential effect is substantial, but heavily conditioned on assumed percolation rates and the timing of successive storm events.

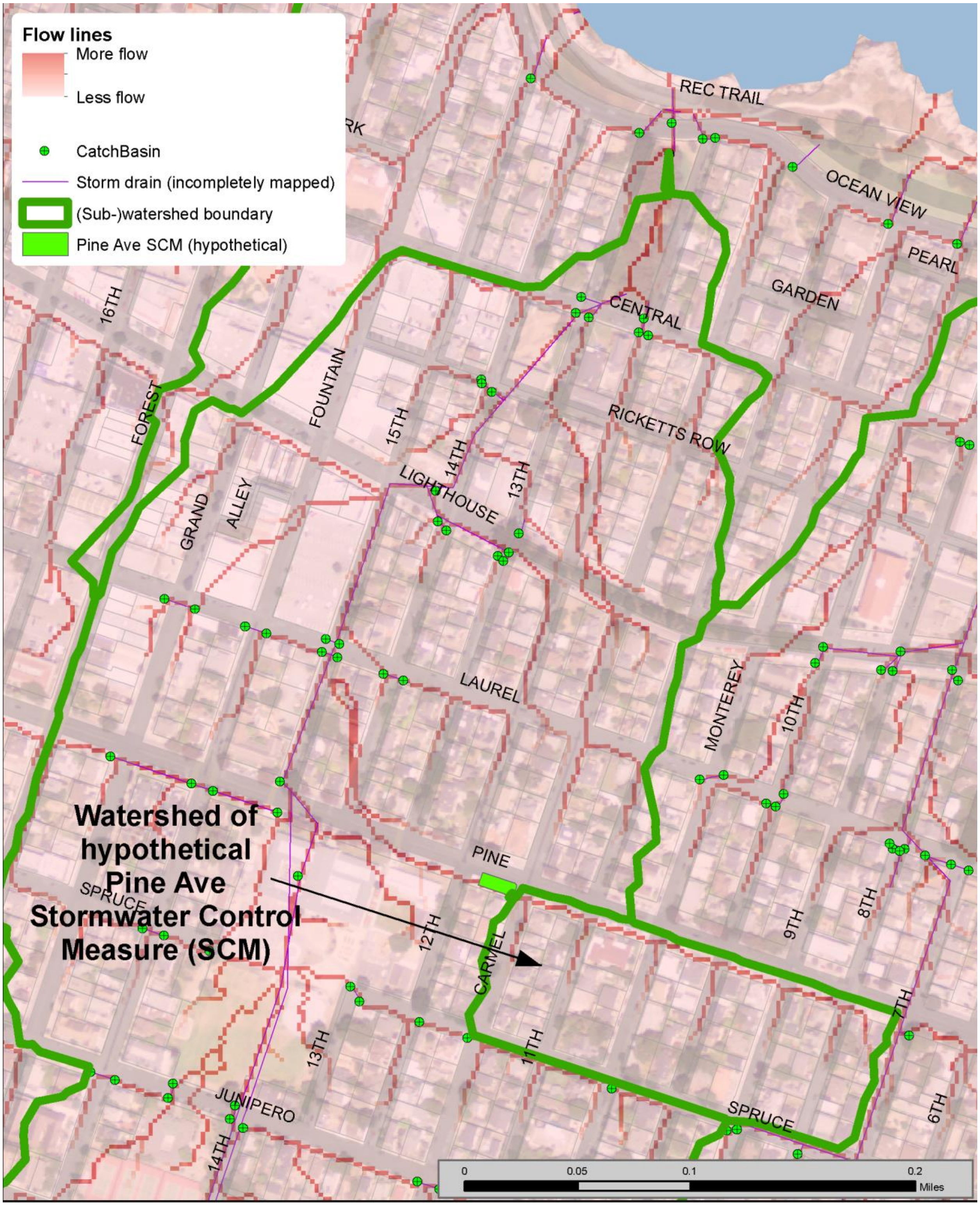

Figure 7-1. Location of a potential stormwater control measure (SCM) on Pine Ave, and the watershed that would drain into this SCM.

Table 7-1. HMS model parameters for potential future stormwater control measure (SCM) on Pine Ave.

Element	PineSCM		
Element type	Reservoir		
Method	Outflow Structures		
Storage Method	Elevation Area	*Elevation-Area Function*	
		Elevation (ft)	Area (ac)
		0	0
		0.1	0.06285
		10	0.06285
Initial Elevation (ft)	0		
Auxillary	Sink-1		
Spillways	2		
Spillway 1			
Method	Specified Spillway		
Direction	Auxillary		
Rating Curve	PinePerc	*Elevation-Discharge Function*	
		Elevation (ft)	Discharge (CFS)
		-100	0
		0	0
		0.1	0.0032
		1	0.0032
		10	0.0032
Spillway 2			
Method	Broad-Crested Spillway		
Direction	Main		
Elevation (ft)	2		
Length (ft)	4		
Coefficient (ft^0.5/s)	3		
Gates	0		

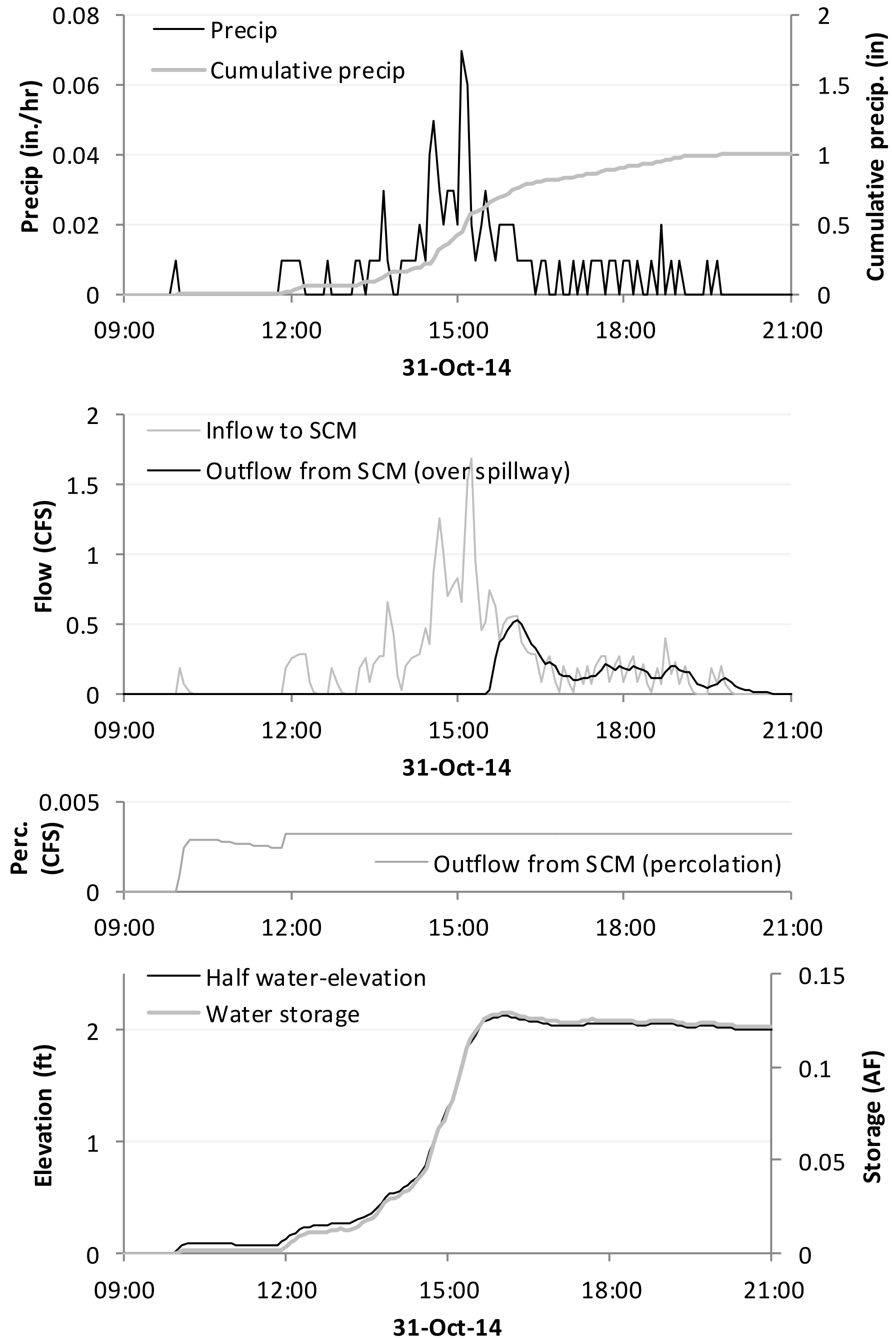

Figure 7-2. Model-predicted impact of Pine Ave SCM on stormwater flow from an 85th percentile rainfall event.

Table 7-2

SCM water balance over Period of Interest (POI) correspoding to 1" storm (~85th percentile): 9:00 AM to 9:00 PM 31-Oct-14

Total input over POI:	0.197 AF	
Total spilled over POI:	0.073 AF	
Total percolated over POI:	0.003 AF	
Residual storage at end of POI:	0.121 AF	
Sum of outputs and residual storage:	0.196 AF	
Rounding error:	0.001 AF	0.46%
Total diverted:	0.124 AF	62.62%

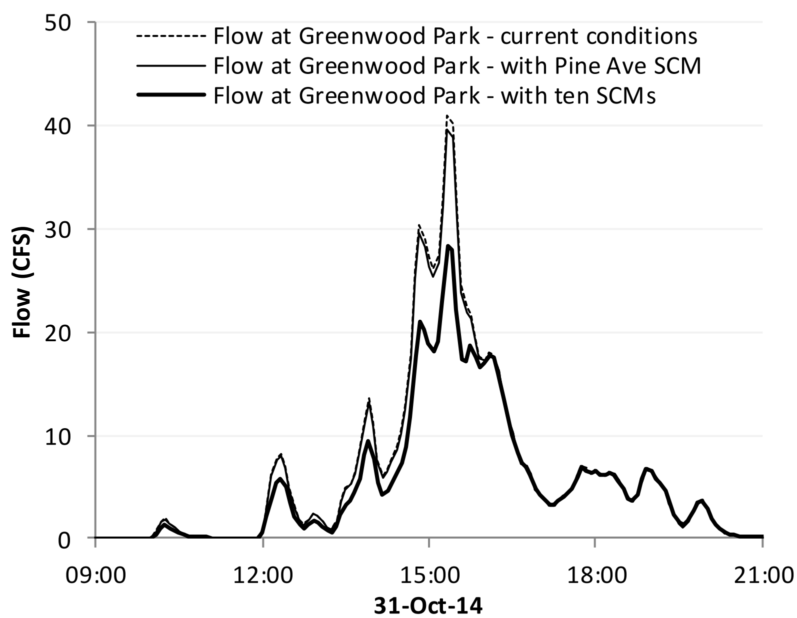

Figure 7-3. Model-predicted impact of ten SCMs (from similarly-sized sub-watersheds and SCMs as at Pine Ave) on total Greenwood Park ocean outfall stormwater flow from an 85th percentile rainfall event.

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