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University Park Neighborhood Rain Gardens Project in Los Angeles, California

Authors
Sadeghi, K Majid

Tam, Wing

Kharaghani, Shahram

et al.

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May 19–23, 2019

Edited by
Gregory F. Scott, P.E.
William Hamilton, Ph.D., P.E.

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WATER, WASTEWATER, AND STORMWATER; URBAN WATER RESOURCES; AND MUNICIPAL WATER INFRASTRUCTURE

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Preface

We are excited to offer the proceedings of the 2019 World Environmental and Water Resources Congress. The proceedings include published papers from an engaging and challenging array of technical sessions, posters, and workshops at the Environmental and Water Resources Institute's (EWRI) 19th Annual Congress, held in Pittsburgh, Pennsylvania, May 19-23, 2019. This conference is a leading venue for professional interaction among engineers and scientists, covering disciplines related to water and environmental resources and infrastructure.

America's infrastructure is in urgent need of attention. The 2017 American Society of Civil Engineers' Report Card for America's Infrastructure estimates that an investment of over $4.5 trillion is needed to return the nation's infrastructure to a state of good repair. Of critical importance to the public's health and safety are the needs of water focused infrastructure. The Environmental Protection Agency (EPA) estimates that wastewater and stormwater collection and treatment needs are $271 billion as of January 2012 and drinking water utilities needs are $472.6 billion as of March 2018. While significant, the needs are not limited to the United States alone. According to the World Health Organization (WHO), contaminated drinking water is estimated to cause 502,000 diarrheal deaths each year, and by 2025, half of the world's population will be living in water-stressed areas. Compounding the state of water infrastructure are on-going changes to the climate. Scientific evidence unequivocally indicates these changes are accelerating. While debate remains as to the causes and how best to slow, stop and/or reverse these changes, it falls to professionals in the water fields to address the challenges to rebuilding the world's water infrastructure to be more resilient and reducing direct impacts such as flooding and indirect impacts such as disruption of critical economical services.

The 2019 EWRI Congress covers a wide range of topics that attempt to provide innovative and sustainable solutions to ensure that our water and environmental infrastructure and resources will be improved and built to secure and protect them for the future. We proudly host the Congress under the auspices of the American Society of Civil Engineers (ASCE).

Within the six (6) volumes of the proceedings, more than 150 written scientific and technical papers from nearly 800 oral and poster presentations focusing on the subject areas of various EWRI Councils are included. A list of subject area tracks is included in the acknowledgements below. We hope these proceedings serve to enhance your knowledge and encourage you to follow up with more detailed publications by the same authors, and related papers, typically found in ASCE technical journals.

This collection contains papers organized by the following EWRI Councils:

- **Water, Wastewater and Stormwater Council** whose purpose is to create, organize and manage the activities of various technical committees dealing with the engineered infrastructure and its effect on the environment, particularly water resources. Attention will be focused on assessing the effects and the important interrelationships of water resources, facilities and installations and necessary environmental and public health protection measures/systems needed for the functioning and sustainability of an adequate infrastructure.
- **Symposium: Stormwater**
  Urban Water Resources Council whose purpose is to advance engineering knowledge and practice through stimulating and guiding research and assisting the financing thereof in the field of urban hydrology; to organize research projects; in cooperation with professional committees, to interpret the findings of research; and to make available information and recommendations resulting from such research. The content fosters the development of improved or advanced urban watershed management and best management practices.
- **Municipal Water Infrastructure Council** whose purpose is to work with professionals in the public and private sectors directly involved in urban water infrastructure. This committee provides a community for practical professional practice individuals to develop products with an emphasis on owner/operator perspectives.

Acknowledgments

Preparation and planning for this Congress strongly depends on the dedication of those individuals who plan session topics, solicit abstracts and papers, oversee reviews of all submissions. We are deeply grateful to all who have provided this considerable effort, especially the track chairs listed below:

17th Groundwater Symposium	Paul Mathisen & Amy Chan-Hilton
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We also acknowledge the members of the Congress Organizing Committee, without whose time and efforts the event would not be possible.

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Finally, we acknowledge and thank EWRI staff who, in the end, makes this conference a reality.

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University Park Neighborhood Rain Gardens Project in Los Angeles, California

K. Majid Sadeghi, Ph.D., P.E.[1]; Wing Tam, P.E.[2]; Shahram Kharaghani, Ph.D., P.E.[3]; and Hugo Loáiciga, Ph.D., P.E.[4]

[1]Watershed Protection Division, LA Sanitation, City of Los Angeles, 1149 South Broadway, Los Angeles, CA 90015; Dept. of Geography, Univ. of California, Santa Barbara, CA 93106. E-mail: majid.sadeghi@lacity.org; majid@ucsb.edu
[2]Watershed Protection Division, LA Sanitation, City of Los Angeles, 1149 South Broadway, Los Angeles, CA 90015. E-mail: wing.tam@lacity.org
[3]Watershed Protection Division, LA Sanitation, City of Los Angeles, 1149 South Broadway, Los Angeles, CA 90015. E-mail: shahram.kharaghani@lacity.org
[4]Dept. of Geography, Univ. of California, Santa Barbara, CA 93106. E-mail: hloaiciga@ucsb.edu

ABSTRACT

Urban runoff/stormwater poses flooding and pollution hazards in metropolitan areas. The impacts of contaminated urban stormwater have given rise to low impact development (LID). City of Los Angeles (City)—LA Sanitation (LASAN) has installed thirty five (35) rain gardens in the University Park neighborhood to capture and infiltrate stormwater. The 35 rain gardens with a total volume of about 46,000 gallons, dimensions of 4'–7' wide by 15' long by 4' deep (void ratio of 0.40). Key elements of the project includes cooling the urban environment with removal of impervious surfaces and adding native vegetation planting; infiltration media to remove pollutants and increase water supply; parkway sediment trap basins to remove pollutants like trash, bacteria, metals, suspended solids, oil, and grease; new Curb-O-Let model inlet system to capture stormwater; easy to maintain pollutants/trash in the sediment trap area. With treatment of dry/wet-weather runoff, water carrying pollutants of concern were prevented from discharging into the Ballona Creek/Santa Monica Bay watershed. Overall project was a success on terms of successful implementation and for demonstrating the use of rain gardens along the City's right-of-way. The relative success of the Project in achieving its objectives may provide a basis for future broader-scale regional programs in implementing similar types of rain gardens, particularly as part total maximum daily load (TMDL) implementation plan. However their future implementations of rain gardens should seek ways to maximize their drainage areas and use larger size footprints. The rain gardens LID approach's is demonstrated in Los Angeles, CA.

INTRODUCTION

Stormwater or urban runoff is a major source of water-quality degradation in rivers, lakes, seas, swamplands, and aquifers, all of which serve natural and socioeconomic functions. The decreasing of water quality in water bodies receiving urban storm runoff is persistent in metropolitan areas across the United States and elsewhere (Hagekhalil et al., 2014; Loáiciga et al., 2015; Sadeghi et al., 2017; Gülbaz and Kazezyılmaz-Alhan 2018). Stormwater exhibits harmful physical-chemical-biological characteristics, large biochemical-oxygen demand (BOD), oil and grease, water-borne pathogens, suspended and total dissolved solids, trash, heavy metals, pesticide and nutrient content that damage the quality of receiving waters. The danger posed by stormwater is that of urban flooding and a protection planning commonly recommends the deployment of Low Impact Developments (LIDs) that capture some of the stormwater at development sites to the extent that soil permeability and other physical constraints permit it. Due to the harmful impact that contaminated stormwater has on receiving waters, State and Federal guidelines in the United States have been enacted to protect stormwater quality. One such tool is the allowable Total Maximum Daily Loads (TMDLs) of pollutants to natural waters from urban storm runoff. The body of technical publications in the arena of stormwater quantity, stormwater quality management, impaired water quality, LIDs, TMDLs, and is voluminous (Davis 2005; City of Los Angeles 2009A, 2009B, and 2009C; Hagekhalil et al., 2014; Sebti et al., 2016; Sadeghi et al., 2016 and 2017; City of Los Angeles 2016; National Association of City Transportation Officials 2017; Clary and Piza 2017; City of Los Angeles 2018). One regulatory mechanism is through the setting of TMDLs, which, in turn, has given rise to a multi-billion-dollar industry of LIDs (Currier et al., 2005; Houle et al., 2013; Kalman et al., 2000; Kurkalova 2015). Figure 1 shows a map of the City of Los Angeles (City) boundaries and the University Park Neighborhood Rain Gardens Project (Project).

The City has an area of 473 squared miles (1,225 km2), and 17,400 miles of streets (28,000 km), with a population of about 4 million people. Los Angeles' storm drain system consists of 1,500 miles of pipes (2,414 km), 100 miles of open channel (161 km). The LIDs in Los Angeles includes about 38,000 screened catch basins and thousands of others. Its average daily dry weather and wet weather runoffs are about 50 million gallons (189,250 m^3) and 10 billion gallons (38 million m^3), respectively [LA Sanitation (LASAN) City of Los Angeles data from 2018]. A peculiar phenomenon observed in the GSI study area, that adversely impacts stormwater quality, is the "first flush" stormwater contamination (Stenstrom and Kayhanian, 2005). This is the generation of large amounts of stormwater pollutants during the first few storms over urban areas following a dry period during the summer season (Larsen et al., 1998). One way to treat first flush stormwater contamination is by deploying LIDs that retain stormwater and its pollutants at the point of origin or through their paths through urban areas (Strecker et al., 2001; Davis, 2005; City of Los Angeles 2016).

The City has instituted a three-pronged approach to improve water quality and meet regulatory requirements: education and outreach to the public on stormwater issues; enforcement of laws, codes, and ordinances to prevent/penalize polluting activities; and the implementation of structural measures (LIDs) such as the Project to remove pollutants from urban runoff. Thus, this Project is one of several measures that through the capture of multiple pollutants, will contribute towards enhancing the beneficial uses of receiving waters, preserving the aquatic marine habitat, and reducing the potential risks to human health and safety. In addition, the Project improve water quality by reducing pollutant loads to the impaired waters and increase the water supply, improving flood management and creating or enhancing open space, habitat, and recreation benefits.

RESULTS AND DISCUSSION

Project Goals

The Project is located in the Ballona Creek (BC) and Santa Monica Bay (SMB) Watershed. The Project's goal was to capture and infiltrate the stormwater from the streets of the University Park neighborhood area located west of the University of Southern California (USC) campus. The area's main thoroughfares are Jefferson Boulevard, Exposition Boulevard, Western Avenue, and Vermont Avenue. The Project is designated as severely disadvantaged community by the California State Parks Community Fact Finder. Curb cuts directed the runoff into 35 rain gardens shown in Figure 2. The rain gardens were landscaped with drought tolerant vegetation that added to the aesthetics of the surroundings. For this Project, each rain garden varied horizontally in size depending on site conditions to match parkway dimensions and included varied landscaping depending on the preference of the adjacent homeowners. LASAN worked with community stakeholders throughout the planning and the implementation phase of the project. The stakeholders were identified and recruited early in the project. A community outreach plan was also developed and implemented. LASAN also used an integrated delivery approach in order to timely complete the project. The goals of the project at the time of grant applications was to support larger efforts such as those of the implementation of the Integrated Resources Plan (IRP) and the Mayor's initiative for making Los Angeles the "Greenest big city" in the United States. Subsequently, this project was also consistent with more recent plans such as the Enhanced Watershed Management Program (EWMP) for the BC and SMB. In addition to reducing stormwater runoff volumes, this project assists in meeting the TMDL standards for BC (City of Los Angeles 2016).

The BC and SMB are impacted by pollutants carried by stormwater runoff and dry weather "urban" runoff. The objectives of the Project are consistent with the goals of the Santa Monica Bay Restoration Plan. These goals are to improve water quality through treatment or elimination of pollutant discharges regulated under the current federal and state framework, to improve water quality through pollution prevention and source control, and to protect public health through achievement of zero beach closures and postings at SMB beaches. The project implemented to reduce contributions towards the TMDL limits for trash, bacteria and metals. While the amount of pollutant loadings reaching SMB will be reduced, the project is also contributing to water supply improvements by replenishing our Los Angeles aquifers and our regional water supply through infiltration and evapotranspiration.

To determine the effectiveness of this project, a monitoring program evaluated the pollutant load reduction accomplished by the rain gardens. During dry weather, no runoff was present, and therefore no samples were collected at five monitoring rain gardens prior to its entry into the gardens. Three samples were collected during wet weather conditions at five rain gardens monitoring locations. The stormwater samples were taken from the flow line before entering the rain gardens. The samples were collected at the inlet and analyzed for bacteria (E. coli, total coliforms and enterococcus), Total Suspended Solids (TSS), metals (cadmium, copper, lead, zinc, and hardness) and organics (pesticides and PCBs). These samples were used to quantify the pollutant concentration in the Project's watershed area. In addition, observations were made during dry and wet weather conditions to estimate the proportion and volume of water that was captured under these respective conditions, so that an assessment of the project can be made in terms of its benefit to meeting water quality objectives of the downstream receiving waters.

The Project evaluation identified the following goals and desired outcomes for the capture and treatment of stormwater. Capture essentially all dry weather runoff that is generated upstream from each of the rain garden installations, thus reducing/eliminating the overall dry weather pollutant load from the Project's watershed area. This will help to meet dry weather TMDL for trash, metals, and bacteria for BC and SMB. In addition, capture the "first flush" of stormwater runoff generated upstream from each of the rain garden installations during storm events, such that the overall storm water pollutant load is significantly reduced. This will help to meet wet weather TMDL for trash, metals, and bacteria for BC and SMB. Figure 3 shows rain garden M35 (a) before, (b) during construction, and (c) after pictures.

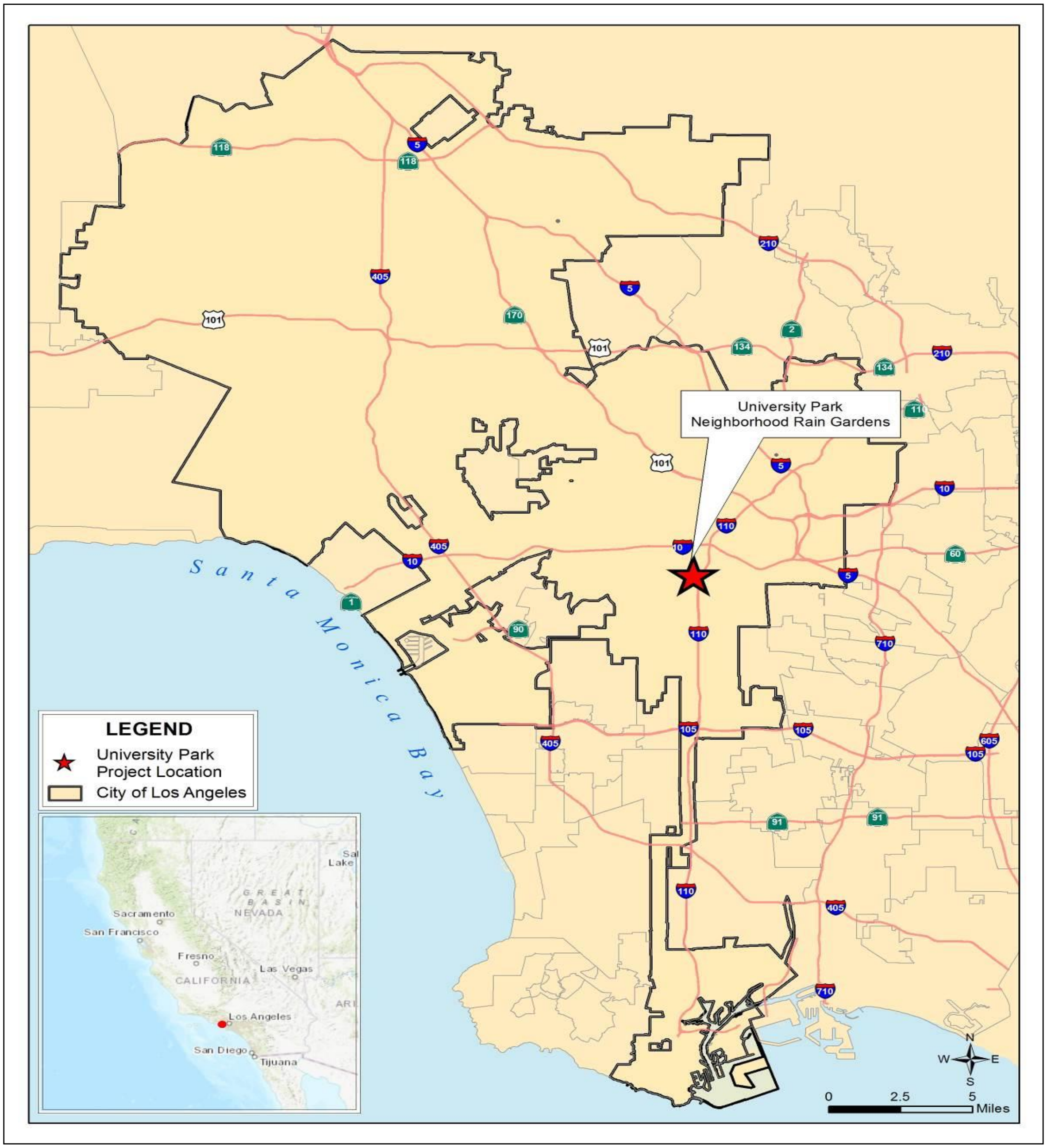


Figure 1. Map of University Park Neighborhood Rain Gardens Project in City of Los Angeles (Source: LA Sanitation).

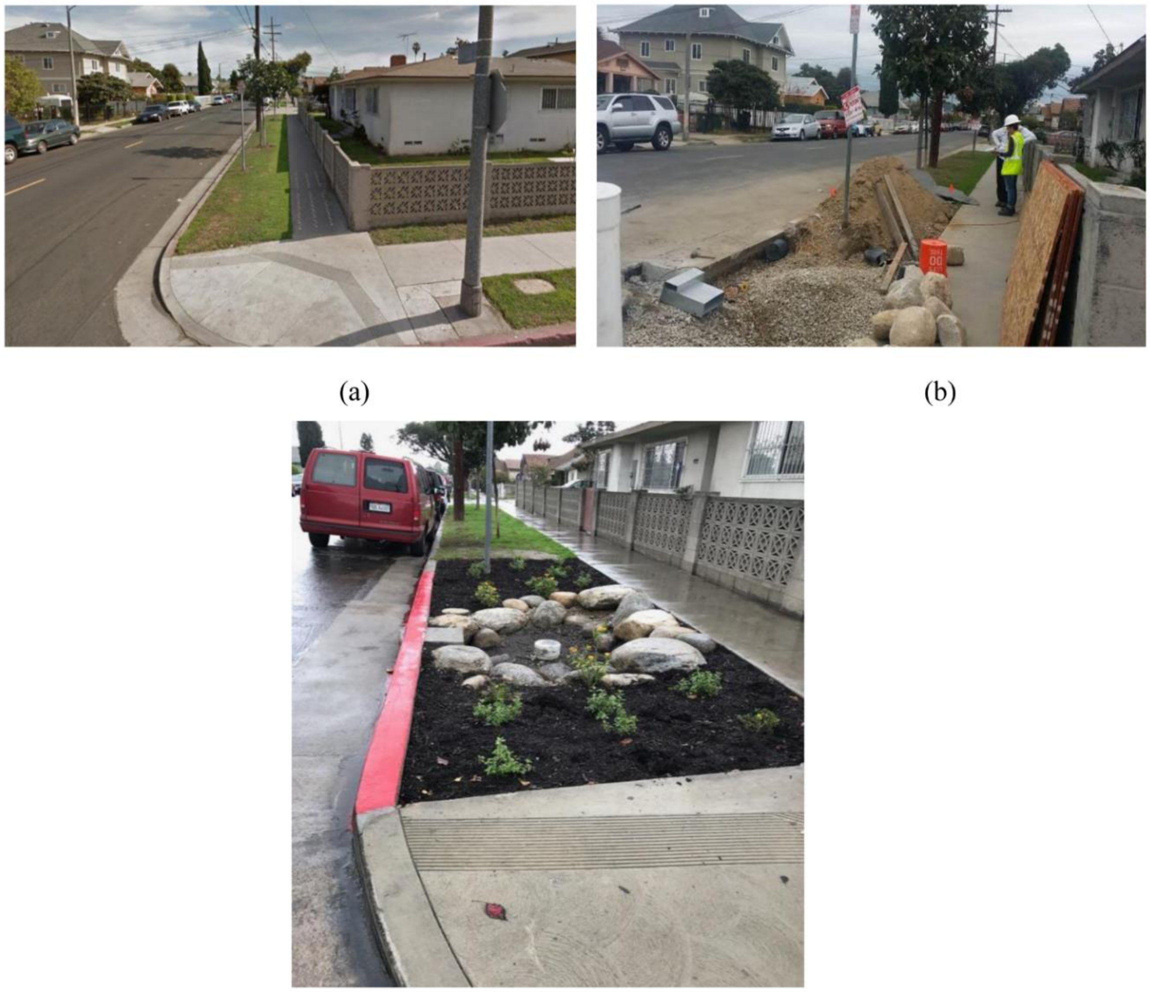
PROJECT DESCRIPTION

The Project is located in the City and is part of the City's multifaceted strategy of stormwater management. The City is implementing a series of source control programs and projects to manage stormwater runoff pollution. These measures are needed to meet the City's stormwater regulations related to the municipal stormwater (MS4) permit and TMDL requirements. The City has implemented many stormwater capture and pollution abatement projects also known as LIDs. This project is an example of LID that retain stormwater and allows it to infiltrate into the groundwater and was designed to abate stormwater pollution from the targeted drainage area.

The Project was constructed in Central Los Angeles in the City's public right of way. The Project scope of work: Siting the Project on the public right-of-way's parkway; Installing thirty five rain gardens; and Directing stormwater runoff into groundwater through infiltration. The Project spans four major streets in the University Park neighborhood. The Project diverts and infiltrates stormwater drain flow from a targeted drainage area of 209 acres into rain gardens that allow stormwater to flow into an underground water table.

Figure 2. Map of University Park Neighborhood Rain Gardens Project Locations (Source: LA Sanitation).

Key benefits/water quality elements of project includes cooling the urban environment with removal of impervious surfaces and adding native vegetation; infiltration in the rain gardens to remove pollutants; rain garden systems with parkway sediment trap basins to remove various pollutants; easy to maintain; new Curb-O-Let model inlet system to route stormwater in the rain gardens. Figures 4A to 4D shows the design plans for the project. The City has many different designs for Green Street Standard Plans (e.g., Parkway Swale, Vegetated Stormwater Curb Extension, Residential Parkway Basin, Interlocking Pavers, Permeable Pavers, etc.) and this Project has implemented several new designs in these rain gardens installed (City of Los Angeles 2017). The rain gardens remove pollutants such as trash, bacteria, metals, sediments and oil and grease thus aiding the City in meeting federal and state water quality regulations. In addition, the project has provided valuable educational opportunities for local students and the community regarding stormwater management. The Project complied with the California Environmental Quality Act (CEQA) and was found to be categorically exempt pursuant to City CEQA Guidelines Article III, Section 1, Class 3(4), which states that "installation of new equipment and/or industrial facilities involving negligible or no expansion of use is exempt from the requirements of CEQA if required for safety, health, the public convenience, or environmental control." The Notice of Exemption document was filed with the LA County Clerk.



(a) (b)

(c)

Figure 3. University Park Neighborhood Rain Garden M35 (a) before, (b) during construction, and (c) after construction pictures (Source: LA Sanitation).

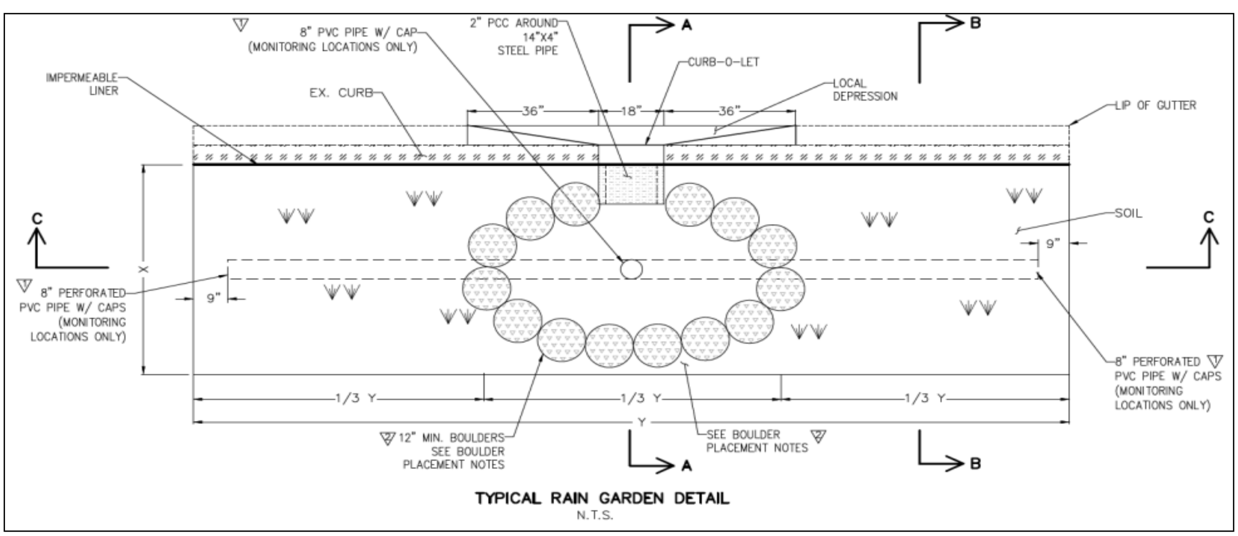


Figure 4A. Typical Rain Gardens Design Details (Source: LA Sanitation).

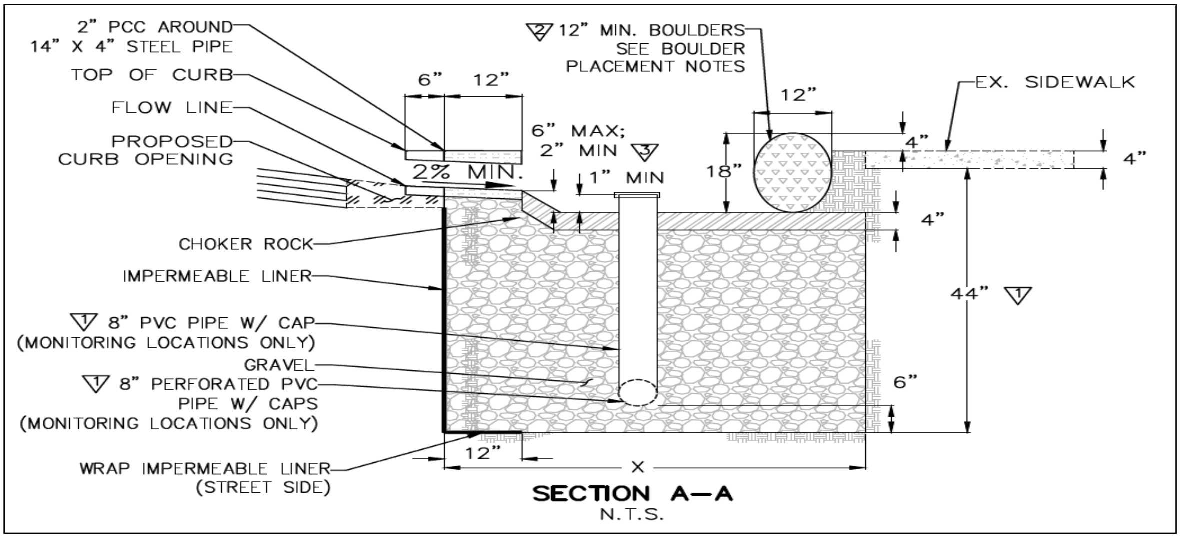


Figure 4B. Typical Rain Gardens Design Details For Section A-A (Source: LA Sanitation).

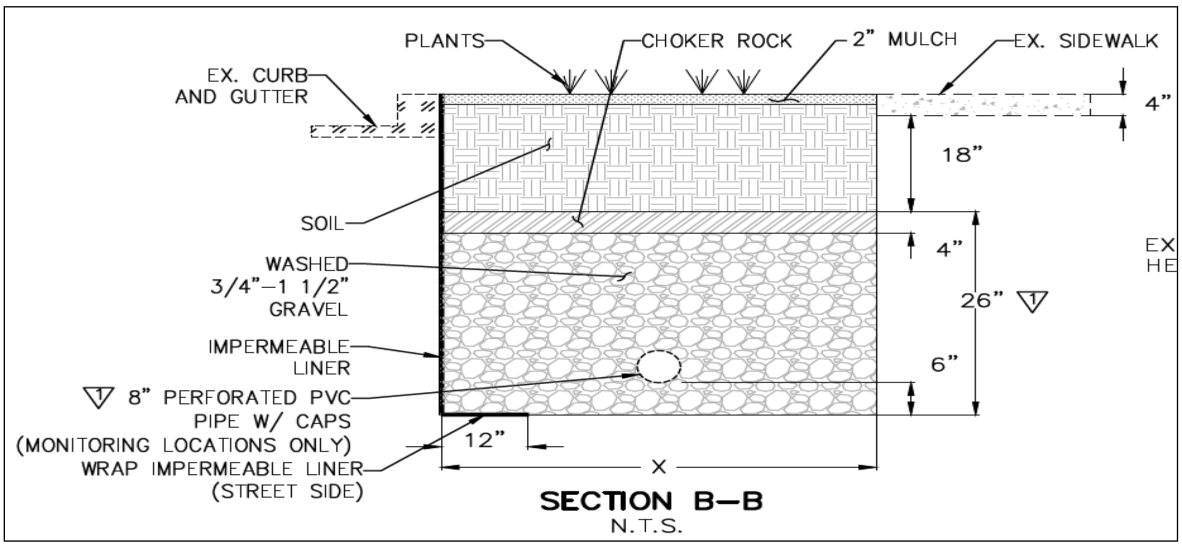


Figure 4C. Typical Rain Gardens Design Details For Section B-B (Source: LA Sanitation).

The 35 rain gardens with a total volume of about 46,000 gallons, the minimum dimensions of 4'-7' wide by 15' long by 4' deep, and a void ratio of approximately 0.40 for each rain garden. The phasing of the Project involved the two key phases of design and construction. These phases were implemented through an integrated design-built contract. The first phase of design also included developing a prototype rain garden. The intent was to test the new design in one location and then perform design modifications based on the performance of the initial rain garden. Subsequently the modified design was used for the remaining 34 rain garden locations. The construction of the project started in December 2016 and was completed in May 2017. The selected contractor implemented the project through the guidance and oversight of LASAN staff and the City's Bureau of Contract Administration (BCA). Water quality monitoring was conducted from January 2018 to March 2018. The budget of the project was $510,000 funded by California State Water Resources Control Board (SWRCB) under the 2012 Proposition 84 Santa Monica Bay Restoration Grant Program. The $510,000 was allotted from the grant for the construction services and remaining amount was LASAN Match amount of $339,462 and upon

Project completion the total cost was $849,462.

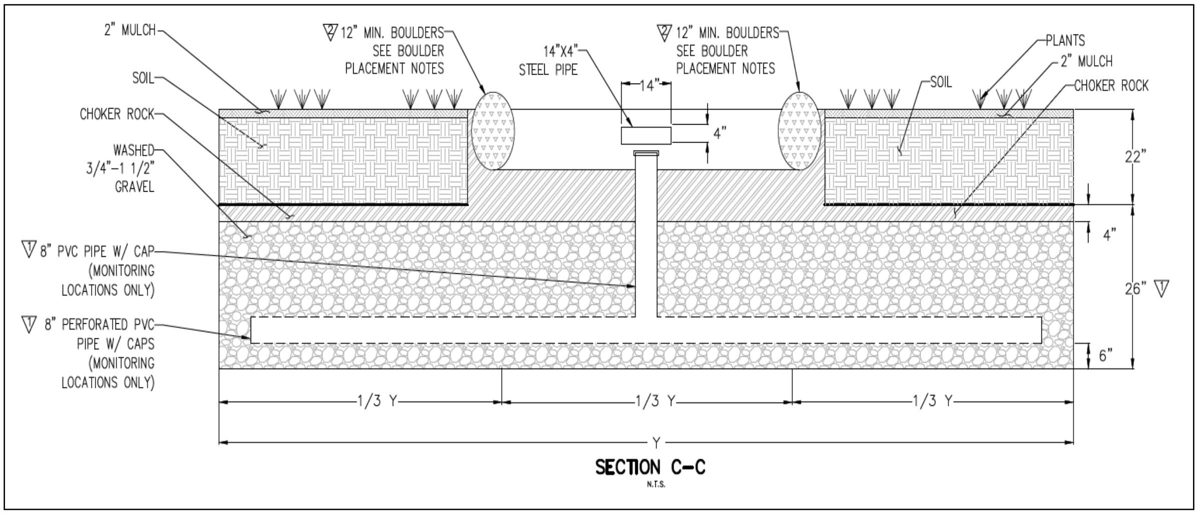


Figure 4D – Typical Rain Gardens Design Details For Section C-C (Source: LA Sanitation).

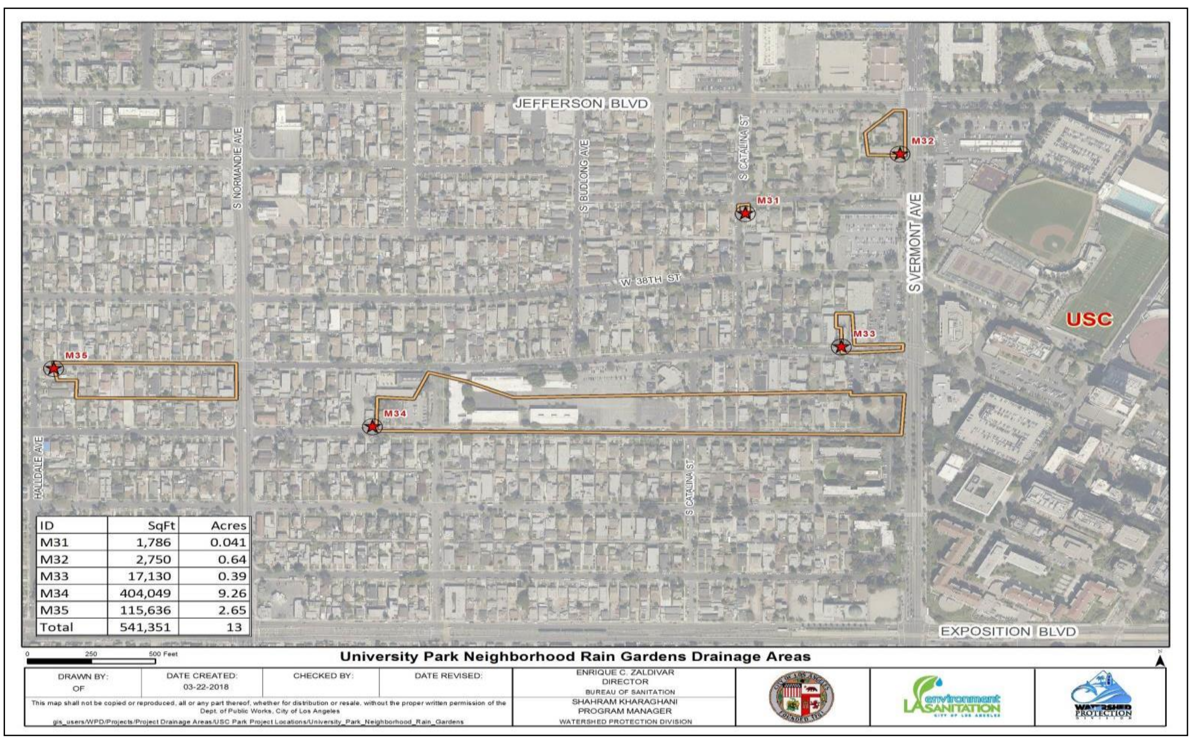


Figure 5. Map of University Park Neighborhood Rain Gardens Project, showing approximate locations of all post-construction monitoring sites (M31 to M35) (Source: LA Sanitation).

MONITORING DATA RESULTS AND POLLUTION LOADS REDUCTION

Urban and stormwater flows were diverted in the rain gardens for infiltration instead of discharging into the storm drain system. With the treatment of dry and wet-weather runoff, water carrying pollutants of concern such as bacteria (total coliforms, E. coli and Enterococcus), suspended solids, and metals (lead, zinc, copper, and cadmium) were prevented from discharging into the BC and SMB Watershed. Thus, water quality in the receiving waters is improved as a result of the implementation of the Project. Three storm events were sampled during the post-construction phase of monitoring on January 8, March 2, and March 21, 2018. These wet and dry post-construction events are shown in Table 1. The January 8th storm event was the largest in magnitude and produced 1.72 inches of accumulated rainfall for its duration total rain amount for 36 hours. The March 2 duration total rain amount for 36 hours events produced approximately 0.35 inches of accumulated rainfall. The March 21 duration total rain amount for 48 hours events produced approximately 0.89 inches of accumulated rainfall. All the rainfall data were taken from the LA County precipitation map (http://dpw.lacounty.gov/wrd/precip/).

Table 1. Post-construction Sampling Schedule

Sampling Event	Dates	Sampling location
Post-construction: *influent* One wet-weather event (#1)	*2/8/18*	Rain gardens sites M31 to M35
Post-construction: *influent* One wet-weather event (#2)	*3/2/18*	Rain gardens sites M31 to M35
Post-construction: *influent* One wet-weather event (#3)	*3/21/18*	Rain gardens sites M31 to M35
Post-construction: *influent** Two dry-weather events	*6/14/2017* *7/21/2017*	Rain gardens sites M31 to M35

*Specific sampling dates were determined by LASAN staff.

Table 2. Pollution Load Reduction Estimates for the Project.

Pollutant	Units	Ave. Concentration	Load Reduction (MPN or LB)	
E. Coli	MPN/100mL	5165	**4.03E+19**	MPN
Enterococcus	MPN/100mL	14,020	**1.09E+20**	MPN
Total Coliforms	MPN/100mL	792,800	**6.19E+21**	MPN
Copper (Total)	ug/l	108	**0.07**	LB
Copper (Dissolved)	ug/l	27	**0.02**	LB
Lead (Total)	ug/l	125	**0.08**	LB
Lead (Dissolved)	ug/l	1.33	**0.001**	LB
Cadmium (Total)	ug/l	1.23	**0.001**	LB
Cadmium (Dissolved)	ug/l	0.05	**0.00003**	LB
Zinc (Total)	ug/l	824	**0.50**	LB
Zinc (Dissolved)	ug/l	148	**0.09**	LB
Total Suspended Solids	mg/l	670	**409**	LB
Total Hardness	mg/l	23	**14**	LB

The project site was also visited during two dry weather condition periods during the post-construction phase of monitoring on June 14 and July 21, 2017. Under dry weather conditions, it was observed that no surface runoff entering the project sites. Therefore, no surface water runoff samples were collected during dry weather. The monitoring occurred during two dry-weather events and was limited to visual observations since there was no runoff for water quality sampling to occur. Visual observations were made that noted minor accumulation of debris and a number of corrective measures for the sites. The average trash capture volume was measured in the five monitoring rain gardens (M31 to M35) to be about 1 cubic feet. The pictures below shows the rain gardens that have accumulated trash and slit in the deep sediment trap. Collected samples were transported to the laboratory located at LASAN's Hyperion Wastewater Treatment Plant. Analyses of those samples were conducted by LASAN's Environmental Monitoring Division (EMD) staff. EMD's laboratory at Hyperion is an EPA-Certified laboratory. The results of the water quality monitoring analyses of the wet weather samples are summarized in Table 2. These results from the three wet weather samples were used to quantify the pollutant loadings that were removed by the project. Figure 5 shows the map of the project of the monitoring samples locations at five different sites in the watershed (rain gardens sites M31 to M35). The total runoff drainage area is about 13 acres for these five monitoring sites (M31 to M35) are shown in Figure 5. These samples are used to quantify the pollutant concentration in the Project's watershed area. The mass loads of pollutants captured by the Project boundary have been quantified and are mentioned below.

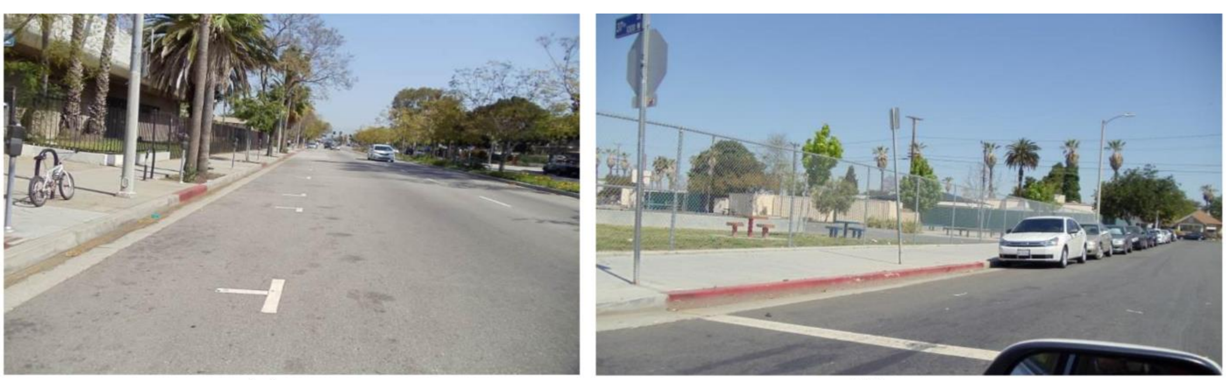
$$\text{Pollutant load quantified by using following formula : Pollutant Load} = \text{Vol}_{\text{captured}} * \text{Concentration}$$

Table 2 tabulates the estimated pollution reduction that is achieved by the project. The load reduction is used by the average of 4% capture of the total surface area of each rain gardens. Using the average the runoff for 0.75 inches is about 9,800 ft^3. The load reduction of the bacterial indicators of E. Coli, Enterococcus, Total Coliforms were 4.03×10^{19}, 1.09×10^{20} and 6.19×10^{21} MPN colonies respectively on an annual basis. With respect to the key heavy metals parameters of Copper (Total), Lead (Total) and Zinc (Total) the reductions were 0.07 lbs, 0.08 lbs and 0.5 lbs respectively. Visual observations was noted the presence or absence of trash, debris, and fecal material; water color, odor, clarity; weather conditions; time; and any maintenance issues along with photos of the inlet taken at the time of sampling.

At a minimum, maintenance of the rain gardens is recommended to be administered twice a year, once at the beginning of the wet season (October) to prepare the system for rain events and ensure it will function properly, and once at the end of the wet season (May) to remove accumulated trash and debris, and to ensure the system will function properly during the dry season. The rain gardens should also be observed periodically to assess the performance and optimize the system as part of maintenance activities. In general, accumulated debris & sediment can be removed with simple maintenance practices in the deep sediment trap parkway basin.

Figures 6 to 12 are pictures for the Project from before construction, landscape design, during construction, after construction, and during the wet weather sampling from the rain gardens:

BEFORE CONSTRUCTION



(a) (b)

Figure 6. University Park Neighborhood Rain Gardens Project Pictures Showing Before Construction (a) and (b) (Source: LA Sanitation).

LANDSCAPE DESIGN

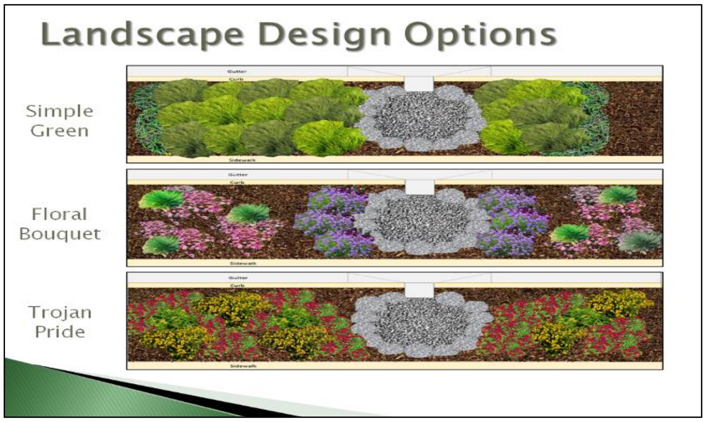


Figure 7. University Park Neighborhood Rain Gardens Project Landscape Design Options (Source: LA Sanitation).

DURING CONSTRUCTION

(a)

(b)

Figure 8. University Park Neighborhood Rain Gardens Project Pictures Showing During Construction (a) and (b) (Source: LA Sanitation).

AFTER CONSTRUCTION

(a) (b)

Figure 9. University Park Neighborhood Rain Gardens Project Pictures Showing After Construction (a) and (b) (Source: LA Sanitation).

WET WEATHER MONITORING

(a) (b)

Figure 10. University Park Neighborhood Rain Gardens Project Pictures Showing Sampling at M35 on January 8, 2018 (a) and (b) (Source: LA Sanitation).

(a) (b)

Figure 11. University Park Neighborhood Rain Gardens Project Pictures Showing Sampling at M34 on March 2, 2018 (a) and (b) (Source: LA Sanitation).

(a) (b) (c)

Figure 12. University Park Neighborhood Rain Gardens Project Pictures Showing Sampling at M35 on March 21, 2018 (a), (b), and (c) (Source: LA Sanitation).

CONCLUSION

Runoff from the targeted neighborhood discharges to BC and subsequently to SMB. These waterbodies are included in Clean Water Act Section 303(d) list as impaired for trash, nutrients, metals, and bacteria. In order to assist the City in meeting TMDL standards for these watersheds, the Project constructed a number of rain gardens to capture and infiltrate the runoff.

These rain gardens provide the following benefits with respect to BC TMDL requirements:

- Metals Reduction – Meet standards for dry and wet weather runoff.
- Bacteria Reduction – Result in effluent that meets the concentration limits or result in fewer exceedance days for upstream sub-watershed.
- Trash reduction – Achieve one hundred (100%) capture of trash from the upstream watershed.

Key conclusions and lessons learned from the implementation of the Project are noted as follows:

- The Project was implemented in a design-built approach and it demonstrated that this project delivery approach is very applicable to these types of projects. It allowed for timely implementation that made-up for the time that was lost during the planning and fund sourcing of the Project.
- The Project provided LASAN staff with valuable experience in implementing this type of project. Through the implementation of the project using a design-built project delivery approach, LASAN staff were fully engaged through-out the design, construction, and monitoring phase of the Project.
- The Project demonstrated the complexity of achieving measurable waste load discharges by targeting relatively small drainage areas and the expected high cost of reaching TMDL compliance.

Overall the project was a success on terms of successful implementation and for demonstrating the use of rain gardens along the City’s right-of-way. The relative success of the Project in achieving its objectives may provide a basis for future broader-scale regional programs in implementing similar types of rain gardens, particularly as part of TMDL Implementation

Plans. However their implementations will seek ways of maximizing drainage areas by using larger size rain gardens. Furthermore, the information obtained from this monitoring program demonstrates how this rain gardens project performs under varying conditions.

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REFERENCES

City of Los Angeles (2009A). "Green Infrastructure for Los Angeles. Addressing Urban Runoff and Water Supply Through Low Impact Development/Green Streets & Green Alleys Design Guidelines Standards." City of Los Angeles, California, (http://www.lastormwater.org/wp-content/files_mf/greenstreetguidelines.pdf).

City of Los Angeles (2009B). "Watershed Protection Division. Water Quality Compliance Master Plan for Urban Runoff." City of Los Angeles, California (http://www.lastormwater.org/wp-content/files_mf/wqcmpur.pdf).

City of Los Angeles (2009C). "Rainwater Harvesting Program - A Homeowner How to Guide. The City of Los Angeles Rainwater Harvesting Program (designed to help homeowners learn to capture rainwater for beneficial use, and reduce the amount of rainwater flowing from their roofs into the storm drain system)." City of Los Angeles, California, (http://www.lastormwater.org/wp-content/files_mf/homeowner_howto_guide.pdf).

City of Los Angeles (2016). "Development Best Management Practices Handbook. Low Impact Development." 5th Edition. City of Los Angeles, California, (http://www.lastormwater.org/wp-content/files_mf/lidmanualfinal.pdf).

City of Los Angeles (2017). "City of Los Angeles – Bureau of Engineering. Green Streets Standard Plans." City of Los Angeles, California, (http://eng2.lacity.org/techdocs/stdplans/s-400.htm).

City of Los Angeles (2018). "Toward a Greener Los Angeles, The Wilmington Urban Greening Plan." City of Los Angeles, California.

Clary, J. and Piza, H. (2017). "Cost of Maintaining Green Infrastructure." ASCE, Virginia, 89 p.

Currier, B. K., Jones, J. M., Moeller, G. L. (2005). "NPDES Stormwater Cost Survey." *Prepared for California Water Resources Control Board, Office of Water Programs*. (Report includes Alternative Approaches to Stormwater Quality Control (2004) by Joseph S. Devinny, Sheldon Kamieniecki and Michael Stenstrom as Appendix H).

Davis, A.P. (2005). "Green Engineering Principles Promote Low-Impact Development." *Environmental Science & Technology*, 8-15: 338-344.

Gülbaz, S. and Kazezyılmaz-Alhan, C.M. (2018). "Impact of LID Implementation on Water Quality in Alibeyköy Watershed in Istanbul, Turkey." *Environmental Processes* 11(5)-Supplement 1 201–212

Hagekhalil, A., Kharaghani, S., Tam, W., Haimann, R., Susilo, K., (2014). "Becoming the Green-Blue City." *Civil Engineering*, December, 68-91.

Houle, J.J., Roseen, R.M., Ballestero, T.P., Puls, T.A., and J. Sherrard, (2013). "Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management." *J. of Environmental Engineering* 139(7): 932-938.

Kalman, O., Lund, J.R., Lew, D.K., Larson, D.M. (2000). "Benefit-Cost Analysis of Stormwater Quality Improvements." *Environmental Management*, 26(6), 615- 628.

Kurkalova, L.A. (2015). "Cost-effective placement of best management practices in a watershed: lessons learned from a conservation effects assessment project." *Journal of the American Water Works Association*, 51(2), 359-372.

Larsen, T., Broch, K., Andersen, M.R. (1998). "First Flush Effects in an Urban Catchment Area in Aalborg." *Wat. Sci & Tec.*, 37(1), 251-257.

Loáiciga, H.A., Sadeghi, K.M., Shivers, S., and Kharaghani, S. (2015). "Stormwater Control Measures: Optimization Methods for Sizing and Selection." *Journal of Water Resources Planning and Management*, 141(9).

National Association of City Transportation Officials (2017). "Urban Street Stormwater Guide." Island Press, Washington, 155 p.

Sadeghi, K.M., Kharaghani, S., Tam, W., Gaerlan, N., and Loáiciga, H.A. (2016). "Avalon Green Alley Network: Low Impact Developments (LID) Demonstration Project in Los Angeles." *ASCE -World Environmental & Water Resources Congress*, 205-214.

Sadeghi, K.M., Loáiciga, H.A, and Kharaghani, S. (2017). "Stormwater Control Measures for Runoff and Water Quality Management in Urban Landscapes". *Journal of the American Water Resources Association*, 1-10. https://doi.org/10.1111/1752-1688.12547.

Sebti, A., Fuamba, M., Bennis, S. (2016). "Optimization model for BMP selection and placement in a combined sewer." *J. of Water Res. Planning and Management*, 142(3):04015068.

Strecker, E.W., Quigley, M.M., Urbonas, B.R., Jones, J.E., and Clary, J.K. (2001). "Determining Urban Storm Water BMP Effectiveness." *Journal of Water Resources Planning and Management*, 127(3):144-149.

Stenstrom, M.K., Kayhanian, M. (2005). *First Flush Phenomenon Characterization*, Report to California Department of Transportation, CTSW-RT-05-73-02.6.