Preliminary Hydromodification Management Study

Avion

Vesting Tentative Map
***PTS* #598173**

City of San Diego, CA
April 24, 2019

Prepared for:
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Prepared by: S. Li
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Debby Reece, PE RCE 56148
Registration Expires 12/31/20

1. INTRODUCTION

This report summarizes hydromodification design for the Avion Project (formerly known as the DebeVoise Project) located in the City of San Diego, CA. The hydromodification calculations were performed utilizing continuous simulation analysis to size the storm water treatment and control facilities. Storm Water Management Model (SWMM) version 5.1 distributed by USEPA is the basis of both existing and proposed conditions modeling within this report. The biofiltration basin sizing and link configuration with the specialized outlet configuration ensures compliance with the Hydromodification Management Plan (HMP) requirements from the San Diego Regional Water Quality Control Board (SDRWQCB).

2. PROJECT DESCRIPTION

The Avion San Diego Project is a proposed community located in the City of San Diego. The site is approximately 13 acres in size and is located south of Carmel Valley Road, and northeast of Black Mountain Road. The property is located in the Black Mountain Ranch Subarea. The surrounding land (except for an adjacent Heritage Bluffs II project area) is designated as open space in the Subarea Plan and is part of the MHPA. The project involves the construction of a residential subdivision with 83 single family residential units and surrounding recreation areas.

3. HYDROMODIFICATION MODELING OVERVIEW

3. 1 Model Description

PCSWMM is a proprietary software which utilizes the EPA's Stormwater Management Model (SWMM) as its computational engine, while providing added processing and analytical capabilities to streamline design. PCSWMM is essentially a user-friendly shell for SWMM that allows rapid development and analysis of SWMM models.

PCSWMM was employed for this study based on the ability to efficiently create, edit and compare models, perform detention routing with the same software, and moreover, due to the tendency for SWMM to produce results that have been found to more accurately represent San Diego area watersheds than the alternative San Diego Hydrology Model (SDHM).

SWMM is a semi-distributed hydrologic and hydraulic modeling software that simulates the rainfall-runoff response of a watershed based on linear-reservoir overland flow routing. This overland flow routine accounts the connectedness of pervious, impervious and Low Impact Development (LID) BMPs to the drainage system. LID BMPs are represented with a module in SWMM that simulates the water balance through standard LID BMP components, accounting for soil percolation, evapotranspiration, underdrain outflow, various media layer storage and subgrade infiltration. These controls provide a wide range of customizability between the various associated parameters and the ability to route underdrain or overflow to other SWMM elements, like storages nodes and conduits to represent most any conceivable LID system.

The outflow from these LID controls, storage components or watersheds is translated into the hydraulic component of the model that utilizes energy and momentum principles to determine flow through conduits, orifices and other structures. The hydraulics may be computed based on either the kinematic or dynamic-wave equations. In this study the former was used because there was no need to take downstream hydraulic grade line effects into consideration.

3.2 Hydromodification Criteria

The San Diego Regional Water Quality Control Board (SDRWQCB) requires the exceedance duration of post-developed flow rates be maintained to within 10% of the pre-developed flow durations. This must occur for flow frequencies ranging from a fraction of the 2-year flow (Q2) to the 10-year flow (Q10). These flow frequency values may be calculated directly from SWMM statistics or estimated based on accepted USGS regression equations. These equations estimate flows based on a correlation with watershed area and the mean annual rainfall developed for the region. For this project the SWMM output was used because of the exceedingly small values calculated by regression equations, which were developed with data from significantly larger watersheds.

The fraction of the Q2 that must be controlled is dependent on the relative erodibility of the channel being discharged to, categorized as either High, Medium or Low susceptibility. By default it is assumed that all channels have a High susceptibility, and that therefore 0.1 of the Q2 must be controlled. A Geomorphic Assessment of Receiving Channels may be performed to indicate whether the channel erosion susceptibility can be categorized as Medium or Low, allowing control to 0.3 or 0.5 of the Q2, respectively.

The low-flow threshold used in the analysis for Avion project is the default 0.1Q2 low-flow threshold, since no geomorphic channel assessment analysis was performed for the downstream locations.

3.3 Model Development

The inputs required for a SWMM model include rainfall, evapotranspiration rates, watershed characteristics and BMP configurations. The sources for some of these parameters are provided in Table 1 below.

Table 1: Hydrology Criteria

Rain Gage	'Poway' – from Project Clean Water website (See Rain Gage Map in Attachment 2)
Evapotranspiration	Daily E-T Rates taken from Table G.1-1 in the City of San Diego BMP Design Manual based on location in Zone 6 of California irrigation Management Information System "Reference Evapotranspiration Zones"
Overland Flow Path Length	Based on available digital topographic data for pre-development conditions and proposed grading plan for post-project conditions.
Soils/Green-Ampt Parameters	Values for Hydrologic Soil Group 'D' taken from Table G.1-4 in the City of San Diego BMP Design Manual.

The drainage management area (DMA) to the point of compliance (POC) was delineated with the project boundary plus small fragments of adjacent land that drain through the site for both existing and proposed conditions. See the Storm Water Quality Management Plan (SWQMP) for more information regarding the pollutant control strategy and DMAs.

The overland flow path lengths were drawn from a visual inspection of the watershed contours, extending from the upper ridge to the apparent flow path, perpendicular to the contours. The percent imperviousness was assumed as a conservative number of 75% based on the known coverages in the site plan to develop the same values used to calculate the Design Capture Volume provided in Attachment 1e of the SWQMP. An electronic copy of the model is provided in Attachment 2 of this report.

4. Modeling for Hydromodification Compliance

The pre-developed conditions for the site were modelled based on the existing topography and landcover with zero imperviousness. For the post-developed conditions the proposed site footprint was represented as an equivalent imperviousness and an overland flow path length typical of urban drainage systems. The lined biofiltration basin was modelled by coupling the bioretention LID component to properly represent the media and underdrain, with the storage component to represent the basin surface storage. The parameters utilized for the biofiltration parameters were based on the published values in the City of San Diego Stormwater Standards. The basin outlets to a new proposed stormdrain pipe that will discharge to the adjacent Creek. It was determined that this BMP would be sufficient to provide flow control with the storage depths and outlet size provided herein based on the SWMM modeling results. The Status Report SWMM output file for the existing condition is provided in Attachment 3 and the proposed condition is provided in Attachment 4.

4.1 Flow Frequency Analysis

The SWMM statistics calculator was used to determine the pre-developed and post developed flow rates for the 2, 5, and 10-year recurrence intervals. These are provided below with the resultant low flow threshold based on the default low flow threshold. The SWMM output used to calculate these values is provided in Attachment 5.

A Geomorphic Assessment of Receiving Channels, often referred to as a SCCWRP analysis, was not performed for Avion project. Thus a default factor of 0.1 is used as to calculate the low flow threshold from the flow rate of the 2-year recurrence interval.

Table 2 – Pre-Developed and Post-Mitigated Flows for the POC

Return Period	Pre-project - Qpeak (cfs)	Post-project - Mitigated Q (cfs)
LF = 0.1xQ2	0.411	0.150
2-year	4.112	1.503
5-year	5.549	3.060
10-year	6.389	4.533

4.2 Biofiltration Basin

The basin is composed of above ground storage as well as biofiltration media. These components were represented as an LID control ("Bio-retention cell") in series with a storage node as simulated in SWMM. The module allows the user to represent the various stages of a biofiltration basin including ponding, media, and gravel storage above and below the underdrain. These layer depths were assigned per the design developed for pollutant control as shown in Table 3 and the parameter values were assigned with the standard values taken from Table G.1-7 in the BMP Design Manual (with some refinement). The underdrain is offset to allow for the dead storage needed. The drain coefficients are calculated based on media infiltration of 5 in/hr and basin layer depth and listed in Table 3.

Table 3 – Biofiltration Model Summary

Biofiltration BMP #	Surface Area (sf)	Layer Depth			Underdrain Orifice (in)	Drain Coefficient
		Ponding (in)	Soil (in)	Gravel Storage (in)		
1	13163	6	21	12	1	0.0995
Media and storage parameters taken from Table G.1-7 in BMP Design Manual, including media infiltration = 5 in/hr						

To control the flows with this configuration, except for underdrain orifices, a series of flow orifices were connected between the biofiltration basin storage node connected to the point of compliance. The orifice design is summarized in Table 4.

Table 4 – Biofiltration Orifice Design

Biofiltration BMP #	Low Flow Orifice		Mid Flow Orifice		High Flow Orifice		Overflow Weir	
	Dia. (in)	Offset (ft)	Dia. (in)	Offset (ft)	Dia. (in)	Offset (ft)	Dia. (ft)	Offset (ft)
1	2	0.5	1	1.5	1	3.0	3.0	3.5

4.3 Flow Duration Curves for Hydromodification Compliance

The pre and post developed flow duration exceedance curves were developed for the hourly flow data using an automatic partial duration series calculator in PCSWMM. These curves are graphed over the flow ranges listed in Table 2-6 and are provided in Attachment 6. In all cases the duration of post developed flows are brought to well within that of the pre developed flows for ten percent of the two-year flow to the ten-year flow, indicating that the suite of BMPs will provide the flow attenuation required for compliance.

5.0 SUMMARY

The predeveloped conditions of the Avion site were modelled in SWMM to determine a baseline of flow durations that would need to be controlled in the post-developed conditions. The proposed development was also modelled in SWMM with biofiltration basin with significant storage. Based on the SWMM model results for this study it is determined that the biofiltration basin will be able to satisfy the hydromodification criteria. This study is intended to demonstrate that these controls as sized are capable of providing hydromodification compliance and a full outlet design will be performed during final engineering.

Attachments

1 – Hydromodification Management Exhibit

2 – SWMM Model w/ Subcatchment Schematics

3 – SWMM Output – Existing Condition

4 – SWMM Output – Proposed Conditions

5 – Flow Frequency Statistical Analysis results

6 – Flow Duration Curves

1

ATTACHMENT 1

Hydromodification Management Exhibit

BMP NOTES:

1. SITE DESIGN BMPS INCLUDE:
   - MINIMIZATION OF IMPERVIOUS FOOTPRINT
2. SOURCE CONTROL BMPs FOR PROJECT INCLUDE:
   - INTEGRATED PEST MANAGEMENT PRINCIPLES
   - EFFICIENT LANDSCAPE AND IRRIGATION DESIGN
   - STORMWATER EDUCATION
   - BUILDING MANAGEMENT PRACTICES (MANAGEMENT OF FIRE SPRINKLER SYSTEM DISCHARGES, AIR CONDITIONING CONDENSATE DISCHARGES, AND THE USE OF NON-TOXIC ROOFING MATERIALS.)
3. THE TREATMENT BMP SELECTED FOR THIS PROJECT IS A LINED BIOFILTRATION BASIN
4. PROJECT WILL OUTLET TO ADJACENT CREEK AND PROJECT IS SUBJECT TO HYDROMODIFICATION REQUIREMENTS
5. THE NRCS SOIL SURVEY CLASSIFIES THE SITE SOILS AS HYDROLOGIC SOIL GROUP 'D'
6. GROUNDWATER LEVEL VARIES, BUT WAS NOT ENCOUNTERED WITHIN 20' OF SURFACE NEAR UPPER PORTIONS OF PROJECT
7. THERE ARE NO CCSYA WITHIN THE PROPERTY OR THE VICINITY.

LEGEND:

(line)	PROJECT BOUNDARY
(heavy line)	DRAINAGE MANAGEMENT AREA (DMA)

SCALE: 1"=40'	PREPARED BY:	CITY OF SAN DIEGO
JOB #: 3255.4	PROJECT DESIGN CONSULTANTS Planning I Landscape Architecture I Engineering I Survey 701 B Street, Suite 800 San Diego, CA 92101 619.235.6471 Tel 619.234.0349 Fax	AVION
CREATED: 8/29/18		HYDROMODIFICATION MAP PROPOSED CONDITIONS EXHIBIT 2A

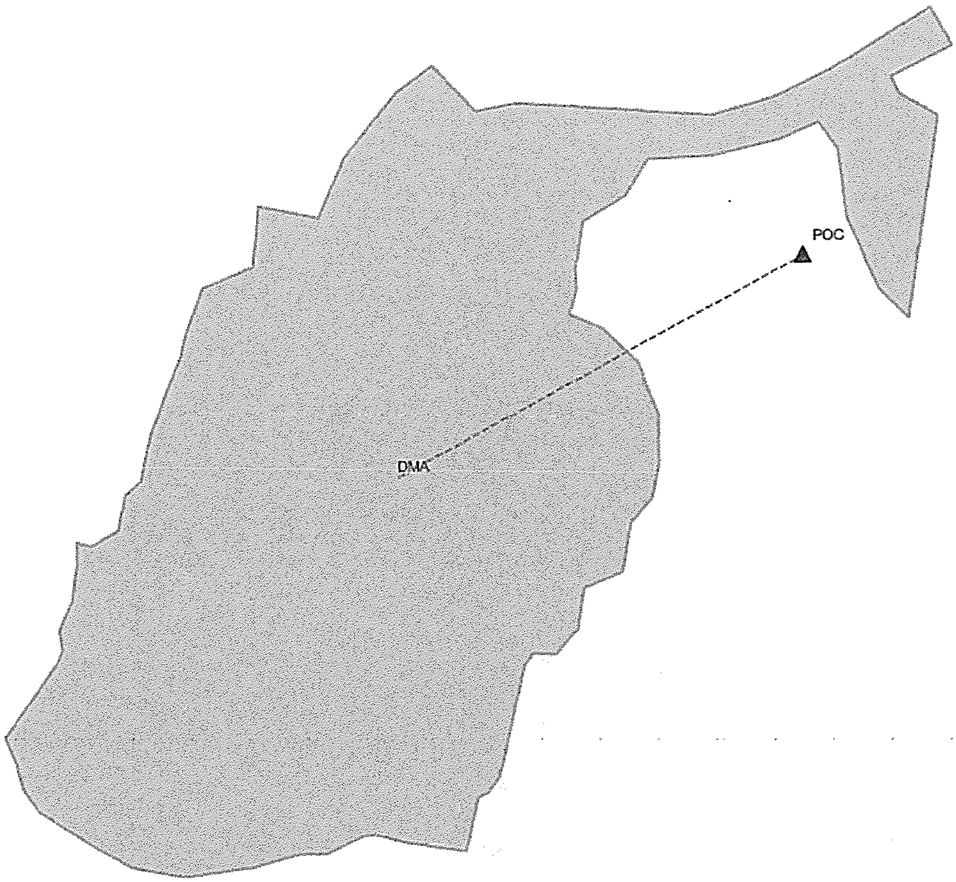
2

ATTACHMENT 2

SWMM Model with

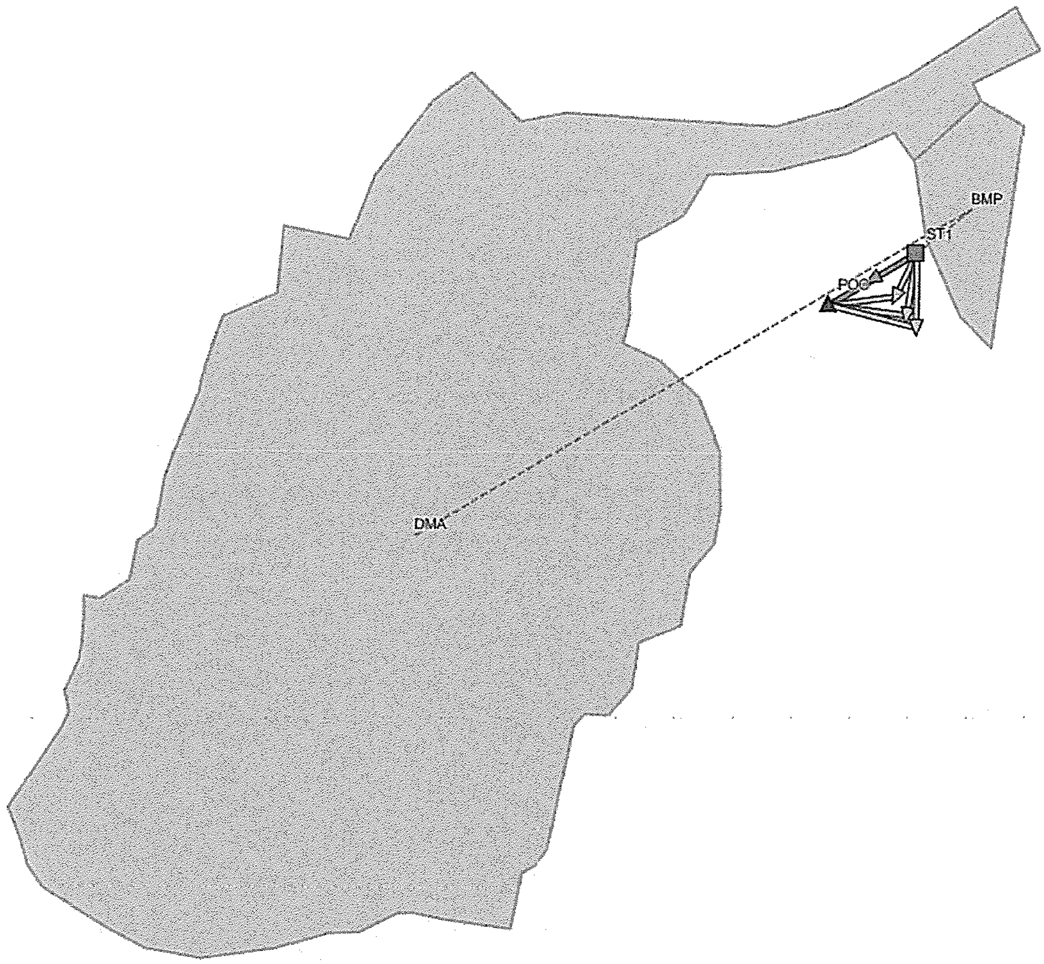
Sub-catchment Parameters and Schematic

Existing Conditions



Name	Rain Gage	Outlet	Area (ac)	Width (ft)	Flow Length (ft)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (in)	Dstore Perv (in)	Zero Imperv (%)	Suction Head (in)	Conductivity (in/hr)	Initial Deficit (frac.)
DMA	Poway	POC	11.23	560	873.534	20.7	0	0.012	0.15	0.05	0.1	25	9	0.025	0.33

Proposed Conditions



Name	Rain Gage	Outlet	Area (ac)	Width (ft)	Flow Length (ft)	Slope (%)	Imperv. (%)	N Imperv	N Perv	Dstore Imperv (in)	Dstore Perv (in)	Zero Imperv (%)	Suction Head (in)	Conductivity (in/hr)	Initial Deficit (frac.)
DMA	Poway	BMP	10.22	560	794.97	14	75	0.012	0.15	0.05	0.1	25	9	0.019	0.33
BMP	Poway	ST1	0.3	96	136.1...	0.5	0	0.012	0.15	0.05	0.1	25	9	0.019	0.33

SWMM Model Flow Coefficient Calculation

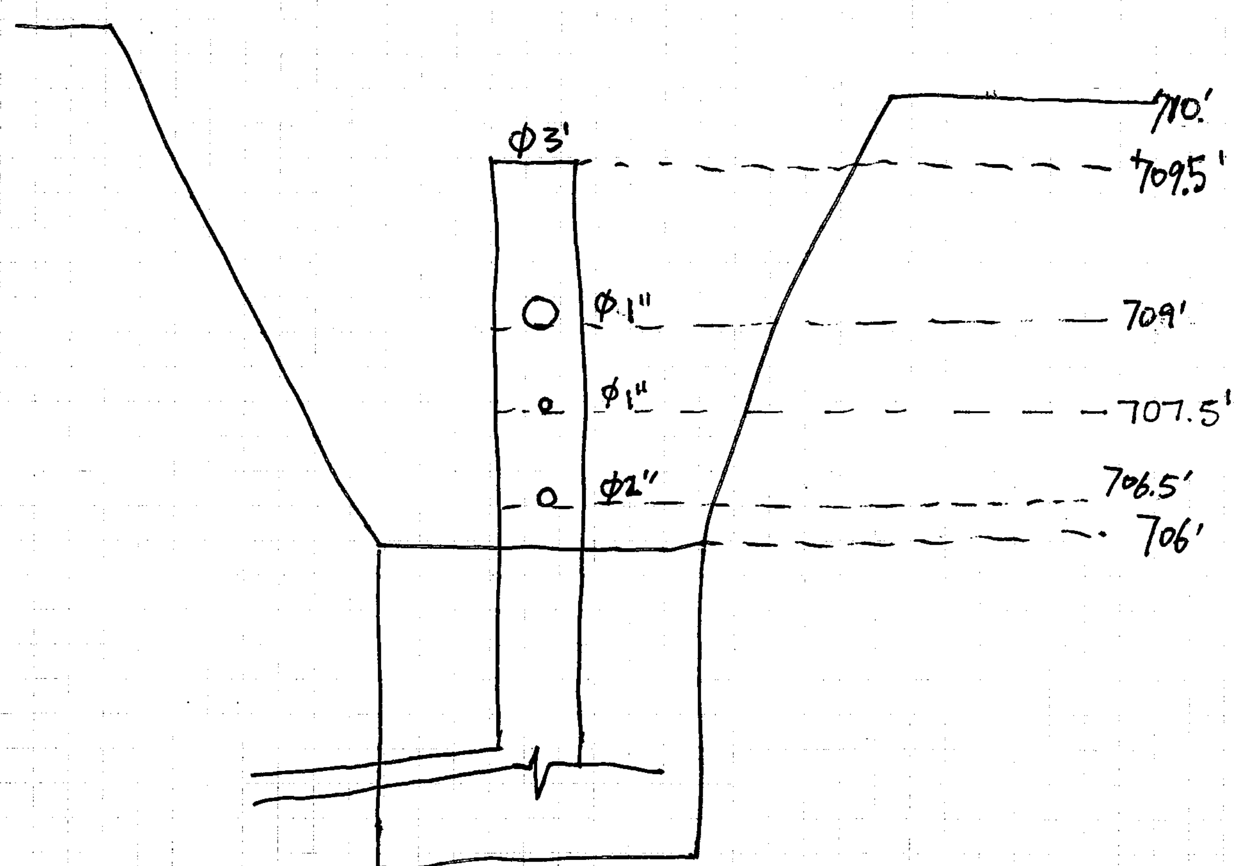
PARAMETER	ABBREV.	Bio-Retention Cell LID BMP	
Ponding Depth	PD	6	in
Bioretention Soil Layer	S	18	in
Gravel Layer	G	12	in
TOTAL		3.0	ft
		36	in
Orifice Coefficient	c_g	0.6	--
Low Flow Orifice Diameter	D	2	in
Drain exponent	n	0.5	--
Flow Rate (volumetric)	Q	0.179	cfs
Ponding Depth Surface Area	A_{PD}	13163	ft^2
Bioretention Surface Area	A_S, A_G	13163	ft^2
	A_S, A_G	0.3022	ac
Porosity of Bioretention Soil	n	1.00	-
Flow Rate (per unit area)	q	0.589	in/hr
Effective Ponding Depth	PD_{eff}	**6.00**	in
Flow Coefficient	C	**0.0995**	--

PROJECT DESIGN CONSULTANTS

PLANNING | LANDSCAPE ARCHITECTURE
ENVIRONMENTAL | ENGINEERING | SURVEY

WWW.PROJECTDESIGN.COM

PROJECT DEBEVOISE
SUBJECT BMP BASIN
PAGE : ______ OF ______ JOB NO. : 3255.4
DRAWN BY : S. LI DATE : 1/16/18
CHECKED BY : ______ DATE : ______



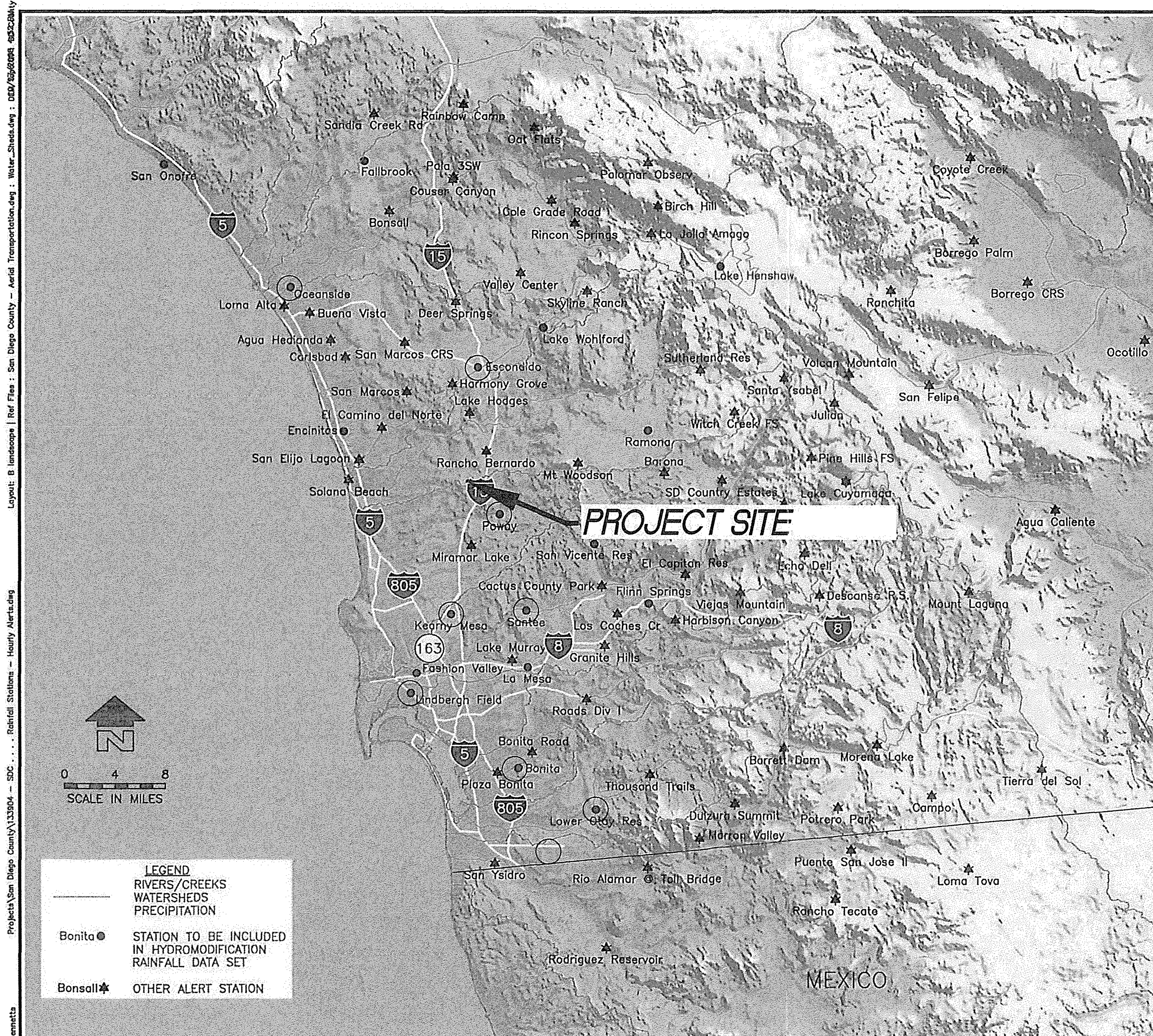
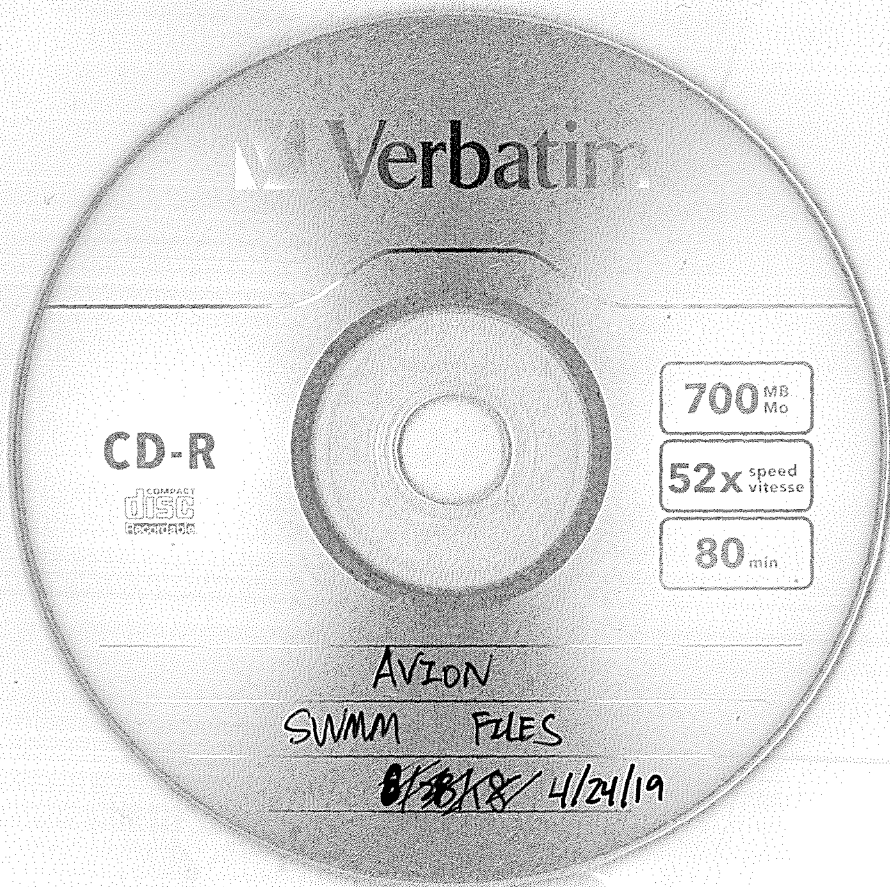


FIGURE 1

RAINFALL STATION MAP

PROJECT LOCATION	DATE	PROJECT NUMBER
SAN DIEGO COUNTY, CALIFORNIA	OCT 2008	133904

BROWN AND CALDWELL
SAN DIEGO, CALIFORNIA


Verbatim
CD-R
COMPACT disc Recordable
700 MB Mo
52x speed vitesse
80 min
AVION
SWMM FILES
4/24/19

3

Attachment 3

SWMM Output – Existing Conditions

```
EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.011)
------------------------------------------------------------

*************
Element Count
*************
Number of rain gages ...... 1
Number of subcatchments ... 1
Number of nodes ........... 1
Number of links ........... 0
Number of pollutants ...... 0
Number of land uses ....... 0


****************
Raingage Summary
****************
                                                    Data        Recording
Name                 Data Source                    Type        Interval
------------------------------------------------------------------------
Poway                POWAY                          INTENSITY   60 min.


********************
Subcatchment Summary
********************
Name                       Area     Width   %Imperv    %Slope Rain Gage            Outlet
-----------------------------------------------------------------------------------------------------------
DMA                       11.23    560.00      0.00   20.7000 Poway                POC


************
Node Summary
************
                                           Invert      Max.    Ponded    External
Name                 Type                   Elev.     Depth      Area    Inflow
-------------------------------------------------------------------------------
POC                  OUTFALL                 0.00      0.00       0.0


*********************************************************
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
*********************************************************

****************
Analysis Options
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... NO
  Water Quality .......... NO
Infiltration Method ...... GREEN_AMPT
Starting Date ............ 10/04/1962 15:00:00
Ending Date .............. 05/23/2008 15:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 01:00:00
Wet Time Step ............ 00:10:00
Dry Time Step ............ 01:00:00


**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Total Precipitation ......       522.401       558.220
Evaporation Loss .........        18.048        19.285
Infiltration Loss ........       422.492       451.460
Surface Runoff ...........        84.680        90.487
Final Storage ............         0.000         0.000
Continuity Error (%) .....        -0.540


**************************        Volume        Volume
```

Flow Routing Continuity	acre-feet	10^6 gal
Dry Weather Inflow	0.000	0.000
Wet Weather Inflow	84.680	27.594
Groundwater Inflow	0.000	0.000
RDII Inflow	0.000	0.000
External Inflow	0.000	0.000
External Outflow	84.680	27.594
Flooding Loss	0.000	0.000
Evaporation Loss	0.000	0.000
Exfiltration Loss	0.000	0.000
Initial Stored Volume	0.000	0.000
Final Stored Volume	0.000	0.000
Continuity Error (%)	0.000	

****
Subcatchment Runoff Summary
****

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
DMA	558.22	0.00	19.29	451.46	90.49	27.59	7.61	0.162

Analysis begun on: Thu Apr 18 16:50:29 2019
Analysis ended on: Thu Apr 18 16:50:34 2019
Total elapsed time: 00:00:05

4

Attachment 4

SWMM Output – Proposed Conditions

EPA STORM WATER MANAGEMENT MODEL - VERSION 5.1 (Build 5.1.011)

****
Element Count
****

Number of rain gages 1
Number of subcatchments ... 2
Number of nodes 2
Number of links 4
Number of pollutants 0
Number of land uses 0

****
Raingage Summary
****

Name	Data Source	Data Type	Recording Interval
Poway	POWAY	INTENSITY	60 min.

****
Subcatchment Summary
****

Name	Area	Width	%Imperv	%Slope	Rain Gage	Outlet
BMP	0.30	96.00	0.00	0.5000	Poway	ST1
DMA	10.22	560.00	75.00	14.0000	Poway	BMP

****
LID Control Summary
****

Subcatchment	LID Control	No. of Units	Unit Area	Unit Width	% Area Covered	% Imperv Treated
BMP	LID	1	10890.00	0.00	83.33	0.00

****
Node Summary
****

Name	Type	Invert Elev.	Max. Depth	Ponded Area	External Inflow
POC	OUTFALL	0.00	0.00	0.0	
ST1	STORAGE	0.00	3.50	0.0	

****
Link Summary
****

Name	From Node	To Node	Type	Length	%Slope	Roughness
2	ST1	POC	ORIFICE			
OR1	ST1	POC	ORIFICE			
OR2	ST1	POC	ORIFICE			
1	ST1	POC	WEIR			

****
Cross Section Summary
****

Conduit	Shape	Full Depth	Full Area	Hyd. Rad.	Max. Width	No. of Barrels	Full Flow

****
NOTE: The summary statistics displayed in this report are
based on results found at every computational time step,
not just on results from each reporting time step.
****

****
Analysis Options

```
****************
Flow Units ............... CFS
Process Models:
  Rainfall/Runoff ........ YES
  RDII ................... NO
  Snowmelt ............... NO
  Groundwater ............ NO
  Flow Routing ........... YES
  Ponding Allowed ........ NO
  Water Quality .......... NO
Infiltration Method ...... GREEN_AMPT
Flow Routing Method ...... KINWAVE
Starting Date ............ 10/04/1962 15:00:00
Ending Date .............. 05/23/2008 15:00:00
Antecedent Dry Days ...... 0.0
Report Time Step ......... 01:00:00
Wet Time Step ............ 00:10:00
Dry Time Step ............ 01:00:00
Routing Time Step ........ 60.00 sec

**************************        Volume         Depth
Runoff Quantity Continuity     acre-feet        inches
**************************     ---------       -------
Initial LID Storage ......         0.037         0.043
Total Precipitation ......       489.373       558.220
Evaporation Loss .........        75.827        86.494
Infiltration Loss ........        92.642       105.675
Surface Runoff ...........       321.734       366.997
LID Drainage .............         2.429         2.771
Final Storage ............         0.083         0.095
Continuity Error (%) .....        -0.675

**************************        Volume        Volume
Flow Routing Continuity        acre-feet      10^6 gal
**************************     ---------     ---------
Dry Weather Inflow .......         0.000         0.000
Wet Weather Inflow .......       324.156       105.631
Groundwater Inflow .......         0.000         0.000
RDII Inflow ..............         0.000         0.000
External Inflow ..........         0.000         0.000
External Outflow .........       324.109       105.616
Flooding Loss ............         0.000         0.000
Evaporation Loss .........         0.000         0.000
Exfiltration Loss ........         0.000         0.000
Initial Stored Volume ....         0.000         0.000
Final Stored Volume ......         0.020         0.006
Continuity Error (%) .....         0.009

********************************
Highest Flow Instability Indexes
********************************
All links are stable.

*************************
Routing Time Step Summary
*************************
Minimum Time Step           :     60.00 sec
Average Time Step           :     60.00 sec
Maximum Time Step           :     60.00 sec
Percent in Steady State     :      0.00
Average Iterations per Step :      1.00
Percent Not Converging      :      0.00

***************************
Subcatchment Runoff Summary
***************************
```

Subcatchment	Total Precip in	Total Runon in	Total Evap in	Total Infil in	Total Runoff in	Total Runoff 10^6 gal	Peak Runoff CFS	Runoff Coeff
BMP	558.22	12915.98	379.25	157.28	12966.52	105.63	8.20	0.962
DMA	558.22	0.00	77.90	104.16	379.15	105.22	8.14	0.679

****
LID Performance Summary
****

Subcatchment	LID Control	Total Inflow in	Evap Loss in	Infil Loss in	Surface Outflow in	Drain Outflow in	Initial Storage in	Final Storage in	Continuity Error %
BMP	LID	558.22	441.51	0.00	0.00	116.59	1.80	1.90	0.00

****
Node Depth Summary
****

Node	Type	Average Depth Feet	Maximum Depth Feet	Maximum HGL Feet	Time of Max Occurrence days hr:min	Reported Max Depth Feet
POC	OUTFALL	0.00	0.00	0.00	0 00:00	0.00
ST1	STORAGE	0.09	3.39	3.39	6348 09:11	3.38

****
Node Inflow Summary
****

Node	Type	Maximum Lateral Inflow CFS	Maximum Total Inflow CFS	Time of Max Occurrence days hr:min	Lateral Inflow Volume 10^6 gal	Total Inflow Volume 10^6 gal	Flow Balance Error Percent
POC	OUTFALL	0.05	8.08	6348 09:11	0.791	106	0.000
ST1	STORAGE	8.16	8.16	6348 09:01	105	105	0.009

****
Node Surcharge Summary
****

No nodes were surcharged.

****
Node Flooding Summary
****

No nodes were flooded.

****
Storage Volume Summary
****

Storage Unit	Average Volume 1000 ft3	Avg Pcnt Full	Evap Pcnt Loss	Exfil Pcnt Loss	Maximum Volume 1000 ft3	Max Pcnt Full	Time of Max Occurrence days hr:min	Maximum Outflow CFS
ST1	1.256	2	0	0	54.237	97	6348 09:11	8.04

****
Outfall Loading Summary
****

Outfall Node	Flow Freq Pcnt	Avg Flow CFS	Max Flow CFS	Total Volume 10^6 gal
POC	22.50	0.04	8.08	105.608

System	22.50	0.04	8.08	105.608

****
Link Flow Summary
****

Link	Type	Maximum |Flow| CFS	Time of Max Occurrence days hr:min	Maximum |Veloc| ft/sec	Max/ Full Flow	Max/ Full Depth
2	ORIFICE	0.02	6348 09:11			0.00
OR1	ORIFICE	0.19	6348 09:11			0.00
OR2	ORIFICE	0.04	6348 09:11			0.00
1	WEIR	7.78	6348 09:11			0.00

****
Conduit Surcharge Summary
****

No conduits were surcharged.

Analysis begun on: Thu Apr 18 17:31:10 2019
Analysis ended on: Thu Apr 18 17:31:27 2019
Total elapsed time: 00:00:17

5

Attachment 5

Flow Frequency Statistical Analysis

Pre-project Flow Frequency - Long-term Simulation

Statistics - Node POC Total Inflow

Rank	Start Date	Event Duration (hours)	Event Peak (CFS)	Exceedance Frequency (percent)	Return Period (years)
1	2/18/1980	77	7.547	0.34	47
2	3/24/1983	12	7.534	0.68	23.5
3	1/9/1978	30	6.733	1.02	15.67
4	1/25/1995	12	6.54	1.36	11.75
5	3/17/1982	21	6.337	1.7	9.4
6	12/17/1978	41	5.936	2.04	7.83
7	2/8/1998	16	5.883	2.38	6.71
8	12/28/2004	21	5.667	2.72	5.88
9	2/3/1998	27	5.562	3.06	5.22
10	11/12/1976	3	5.532	3.4	4.7
11	2/28/1970	4	5.505	3.74	4.27
12	11/5/1987	3	5.325	4.08	3.92
13	3/1/1983	69	5.167	4.42	3.62
14	12/28/1978	40	5.138	4.76	3.36
15	1/28/1980	46	4.886	5.1	3.13
16	11/29/1982	23	4.858	5.44	2.94
17	1/6/1974	33	4.844	5.78	2.76
18	1/5/1979	24	4.833	6.12	2.61
19	2/14/1998	7	4.793	6.46	2.47
20	2/8/1983	6	4.737	6.8	2.35
21	1/9/2005	23	4.474	7.14	2.24
22	4/18/1995	6	4.212	7.48	2.14
23	2/27/2001	12	4.129	7.82	2.04
24	2/8/1993	7	4.095	8.16	1.96
25	2/12/2003	10	3.935	8.5	1.88
26	11/16/1972	22	3.879	8.84	1.81
27	2/17/1998	10	3.775	9.18	1.74
28	2/21/2000	7	3.741	9.52	1.68
29	3/8/1974	10	3.74	9.86	1.62
30	11/22/1965	19	3.725	10.2	1.57
31	11/30/2007	13	3.621	10.54	1.52
32	2/16/1980	5	3.618	10.88	1.47
33	4/1/1982	4	3.553	11.22	1.42
34	12/4/1974	4	3.466	11.56	1.38
35	3/17/1983	30	3.457	11.9	1.34
36	1/4/1995	8	3.395	12.24	1.31
37	12/9/1965	29	3.299	12.59	1.27
38	1/9/1998	31	3.271	12.93	1.24
39	10/27/2004	12	3.222	13.27	1.21
40	3/17/1963	2	3.201	13.61	1.17
41	2/21/2005	12	3.187	13.95	1.15
42	3/5/1995	19	3.174	14.29	1.12
43	11/21/1996	9	3.16	14.63	1.09
44	2/6/1998	9	3.134	14.97	1.07
45	1/15/1993	81	3.006	15.31	1.04
46	1/24/1969	23	2.924	15.65	1.02
47	4/20/1988	40	2.898	15.99	1

10-year Q:	6.389	cfs
5-year Q:	5.549	cfs
2-year Q:	4.112	cfs
Lower Flow Threshold:	10%	
0.1xQ2 :	0.411	cfs

Post-project Flow Frequency - Long-term Simulation

Statistics - Node POC Total Inflow

Rank	Start Date	Event Duration (hours)	Event Peak (CFS)	Exceedance Frequency (percent)	Return Period (years)
1	2/13/1980	348	7.778	0.19	47
2	2/3/1998	659	5.863	0.39	23.5
3	12/27/1978	406	5.074	0.58	15.67
4	1/27/1980	220	5.047	0.77	11.75
5	12/23/1977	774	4.357	0.96	9.4
6	11/30/2007	309	3.942	1.16	7.83
7	11/14/1965	383	3.869	1.35	6.71
8	1/3/1995	697	3.67	1.54	5.88
9	12/17/1978	210	3.07	1.73	5.22
10	12/3/1966	244	3.047	1.93	4.7
11	2/24/1983	370	2.831	2.12	4.27
12	2/27/1978	445	2.719	2.31	3.92
13	12/28/2004	498	2.422	2.5	3.62
14	10/17/2004	406	2.289	2.7	3.36
15	11/29/1982	336	2.143	2.89	3.13
16	12/27/1992	686	2.12	3.08	2.94
17	3/3/1995	366	2.112	3.28	2.76
18	2/27/1991	198	1.985	3.47	2.61
19	3/11/1982	645	1.958	3.66	2.47
20	1/4/1974	258	1.927	3.85	2.35
21	1/7/1980	360	1.865	4.05	2.24
22	2/11/2005	452	1.86	4.24	2.14
23	2/3/1976	299	1.605	4.43	2.04
24	2/15/1986	167	1.234	4.62	1.96
25	12/9/1965	381	1.029	4.82	1.88
26	4/5/1975	240	1.016	5.01	1.81
27	2/18/2004	381	0.928	5.2	1.74
28	1/20/1982	255	0.868	5.39	1.68
29	11/21/1996	186	0.62	5.59	1.62
30	2/28/1970	301	0.571	5.78	1.57
31	2/9/1963	198	0.341	5.97	1.52
32	3/17/1983	334	0.257	6.17	1.47
33	1/14/1969	467	0.257	6.36	1.42
34	2/7/1993	179	0.254	6.55	1.38
35	3/11/1991	554	0.247	6.74	1.34
36	4/14/1988	332	0.232	6.94	1.31
37	2/18/1993	266	0.228	7.13	1.27
38	11/24/1985	318	0.228	7.32	1.24
39	11/12/1976	159	0.227	7.51	1.21
40	12/4/1974	157	0.219	7.71	1.17
41	2/23/2001	257	0.218	7.9	1.15
42	1/8/2001	244	0.218	8.09	1.12
43	1/23/1983	532	0.216	8.29	1.09
44	2/25/1981	304	0.215	8.48	1.07
45	12/26/1984	169	0.214	8.67	1.04
46	12/16/1987	177	0.212	8.86	1.02
47	4/16/1995	208	0.209	9.06	1

10-year Q:	4.533	cfs
5-year Q:	3.060	cfs
2-year Q:	1.503	cfs
Lower Flow Threshold:	10%	
0.1xQ2:	0.150	cfs

Post-project Flow Frequency - Long-term Simulation

Statistics - Node POC Total Inflow

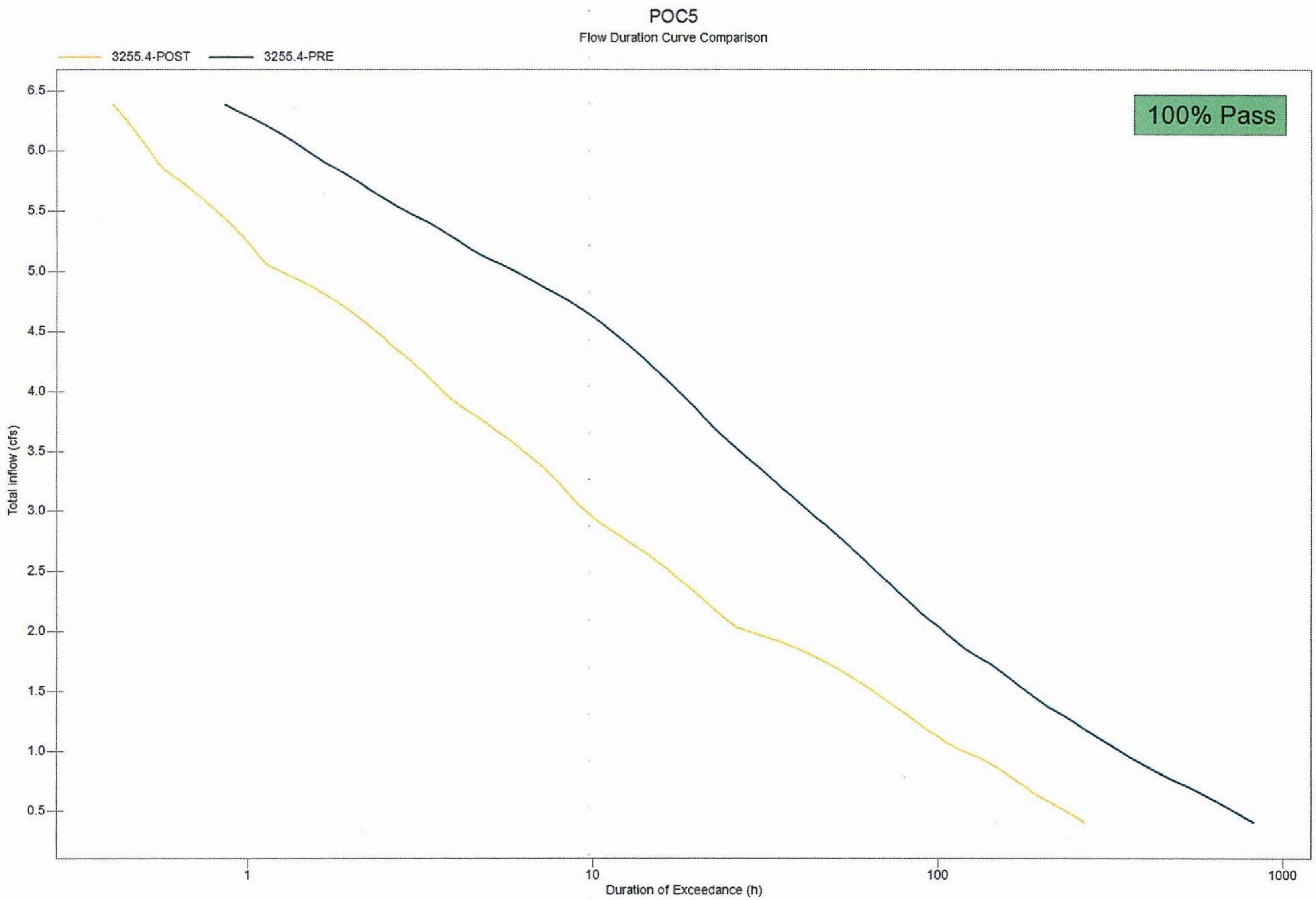
Rank	Start Date	Event Duration (hours)	Event Peak (CFS)	Exceedance Frequency (percent)	Return Period (years)
1	2/13/1980	348	7.429	0.19	47
2	2/3/1998	655	5.557	0.39	23.5
3	1/27/1980	220	4.844	0.58	15.67
4	12/27/1978	406	4.815	0.77	11.75
5	11/30/2007	307	3.775	0.96	9.4
6	11/14/1965	382	3.713	1.16	7.83
7	1/3/1995	695	3.522	1.35	6.71
8	12/17/1978	209	2.925	1.54	5.88
9	12/23/1977	773	2.877	1.73	5.22
10	12/3/1966	244	2.804	1.93	4.7
11	2/24/1983	369	2.717	2.12	4.27
12	2/27/1978	443	2.346	2.31	3.92
13	12/28/2004	498	2.223	2.5	3.62
14	10/17/2004	405	2.195	2.7	3.36
15	12/27/1992	686	2.032	2.89	3.13
16	11/29/1982	334	2.029	3.08	2.94
17	3/11/1982	643	1.87	3.28	2.76
18	2/27/1991	198	1.82	3.47	2.61
19	1/7/1980	359	1.79	3.66	2.47
20	2/3/1976	298	1.541	3.85	2.35
21	3/3/1995	364	1.277	4.05	2.24
22	2/11/2005	452	1.25	4.24	2.14
23	2/15/1986	167	1.153	4.43	2.04
24	1/4/1974	258	1.087	4.62	1.96
25	12/9/1965	380	0.976	4.82	1.88
26	4/5/1975	240	0.975	5.01	1.81
27	1/20/1982	255	0.823	5.2	1.74
28	2/18/2004	380	0.709	5.39	1.68
29	2/28/1970	299	0.396	5.59	1.62
30	11/21/1996	186	0.384	5.78	1.57
31	1/14/1969	465	0.25	5.97	1.52
32	3/17/1983	332	0.249	6.17	1.47
33	2/7/1993	177	0.247	6.36	1.42
34	3/11/1991	553	0.242	6.55	1.38
35	2/9/1963	197	0.23	6.74	1.34
36	4/14/1988	329	0.225	6.94	1.31
37	11/24/1985	316	0.221	7.13	1.27
38	11/12/1976	157	0.221	7.32	1.24
39	2/18/1993	265	0.218	7.51	1.21
40	2/23/2001	254	0.214	7.71	1.17
41	1/23/1983	529	0.212	7.9	1.15
42	12/4/1974	154	0.211	8.09	1.12
43	1/8/2001	242	0.21	8.29	1.09
44	12/26/1984	167	0.209	8.48	1.07
45	3/27/1979	180	0.204	8.67	1.04
46	2/5/1978	344	0.204	8.86	1.02
47	2/25/1981	302	0.204	9.06	1

10-year Q:	4.041	cfs
5-year Q:	2.846	cfs
2-year Q:	1.114	cfs
Lower Flow Threshold:	10%	
0.1xQ2:	0.111	cfs

6

Attachment 6

Flow Duration Comparison Curve



POC5
Flow Duration Curve Comparison
3255.4-POST
3255.4-PRE
100% Pass
Total Inflow (cfs)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
1
10
100
1000
Duration of Exceedance (h)