Geosyntec consultants

1111 Broadway, 6th Floor
Oakland, California 94607
PH 510.836.3034
www.geosyntec.com

1. INTRODUCTION

Geosyntec Consultants, Inc. (Geosyntec) performed continuous simulation hydrologic and hydraulic (H&H) modeling to analyze the footprint sizing benefits of using the DeepRoot Marino Cell (Marino Cell) product in bioretention facilities. The H&H modeling approach compared bioretention footprint sizes with and without the Marino Cell using several rainfall gauges located in dense urban areas throughout California. This memorandum summarizes the H&H model inputs, assumptions, and results of the analyses.

2. METHODOLOGY AND DATA

To understand the sizing benefits of using Marino Cell, Geosyntec used the USEPA's Stormwater Management Model (SWMM) to perform continuous long-term simulations. Geosyntec modeled six configurations of bioretention facilities with 10 years of hourly rainfall to determine the required facility footprint to capture 80% of the average annual runoff from a one-acre impervious catchment. The requirement to size stormwater treatment facilities to capture 80% average annual runoff, or its equivalent (i.e., the 85th percentile, 24-hour storm) is found in most major permits throughout California. Geosyntec calculated the comparative difference in the footprints of the standard bioretention facility and the bioretention-with-Marino Cell. These comparative models were conducted for five rainfall gauges located throughout California.

Geosyntec modeled three scenarios: 1) Standard Bioretention with Aggregate, 2) Bioretention with 6-in of Marino Cell, and 3) Bioretention with 12-in of Marino Cell. The vertical profiles and their corresponding modeling assumptions are summarized in Table 1 below. The vertical profiles of the Standard Bioretention with Aggregate are based on the C.3. guidebooks from Alameda County and Contra Costa County (ACCWP 2023 & CCCWP 2024). The three scenarios were modeled both with a liner (i.e., for situations where infiltration is infeasible) and unlined. An infiltration rate of 0.2 inches per hour was assumed for the unlined facility models.

A drawdown rate of 5 inches per hour was assumed for all models, consistent with the requirement of the San Francisco Bay Municipal Regional Stormwater Permit for biotreatment soil media.

Table 1: Vertical Profiles of Modeled Bioretention Facility Scenarios

Standard Bioretention	Bioretention with 6" Marino Cell	Bioretention with 12" Marino Cell
Vertical Profile: • 6" Ponding • 3" Mulch • 18" Soil Media • 12" Gravel (n^1 = 40%) Total Depth = 39"	Vertical Profile: • 6" Ponding • 3" Mulch • 18" Soil Media • 3" Choke Stone • 6" Marino Cell (n^1 = 93%) • 3" Gravel (n^1 = 40%) Total Depth = 39"	Vertical Profile: • 6" Ponding • 3" Mulch • 18" Soil Media • 3" Choke Stone • 12" Marino Cell (n^1 = 93%) • 3" Gravel (n^1 = 93%) Total Depth = 45"

[1] n stands for porosity. The porosity values of the ponding, mulch, soil media, and choke stone layers were assumed to be 100%, 40%, 25%, and 40 %, respectively.

Geosyntec modeled the bioretention facility scenarios for five rain gauges in major urban areas throughout California, selected per input from DeepRoot. Table 2 summarizes the rain gauge locations, rainfall record time periods, and the average annual precipitation for each rain gauge. The five selected rain gauges cover most of the range of average annual precipitation in the major urban areas in Northern and Southern California (see PRISM map, Figure 1).

Table 2: Summary of Selected Rain Gauges

Gauge Name	County	Region	Time Period[1]	Average Annual Rainfall (in)	Data Source
Bonita	San Diego County	Southern CA	WY1999 - WY2008	6.3	Project Clean Water[2]
LAX	LA County	Southern CA	WY2000 - WY2009	10.6	LACDPW[3]
San Jose Airport	Santa Clara County	Northern CA	WY2000 - WY2009	14.6	NCDC[4]
Dublin Fire Station, San Ramon	Contra Costa County	Northern CA	WY2000 - WY2009	17.3	CCCFCD[5]
Saint Mary's College, Moraga	Contra Costa County	Northern CA	WY2000 - WY2009	28.9	CCCFCD

[1]WY stands for Water Year, which is assumed to start on October 1st of the previous calendar year and ends on September 30th.
[2]Data was processed and retrieved from Project Clean Water (https://projectcleanwater.org/).
[3]Data for the LAX gauge is located in Los Angeles Airport and obtained from the Los Angeles County Department of Public Work.
[4]Data for the San Jose gauge was obtained from the National Climate Data Center (NCDC), gauge # 047821.
[5]Contra Costa County gauge data is collected by the Flood Control District and was provided to Geosyntec by Dubin Engineering.

A total of thirty models were run iteratively to determine the footprint sizes needed to satisfy the long-term 80% average annual runoff capture requirement, representing the six modeling configurations for each of the five rainfall gauge locations.

3. RESULTS

Table 3 summarizes the bioretention footprint size required to achieve 80% average annual runoff capture requirement under each scenario.

Table 3: Required Bioretention Footprint Size, as Percent of Impervious Tributary Area

	Lined			With Infiltration (0.2 inches per hour)		
Gauge Locations	**Standard Bioretention**	**Bioretention with 6" Marino Cell**	**Bioretention with 12" Marino Cell**	**Standard Bioretention**	**Bioretention with 6" Marino Cell**	**Bioretention with 12" Marino Cell**
Bonita	1.70%	1.45%	1.19%	1.63%	1.38%	1.15%
LAX	2.32%	1.95%	1.63%	2.20%	1.86%	1.56%
San Jose Airport	1.35%	1.15%	0.96%	1.29%	1.10%	0.92%
Dublin Fire Station, San Ramon	1.70%	1.42%	1.19%	1.61%	1.35%	1.15%
Saint Mary's College, Moraga	2.62%	2.18%	1.84%	2.50%	2.09%	1.77%

Table 4 below summarizes the percent reduction in required bioretention footprint size when using Marino Cell in the bioretention facility as compared to standard bioretention setups. Bioretention including 12” Marino Cell consistently achieves 29 – 30 % footprint reduction from standard bioretention, with lined or unlined bottoms. The 6” Marino Cell scenario achieves 14 to 17% footprint reduction depending on whether the facility is lined or infiltrates at 0.2 inches per hour, and the location of the facility.

Table 4: Summary of Footprint Reduction as Percent of Standard Bioretention Footprints

	Lined		With Infiltration	
Gauge Locations	**Bioretention with 6'' Marino Cell**	**Bioretention with 12'' Marino Cell**	**Bioretention with 6'' Marino Cell**	**Bioretention with 12'' Marino Cell**
Bonita	15%	30%	15%	30%
LAX	16%	30%	16%	29%
San Jose Airport	15%	29%	14%	29%
Dublin Fire Station, San Ramon	16%	30%	16%	29%
Saint Mary's College, Moraga	17%	30%	17%	29%

The analyses demonstrate that the additional storage capacity provided by the Marino Cell can significantly lower the bioretention footprint needed to achieve the 80% average annual runoff capture requirement across the selected dense urban areas.

4. REFERENCES

ACCWP, 2023. C.3 Stormwater Technical Guidance, A handbook for developers, builders, and project applicants, Version 8, March 2023.

CCCWP, 2024. Stormwater C.3 Guidebook, Stormwater Quality Requirements for Development Applications, 9th Edition, July 2024.

Dubin, 2017. Green Infrastructure Facility Sizing For Non-Regulated Street Projects, Dubin Environmental, December 2017.

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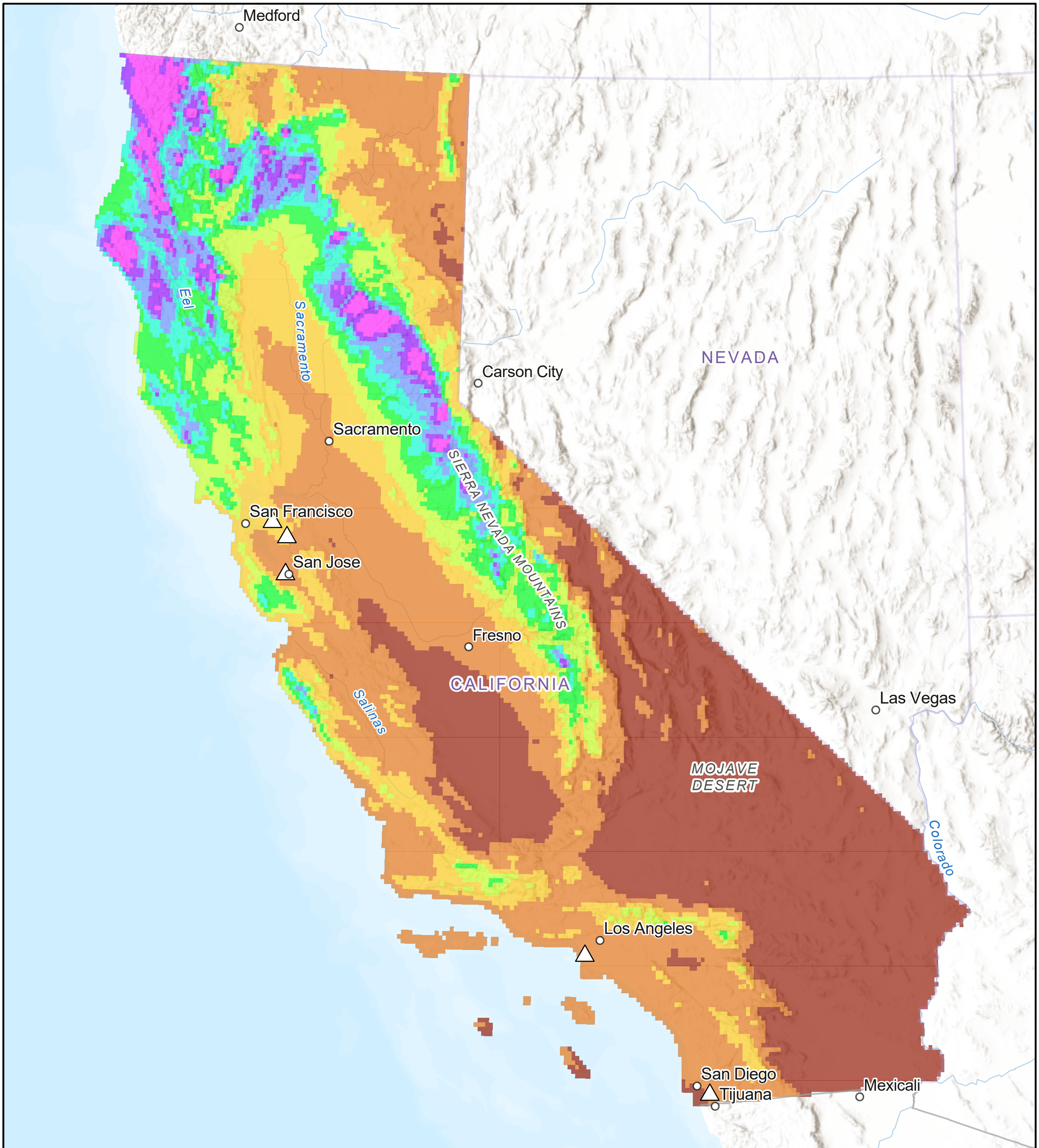
Figure 1

PRISM and Rain Gauge Locations Map



Legend

△ Rain Gauge Locations

Annual Precipitationin (in.)[1]

- 0 - 10
- 10 - 20
- 20 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- > 80

N

0 80 Miles

Notes:
[1]Annual Precipitation represents the average annual precipitation during 1991 to 2020. The data is obtained from PRISM Climate Group. (https://www.prism.oregonstate.edu/normals/)

PRISM Annual Precipitation and Rain Gauge Locations Map

California, USA

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CWR0968	October 2024	Figure 1

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