VICTORIA GREENS
TENTATIVE TRACT 78226
City of Carson, CA

PRELIMINARY
HYDROLOGY REPORT AND LID PLAN
April 27, 2018

Prepared For:

Integral Communities
888 San Clemente, Suite 100
Newport Beach, CA

Prepared By:

URBAN RESOURCE
CONSULTING CIVIL ENGINEERS

Urban Resource Corporation
23 Mauchly, Suite 110
Irvine, CA 92618

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Terry P. Au, P.E.
State of California No. 68466

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INTRODUCTION

The following site, Tentative Tract 78226 is located in the City of Carson, at the northeast corner of the intersection of Victoria Street and Central Avenue, in the County of Los Angeles.

The existing site will require demolition of a small parking lot for the proposed development. Post development conditions will maintain pre-development drainage patterns. Refer to hydrology map provided herewith, for proposed condition drainage.

The proposed development is for approximately 176 Multi-Family Condominium Units within 25 separate buildings ranging in size from 5-Plex to 11-Plex buildings. There is also a recreation area with a pool that will have a pool / restroom building.

There is an existing 33" RCP storm drain main in Central Avenue, maintained by the City of Carson, that will be the point of connection for the project's stormwater flows.

APPROACH

The objective of this drainage and LID report is to address the performance criteria required and demonstrate compliance with the 2012 MS4 Permit within the Coastal Watersheds of Los Angeles County (CAS004001, Order No. 2012-0175), utilizing the Los Angeles County Department of Public Works' Low Impact Development Standards Manual, dated February 2014, and to mitigate the hydrologic impact, if any, of the development, to the existing storm drain system. These objectives will be satisfied with the proposed following:

1. Implement LID BMPs in accordance with the County of Los Angeles Low Impact Development Standards Manual, to improve water quality and mitigate potential water quality impacts caused by the development, prior to discharging developed condition storm flows offsite. This development is considered a Designated Project. The LID Plan Checklist Form PC-1 is included in Appendix B.
2. Mitigate increase in peak flow rates with proposed onsite storage/detention. The 10 year 24 hour rain event and the 50 year 24 hour rain event will be analyzed for the existing and proposed condition, and increases in peak flow rates will be reduced to less than or equal to the existing condition peak flow rate.

To address water quality requirements, the water quality design volume (SWQDv) is calculated utilizing either the 0.75-inch, 24 hour rain event, or the 85th percentile, 24 hour rain event, with the larger SWQDv value governing. Feasibility of BMPs would be analyzed in the following order of priority: 1. Infiltration Systems, 2. Stormwater Capture and Reuse, 3. High Efficiency Biofiltration/Bioretention Systems, 4. Combination of the previous three, if applicable. Alternative compliance measure is applicable if infiltration or capture and reused is deemed infeasible; however, biofiltration BMPs would have to be sized for 150% of the design capture volume (or the equivalent treatment flow).

1

The hydrology calculations were performed utilizing the Los Angeles County Department of Public Works (LACDPW) Modified Rational Methodology (MODRAT) and in accordance with the requirements of the January 2006 Los Angeles County Department of Public Works Hydrology Manual. The Los Angeles Isohyet maps indicate that the 10-year, 24-hour precipitation is 4.43 inches, the 50-year, 24-hour precipitation is 6.20 inches, and the soil classification area is 013, per Isohyet 1-H1.5. The County Hydrology Map GIS Viewer indicates the 85th Percentile 24-hour Precipitation is 0.83". To total area analyzed is 7.63 acres, and does not include the future Prologis parcel of 0.44 acres, that drains northerly away from the proposed development. The existing condition is modeled as one subarea with one outlet, and the proposed condition is modeled with two subareas with one outlet for each subarea.

All data has been calculated with the use of HydroCalc as provided by the County of Los Angeles Public Works.

Refer to the calculations provided in Appendix A, and the hydrology and LID maps in Appendix B for additional details.

STORMWATER QUALITY DESIGN

1. Infiltration: Infiltration/retention for the site is deemed infeasible based on the Due Diligence Geotechnical Exploration report prepared by Leighton and Associates Inc, dated November 11, 2017. Infiltration results from the field exploration indicate very low infiltration rates at the tested locations and depth that do not the requirement for stormwater infiltration feasibility of 0.3"/hr. The report is included herewith in Appendix B.
2. Capture and Reuse: The project would not provide sufficient irrigation water demand for any captured and stored stormwater due to the limited landscaping as well as the planting of drought tolerant vegetation, and therefore, Capture and Reuse is deemed infeasible.

For Designated Projects that are unable to fully retain the SWQDv onsite through retention based stormwater quality control measure, alternative compliance measures must be implemented. Onsite biofiltration of 1.5 times the Design Capture Volume (or equivalent treatment flow), that is not reliably retained onsite, is required.

Based on the proposed development (Multi-Family Residential), the project's typical Pollutants of Concern, per Table 7-3 of the LID Manual, are the following:

- Suspended Solids
- Cadmium, Total
- Chromium, Total
- Copper, Total
- Zinc, Total

Review of the Biofiltration Fact Sheet BIO-1, indicates that it does not address the project's pollutants of concern for Suspended Solids, Cadium (Total), Copper (Total), and Zinc (Total). Therefore, Biofiltration BIO-1 is not utilized.

Treatment in the form of VEG-3: Tree Well Filter (ie. Contech Engineered Solutions Filterra) will be proposed to address stormwater runoff quality from the project site, which is included in the LA County Department of Public Works "List of Proprietary BMPs Acceptable for Maintenance by LACDPW". The list is included herewith in Appendix B for reference. The Filterra provides a high level of treatment, and provides treatment for the required project pollutants of concern. The Technical White Paper provided by Contech Engineered Solutions evaluating the performance of the Filterra Bioretention Systems is included in Appendix B for reference.

The governing water quality sizing event is the 85th Percentile 24 hour rain event, based on a comparison of calculation results, relative to the 0.75-inch 24 hour rain event calculations. The results of the HydroCalc Peak Flow Hydrologic Analysis for the 85th Percentile 24 hour rain event is: SWQDv = 16,389cu-ft (subarea 1+subarea 2), SWQDf = 1.03cfs (subarea 1+subarea 2). Since onsite biofiltration needs to provide mitigation for 1.5 times the calculated values, the project water quality treatment criteria is SWQDv = 24,584cu-ft, SWQDf = 1.55cfs. Accordingly to Contech's Filterra Sizing Chart, five 8x18 Filterra units, each with a treatment capacity of 0.3333cfs, will be required to provide treatment for the SWQDf of 1.55cfs. Varying sizes and more than five units are also available options to provide the required project treatment.

HYDROMODIFICATION

The proposed development will result in an increase to the peak flow rate in the 10 year storm event, as well as an increase to volume of runoff due to the increased site imperviousness. The project will limit the peak flowrate in the developed condition to less than or equal to the flow in the existing condition with proposed underground storage systems. Furthermore, the project's storm flows outlet into an existing RCP storm drain, and ultimately outlets into the Dominguez Channel, which is <u>Channelized</u>. Therefore, implementation of hydromodification controls are not required for this project.


CONCLUSION

Based on the preliminary hydrology analysis, the proposed development will increase peak flowrates for the 10 year storm events in the developed condition, when compared to the existing condition. There is a small, but negligible, increase in peak flowrate for the 50 year storm event in the developed condition. A summary table comparing the peak flowrates is provided below. Due to the increase in peak flowrate, underground detention/storage system(s), or similar, will be proposed to mitigate the increase in peak flowrate in the developed condition.

	Condition		Increase (cfs)
	Existing	Developed	
Q50 (cfs)	19.27	19.52	0.25
Q10 (cfs)	10.24	12.29	2.61

Note: Developed condition flows based on sum of subarea 1 and subarea 2.

To address water quality impacts caused by the development, the project will implement the proposed Contech Engineering Solution Filterra units, sized at 1.5 times the SWQDv, to treat stormwater runoff prior to discharging offsite.

The conclusions of this analysis prepared for this proposed project site demonstrates that through the implementation of the proposed drainage and water quality measures discussed in this report, the requirements of the current MS4 permit have been adequately addressed.
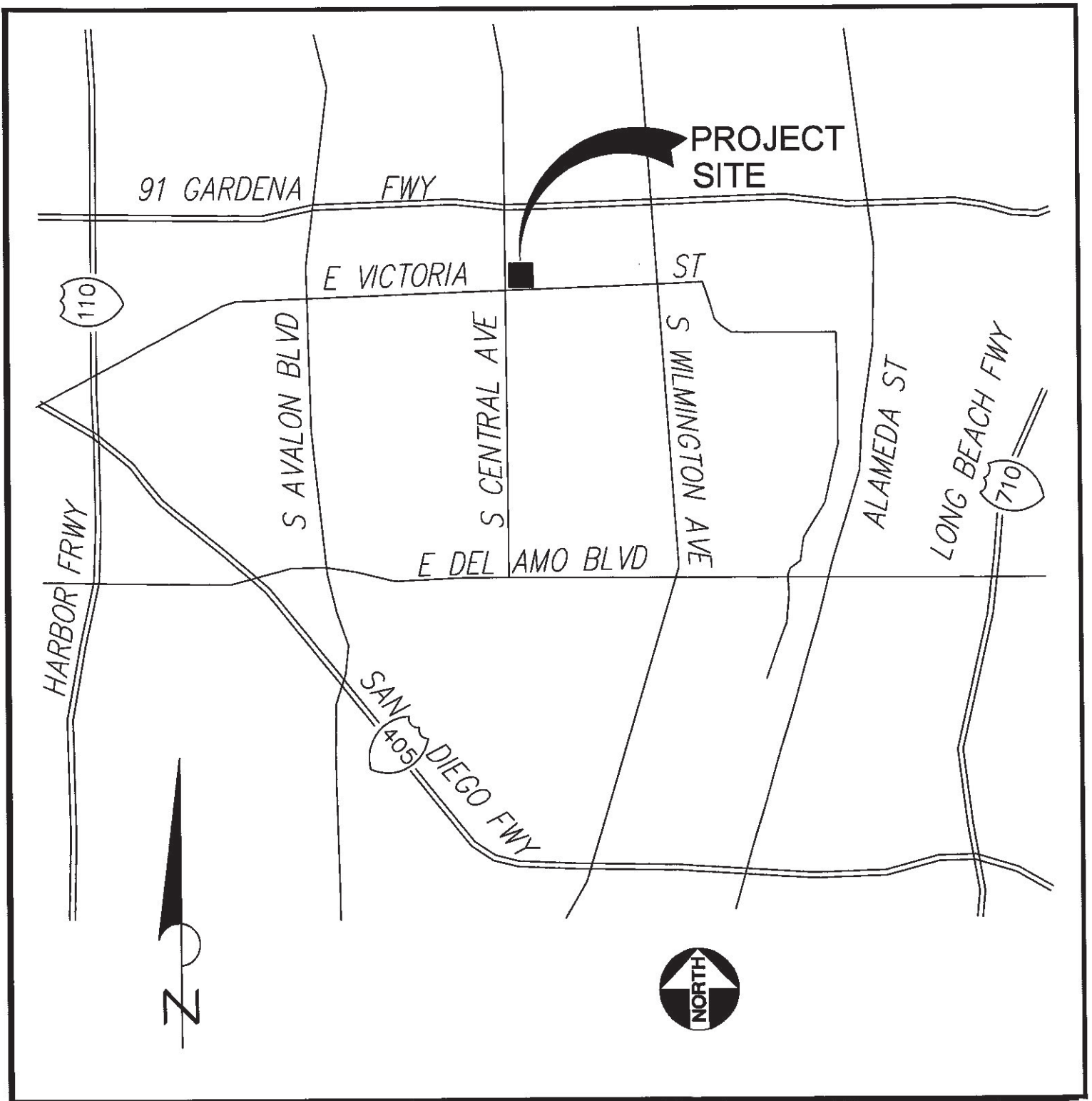
LOCATION MAP

II.   REFERENCES

1. Hydrology Manual, Los Angeles County Department of Public Works, January 2006.
2. Low Impact Development Standards Manual, Los Angeles County Department of Public Works, February 2014.
3. HydroCalc Version 1.0.3, Los Angeles County Department of Public Works, Released 2/21/2018.

APPENDICES

APPENDIX A – HYDROLOGY CALCULATIONS
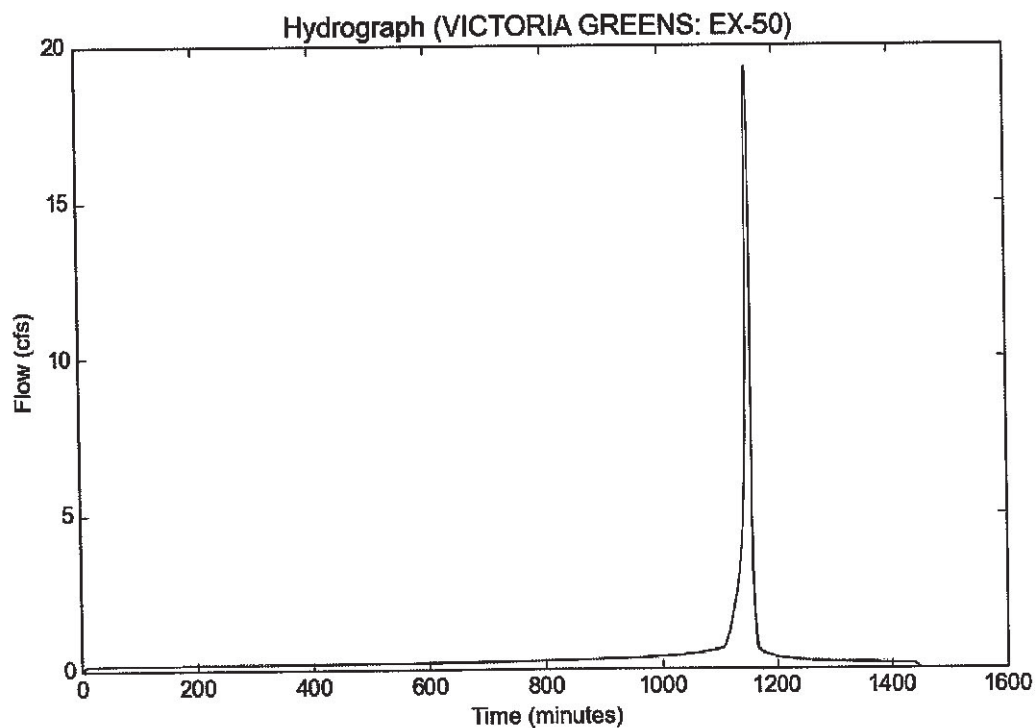
Peak Flow Hydrologic Analysis

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	EX-50
Area (ac)	7.63
Flow Path Length (ft)	960.0
Flow Path Slope (vft/hft)	0.02
50-yr Rainfall Depth (in)	6.2
Percent Impervious	0.05
Soil Type	13
Design Storm Frequency	50-yr
Fire Factor	0
LID	False

Output Results

|	
Modeled (50-yr) Rainfall Depth (in)	6.2
Peak Intensity (in/hr)	2.8062
Undeveloped Runoff Coefficient (Cu)	0.9
Developed Runoff Coefficient (Cd)	0.9
Time of Concentration (min)	9.0
Clear Peak Flow Rate (cfs)	19.2701
Burned Peak Flow Rate (cfs)	19.2701
24-Hr Clear Runoff Volume (ac-ft)	0.8748
24-Hr Clear Runoff Volume (cu-ft)	38106.807

Hydrograph (VICTORIA GREENS: EX-50)

Peak Flow Hydrologic Analysis

File location: P:/316.598/HYDROLOGY/CALCS/VICTORIA GREENS Report042418.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR1-50
Area (ac)	5.83
Flow Path Length (ft)	940.0
Flow Path Slope (vft/hft)	0.02
50-yr Rainfall Depth (in)	6.2
Percent Impervious	0.75
Soil Type	13
Design Storm Frequency	50-yr
Fire Factor	0
LID	False

Output Results

|	
Modeled (50-yr) Rainfall Depth (in)	6.2
Peak Intensity (in/hr)	2.8062
Undeveloped Runoff Coefficient (Cu)	0.9
Developed Runoff Coefficient (Cd)	0.9
Time of Concentration (min)	9.0
Clear Peak Flow Rate (cfs)	14.7241
Burned Peak Flow Rate (cfs)	14.7241
24-Hr Clear Runoff Volume (ac-ft)	2.1569
24-Hr Clear Runoff Volume (cu-ft)	93956.2744
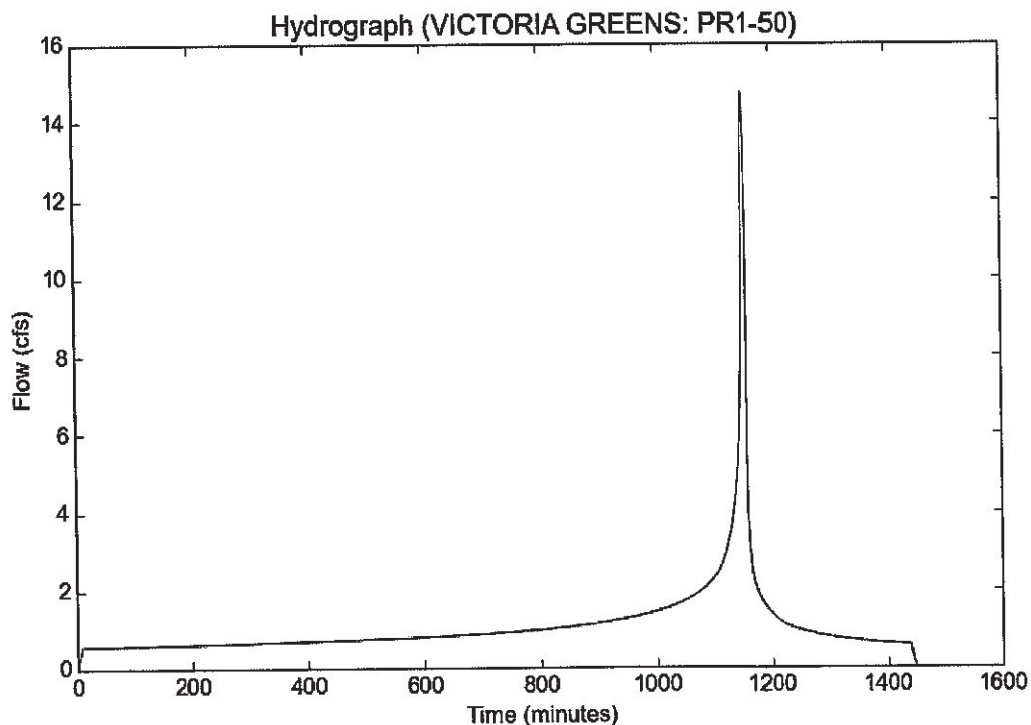
Hydrograph (VICTORIA GREENS: PR1-50)

Peak Flow Hydrologic Analysis

File location: P:/316.598/HYDROLOGY/CALCS/VICTORIA GREENS Report042418.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR2-50
Area (ac)	1.8
Flow Path Length (ft)	680.0
Flow Path Slope (vft/hft)	0.015
50-yr Rainfall Depth (in)	6.2
Percent Impervious	0.85
Soil Type	13
Design Storm Frequency	50-yr
Fire Factor	0
LID	False

Output Results

|	
Modeled (50-yr) Rainfall Depth (in)	6.2
Peak Intensity (in/hr)	2.9659
Undeveloped Runoff Coefficient (Cu)	0.9
Developed Runoff Coefficient (Cd)	0.9
Time of Concentration (min)	8.0
Clear Peak Flow Rate (cfs)	4.8048
Burned Peak Flow Rate (cfs)	4.8048
24-Hr Clear Runoff Volume (ac-ft)	0.7315
24-Hr Clear Runoff Volume (cu-ft)	31866.0516
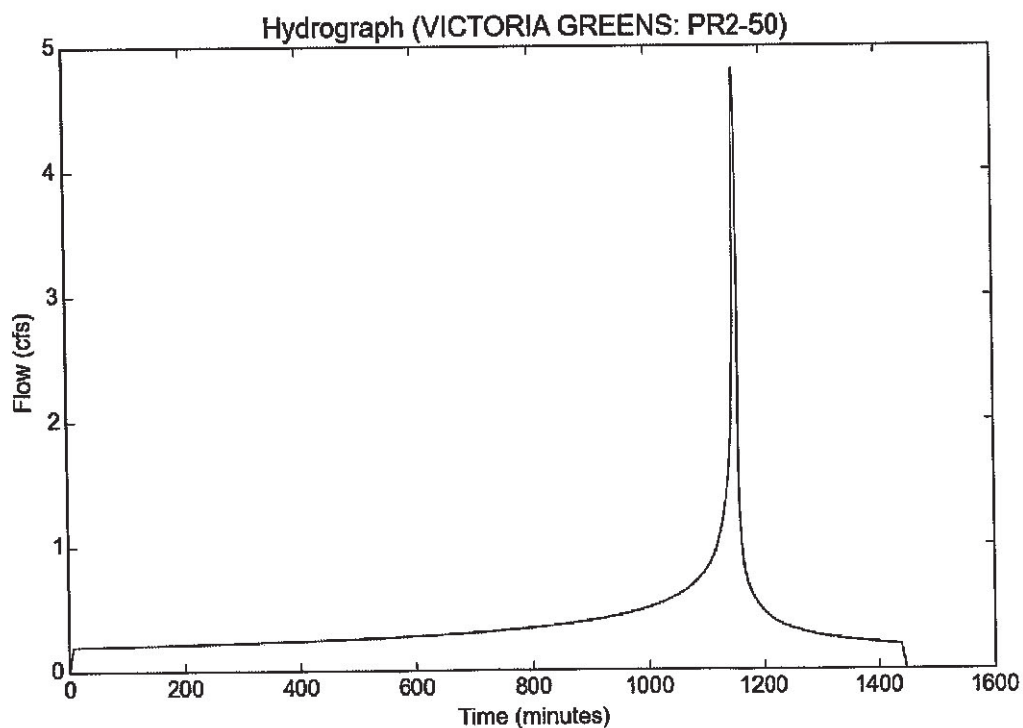
Hydrograph (VICTORIA GREENS: PR2-50)

Peak Flow Hydrologic Analysis

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	EX-10
Area (ac)	7.63
Flow Path Length (ft)	960.0
Flow Path Slope (vft/hft)	0.02
50-yr Rainfall Depth (in)	6.2
Percent Impervious	0.05
Soil Type	13
Design Storm Frequency	10-yr
Fire Factor	0
LID	False

Output Results

|	
Modeled (10-yr) Rainfall Depth (in)	4.4268
Peak Intensity (in/hr)	1.6856
Undeveloped Runoff Coefficient (Cu)	0.7452
Developed Runoff Coefficient (Cd)	0.753
Time of Concentration (min)	13.0
Clear Peak Flow Rate (cfs)	9.6842
Burned Peak Flow Rate (cfs)	9.6842
24-Hr Clear Runoff Volume (ac-ft)	0.544
24-Hr Clear Runoff Volume (cu-ft)	23697.661
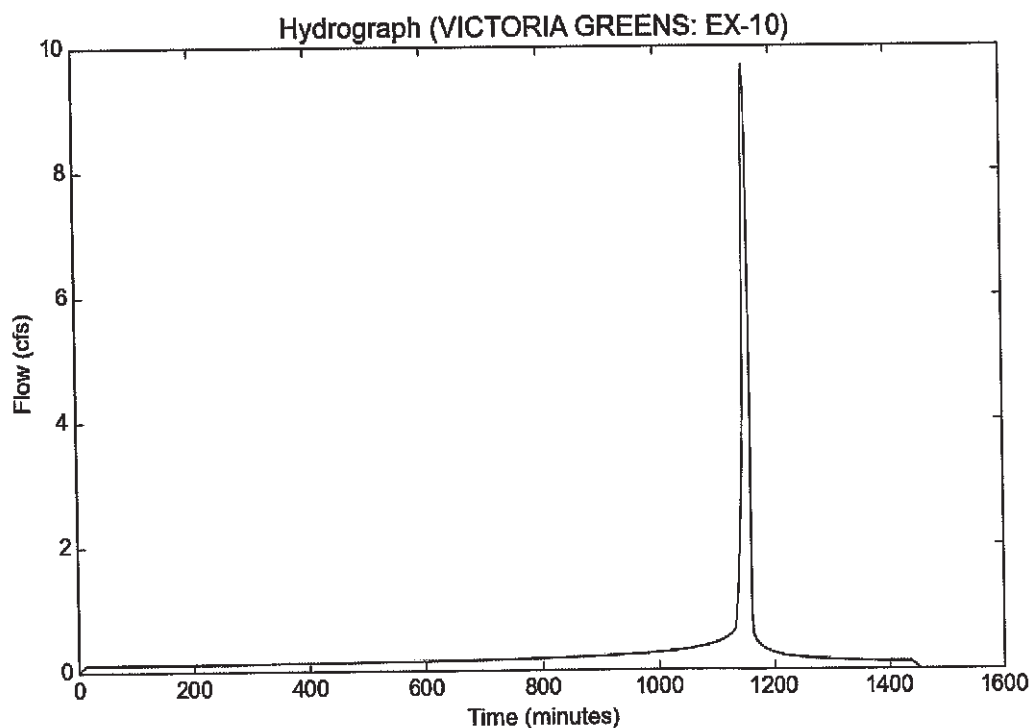
Hydrograph (VICTORIA GREENS: EX-10)

Peak Flow Hydrologic Analysis

File location: P:/316.598/HYDROLOGY/CALCS/VICTORIA GREENS Report042418.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR1-10
Area (ac)	5.83
Flow Path Length (ft)	940.0
Flow Path Slope (vft/hft)	0.02
50-yr Rainfall Depth (in)	6.2
Percent Impervious	0.75
Soil Type	13
Design Storm Frequency	10-yr
Fire Factor	0
LID	False

Output Results

|	
Modeled (10-yr) Rainfall Depth (in)	4.4268
Peak Intensity (in/hr)	1.8233
Undeveloped Runoff Coefficient (Cu)	0.7803
Developed Runoff Coefficient (Cd)	0.8701
Time of Concentration (min)	11.0
Clear Peak Flow Rate (cfs)	9.2486
Burned Peak Flow Rate (cfs)	9.2486
24-Hr Clear Runoff Volume (ac-ft)	1.5243
24-Hr Clear Runoff Volume (cu-ft)	66399.4572
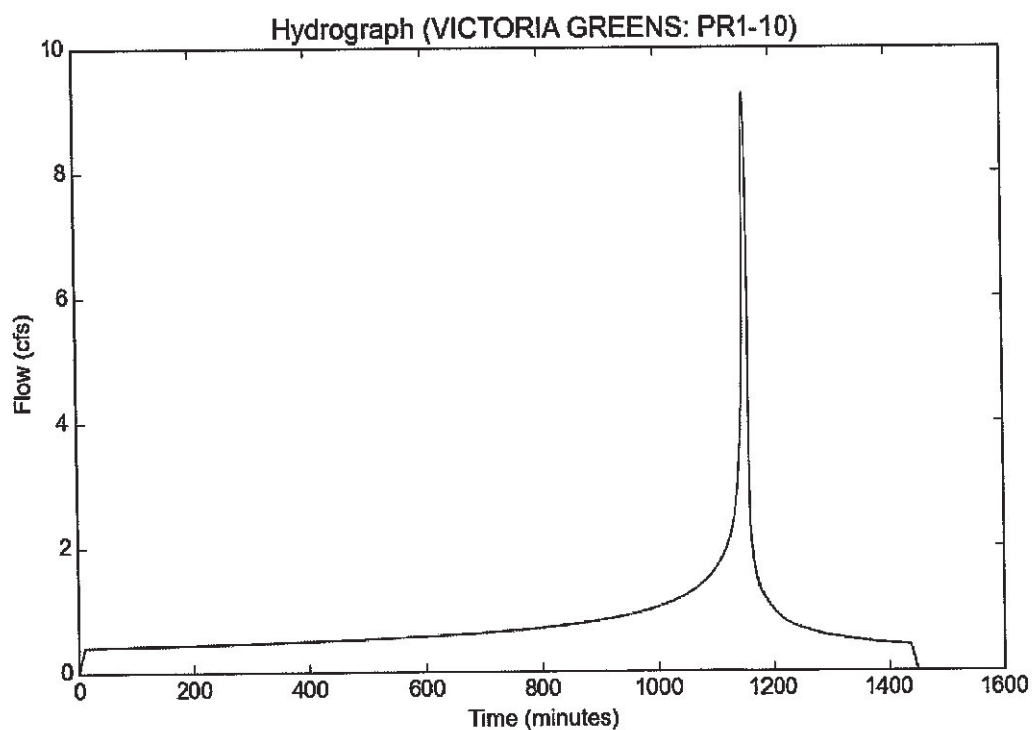
Hydrograph (VICTORIA GREENS: PR1-10)

Peak Flow Hydrologic Analysis

File location: P:/316.598/HYDROLOGY/CALCS/VICTORIA GREENS Report042418.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR2-10
Area (ac)	1.8
Flow Path Length (ft)	680.0
Flow Path Slope (vft/hft)	0.015
50-yr Rainfall Depth (in)	6.2
Percent Impervious	0.85
Soil Type	13
Design Storm Frequency	10-yr
Fire Factor	0
LID	False

Output Results

|	
Modeled (10-yr) Rainfall Depth (in)	4.4268
Peak Intensity (in/hr)	1.9068
Undeveloped Runoff Coefficient (Cu)	0.8015
Developed Runoff Coefficient (Cd)	0.8852
Time of Concentration (min)	10.0
Clear Peak Flow Rate (cfs)	3.0384
Burned Peak Flow Rate (cfs)	3.0384
24-Hr Clear Runoff Volume (ac-ft)	0.5195
24-Hr Clear Runoff Volume (cu-ft)	22629.4134
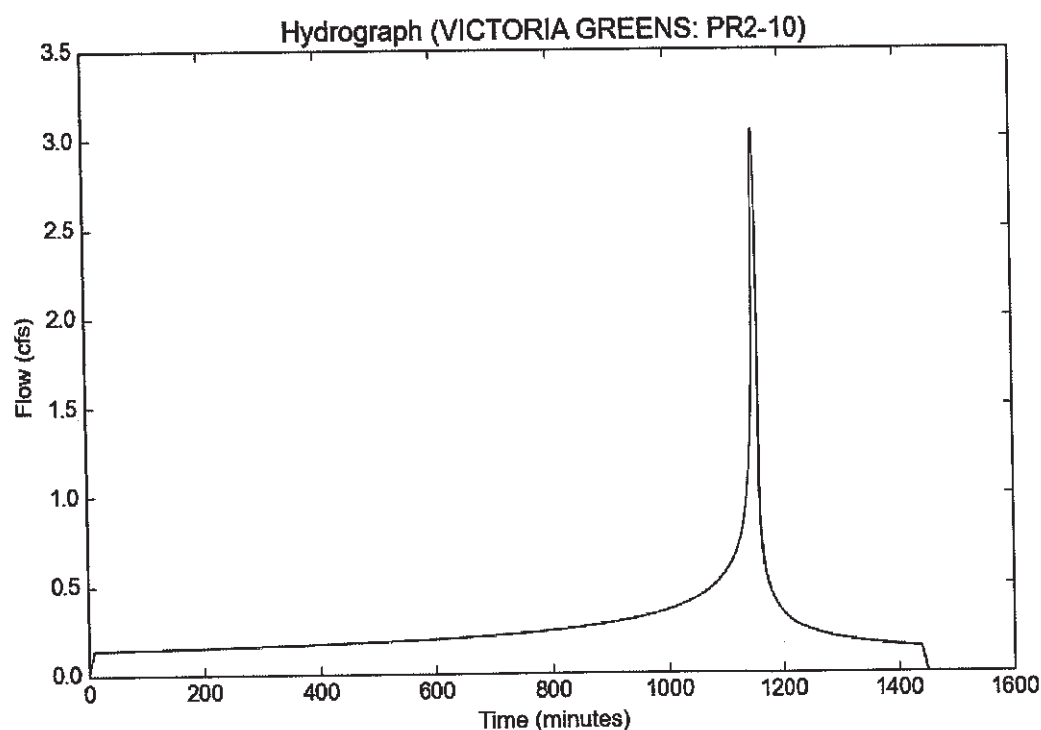
Hydrograph (VICTORIA GREENS: PR2-10)

Peak Flow Hydrologic Analysis

File location: P:/316.598/HYDROLOGY/CALCS/VICTORIA GREENS Report042418.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	EX-0.75
Area (ac)	7.63
Flow Path Length (ft)	960.0
Flow Path Slope (vft/hft)	0.02
0.75-inch Rainfall Depth (in)	0.75
Percent Impervious	0.05
Soil Type	13
Design Storm Frequency	0.75 inch storm
Fire Factor	0
LID	True

Output Results

|	
Modeled (0.75 inch storm) Rainfall Depth (in)	0.75
Peak Intensity (in/hr)	0.0944
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.14
Time of Concentration (min)	137.0
Clear Peak Flow Rate (cfs)	0.1008
Burned Peak Flow Rate (cfs)	0.1008
24-Hr Clear Runoff Volume (ac-ft)	0.0662
24-Hr Clear Runoff Volume (cu-ft)	2884.8823
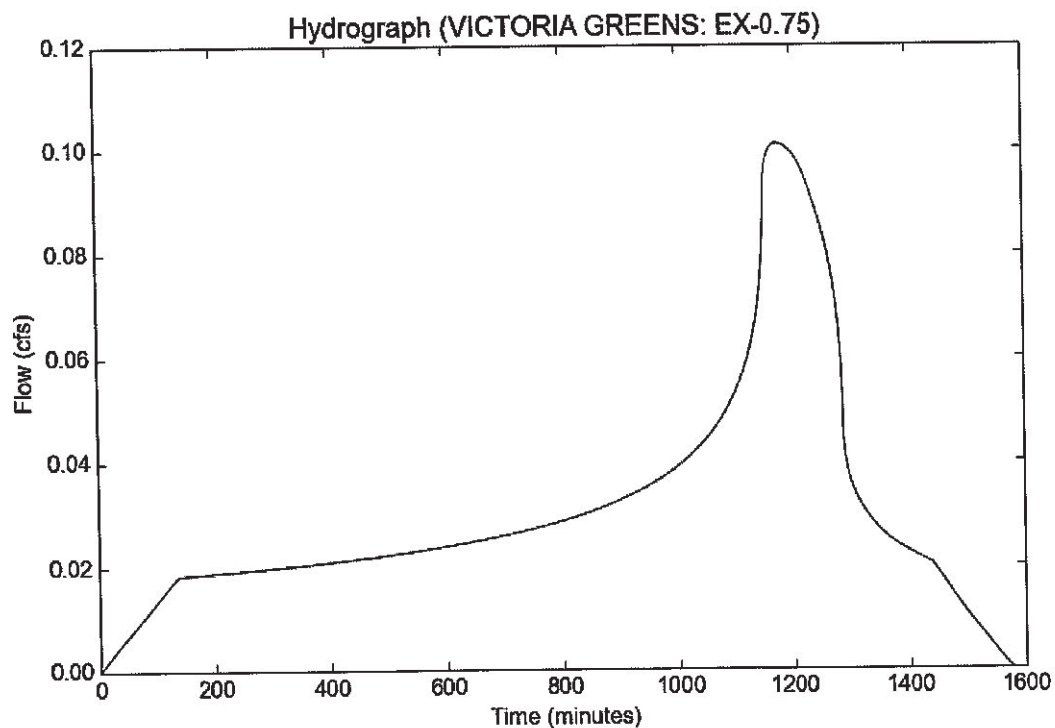
Hydrograph (VICTORIA GREENS: EX-0.75)

Peak Flow Hydrologic Analysis

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR1-0.75
Area (ac)	5.83
Flow Path Length (ft)	940.0
Flow Path Slope (vft/hft)	0.02
0.75-inch Rainfall Depth (in)	0.75
Percent Impervious	0.75
Soil Type	13
Design Storm Frequency	0.75 inch storm
Fire Factor	0
LID	True

Output Results

|	
Modeled (0.75 inch storm) Rainfall Depth (in)	0.75
Peak Intensity (in/hr)	0.1593
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.7
Time of Concentration (min)	45.0
Clear Peak Flow Rate (cfs)	0.6502
Burned Peak Flow Rate (cfs)	0.6502
24-Hr Clear Runoff Volume (ac-ft)	0.253
24-Hr Clear Runoff Volume (cu-ft)	11018.9875
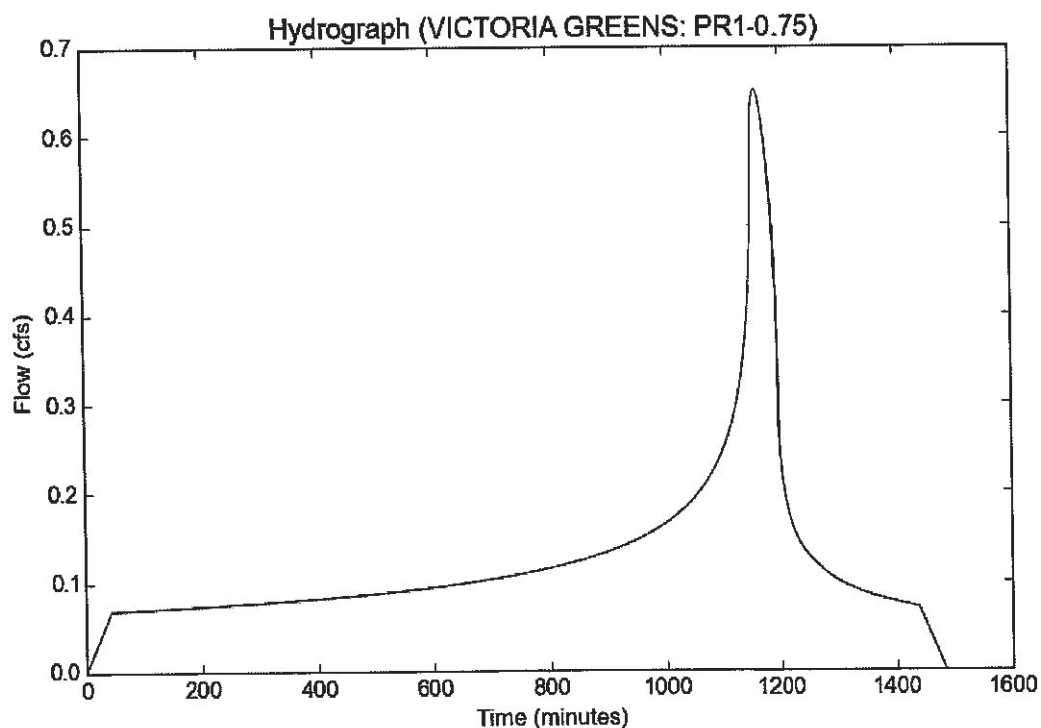
Hydrograph (VICTORIA GREENS: PR1-0.75)

Peak Flow Hydrologic Analysis

File location: P:/316.598/HYDROLOGY/CALCS/VICTORIA GREENS Report042418.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR2-0.75
Area (ac)	1.8
Flow Path Length (ft)	680.0
Flow Path Slope (vft/hft)	0.015
0.75-inch Rainfall Depth (in)	0.75
Percent Impervious	0.85
Soil Type	13
Design Storm Frequency	0.75 inch storm
Fire Factor	0
LID	True

Output Results

|	
Modeled (0.75 inch storm) Rainfall Depth (in)	0.75
Peak Intensity (in/hr)	0.1769
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.78
Time of Concentration (min)	36.0
Clear Peak Flow Rate (cfs)	0.2484
Burned Peak Flow Rate (cfs)	0.2484
24-Hr Clear Runoff Volume (ac-ft)	0.087
24-Hr Clear Runoff Volume (cu-ft)	3790.8629
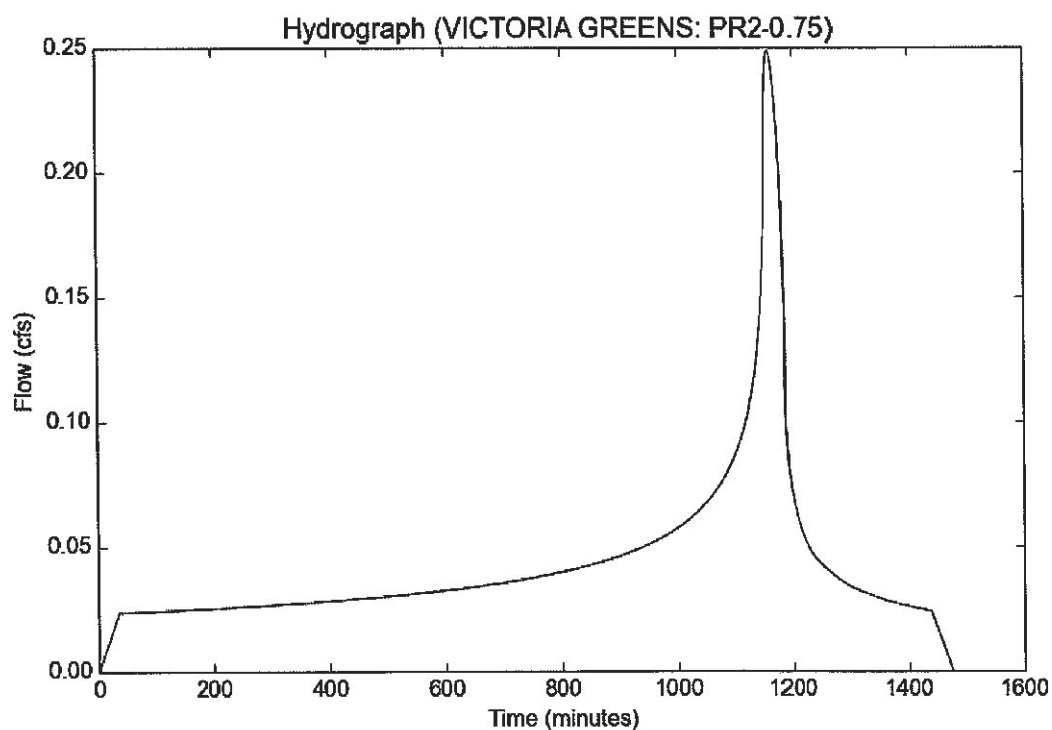
Hydrograph (VICTORIA GREENS: PR2-0.75)

Peak Flow Hydrologic Analysis

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	EX-85th
Area (ac)	7.63
Flow Path Length (ft)	960.0
Flow Path Slope (vft/hft)	0.02
85th Percentile Rainfall Depth (in)	0.83
Percent Impervious	0.05
Soil Type	13
Design Storm Frequency	85th percentile storm
Fire Factor	0
LID	True

Output Results

|	
Modeled (85th percentile storm) Rainfall Depth (in)	0.83
Peak Intensity (in/hr)	0.1079
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.14
Time of Concentration (min)	128.0
Clear Peak Flow Rate (cfs)	0.1152
Burned Peak Flow Rate (cfs)	0.1152
24-Hr Clear Runoff Volume (ac-ft)	0.0733
24-Hr Clear Runoff Volume (cu-ft)	3192.4942
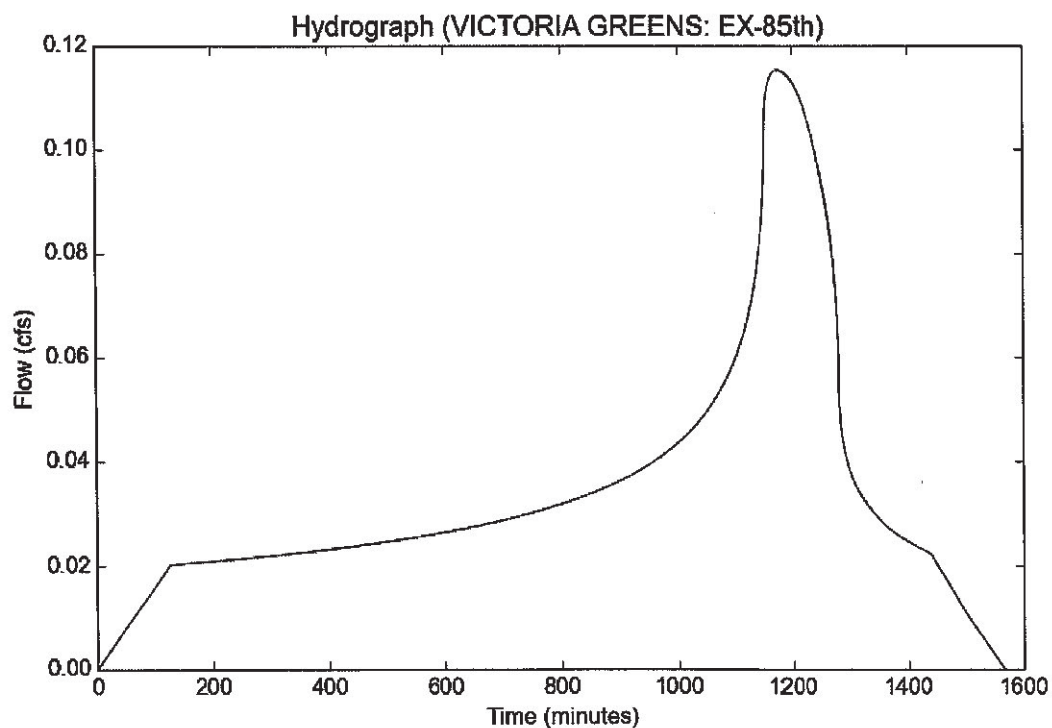
Hydrograph (VICTORIA GREENS: EX-85th)

Peak Flow Hydrologic Analysis

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR1-85th
Area (ac)	5.83
Flow Path Length (ft)	940.0
Flow Path Slope (vft/hft)	0.02
85th Percentile Rainfall Depth (in)	0.83
Percent Impervious	0.75
Soil Type	13
Design Storm Frequency	85th percentile storm
Fire Factor	0
LID	True

Output Results

|	
Modeled (85th percentile storm) Rainfall Depth (in)	0.83
Peak Intensity (in/hr)	0.1821
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.7
Time of Concentration (min)	42.0
Clear Peak Flow Rate (cfs)	0.7433
Burned Peak Flow Rate (cfs)	0.7433
24-Hr Clear Runoff Volume (ac-ft)	0.2799
24-Hr Clear Runoff Volume (cu-ft)	12194.3046
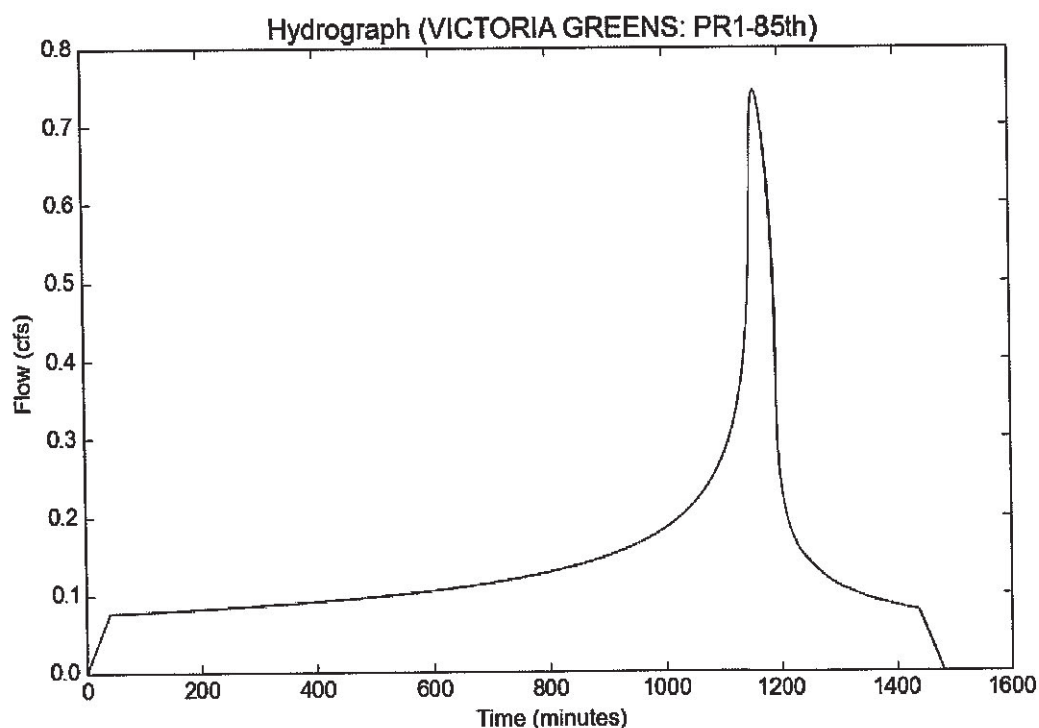
Hydrograph (VICTORIA GREENS: PR1-85th)

Peak Flow Hydrologic Analysis

File location: P:/316.598/HYDROLOGY/CALCS/VICTORIA GREENS Report042418.pdf
Version: HydroCalc 1.0.3

Input Parameters

Project Name	VICTORIA GREENS
Subarea ID	PR2-85th
Area (ac)	1.8
Flow Path Length (ft)	680.0
Flow Path Slope (vft/hft)	0.015
85th Percentile Rainfall Depth (in)	0.83
Percent Impervious	0.85
Soil Type	13
Design Storm Frequency	85th percentile storm
Fire Factor	0
LID	True

Output Results

Modeled (85th percentile storm) Rainfall Depth (in)	0.83
Peak Intensity (in/hr)	0.204
Undeveloped Runoff Coefficient (Cu)	0.1
Developed Runoff Coefficient (Cd)	0.78
Time of Concentration (min)	33.0
Clear Peak Flow Rate (cfs)	0.2864
Burned Peak Flow Rate (cfs)	0.2864
24-Hr Clear Runoff Volume (ac-ft)	0.0963
24-Hr Clear Runoff Volume (cu-ft)	4195.2104

Hydrograph (VICTORIA GREENS: PR2-85th)
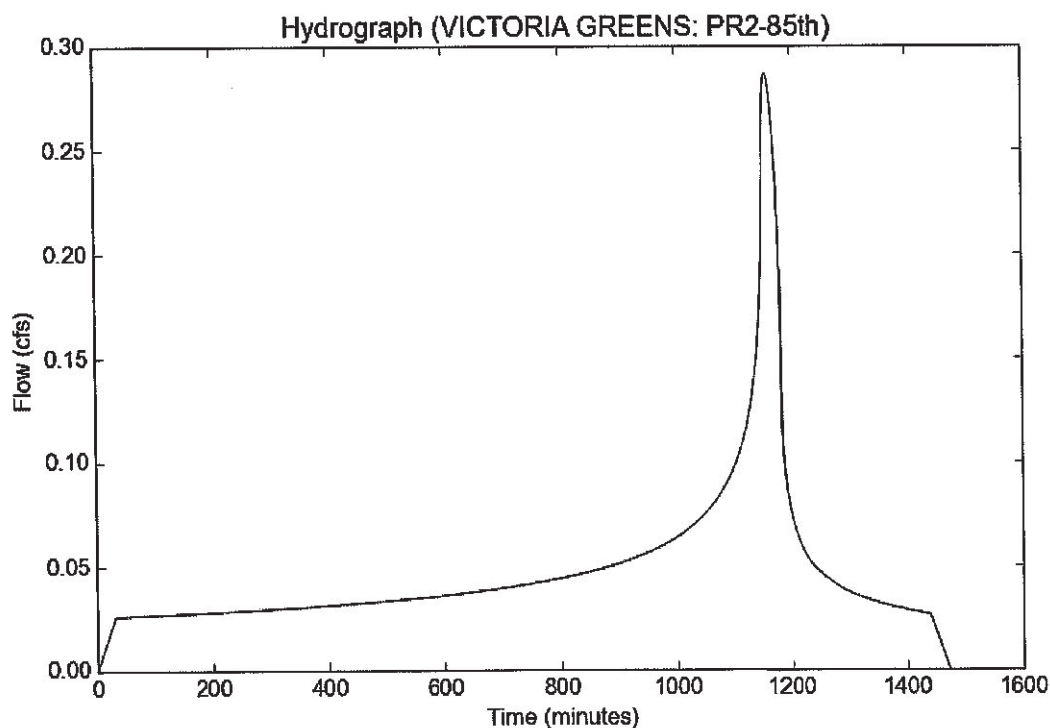
APPENDIX B – REFERENCE DOCUMENTS

STORMWATER PLANNING PROGRAM LID PLAN CHECKLIST

FORM **PC-1**

Project Name	Owner Name	Developer Name
Victoria Greens Condo	Integral Communities	
Project Address	**Owner Address**	**Developer Address**
1300 Victoria Street	888 San Clemente Dr #100, NB	
Owner Phone	**Owner Fax**	**Developer Phone**
949-720-3612	949-720-3613	

Does the proposed project fall into one of the following categories? Please check Yes/No	YES	NO
PRIORITY LID* PROJECTS		
1. Construction* of a new restaurant (SIC 5812) with 5,000 square feet or more of surface area	☐	☒
2. Construction* of a new industrial park with 10,000 square feet or more of surface area	☐	☒
3. Construction* of a new commercial mall with 10,000 square feet or more surface area	☐	☒
4. Construction* of a new retail gasoline outlet with 5,000 square feet or more of surface area	☐	☒
5. Construction* of a new parking lot with either 5,000 ft² or more of impervious* surface or with 25 or more parking spaces	☐	☒
6. Construction* of a new automotive service facility (SIC 5013, 5014, 5511, 5541, 7532-7534 and 7536-7539) with 5,000 square feet or more of surface area	☐	☒
7. Construction* of a new project equal to 1 acre or greater of disturbed area and adding more than 10,000 square feet of impervious* surface area	☒	☐
8. Projects located in or directly adjacent to, or discharging directly to a Significant Ecological Area (SEA), where the development will: a. Discharge stormwater runoff that is likely to impact a sensitive biological species or habitat; and b. Create 2,500 square feet or more of impervious surface area	☐	☒
9. Redevelopment* of 5,000 square feet or more in one of the categories listed above	☒	☐
10. Redevelopment* of 10,000 square feet or more to an existing Single Family Home	☐	☒

If any of the boxes 1-10 are checked YES, this project will require the preparation of a Low Impact Development (LID)* Plan with a Maintenance Agreement*

A LID Plan containing special provisions is required for all private & public projects that 1) do not qualify as a Priority LID Project and 2) satisfy any of the following:

SPECIAL PROVISION LID PROJECTS		
11. Small site LID with 500 square feet or more surface area disturbance*	☐	☐
12. Green street* project with 10,000 square feet or more of impervious surface area	☐	☐
13. Single family hillside* home	☐	☐

If any of the boxes 11-13 are checked YES, this project will require the preparation of a plan with special provisions associated with the type of development   * Defined on back

Terry Au, Principal, Urban Resource
_____
Applicant Name & Title

4-27-18
_____
Applicant Signature / Date

For City Staff Only:

Verified by Staff Name:_____ Staff Signature:_____ Date:_____

Rev: 01/01/2017 12:00 PM

33° 52' 30"

-118° 05' 00"

DPA - 6

003

006

006

003

00

009

013

013

003

16

6.2

006

006

006

5.6

5.4

006

003

DPA - 7

003

007

014

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6.0

010

014

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003

015

006

010

006

014

014

014

013

013

5.8

017

009 003 014 009 003

5.6 003

015

5.4

015

5.2

003

5.0

015

5.0

015

003 003

4.8

4.6

LONG BEACH

SAN   PEDRO   BAY

PACIFIC   OCEAN

-118° 07' 30"

33° 43' 30"

TORRANCE 1-H1.4

LOS ALAMITOS 1-H1.6

| | 1 | 0 | 1 | 2 Miles |

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LONG BEACH   **1-H1.5**
50-YEAR 24-HOUR ISOHYET

N
W   E
S

016   SOIL CLASSIFICATION AREA

7.2   INCHES OF RAINFALL

DPA - 6   DEBRIS POTENTIAL AREA

LOS ANGELES COUNTY
PUBLIC WORKS
Public Service That Works

Department of Public Works
dpw.lacounty.gov

search our site...

Basemaps ▼

Hydrology Map A GIS viewer application to view the data for the hydrology manual.

LAYERS

- 50yr Two Tenths (Rainfall)
- DPA Zones
- Soils 2004
- Final 85th Percentile, 24-hr Rainfall
- Final 95th Percentile, 24-hr Rainfall
- 1-year, 1-hour Rainfall Intensity

SEARCH

Enter Address, Cross Street, or Parcel No.:
(ex: 900 S. Fremont Ave. Fremont@Valley; 5342006904) | carson, ca

Search

Address Search Results:
carson ca

lacounty.gov | Public Works FAQ | Privacy / Terms of Use | Feedback |
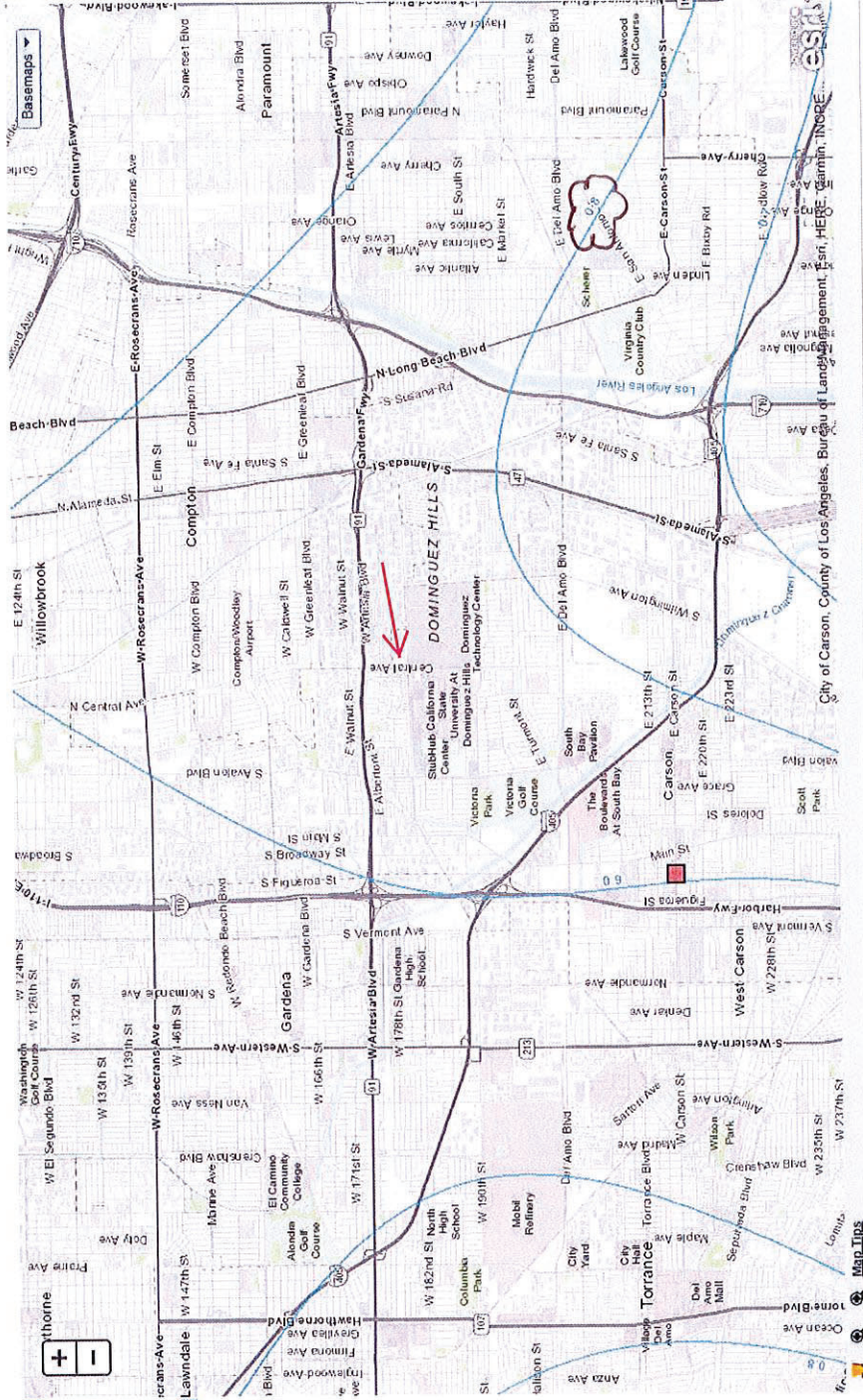
85th Percentile 24 Hour
Rain Event

interpolate = 0.83"

City of Carson

Existing Catch Basins by Owner and Drainage Area

Catch Basin by Owner

- ■ CARSON (1918)
- ■ CAL (58)
- ■ DEPT OF WATER AND POWER (54)
- ■ LBE (15)
- ■ LOS ANGELES FLOOD CONTROL DISTRICT (9)
- ■ OTHERS (4)

Storm Drains

- → Lateral Storm Drain Lines
- → Main Storm Drain Lines

Sub Water Basins

- Drains to Compton Creek
- Drains to Dominguez Channel
- Drains to Machado Lake
- Drains to Los Angeles River
- Drains to Pacific Ocean
- Channels

Machado Lake

Los Angeles River

0 0.25 0.5 0.75 1

Miles

RTONI ST

FARMICK CT

AMANTHA AVE

LM D

RADBARD ST

MAGNOLIA DR

CENTRAL AVE

MAPLE DR

WILLOW WY

ASPEN HILL RD

WLM ST

PEPPERWOOD CT

LEMON CT

REDWOOD CT

VICTORIA ST

BISHOP AVE

CHARLES WILLARD ST

CHARLES

REPORT OF DUE-DILIGENCE GEOTECHNICAL EXPLORATION PROPOSED RESIDENTIAL DEVELOPMENT PROPERTY LOCATED AT THE NORTHEAST CORNER OF CENTRAL AVENUE AND VICTORIA STREET CARSON, CALIFORNIA

Prepared for:

Rutan & Tucker, LLP

611 Anton Boulevard, 14th Floor
Costa Mesa, California 92626

Project No. 11738.001
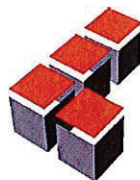
November 11, 2017

Leighton and Associates, Inc.

A LEIGHTON GROUP COMPANY

Leighton and Associates, Inc.
A LEIGHTON GROUP COMPANY

November 11, 2017

Project No. 11738.001

Privileged and Confidential; Protected by Attorney Work Product Privileges;
Prepared in Anticipation of Litigation

Rutan & Tucker, LLP
611 Anton Boulevard, 14th Floor
Costa Mesa, California 92626

Attention: Ms. Anna Amarandos

Subject: **Report of Due Diligence Geotechnical Exploration**
Proposed Residential Development
Property Located at the Northeast Corner of
Central Avenue and Victoria Street
Carson, California

In accordance with our revised proposal dated August 21, 2017, authorized by you on August 22, 2017, Leighton and Associates, Inc. (Leighton) is pleased to present this due diligence geotechnical exploration report for the subject project. Based on review of the site plan (Urban Arena, 2017), the planned residential development consists of 26 attached, multi-family residential structures totaling 184 units, with associated private drive aisles, gated entry, clubhouse and pool area, tot lot, dog park and surface parking. We assumed the planned residential structures will be no more than three stories in height, wood frame construction and ancillary improvements will include associated backbone utility and infrastructure with landscaping. No subterranean structures are planned at this time. The planned development wraps around the existing commercial facility located at 17900 Central Avenue, which we understand is not part of the project.

The purpose of our study was to evaluate the geotechnical conditions at the site and to provide preliminary geotechnical information to support preparation of a grading and drainage plan by the civil engineer for the project as currently proposed. More specifically, our field exploration was intended to evaluate and quantify, to the extent

possible through geotechnical exploration, the approximate depth of undocumented artificial fill materials and former foundation remnants across the site. This information will allow you to budget and plan for the remedial grading that will be required for site development as currently proposed.

Based on our exploration and analysis, the proposed project is considered feasible from a geotechnical standpoint. Conventional spread footings established on compacted engineered fill may be used to support the proposed residential structures and other site improvements. Preliminary geotechnical recommendations with respect to site grading and foundation design are presented in this report. It should be noted that this report is not suitable for submittal purposes in order to obtain a building permit for the project. Therefore, additional field exploration, laboratory testing and engineering analysis will be required during the design phase of the project and the geotechnical recommendations may change once actual plans are prepared and reviewed by the geotechnical engineer for the site.

We appreciate this opportunity to be of continued service and look forward to assisting you in successful completion of the project. If you have any questions regarding this report, please contact us at your convenience. The undersigned can be reached at **(866) *LEIGHTON***, specifically at the phone extension and e-mail address listed below.

Respectfully submitted,

LEIGHTON AND ASSOCIATES, INC.

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JMP/CCK/lr

Distribution: (1) Addressee
               (1) Integral Communities: Attention: Mr. Spencer Oliver

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1.0   INTRODUCTION

1.1   Site Description

The project site is irregular in shape, approximately 8 acres in size and located at the northeast corner of Central Avenue and Victoria Street in the city of Carson, California (Figure 1, *Site Location Map*). The site is bordered by commercial properties to the north and east, by Central Avenue and existing commercial facilities (MCI and Southern California Gas Company) to the west, and by Victoria Street to the south. The site is currently a vacant dirt lot with a small paved parking area in the northwest corner of the site area. Review of the site plans *The City of Carson Vesting Tentative Tract Map No. 78226 for Condominium Purposes (6 Sheets,* Scale 1"=40')*, prepared by Urban Resource Consulting Civil Engineers (dated September 11, 2017), indicates the site is relatively flat with sheet flow gently downward sloping toward the northwest from approximately Elevation (El.) ±151 feet mean sea level (msl) in the northwest to El. ±171 feet msl in the southeast.

Review of publicly available information from the Regional Water Quality Control Board Los Angeles Region (RWQCBLAR) indicate this former site is known as the Hellman Property, which encompasses approximately 8 acres and is part of the former 100-acre Dominguez Oil Field in Carson that was used for crude oil and natural gas production beginning in the 1920's. Brea Canon Oil Company purchased the subject property from Unocal in 1991, and subsequently transferred the property to Little Blackfoot, LLC. According to the RWQCBLAR; by June 1999, all oil wells on the 8-acre Hellman Property had been abandoned according to the requirements established by the California Division of Oil and Gas and Geothermal Resources (DOGGR). Based on review of the DOGGR Well Finder Website (DOGGR, 2017), eight oil production or injection wells listed by DOGGR as plugged and abandoned are located within the project site boundary. Four of the wells (API #'s 03707332, 03707335, 03707339 and 03707351) are located in the northeastern portion of the project site, and four of the wells (API #'s 03707309, 03707324, 03707348 and 03707353) are located in the western portion of the site immediately east of the existing MCI facility. The locations of the wells are shown on Plate 1, *Geotechnical Map*. In addition, based on review of the "No Further Action" determination letter prepared for the site by the RWQCBLAR dated August 13, 2008, we understand that no further

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soil or groundwater investigation or remediation action is necessary for the site, and no known petroleum hydrocarbon soil contamination has been left-in-place that exceeds the Regional Board's soil cleanup criteria for protection of groundwater resources. However, this letter indicates that within the Hellman Parcel, approximately 12,800 cubic yards of hydrocarbon impacted soils were excavated from the site and placed within treatment cells for biological landfarming treatment. The exact lateral limits and depths of the areas impacted by the soil remediation are unknown; however, we assume that fill materials associated with these remediation activities have been placed across this site without engineering control (compaction testing).

1.2   Proposed Development

Based on review of the site plan (Urban Arena, 2017), the planned residential development consists of 26 attached multi-family residential structures totaling 184 units, with associated private drive aisles, gated entry, clubhouse and pool area, tot lot, dog park and surface parking. We assume the planned residential structures will be no more than three stories in height, wood frame construction and ancillary improvements will include associated backbone utility and infrastructure with landscaping. No subterranean structures are planned at this time. The planned development wraps around the existing commercial facility located at 17900 Central Avenue, which we understand is not part of the project.

1.3   Purpose and Scope of Exploration

The purpose of our due diligence geotechnical exploration was to evaluate the general geotechnical conditions at the site and to provide preliminary geotechnical information to support preparation of a grading and drainage plan for the project.

The scope of this geotechnical report included the following tasks:

- *Background Review* – A background review was performed of readily available, relevant geotechnical and geological literature and plans pertinent to the project site. References used in preparation of this report are listed in Section 7.0.

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- *Field Exploration* – Our field exploration was performed on August 31, and September 1, 2017, and consisted of 17 geotechnical test pits (TP-1 through TP-15, TP-1A and TP-12A) excavated across the site with a conventional rubber tire backhoe to assess the depth and characteristics of near surface materials and to quantify to the extent possible the approximate depth of undocumented artificial fill materials and former foundation remnants across the site. The test pits were excavated to depths between approximately 4 and 9.5 feet below existing ground surface (bgs). Test pits TP-1A and TP-12A were excavated specifically to perform percolation testing in the vicinity of the proposed stormwater infiltration areas. The approximate locations of the test pits performed by Leighton are shown on Plate 1, *Geotechnical Map*. Prior to the field exploration, the test pit locations were marked and Underground Service Alert (USA) was notified for utility clearance.

During excavation, bulk samples were obtained from the test pits for geotechnical laboratory testing. The test pits were logged in the field by a State of California certified engineering geologist from our staff. The exposed soils and collected samples were reviewed and described in general accordance with the Unified Soil Classification System (USCS). The samples were sealed and packaged for transportation to our laboratory. After completion of excavation, the test pits were backfilled with soils generated during the exploration. The test pit logs are presented in Appendix A, *Field Exploration Logs*.

On October 19, 2017, the environmental consultant for the project (Hayley & Aldrich, Inc.) performed 4 supplemental direct push borings (HA-50 through HA-53) in the western portion of the site to supplement their previous environmental study that included 49 direct push borings. A staff geologist from Leighton was onsite during the field exploration for the 4 supplemental direct push borings in order to co-log the soils encountered and determine the thickness of undocumented fills in the western portion of the site. The approximate locations of the supplemental direct push borings co-logged by Leighton (HA-50 through HA-53) are shown on Plate 1 and independent logs of these borings are included in Appendix A, *Field Exploration Logs*.

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- *Laboratory Testing* – Laboratory tests were performed on representative soil samples to evaluate geotechnical engineering properties of subsurface materials. The following laboratory tests were performed:

  — Expansion Index (ASTM D4829);

  — Soluble sulfate, soluble chloride, pH and minimum resistivity (CTM 417 Part II, CTM 422, and CTM 643); and

  — Sieve Analysis (ASTM D 422);

  The results of the laboratory tests are presented in Appendix B, *Laboratory Test Results.*

- *Percolation Testing* – In-situ percolation testing was performed on September 7, 2017 in test pits TP-1A and TP-12A in general accordance with the *Excavation Percolation Test Procedure* as outlined in the County of Los Angeles Department of Public Works *Guidelines for Design, Investigation, and Reporting Low Impact Development Stormwater Infiltration* (LADPW, 2014). Refer to the discussion presented in Section 2.5 and the infiltration test data provided in Appendix C, *Percolation Test Results.*

- *Engineering Analysis* – Geotechnical analysis was performed on the collected data to develop conclusions and preliminary recommendations for design and earthwork construction presented in this report.

- *Report Preparation* - This geotechnical report presents our findings, conclusions, and preliminary recommendations.

It should be noted that the preliminary recommendations in this report are subject to the limitations presented in Section 6.0. An information sheet prepared by ASFE (the Association of Engineering Firms Practicing in the Geosciences) is also included at the rear of the text. We recommend that all individuals using this report read the limitations along with the attached document.

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2.0   GEOTECHNICAL FINDINGS

2.1   Geologic Setting

The project site is located in the Dominguez Hills area at the southwestern edge of the Los Angeles basin. The basin is located at the northern end of the Peninsular Ranges geomorphic province which extends 900 miles southward from the Santa Monica Mountains to the tip of Baja California (Yerkes, et al., 1965). The province is characterized by northwest-trending mountain ridges separated by sediment-floored valleys. However, the most dominant structural features of the province are the northwest trending fault zones, most of which either die out, merge with, or are terminated by the steep reverse faults at the southern margin of the Transverse Ranges province. The northwest trending fault zones include the Newport-Inglewood, San Jacinto, Whittier-Elsinore, and Palos Verdes. The Newport-Inglewood fault zone includes a series of northwest trending faults and folds marked at the surface by low eroded scarps and a chain of elongated low hills and mesas that extend from Newport Bay to Beverley Hills, which include the Dominguez Hills. Several of these fault segments, including the Avalon-Compton fault located to the north of the Dominguez Hills and the Cherry Hill fault located to the south, have been assigned Alquist-Priolo Earthquake Fault Hazard Zones by the California Geological Survey (CGS). However, CGS has not assigned an Alquist-Priolo Earthquake Fault Hazard Zone to the gap between the Avalon-Compton fault and the Cherry Hill fault.

Approximately 65 million years ago (at the end of the Cretaceous Period) a deep, structural trough existed off the coast of southern California (Yerkes, 1972). Overtime, sedimentation would slowly fill the trough with tremendous amounts of sediments. About 7 million years ago, as sedimentation continued, an eastward shift of the boundary between the Pacific and North American plates to its present position would begin shaping the Los Angeles basin from this deep trough. Today the Los Angeles basin refers to the area defined by the Santa Monica, Whittier and Palos Verdes faults, and the San Joaquin Hills, and its depth is limited to the sediments deposited in the last 7 million years (Wright, 1991). The deepest part of the Los Angeles basin is north and northwest of the site where approximately 24,000 feet of Tertiary to Quaternary-aged, marine and non-marine sedimentary rocks are deposited (Wright, 1991; Yerkes, et al., 1965). During the Pleistocene epoch (the last two million years) the region was inundated

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as sea level rose and warped gently upward until the present shoreline and topography formed (Yerkes et al., 1965; Wright, 1991). The geologic map of the area is shown on Figure 2, *Regional Geology Map*.

2.2 Subsurface Soil Conditions

Our subsurface explorations indicate the site is generally underlain by undocumented artificial fill materials overlying Quaternary-age old alluvial valley or flood plain deposits (Saucedo et al., 2003; Roffers and Bedrossian, 2010). The stratigraphy of the subsurface soils encountered in each test pit is presented in the test pit logs (Appendix A), and a general description of the earth materials as encountered are described below.

Artificial Fill, Undocumented (Afu)

The existing undocumented artificial fill soils encountered in the test pits generally varied in depth across the site from approximately 1 to 7.5 feet bgs, with the exception of test pit location TP-9 (see Plate 1), located in the eastern portion of the site where the bottom of the artificial fill materials at test pit TP-9 was not encountered. The approximate depth of artificial fill as encountered in each test pit is shown on Plate 1, *Geotechnical Map*. Localized thicker accumulations of fill materials should be anticipated during future earthwork construction between explored locations. The existing artificial fill materials encountered at the site generally consist of variable proportions of clay, silt, sand and gravel with some concrete and asphalt and other miscellaneous debris intermixed and are likely associated with the previous improvements and former oil production/bioremediation activities performed at the site. Concrete debris up to approximately 12 inches in largest dimension was encountered, larger debris may be encountered during rough grading. Records documenting observation and testing for compaction during fill placement were not available for review.

Test pit TP-9 was terminated at 7 feet bgs prior to reaching the base of the artificial fill due to stained soil that was encountered between approximately 5.3 and 7 feet bgs. It was decided in the field at the time of excavation per discussions with the onsite environmental consultant for the project (Hayley & Aldrich, Inc.) to terminate the excavation at this location to avoid excavating large quantities of stained soil without having a clear understanding of the contaminates of concern (COC). The stained soils excavated from the test pit

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were sampled, tested for environmental classification and drummed for offsite disposal by Hayley & Aldrich, Inc. Several step-out direct push test borings were subsequently performed by Haley & Aldrich, Inc. in 4 directions from test pit TP-9 to further evaluate the depth and lateral extent of the stained soil encountered in the area. Based on interpretations of fill thickness provided by Hayley & Aldrich, Inc., undocumented artificial fill in this area is on the order of up to roughly 25 feet below existing grade, and appears to be generally isolated to an area (in map view) roughly 100 feet long by 60 to 70 feet wide. The approximate area where thicker accumulations of artificial fill are anticipated in this portion of the project site is shown on Plate 1. In addition, thicker accumulations of artificial fill should also be anticipated in the northeastern portion of the project site and in the western portion of the project site in the vicinity of the 8 wells that are reported to be plugged and abandoned.

Quaternary Old Alluvial Valley Deposits (Qoa)

The Quaternary age (Pleistocene age 11,700 to 1.8 million years) old alluvial valley deposits encountered below the fill consist of sediments deposited over a broad floodplain or valley primarily as sheet flow during regional flooding events. These sediments are characterized as slightly to moderately consolidated clay, silt, sand and gravel. As encountered in the test pits excavated at the site, the native alluvial soils are variable and generally consist of brown, reddish brown and yellow brown, slightly moist to moist, silty sand, sandy silt, clayey silt, sandy clay silty clay and clay with some calcium carbonate observed through reaction with diluted hydrochloric acid.

More detailed description of the subsurface soils encountered in the test pits are presented on the test pit logs included in Appendix A. Some of the engineering properties of these soils are described in the following subsections.

2.2.1 Expansive Soil

Expansive soils contain significant amounts of clay particles that swell considerably when wetted and shrink when dried. Foundations constructed on these soils are subject to uplifting forces caused by the swelling. Without proper mitigation measures, heaving and cracking of both building foundations and slabs-on-grade could result. Based on our field exploration and laboratory testing of representative near-surface soil

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samples, the onsite soils are generally considered to have a moderate potential for expansion (Expansion Index [EI] of 50 and 81).

It is our opinion that the proposed residential buildings will not be adversely impacted by soil expansion provided recommendations in this report are included in design and followed during construction of the residential buildings. Additional testing is recommended upon completion of rough grading to confirm the assumptions made in this report.

2.2.2 Soil Corrosivity

For screening purposes, two representative near-surface bulk soil samples were tested for corrosivity to preliminarily evaluate corrosion potential to buried concrete (e.g., footings, retaining walls). The chemical analysis test results are included in Appendix B of this report and are summarized below.

Corrosivity Test Results

Test Parameter	Test Results TP-5 @ 0'-5' and TP-10 @ 2.5'-5'	General Classification of Hazard
Water-Soluble Sulfate in Soil (ppm)	151 to 242	Negligible sulfate exposure to buried concrete
Water-Soluble Chloride in Soil (ppm)	61 to 305	Non-corrosive to buried concrete
pH	6.52 to 7.12	Mildly acidic to mildly alkaline
Minimum Resistivity (saturated, ohm-cm)	914 to 1145	Severely corrosive to buried ferrous pipes (per Caltrans)

The results of the resistivity test indicate that the underlying soil is severely corrosive to buried ferrous metals per ASTM STP 1013. Based on the measured water-soluble sulfate contents from the soil samples, concrete in contact with the soil is expected to have negligible exposure to sulfate attack per ACI 318-11. The samples tested for water-soluble chloride content indicate a low potential for corrosion of steel in concrete due to the chloride content of the soil.

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2.3 Groundwater

Groundwater was not encountered during our field exploration. The historical high groundwater levels in the Dominguez Hills area were not extensively evaluated by the California Geological Survey (CGS, 1998) since groundwater is deep in this area (at least greater than 40 feet bgs). In addition, the Dominguez Hills are generally composed of slightly elevated and older (Pleistocene age) alluvial soil that is generally not considered to be a significant water bearing geologic unit.   Based on the currently proposed development scheme, groundwater is not expected to pose a constraint during and after construction.

Although groundwater is not considered a constraint for the project, localized zones of perched water or elevated moisture in near-surface soils may develop once site development is completed and stormwater infiltration and landscape irrigation commences.

2.4 Soil Infiltration Characteristics

In-situ percolation testing was performed at the site in general accordance with the *Excavation Percolation Test Procedure* as outlined in the County of Los Angeles Department of Public Works (LADPW) *Guidelines for Design, Investigation, and Reporting Low Impact Development Stormwater Infiltration* (LADPW, 2014). Test Pits TP-1A and TP-12A located in the western portion of the site were excavated to depths of approximately 3 feet and 3.5 feet bgs, respectively, for evaluation of the near-surface soil infiltration characteristics at the site (Plate 1, *Geotechnical Map*). A 1 foot wide by 1 foot long by 1 foot deep hole was hand dug at the bottom of each test pit for infiltration evaluation. The percolation test holes were pre-soaked prior to the testing. The testing was performed by filling each test hole with water and measuring the water level drop over each time interval. After the conclusion of the percolation test, the test pits were backfilled with excess soil cuttings.

The measured infiltration rates for the percolation tests were calculated by dividing the preadjusted percolation rate (average drop of the stabilized rate over the last three readings) by a reduction factor provided in the LADPW (2014) guidelines to account for the discharge of water from both the sides and bottom of the test holes. Detailed results of the field testing data and measured

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infiltration rates for the test holes are presented in Appendix C, *Percolation Test Results*. The test results are summarized below:

Measured (Unfactored) Infiltration Rate

Percolation Test Pit Designation	Approximate Depth of Test Zone Below Ground Surface (feet)	Measured Infiltration Rate (inch per hour)
TP-1A	3 to 4	0.41
TP-12A	3.5 to 4.5	0.18

The test results indicate very low infiltration rates at the tested locations and depths. Once a minimum recommended correction factor of 2 is applied to the measured infiltration rates at test locations TP-1A and TP-12A (Plate 1), these rates do not meet the minimum requirement for stormwater infiltration feasibility (0.3 inch per hour) per the LADPW (2014) guidelines.

Based on our current subsurface exploration, the near-surface native soils beneath the site are generally fine grained silty sand, sandy silt, clayey silt, sandy clay silty clay and clay silty clay, sandy clay and clayey silt and generally do not provide adequate infiltration potential as indicated by the very low infiltration rates.

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Approximate Site Boundary

N

0	2,000	4,000

Feet

Project: 11738.001	Eng/Geol: CCK/JMP	**SITE LOCATION MAP**	Figure 1
Scale:1 " = 2,000 '	Date: September 2017	Proposed Residential Development NE Corner of Central Avenue and Victoria Street Carson, California	
Base Map: ESRI ArcGIS Online 2017 Thematic Information: Leighton Author: Leighton Geomatics (btran)			Leighton

Map Saved as V:\Drafting\11738\001\Maps\11738-001_F01_SLM_2017-09-15.mxd on 9/12/2017 11:48:30 AM

APPENDIX C

PERCOLATION TEST RESULTS

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Excavation Percolation Test Data Sheet

Project Number:	11738.001	**Test Hole Number:**	TP-1A
Project Name:	Integral Carson	**Date Excavated:**	9/1/2017
Earth Description:	Alluvium	**Date Tested:**	9/7/2017
Liquid Description:	Tap water	**Depth of test hole (in):**	12
Tested By:	JMP	**Length of test hole (in):**	12
Time Interval Standard		**Width of test hole (in):**	12
Standard Time Interval Between Readings, mins:	30	**Equivalent Boring Diameter, DIA (in):**	13.5

Percolation Data

Reading	Time	Time Interval, Δt (min.)	Initial/Final Depth to Water (in.)	Initial/Final Water Height, H_o/H_f (in.)	Total Water Drop, Δd (in.)	Percolation Rate (in./hr.)
1	7:42	30	0.00	12.00	1.63	3.25
	8:12		1.63	10.38		
2	8:12	30	0.00	12.00	1.13	2.25
	8:42		1.13	10.88		
3	8:42	30	0.00	12.00	0.75	1.50
	9:12		0.75	11.25		
4	9:12	30	0.00	12.00	0.75	1.50
	9:42		0.75	11.25		
5	9:42	30	0.00	12.00	0.63	1.25
	10:12		0.63	11.38		
6	10:12	30	0.00	12.00	0.63	1.25
	10:42		0.63	11.38		
7	10:42	30	0.00	12.00	0.50	1.00
	11:12		0.50	11.50		
8	11:12	30	0.00	12.00	0.56	1.13
	11:42		0.56	11.44		

Preadjusted Percolation Rate = Average drop of the stabilized rate over last 3 readings

Reduction Factor $(R_f) = [(2H_o - \Delta d)/DIA] + 1$

Infiltration Rate (I) = Preadjusted Percolation Rate / Reduction Factor

Reduction Factor, R_f =   2.73

Infiltration Rate, I =   **0.41**   in./hr.

Excavation Percolation Test Data Sheet

Project Number:	11738.001	**Test Hole Number:**	TP-12A
Project Name:	Integral Carson	**Date Excavated:**	9/1/2017
Earth Description:	Alluvium	**Date Tested:**	9/7/2017
Liquid Description:	Tap water	**Depth of test hole (in):**	12
Tested By:	JMP	**Length of test hole (in):**	12
Time Interval Standard		**Width of test hole (in):**	12
Standard Time Interval Between Readings, mins:	30	**Equivalent Boring Diameter, DIA (in):**	13.5

Percolation Data

Reading	Time	Time Interval, Δt (min.)	Initial/Final Depth to Water (in.)	Initial/Final Water Height, H_o/H_f (in.)	Total Water Drop, Δd (in.)	Percolation Rate (in./hr.)
1	6:51	30	0.00	12.00	1.75	3.50
	7:21		1.75	10.25		
2	7:21	30	0.00	12.00	1.13	2.25
	7:51		1.13	10.88		
3	7:51	30	0.00	12.00	0.75	1.50
	8:21		0.75	11.25		
4	8:21	30	0.00	12.00	0.25	0.50
	8:51		0.25	11.75		
5	8:51	30	0.00	12.00	0.38	0.75
	9:21		0.38	11.63		
6	9:21	30	0.00	12.00	0.25	0.50
	9:51		0.25	11.75		
7	9:51	30	0.00	12.00	0.25	0.50
	10:21		0.25	11.75		
8	10:21	30	0.00	12.00	0.25	0.50
	10:51		0.25	11.75		

Preadjusted Percolation Rate = Average drop of the stabilized rate over last 3 readings

Reduction Factor $(R_f) = [(2H_o - \Delta d)/DIA] + 1$

Infiltration Rate (I) = Preadjusted Percolation Rate / Reduction Factor
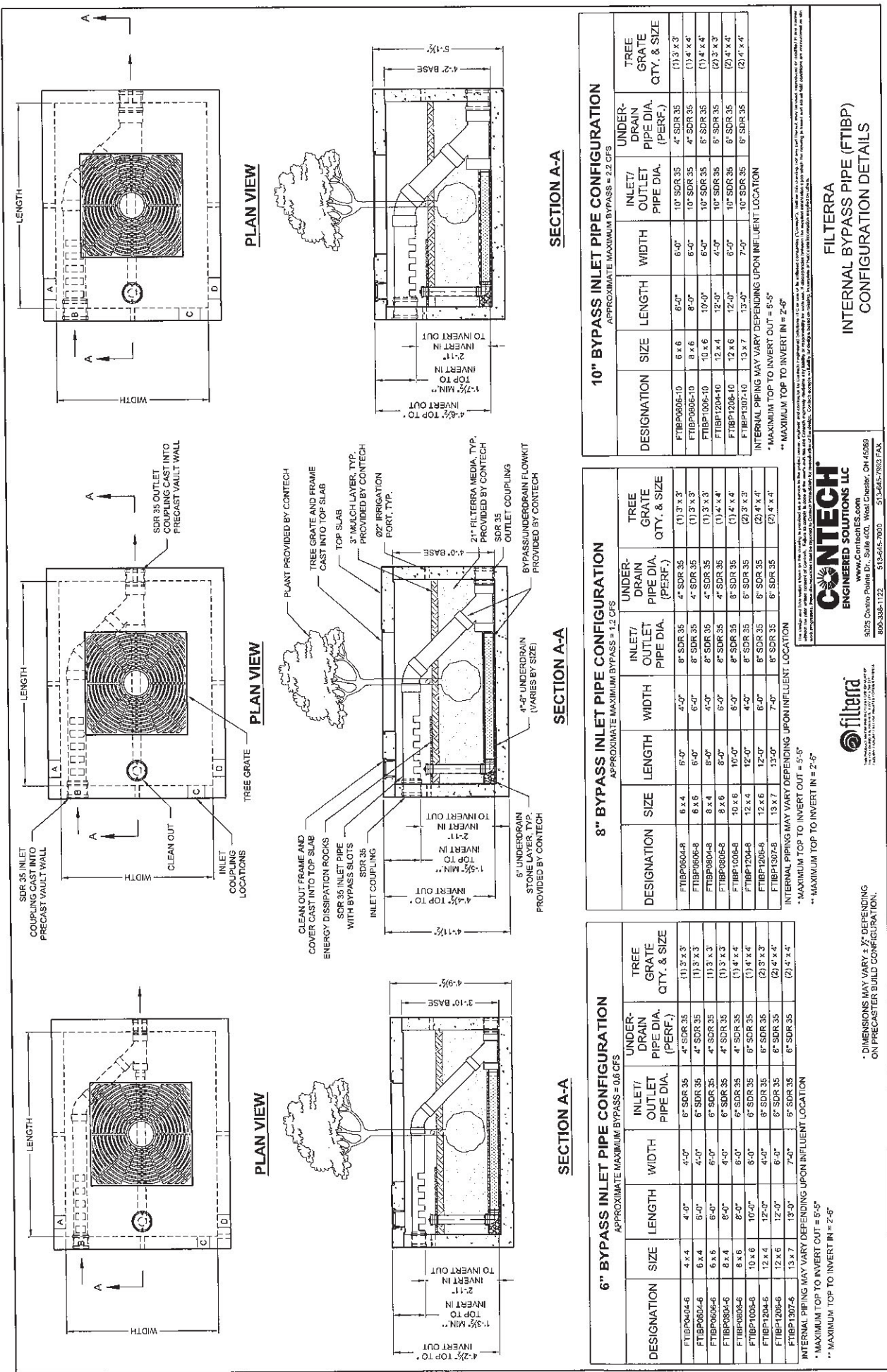
Reduction Factor, R_f =   2.75

Infiltration Rate, I =   0.18   in./hr.

CITY OF CARSON
COMMUNITY DEVELOPMENT DEPARTMENT

CONSTRAINTS MAP
FOR CONDOMINIUM PURPOSES

VESTING TENTATIVE TRACT MAP NO. 78226

INTEGRAL COMMUNITIES

URBAN RESOURCE

GRAPHIC SCALE
(IN FEET)
1 inch = 40 feet

PROJECT SITE BOUNDARY

Streets and Roads: CENTRAL AVENUE, ASPEN HILL ROAD, VICTORIA STREET

CITY OF COMPTON / CITY OF CARSON

TRACT BOUNDARY

PARCEL MAP 11180 — PMB 107/25
TRACT 52103
PARCEL 2 — PARCEL MAP 289/14 — PMB 289/14 — APN 7319-003-104
PARCEL 1 — PARCEL MAP 24971 — PMB 289/14 — APN 7319-003-108
PARCEL 3 — PARCEL MAP 24971 — PMB 289/14 — APN 7319-003-105
PARCEL 5 — PARCEL MAP 24971 — APN 7319-003-106
PARCEL 6 — PARCEL MAP 24971 — PMB 278/35-40
PARCEL 4 — PARCEL MAP 21929 — PMB 278/35-40
PARCEL 2 — PARCEL MAP 21929 — PMB 278/35-40

NOT A PART

EASEMENT NOTES

UTILITY PURVEYORS

WATER — CALIFORNIA WATER SERVICE COMPANY
CABLE — THE WARNER CABLE
GAS — SOUTHERN CALIFORNIA GAS CO.
ELECTRICAL — SOUTHERN CALIFORNIA EDISON CO.
TELEPHONE — AT&T
TRASH — WASTE MANAGEMENT
STORM DRAIN — CITY OF CARSON

LEGEND

TP-15 — Approximate location of geotechnical test pit (TP)
4'-6" — Approximate depth of undocumented artificial fill in feet
HA-53 — Approximate location of direct push boring

Department of Public Works
dpw.lacounty.gov

LIST OF PROPRIETARY STORMWATER BMPs ACCEPTABLE FOR MAINTENANCE BY LACDPW

Products on this list were evaluated by County Department of Public Works staff according to specific operational and maintenance criteria and were judged acceptable for installation in the Flood Control District drainage system under certain conditions and limitations. The absence of a proprietary product on this list does not mean it is unsuitable for private use and maintenance. For more information and a report of the conditions and limitations, contact the vendor by clicking on the vendor name.

PRODUCT	MODEL	DATE OF ACCEPTANCE	VENDOR
Filterra		02/17/2010	Contech Enginnered Solutions
Coanda Screen		06/01/2011	Coanda, Inc.
Clean Screen III		07/20/2009	United Stormwater, Inc.
Cam Debris Gate		07/20/2009	G2 Construction
West Coast Storm Screen		07/20/2009	West Coast Storm, Inc.
Surf Gate		07/20/2009	American Stormwater
Bacterra		02/17/2010	Contech Engineered Solutions
Top Swing Gate		07/20/2009	Waterway Solutions, LLC
Urban Green Biofilter		10/06/2011	Contech, Inc.
Jellyfish	JF4, JF6, JF8, JF10, JF12	12/14/2010	Contech Engineered Solutions
STS-1		02/14/2011	EnviroEnergy, Inc.
CDS		02/25/2013	CONTECH Engineered Solutions
Grate Inlet Skimmer Box	GISB-39.68-25-24-LAC	08/06/2013	Bio Clean Environmental Services, Inc.

PLAN VIEW

PLAN VIEW

PLAN VIEW

SECTION A-A

SECTION A-A

SECTION A-A

LENGTH
WIDTH

SDR 35 OUTLET COUPLING CAST INTO PRECAST VAULT WALL

SDR 35 INLET COUPLING CAST INTO PRECAST VAULT WALL
CLEAN OUT
INLET COUPLING LOCATIONS
TREE GRATE

PLANT PROVIDED BY CONTECH
TREE GRATE AND FRAME CAST INTO TOP SLAB
TOP SLAB
3" MULCH LAYER, TYP. PROVIDED BY CONTECH
18" IRRIGATION PORT, TYP.
21" FILTERRA MEDIA, TYP. PROVIDED BY CONTECH
SDR 35 OUTLET COUPLING
BYPASS/UNDERDRAIN FLOWKIT PROVIDED BY CONTECH

CLEAN OUT FRAME AND COVER CAST INTO TOP SLAB
ENERGY DISSIPATION ROCKS
SDR 35 INLET PIPE WITH BYPASS SLOTS
SDR 35 INLET COUPLING
4"-6" UNDERDRAIN (VARIES BY SIZE)
6" UNDERDRAIN STONE LAYER, TYP. PROVIDED BY CONTECH

INVERT OUT
TO INVERT OUT
1'-3½" MIN.
TOP TO INVERT IN
2'-11"
TO INVERT OUT
4'-6½" TOP TO

4'-0" BASE
4'-11½"

10" BYPASS INLET PIPE CONFIGURATION
APPROXIMATE MAXIMUM BYPASS = 2.2 CFS

DESIGNATION	SIZE	LENGTH	WIDTH	INLET/OUTLET PIPE DIA.	UNDER-DRAIN PIPE DIA. (PERF.)	TREE GRATE QTY. & SIZE
FTIBP0606-10	6 x 6	6'-0"	6'-0"	10" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0806-10	8 x 6	8'-0"	6'-0"	10" SDR 35	4" SDR 35	(1) 4' x 4'
FTIBP1006-10	10 x 6	10'-0"	6'-0"	10" SDR 35	6" SDR 35	(1) 4' x 4'
FTIBP1204-10	12 x 4	12'-0"	4'-0"	10" SDR 35	6" SDR 35	(2) 3' x 3'
FTIBP1206-10	12 x 6	12'-0"	6'-0"	10" SDR 35	6" SDR 35	(2) 4' x 4'
FTIBP1307-10	13 x 7	13'-0"	7'-0"	10" SDR 35	6" SDR 35	(2) 4' x 4'

INTERNAL PIPING MAY VARY DEPENDING UPON INFLUENT LOCATION
* MAXIMUM TOP TO INVERT OUT = 5'-5"
** MAXIMUM TOP TO INVERT IN = 2'-6"

8" BYPASS INLET PIPE CONFIGURATION
APPROXIMATE MAXIMUM BYPASS = 1.2 CFS

DESIGNATION	SIZE	LENGTH	WIDTH	INLET/OUTLET PIPE DIA.	UNDER-DRAIN PIPE DIA. (PERF.)	TREE GRATE QTY. & SIZE
FTIBP0604-8	6 x 4	6'-0"	4'-0"	8" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0606-8	6 x 6	6'-0"	6'-0"	8" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0804-8	8 x 4	8'-0"	4'-0"	8" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0806-8	8 x 6	8'-0"	6'-0"	8" SDR 35	4" SDR 35	(1) 4' x 4'
FTIBP1006-8	10 x 6	10'-0"	6'-0"	8" SDR 35	6" SDR 35	(1) 4' x 4'
FTIBP1204-8	12 x 4	12'-0"	4'-0"	8" SDR 35	6" SDR 35	(2) 3' x 3'
FTIBP1206-8	12 x 6	12'-0"	6'-0"	8" SDR 35	6" SDR 35	(2) 4' x 4'
FTIBP1307-8	13 x 7	13'-0"	7'-0"	8" SDR 35	6" SDR 35	(2) 4' x 4'

INTERNAL PIPING MAY VARY DEPENDING UPON INFLUENT LOCATION
* MAXIMUM TOP TO INVERT OUT = 5'-5"
** MAXIMUM TOP TO INVERT IN = 2'-6"

6" BYPASS INLET PIPE CONFIGURATION
APPROXIMATE MAXIMUM BYPASS = 0.6 CFS

DESIGNATION	SIZE	LENGTH	WIDTH	INLET/OUTLET PIPE DIA.	UNDER-DRAIN PIPE DIA. (PERF.)	TREE GRATE QTY. & SIZE
FTIBP0404-6	4 x 4	4'-0"	4'-0"	6" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0604-6	6 x 4	6'-0"	4'-0"	6" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0606-6	6 x 6	6'-0"	6'-0"	6" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0804-6	8 x 4	8'-0"	4'-0"	6" SDR 35	4" SDR 35	(1) 3' x 3'
FTIBP0806-6	8 x 6	8'-0"	6'-0"	6" SDR 35	6" SDR 35	(1) 4' x 4'
FTIBP1006-6	10 x 6	10'-0"	6'-0"	6" SDR 35	6" SDR 35	(2) 3' x 3'
FTIBP1204-6	12 x 4	12'-0"	4'-0"	8" SDR 35	6" SDR 35	(2) 4' x 4'
FTIBP1206-6	12 x 6	12'-0"	6'-0"	6" SDR 35	6" SDR 35	(2) 4' x 4'
FTIBP1307-6	13 x 7	13'-0"	7'-0"	6" SDR 35	6" SDR 35	(2) 4' x 4'

INTERNAL PIPING MAY VARY DEPENDING UPON INFLUENT LOCATION
* MAXIMUM TOP TO INVERT OUT = 5'-5"
** MAXIMUM TOP TO INVERT IN = 2'-6"

FILTERRA
INTERNAL BYPASS PIPE (FTIBP)
CONFIGURATION DETAILS

* DIMENSIONS MAY VARY ± ½" DEPENDING ON PRECASTER BUILD CONFIGURATION.

C:\USERS\NGUTOSELL\DESKTOP\FILTERRA\FTIBP-FTIBP CONFIGURATION DETAIL.DWG 12/17/2015 2:12 PM

Contech Engineered Solutions LLC
9025 Centre Pointe Drive, Suite 400
West Chester, OH 45069
Phone: (513) 645-7000
Fax: (513) 645-7993
www.ContechES.com

Guidance for Designing Filterra® Systems with Full Grate Covers

Figures 1 & 2. Filterra with Full Grate Installed

System Design

- Systems should be designed following all typical design guidance for standard Filterra configurations (FT, FTIBC, FTIBP, etc).

- Maximum distance from rim to media must be less than or equal to 3 feet.

- Plants <u>must</u> be utilized for proper performance and to maintain Contech's 1-year warranty.

Plant Selection

- Low Growing Shade Tolerant plant species should be selected.

- The following list provides options, but other available species may be considered by Contech upon request:

Latin Name	Common Name	Height	Availability
Acorus gramineus 'Ogon'	Yellow-leaved Calamus	1'	Southwest
Asplenium trichomanes	Maidenhair spleenwort fern	1'	Northwest
Carex morowii	Ice Dance Japanese Sedge	1' - 2'	East
Carex obnupta	Slough Sedge	1' - 3'	Northwest, Southwest
Carex oshimensis 'Evergold'	Variegated Japanese Sedge	1' - 2'	Southwest
Hakonechloa macra	Japanese Forest Grass	1' - 2'	East, Northwest
Heuchera maxima	Island Alum Root	1'	Southwest
Hosta	Hosta	1' - 3'	East, Northwest
Juncus patens	California Gray Rush	1' – 2'	Southwest
Ophiopogon nigrescens	Black Mondo Grass	1'	Northwest
Pennisetum alopecuroides 'Hameln'	Fountain Grass	1' -3'	East, Northwest
Salvia spathacea	Hummingbird Sage	1' - 2'	Southwest

WHITE PAPER

Filterra® Bioretention Systems: Technical Basis for High Flow Rate Treatment and Evaluation of Stormwater Quality Performance

Prepared by

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consultants

September 20, 2010

Abstract

Media flow rate is one of many variables that influence the performance of bioretention systems. While conventional thinking is that bioretention systems with lower media flow rates provide better pollutant removal, a review of scientific principles and monitoring data suggests otherwise. Based on a review of scientific principles, the Filterra® Bioretention Stormwater Treatment System is expected to be capable of achieving pollutant removal efficiencies and system longevity on par with conventional slow flow rate bioretention systems. A review of monitoring data demonstrates that Filterra® systems are capable of achieving higher pollutant removal efficiency ratios and lower effluent concentrations, on average, compared to similar categories of non-proprietary stormwater treatment best managements practices (BMPs). In addition, Filterra® systems showed statistically significant removals for a broader range of pollutants than similar classes of non-proprietary BMPs. Finally, hydraulic performance data demonstrate sustained high media flowrates in Filterra® systems over a variety of ages. Overall, this paper finds that incorporation of a specialized media that can efficiently treat stormwater at a high flow rate while supporting biological processes within a relatively small footprint makes the Filterra® Bioretention System an effective tool based on low impact development (LID) principles.

1. Executive Summary

Conventional thinking is that slow flow rate bioretention media works better than high flow rate bioretention media to remove pollutants from stormwater; however, an understanding of the pollutant removal mechanisms of bioretention systems and analysis of water quality data collected from high flow rate systems demonstrates that this is not the case. In addition, the common use of high flow rate media and natural high flow systems for both water and wastewater treatment provides long standing empirical evidence of the effectiveness of these types of systems.

The dominant unit treatment processes provided by bioretention systems occur predominantly during storm events and consist of inert and reactive filtration. A review of the scientific principles behind these mechanisms suggests that high flow rate bioretention media would not necessarily achieve significantly lower removal of particulate-bound and dissolved constituents than low flow rate media. Processes occurring between storm events are also critical for the retention of captured pollutants and the preservation or regeneration of hydraulic capacity and the function of the dominant treatment mechanisms. Inter-storm processes, including microbially-mediated transformations, biological uptake and sequestration, volatilization, bacterial inactivation processes, soil processes, and routine maintenance, do not vary significantly between high flow rate and slow flow rate bioretention systems. The Filterra® Bioretention System (Filterra® system) is designed to promote the within-storm and inter-storm treatment processes characteristic of bioretention systems through the incorporation of mulch, specialized media, and biologically active components. Based on a review of scientific principles, the Filterra® system is expected to be capable of achieving pollutant removal efficiencies and system longevity on par with conventional slow flow rate bioretention systems.

Third-party analyses of the Filterra® system have demonstrated sustained high media flow rates and treatment performance. Laboratory scale testing results support media filtration rates of greater than 100 inches per hour. Results from field scale testing of hydraulic function of systems of a variety of ages support the current design flow rate recommendation of 100 to 140 inches per hour. Field scale testing of treatment performance has demonstrated variable, but generally high and sustained performance. Results from five field studies were fairly consistent for total suspended solids (TSS) with efficiency ratios ranging from 83 to 88 percent. The efficiency ratio for total phosphorus had a much wider range from 9 to 70 percent, across five studies; the low end of this range was due to low total phosphorus concentrations and high fractions of soluble reactive phosphorus measured during one study. Total Kjeldahl nitrogen (TKN) had an efficiency ratio of 40 percent in one study. The efficiency ratio for total copper ranged from 33 to 77 percent in three studies, while dissolved copper had an efficiency ratio of 48 percent in one study. The efficiency ratio for total zinc removal ranged from 48 to 79 percent in three studies, while dissolved zinc had an efficiency ratio of 55 percent in one study. The oil and grease efficiency ratio was lower than expected (59 percent) due to low influent concentrations near the detection limit in one study; however, the total petroleum hydrocarbon (TPH) efficiency ratio was 96 percent in a different study.

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Effluent concentrations achieved in the full-scale studies were generally equal to or lower than median effluent concentrations for the biofilter and media filter classes of best management practices (BMPs) reported in the International Stormwater BMP Database. In addition, Filterra® systems showed statistically significant removals for a broader range of pollutants than were shown for the biofilter and media filter categories in the International Stormwater BMP Database.

In summary, the Filterra® Bioretention System incorporates a specialized media that can treat stormwater at a high flow rate to provide pollutant removal capabilities using a relatively small footprint compared to slow flow rate bioretention systems. These design characteristics make the Filterra® system a well-suited BMP, designed based on low impact development (LID) principles, for a wide variety of conditions, allowing pollutant loads to be addressed close to their source even on space-constrained sites where the use of traditional slow flow rate systems would be problematic or infeasible. The Filterra® system also supports inter-storm processes that work to preserve and restore treatment capacity and hydraulic function. These processes are believed to help preserve the longevity of the system and reduce the need for major maintenance and media replacement.

2. Introduction

Conventional thinking is that slow flow rate bioretention media works better than high flow rate bioretention media to remove pollutants from stormwater; however, an understanding of the pollutant removal mechanisms of bioretention systems and analysis of water quality data collected from high flow rate systems demonstrates that this is not necessarily the case. This paper discusses the pollutant removal mechanisms and presents the technical basis to demonstrate the effectiveness of high flow rate media used in the Filterra® Bioretention Stormwater Treatment System (Filterra® system) developed by Americast, Inc.

Similar to rain gardens and planter boxes, the Filterra® system design is based on bioretention and LID principles. Bioretention technologies operate similarly to media filters (e.g., sand or organic/sand filters) in terms of particulate removal and sorption of reactive constituents. Additional unit treatment processes inherent to bioretention designs include microbially-mediated transformations, biological uptake, evapotranspiration, and other processes associated with the vegetation and root structure. A key difference between bioretention systems and biologically inactive media filtration systems is the contribution of these biological processes to the retention and sequestration of captured pollutants and preservation and regeneration of hydraulic function and pollutant removal capacity; therefore, bioretention systems can be considered a sustainable design.

Bioretention technology design ranges from conventional bioretention media facilities (with large unit storage volumes and a relatively slow filtration rate) to specialized media facilities (with small unit storage volumes and a high filtration rate). Filterra® systems lie near the latter end of this continuum by treating stormwater near its source, filtering stormwater at a high rate,

allowing for a small footprint, and providing a standardized, easily installed and maintained design. Specialized media in the Filterra® system is designed to optimize both a high flow rate and the treatment capacity of the system. Inter-storm processes help to maintain these higher flow rates and partially regenerate the pollutant removal capacity of the media. High flow rate media and natural high flow systems are commonly used in both water and wastewater treatment (Crites and Tchobanoglous 1998).

Section 3 of this white paper discusses treatment processes inherent to bioretention systems, with a specific discussion of how media flow rates are expected to affect system performance. The unit treatment mechanisms provided by Filterra® systems are discussed in Section 4.1, and a summary of laboratory and field-scale evaluations of Filterra® system performance are provided in Sections 4.2, and 4.3, respectively. Results from flow rate longevity studies and recommendations for system maintenance are provided in Section 4.4.

3. Review of Unit Treatment Processes Provided by Bioretention Systems

3.1 The Unit Treatment Process Approach

The unit treatment process approach to stormwater BMP selection and design is a widely accepted approach that explicitly considers the characteristics of the pollutants of concern to identify effective removal mechanisms that target those pollutants. The stormwater treatment system is then designed to include components that provide the identified removal mechanisms. This approach has been recommended in stormwater guidance documents published by respected national research organizations (WERF 2005; NCHRP 2006) and is recognized as a robust approach for BMP selection and design.

Bioretention systems provide numerous removal mechanisms to address a variety of stormwater pollutants. For the purposes of this white paper, the key unit treatment processes provided by bioretention areas are classified as *within-storm treatment processes* and *inter-storm treatment processes*:

> *Within-storm treatment processes* act on stormwater as it fills the bioretention system, flows through the system, and is drawn down after the event. Most bioretention systems are designed to:
>
> 1. Process a significant volume of water during an event
> 2. Draw down the remaining volume relatively quickly following an event
> 3. Retain little water between events
>
> Therefore, within-storm processes are considered the most important for the removal of pollutants from stormwater; the bulk of load reductions occur as stormwater is briefly retained on the vegetated surface and then passed through the underlying porous media to the bioretention system underdrains or to the underlying native soils.

Inter-storm treatment processes act on water and pollutants remaining in the bioretention system (i.e., within soil pore spaces) for days, weeks, or months between storm events. Inter-storm treatment processes do not provide a significant direct contribution to pollutant removal due to the relatively small volume of water retained within media pore spaces after an event, but are critical for the retention of captured pollutants and the preservation or regeneration of within-storm treatment mechanisms. For example, mechanisms like microbially-mediated transformations and biological uptake can stabilize pollutants and regenerate sorption sites.

Bioretention systems provide the following key pollutant removal mechanisms:

Within-storm Treatment Processes	**Inter-storm Treatment Processes**
▪ Inert Filtration (including surface sedimentation)	▪ Microbially-mediated Transformations
▪ Reactive Filtration	▪ Biological Uptake and Sequestration
	▪ Volatilization
	▪ Bacterial Inactivation Processes
	▪ Soil Processes
	▪ Routine Maintenance

In addition to the efficiency of a BMP in removing of pollutants from treated water, the overall effectiveness of a BMP in reducing pollutant loads is a function of the percentage of the long term stormwater runoff volume that the BMP captures and treats (i.e., the capture efficiency), and percentage of this volume that is lost to infiltration and evapotranspiration and is not discharged (i.e., volume reduction). Capture efficiency is dependent on runoff patterns, the storage volume of the BMP, the rate at which water is processed during a storm event, and the rate at which the stored water is drawn down after an event. Bioretention systems with higher media flow rates can achieve relatively high capture efficiency in smaller footprints, while bioretention systems with slower flow rates generally require more storage volume and a larger footprint to achieve the same capture efficiency. Volume reduction is a function of the surface area of the BMP, the infiltration rate of underlying soils, depth to groundwater, the moisture retention capacity of the media, and the evapotranspiration rates during the periods between storm events. For bioretention systems without an impermeable liner, volume loss to infiltration can be an important mechanism for removal of pollutant loads; volume losses to evapotranspiration tend to be relatively minor for both lined and unlined bioretention systems.

3.2   Within-storm Treatment Processes

As mentioned above, within-storm treatment processes for bioretention systems primarily include those that are associated with surface detention and filtration. For the purpose of discussion, removal mechanisms are divided into two types of filtration:

1.   ***Inert filtration:*** filtration components that remove particulate-bound pollutants through physical processes (e.g., straining); sedimentation at the surface of a filter bed is considered to be a component of inert filtration

2.   ***Reactive filtration:*** filtration components that remove dissolved and colloidal pollutants through chemical or biological processes

The following sections describe these processes as they apply to conventional and high flow rate bioretention systems.

3.2.1   Inert Filtration

Inert filtration involves six distinct mechanisms (Metcalf and Eddy 2003):

1.   ***Straining*** – surficial straining or chance contact within the filter

2.   ***Sedimentation*** – particles settle on the filtering medium within the filter

3.   ***Impaction*** – heavy particles cannot follow the flow streamlines

4.   ***Interception*** – particles following streamlines are removed upon contact with media surfaces

5.   ***Adhesion*** – particles become attached to surfaces as they pass by

6.   ***Flocculation*** – large particles overtake small particles and join them to form larger particles

Inert filtration is the dominant treatment mechanism for particulate-bound pollutants in bioretention systems where removal is primarily accomplished by sedimentation and retention of particles near the surface via surface straining, cake filtration, and shallow depth filtration. Surface straining is the retention of particles larger than the pore size at the surface of the media bed. Cake filtration occurs after particles have accumulated on the surface and this "cake" layer begins to control the filtration process. Depth filtration retains small particles that are unable to follow the convoluted paths through the media, where removal is primarily caused by electrostatic attraction of particles to media, and micro-settling when laminar zones around the media particles are formed.

Vegetation and mulch at the surface of bioretention systems also play an important role in inert filtration processes by helping to promote localized settling and inhibiting the re-suspension of settled pollutants. The roots and stems of plants also help keep soils open for infiltration, effectively counteracting clogging mechanisms associated with filtration.

For poorly-graded media beds (i.e., uniformly-graded sand), the ability of inert filtration to retain a specific particle size is primarily a function of filter media particle size and bed depth. As a general rule, when the median particle size of the influent is greater than one-tenth the median particle size of the media, surface filtration (also known as cake filtration) will dominate (Sansalone and Teng 2004; Teng and Sansalone 2004). Depth filtration also occurs for smaller particles, but as influent particles become very small relative to the median particle size of the media, mechanical filtration is no longer effective and sorption processes tend to dominate.

The depth of the media bed becomes a critical design factor when depth filtration and sorption processes dominate. However, depths greater than 24 inches are typically not needed to achieve high sediment removal in granular media filters (Crites and Tchabanoglous 1998). Further, the top layer of the soil column represents the biologically active zone in which much of the microbial, animal, and plant activity takes place.

Table 1 summarizes the dominant filtration mechanism by median diameter of the media ($D50_{media}$) and median diameter of the influent particles ($D50_{influent}$).

Table 1. **Dominant filtration mechanism based on media and influent particle size.**

Condition	Dominant Removal Mechanisms for Particles
$D50media / D50influent < 10$	Surface filtration (cake filtration)
$10 < D50media / D50 influent < 20$	Depth filtration of particulates
$D50media / D50 influent > 20$	Physical sorption of colloidal particulates

Source: Sansalone and Teng (2004)

$D50_{media}$ is the median diameter of the media (by mass).

$D50_{influent}$ is the median diameter of the influent particles (by mass).

Based on the classical model of a uniformly-graded media bed filter developed by O'Melia and Ali (1978), permeability is inversely proportional to the square of the specific surface area of the filter (internal surface area per bed volume). Because the internal surface area decreases as the media particle size increases, larger media particle sizes are required to increase the treatment flow rate. As shown by the relationships presented in Table 1, an increase in media particle size would tend to result in less removal by cake filtration, and more removal by depth filtration for a given stormwater particle size distribution. Thus, an increase in media particle size requires an increase in bed depth to achieve equivalent particle removal performance (Yao 1971). However, Johnson et al. (2003) found that particle removal within various media filters did not increase as contact times increased beyond about 3 minutes.

While the classical model is useful in understanding filtration concepts, bioretention systems may behave differently. Bioretention media beds are not commonly designed to utilize the full depth of filtration. Media bed depth is typically selected to provide sufficient contact time for reactive filtration processes rather than to provide greater depth for inert bed filtration. Li and Davis (2008) found that TSS particles typically will not penetrate beyond the first 2 to 8 inches (5 to 20 centimeters) of bioretention media. By comparison, bioretention filter beds

are commonly designed to be 18 to 36 inches deep. Therefore, an increase in the particle size distribution of bioretention media (and infiltration rate) may not result in a significant reduction in performance; instead, it may promote a greater utilization of the filter bed depth while achieving similar overall performance.

For well-graded media beds (i.e., beds with a well-distributed range of particle sizes), the median grain size is a poor proxy for the average pore size, and smaller particles may be retained through cake and depth filtration mechanisms. Compared to sand filter media, bioretention media typically contains a more heterogeneous mix of granular materials and organic materials, which would limit the depth of particle penetration to a smaller depth than predicted by the classical model based on median particle diameter.

The combination of these factors suggests that high flow rate bioretention media would not necessarily achieve significantly lower particle removal than low flow rate media. This is supported by Filterra® performance monitoring data as introduced and discussed later in this paper.

3.2.2 Reactive Filtration

Beyond the mechanisms provided by inert filtration, reactive filtration involves three primary mechanisms (Metcalf and Eddy 2003):

1. **Chemical adsorption** – bonding and chemical interaction

2. **Physical adsorption** – electrostatic forces, electrokinetic forces, and van der Waals forces

3. **Biological growth** – growth of biological film; can be significant in continuously-fed filters, but is uncommon in well-drained filters that are allowed to dry between events

While inert filtration is the dominant removal mechanism for solids and particulate-bound pollutants in bioretention systems, reactive filtration can play a major role in the removal of dissolved constituents and very fine particles. In well drained systems (i.e., bioretention systems), biological (biofilm) growth is limited. Therefore, reactive filtration generally includes chemical and physical sorption processes—specifically precipitation, ion exchange, and adsorption.

Precipitation primarily occurs when carbonates are released by the media and combined by constituents in solution to form solid precipitates that are subsequently filtered by the media matrix. Ion exchange involves the replacement of a charged media particle (e.g., Mn^{2+}, Fe^{2+}, Ca^{2+}) with a charged particle in solution (e.g., Cu^{2+}, Zn^{2+}). Adsorption primarily involves the incorporation of constituents onto the surface of media particles by bonding, chemical interactions, and to a lesser extent, molecular dipole attractions (i.e., van der Waals forces). The

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cation exchange capacity (CEC) of a reactive medium defines the bulk quantity of positively-charged ions that can be exchanged or adsorbed. Materials such as granulated activated carbon (GAC), zeolite, rhyolite, clays, diatomaceous earth, and organic matter all can have high CECs.

When analyzing pollutant affinity and reaction kinetics, two primary media characteristics are of interest:

1. *Equilibrium capacity* – how much pollutant the media can retain
2. *Reaction rate* – how fast the media can retain the pollutant

Equilibrium capacity is defined by sorption isotherms that can be used to predict the amount of pollutant removed at a known concentration for a fixed mass of media at a constant temperature and pH. While various researchers have reported coefficients for their fitted isotherm models, isotherms are not readily transferrable since they are specific to the media, solids gradation, and water chemistry used in their development (WERF 2005). The reaction rates for the various mechanisms also depend on the pollutant type, stormwater characteristics, water (e.g., pH, temperature, etc.), and media characteristics. For example, phosphorus can generally be removed in reactive filters through a combination of sorption and precipitation, depending on pH, with reaction rates of minutes to several hours (WERF 2005).

Various materials used in media filters have a wide range of capacities and reaction rates to accumulate and retain dissolved pollutants. Materials can be specifically selected and engineered to have more reactive surfaces and a higher density of sorption sites. Based on extensive testing of various media types, Johnson et al. (2003) found that a peat-sand mix, zeolite, compost, and iron oxide-coated sand generally showed the best overall performance at removing dissolved metals from stormwater. Literature suggests that contact times of several hours may be needed for conventional materials found in bioretention media such as silica sand, loam soil, and compost (e.g., Wanielista and Chang 2008; Sun and Davis 2007), but only a few minutes may be needed for highly reactive media such as magnesium oxide-coated sand (e.g., Liu et al. 2004). Johnson et al. (2003) found that increasing contact times beyond the scale of several minutes does not to significantly improve treatment efficiency.

An optimized point can therefore be identified where the ability to treat a higher fraction of the stormwater runoff volume is balanced with the ability to provide longer residence times. With consideration of observed diminishing returns in treatment efficiency beyond the scale of several minutes of residence time, the optimal design for space constrained locations likely lies in a system with high media flow rate, specialized media, and relatively small footprint per unit volume of water captured.

3.3 Inter-storm Treatment Processes

For well-drained bioretention systems, the inter-event volume stored equals the water content associated with the field capacity of the porous media. The treatment processes that act upon this inter-event volume include microbially-mediated transformations, biological uptake and storage,

and volatilization. These processes are considered critical to retaining pollutants that have been removed by within-storm processes and regenerating the capacity of reactive filtration processes.

Other important processes that occur between events include evaporation, surface drying/ cracking, plant activity (e.g., root growth/penetration, vegetative stabilization), and animal activity (e.g., earthworm, insect, etc.), considered collectively as soil processes. These processes are believed to be important to preserve the hydraulic function of bioretention media. Routine maintenance is also considered to be an important inter-storm pollutant removal process.

3.3.1 Microbially-Mediated Transformations

Microbially-mediated transformations include the metabolic activity of bacteria, algae and fungi that promotes degradation of organic pollutants and oxidation or reduction of inorganic pollutants (WERF 2005). Metabolic activity is primarily associated with the natural biochemical cycles of carbon, nitrogen, phosphorus, and sulfur (Crites and Tchabanoglous 1998). However, xenobiotic metabolism (i.e., biotransformation of chemicals foreign to an organism) can play a significant role in the transformation, stabilization, and detoxification of heavy metals and organic chemicals.

Stormwater bioretention systems are variably-saturated and include root zone biomass that can create pockets of aerobic and anaerobic conditions that promote diverse microbial activity. For example, an aerobic environment is generally needed for nitrification (ammonia → nitrite → nitrate) and an anaerobic environment is needed for denitrification (nitrate → nitrogen gas). If this process is completed within a bioretention system, nitrogen can be removed. However, anaerobic conditions are often not prevalent enough to cause large nitrate reductions. Clark and Pitt (2009) evaluated the retention of pollutants for a variety of media types and found that dissolved metals adsorbed to media are likely to be retained by most media types under both aerobic and anaerobic conditions, but phosphorus release may occur during anaerobic conditions, especially if the media contains highly organic compost.

Microorganisms within the root zone of plants can alter the pH and redox potential within the soil, which can degrade organic chemicals, cause metals to precipitate, or convert various pollutants into a form that can be accumulated or adsorbed by plants and microbes (McCutcheon and Schnoor 2003). These microbially-mediated transformations have the ability to regenerate the sorption capacity of filtration media between storms.

3.3.2 Biological Uptake and Sequestration

Biological uptake and sequestration as a pollutant removal mechanism refers to the removal of organic and inorganic constituents from stormwater by plants and microorganisms through nutrient uptake and bioaccumulation. Biological uptake results in the conversion of nutrients in stormwater into living tissue, while bioaccumulation results in the sequestering of pollutants into organisms regardless of what is immediately needed (WERF 2005). Organisms may assimilate macronutrients such as phosphorus for metabolism and growth, in addition to micronutrients

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(i.e., some trace metals), and nonessential constituents (i.e., other trace metals). Phosphorus uptake by plants and microbes may improve the capacity of the soil to adsorb other constituents. Some plants sequester metals in the root zone, and expel matter that can foster metals precipitation. Uptake of metals depends on bioavailability; some chemical forms are more reactive and readily assimilated by biological matrices than others.

Uptake as a within-storm removal process may not be significant in high flow rate BMPs due to the time needed for such processes; however, biological uptake is believed to help regenerate media function between storms by freeing sorption sites and providing more permanent pollutant retention mechanisms within biomass in the media.

3.3.3   *Volatilization*

Volatilization is the process of liquids and solids vaporizing and escaping to the atmosphere. Compounds that readily evaporate at normal pressures and temperatures are considered volatile compounds. While these compounds are not frequently detected in urban runoff, volatile organic compounds (VOCs) or semi-volatile organic compounds (SVOCs) are sometimes present, including various petroleum hydrocarbons (e.g., BTEX[1] and PAHs[2]), gasoline oxygenates (e.g., MTBE[3]), herbicides, and pesticides. VOCs can also be formed during some microbial and phytochemical redox transformations of other pollutants in urban runoff. Volatile compounds are usually highly soluble in water and can easily pass through bioretention systems if they are not volatilized between storm events.

3.3.4   *Bacterial Inactivation Processes*

The term "inactivation" with respect to bacteria is analogous to sequestration of non-living pollutants. Bacteria are removed from stormwater by the within-storm processes; particulate-bound bacteria are predominantly addressed by physical filtration while free-floating bacteria are predominantly addressed by reactive components of filtration (sorption). Once removed, other processes may work to inactivate the bacteria so that they do not multiply or wash out in subsequent events.

While limited study has been conducted, it is believed that inactivation processes of bacteria in bioretention systems may include predation by other microorganisms (Ruby 2008), solar irradiation of material retained on the surface of the media, and development of conditions inhospitable for growth, including drying of media between storm events (Hunt and Lord 2010). It is believed that the media goes through a maturation process where it develops a complex microbiological ecosystem that enhances predation of bacteria (Ruby 2008). Studies have found that long term removal efficiencies of over 90 percent can be achieved by bioretention systems (Ruby 2008; Hunt and Lord 2006), indicating that slow media flow rates do not necessarily result in higher initial removal and inactivation (Ruby 2008).

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[1] Benzene, toluene, ethylbenzene, and xylenes
[2] Polycyclic aromatic hydrocarbon
[3] Methyl tert-butyl ether

3.3.5   Soil Processes

Soil processes means evapotranspiration, surface weathering, plant activity (e.g., root growth and penetration, vegetative stabilization), animal activity (e.g., earthworms, insects), and other processes (e.g., fungal activity).

- *Evapotranspiration* is the combined effects of evaporation and transpiration in reducing the volume of water in a vegetated area during a specific period of time. The volume of water in the root zone of soils is taken up by roots and then transpired through the leaves of the plant. The suction pressure exerted by evapotranspiration may have the effect of loosening soil that may have been compacted by hydraulic impact (i.e., the downward forces of incoming stormwater) during an event. Drying of the media can exert environmental stress on pathogenic bacteria that are retained in the media via desiccation, contributing to inactivation of these constituents (Crites and Tchobanoglous 1998).

- *Weathering* (i.e., drying or cracking) is caused by evaporation, media expansion and contraction, and other physical processes and that can break up accumulated surface sediment and cause internal adjustments to the structure of the media matrix. Unlike mineral sands; peats, zeolites, and loams have high internal porosity and therefore, can exhibit more dramatic expansion and contraction during hydration and dehydration processes. Li and Davis (2008) state that compared to rigid sand filter media, bioretention media is relatively plastic, allowing for media shape adjustments to incorporate captured particles and improve the infiltration capacity during the dry period.

- *Plant activity* in the media layer can be important for preserving and regenerating hydraulic function, stabilizing accumulated sediment, and preserving/increasing levels of organic matter in the soil. In addition, the movement of plant stalks due to wind and bird activity can break up surface crusts thereby maintaining or increasing infiltration rates. Plant roots contract and expand depending on water availability which helps to develop preferential flow pathways. Plant roots also increase aeration and void space by breaking up the media for water and oxygen to permeate. Root growth aids in the development of healthy and biologically-active soil structures and can increase infiltration rates over time due to the creation of macropores in the media (Facility for Advancing Water Biofiltration in Australia 2008; PGC-DER 2009).

- *Animal activity* in the soil layer can be important for maintaining or increasing porosity, preserving hydraulic function over the long term, preserving or increasing the organic content of the soil, and stimulating microbial activity (Nogaro et al. 2006; Nogaro et al. 2007; Derouard 1997). Worms aid in the development of natural soil structure over time,

which can increase infiltration rates. Worms create cavities and worm castings can help with soil aggregation as well as pollutant removal.

- *Other processes*, such as those performed by fungi, also may play a critical role in maintaining aggregate stability within the media. For example, fungi contain individual fungal filaments known as hyphae, which together form mycelia and aid in soil structure stabilization. Fungi also excrete microbial slime that aids in aggregation. In addition, mycorrhizae fungi located on and within the plant root system aid in water and pollutant uptake.

3.3.6 *Routine Maintenance as a Pollutant Removal Mechanism*

Particulate "break-through" in bioretention systems may occur if fine particles migrate through the media bed. In addition, reductions in hydraulic capacity may result from an increase in the percentage of fine particles in the media bed, resulting in greater frequency of bypass of the system. Finally, dissolved constituent break-through is possible due to short-circuiting or depletion of adsorption sites. Maintenance activities, in addition to inter-storm processes, can promote effective long-term inert and reactive filtration. The removal of accumulated sediment at the surface of the system and removal and replacement of the surface mulch layer may have the following effects:

- Reduces the potential for migration of particles from the surface cake layer into the media bed

- Permanently removes the dissolved constituents adsorbed to accumulated sediment and mulch

- Refreshes the adsorption capacity of the entire bed through the addition of new mulch

The accumulation of fines in the filter media theoretically improves the ability of the media to remove pollutants; however, these fines also tend to decrease the media filtration rate over time which can reduce the capture efficiency of the BMP. The effect of reduction in media flow rate on the capture efficiency achieved by a Filterra® system is shown for an example location in Figure 1. As this figure illustrates, the influence of reduction in media flow rate on capture efficiency is relatively minor; a reduction in media flow rate of 50 percent from 140 to 70 inches/hour results in an expected decline in capture efficiency of less than 10 percent. This is explained by the fact that smaller, more frequent storms contribute the majority of average annual runoff volume. Relationships will vary based on precipitation patterns of an area, but the general nonlinear trend is expected to be consistent across a wide range of climates.

3.4 Summary of Unit Treatment Processes

Table 2 summarizes unit treatment processes provided by bioretention systems and the pollutant or conditions that they are intended to address or support.
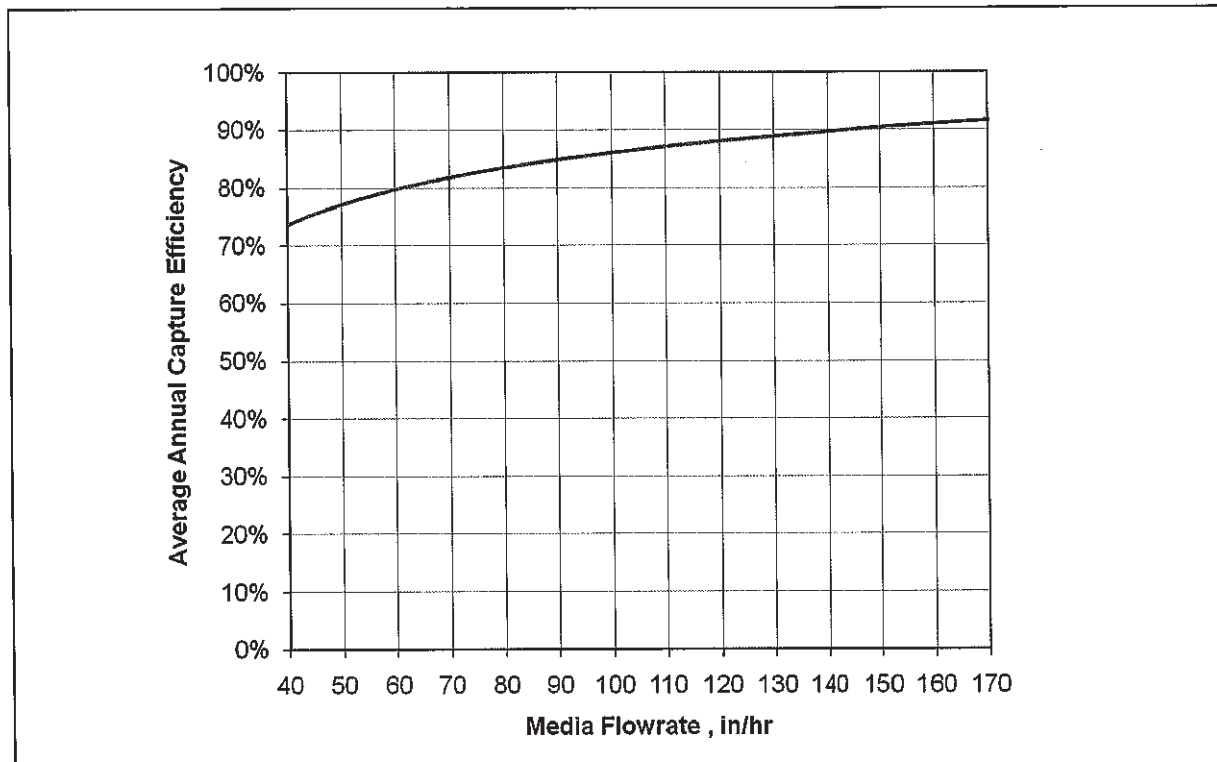
Figure 1. **Effect of media flow rate on capture efficiency in Fairfax County, Virginia (adapted from Geosyntec 2008a, 6'× 6' Filterra®, 0.23-acre tributary area).**

Table 2. Summary of unit treatment processes and pollutant removal.

Unit Removal Processes Potentially Provided by Bioretention Systems	Pollutant Removal							Other Performance Factors	
	Particulates and Particulate-bound	Dissolved Metals	Dissolved Nitrogen	Dissolved Phosphorus	Bacteria	Oil and Grease	VOCs and SVOCs	Hydraulic Capture Efficiency	Volume Reduction
Inert Filtration	◆	○	○	○	◆	◆	○	NA	NA
Reactive Filtration	○	◆	◇M	◆	◆	○	◇M	NA	NA
Microbially-mediated Transformations	Ⓢ	Ⓢ	Ⓢ	Ⓢ	○	Ⓢ	○	NA	NA
Biological Uptake and Storage	○	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	○	NA	NA
Volatilization	○	○	Ⓢ	○	○	○	◇M	NA	NA
Bacterial Inactivation Processes	○	○	○	○	Ⓢ	○	Ⓢ	NA	NA
Soil Processes	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ
Routine Maintenance	◆	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	Ⓢ	NA

◆ Primary removal mechanism in bioretention systems

◇M Generally limited removal mechanism in bioretention systems unless specific design attributes are included

Ⓢ Supporting process in well-drained bioretention systems

○ Process with no contribution or unknown contribution to pollutant removal

NA: not applicable; VOCs: volatile organic compounds; SVOCs: semi-volatile organic compounds

4. Filterra® Bioretention Stormwater Treatment System

4.1 System Components and Unit Treatment Processes

The Filterra® system is housed in a precast concrete curb inlet structure with a tree frame and grate cast in the top slab, and includes engineered filter media topped with mulch that supports a tree or other type of plant (Figure 2). The following sections describe the three key pollutant removal components of the Filterra® system: mulch, engineered filter media, and vegetation and other system biota.
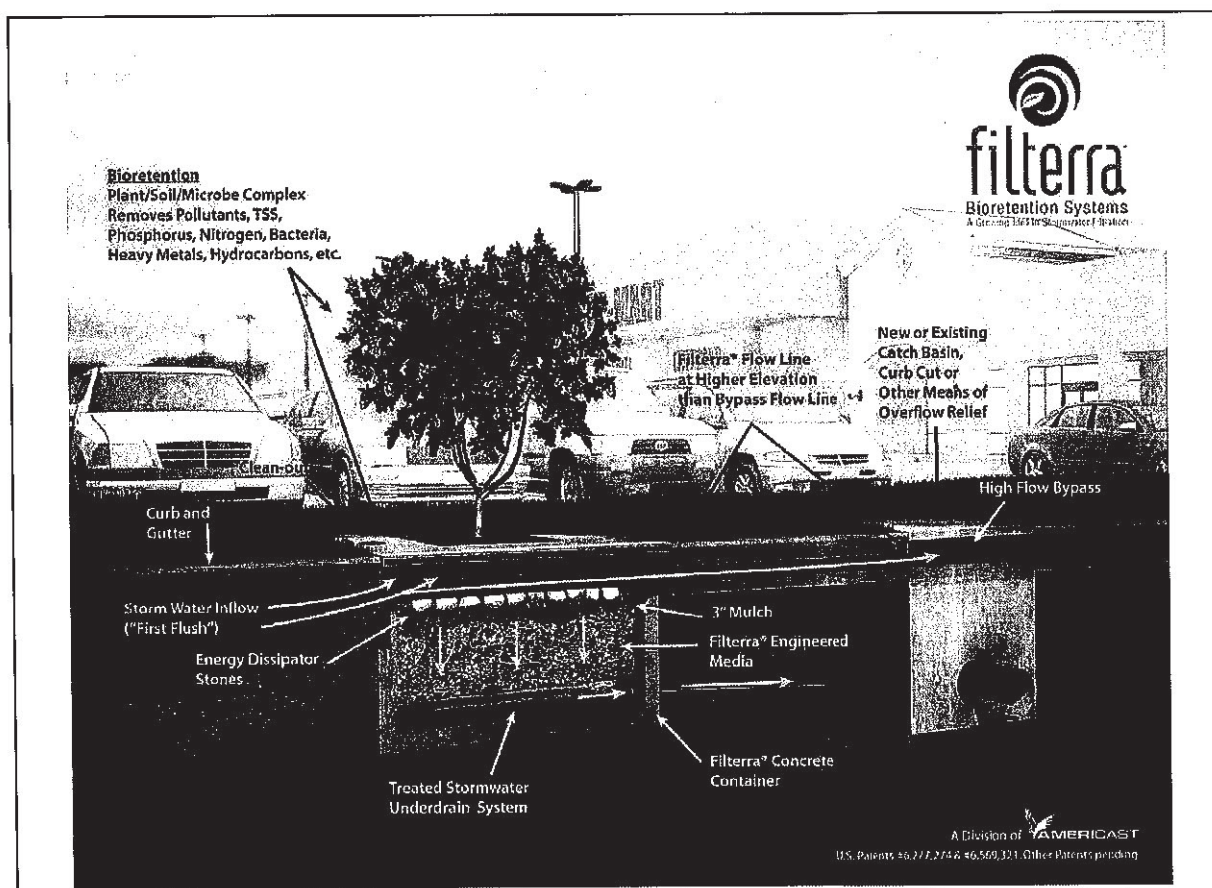

Figure 2. Typical Filterra® system design.

4.1.1 Mulch

The Filterra® system includes a 3-inch layer of shredded wooden mulch. The mulch provides pretreatment and protection of the engineered filter media, and is expected to perform the following within-storm unit treatment processes:

- Inert filtration
- Reactive filtration

To promote filtration, the Filterra® system is typically designed with approximately 6 inches of freeboard above the top of the mulch to the gutter elevation at the curb face. This ponding area provides surface storage for a portion of the water quality treatment volume and promotes settling of fine particles present in the stormwater on the surface of the mulch (CWP 1996). The mulch layer filters out large particles (gross and suspended solids) present in the stormwater that might otherwise prematurely clog the media. Because the mulch is heterogeneous, it captures relatively small particles without limiting the hydraulics of the system. The amount of inert filtration that occurs in the mulch layer is a function of particle density, size, and water density.

Mulch also supports reactive filtration processes. Due to the high CEC present in organic matter contained in the mulch layer, the mulch adsorbs dissolved pollutants, such as heavy metals. Mulch also provides a constant supply of organic material to the media from mulch fines to sustain the CEC of the media for removal of dissolved constituents.

The mulch layer also helps to retain moisture in the Filterra® system, which supports vegetation growth, decomposition of organic matter, and microbial communities (CWP 1996). This moisture retention may lead to a lower frequency of irrigation requirements for system maintenance. Semi-annual removal and replacement of the mulch layer allows for removal of pollutants that have been absorbed by the mulch, as well as trash, debris, and silt that have accumulated on top of the mulch layer.

4.1.2 Media

The mulch layer is underlain by 1.5 to 3.5 feet of engineered filter media, consisting of a specified gradation of washed aggregate and organic material homogeneously blended under strict quality controlled conditions. The engineered filter media is tested for hydraulic functionality, fertility, and particle size distribution to ensure uniform performance. At a design infiltration rate of 100 to 140 inches/hour, a media bed depth of 2.0 feet, and a porosity of 40 percent, the steady state residence time in the media layer would be approximately 4 to 6 minutes. While initial flows entering a dry system may begin to discharge somewhat more quickly than steady state as a result of initial wetting processes, the calculated steady state residence time (4 to 6 minutes) is expected to be provided for the great majority of volume during each storm event and is therefore considered to be characteristic of Filterra® system operation. The media is expected to perform the following within-storm unit treatment processes:

- Inert filtration
- Reactive filtration

Using data from studies conducted by the University of Virginia (2001), the filter media was optimized to operate under high flow rates while maintaining pollutant removal performance. The engineered filter media contains hydrophilic adsorbents such as aluminosilicates (sand) and hydrophobic adsorbents such as carbonaceous/organic matter, which have been included to promote the partitioning of pollutants to the soil particles. The combination of hydrophilic and hydrophobic adsorbents is designed to capture a wide range of pollutants through physical

adsorption (e.g., electrostatic forces). The amount of adsorption that occurs is a function of the available surface area and the polarity of the constituents passing through the Filterra® system. As discussed in the previous section, media specifically designed for rapid reactive filtration can achieve significant removal on the order of several minutes (consistent with the 4- to 6-minute characteristic residences time calculated for the Filterra® system).

The media is also expected to perform the following inter-storm unit treatment processes:

■ Microbially-mediated transformations
■ Biological uptake and storage
■ Volatilization

The engineered filter media is designed with a high percentage of organic material for uptake of nutrients and other pollutants. Organic material is added for initial organic complexing (i.e., cation exchange) with pollutants and to help promote biological growth. The mulch, rhizosphere degradation, and runoff continuously add organics to the media to replace the amount lost to microbiological processes.

Bacterial growth, supported by the root system and organic soil content, also contributes to pollutant removal and are a function of moisture, temperature, pH, salinity, pollutant concentrations (particularly toxins), and available oxygen. In addition, volatilization may also occur if VOCs (i.e., gasoline) are captured in the filter media.

Finally, the wetting and drying of the media during and after storm events expand and contract organics in the system, which help in the creation of preferential flow pathways (Americast, Inc. 2009a).

4.1.3 Vegetation and Other System Biota

The Filterra® system includes a vegetation component selected based on aesthetics, local climatic conditions, traffic safety (i.e., limiting the height or breadth of the vegetation), and maintenance considerations (i.e., may restrict deciduous vegetation).

The selected vegetation may include flowers, grasses, a shrub, or a tree, and is expected to perform the following inter-storm unit treatment processes:

■ Microbially-mediated transformations
■ Biological uptake and storage
■ Soil processes

As discussed previously, microorganisms present in the root zone of the vegetation in the Filterra® system can assist with adsorption of pollutants into the media layer and regeneration of the sorption capacity of the media between storm events. Bacterial growth on the root system can bind with particulate organic matter and heavy metals. Growth of vegetation in the Filterra®

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system also requires macronutrients (i.e., nitrogen and phosphorus) and micronutrients (i.e., metals) found in stormwater runoff for metabolic processes (i.e., energy production and growth).

As the biomass (i.e., plant and microbes) of the Filterra® system grows, it is assumed that the system's capacity to capture and process more pollutants increases (Ruby and Appleton 2010). This increase in biomass not only increases infiltration rates but also the surface area of the roots, allowing for increased pollutant adsorption and creation of additional pore space in the media layer. Filterra® systems have also been observed to contain fungi and worms which help with media stabilization, aggregation, and development of the media structure over time, maintaining the flow rate capacity of the system.

4.2   Results Documenting High Flow Rate Treatment from Bench-scale Testing

Third-party bench-scale testing efforts have been conducted to evaluate achievable treatment flow rates and particle removal performance of the media in the Filterra® system. Summaries of these independent studies are provided below.

4.2.1   Media Flow Rates in Bench-scale Testing

Column tests were completed by GeoTesting Express (2005) to support Technology Assessment Protocol-Ecology (TAPE) monitoring in Washington State. The specific goal of these column tests was to evaluate flow rates in heavily- and lightly-compacted media. Measured infiltration rates were approximately 50 inches/hour for heavily-compacted media, and 300 inches/hour for lightly-compacted media. Under normal operating conditions and maintenance schedules, the Filterra® system media is expected to perform between these extremes. The concrete top slab covering the Filterra® system is also designed to protect the media from vehicular and foot traffic which would prevent heavy compaction of the media from occurring and would maintain the high flow rate capacity of the system.

4.2.2   Bench-scale Testing of TSS Removal

Two bench-scale analyses were conducted to evaluate removal of TSS by Filterra® system media.

Geosyntec Consultants (2006) conducted a column study to analyze the TSS treatment performance of the Filterra® system media. A manufactured silica product (Sil-Co-Sil 106) with a size distribution consisting of 80 percent of the particle mass less than 50 microns (μm) was selected to simulate expected influent TSS from an urban setting. A total of 15 treatment simulations were conducted, with influent TSS concentrations ranging from 8.3 to 260 milligrams per liter (mg/L) and hydraulic loading rates of 50 to 55 inches/hour. The effluent TSS concentrations were consistently less than 20 mg/L for all simulations and the median

effluent TSS concentration was 7.8 mg/L. The TSS removal ranged from 70 to 95 percent with a median removal of 90.7 percent[4].

Americast, Inc. conducted a second column study in 2009 to investigate how hydraulic loading affects the TSS treatment performance of the Filterra® system media. Sil-Co-Sil 106 was used to represent the particle size distribution typical of TSS in urban runoff. Thirty events were simulated with flow rates ranging from 25 to 150 inches/hour and influent TSS concentrations ranging from 42 to 252 mg/L. The effluent TSS concentration ranged from 0.8 to 42.8 with a median of 5.1 mg/L. The TSS removal ranged from 25 to 99.5 percent with a median removal of 96.7 percent. Mehta and Williamson (2009) conducted a third-party review of this study. No statistically significant correlation was found between hydraulic loading and effluent concentration (Mehta and Williamson 2009). Similarly, no significant correlations between influent and effluent TSS concentrations were found. Figure 3 compares the effluent TSS concentrations to flow rates and influent TSS concentrations. Note the very low coefficient of determination (R^2) and the statistically insignificant p-value (>0.05) for both regression lines.
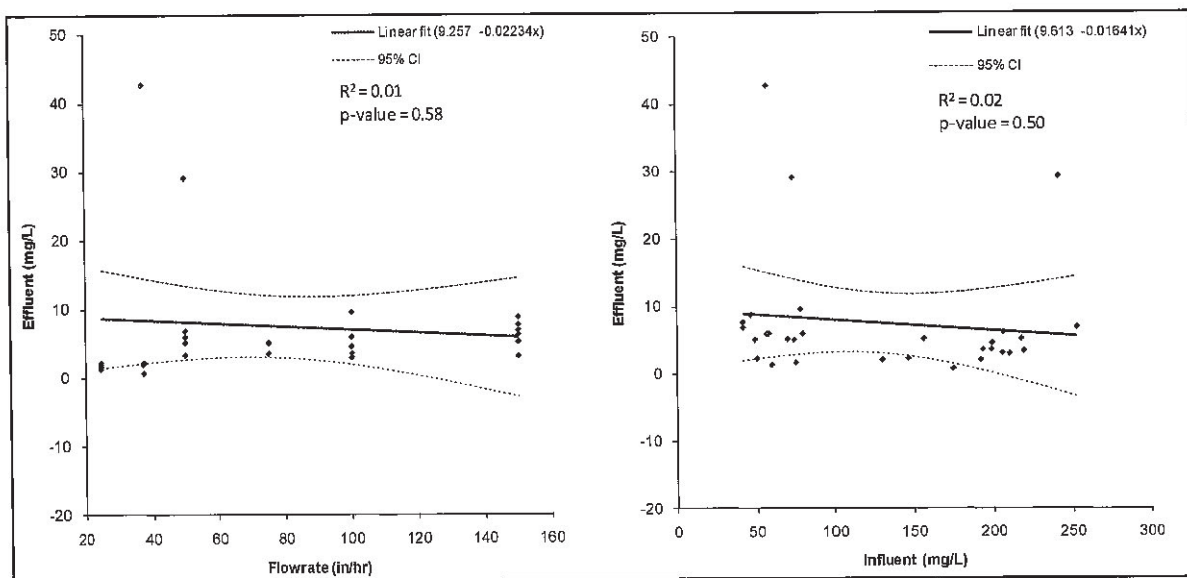
Figure 3.   Effluent TSS concentration compared to flow rate and influent TSS concentration.

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[4] In general, the concept of a percent reduction should be applied with caution as a sole means of quantifying stormwater treatment performance, particularly because this estimator is inherently biased towards "dirtier" sites, (i.e., those with relatively high influent levels) (Strecker et al. [2001]). When influent levels are low, it becomes increasingly difficult to achieve a dramatic percent reduction; furthermore, variability inherent to the analysis methods, sampling procedures and other factors unrelated to actual treatment performance have an exaggerated influence on the result when influent is very close to effluent. Where used, percent reductions should be reported with observed influent and effluent concentrations.

4.2.3 *Applicability of Bench-scale Testing to Field Performance*

The controlled lab experiments indicate that media flow rates greater than 100 inches/hour and significant removal of small particles are possible using Filterra® system media. Both studies described previously were performed using a rigorous testing protocol designed to mimic typical stormwater characteristics and media placement in the field. Compared to field studies, laboratory studies allow for control of environmental conditions, flow rates, influent concentrations, and particle size distributions. Controlled experiments reduce the number of variables that may influence performance, providing higher confidence in the collected data and eliminating the site specificity of the study. For these reasons, the results of the laboratory studies can be more generally applicable than field study results at a particular location.

Because stormwater characteristics vary significantly from site to site, the results of laboratory studies are not a reliable predictor of performance for a specific site during a specific storm event. However, these studies can inform estimates of average performance under average stormwater conditions, and provide cross-validation of results obtained during field-scale testing.

4.3 Results Documenting High Flow Rate Treatment from Full-scale Testing

4.3.1 *Evaluation of Hydrologic Performance*

Maximum capacity flow rate tests performed on 10 different Filterra® systems of varying age (recently activated to 3 years) and varying maintenance periods (recently maintained to 2 years without maintenance) demonstrated that the saturated hydraulic conductivity (K_{sat}) of Filterra® media ranged from 86 inches per hour to 205 inches per hour, with a 95th percent confidence interval on the median of 129 to 197 inches per hour. Tests included two systems with greater than or equal to 4.5 inches of sediment accumulation. While the results from the sediment-laden systems were not found to be true statistical outliers, the range of observed K_{sat} without these studies was 152 to 205 inches per hour. From these tests, a design media flow rate of 140 inches per hour was recommended, based on the lower 95th percent confidence limit of all data points (including sediment-laden system), adjusted to account for driving head on the system under normal operation (Geosyntec 2008b). Different wetting periods were also tested during these flow rate studies, looking at both constant and periodic wetting. These studies showed that Filterra® systems that received a periodic introduction of runoff (i.e., similar to that of a typical storm event) achieved the highest flow rate. In general, the media is well drained under normal operating conditions.

Core samples collected from 11 Filterra® systems of different ages (6 to 18 months) with no maintenance showed that there was not a significant change in the particle size distribution of the media and the amount of silts and clays up to 18 months after installation (Brim 2007). Four core samples were collected from each Filterra® system and the particle size distribution in the top 10 centimeters of the media was evaluated. All of the evaluated systems contained a percentage of fine particles that matched the Filterra® system media specification, demonstrating that significant media degradation had not occurred. (However, the younger systems had relatively higher accumulations of fine particles than the older systems due to a difference in drainage area

size and stormwater runoff quality.) These findings reinforce the important role that the mulch plays in capturing relatively small particles without limiting the hydraulic capacity of the system.

4.3.2 *Evaluation of Water Quality Treatment Performance*

This section presents water quality treatment performance data collected from the following Filterra® installations:

- One Filterra® system installation in Falls Church, Virginia (Technology Acceptance Reciprocity Partnership [TARP] study and TARP addendum)

- Three Filterra® system installations in Maryland and Virginia (performance over time study)

- Two Filterra® system installations at the Port of Tacoma in Tacoma, Washington (TAPE study)

- One Filterra® system installation in Bellingham, Washington (Bellingham study)

The TARP study was conducted from October 2004 through November 2005 to obtain approval for basic treatment in California, Massachusetts, Maryland, New Jersey, Pennsylvania, and Virginia (Yu and Stanford 2006). The TARP addendum study using simulated storm events was conducted in December 2006 and January 2007 to supplement the TSS and total phosphorus data presented in the TARP (ATR Associates 2009). The performance over time study was conducted from January 2008 through February 2010 on three Filterra® systems installed in restaurant, oil service station, and gas station parking lots (Americast, Inc. 2009b). The Filterra® systems monitored for the performance over time study ranged in age from 2 years (restaurant parking lot) to 5 years (gas station parking lot). The TAPE study was conducted from May 2008 through May 2009 at two sites at the Port of Tacoma (POT1 and POT2 test systems) to obtain a General Use Level Designation (GULD) basic, enhanced (dissolved metals), and oil treatment from the Washington Department of Ecology (Ecology) (Herrera 2009). The Bellingham study was conducted from March 2009 through April 2010 to test the phosphorus removal performance of the Filterra® system (M. Ruby, personal communication, June 8, 2010).

The pollutant removal performance of these systems was evaluated based on flow-weighted composite samples and discrete grab samples that were collected from influent and effluent of each system during storm events. Automated samplers were used to collect flow-weighted composite samples of the influent and effluent during discrete storm events for the TARP, TAPE, and Bellingham studies. Flow-weighted composite samples were manually collected during the TARP addendum study. Discrete grab samples were also collected for the TAPE study for TPH analysis. All samples collected for the performance over time study were discrete grab samples.

The pollutant removal performance was quantified based on efficiency ratios that were calculated for each parameter using the following equation:

$$EF = 1 - \frac{C_{Effluent}}{C_{Infleunt}}$$

where:

   EF = efficiency ratio

   $C_{effluent}$ = mean or median effluent concentration

   $C_{influent}$ = mean or median influent concentration

The efficiency ratio is a commonly used method for calculating pollutant removal performance (Geosyntec et al. 2002; CWP 2008). It was calculated based on event mean concentrations (EMC) from the flow-weighted composite samples that were collected for the TARP and TAPE studies, and concentrations from discrete samples that were collected for the performance over time study. In each case, the efficiency ratios were computed based on the mean influent and effluent concentrations if the associated data were found to potentially arise from a normal distribution (i.e., the null hypothesis that the data come from a normal distribution could not be rejected at an alpha significance level of 0.05 using a Shapiro-Wilk test). If the data had a non-normal distribution, a natural logarithmic transformation was applied to the influent and effluent concentrations. The transformed data were then analyzed to determine if they have a normal distribution. If this proved to be the case, the mean and standard deviation of the log transformed data were used to calculate arithmetic estimates of the means in their original units and used to calculate the efficiency ratios. If the log transformed data of either the influent or effluent did not have a normal distribution, the efficiency ratios were calculated based on the median influent and effluent concentrations.

Results from all five studies were fairly consistent for TSS with efficiency ratios ranging from 83.3 percent (ATR Associates 2009) to 88.3 percent (Americast, Inc. 2009b) (Table 3). The efficiency ratio for total phosphorus had a much wider range from 8.5 percent (Herrera 2009) to 69.5 percent (ATR Associates 2009) due to low total phosphorus concentrations and high soluble reactive phosphorus fractions measured during the TAPE study. Follow-up field testing in two more typical urban applications for phosphorus monitoring under TAPE is pending. TKN was only measured during the TARP study and had a removal efficiency of 39.5 percent (Yu and Stanford 2006). The efficiency ratio for total copper ranged from 33.2 percent (Yu and Stanford 2006) to 76.9 percent (Americast, Inc. 2009b), while dissolved copper was only monitored during the TAPE study and had an efficiency ratio of 48.0 percent. The efficiency ratio for total zinc removal ranged from 48.1 percent (Yu and Stanford 2006) to 78.7 percent (Americast, Inc. 2009b), while dissolved zinc had an efficiency ratio of 54.9 percent during the TAPE study. The oil and grease efficiency ratio measured during the performance over time study was lower than expected (58.6 percent) due to low influent concentrations near the detection limit; however, the TPH efficiency ratio calculated for the TAPE study was 96.1 percent (Herrera 2009).

Table 3.   Pollutant removal performance of the Filterra® system.

Pollutant	n	Median Influent (mg/L) [a]	Median Effluent (mg/L) [a]	Mean Influent (mg/L) [a]	Mean Effluent (mg/L) [a]	Effluent < Influent?	Efficiency Ratio	Reference
Total Suspended Solids	11	20	2.5 U	28.8	5.2	Yes [b]	87.5% [d]	TARP
	7	63.4	11.6	66.3	11.1	Yes [c]	83.3% [e]	TARP Addendum
	34	38.0	4.1	71.0 [f]	8.3 [f]	Yes [e]	88.3% [f]	Perf. Over Time
	18	36.3	4.8	68.9	7.4	Yes [b]	86.9% [d]	Bellingham [g]
	10	27.5	4.2	28.8	4.3	Yes [c]	85.2% [e]	TAPE [g]
Total Phosphorus	14	0.14	0.076	0.23	0.090	Yes [c]	59.7% [f]	TARP
	6	0.52	0.16	0.59	0.18	Yes [c]	69.5% [f]	TARP Addendum
	41	0.29	0.16	1.15	0.49	Yes [b]	44.8% [d]	Perf. Over Time
	15	0.12	0.054	0.16	0.065	Yes [b]	56.5% [d]	Bellingham [h]
	12	0.15	0.14	0.19 [f]	0.17 [f]	No [c]	8.5% [f]	TAPE [h,i]
Total Kjeldahl Nitrogen	6	1.90	1.15	2.22	1.27	Yes [b]	39.5% [d]	TARP
Total Copper	8	0.012	0.01 U	0.015	0.01 U	No [c]	33.2% [f]	TARP
	30	0.061	0.014	0.083	0.029	Yes [b]	76.9% [d]	Perf. Over Time
	29	0.0081	0.0034	0.0082	0.0037	Yes [b]	58.0% [d]	TAPE
Dissolved Copper	23	0.0056	0.0033	0.0070 [f]	0.0036 [f]	Yes [c]	48.0% [f]	TAPE [j]
Total Zinc	16	0.039	0.02 U	0.070	0.023	Yes [b]	48.1% [d]	TARP
	30	0.355	0.08	88.7	18.1	Yes [b]	78.7% [d]	Perf. Over Time
	29	0.384	0.102	0.516	0.230	Yes [b]	73.4% [d]	TAPE
Dissolved Zinc	23	0.194	0.082	0.267 [f]	0.120 [f]	Yes [c]	54.9% [f]	TAPE [k]
Oil & Grease	20	7.0	2.9	26.8	4.2	Yes [b]	58.6% [d]	Perf. Over Time [l]
TPH	12	43.4	1.2	55.7 [f]	2.2 [f]	Yes [c]	96.1% [f]	TAPE [m]

mg/L: milligrams per liter
U: at or below detection limit
TARP: Technology Acceptance Reciprocity Partnership study conducted in Falls Church, Virginia (Yu and Stanford 2006)
TARP Addendum: Technical Report Addendum Additional Field Testing and Statistical Analysis conducted in Falls Church, Virginia (ATR Associates 2009)
Perf. Over Time: Performance Over Time study conducted in Maryland and Virginia (Americast 2009b)
Bellingham: study conducted in Bellingham, Washington, not all data summarized meets storm coverage criteria and post-storm dry period data required by TAPE (M. Ruby, personal communication, June 8, 2010)
TAPE: Technology Assessment Protocol – Ecology study conducted in Tacoma, Washington (Herrera 2009)
[a] Non-detect values (U) assigned a value of one-half the detection limit in calculations.
[b] Based on a Wilcoxon signed-rank test (1-tailed) test with a significance level at $p<0.05$.
[c] Based on a paired t-test with a significance level at $p<0.05$.
[d] Based on median influent and effluent concentrations.
[e] Based on mean influent and effluent concentrations.
[f] Based on arithmetic estimate of the mean computed from log-transformed influent and effluent concentrations.
[g] TSS data in the influent range accepted by Ecology (20 mg/L and greater).
[h] TP data in the influent range accepted by Ecology (0.1 to 0.5 mg/L).
[i] Low TP removal due to anomalous phosphorus data collected at the Port of Tacoma included very low TP influent concentrations and a high fraction of soluble reactive phosphorus.
[j] Dissolved copper data in the influent range accepted by Ecology (0.0029 to 0.02 mg/L).
[k] Dissolved zinc data in the influent range accepted by Ecology (0.02 to 0.6 mg/L).
[l] Low oil and grease removal due to low influent concentrations near the detection limit (5.0 mg/L).
[m] TPH data in the influent range accepted by Ecology (10 mg/L and greater).

Table 4 compares effluent concentrations for the Filterra® system from the five studies identified above to typical effluent concentrations for biofilters and media filters; two categories of BMPs reported in the International Stormwater BMP Database that generally provide similar unit treatment processes to Filterra® systems. Performance summaries for the biofilter and media filter classes of BMPs were derived from studies of the International Stormwater BMP Database (Geosyntec and WWE 2008a, 2008b). For reference, Table 4 also presents influent concentrations that were measured during the sampling of each system. These data generally show that effluent concentrations for the Filterra® system are equivalent or slightly lower than those from the other two BMP types. All the systems were able to achieve significant reductions in influent concentrations for the following parameters: TSS, total zinc, dissolved zinc and total copper, and dissolved copper. Biofilters and Filterra® systems were also able to achieve significant reductions in influent dissolved zinc concentrations. Finally, media filters and Filterra® systems were able achieve significant reductions in influent total phosphorus concentrations.

4.3.3 *Evaluation of Hydraulic Loading Rate*

To evaluate Filterra® system performance as a function of hydraulic loading, the following three types of hydraulic loading rates were calculated from data collected during the TAPE study:

1. *Average hydraulic loading rate:* average flow rate across entire sampled storm event

2. *Peak hydraulic loading rate:* maximum flow rate across entire sampled storm event

3. *Average instantaneous hydraulic loading rate:* average of flow rates measured during collection of individual aliquots for flow-weighted composite samples

All three types of hydraulic loading rates were calculated for each of the 22 sampled storm events sampled for TSS during the TAPE study (POT1 test system). Based on these calculations, the average hydraulic loading rate from storm events sampled for TSS ranged from 5 to 36 inches/hour, the peak hydraulic loading rates ranged from 14 to 133 inches/hour, and the average instantaneous hydraulic loading rates ranged from 8.6 to 53 inches per hour. Because composite samples are flow-weighted, the samples tend to be weighted towards system performance under higher hydraulic loading; therefore, the majority of the runoff volume in the sampled storms occurred during periods of high flow.

The average and peak hydraulic loading rates were also calculated for each of the 23 sampled storm events sampled for dissolved metals during the TAPE study (POT1 and POT2 test systems). Based on these calculations, the average hydraulic loading rate from storm events sampled for dissolved metals ranged from 5 to 55 inches/hour, the peak hydraulic loading rates ranged from 14 to 133 inches/hour, and the average instantaneous hydraulic loading rate ranged from 8.6 to 81 inches per hour.

Table 4. Typical influent and effluent concentrations in the International Stormwater Best Management Practice Database and for the Filterra® system.

Pollutant	Units	Biofilter			Media Filter			Filterra® System		
		Influent Range	Effluent Range	Effluent < Influent?[a]	Influent Range	Effluent Range	Effluent < Influent?[a]	Influent Range	Effluent Range	Effluent < Influent?[b]
Total Suspended Solids	mg/L	41-63	15-33	Yes	27-60	9.7-22	Yes	31-41	3.5-5.0	Yes
Total Phosphorus	mg/L	0.22-0.28	0.26-0.41	No	0.15-0.26	0.11-0.16	Yes	0.16-0.25	0.08-0.14	Yes
Total Copper	µg/L	25-39	7.7-14	Yes	11-18	8.2-12	Yes	9.3-26	4.3-10	Yes
Dissolved Copper	µg/L	10-18	5.7-12	Yes	4.6-11	7.3-11	No	4.5-7.0	2.6-3.9	Yes
Total Zinc	µg/L	128-225	28-52	Yes	52-132	17-59	Yes	158-290	41-80	Yes
Dissolved Zinc	µg/L	33-79	19-32	Yes	38-101	29-74	Yes	177-322	75-110	Yes

mg/L: milligrams per liter

µg/L: micrograms per liter

Influent and effluent ranges are calculated based on the 95 percent confidence intervals about the median for the ISBMPD (Geosyntec and WWE 2008a) and five Filterra® field studies (Yu and Stanford 2006; ATR Associates 2009; Americast, Inc. 2009; Herrera 2009b; Herrera 2009; M. Ruby personal communication, June 8, 2010).

[a] Based on a non-parametric analysis of the difference in median values of site averages (Geosyntec and WWE 2008b).

[b] Based on a Wilcoxon signed-rank (1-tailed) test with a significance level at p<0.05.

To evaluate potential influences on system performance, correlation analyses were performed on the TSS, dissolved copper, and dissolved zinc data from the TAPE study to determine if effluent concentrations varied in relation to any of the following variables: influent concentration, average hydraulic loading, average instantaneous hydraulic loading, and peak hydraulic loading. Computed correlation coefficients (Spearman's rho) from these analyses are presented in Table 5 while graphical representations of these relationships are shown in Figure 4 using matrix scatter plots. These results indicate that effluent concentrations for all three parameters show a significant positive correlation with influent concentrations; in other words, effluent concentrations decreased when influent concentrations decreased. When the various measures of hydraulic loading are examined, the results indicate that dissolved copper shows a negative correlation with both average instantaneous hydraulic loading, and peak hydraulic loading. In addition, dissolved zinc shows a negative correlation with peak hydraulic loading.

Table 5. **Correlation between influent concentration, effluent concentration, and hydraulic loading at the Port of Tacoma in Tacoma, Washington.**

Pollutant	Correlation Parameter	Influent Concentration	Average Hydraulic Loading	Average Instantaneous Hydraulic Loading	Peak Hydraulic Loading
Total Suspended Solids	Spearman's rho	0.49	-0.15	0.11	0.15
	95% Confidence Interval	0.09 to 0.76	-0.54 to 0.29	-0.33 to 0.51	-0.29 to 0.54
	p-value	**0.020**	0.493	0.636	0.514
Dissolved Copper	Spearman's rho	0.91	-0.32	-0.43	-0.45
	95% Confidence Interval	0.8 to 0.96	-0.65 to 0.1	-0.71 to -0.02	-0.73 to -0.04
	p-value	**0.000**	0.134	**0.042**	**0.032**
Dissolved Zinc	Spearman's rho	0.51	-0.23	-0.28	-0.50
	95% Confidence Interval	0.06 to 0.79	-0.63 to 0.26	-0.66 to 0.21	-0.78 to -0.04
	p-value	**0.030**	0.351	0.253	**0.034**

Bolded values are significant at $p < 0.05$ at the 95% confidence level.

While these results would seem to indicate that effluent concentrations are decreasing as hydraulic loading increases, it is more likely that other confounding factors are influencing these relationships. Specifically, influent concentrations of both dissolved copper and zinc may be decreasing as hydraulic loading increases due to dilution. Therefore, the primary influence in these relationships is likely influent concentration and not hydraulic loading; as noted above, the correlations analyses show that effluent concentrations for these parameters decrease when influent concentrations decrease.

Correlations analyses were also performed to determine if percent removal for the parameters identified above varied in relations to average hydraulic loading, average instantaneous hydraulic loading, and peak hydraulic loading. Computed correlation coefficients from these analyses are presented in Table 6 while graphical representations of these relationships are shown in Figure 5 using matrix scatter plots. These results show there was generally no correlation between the various measures of hydraulic loading and percent removal with one exception: percent removal

for dissolved copper was negatively correlated with average hydraulic loading rate. Again, the primary influence in this relationship is likely influent concentration and not hydraulic loading. Specifically, as average hydraulic loading rate increases, influent concentrations decrease and become more difficult to treat.
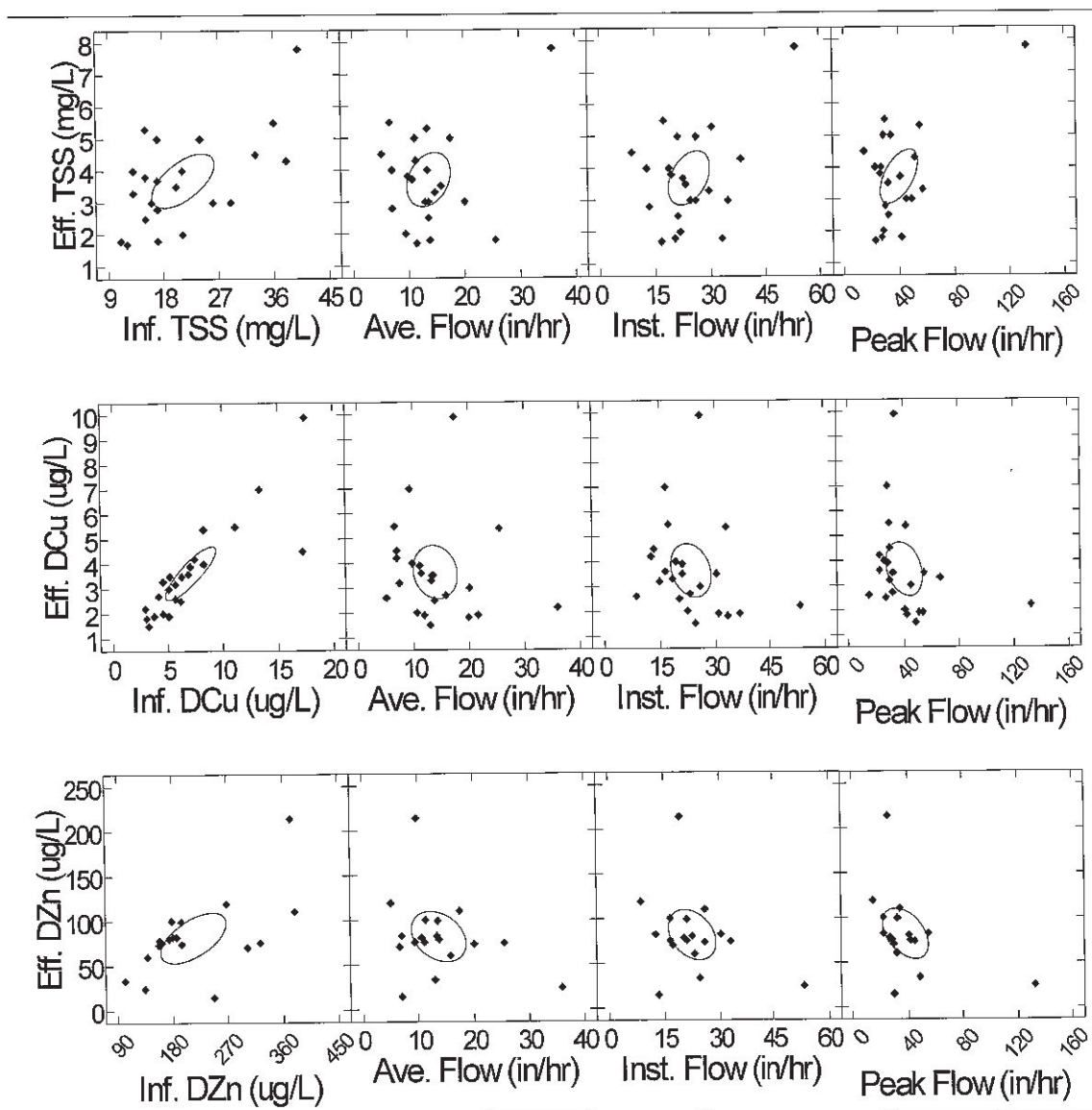

Figure 4. Matrix scatter plots showing relationships between effluent concentration and the following variables: influent concentration, average hydraulic loading, average instantaneous hydraulic loading, and peak hydraulic loading.

Table 6. **Correlation between percent removal and hydraulic loading at the Port of Tacoma in Tacoma, Washington.**

Pollutant	Correlation Parameter	Average Hydraulic Loading	Average Instantaneous Hydraulic Loading	Peak Hydraulic Loading
Total Suspended Solids	Spearman's rho	-0.17	-0.05	-0.10
	95% Confidence Interval	-0.55 to 0.27	-0.46 to 0.38	-0.5 to 0.33
	p-value	0.450	0.832	0.645
Dissolved Copper	Spearman's rho	-0.47	-0.29	-0.36
	95% Confidence Interval	-0.74 to -0.08	-0.63 to 0.13	-0.67 to 0.06
	p-value	**0.022**	0.173	0.090
Dissolved Zinc	Spearman's rho	-0.04	0.13	0.34
	95% Confidence Interval	-0.49 to 0.44	-0.36 to 0.56	-0.15 to 0.7
	p-value	0.887	0.616	0.168

Bolded values are significant at $p < 0.05$ at the 95% confidence level.

in/hr: inches per hour

mg/L: milligrams per liter

4.4 Maintenance

The major challenge to the longevity of the Filterra® system is sediment buildup on the surface of the Filterra® system, which could restrict free flow of runoff, trash and debris into the system. As long as routine maintenance is performed, the Filterra® system will theoretically last indefinitely, since it essentially sequesters and recycles nutrients, metals, and organics in the biomass (i.e., plant and microbes). The only major maintenance required would be replacement of the plant if it should die. As long as the plant is thriving, the Filterra® system should function as designed.

Contech Engineered Solutions recommends a semiannual maintenance schedule for installations on the east coast and an annual maintenance schedule for installations on the west coast. However, in industrial areas with heavy petroleum loading, the frequency of maintenance may need to be increased to maintain the flow rate of the mulch layer that protects the filtration media. For other land use applications where petroleum loadings are expected to be lower, progressive accumulation of petroleum that leads to reduction in hydraulic capacity and more frequent bypasses of the treatment system is not expected to be a significant issue.

As mentioned previously, maximum capacity flow rate tests performed on 10 different Filterra® systems demonstrated that the influent flow rate was maintained at or above the design flow rate (100 to 140 inches/hour) for systems of varying age (recently activated to 3 years) and varying maintenance periods (recently maintained to 2 years without maintenance) (Geosyntec 2008b).
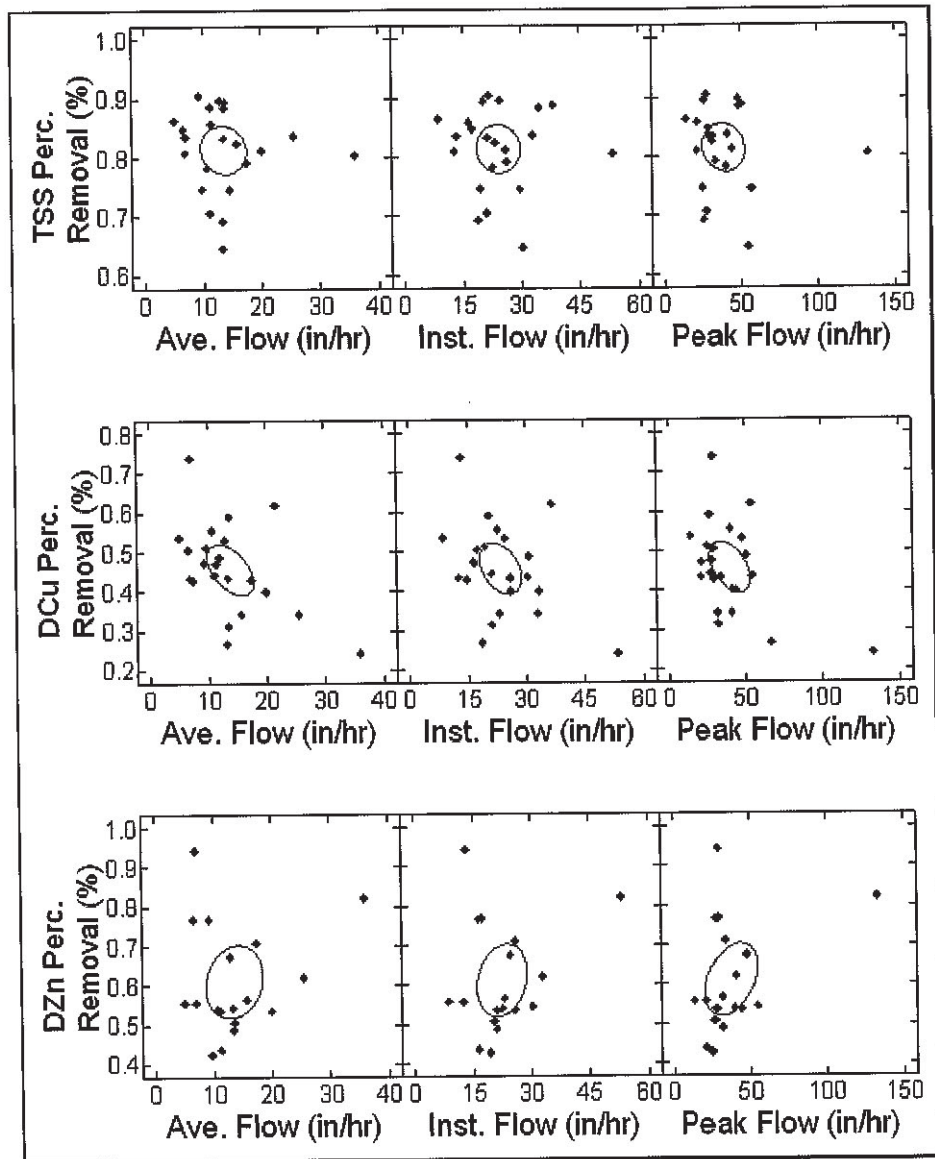
Figure 5. Matrix scatter plots showing relationships between percent removal and the following variables: average hydraulic loading, average instantaneous hydraulic loading, and peak hydraulic loading.

5. Conclusion

The Filterra® system design is based on bioretention technology and involves similar unit treatment processes. The mulch and the media layer perform inert and reactive filtration processes during storm events. The media layer also is expected to perform microbially-mediated transformations, biological uptake and sequestration, bacterial inactivation processes, and volatilization between storm events. In addition to microbially-mediated transformations and

biological uptake and sequestration, soil processes such as evapotranspiration, surface weathering, plant activity, and animal activity occur in and around the vegetation component and its root system. These inter-storm processes support the retention of captured pollutants and the preservation and regeneration of hydraulic function and pollutant removal capacity.

Filterra® systems filter stormwater at a high rate, allowing for a small footprint and providing a standardized, easily installed and maintained design. Field flow rate tests performed on Filterra® systems of varying age and varying maintenance periods resulted in a recommended design flow rate of 140 inches per hour. Bench-scale experiments indicated that media flow rates greater than 100 inches/hour and significant removal of small particles is possible using Filterra® system media. Five full-scale studies evaluating water quality treatment performance also found:

- TSS efficiency ratio of 83 to 88 percent; median TSS effluent concentration of less than 2.5 to 11.6 mg/L

- Total phosphorus efficiency ratio of 9 to 70 percent; median TP effluent concentration of 0.054 to 0.16 mg/L

- TKN efficiency ratio of 40 percent; median TKN effluent concentration of 1.15 mg/L Total copper efficiency ratio of 33 to 77 percent; median total copper effluent concentration of 0.0034 to 0.014 mg/L

- Dissolved copper efficiency ratio of 48 percent; median dissolved copper effluent concentration of 0.0033 mg/L

- Total zinc efficiency ratio of 48 to 78 percent; median total zinc effluent concentration of less than 0.02 to 0.102 mg/L

- Dissolved zinc efficiency ratio of 55 percent; median dissolved zinc effluent concentration of 0.082 mg/L

- Oil and grease efficiency ratio of 59 percent; median oil and grease effluent concentration of 2.9 mg/L

- TPH efficiency ratio of 96 percent; median TPH effluent concentration of 1.2 mg/L

Effluent concentrations achieved in the full-scale studies were generally equal to or lower than median effluent concentrations for the biofilter and media filter classes of BMPs reported in the International Stormwater BMP Database. In addition, Filterra® systems showed statistically significant removals for a broader range of pollutants than were shown for the biofilter and media filter categories in the International Stormwater BMP Database.

Correlation analyses performed on effluent concentrations and computed percent removals for TSS, dissolved copper, and dissolved zinc showed that system performance varied with influent

concentration; however, these same analyses indicated that there is likely not a direct relationship between system performance and hydraulic loading rate.

The semiannual maintenance schedule recommended by Contech Engineered Solutions. for east coast installations and annual maintenance schedule for west coast installations appears to be sufficient, based on results from maximum capacity flow rate tests demonstrating that the media flow rate was maintained at or above 100 to 140 inches/hour for Filterra® systems of varying age and varying maintenance periods. In industrial areas with heavy petroleum loading, the maintenance frequency for the Filterra® system may need to be increased to maintain the flow rate of the mulch layer protecting the filtration media.

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Note: Filterra® Bioretention Systems became part of Contech Engineered Solutions, LLC in September 2014.

APPENDIX C – HYDROLOGY MAPS

TRACT 52103

PARCEL 1   APN 7319-003-107

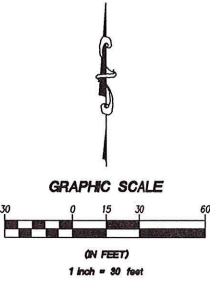FUTURE PROLOGIS PARCEL

ASPEN HILL
ROAD

Q10=9.25 CFS
Q50=14.72 CFS

CENTRAL AVENUE

N.A.P.
S.D.F. 2274-19-2 PAR. 1
APN 7319-003-809

TRACT 52103

N.A.P.
APN 7319-003-805

Q10=3.04 CFS
Q50=4.80 CFS

REC.
BLDG.

L=940'
S=0.02
Tc (10-YR)=11 MIN.
Tc (50-YR)=9 MIN.

5.83
75%

FF=160.2
P=159.7

FF=161.88   FF=162.31   FF=162.86
P=181.21   P=161.64   P=162.19

FF=184.08   FF=184.60
P=163.39   P=163.83

FF=182.7   FF=183.31
P=182.05   P=182.64

FF=184.76   FF=185.30
P=184.09   P=184.83

FF=183.35
P=183.35

FF=186.11   FF=186.84
P=165.44   P=165.97

FF=183.84
P=183.17

FF=183.84
P=183.17

FF=184.54   FF=184.97   FF=185.51
P=163.87   P=184.30   P=164.84

FF=186.60   FF=187.13
P=185.93   P=166.46

FF=184.49   FF=184.49
P=163.82   P=163.82

FF=185.72   FF=186.88
P=185.05   P=185.48   P=186.01

FF=188.95   FF=188.89
P=187.69   P=168.22

2
1.80
85%

L=680'
S=0.015
Tc (10-YR)=10 MIN.
Tc (50-YR)=8 MIN.

FF=183.39   FF=164.06   FF=165.83   FF=186.50
P=162.72   P=183.39   P=165.16   P=185.83

FF=189.39
P=168.69

VICTORIA STREET

GRAPHIC SCALE
30   0   15   30   60
(IN FEET)
1 inch = 30 feet

LEGEND

—————— DRAINAGE BOUNDARY

- - - - - FLOWPATH AND DIRECTION OF FLOW

X   SUB-AREA LABEL
Y   AREA (ACRES)
Z   % IMPERVIOUSNESS

ΣQ10   TOTAL 10 YEAR PEAK FLOW (CFS)
ΣQ50   TOTAL 50 YEAR PEAK FLOW (CFS)
Q10   10 YEAR PEAK FLOW (CFS)
Q50   50 YEAR PEAK FLOW (CFS)
CFS   CUBIC FEET PER SECOND
L=888'   LENGTH OF FLOWPATH (FT)
S=0.01   SLOPE OF FLOWPATH (FT./FT.)
Tc (10-YR) TIME OF CONCENTRATION (MIN.)

HYDROLOGY DATA:
SOIL TYPE NO. 013
ISOHYET (IN.): 10-YR: 4.43
              50-YR: 6.20
DESIGN STORM FREQUENCIES 10-YR AND 50-YR

VICTORIA GREENS
PRELIMINARY HYDROLOGY ANALYSIS
PROPOSED CONDITION

CITY OF CARSON   SHEET 1 OF 1

6
5
4
3
2
1
NO.   DATE   REVISIONS   APP.   DATE

JOB NO. 318.848

CENTRAL AVENUE

VICTORIA STREET

Q10=9.68 CFS
Q50=19.27 CFS

L=960'
S=0.02
Tc (10-YR)=13 MIN.
Tc (50-YR)=9 MIN.

| 1 |
| 7.63 |
| 5% |

GRAPHIC SCALE

30   0   15   30   60

(IN FEET)
1 inch = 30 feet

LEGEND

▬▬▬▬	DRAINAGE BOUNDARY
——·——	FLOWPATH AND DIRECTION OF FLOW
X	SUB-AREA LABEL
Y	AREA (ACRES)
Z	% IMPERVIOUSNESS
Σ Q10	TOTAL 10 YEAR PEAK FLOW (CFS)
Σ Q50	TOTAL 50 YEAR PEAK FLOW (CFS)
Q10	10 YEAR PEAK FLOW (CFS)
Q50	50 YEAR PEAK FLOW (CFS)
CFS	CUBIC FEET PER SECOND
L=888'	LENGTH OF FLOWPATH (FT)
S=0.01	SLOPE OF FLOWPATH (FT./FT.)
Tc (10-YR)	TIME OF CONCENTRATION (MIN.)

HYDROLOGY DATA:
SOIL TYPE NO. 013
ISOHYET (IN.): 10-YR: 4.43
                     50-YR: 6.20
DESIGN STORM FREQUENCIES 10-YR AND 50-YR

PREPARED BY:
URBAN RESOURCE
CONSULTING CIVIL ENGINEERS
23 MAUCHLY, SUITE 110
IRVINE, CA 92618
PHONE: 949-727-9015
FAX: 949-727-9018

ENGINEER'S SEAL
C 68465
EXP. 9-30-19
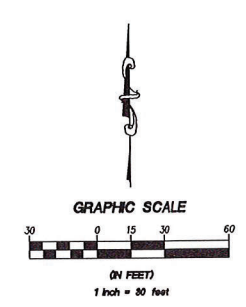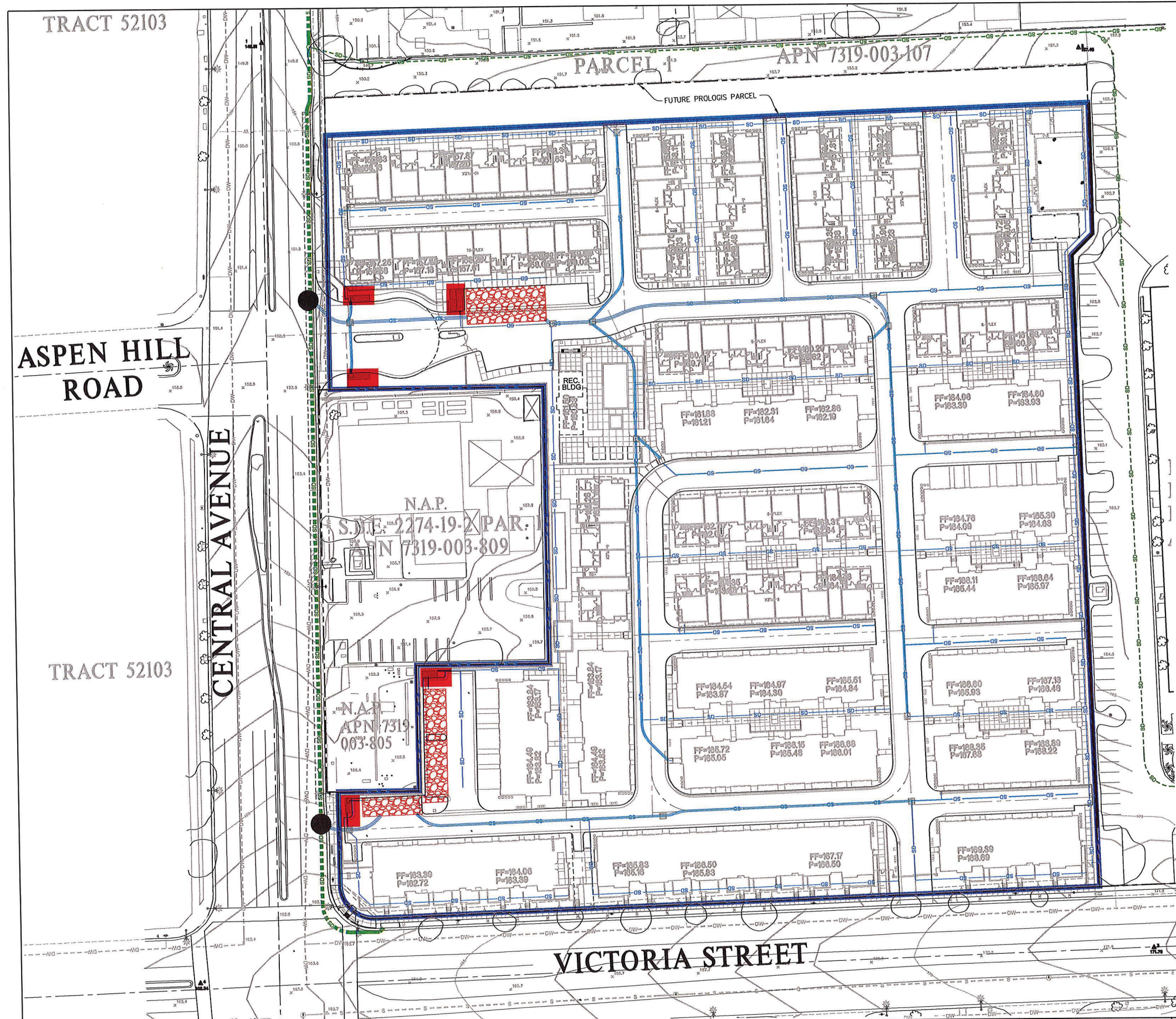
PREPARED FOR:
INTEGRAL COMMUNITIES

VICTORIA GREENS
PRELIMINARY HYDROLOGY ANALYSIS
EXISTING CONDITION

CITY OF CARSON   SHEET 1 OF 1

NO.	DATE	REVISIONS	APP.	DATE
6				
5				
4				
3				
2				
1				

JOB NO. 198.888

PLAN SET: A
DATE: 4-19-18

TRACT 52103

PARCEL 1   APN 7319-003-107

FUTURE PROLOGIS PARCEL

ASPEN HILL ROAD

CENTRAL AVENUE

TRACT 52103

N.A.P.
S.D. F. 2274-19-2 PAR.
APN 7319-003-809

N.A.P.
APN 7319-003-805

REC. BLDG

VICTORIA STREET

GRAPHIC SCALE

30   0   15   30   60

(IN FEET)
1 inch = 30 feet

LEGEND

—————— DRAINAGE AREA BOUNDARY

——SD—— EXISTING RCP STORM DRAIN

——SD—— PROPOSED STORM DRAIN

◼ PROPOSED CONTECH FILTERRA UNIT

▨ PROPOSED UNDERGROUND DETENTION/STORAGE

● PROPOSED ONSITE STORM DRAIN OUTLET LOCATION TO OFFSITE STORM DRAIN

PREPARED BY:
URBAN RESOURCE
CONSULTING CIVIL ENGINEERS
23 MAUCHLY, SUITE 110
IRVINE, CA 92618
PHONE: 949-727-9015
FAX: 949-727-9016

PREPARED FOR: INTEGRAL COMMUNITIES

ENGINEER'S SEAL

VICTORIA GREENS
PRELIMINARY LID PLAN

CITY OF CARSON   SHEET 1 OF 1

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