# Appendix J

Preliminary Storm Water Control & Treatment Strategy and
Preliminary Drainage Report

# SAN LUIS RANCH

# Preliminary Storm Water Control & Treatment Strategy

*Prepared for*
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P.O. Box 13
Pismo Beach, CA 93448

*Prepared by*
Cannon
1050 Southwood Drive
San Luis Obispo, CA 93401

July 28, 2016

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# 1. INTRODUCTION

San Luis Ranch is a 131 acre infill site located west of U.S. Highway 101 and East of Madonna Road. Currently in the County of San Luis Obispo the project plans are being processed through the City of San Luis Obispo with the intent of annexation to the city. Portions of the property are subject to flooding from the 100-year storm and through grading of the property and modifications to existing drainage facilities, development will be removed from the flood plain. Remapping of the FIRM through processing of a CLOMR and LOMR are being handled by Wallace Group. That work, along with information related to the widening of Cerro San Luis Channel, and bench widening along a portion of Prefumo Creek is addressed in a separate document.

It is the intent of this document to describe the project strategy to meet requirements for stormwater peak flow management and treatment as required by the governing agency. This project is subject to requirements for stormwater peak flow management as identified in the City Drainage Design Manual, and for runoff reduction and treatment as dictated by Resolution R3-2013-0032 of the California Regional Water Quality Control Board, Central Coast Region.

The project site plan, with stormwater control measures noted, is provided as Exhibit 1.

# 2. Stormwater Peak Flow Management

It is the goal of the San Luis Ranch project to provide an abundance of workforce housing with open space along the existing creek and channel while maintaining an expanse of the existing agricultural uses. The development of a peak flow management strategy for this project was based on the need to provide detention in a manner which supports those development goals; that is to provide detention in a manner which would combine the required detention with another land use.

The design of storm water detention for the San Luis Ranch project employs the concept of “over-detention” on the upstream side of the property through the construction of a diversion structure at Cerro San Luis Channel which will divert flows to underground storage chambers within the Commercial site. Flows from these chambers will be released through a metered outlet structure to a storm drain which will outfall to Prefumo Creek south of the Froom Ranch Way Bridge. Design of the chambers and the outflow structure are based on City of San Luis Obispo requirements as stated in their Drainage Design Manual, matching post development flows to pre-development for the 2 through 100-year storm events. The detention structure is designed to address increased runoff from the proposed residential properties (large lot and small lot single family and multi- family properties, as well as increased runoff due to development of the project infrastructure roadways). Detention for commercial properties (hotel, office and commercial) is to be incorporated into the designs for those projects.

The basin as designed will hold a maximum of 310,000 cubic feet of water, and release flows at rates varying from approximately 12 cfs (2 year storm) to 67 cfs (100 year storm) through a 48” storm drain main. Details for the basin and diversion structure can be seen in **Exhibit 2**.

Proposed drainage basins are identified in **Exhibit 3** and **Exhibit 4** contains a summary of peak flow rates off of the site for the 2-year through 100-year storms.

## 3. Stormwater Treatment

Through adoption of Resolution R3-2013-0032 the Central Coast Regional Water Quality Control Board has made findings that Central Coast municipalities must implement the Post Construction requirements in order to comply with the statewide Phase II Municipal General Permit which requires small MS4s to develop and implement Best Management Practices to reduce the discharge of pollutants and protect water quality. Those measures and the manner in which the project will comply are described below.

1. **Runoff Reduction**. Requirements here include limiting disturbance to creeks and drainage features, minimize compaction of permeable soils, limiting the clearing and grading of vegetation, and minimizing impermeable surfaces. The San Luis Ranch project will maintain open space areas along Prefumo Creek and Cerro San Luis Channel thereby limiting disturbance to those areas as well as limiting the clearing and grading of vegetation. Measures to minimize impermeable surfaces will be incorporated into individual site designs for the residential and commercial projects.

2. **Water Quality Treatment.** The strategy for the San Luis Ranch project is to limit the release of "first flush" water from the site by providing onsite retention for those flows. The proposed retention will equal the runoff volume of the $95^{th}$ percentile 24-hr storm which exceeds the requirement for Water Quality Treatment in order to comply with the requirements for Runoff Retention described below. By addressing some of the retention requirements in localized biofiltration areas the project will achieve treatment beyond that required.

3. **Runoff Retention** – As noted under Stormwater Treatment, the retention designs for San Luis Ranch incorporate the water quality treatment requirements. Runoff from the proposed single family residential development areas is proposed to be retained within underlying rock below biofiltration areas scattered throughout the residential developments and within a below ground retention basin at the proposed public park. Designs for Water Quality Treatment measures for the multi-family and commercial properties will be incorporated into the designs of those properties.

   **Exhibit 5** gives a cross section of the bioretention areas. **Exhibit 6** provides information on the underground retention chambers, and **Exhibit 7** indicates proposed treatment areas. **Exhibit 8** indicates required vs provided retention for each of the areas depicted in Exhibit 6. It should be noted that for those areas in which the proposed treatment is less than the required, required treatment is made up in overflow to other areas with capacity.

4. **Peak Management**. Storm Water Detention requirements as dictated by the City Drainage Design Manual noted above exceed the requirements of the Regional Board. Compliance with city requirements dictates compliance here. See above for discussion on proposed measures.

PROPOSED STORM WATER DETENTION

PROPOSED DETENTION OUTFALL

PROPOSED RETENTION

PROPOSED BIOFILTRATION AND RETENTION


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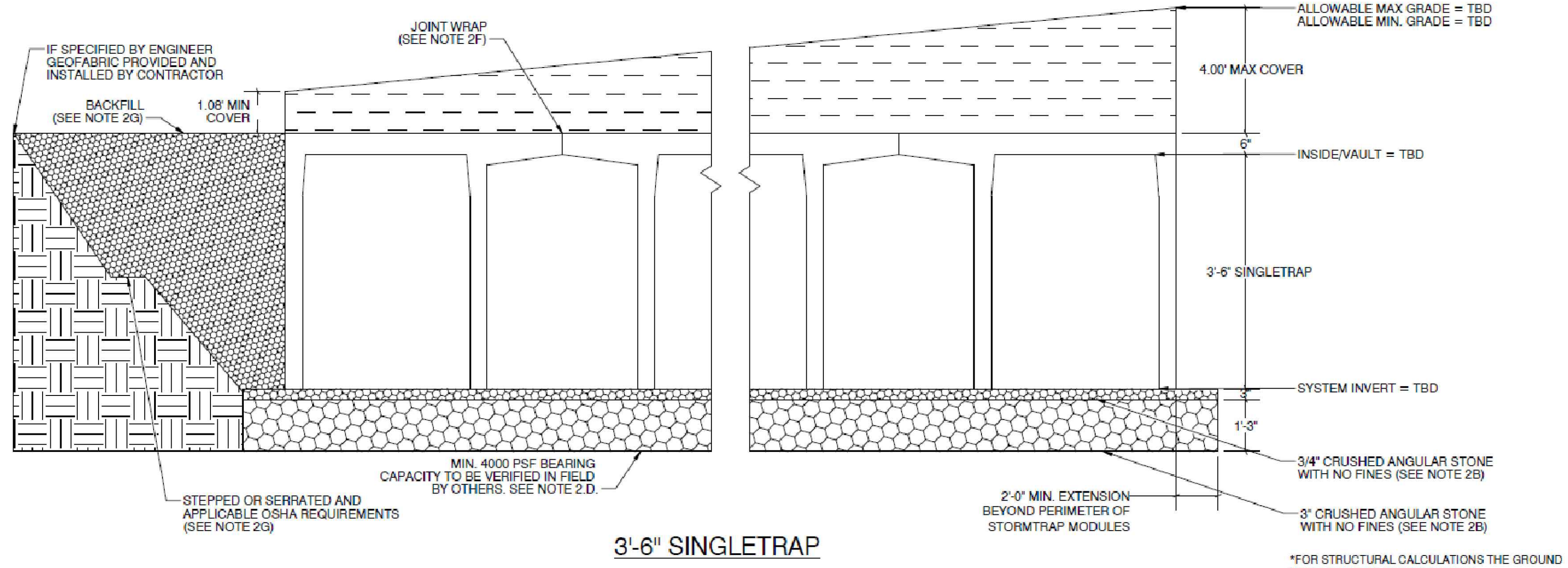
# EXHIBIT 1
# SITE PLAN
# SAN LUIS RANCH
## SAN LUIS OBISPO, CA

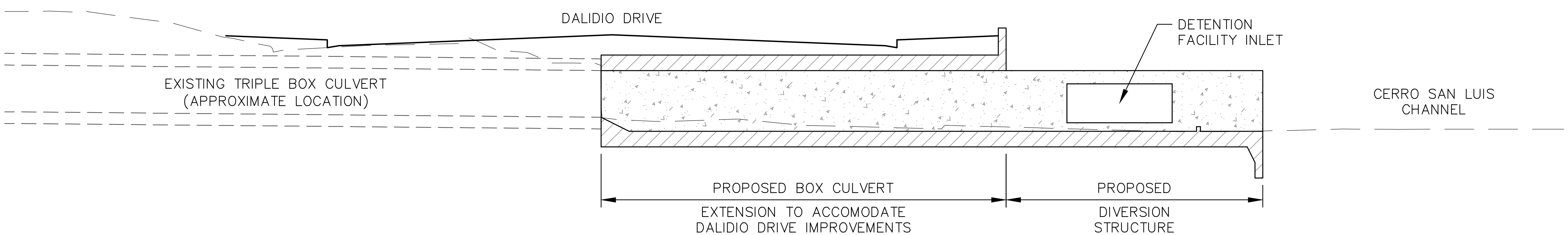
| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| JW | 07/26/16 | 140310 |
| CHECKED BY SR | SCALE 1" = 400' | SHEET 1 OF 1 |




*FOR STRUCTURAL CALCULATIONS THE GROUND WATER TABLE IS ASSUMED TO BE BELOW THE SYSTEMS INVERT. IF WATER TABLE IS DIFFERENT THAN ASSUMED, CONTACT STORMTRAP.

## UNDERGROUND DETENTION FACILITY CROSS-SECTION (X)

TYPICL SECTION




## DIVERSION STRUCTURE LONGITUDINAL SECTION (X)

TYPICL SECTION LOOKING EAST

F:\proj\2014\140310\3 Project Design\Civil\Construction Drawings\EIR Coordination\2016-07-28 EIR Grading Summary\Exhibits\CE140310EX0002.dwg 7-28-16 02:20:22 PM JeffreyW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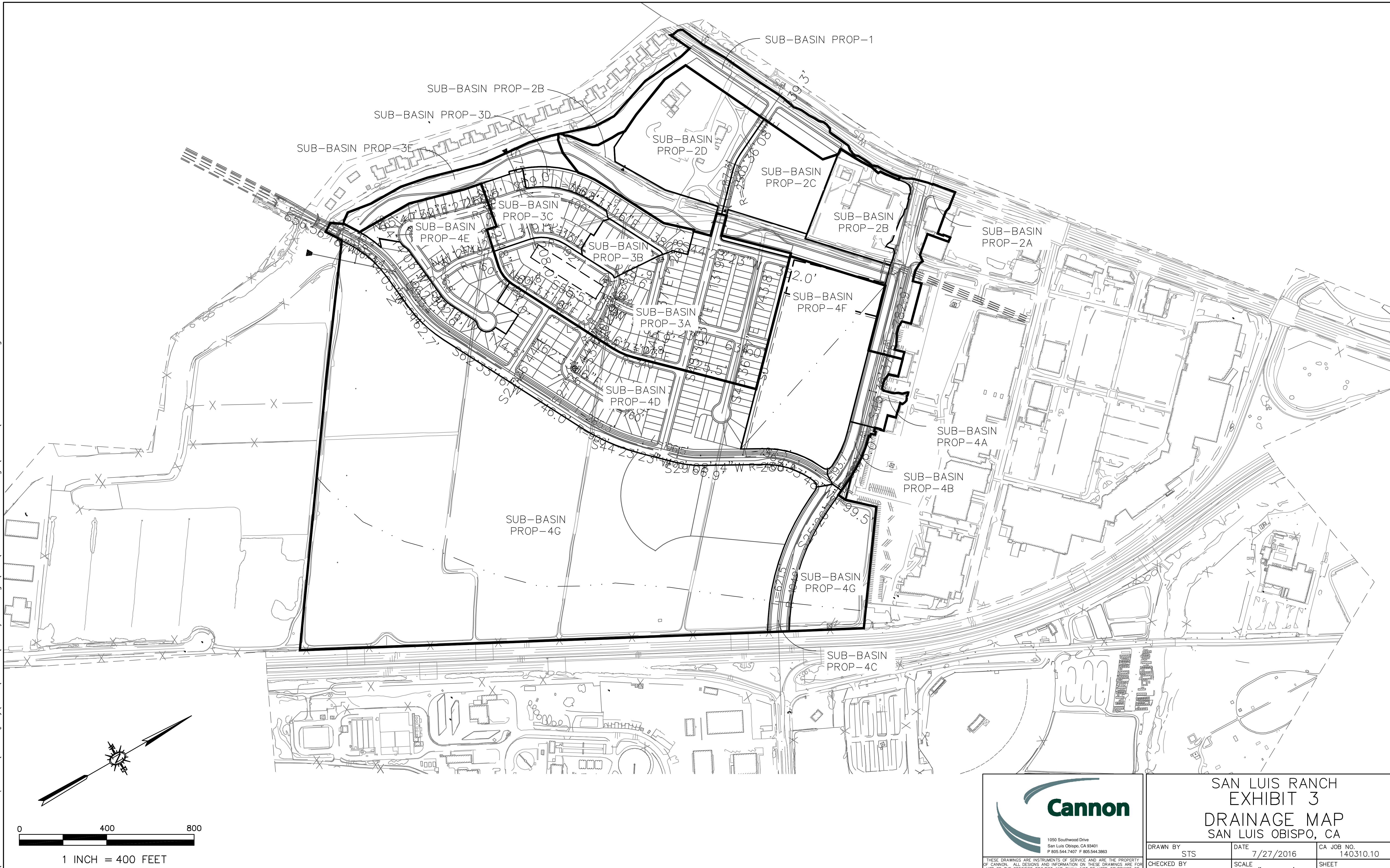
SAN LUIS RANCH
EXHIBIT 2 – STORM WATER DETENTION BASIN
SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| WGC | 2016-07-25 | 140310 |
| CHECKED BY | SCALE | SHEET |
| | N.T.S. | 2 OF 6 |

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SAN LUIS RANCH
EXHIBIT 3
DRAINAGE MAP
SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| STS | 7/27/2016 | 140310.10 |
| CHECKED BY | SCALE 1" = 400' | SHEET X OF XX |

***Combined Peak Discharge from Areas Shown on Drainage Map Proposed Conditions & Cerro San Luis Channel***

Date: 7/27/16

***EXHIBIT 4***

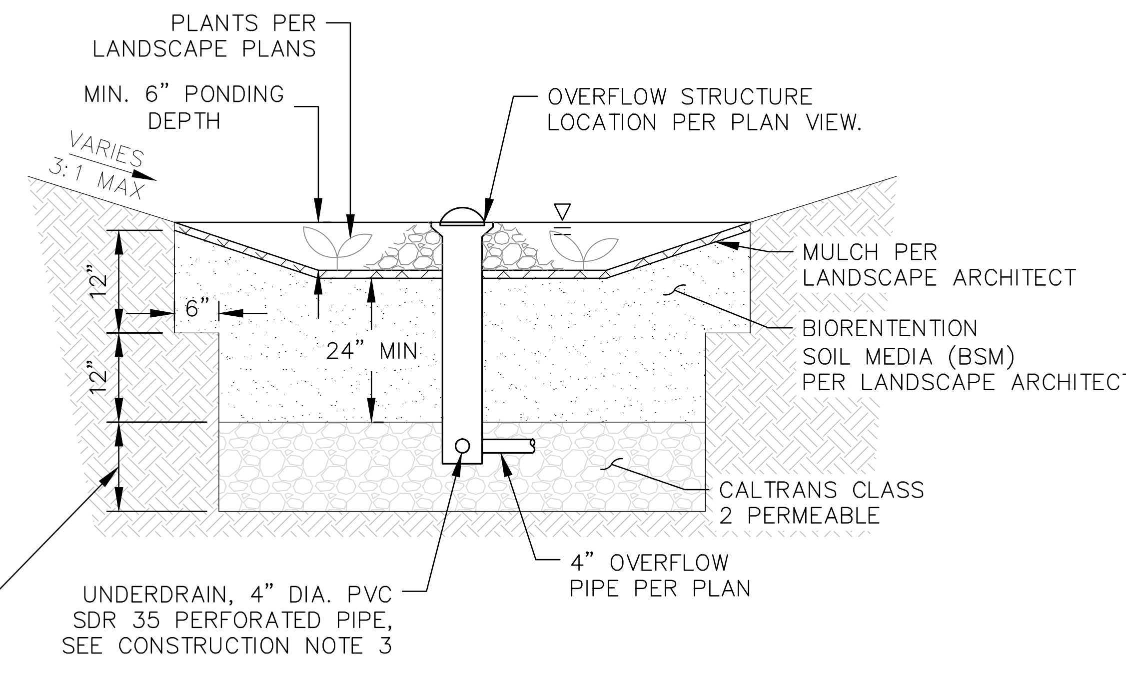
| | Peak Flow (cfs)* | | | | |
|---|---|---|---|---|---|
| **Scenario** | **2-year** | **10-year** | **25-year** | **50-year** | **100-year** |
| Existing Conditions | 262.20 | 505.92 | 673.51 | 804.08 | 906.47 |
| Proposed Conditions | 265.39 | 495.44 | 646.58 | 756.81 | 861.59 |
| Difference | 3.20 | -10.48 | -26.93 | -47.27 | -44.88 |
| % Change | 1.2%** | -2.1% | -4.0% | -5.9% | -5.0% |

*Peak flows shown are preliminary and are subject to change as the design develops

**SLO City Drainage Deisgn Manual (Section 3.3) allows up to a 5% increase in peak flows from existing conditions

## BIORETENTION CONSTRUCTION NOTES

1. SCARIFY SUBGRADE BEFORE INSTALLING BIORETENTION AREA BSM.
2. FACILITY EXCAVATION TO ALLOW FOR SPECIFIED SOIL AND MULCH DEPTHS TO ACHIEVE FINISHED GRADE ELEVATION ON PLAN.
3. INSTALL UNDERDRAIN WITH HOLES FACING DOWN. UNDERDRAIN DISCHARGE ELEVATION SHALL BE NEAR TOP OF AGGREGATE LAYER. UNDERDRAIN SLOPE MAY BE FLAT.
4. COMPACT EACH 6" LIFT OF BSM WITH LANDSCAPE ROLLER OR BY LIGHTLY WETTING. IF WETTING, ALLOW TO DRY OVERNIGHT BEFORE PLANTING.
5. DO NO WORK WITHIN BIORETENTION ARE DURING RAIN OR UNDER WET CONDITIONS.
6. KEEP HEAVY MACHINERY OUTSIDE BIORETENTION AREA LIMITS.




# TYPICAL BIORETENTION FACILITY CROSS-SECTION

TYPICL SECTION

X

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SAN LUIS RANCH
EXHIBIT 5 – TYPICAL BIORETENTION AREA
SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| WGC | 2016-07-25 | 140310 |
| CHECKED BY | SCALE | SHEET |
| | N.T.S. | 4 OF 6 |

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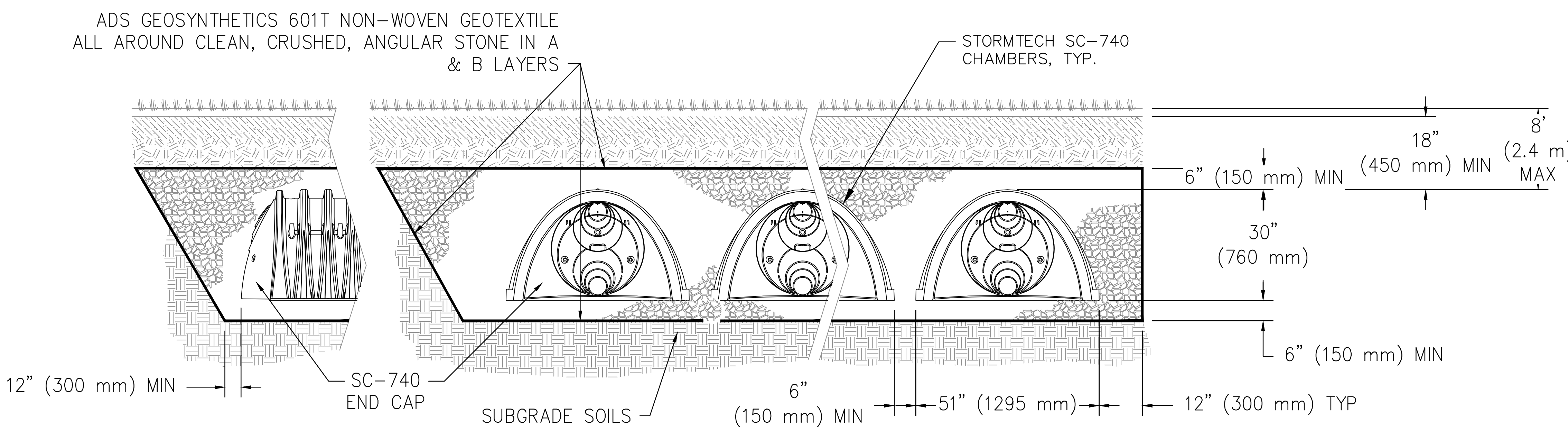


# UNDERGROUND STORMWATER RETENTION FACILITY CROSS-SECTION

TYPICL SECTION

X

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SAN LUIS RANCH
EXHIBIT 6
UNDERGROUND RETENTION
SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| WGC | 2016-07-25 | 140310 |
| CHECKED BY | SCALE N.T.S. | SHEET 5 OF 6 |

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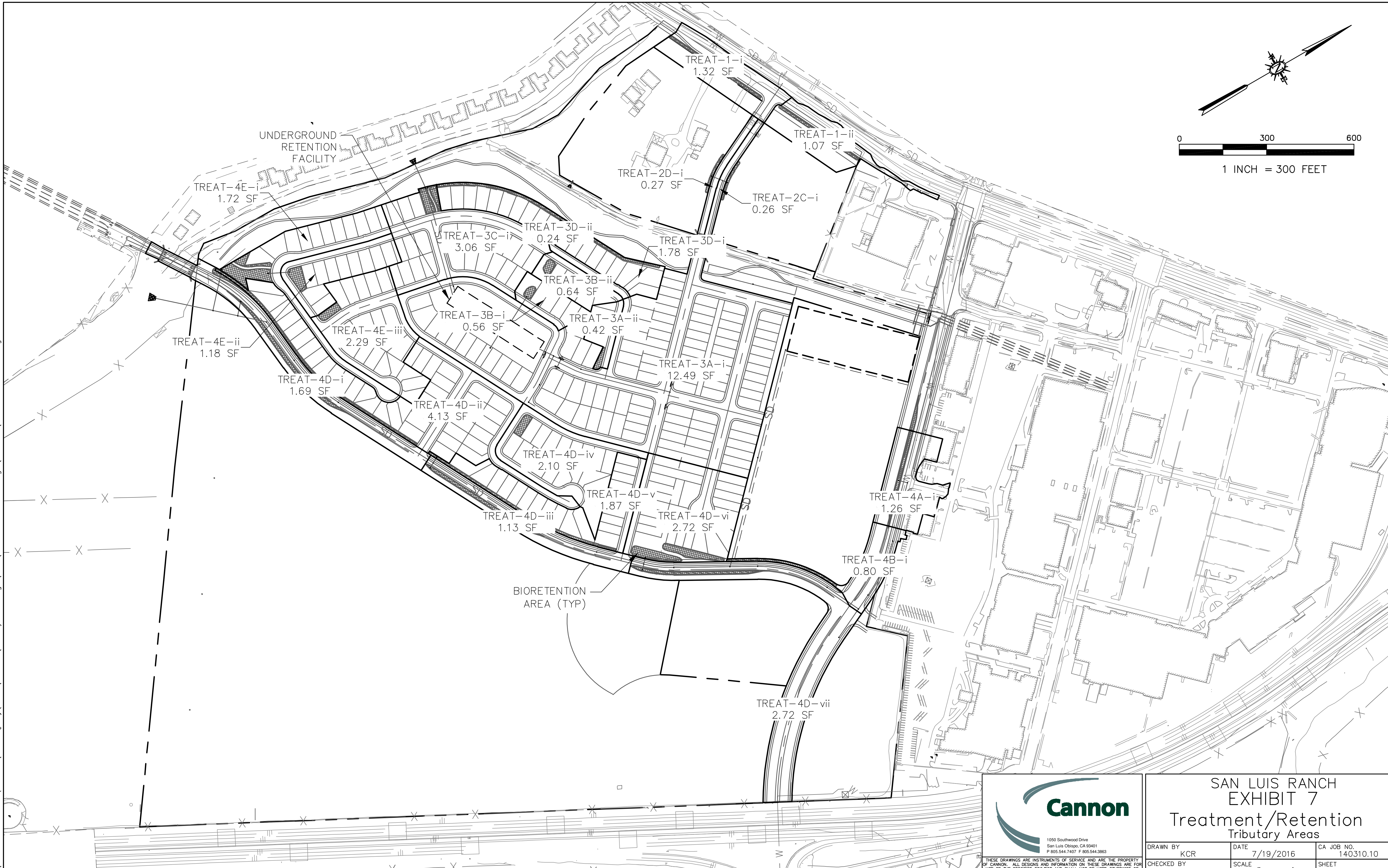


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SAN LUIS RANCH
# EXHIBIT 7
## Treatment/Retention
Tributary Areas

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| KCR | 7/19/2016 | 140310.10 |
| CHECKED BY | SCALE 1" = 300' | SHEET X OF XX |

***Summary of Retetion Volume Calculations***

Date: 7/27/16

EXHIBIT 8

| Sub-basin | Total Required Retention Volume (cf) | Provided Retention Volume (cf) | Notes |
|---|---|---|---|
| TREAT-1-i | 3,281 | 4,418 | |
| TREAT-1-ii | 2,207 | 4,194 | |
| TREAT-2C-i | 1,710 | 1,847 | |
| TREAT-2D-i | 1,740 | 1,850 | |
| TREAT-3A-i | 48,854 | 50,450 | Underground Retention Facility |
| TREAT-3A-ii | 1,743 | 1,915 | |
| TREAT-3B-i | 1,816 | 1,923 | |
| TREAT-3B-ii | 2,266 | 2,297 | |
| TREAT-3C-i | 13,453 | 14,085 | |
| TREAT-3D-i | 5,788 | 10,657 | |
| TREAT-3D-ii | 958 | 1,028 | |
| TREAT-4A-i | 5,168 | 5,873 | |
| TREAT-4B-i | 3,264 | 5,024 | |
| TREAT-4D-i | 7,446 | 8,518 | |
| TREAT-4D-ii | 22,473 | 24,000 | |
| TREAT-4D-iii | 4,928 | 7,631 | |
| TREAT-4D-iv | 9,163 | 3,455 | Accounted for in TREAT-4D-ii |
| TREAT-4D-v | 6,350 | 9,373 | |
| TREAT-4D-vi | 9,254 | 15,102 | |
| TREAT-4D-vii | 12,116 | 13,837 | |
| TREAT-4E-i | 12,833 | 13,948 | |
| TREAT-4E-ii | 11,460 | 5,287 | Accounted for in TREAT-4E-i |
| TREAT-4E-iii | 10,014 | 3,397 | Accounted for in TREAT-4E-ii |

*Retention volumes shown are preliminary and are subject to change as the design develops

# Preliminary Drainage Report

# San Luis Ranch
# Tentative Tract Map
# Tract 3096

*Prepared for*
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*Prepared by*
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10/14/2016

## Table of Contents



### Figures



### Appendices

# 1. Introduction and Background

## 1.1. Introduction

Coastal Community Builders (CCB) is proposing a new residential development in the City of San Luis Obispo. A drainage study was conducted to be submitted with the Tentative Tract Map application for the proposed project. The intent of that study was to establish the major drainage components that will be included with the proposed project, and to determine their effects on the horizontal and vertical layout of lots, roads, grading, and utilities. This report presents the methods and results generated from that study.

## 1.2. Project Location and Site Description

The proposed project is located in the City of San Luis Obispo in San Luis Obispo County. The project site is located to the south of the intersection of Madonna Road and Dalidio Drive. The site consists of approximately 131.4 acres of mostly agricultural land, along with wooded land, a few residences and miscellaneous farm structures, and the two channel corridors associated with Prefumo Creek and Cerro San Luis Channel. Prefumo Creek, a seasonal creek, runs along the western portion of the property. The project site is bisected by a seasonal drainage called Cerro San Luis Channel, which conveys flow that discharges from underground culverts and surface flow at Dalidio Drive to lower Prefumo Creek.

## 1.3. Project Description

The project consists of the construction of a new 302 lot residential development. Single family houses will be constructed on each of the 302 lots. In general, the lots vary in size from about 2,400 sf to 3,200 sf, although there are some larger lots. The project includes a large central park, along with several small parks dispersed around the proposed development. There are also open space areas proposed along the stream corridors. Several streets are proposed within the development to provide access to the lots.

The proposed project includes extensions of and improvements to existing arterial and collector streets, including Froom Ranch Way and Dalidio Drive, to improve regional access. The project also includes mass grading of pads for future development of commercial and multi-family residential lots.

# 2. Stormwater Regulations and Design Criteria

There are several governing bodies that have regulations and design criteria pertaining to stormwater management for new development. The project is currently located within San Luis Obispo County, but is planned to be annexed into the City of San Luis Obispo. For purposes of this study, it was assumed that the project is located within the City of San Luis Obispo. This project is within the jurisdictions of the following agencies:

- City of San Luis Obispo

- Central Coast Regional Water Quality Control Board (RWQCB)
- California Department of Fish and Wildlife (CDFW)
- Federal Emergency Management Agency (FEMA)
- US Army Corps of Engineers (USACE)

## 2.1. City of San Luis Obispo

The City of San Luis Obispo has several regulations and standards that pertain to stormwater management, including:

- Municipal Code
- Waterway Management Plan (which includes the Drainage Design Manual)
- Standard Specifications and Engineering Standards

## 2.2. Municipal Code

There following sections of the Municipal Code pertain to stormwater management.

*Creek Setbacks (Municipal Code 17.16.025)*

The City's Creek Setback requirement applies to all creeks that are shown on Figure 9 of the Conservation and Open Space Element in the General Plan. Prefumo Creek is shown on that figure as a "perennial creek with good riparian corridor." Per the code, a 35-foot setback is required for Prefumo Creek "from the existing top of bank (or the future top of bank resulting from a creek alteration reflected in a plan approved by the city), or from the edge of the predominant pattern of riparian vegetation, whichever is farther from the creek flow line".

Cerro San Luis Channel is shown on Figure 9 of the Conservation and Open Space Element in the General Plan as an "intermittent creek with good riparian corridor". Per the code, a 20-foot setback is required for Prefumo Creek "from the existing top of bank (or the future top of bank resulting from a creek alteration reflected in a plan approved by the city), or from the edge of the predominant pattern of riparian vegetation, whichever is farther from the creek flow line".

*Floodplain Management Regulations (Municipal Code 17.84)*

The City's Floodplain Management Regulations apply to areas of special flood hazard as identified by FEMA, which are areas that FEMA has identified as subject to inundation by the 1% annual chance flood (100-year flood). The FEMA Flood Insurance Rate Map Number 06079C1069G, Panel 1068 (Appendix A) shows a large portion the project site to be within Zone A of the 1% annual chance floodplain boundary (100-year floodplain). Zone A includes areas where no base flood elevations have been determined, and floodplains in these areas are typically determined using approximate methodologies and not a detailed hydraulic analysis. Per the code, the following pertain to the proposed project:

- The proposed development is within a special floodplain management zone as defined by the City of San Luis Obispo (see requirements from Waterway Management Plan below), so the requirements in the Drainage Design Manual for those zones must be met
- Base flood elevations for the project site must be determined
- A approved Letter of Map Revision (LOMR) is required prior to issuance of building permits
- All proposed nonresidential structures require certification from a registered civil engineer or architect that they are flood-proofed in accordance with Section 17.84.050(A)(3) of the Municipal Code
- All proposed residential structures require post-construction certification from a registered civil engineer or licensed land surveyor that their lowest floors are one foot above the base flood elevation
- Public utilities and facilities such as sewer, gas, electrical and water systems are to be located and constructed to minimize flood damage

### 2.3. Waterway Management Plan (which includes the Drainage Design Manual)

The Waterway Management Plan (WMP) is a watershed-based management plan for San Luis Obispo Creek and its tributaries. The Drainage Design Manual (DDM) is Volume 3 of the WMP, and provides design guidance and criteria intended to meet surface water management objectives. The following are some of the sections that pertain to the proposed project:

*Off-Site Facility Analysis, Design, and Mitigation (DDM 3.3)*

Runoff shall be managed to prevent any significant increase in downstream peak flows, including 2-year, 10-year, 50-year, and 100-year events. Significant generally means an increase of over 5 percent at and immediately downstream of the project site.

*Special Floodplain Management Zone Regulations (DDM 3.5.3)*

A large portion of the project site is located in Special Floodplain Management Zone #2, as identified by Figure DDM 3-1 (Appendix A) in the DDM. These areas have been determined to have a potentially significant effect on downstream flooding and bank stability, and therefore development of these areas is restricted in the following ways:

- The project shall not cause the 100-year flood elevation to increase more than 2.5 inches
- The project shall not cause stream velocities to increase more than 0.3 ft/s
- The project shall not cause a significant net decrease in floodplain storage volume unless several exceptions are met.

*Erosion Control and Stormwater Quality Requirements (DDM 3.7)*

The proposed project is over 2.5 hectares in size, so a detailed erosion control plan is required and shall be prepared in accordance with Section 10.0 of the DDM.

*Analysis and Design of Bank Stabilization Structures (DDM 6.0)*

The proposed bench for Prefumo Creek and widened section of Cerro San Luis Channel shall be designed in accordance with Section 6.0 of the DDM to provide for bank stability and to minimize impacts to aquatic and riparian habitat.

*Channel and Conduit Capacity (DDM 7.2.1) and Hydraulic Gradient (7.2.10)*

This section requires that conveyance systems shall be designed to convey the peak runoff for the 10-year design storm with the hydraulic gradient a minimum of 6 inches below the elevation of the inlet grates and manhole covers. In addition, an overland conveyance shall be provided for the 100-year event such that the water surface elevation is at least 1 foot below the finish floor of adjacent structures.

*Inlets and Catch Basins (DDM 7.2.7)*

Inlets shall be spaced so that gutter flow does not exceed a depth of 6 inches at the face of the curb for a 10-year storm and so that a 100-year storm will not cause any damage and can be contained within the right of way.

*Outfalls/Open Channel & Pipe Systems (DDM 7.4.5)*

Outfalls shall be above the mean low water (2-year flow) level unless the City approves an exception.

### 2.4. Central Coast Regional Water Quality Control Board (RWQCB)

The RWQCB is responsible for administering and enforcing the National Pollutant Discharge Elimination System (NPDES) permit program, as authorized by the federal Clean Water Act. This program regulates the quality of stormwater that is discharged to surface water bodies. There are two separate permits that this project is required to obtain coverage under, one that applies to stormwater discharges during construction, and one that applies to stormwater discharges after construction is complete.

*During Construction – Construction General Permit*

Construction projects that disturb one or more acres of soil during construction are required to obtain coverage under the Construction General Permit. This permit requires the development and implementation of a Storm Water Pollution Prevention Plan (SWPPP). The SWPPP must list Best Management Practices (BMPs) the discharger will use to protect stormwater runoff and the placement of those BMPs. Additionally, the SWPPP must contain a visual monitoring program and a chemical monitoring program for "non-visible" pollutants to be implemented if there is a failure of BMPs. Section A of the Construction General Permit describes the elements that must be contained in a SWPPP.

*Post-Construction – Phase II Municipal General Permit*

The Phase II Municipal General Permit applies to stormwater discharges from small Municipal Separate Storm Sewer Systems (MS4s). To comply with the requirements of the Phase II Municipal General Permit, the RWQCB approved Post-Construction Stormwater Management Requirements for Development Projects in the Central Coast

Region (Post-Construction Requirements) through adoption of Resolution R3-2013-0032. A summary of the post-construction requirements is as follows:

- *Performance Requirement No. 1: Site Design and Runoff Reduction*
  This requirement is intended to limit the disturbance creeks and natural drainage features, minimize compaction of highly permeable soils, limit clearing and grading of native vegetation, minimize impervious surfaces, and minimizing stormwater runoff by collecting it for reuse and by infiltrating it onsite.
- *Performance Requirement No. 2: Water Quality Treatment*
  This requirement is intended to provide onsite retention or treatment (physical, biological, or chemical) of stormwater runoff from developed areas to reduce the discharge of pollutants from the site.
- *Performance Requirement No. 3: Runoff Retention*
  The requirement is intended to maintain the pre-developed hydrology with respect to volume, flow rate, and duration for the site by reducing overland flow and promoting groundwater recharge. The project site is located in Watershed Management Zone 1 per the map included in Resolution R3-2013-0032, which are areas subject to Performance Requirement No. 3.
- *Performance Requirement No. 4: Peak Management*
  The requirement is intended to maintain the pre-developed hydrology with respect to peak discharge from the site. This requirement states that the post-development peak flows discharged from the site shall not exceed the pre-project peak flows for the 2-though 10-year storm events.

## 2.5. California Department of Fish and Wildlife (CDFW)

A biological study was conducted to define the limits of jurisdiction for the California Department of Fish and Wildlife (CDFW), which includes portions along Prefumo Creek and Cerro San Luis Channel. Any work that is within CDFW jurisdiction will require permitting through CDFW.

## 2.6. Federal Emergency Management Agency (FEMA)

The Federal Emergency Management Agency (FEMA) has established flood insurance zones throughout the City of San Luis Obispo. Development within these zones must be in compliance with both the City and FEMA regulations.

The FEMA Flood Insurance Rate Map Number 06079C1331G (Appendix A) shows a large portion of the project site within the Zone A of the 1% annual chance floodplain boundary (100-year floodplain). Zone A includes areas where no base flood elevations have been determined, and floodplains in these areas are typically determined using approximate methodologies and not a detailed hydraulic analysis.

The Conditional Letter of Map Revision (CLOMR) and Letter of Map Revision (LOMR) processes will be required to modify flood insurance zones on project property and, if necessary, in the adjacent areas affected by the proposed project.

2.7. US Army Corps of Engineers (USACE)

A biological study was conducted to define the limits of jurisdiction for the US Army Corps of Engineers (USACE), which includes Federal Wetlands and Other Waters of the United States as defined by Section 404 of the Clean Water Act. Both types of waterbodies were defined along portions of Prefumo Creek and Cerro San Luis Channel. Any work that is within USACE jurisdiction will require permitting through USACE.

## 3. Existing Drainage Conditions

3.1. Description of Existing Offsite Flows that Discharge onto Project

Prefumo Creek, a seasonal creek, runs along the western portion of the project site and flows north to south. The reach of Prefumo Creek that passes through the site is immediately downstream of Laguna Lake and upstream of the confluence with San Luis Creek and is referred to as lower Prefumo Creek. Flow in lower Prefumo Creek is attenuated by Laguna Lake, which has an outlet control structure and functions as a detention pond (SLO WMP, Vol. 1).

The project site is bisected by a seasonal drainage called Cerro San Luis Channel. This channel conveys flow that discharges from underground culverts and surface flow at Dalidio Drive to lower Prefumo Creek. The underground culverts extend from the north corner of the intersection of Madonna Road and the Madonna Inn entrance through the Madonna Plaza and SLO Promenade commercial centers and discharge into Cerro San Luis Channel at Dalidio Drive near the east corner of the US Post Office. Areas that contribute flow to the culverts include a portion of Cerro San Luis, the Madonna Inn, Madonna Road, and the Madonna Plaza and SLO Promenade commercial centers. The culverts consist of three approximately 3-ft high by 7-ft wide box culverts from Madonna Road to El Mercado, where they transition to three approximately 3-ft high by 9-ft wide box culverts from El Mercado to Dalidio Drive ("As-Built" Drawings for San Luis Obispo Mall Project prepared by Contract Survey and Design, Inc., 10/3/87).

In addition to the two channels described above, a significant amount of offsite flow enters the project site at the north-east corner of the property adjacent to Hwy. 101 and the Embassy Suites parking lot (Wallace Group, 2014). There is an existing structure along the Embassy Suites parking lot that consists of a flat gutter and curb. It appears that the intent of this structure was that it would function as a weir and discharge flow evenly across its length. However, due to grading along the flow spreader structure and portions of it being modified, it appears that discharge would be concentrated along the Hwy. 101 side of the structure and onto the eastern side of the project site. In addition to the flow from the commercial center, during a 100-yr flood event, flow from San Luis Creek overtops Hwy. 101 and enters the project site from the east (Wallace Group, 2014).

## 3.2. Description of Existing Onsite Drainage Conditions

The site consists of approximately 131.4 acres of mostly agricultural land, along with wooded land, a few residences and miscellaneous farm structures, and the two channel corridors associated with Prefumo Creek and Cerro San Luis Channel. The area considered for this study is shown on Figure 2. The study area for the existing conditions was divided into four sub-basins based on the reach of the channel to which they contribute.

Sub-basin Exist-1 includes the area that drains to the reach of Prefumo Creek between Madonna Road and the confluence with Cerro San Luis Channel, referred to in this study as Reach 1. This area includes wooded land, residences and miscellaneous farm structures, and a portion of Madonna Road.

Sub-basin Exist-2 includes the area the drains to Cerro San Luis Channel, referred to in this study as Reach 2. This area includes agricultural land, wooded land, residences and miscellaneous farm structures, the US Post Office and a portion of Dalidio Drive.

Sub-basin Exist-3 includes the area that drains to the reach of Prefumo Creek between the confluence with Cerro San Luis Channel and the proposed Froom Ranch Way bridge, referred to in this study as Reach 3. This area includes agricultural and wooded land.

Sub-basin Exist-4 includes the area that drains to the reach of Prefumo Creek downstream of the proposed Froom Ranch Way bridge, referred to in this study as Reach 4. This area includes the majority of the agricultural area, which generally sheet flows from north to south and enters Prefumo Creek downstream of the project site.

## 3.3. Hydrologic Analyses of Existing Conditions

*Hydrologic Analysis of Study Area*

Hydrologic analyses were performed as part of this study to estimate the magnitudes of the stormwater runoff from the project study area considering the existing condition of the site. The project study area is shown on Figure 2. The US Army Corps of Engineers' HEC-HMS (Version 4.1) model was used to perform the hydrologic analyses and is based on the following methodology:

- Watershed Model
    - Loss Method: SCS Curve Number (CN)
    - Hydrograph Transformation Method: SCS Unit Hydrograph lag time
    - Baseflow Method: None
- Flow Routing: None
- Precipitation Model: Specified Hyetograph – 24-hour Storm A hyetographs from City of San Luis Obispo HEC-HMS Model (rainfall depths from Table C-3 SLO WMP, Vol. 1)
    - 2-year rainfall depth: 3.3 inches
    - 10-year rainfall depth: 4.6 inches

    - 25-year rainfall depth: 5.7 inches
    - 50-year rainfall depth: 6.5 inches
    - 100-year rainfall depth: 6.7 inches
- Time Interval: 5 minutes

Composite curve numbers and lag times were calculated for each sub-basin, and those calculations are included in Appendix B. These parameters, along with the sub-basin areas, were input into the HEC-HMS model for each sub-basin and runoff hydrographs for several design storms were generated. The combined hydrographs for all sub-basins in the study area are included in Appendix B and a summary of the peak flows is shown in Table 1.

**Table 1 - Summary of peak flows for discharge from study area for existing conditions**

| Storm Event | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | Sub-basin Exist-1 | Sub-basin Exist-2 | Sub-basin Exist-3 | Sub-basin Exist-4 | Total Combined |
| 2-year | 3.73 | 16.3 | 5.4 | 41.2 | 54.2 |
| 10-year | 6.58 | 28.6 | 9.7 | 74.2 | 96.7 |
| 25-year | 8.21 | 35.6 | 12.3 | 93.6 | 122 |
| 50-year | 9.52 | 41.2 | 14.2 | 108 | 140 |
| 100-year | 10.7 | 46.0 | 16.0 | 122 | 158 |

*Hydrologic Analysis of Study Area and Cerro San Luis Channel*

The proposed approach to peak flow management for this project involves diverting flow out of the upstream end of Cerro San Luis Channel, detaining it, and then reintroducing it into the system at a lower flow, resulting in an overall reduction in peak flow for the system. Therefore, the “existing condition” for peak flow management includes the combined flows from the study area in its existing condition and the inflow into Cerro San Luis Channel. For that reason, the flows from offsite that are discharged into Cerro San Luis Channel had to be estimated as part of this study.

Wallace Group has studied the hydrology for Cerro San Luis Channel and they provided the basis for the estimation of flows that are discharged into the upstream end of the channel. They used the City of San Luis Obispo’s HEC-HMS model as a starting point for the analysis. The sub-basins within the City’s model that contribute flow to Cerro San Luis Channel include the Madonna Inn and Lower Prefumo sub-basins. The Madonna Inn sub-basin is the area that contributes flow to the upstream end of the triple box culvert at Madonna Road. Wallace extracted from the Lower Prefumo sub-basin the area upstream of the San Luis Ranch project and designated it the Madonna Plaza sub-basin. Only a portion of the flow from the Madonna Plaza sub-basin contributes to Cerro San Luis Channel, as the remainder enters the project site at the north-east corner near Embassy Suites. Wallace estimated that 72% of the runoff from the Madonna Plaza sub-basin discharges into Cerro San Luis Channel.

Wallace provided hydrographs for the Madonna Inn and Madonna Plaza sub-basins. Hydrographs for the flow into the upstream end of Cerro San Luis Channel were developed by combing the hydrograph from the Madonna Inn sub-basin and 72% of the hydrograph from the Madonna Plaza sub-basin. The resulting hydrographs for inflow into Cerro San Luis Channel for all of the design storms are shown in Appendix B.

For purposes of this analysis, it was assumed that all flow that enters Cerro San Luis Channel stays within the channel. Hydraulic modeling performed by Wallace shows that at high flows the channel is overtopped and the flow that leaves the channel flows across the agricultural area and enters Prefumo Creek downstream of the confluence of the two channels. Based on that, the assumption stated above is violated when flows within Cerro San Luis Channel are high. However, the peak flow in Prefumo Creek is mostly due to the outflow from Laguna Lake which occurs after the peak in Cerro San Luis Channel. When the peak flow in Prefumo Creek occurs, the flow in Cerro San Luis Channel is contained within the channel, so the assumption when considering flows in Prefumo Creek.

The hydrographs developed for the inflow to Cerro San Luis Channel were combined with the hydrographs developed for the study area to develop peak flows for each stream reach. The hydrographs developed for Reach 4 is included in Appendix B and the peak flows for all reaches are shown in Table 2. These are the peak flows for the "existing conditions" that were used to design the stormwater detention system for peak flow management.

**Table 2 - Summary of peak flows for combined discharge from study area and Cerro San Luis Channel for existing conditions**

| Storm Event | Peak Flow (cfs) | | | |
|---|---|---|---|---|
| | Reach 1 | Reach 2 | Reach 3 | Reach 4 |
| 2-year | 3.73 | 236 | 243 | 266 |
| 10-year | 6.58 | 459 | 471 | 512 |
| 25-year | 8.21 | 604 | 620 | 674 |
| 50-year | 9.52 | 726 | 743 | 804 |
| 100-year | 10.7 | 819 | 839 | 906 |

*Hydrologic Analysis of Study Area, Cerro San Luis Channel, and Laguna Lake Outflow*

While the peak flows given in Table 2 were used for the basis of design of the detention system, they do not account for the flows out of Laguna Lake. The actual flows in Prefumo Creek will be much higher than the flows presented in Table 2 as a result of the flow out of Laguna Lake. To provide a more thorough analysis of the effect of the proposed project on the flows in Prefumo Creek, the flows out of Laguna Lake were considered.

The flows out of Laguna Lake were estimated using the City of San Luis Obispo's HEC-HMS model (Version 3.0.0) and the following parameters:

- Precipitation Model: Specified Hyetograph – 24-hour Storm A hyetographs from City of San Luis Obispo HEC-HMS Model (rainfall depths from Table C-3 SLO WMP, Vol. 1)
- Beginning Lake Elevation:

  - 2-yr: 36.65 m
  - 10-yr: 38.39 m
  - 25-yr: 38.97 m
  - 50-yr: 39.15 m
  - 100-yr: 39.47 m
- Elevation-Area Function: Laguna Lake (Prefumo Creek)
- Elevation-Discharge Function: Laguna Lake (Prefumo Creek)

The resulting hydrographs for flow out of Laguna Lake for all of the design storms are shown in Appendix B and the resulting peak flows are shown in Table 3.

**Table 3 - Summary peak flows from Laguna Lake outflow**

| Storm Event | Peak Flow (cfs) |
|---|---|
| 2-year | 418 |
| 10-year | 987 |
| 25-year | 1,421 |
| 50-year | 1,699 |
| 100-year | 2,036 |

The hydrographs developed for the outflows from Laguna Lake were combined with the hydrographs developed for the study area and Cerro San Luis Channel to develop peak flow for each stream reach. Channel routing was not accounted for as the reach lengths are relatively short. The hydrographs developed for Reach 4 is included in Appendix B and the peak flows for all reaches are shown in Table 4.

**Table 4 - Summary peak flows for combined discharge from study area, Cerro San Luis Channel, and Laguna Lake outflow for existing conditions**

| Storm Event | Peak Flow (cfs) | | | |
|---|---|---|---|---|
| | Reach 1 | Reach 2 | Reach 3 | Reach 4 |
| 2-year | 418 | 236 | 445 | 451 |
| 10-year | 988 | 459 | 1,045 | 1,062 |
| 25-year | 1,093 | 604 | 1,502 | 1,526 |
| 50-year | 1,700 | 726 | 1,796 | 1,820 |
| 100-year | 2,037 | 819 | 2,142 | 2,172 |

## 4. Proposed Drainage Conditions

4.1. <u>Description of Proposed Drainage Conditions</u>

The project consists of the construction of a new 302 lot residential development. Single family houses will be constructed on each of the 302 lots. In general, the lots vary in size from about 2,400 sf to 3,200 sf, although there are some larger lots. The other major surface improvements are new streets and sidewalks. The major proposed drainage features are shown on Figure 4 and include a culvert extension/diversion structure at the upstream end of Cerro San Luis Channel, an underground detention system adjacent to the Cerro San Luis Channel on a future commercial lot, an underground retention facility beneath the proposed park, two storm drain outfalls in Prefumo Creek, and two storm drain outfalls in Cerro San Luis Channel. Per the recommendations in *San Luis Ranch Preliminary Drainage Report* (Wallace 2014), the proposed drainage improvements also include widening Cerro San Luis Channel by approximately 30-feet to provide capacity for the 100-year peak flow, and constructing a bench (approximately 19-feet wide by 3-feet deep) on the east bank of Prefumo Creek between the confluence with Cerro San Luis Channel and the proposed Froom Ranch Way bridge to provide additional capacity to reduce the risk of flooding the existing homes adjacent to the creek in that area. There are also proposed bridges where Froom Ranch Way crosses Prefumo Creek and where “A” Street crosses Cerro San Luis Channel.

Most of the proposed lots will drain to the streets, although several along the exterior of the development will drain directly to bioretention areas. Runoff that collects in the sidewalks and streets is proposed to be conveyed by surface flow in the gutters and streets to curb inlets or bioretention facilities with inlets. The inlets will be connected to underground pipes that will ultimately convey the runoff to one of the outfalls. There are three emergency overland flow routes proposed for the single family residential area, and one for the Froom Ranch Way bridge, and those are shown on Figure 4.

The area considered for this study is shown on Figure 3. The study area for the proposed conditions was divided into four major sub-basins based on the reach of the channel to which they contribute. Major sub-basins Prop-2, -3, and -4 were divided into minor sub-basins, for example, sub-basin Prop-3C is a minor sub-basin to the major sub-basin Prop-3.

Sub-basin Prop-1 includes the area that drains to the reach of Prefumo Creek between Madonna Road and the confluence with Cerro San Luis Channel, referred to in this study as Reach 1. This area includes wooded land, future landscape areas, and a portion of Madonna Road.

Sub-basin Prop-2 includes the area the drains to Cerro San Luis Channel, referred to in this study as Reach 2. This area includes wooded land, future multi-family residential areas, the US Post Office and a portion of Dalidio Drive.

Sub-basin Prop-3 includes the area that drains to the reach of Prefumo Creek between the confluence with Cerro San Luis Channel and the proposed Froom Ranch Way bridge, referred to in this study as Reach 3. This area includes wooded land and single family residential development.

Sub-basin Prop-4 includes the area that drains to the reach of Prefumo Creek downstream of the proposed Froom Ranch Way bridge, referred to in this study as Reach 4. This area includes agricultural area, proposed single family residential areas and rough graded pads for future commercial development.

The proposed approach to peak flow management for this project involves diverting flow out of the upstream end of Cerro San Luis Channel, detaining it in an underground detention facility, and then reintroducing it into Prefumo Creek at a lower flow, resulting in an overall reduction in peak flow for the system. The proposed facility was designed to account for the increase in peak flow associated with the proposed single family residential development and streets shown on Figure 3, and also for future multi-family development to occur at sub-basins Prop-2C and Prop-2D. The areas of the site planned for future commercial development were considered to be undeveloped as part of this study, so those properties will need their own detention facilities as part of their development.

## 4.2. Hydrologic Analysis of Proposed Conditions

*Hydrologic Analysis of Study Area*

Hydrologic analyses were performed as part of this study to estimate the magnitudes of the stormwater runoff from the project study area considering the proposed condition of the site. The US Army Corps of Engineers' HEC-HMS model was used to perform the hydrologic analyses and is based on the methodology described in Section 3.3.

Composite curve numbers and lag times were calculated for each sub-basin, and those calculations are included in Appendix C. These parameters, along with the sub-basin areas, were input into the HEC-HMS model for each sub-basin and runoff hydrographs for several design storms were generated. The combined hydrographs for all sub-basins in the study area are included in Appendix C and a summary of the peak flows is shown in Table 5.

**Table 5 - Summary of peak flows for discharge from study area for proposed conditions**

| Storm Event | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | Sub-basin Prop-1 | Sub-basin Prop-2 | Sub-basin Prop-3 | Sub-basin Prop-4 | Total Combined |
| 2-year | 3.68 | 23.5 | 23.4 | 38.0 | 88.6 |
| 10-year | 6.48 | 39.7 | 40.2 | 67.0 | 153 |
| 25-year | 8.10 | 48.6 | 49.7 | 85.4 | 192 |
| 50-year | 9.38 | 55.8 | 57.3 | 97.9 | 220 |
| 100-year | 10.4 | 61.9 | 63.6 | 109 | 244 |

*Hydrologic Analysis of Study Area and Cerro San Luis Channel*

As described above, the proposed approach to peak flow management for this project involves diverting flow out of the upstream end of Cerro San Luis Channel, detaining it, and then reintroducing it into the system at a lower flow, resulting in an overall reduction in peak flow for the system. Therefore the "proposed condition" for peak flow management includes the combined flows from the study area in its proposed condition, the flows in Cerro San Luis Channel downstream of the proposed diversion structure, and the discharge from the proposed detention facility.

A model was developed to estimate the effect of the proposed diversion structure and underground detention facility on the inflows to Cerro San Luis Channel. The development of the hydrographs for the inflow to Cerro San Luis Channel is described in Section 3.3, and these hydrographs were input into the model. The model takes the input hydrographs for the flow into the diversion structure and estimates hydrographs for flow that remains in Cerro San Luis Channel and flow out of the detention facility. See Appendix E for more information on the model that was developed for the diversion structure and detention facility.

The hydrographs developed for the flow that remains in Cerro San Luis Channel and flow out of the detention facility were combined with the hydrographs developed for the study area to develop peak flows for each stream reach. The flow out of the detention facility is proposed to be discharged into Reach 4 (Prefumo Creek downstream of the proposed Froom Ranch Way bridge) to distribute flow in a manner more consistent with the existing drainage conditions. The hydrographs developed for Reach 4 is included in Appendix C and the peak flows for all reaches are shown in Table 6 through Table 9. These are the peak flows for the "proposed conditions" that were used to design the stormwater detention system for peak flow management. The flows for the "existing conditions" are also shown in Table 6 through Table 9. The estimated peak flows for all reaches for all design storms are lower in the proposed condition than the existing condition.

**Table 6 - Summary of peak flows for combined discharge from study area and Cerro San Luis Channel for Reach 1**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 3.73 | 6.58 | 8.21 | 9.52 | 10.7 |
| Proposed Conditions | 3.68 | 6.48 | 8.10 | 9.38 | 10.4 |
| Difference | -0.06 | -0.10 | -0.11 | -0.14 | -0.22 |
| % Change | -1.5% | -1.5% | -1.4% | -1.4% | -2.0% |

**Table 7 - Summary of peak flows for combined discharge from study area and Cerro San Luis Channel for Reach 2**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 236 | 459 | 604 | 726 | 819 |
| Proposed Conditions | 203 | 364 | 469 | 548 | 623 |
| Difference | -32.5 | -94.6 | -135 | -178 | -196 |
| % Change | -13.8% | -20.6% | -22.4% | -24.6% | -24.0% |

**Table 8 - Summary of peak flows for combined discharge from study area and Cerro San Luis Channel for Reach 3**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 243 | 471 | 620 | 743 | 839 |
| Proposed Conditions | 226 | 403 | 517 | 603 | 684 |
| Difference | -16.7 | -67.7 | -103 | -141 | -155 |
| % Change | -6.9% | -14.4% | -16.6% | -18.9% | -18.4% |

**Table 9 - Summary of peak flows for combined discharge from study area and Cerro San Luis Channel for Reach 4**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 266 | 512 | 674 | 804 | 906 |
| Proposed Conditions | 265 | 483 | 624 | 731 | 830 |
| Difference | -0.6 | -29.3 | -49.2 | -73.0 | -76.2 |
| % Change | -0.2% | -5.7% | -7.3% | -9.1% | -8.4% |

*Hydrologic Analysis of Study Area, Cerro San Luis Channel, and Laguna Lake Outflow*

While the peak flows given in Table 6 through Table 9 were used for the basis of design of the detention system, they do not account for the flows out of Laguna Lake. The actual flows in Prefumo Creek will be much higher than the flows presented in Table 6 through Table 9 as a result of the flow out of Laguna Lake. To provide a more thorough analysis of the effect of the proposed project on the flows in Prefumo Creek, the flows out of Laguna Lake were considered.

The hydrographs developed for the outflows from Laguna Lake (described in Section 3.3) were combined with the hydrographs developed for the study area and Cerro San Luis Channel to develop peak flow for each stream reach. Channel routing was not accounted for as the reach lengths are relatively short. The hydrographs developed for Reach 4 is included in Appendix C and the peak flows for all reaches are shown in Table 10 through Table 13.

**Table 10 - Summary of peak flows for combined discharge from study area, Cerro San Luis Channel, and Laguna Lake outflow for Reach 1**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 418 | 988 | 1,422 | 1,700 | 2,037 |
| Proposed Conditions | 418 | 988 | 1,421 | 1,700 | 2,037 |
| Difference | -0.02 | -0.23 | -0.25 | -0.28 | -0.39 |
| % Change | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |

**Table 11 - Summary of peak flows for combined discharge from study area, Cerro San Luis Channel, and Laguna Lake outflow for Reach 2**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 236 | 459 | 604 | 726 | 819 |
| Proposed Conditions | 203 | 364 | 469 | 548 | 623 |
| Difference | -32.5 | -94.6 | -135 | -178 | -196 |
| % Change | -13.8% | -20.6% | -22.4% | -24.6% | -24.0% |

**Table 12 - Summary of peak flows for combined discharge from study area, Cerro San Luis Channel, and Laguna Lake outflow for Reach 3**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 445 | 1,045 | 1,502 | 1,796 | 2,142 |
| Proposed Conditions | 446 | 1,047 | 1,501 | 1,793 | 2,138 |
| Difference | 1.0 | 1.6 | -0.8 | -2.7 | -4.1 |
| % Change | 0.2% | 0.2% | -0.1% | -0.1% | -0.2% |

**Table 13 - Summary of peak flows for combined discharge from study area, Cerro San Luis Channel, and Laguna Lake outflow for Reach 4**

| Scenario | Peak Flow (cfs) | | | | |
|---|---|---|---|---|---|
| | 2-year | 10-year | 25-year | 50-year | 100-year |
| Existing Conditions | 451 | 1,062 | 1,526 | 1,820 | 2,172 |
| Proposed Conditions | 452 | 1,063 | 1,530 | 1,824 | 2,179 |
| Difference | 0.8 | 1.0 | 3.8 | 4.1 | 7.5 |
| % Change | 0.2% | 0.1% | 0.2% | 0.2% | 0.3% |

Table 12 and Table 13 show slight increases in the flows in the reaches of Prefumo Creek that are downstream of the confluence with Cerro San Luis Channel. These increases are minor, not exceeding 0.3% for any of the design storms.

## 4.3. Major Drainage Features

*Cerro San Luis Channel Culvert Extension & Diversion Structure*

The proposed improvements include widening Dalidio Drive where the existing triple box culvert discharges into the upstream of Cerro San Luis Channel. The culverts need to be extended to account for the road widening. The proposed improvements also include widening Cerro San Luis Channel by 30-feet, so the culverts need to transition to a wider footprint to match the channel width. It is also anticipated that a substantial amount of surface flow from the SLO Promenade and Dalidio Drive will be collected by the proposed inlets on the south side of Dalidio Drive and discharged into the culverts, so the culvert widening will provide additional capacity for the additional flow added to them.

It is proposed that a diversion structure be included with the culvert extension. The diversion structure will divert water out of Cerro San Luis Channel and into the underground detention facility where it will be temporarily stored, then discharged at a lower rate into Prefumo Creek. Flow will enter the detention facility through a large opening (13.50' wide by 2.50' high) in the eastern wall of the diversion structure. The opening will function as weir until fully submerged, at which point it will function as an orifice. A numerical model was developed as part of this study to estimate the distribution of flow between the detention facility and Cerro San Luis Cannel for flow that enters the diversion structure. A description of that model is included in Appendix E.

Water that leaves the diversion structure though the detention facility inlet will be conveyed by the detention intake channel to the detention facility. The intake channel has been sized to reduce headloss for flow passing through it so that it has an insignificant impact on the function of the inlet. The channel was modeled using the gradually varied flow equation, which is included in Appendix D.

*Detention Facility*

The proposed detention facility is shown in Figure 4 and will temporarily store water diverted out of Cerro San Luis Channel and then reintroducing it into Prefumo Creek downstream of the proposed Froom Ranch Way bridge at a lower flow rate. The reason for discharging the flow into Prefumo Creek rather than back into Cerro San Luis Channel is to better match the existing distribution of flows among the stream reaches, and to reduce the risk of flooding for the existing residences along Prefumo Creek.

The proposed detention facility is composed of open-bottom concrete chambers underlain by rock. This facility will promote infiltration and will provide for some stormwater retention as the proposed outlet pipe is above the bottom of the rock. Flow out of the detention system will be controlled by a flow control structure that contains orifices or weirs, or both. As part of this study, the outlet structure was modeled as a Cipoletti weir with a bottom width of 2-feet. A numerical model was developed as part of this study to estimate the flow into, flow out of, and water surface elevation within the proposed detention structure. Graphs showing those variables for each design storm are included in Appendix C. A description of the model that was developed for the detention system routing is included in Appendix E.

*Outfalls to Channels*

There are four proposed storm drain outfalls for this project, and they are shown on Figure 4. Two outfalls are proposed into Cerro San Luis Channel for the runoff from north side of the channel, which includes the future multi-family residential development planned for that area. The third outfall is proposed in Prefumo Creek between the confluence with Cerro San Luis Channel and the Froom Ranch Way bridge which will discharge runoff from a large portion of the single family residential development. The fourth outfall is proposed in Prefumo Creek downstream of the Froom Ranch Way bridge which will discharge the outflow from the detention system, and also the runoff from a large portion of the single family residential development, Froom Ranch Way, and Dalidio Drive.

The proposed outfalls consist of pipes that discharge through a headwall onto riprap aprons. Preliminary sizing of the pipes and riprap aprons has been performed as part of this study and those calculations are included in Appendix D.

*Retention Facilities*

Retention facilities are proposed as part of this project to comply with the requirements of the RWQCB, and they include several vegetated bioretention facilities and a large underground facility. The bioretention facilities will provide retention volume in surface depressions, porosity in the topsoil, and porosity in sub-surface rock beneath the facilities. The underground facility will provide retention in plastic arch chambers and porosity in rock beneath and around the chambers. The sizing of these facilities is included in the *Stormwater Control Plan for Post-construction Requirements* prepared by Cannon under separate cover.

*Bridges*

There are two bridges proposed as part of this project; one where Froom Ranch Way crosses Prefumo Creek, and one where Street "A" crosses Cerro San Luis Channel. The proposed bridges are planned to span the 100-yr floodplain and provide 12-inches of freeboard from the bottom of the bridges to the 100-yr water surface elevation.

*Emergency Overland Flow Routes*

There are three emergency overland flow routes for the single family residential portion of the project. The routes correspond with localized low points in the site and are intended to provide a route for stormwater to drain from the site without damaging residences in the event that the storm drain infrastructure were to fail.

There is also a proposed emergency overland flow route for the Froom Ranch Way bridge in the event that debris were to block a portion of the flow path under the bridge. A low point has been designed into Froom Ranch Way east of the bridge to be below the finished floor elevations of the existing residences along Prefumo Creek to help reduce the risk of flooding those structures.

## 4.4. Post-construction Phase II Municipal General Permit Requirements

The post-construction requirements associated with the Phase II Municipal General Permit are summarized in Section 2.4. Compliance with these requirements is intended to be achieved by implementing strategies that include maintaining creek setbacks and constructing retention and detention facilities. A *Stormwater Control Plan for Post-*

*construction Requirements* was prepared for the project by Cannon under separate cover.

4.5. Floodplain Analysis

The FEMA Flood Insurance Rate Map Number 06079C1331G (Appendix A) shows a large portion of the project site within the Zone A of the 1% annual chance floodplain boundary (100-year floodplain). In addition, Figure DDM 3-2c (Appendix A) from the Drainage Design Manual shows a large portion of the project site within the 100-year floodplain.

The proposed improvements incorporate significant modifications within the existing floodplain, including placing fill within the floodplain to remove the proposed development from the floodplain, widening Cerro San Luis Channel to increase its capacity, and adding a bench to Prefumo Creek to increase its capacity.

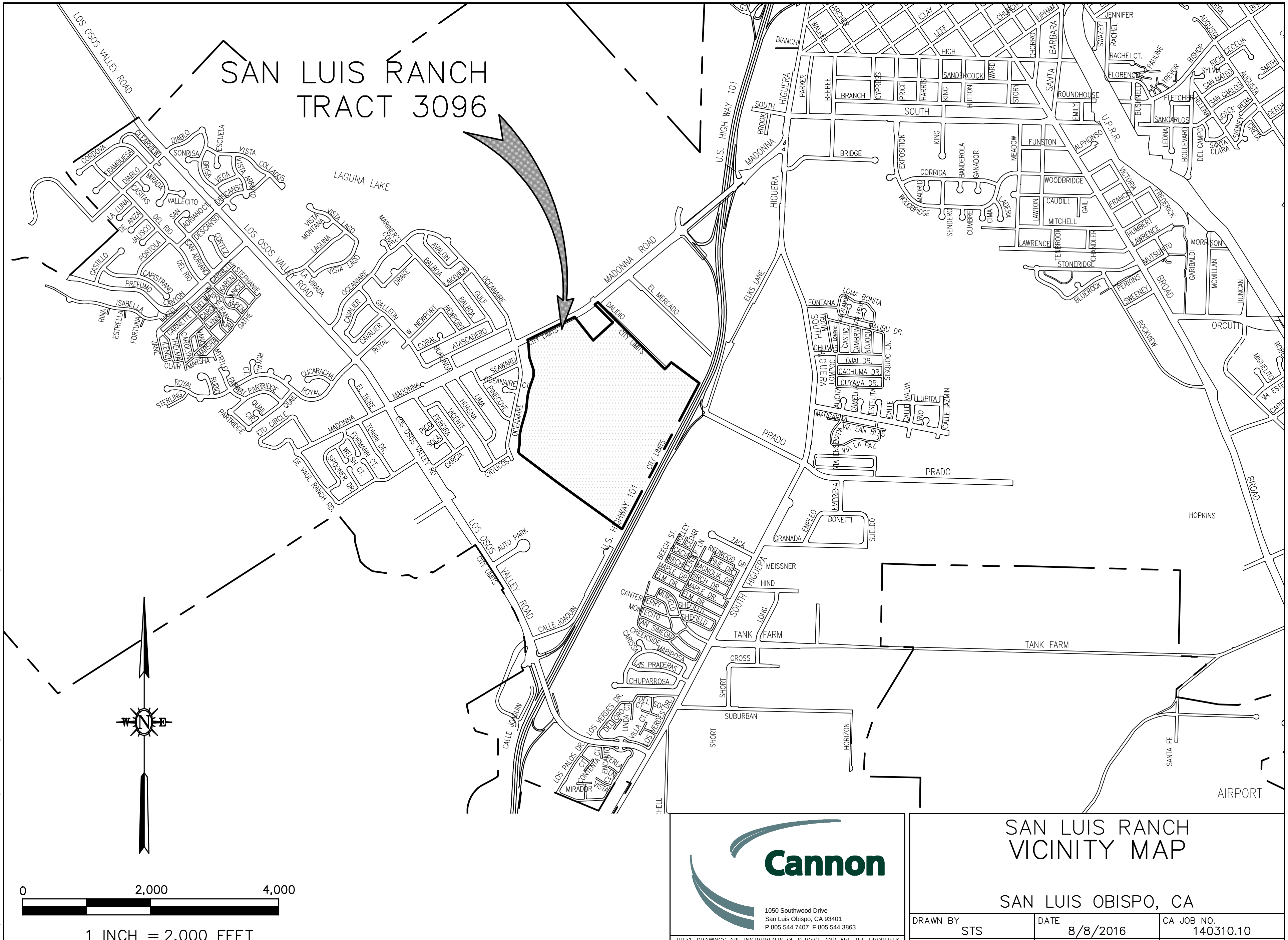
Wallace Group is conducting the floodplain analysis for this study under separate cover. They have developed a hydraulic model for the project area and have established base flood elevations for the project in its existing and proposed conditions. Those elevations were used as the basis of design for the proposed grading and drainage design. Wallace Group is also preparing the Conditional Letter of Map Revision (CLOMR) associated with this project for processing through the City of San Luis Obispo and FEMA.

## References

City of San Luis Obispo Department of Public Works and County of San Luis Obispo Flood Control District. 2003. *San Luis Obispo Creek Waterway Management Plan Volume I San Luis Obispo Creek Watershed*.

City of San Luis Obispo Department of Public Works and County of San Luis Obispo Flood Control District. 2003. *San Luis Obispo Creek Waterway Management Plan Volume III Drainage Design Manual*.

Wallace Group. November 2014. *San Luis Ranch Preliminary Drainage Report - Draft*.




F:\proj\2014\140310\3 Project Design\Civil\Construction Drawings\Exhibits\CE140310EX0027.dwg 8-08-16 03:27:26 PM seths

**Cannon**

1050 Southwood Drive
San Luis Obispo, CA 93401
P 805.544.7407 F 805.544.3863

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# SAN LUIS RANCH VICINITY MAP

SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| STS | 8/8/2016 | 140310.10 |
| CHECKED BY | SCALE 1" = 2,000' | SHEET FIGURE 1 |


0 400 800

1 INCH = 400 FEET

LEGEND

- STUDY AREA BOUNDARY
- SUB-BASIN BOUNDARY
- ROUTE USED FOR TIME OF CONCENTRATION CALCULATION
- SURFACE RUNOFF FLOW DIRECTION

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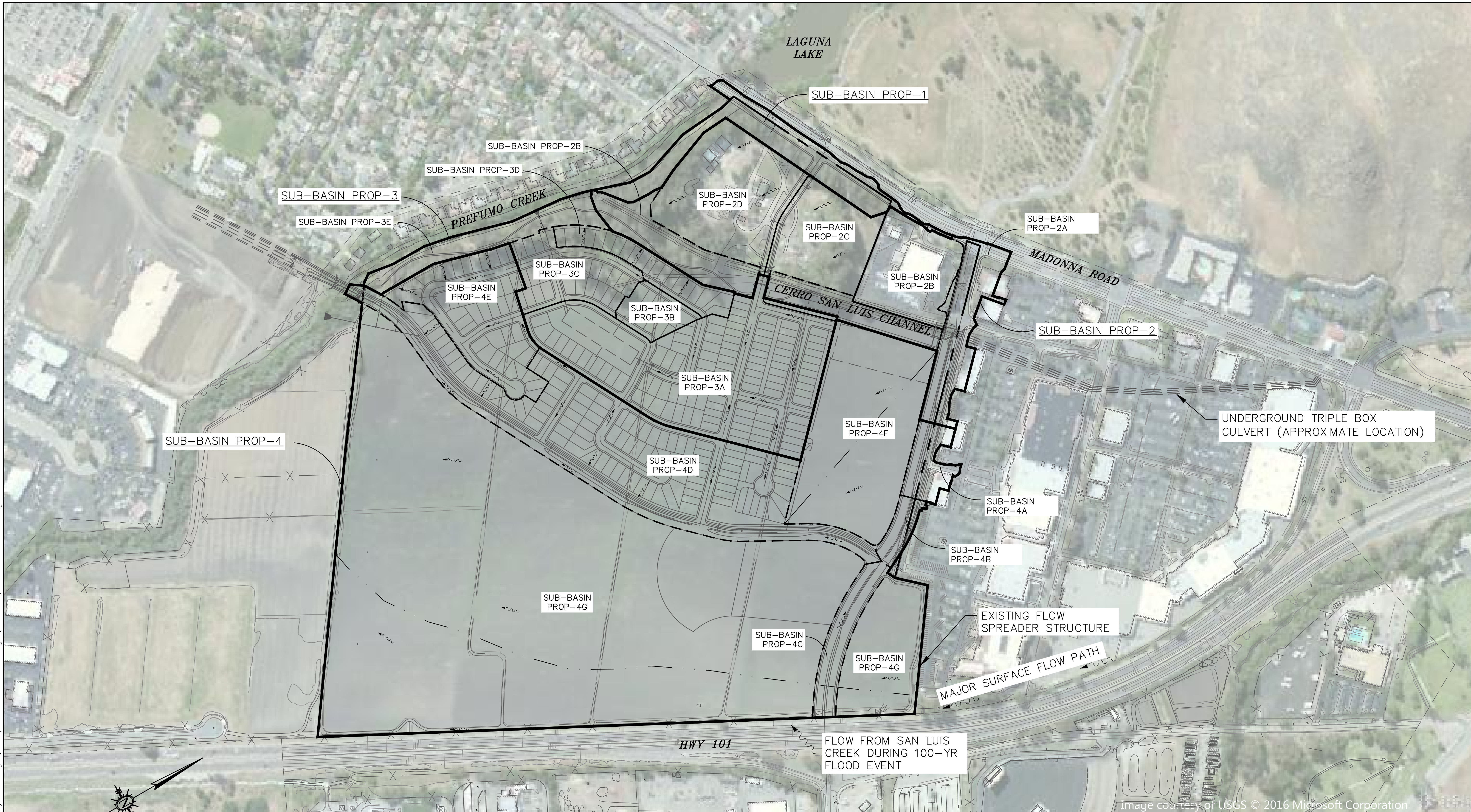
SAN LUIS RANCH
DRAINAGE MAP
EXISTING CONDITIONS
SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| STS | 8/5/2016 | 140310.10 |
| CHECKED BY | SCALE | SHEET |
| | 1" = 400' | FIGURE 2 |




0 400 800

1 INCH = 400 FEET

LEGEND

- MAJOR SUB-BASIN BOUNDARY
- MINOR SUB-BASIN BOUNDARY
- ROUTE USED FOR TIME OF CONCENTRATION CALCULATION
- SURFACE RUNOFF FLOW DIRECTION

Cannon
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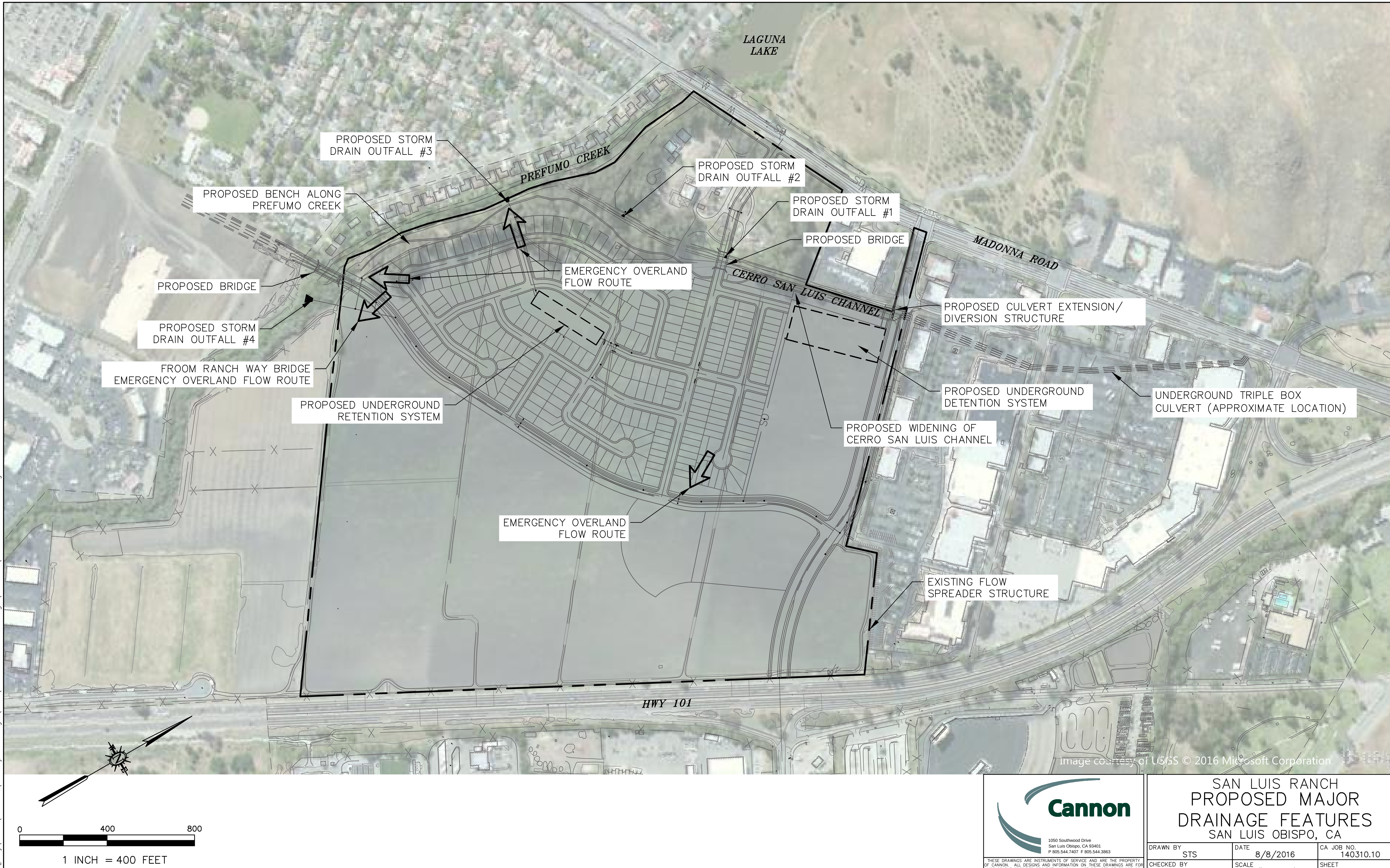
SAN LUIS RANCH
DRAINAGE MAP
PROPOSED CONDITIONS
SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| STS | 8/5/2016 | 140310.10 |
| CHECKED BY | SCALE | SHEET |
| | 1" = 400' | FIGURE 3 |

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SAN LUIS RANCH

# PROPOSED MAJOR DRAINAGE FEATURES

SAN LUIS OBISPO, CA

| DRAWN BY | DATE | CA JOB NO. |
|---|---|---|
| STS | 8/8/2016 | 140310.10 |
| CHECKED BY | SCALE 1" = 400' | SHEET FIGURE 4 |

# Appendix A

*Site Data*


ance Program at 1-800-638-6620.

MAP SCALE 1" = 500'

0 250 500 750 1,000 FEET

NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1068G

# FIRM

## FLOOD INSURANCE RATE MAP

## SAN LUIS OBISPO COUNTY, CALIFORNIA

**AND INCORPORATED AREAS**

**PANEL 1068 OF 2050**

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

| COMMUNITY | NUMBER | PANEL | SUFFIX |
|---|---|---|---|
| SAN LUIS OBISPO COUNTY | 060304 | 1068 | G |
| SAN LUIS OBISPO, CITY OF | 060310 | 1068 | G |

Notice to User: The **Map Number** shown below should be used when placing map orders; the **Community Number** shown above should be used on insurance applications for the subject community.

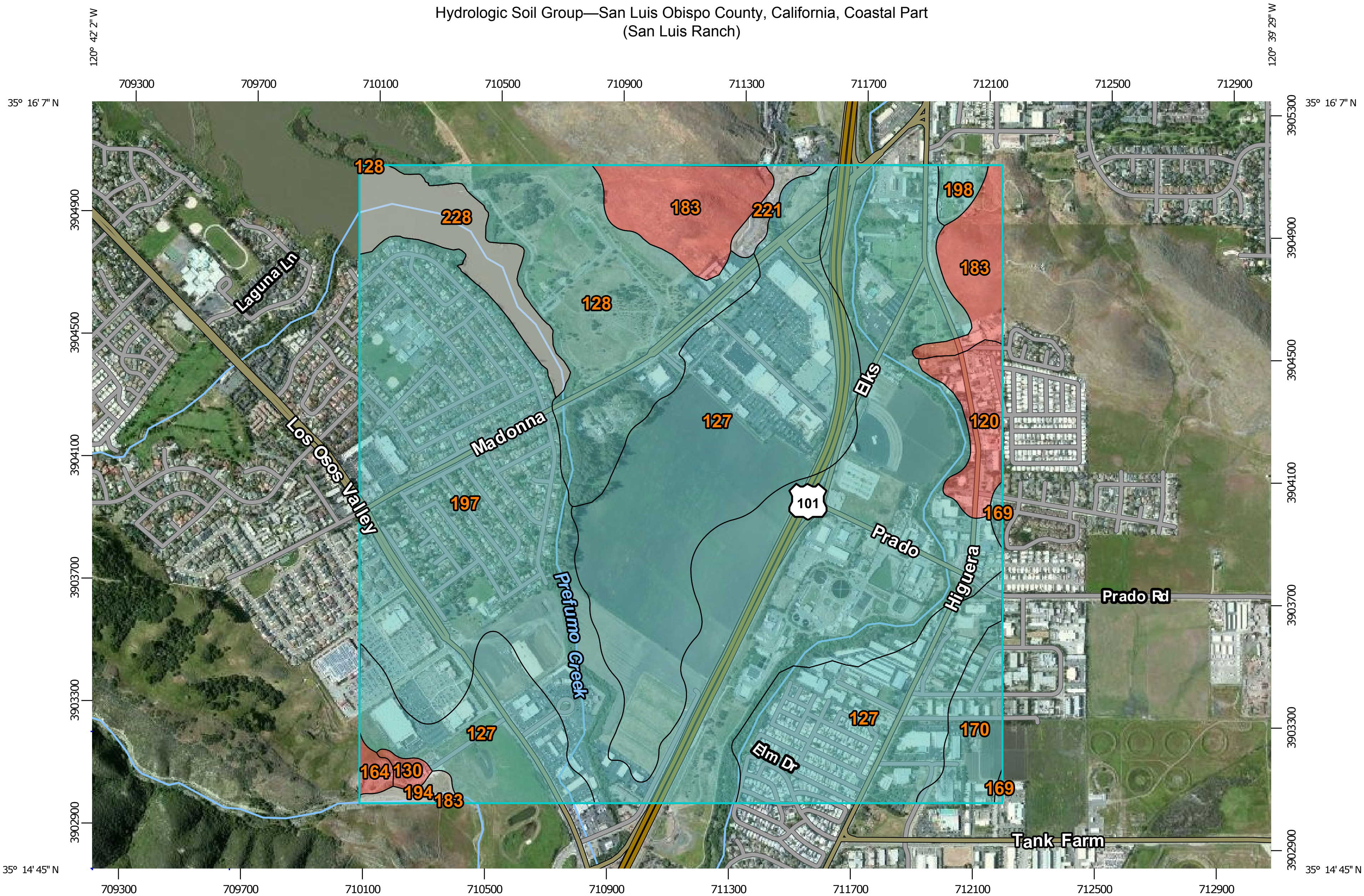
**MAP NUMBER**
**06079C1068G**

**MAP REVISED**
**NOVEMBER 16, 2012**

**Federal Emergency Management Agency**

This is an official copy of a portion of the above referenced flood map. It was extracted using F-MIT On-Line. This map does not reflect changes or amendments which may have been made subsequent to the date on the title block. For the latest product information about National Flood Insurance Program flood maps check the FEMA Flood Map Store at www.msc.fema.gov

Hydrologic Soil Group—San Luis Obispo County, California, Coastal Part
(San Luis Ranch)




Map Scale: 1:17,700 if printed on A landscape (11" x 8.5") sheet.

Meters: 0, 250, 500, 1000, 1500

Feet: 0, 500, 1000, 2000, 3000

N

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 10N WGS84

## MAP LEGEND

**Area of Interest (AOI)**

Area of Interest (AOI)

**Soils**

**Soil Rating Polygons**

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

**Soil Rating Lines**

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

**Soil Rating Points**

- A
- A/D
- B
- B/D
- C
- C/D
- D
- Not rated or not available

**Water Features**

Streams and Canals

**Transportation**

- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

**Background**

Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL: http://websoilsurvey.nrcs.usda.gov
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: San Luis Obispo County, California, Coastal Part
Survey Area Data: Version 6, Sep 26, 2014

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: May 8, 2010—May 21, 2010

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

# Hydrologic Soil Group

| Hydrologic Soil Group— Summary by Map Unit — San Luis Obispo County, California, Coastal Part (CA664) | | | | |
|---|---|---|---|---|
| Map unit symbol | Map unit name | Rating | Acres in AOI | Percent of AOI |
| 120 | Concepcion loam, 2 to 5 percent slopes | D | 21.0 | 1.9% |
| 127 | Cropley clay, 0 to 2 percent slopes | C | 328.8 | 30.2% |
| 128 | Cropley clay, 2 to 9 percent slopes | C | 114.4 | 10.5% |
| 130 | Diablo and Cibo clays, 9 to 15 percent slopes | D | 3.1 | 0.3% |
| 164 | Los Osos-Diablo complex, 15 to 30 percent slopes | D | 3.6 | 0.3% |
| 169 | Marimel sandy clay loam, occasionally flooded | C | 2.0 | 0.2% |
| 170 | Marimel silty clay loam, drained | C | 23.1 | 2.1% |
| 183 | Obispo-Rock outcrop complex, 15 to 75 percent slopes | D | 57.8 | 5.3% |
| 194 | Riverwash | | 4.5 | 0.4% |
| 197 | Salinas silty clay loam, 0 to 2 percent slopes | C | 484.0 | 44.4% |
| 198 | Salinas silty clay loam, 2 to 9 percent slopes | C | 5.7 | 0.5% |
| 221 | Xererts-Xerolls-Urban land complex, 0 to 15 percent slopes | | 5.9 | 0.5% |
| 228 | Water | | 36.1 | 3.3% |
| **Totals for Area of Interest** | | | **1,089.9** | **100.0%** |

## Description

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

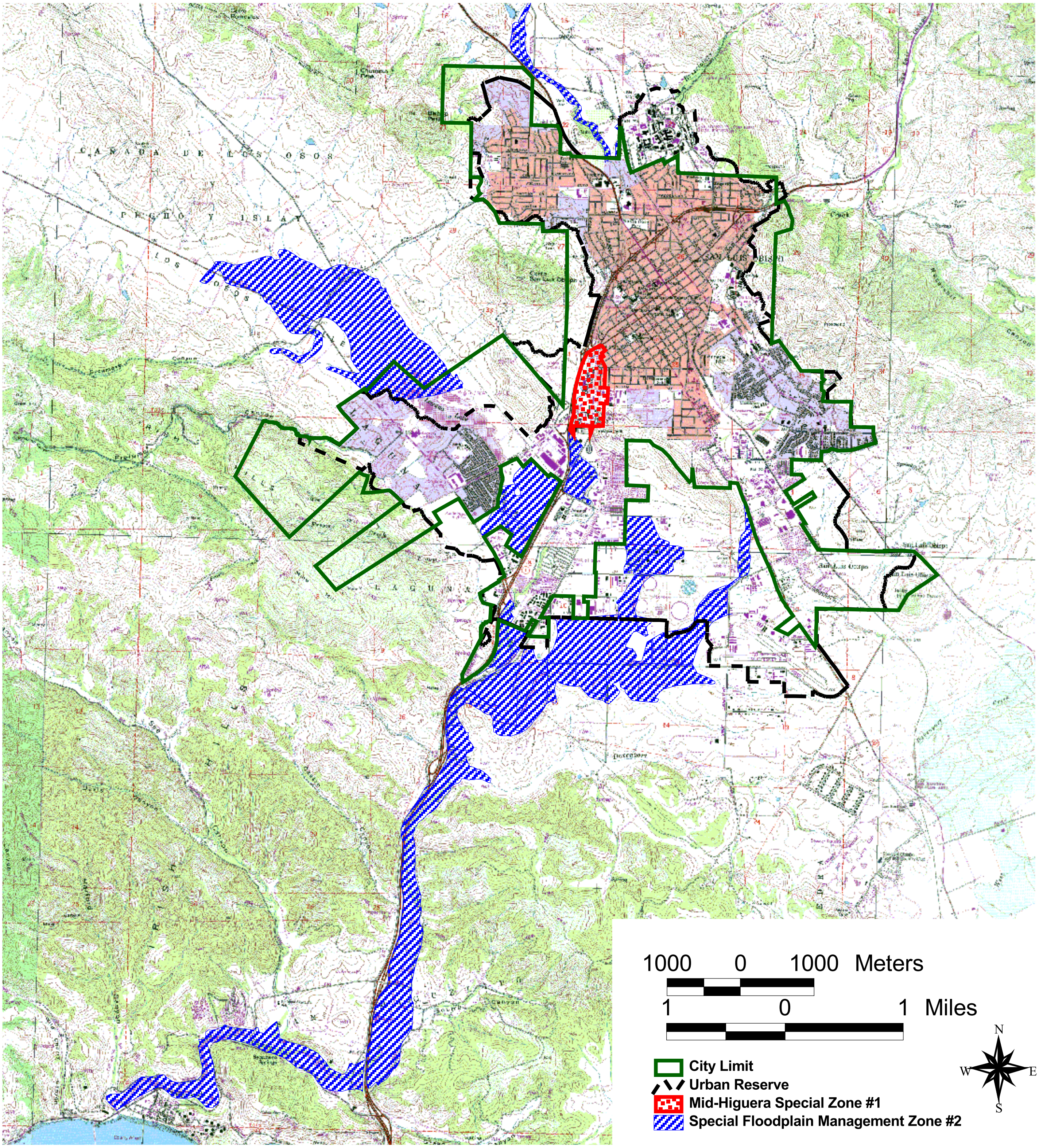
If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that in their natural condition are in group D are assigned to dual classes.

## Rating Options

*Aggregation Method:* Dominant Condition

*Component Percent Cutoff:* *None Specified*

*Tie-break Rule:* Higher




city of san luis obispo

PUBLIC WORKS DEPARTMENT

## Special Floodplain Management Zones

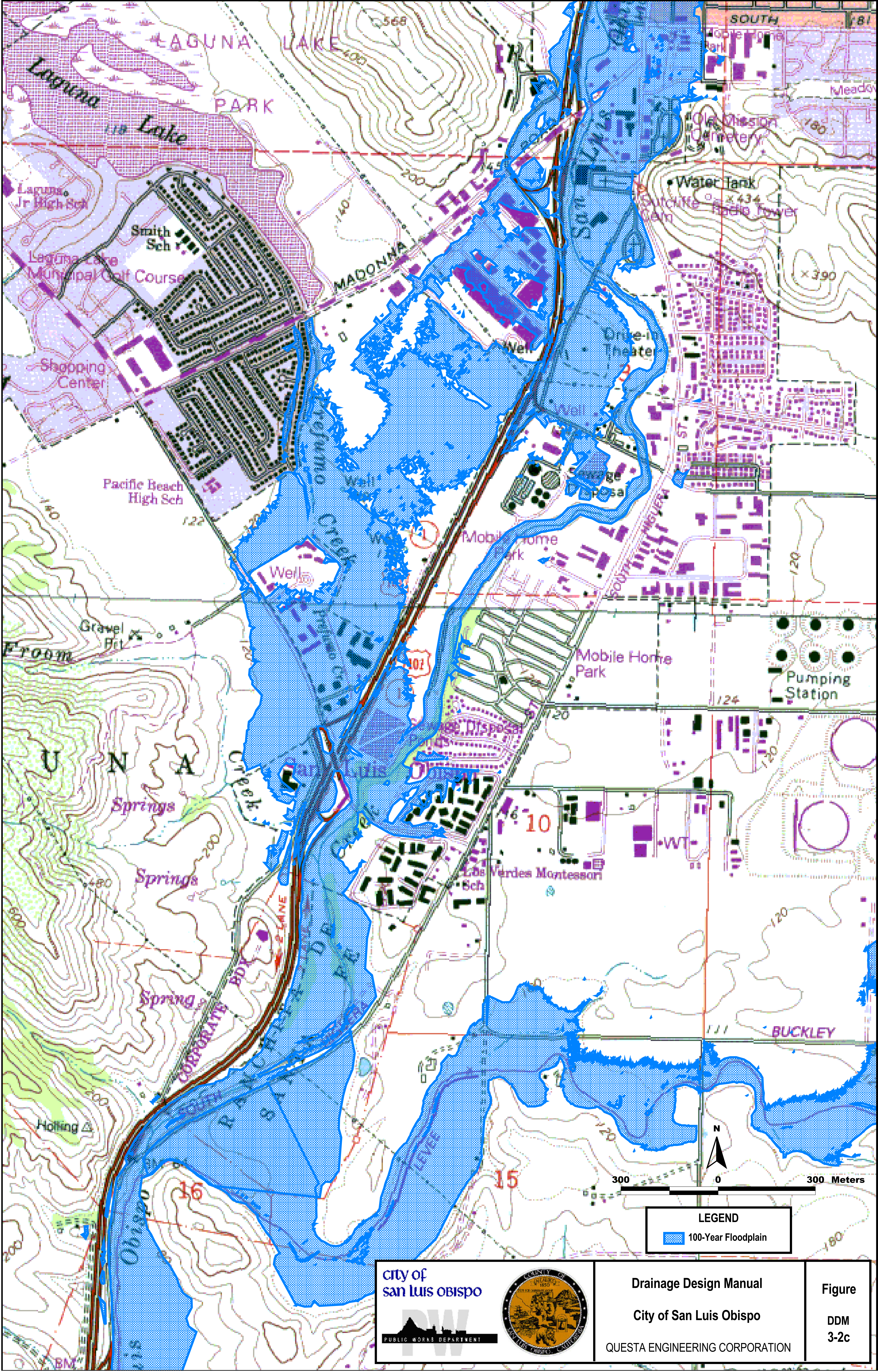
**Drainage Design Manual**
**City of San Luis Obispo**

QUESTA ENGINEERING CORPORATION

**Figure**

**DDM**
**3-1**

FILE REFERENCE: c:\arcview projects\98202 slo phase ii\98202_floodplain_management.apr
LAYOUT: 8.5x11
DATE: Nov 26, 2001 4:32 PM




city of san luis obispo

PUBLIC WORKS DEPARTMENT

Drainage Design Manual

City of San Luis Obispo

QUESTA ENGINEERING CORPORATION

Figure DDM 3-2c

# Appendix B

*Hydrologic Analyses of Existing Conditions*

## Composite Runoff Coefficient and Curve Number Calculations - Existing Conditions

**Project:** San Luis Ranch - Tentative Map
**Updated:** 6/7/2016

***Runoff Coefficients (from Table 4-1 SLO DDM) and Curve Numbers (from Table 2-2a TR-55)***

| Type of Development | Hydrologic Soil Goup | Runoff Coefficient, *C* | Curve Number, *CN* | Description |
|---|---|---|---|---|
| Moderate Vegetation (s < 2%) | C | 0.25 | 82 | SLO DDM: Moderate Vegetation; TR-55: Woods-grass Combination (poor hydrologic condition) |
| Moderate Vegetation (s < 2%) | D | 0.25 | 86 | |
| Moderate Vegetation (s = 2-10%) | C | 0.30 | 82 | |
| Moderate Vegetation (s = 2-10%) | D | 0.35 | 86 | |
| Moderate Vegetation (s > 10%) | C | 0.35 | 82 | |
| Moderate Vegetation (s > 10%) | D | 0.45 | 86 | |
| Agricultural (s < 2%) | C | 0.15 | 82 | SLO DDM: Agriculture; TR-55: Row Crops, Straight Rows, Crop Residue Cover (good hydrologic condition) |
| Agricultural (s < 2%) | D | 0.20 | 85 | |
| Agricultural (s = 2-10%) | C | 0.15 | 82 | |
| Agricultural (s = 2-10%) | D | 0.20 | 85 | |
| Agricultural (s > 10%) | C | 0.20 | 82 | |
| Agricultural (s > 10%) | D | 0.25 | 85 | |
| Impervious (s < 2%) | C | 0.80 | 98 | Impervious Surfaces |
| Impervious (s <2%) | D | 0.85 | 98 | |
| Impervious (s = 2-10%) | C | 0.85 | 98 | |
| Impervious (s = 2-10%) | D | 0.87 | 98 | |
| Impervious (s > 10%) | C | 0.90 | 98 | |
| Impervious (s > 10%) | D | 0.90 | 98 | |
| Parks (s < 2%) | C | 0.10 | 74 | SLO DDM: Unimproved Vacant Lots; TR-55: Moderate Vegetation (good hydrologic condition) |
| Parks (s < 2%) | D | 0.15 | 80 | |
| Parks (s = 2-10%) | C | 0.15 | 74 | |
| Parks (s = 2-10%) | D | 0.20 | 80 | |
| Parks (s > 10%) | C | 0.20 | 74 | |
| Parks (s > 10%) | D | 0.30 | 80 | |

***Calculation Description***

Composite runoff coefficients and curve numbers are calculated by using the Area Weighted Average method as follows:

$$Composite\ C = \frac{\sum(C_1A_1 + C_2A_2 + \ldots + C_nA_n)}{\sum(A_1 + A_2 + \ldots + A_n)}$$

***Composite Runoff Coefficient and Curve Number Calculation***

| Sub-basin | Total Area (sf) | Total Area, *A* (ac) | Hydrologic Soil Group | Moderate Vegetation Area (sf) | | | Agricultural Area (sf) | | | Impervious Area(sf) | | | Park Area (sf) | | | Composite Runoff Coefficient, *C* | Composite Curve Number, *CN* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | | |
| EXIST-1 | 219,952 | 5.05 | C | 0 | 172,181 | 0 | 0 | 0 | 0 | 47,771 | 0 | 0 | 0 | 0 | 0 | 0.41 | 85 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| EXIST-2 | 878,271 | 20.16 | C | 263,340 | 263,340 | 0 | 118,409 | 0 | 0 | 233,183 | 0 | 0 | 0 | 0 | 0 | 0.40 | 86 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| EXIST-3 | 554,752 | 12.74 | C | 225,139 | 0 | 0 | 329,613 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.19 | 82 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| EXIST-4 | 4,391,148 | 100.81 | C | 0 | 0 | 0 | 4,391,148 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.15 | 82 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| **Total:** | **6,044,123** | **138.75** | | **488,479** | **435,521** | **0** | **4,839,170** | **0** | **0** | **280,954** | **0** | **0** | **0** | **0** | **0** | | |

## Time of Concentration Calculation - Existing Conditions

**Project:** San Luis Ranch - Tentative Map
**Updated:** 6/7/2016

***Calculation Description***

The following calculations are based on the procedures presented in the San Luis Obispo Drainage Design Manual and the NRCS publication TR-55: Urban Hydrology for Small Watersheds (June 1986 edition)

**Sheet Flow (Flow Over Plane Surfaces)**

$$T_{sf} = \frac{0.007(nL)^{0.8}}{(I_2)^{0.5} s^{0.4}} * (60\, min/hr)$$

$T_{sf}$ = Travel Time for Sheet Flow (min)
n = Manning's Roughness Coefficient (from Table 3-1)
$I_2$ = 2-year, 24-hour rainfall (in)
L = Flow Length (ft) - 300 ft maximum
s = Land Slope (ft/ft)

*Table 3-1 from TR-55*

**Table 3-1** Roughness coefficients (Manning's n) for sheet flow

| Surface description | n [1] |
|---|---|
| Smooth surfaces (concrete, asphalt, gravel, or bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated soils: | |
| Residue cover ≤20% | 0.06 |
| Residue cover >20% | 0.17 |
| Grass: | |
| Short grass prairie | 0.15 |
| Dense grasses [2] | 0.24 |
| Bermudagrass | 0.41 |
| Range (natural) | 0.13 |
| Woods: [3] | |
| Light underbrush | 0.40 |
| Dense underbrush | 0.80 |

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

**Shallow Concentrated Flow**

$$T_{sc} = \frac{L}{60V} \qquad V = K_u k S_p^{0.5}$$

$T_{sc}$ = Travel Time for Shallow Concentrated Flow (min)
L = Flow Length (ft) - 1000 ft maximum
V = Velocity (ft/s) (per Equation Above)
$K_u$ = 3.28
k = Interception Coefficient
= 0.457 (Grassed Waterway)
= 0.491 (Unpaved)
= 0.619 (Paved Areas; Small Upland Gullies)
$S_p$ = Slope (%)

**Channel Flow**

$$T_{ch} = \frac{L}{60V} \qquad V = \frac{1.49 R^{2/3} s^{0.5}}{n}$$

$T_{ch}$ = Travel Time for Channel Flow (min)
V = Velocity (ft/s) (per Manning Equation Above)
R = Hydraulic Radius (ft) = $A/P_w$
A = Cross-sectional Flow Area (sf)
$P_w$ = Wetted Perimeter (ft)
s = Channel Slope (ft/ft)
n = Manning's Roughness Coefficient

**Time of Concentration to Inlet**

$T_c = T_{sf} + T_{sc} + T_{ch}$

**Lag Time**

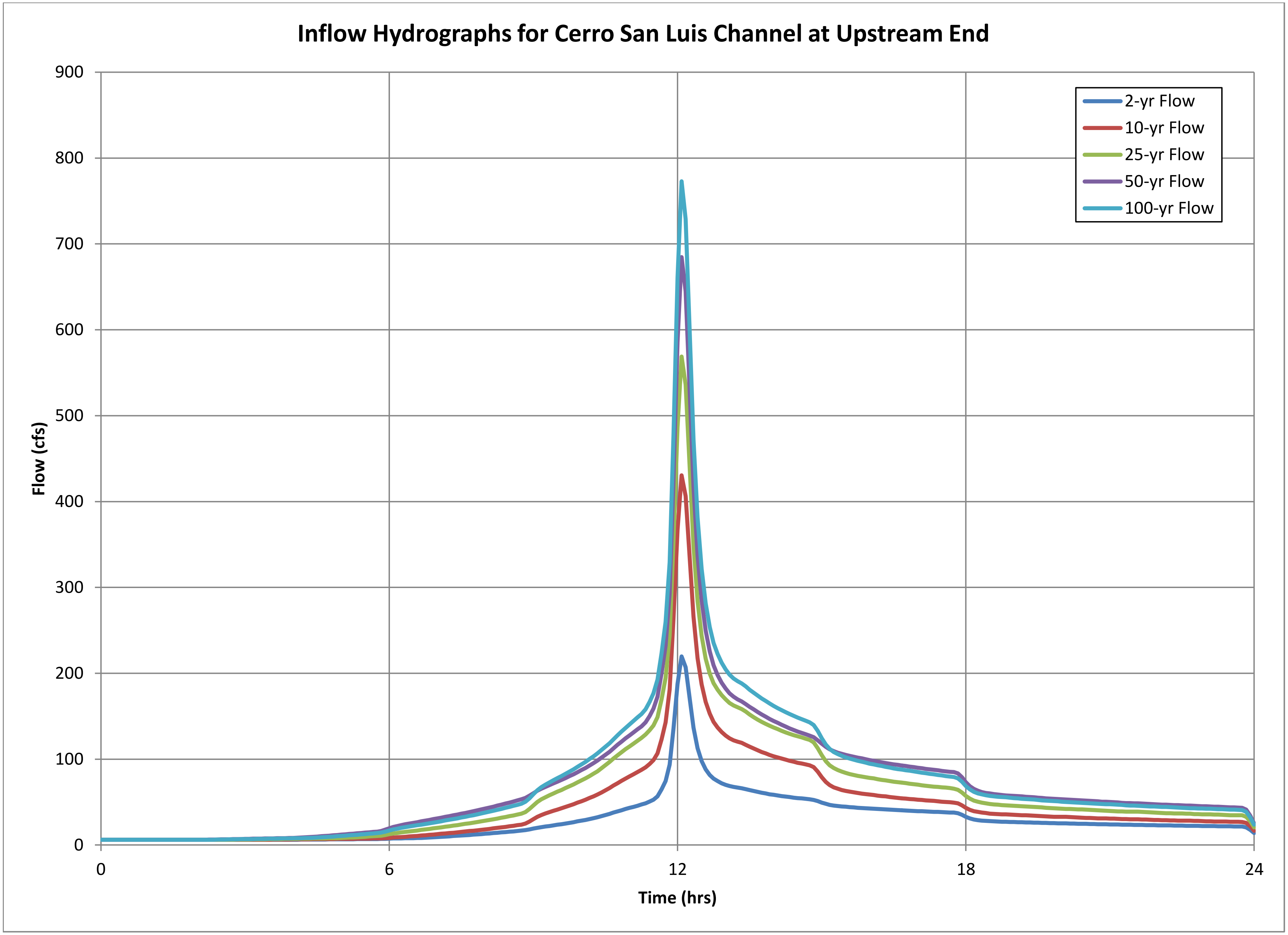
$T_L = 0.6 * T_c$

***Time of Concentration Calculation***

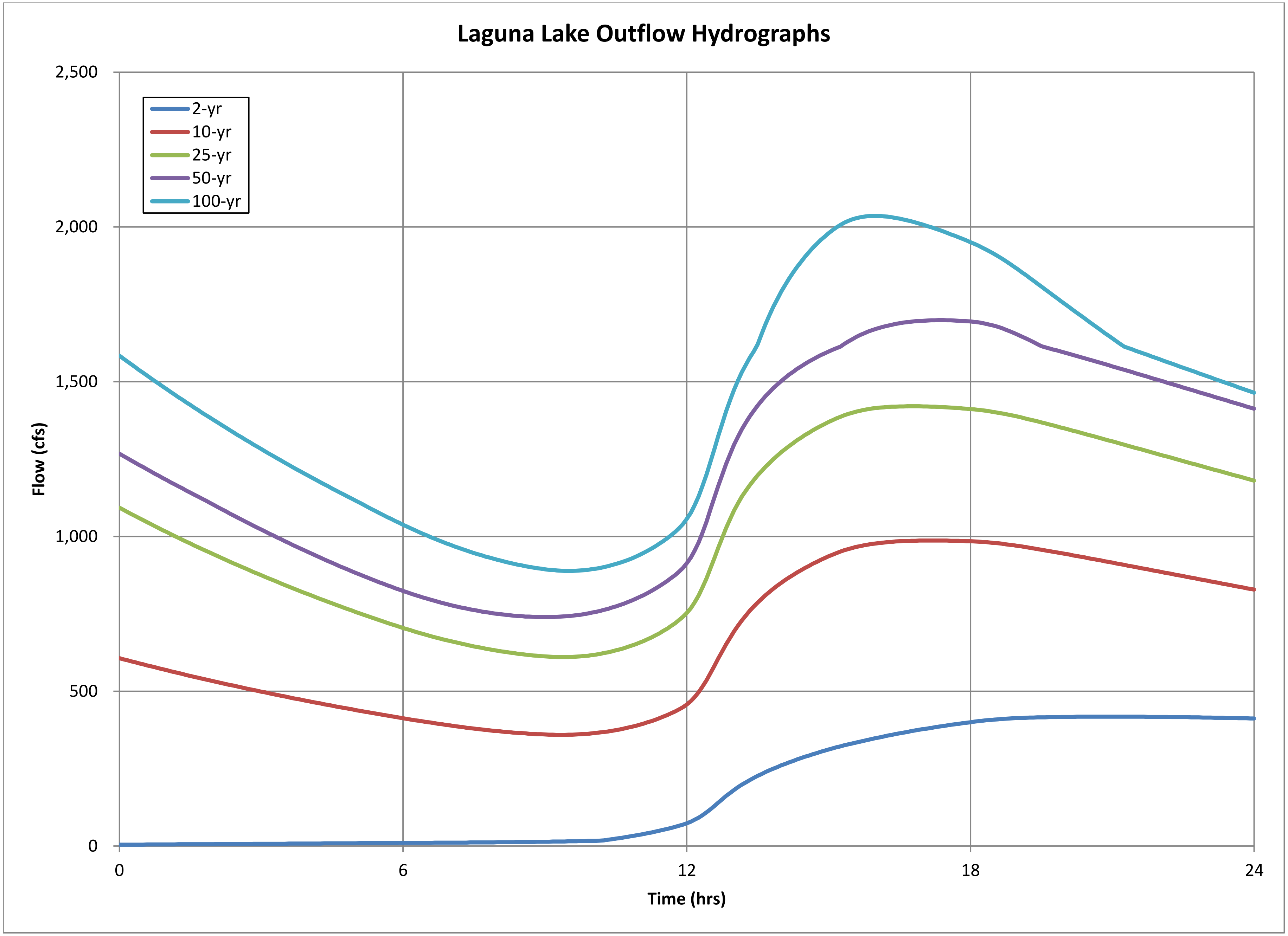
| Sub-basin | Point of Discharge | Sheet Flow Time Calculation: n | Upper Elev (ft) | Lower Elev (ft) | L (ft) | $I_2$ (in) | s (ft/ft) | $T_{SF}$ (min) |
|---|---|---|---|---|---|---|---|---|
| EXIST-1 | Prefumo Reach 1 | 0.130 | 135.20 | 130.30 | 300 | 3.28 | 0.016 | 22.5 |
| EXIST-2 | Cerro San Luis Channel | 0.130 | 136.30 | 130.00 | 165 | 3.28 | 0.038 | 9.9 |
| EXIST-3 | Prefumo Reach 2 | 0.170 | 132.60 | 131.30 | 300 | 3.28 | 0.004 | 47.5 |
| EXIST-4 | Prefumo Reach 3 | 0.170 | 134.70 | 132.10 | 300 | 3.28 | 0.009 | 36.0 |

| Sub-basin | Shallow Concentrated Flow Time Calculation: Upper Elev (ft) | Lower Elev (ft) | L (ft) | k | Sp (%) | V (ft/s) | $T_{sc}$ (min) |
|---|---|---|---|---|---|---|---|
| EXIST-1 | 130.3 | 120.1 | 412 | 0.457 | 2.5 | 2.36 | 2.9 |
| EXIST-2 | 130.0 | 129.0 | 404 | 0.457 | 0.2 | 0.75 | 9.0 |
| EXIST-3 | 131.3 | 127.1 | 1,000 | 0.457 | 0.4 | 0.97 | 17.2 |
| EXIST-4 | 132.1 | 120.5 | 2,449 | 0.457 | 0.5 | 1.03 | 39.6 |

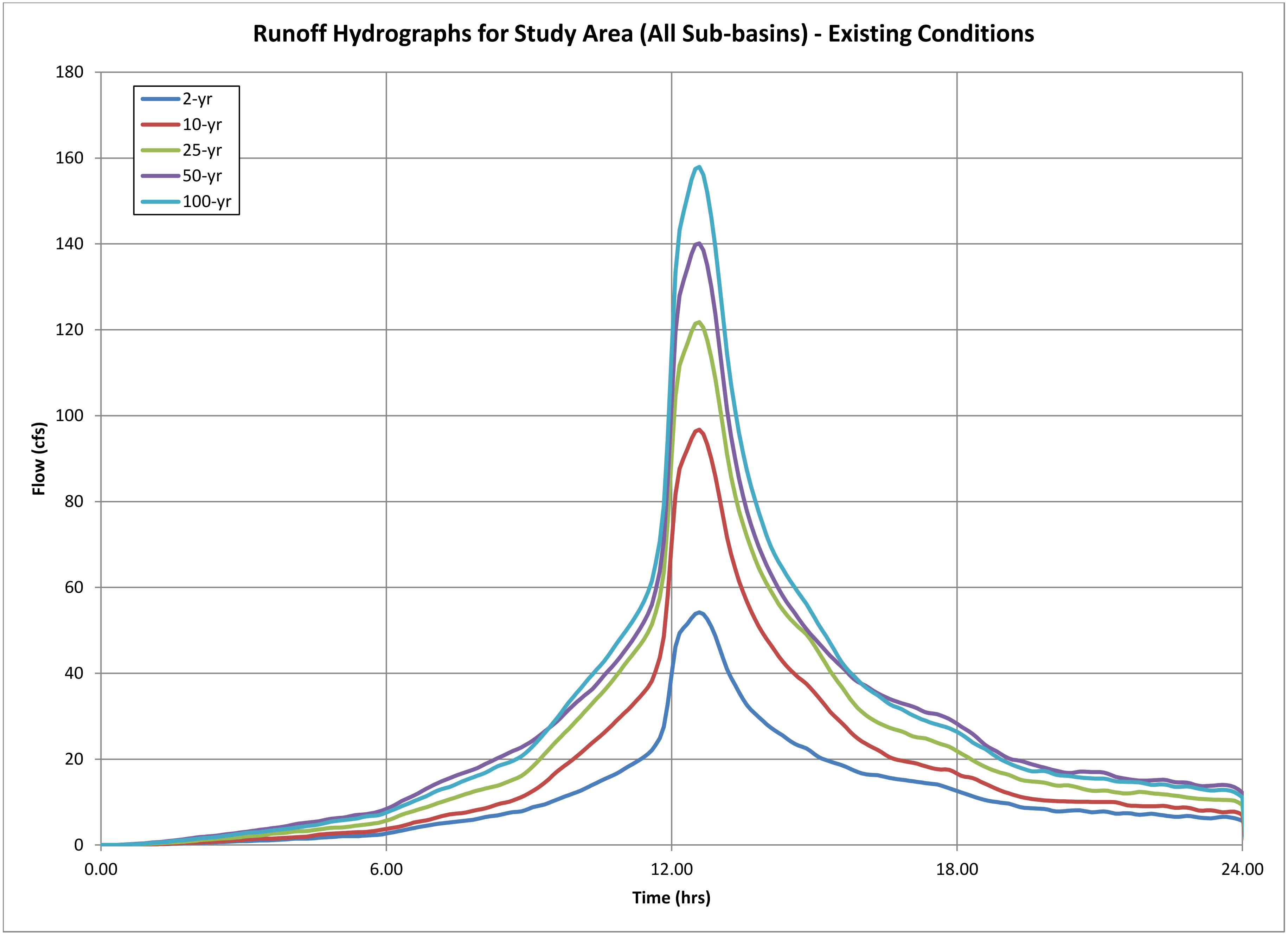
| Sub-basin | Channel Flow Time Calculation: Upper Elev (ft) | Lower Elev (ft) | L (ft) | A (sf) | $P_w$ (ft) | R (ft) | s (ft/ft) | n | V (ft/s) | $T_{ch}$ (min) | Time of Conc. $T_c$ (min) | Lag Time $T_L$ (min) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EXIST-1 | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 25.5 | 15.3 | |
| EXIST-2 | 125.7 | 116.7 | 996 | 80.00 | 29.89 | 2.68 | 0.009 | 0.045 | 6.07 | 2.7 | 21.7 | 13.0 | *Channel Flow Calculations performed in Flo |
| EXIST-3 | 127.1 | 124.1 | 619 | 2.00 | 4.47 | 0.45 | 0.005 | 0.030 | 2.02 | 5.1 | 69.8 | 41.9 | *Channel Flow Calculations performed in Flo |
| EXIST-4 | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 75.6 | 45.3 | |



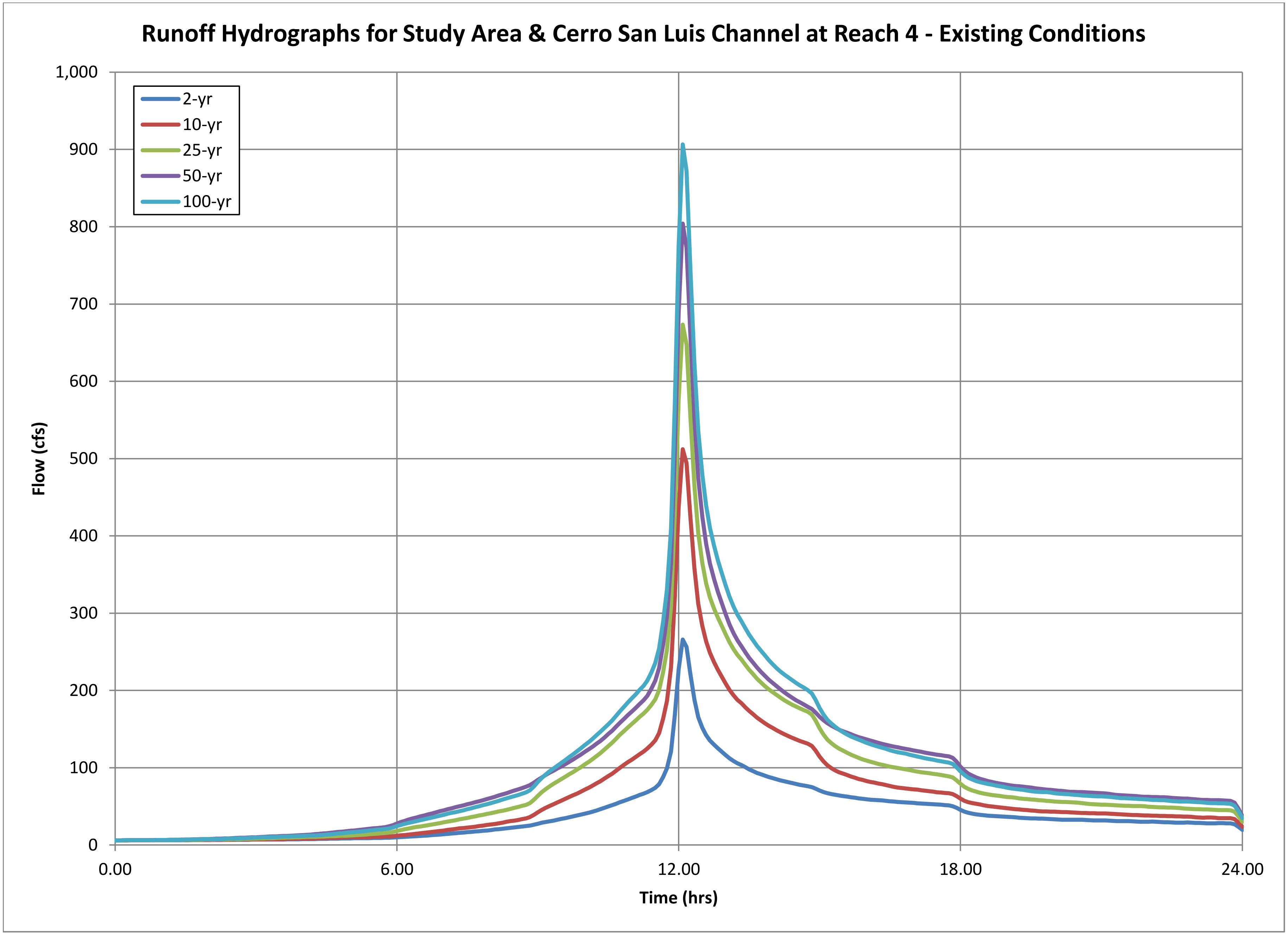
Inflow Hydrographs for Cerro San Luis Channel at Upstream End
900
800
700
600
500
400
300
200
100
0
Flow (cfs)
0
6
12
18
24
Time (hrs)
2-yr Flow
10-yr Flow
25-yr Flow
50-yr Flow
100-yr Flow



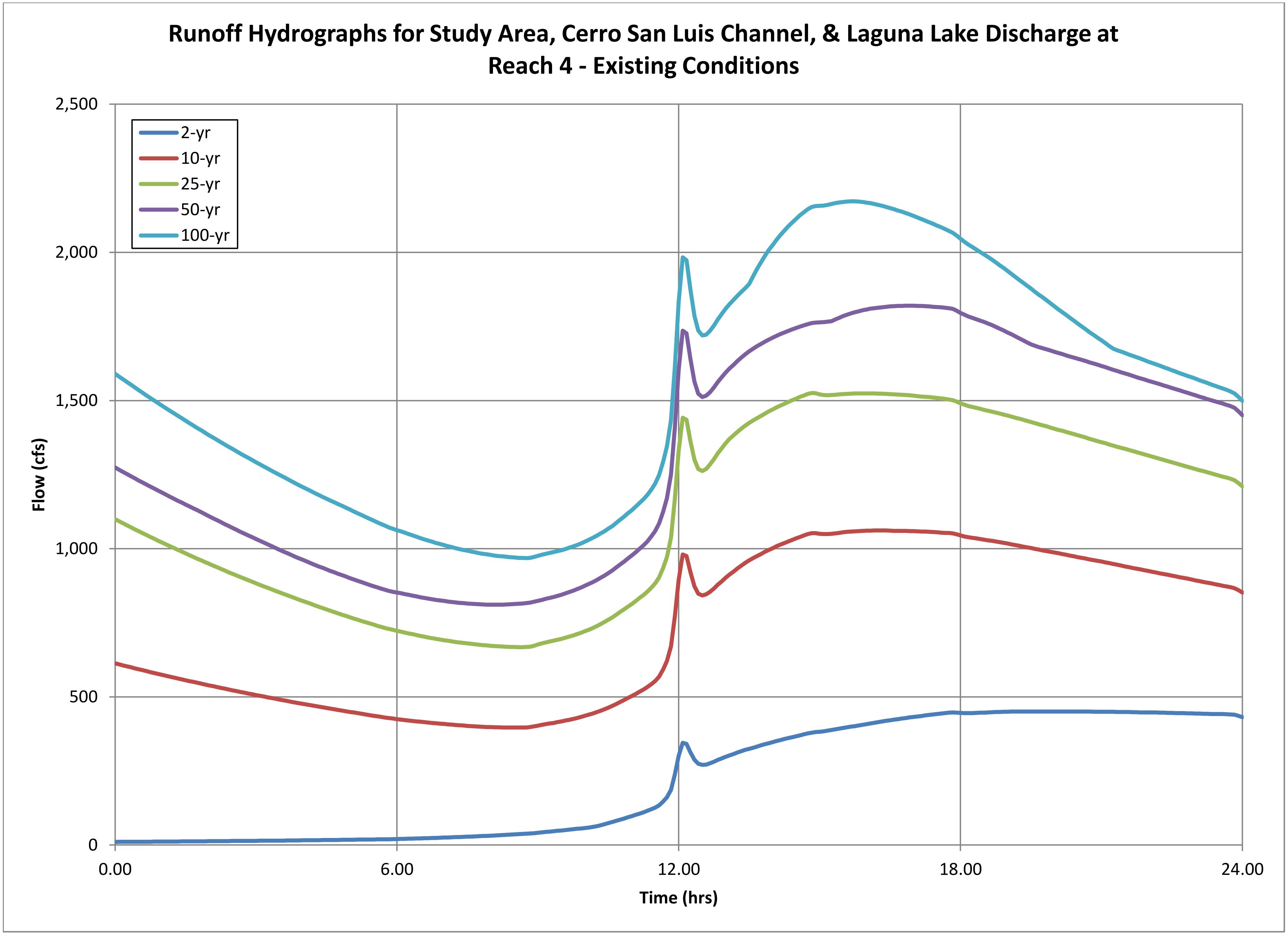
Laguna Lake Outflow Hydrographs
2-yr
10-yr
25-yr
50-yr
100-yr
2,500
2,000
1,500
1,000
500
0
Flow (cfs)
0
6
12
18
24
Time (hrs)



Runoff Hydrographs for Study Area (All Sub-basins) - Existing Conditions
180
160
140
120
100
80
60
40
20
0
Flow (cfs)
0.00
6.00
12.00
18.00
24.00
Time (hrs)
2-yr
10-yr
25-yr
50-yr
100-yr



Runoff Hydrographs for Study Area & Cerro San Luis Channel at Reach 4 - Existing Conditions
Flow (cfs)
Time (hrs)
1,000
900
800
700
600
500
400
300
200
100
0
0.00
6.00
12.00
18.00
24.00
2-yr
10-yr
25-yr
50-yr
100-yr


Runoff Hydrographs for Study Area, Cerro San Luis Channel, & Laguna Lake Discharge at Reach 4 - Existing Conditions
2-yr
10-yr
25-yr
50-yr
100-yr
2,500
2,000
1,500
1,000
500
0
Flow (cfs)
0.00
6.00
12.00
18.00
24.00
Time (hrs)

# Appendix C

*Hydrologic Analyses of Proposed Conditions*

**Composite Runoff Coefficient and Curve Number Calculations - Proposed Conditions**

**Project:** San Luis Ranch - Tentative Map
**Updated:** 7/27/2016

***Runoff Coefficients (from Table 4-1 SLO DDM) and Curve Numbers (from Table 2-2a TR-55)***

| Type of Development | Hydrologic Soil Goup | Runoff Coefficient, *C* | Curve Number, *CN* | Description |
|---|---|---|---|---|
| SFR Medium (s < 2%) | C | 0.45 | 90 | SLO DDM: 6,000 sf lots; TR-55: 1/8 acres or less (town houses) |
| SFR Medium (s < 2%) | D | 0.50 | 92 | |
| SFR Medium (s = 2-10%) | C | 0.50 | 90 | |
| SFR Medium (s = 2-10%) | D | 0.60 | 92 | |
| SFR Medium (s > 10%) | C | 0.60 | 90 | |
| SFR Medium (s > 10%) | D | 0.65 | 92 | |
| SFR Medium-High (s < 2%) | C | 0.48 | 92 | Average of LDR and HDR |
| SFR Medium-High (s < 2%) | D | 0.55 | 94 | |
| SFR Medium-High (s = 2-10%) | C | 0.55 | 92 | |
| SFR Medium-High (s = 2-10%) | D | 0.65 | 94 | |
| SFR Medium-High (s > 10%) | C | 0.65 | 92 | |
| SFR Medium-High (s > 10%) | D | 0.73 | 94 | |
| MFR High(s < 2%) | C | 0.50 | 94 | SLO DDM: Apartments; TR-55: Commercial |
| MFR High(s < 2%) | D | 0.60 | 95 | |
| MFR High(s = 2-10%) | C | 0.60 | 94 | |
| MFR High(s = 2-10%) | D | 0.70 | 95 | |
| MFR High(s > 10%) | C | 0.70 | 94 | |
| MFR High(s > 10%) | D | 0.80 | 95 | |
| Commercial (s < 2%) | C | 0.50 | 94 | SLO DDM: Neighborhood Commercial; TR-55: Commerical |
| Commercial (s < 2%) | D | 0.65 | 95 | |
| Commercial (s = 2-10%) | C | 0.60 | 94 | |
| Commercial (s = 2-10%) | D | 0.75 | 95 | |
| Commercial (s > 10%) | C | 0.70 | 94 | |
| Commercial (s > 10%) | D | 0.80 | 95 | |
| Impervious (s < 2%) | C | 0.80 | 98 | Impervious Surfaces |
| Impervious (s <2%) | D | 0.85 | 98 | |
| Impervious (s = 2-10%) | C | 0.85 | 98 | |
| Impervious (s = 2-10%) | D | 0.87 | 98 | |
| Impervious (s > 10%) | C | 0.90 | 98 | |
| Impervious (s > 10%) | D | 0.90 | 98 | |
| Moderate Vegetation (s < 2%) | C | 0.25 | 82 | SLO DDM: Moderate Vegetation; TR-55: Woods-grass Combination (poor hydrologic condition) |
| Moderate Vegetation (s < 2%) | D | 0.25 | 86 | |
| Moderate Vegetation (s = 2-10%) | C | 0.30 | 82 | |
| Moderate Vegetation (s = 2-10%) | D | 0.35 | 86 | |
| Moderate Vegetation (s > 10%) | C | 0.35 | 82 | |
| Moderate Vegetation (s > 10%) | D | 0.45 | 86 | |
| Park/Treatment (s < 2%) | C | 0.10 | 74 | SLO DDM: Unimproved Vacant Lots; TR-55: Moderate Vegetation (good hydrologic condition) |
| Park/Treatment (s < 2%) | D | 0.15 | 80 | |
| Park/Treatment (s = 2-10%) | C | 0.15 | 74 | |
| Park/Treatment (s = 2-10%) | D | 0.20 | 80 | |
| Park/Treatment (s > 10%) | C | 0.20 | 74 | |
| Park/Treatment (s > 10%) | D | 0.30 | 80 | |
| Agricultural (s < 2%) | C | 0.15 | 82 | SLO DDM: Agriculture; TR-55: Row Crops, Straight Rows, Crop Residue Cover (good hydrologic condition) |
| Agricultural (s < 2%) | D | 0.20 | 85 | |
| Agricultural (s = 2-10%) | C | 0.15 | 82 | |
| Agricultural (s = 2-10%) | D | 0.20 | 85 | |
| Agricultural (s > 10%) | C | 0.20 | 82 | |
| Agricultural (s > 10%) | D | 0.25 | 85 | |

***Calculation Description***

Composite runoff coefficients and curve numbers are calculated by using the Area Weighted Average method as follows:

$$Composite\ C = \frac{\sum(C_1A_1 + C_2A_2 + \ldots + C_nA_n)}{\sum(A_1 + A_2 + \ldots + A_n)}$$

***Composite Runoff Coefficient and Curve Number Calculation***

| Sub-basin | Total Area (sf) | Total Area, *A* (ac) | Hydrologic Soil Group | SFR Medium Density Area (sf) | | | SFR Medium-High Density Area (sf) | | | MFR High Density Area (sf) | | | Commericial Area (sf) | | | Impervious (sf) | | | Moderate Vegetation Area (sf) | | | Park/Treatment Area (sf) | | | Agricultural Area (sf) | | | Composite Runoff Coefficient, *C* | Composite Curve Number, *CN* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | s < 2% | s = 2-10% | s > 10% | | |
| PROP-1 | 157,587 | 3.62 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 55,287 | 0 | 0 | 0 | 102,300 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.48 | 88 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-2A | 125,139 | 2.87 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100,677 | 0 | 0 | 18,475 | 0 | 0 | 5,987 | 0 | 0 | 0 | 0 | 0 | 0.69 | 94 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-2B | 349,480 | 8.02 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 126,959 | 0 | 0 | 111,261 | 111,261 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.47 | 88 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-2C | 161,647 | 3.71 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 150,146 | 0 | 0 | 0 | 0 | 11,501 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.61 | 94 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-2D | 259,375 | 5.95 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 247,672 | 0 | 0 | 0 | 0 | 11,703 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.61 | 94 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-3A | 561,436 | 12.89 | C | 133,144 | 0 | 0 | 177,300 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 187,149 | 0 | 0 | 0 | 0 | 0 | 63,843 | 0 | 0 | 0 | 0 | 0 | 0.53 | 91 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-3B | 53,499 | 1.23 | C | 32,153 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11,962 | 0 | 0 | 0 | 0 | 0 | 9,384 | 0 | 0 | 0 | 0 | 0 | 0.47 | 89 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-3C | 133,093 | 3.06 | C | 81,760 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 45,956 | 0 | 0 | 0 | 0 | 0 | 5,377 | 0 | 0 | 0 | 0 | 0 | 0.56 | 92 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-3D | 87,818 | 2.02 | C | 66,995 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7,869 | 0 | 0 | 0 | 0 | 0 | 12,954 | 0 | 0 | 0 | 0 | 0 | 0.43 | 88 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-3E | 102,817 | 2.36 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6,346 | 0 | 0 | 48,236 | 48,236 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.31 | 83 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-4A | 55,029 | 1.26 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 42,284 | 0 | 0 | 0 | 5,035 | 0 | 7,710 | 0 | 0 | 0 | 0 | 0 | 0.66 | 93 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-4B | 30,577 | 0.70 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 26,677 | 0 | 0 | 0 | 863 | 0 | 3,037 | 0 | 0 | 0 | 0 | 0 | 0.72 | 95 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-4C | 71,202 | 1.63 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 58,506 | 0 | 0 | 0 | 0 | 0 | 12,696 | 0 | 0 | 0 | 0 | 0.73 | 94 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-4D | 640,780 | 14.71 | C | 237,897 | 0 | 0 | 103,335 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 225,106 | 0 | 0 | 1,679 | 0 | 0 | 72,763 | 0 | 0 | 0 | 0 | 0 | 0.54 | 91 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-4E | 226,440 | 5.20 | C | 146,200 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 69,816 | 0 | 0 | 0 | 0 | 0 | 10,424 | 0 | 0 | 0 | 0 | 0 | 0.54 | 92 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-4F | 394,644 | 9.06 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 394,644 | 0 | 0 | 0.15 | 82 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| PROP-4G | 2,637,322 | 60.54 | C | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2,637,322 | 0 | 0 | 0.15 | 82 |
| | | | D | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| **Total:** | **6,047,885** | **138.84** | | **698,149** | **0** | **0** | **280,635** | **0** | **0** | **0** | **397,818** | **0** | **0** | **0** | **0** | **929,292** | **58,506** | **0** | **179,650** | **267,694** | **0** | **191,479** | **12,696** | **0** | **3,031,966** | **0** | **0** | | |

## Time of Concentration Calculation - Proposed Conditions

**Project:** San Luis Ranch - Tentative Map
**Updated:** 7/27/2016

***Calculation Description***

The following calculations are based on the procedures presented in the San Luis Obispo Drainage Design Manual and the NRCS publication TR-55: Urban Hydrology for Small Watersheds (June 1986 edition)

**Sheet Flow (Flow Over Plane Surfaces)**

$$T_{sf} = \frac{0.007(nL)^{0.8}}{(I_2)^{0.5} s^{0.4}} * (60\,min/hr)$$

$T_{sf}$ = Travel Time for Sheet Flow (min)
n = Manning's Roughness Coefficient (from Table 3-1)
$I_2$ = 2-year, 24-hour rainfall (in)
L = Flow Length (ft) - 300 ft maximum
s = Land Slope (ft/ft)

*Table 3-1 from TR-55*

**Table 3-1** Roughness coefficients (Manning's n) for sheet flow

| Surface description | n [1] |
|---|---|
| Smooth surfaces (concrete, asphalt, gravel, or bare soil) | 0.011 |
| Fallow (no residue) | 0.05 |
| Cultivated soils: | |
| Residue cover ≤20% | 0.06 |
| Residue cover >20% | 0.17 |
| Grass: | |
| Short grass prairie | 0.15 |
| Dense grasses [2] | 0.24 |
| Bermudagrass | 0.41 |
| Range (natural) | 0.13 |
| Woods:[3] | |
| Light underbrush | 0.40 |
| Dense underbrush | 0.80 |

1 The n values are a composite of information compiled by Engman (1986).
2 Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.
3 When selecting n , consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

**Shallow Concentrated Flow**

$$T_{sc} = \frac{L}{60V} \qquad V = K_u k S_p^{0.5}$$

$T_{sc}$ = Travel Time for Shallow Concentrated Flow (min)
L = Flow Length (ft) - 1000 ft maximum
V = Velocity (ft/s) (per Equation Above)
$K_u$ = 3.28
k = Interception Coefficient
= 0.457 (Grassed Waterway)
= 0.491 (Unpaved)
= 0.619 (Paved Areas; Small Upland Gullies)
$S_p$ = Slope (%)

**Channel Flow**

$$T_{ch} = \frac{L}{60V} \qquad V = \frac{1.49R^{2/3}s^{0.5}}{n}$$

$T_{ch}$ = Travel Time for Channel Flow (min)
V = Velocity (ft/s) (per Manning Equation Above)
R = Hydraulic Radius (ft) = $A/P_w$
A = Cross-sectional Flow Area (sf)
$P_w$ = Wetted Perimeter (ft)
s = Channel Slope (ft/ft)
n = Manning's Roughness Coefficient

**Time of Concentration to Inlet**

$T_c = T_{sf} + T_{sc} + T_{ch}$

**Lag Time**

$T_L = 0.6*T_c$

***Time of Concentration Calculation***

| Sub-basin | Point of Discharge | Sheet Flow Time Calculation | | | | | | | Shallow Concentrated Flow Time Calculation | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n | Upper Elev (ft) | Lower Elev (ft) | L (ft) | $I_2$ (in) | s (ft/ft) | $T_{SF}$ (min) | Upper Elev (ft) | Lower Elev (ft) | L (ft) | k | Sp (%) | V (ft/s) | $T_{sc}$ (min) |
| PROP-1 | Prefumo Reach 1 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-2A | Cerro San Luis Channel | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-2B | Cerro San Luis Channel | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-2C | Cerro San Luis Channel | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-2D | Cerro San Luis Channel | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-3A | Prefumo Reach 2 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-3B | Prefumo Reach 2 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-3C | Prefumo Reach 2 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-3D | Prefumo Reach 2 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-3E | Prefumo Reach 2 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-4A | Prefumo Reach 3 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-4B | Prefumo Reach 3 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-4C | Prefumo Reach 3 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-4D | Prefumo Reach 3 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-4E | Prefumo Reach 3 | | | | | 3.28 | #DIV/0! | #DIV/0! | 0.0 | | | | #DIV/0! | #DIV/0! | #DIV/0! |
| PROP-4F | Prefumo Reach 3 | 0.170 | 136.000 | 134.800 | 300 | 3.28 | 0.004 | 49.0 | 134.8 | 132.0 | 600 | 0.457 | 0.5 | 1.02 | 9.8 |
| PROP-4G | Prefumo Reach 3 | 0.170 | 133.000 | 131.400 | 300 | 3.28 | 0.005 | 43.7 | 131.4 | 120.5 | 2,331 | 0.457 | 0.5 | 1.03 | 37.9 |

| Sub-basin | Channel Flow Time Calculation | | | | | | | | | | Time of Conc. | Lag Time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Upper Elev (ft) | Lower Elev (ft) | L (ft) | A (sf) | $P_w$ (ft) | R (ft) | s (ft/ft) | n | V (ft/s) | $T_{ch}$ (min) | $T_c$ (min) | $T_L$ (min) |
| PROP-1 | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-2A | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-2B | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-2C | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-2D | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-3A | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-3B | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-3C | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-3D | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-3E | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-4A | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-4B | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-4C | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-4D | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-4E | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 10.0 | 6.0 |
| PROP-4F | 0.0 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.000 | 0.000 | 0.00 | 0.0 | 58.8 | 35.3 |
| PROP-4G | 120.5 | | | | | | #DIV/0! | | 0.00 | 0.0 | 81.6 | 49.0 |

## Peak Flow Calculations Using Rational Method - Proposed Conditions

**Project:** San Luis Ranch - Tentative Map
**Updated:** 7/27/2016

***Calculation Description***

The following calculations are based on the Rational Method as

$Q = C*i*C_a*A$

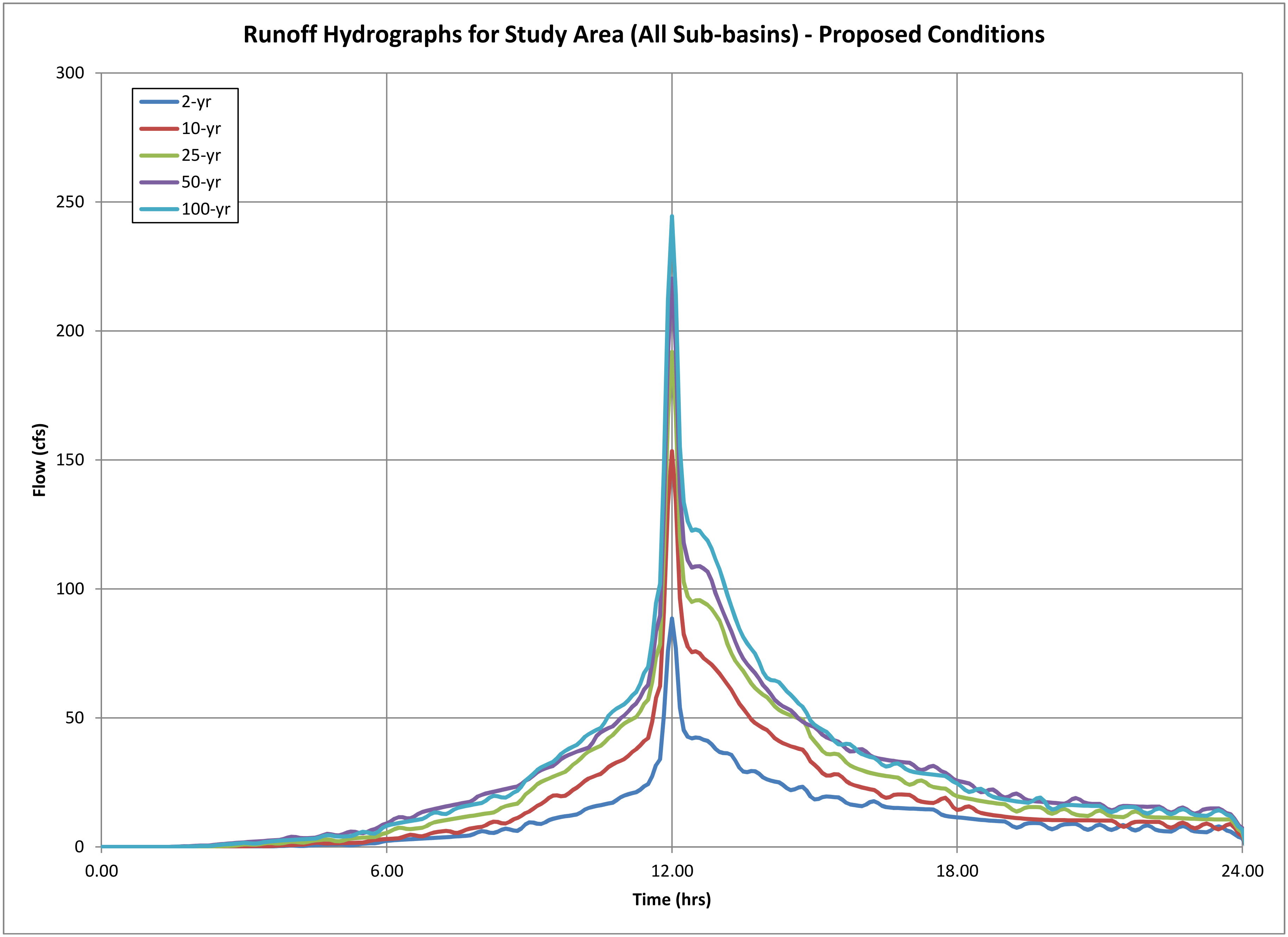
Q = Peak Rate of Runoff (cfs)
C = Runoff Coefficient
i = Rainfall Intensity (in/hr)
$C_a$ = Antecedent Moistuer Factor
A = Drainage Area (acres)

***Parameters for Peak Flow Calculations for Areas with 550 mm to 700 mm Annual Rainfall (from Table 4-2 and Table 4-6 SLO DDM)***

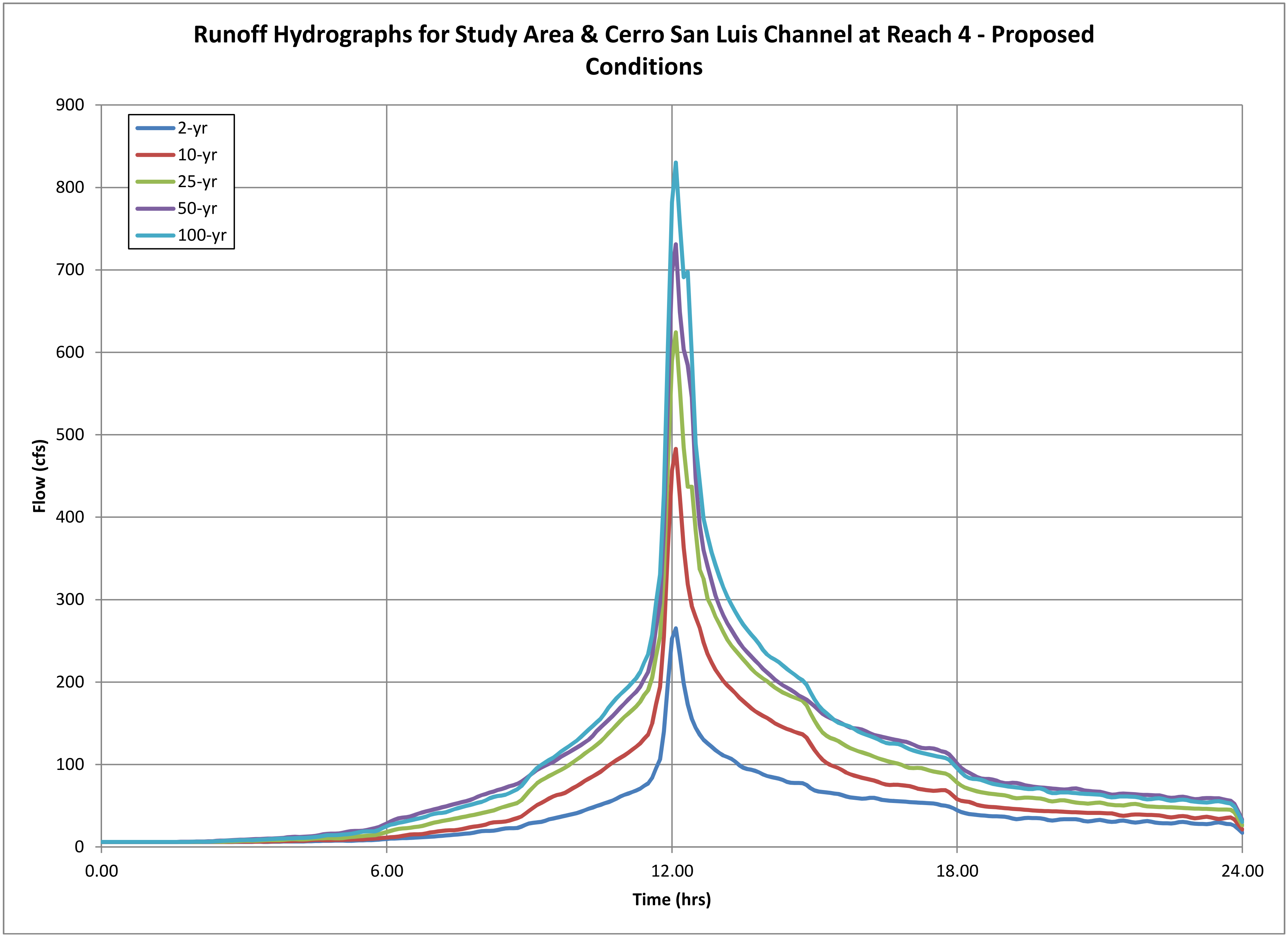
| Recurrence Interval (years) | Antecedent Moisture Factor, $C_a$ | Rainfall Intensity (in/hr) for Duration Given | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 min | 15 min | 30 min | 60 min | 120 min | 180 min |
| 2 | 1.00 | 2.09 | 1.81 | 1.18 | 0.75 | 0.55 | 0.47 |
| 10 | 1.00 | 3.58 | 2.99 | 2.09 | 1.30 | 0.91 | 0.83 |
| 25 | 1.10 | 4.02 | 3.50 | 2.40 | 1.50 | 1.10 | 0.98 |
| 50 | 1.20 | 4.61 | 3.90 | 2.60 | 1.69 | 1.30 | 1.14 |
| 100 | 1.25 | 5.00 | 4.29 | 2.91 | 1.85 | 1.38 | 1.22 |

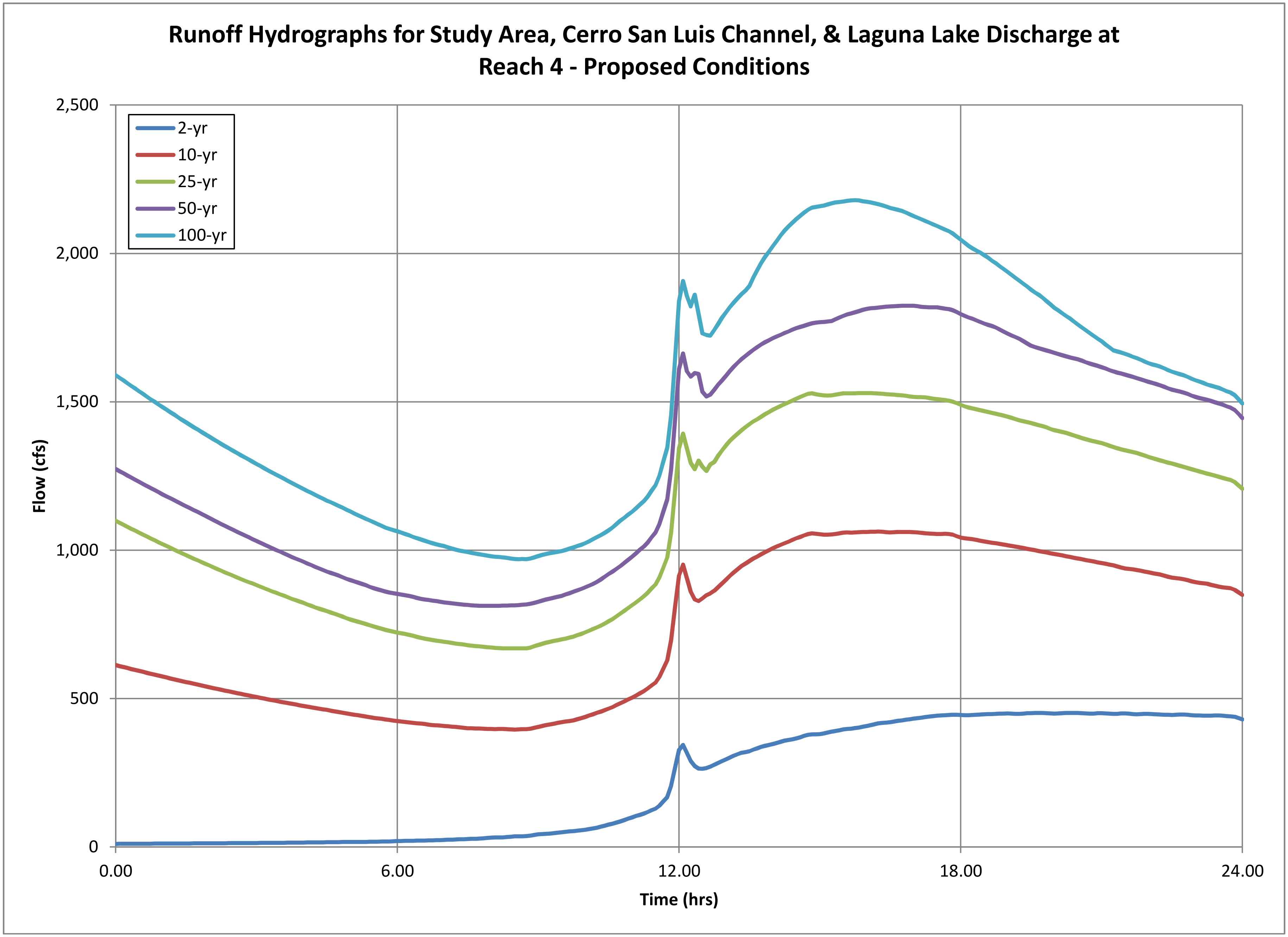
***Peak Flow Calculations***

| Sub-basin | Total Area, *A* (ac) | Composite Runoff Coefficient, *C* | Time of Conc. $T_c$ (min) | Rainfall Intensity, *i* (in/hr) | | | | | Peak Flow (cfs) ($Q=C*i*C_a*A$) | | | | | Point of Discharge |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 2-yr | 10-yr | 25-yr | 50-yr | 100-yr | 2-yr | 10-yr | 25-yr | 50-yr | 100-yr | |
| PROP-1 | 3.62 | 0.48 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 3.59 | 6.16 | 7.60 | 9.51 | 10.75 | Prefumo Reach 1 |
| PROP-2A | 2.87 | 0.69 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 4.11 | 7.05 | 8.70 | 10.88 | 12.30 | Cerro San Luis Channel |
| PROP-2B | 8.02 | 0.47 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 7.80 | 13.39 | 16.51 | 20.65 | 23.35 | Cerro San Luis Channel |
| PROP-2C | 3.71 | 0.61 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 4.76 | 8.17 | 10.07 | 12.60 | 14.25 | Cerro San Luis Channel |
| PROP-2D | 5.95 | 0.61 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 7.57 | 12.99 | 16.02 | 20.05 | 22.66 | Cerro San Luis Channel |
| PROP-3A | 12.89 | 0.53 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 14.38 | 24.69 | 30.45 | 38.10 | 43.08 | Prefumo Reach 2 |
| PROP-3B | 1.23 | 0.47 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 1.20 | 2.05 | 2.53 | 3.17 | 3.58 | Prefumo Reach 2 |
| PROP-3C | 3.06 | 0.56 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 3.55 | 6.09 | 7.51 | 9.40 | 10.63 | Prefumo Reach 2 |
| PROP-3D | 2.02 | 0.43 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 1.81 | 3.10 | 3.83 | 4.79 | 5.41 | Prefumo Reach 2 |
| PROP-3E | 2.36 | 0.31 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 1.51 | 2.60 | 3.21 | 4.01 | 4.53 | Prefumo Reach 2 |
| PROP-4A | 1.26 | 0.66 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 1.73 | 2.97 | 3.66 | 4.58 | 5.18 | Prefumo Reach 3 |
| PROP-4B | 0.70 | 0.72 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 1.05 | 1.80 | 2.22 | 2.78 | 3.14 | Prefumo Reach 3 |
| PROP-4C | 1.63 | 0.73 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 2.47 | 4.25 | 5.24 | 6.55 | 7.41 | Prefumo Reach 3 |
| PROP-4D | 14.71 | 0.54 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 16.47 | 28.29 | 34.88 | 43.64 | 49.35 | Prefumo Reach 3 |
| PROP-4E | 5.20 | 0.54 | 10.0 | 2.09 | 3.58 | 4.02 | 4.61 | 5.00 | 5.88 | 10.09 | 12.44 | 15.57 | 17.60 | Prefumo Reach 3 |
| PROP-4F | 9.06 | 0.15 | 58.8 | 0.77 | 1.33 | 1.53 | 1.73 | 1.89 | 1.04 | 1.81 | 2.29 | 2.82 | 3.22 | Prefumo Reach 3 |
| PROP-4G | 60.54 | 0.15 | 81.6 | 0.68 | 1.16 | 1.35 | 1.55 | 1.68 | 6.15 | 10.51 | 13.53 | 16.90 | 19.07 | Prefumo Reach 3 |
| **Total:** | **138.84** | | | | | | | | **78.91** | **135.51** | **167.14** | **209.10** | **236.46** | |

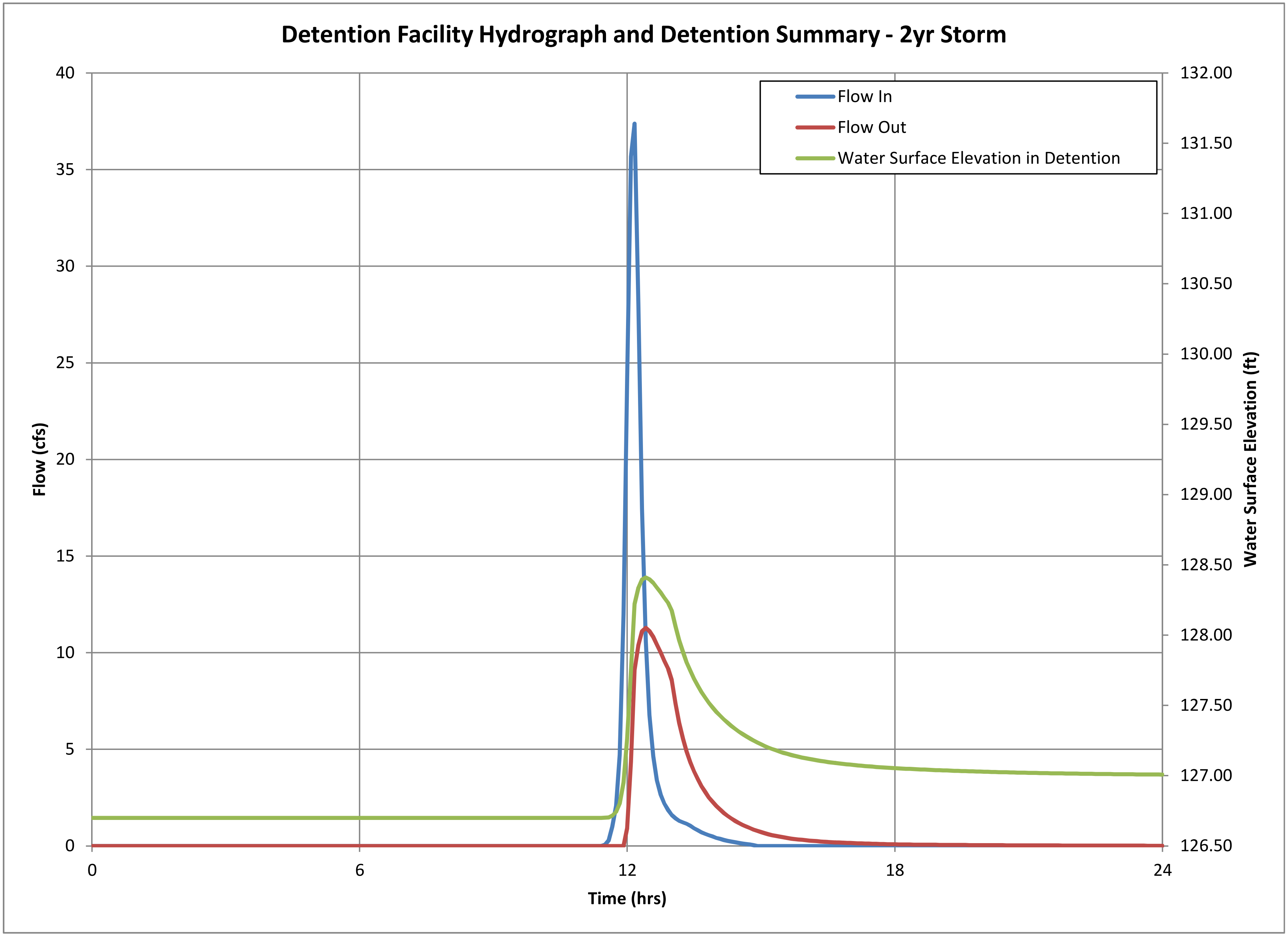


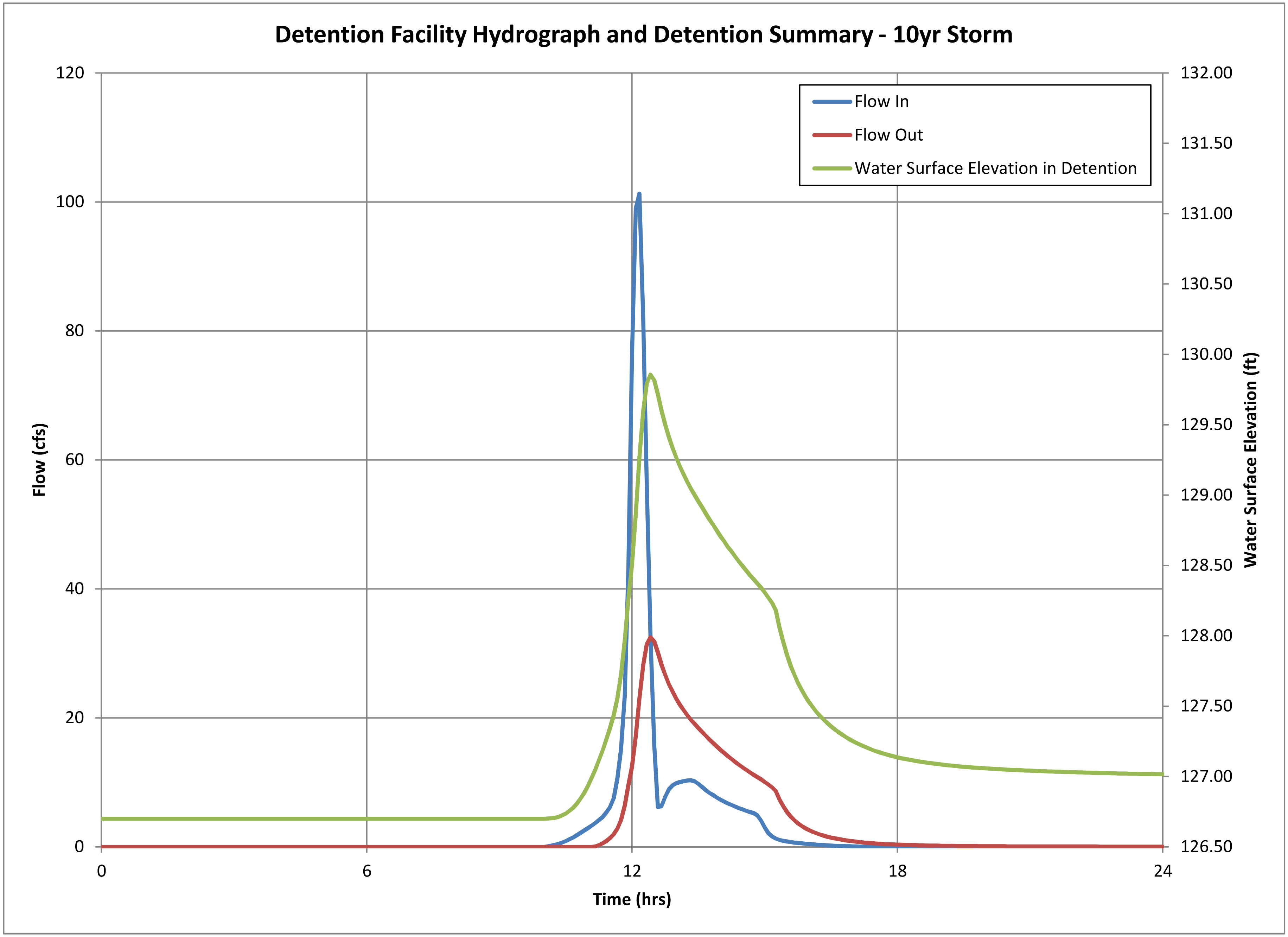
Runoff Hydrographs for Study Area (All Sub-basins) - Proposed Conditions
300
250
200
150
100
50
0
Flow (cfs)
0.00
6.00
12.00
18.00
24.00
Time (hrs)
2-yr
10-yr
25-yr
50-yr
100-yr

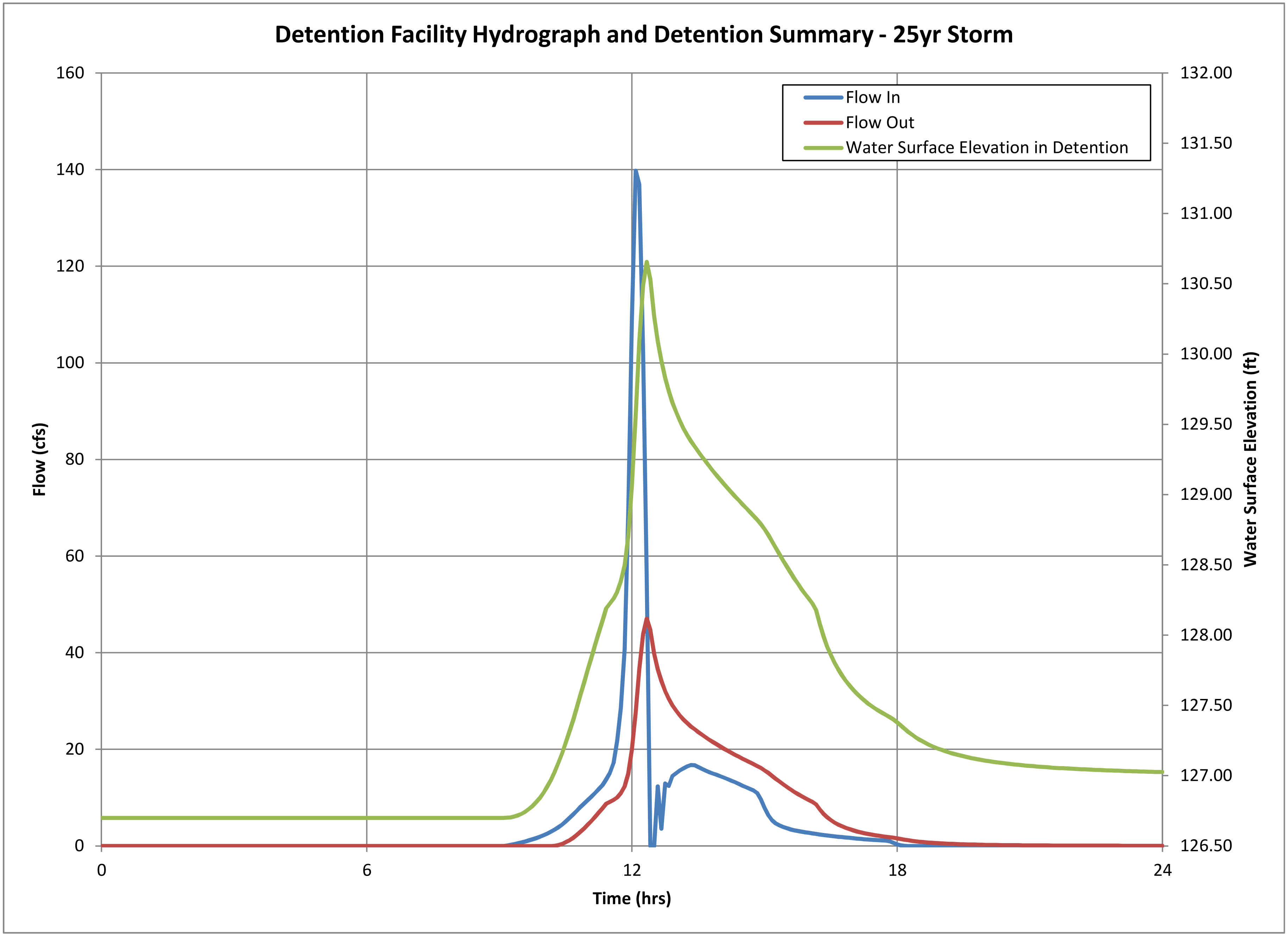

Runoff Hydrographs for Study Area & Cerro San Luis Channel at Reach 4 - Proposed Conditions
2-yr
10-yr
25-yr
50-yr
100-yr
Flow (cfs)
900
800
700
600
500
400
300
200
100
0
0.00
6.00
12.00
18.00
24.00
Time (hrs)



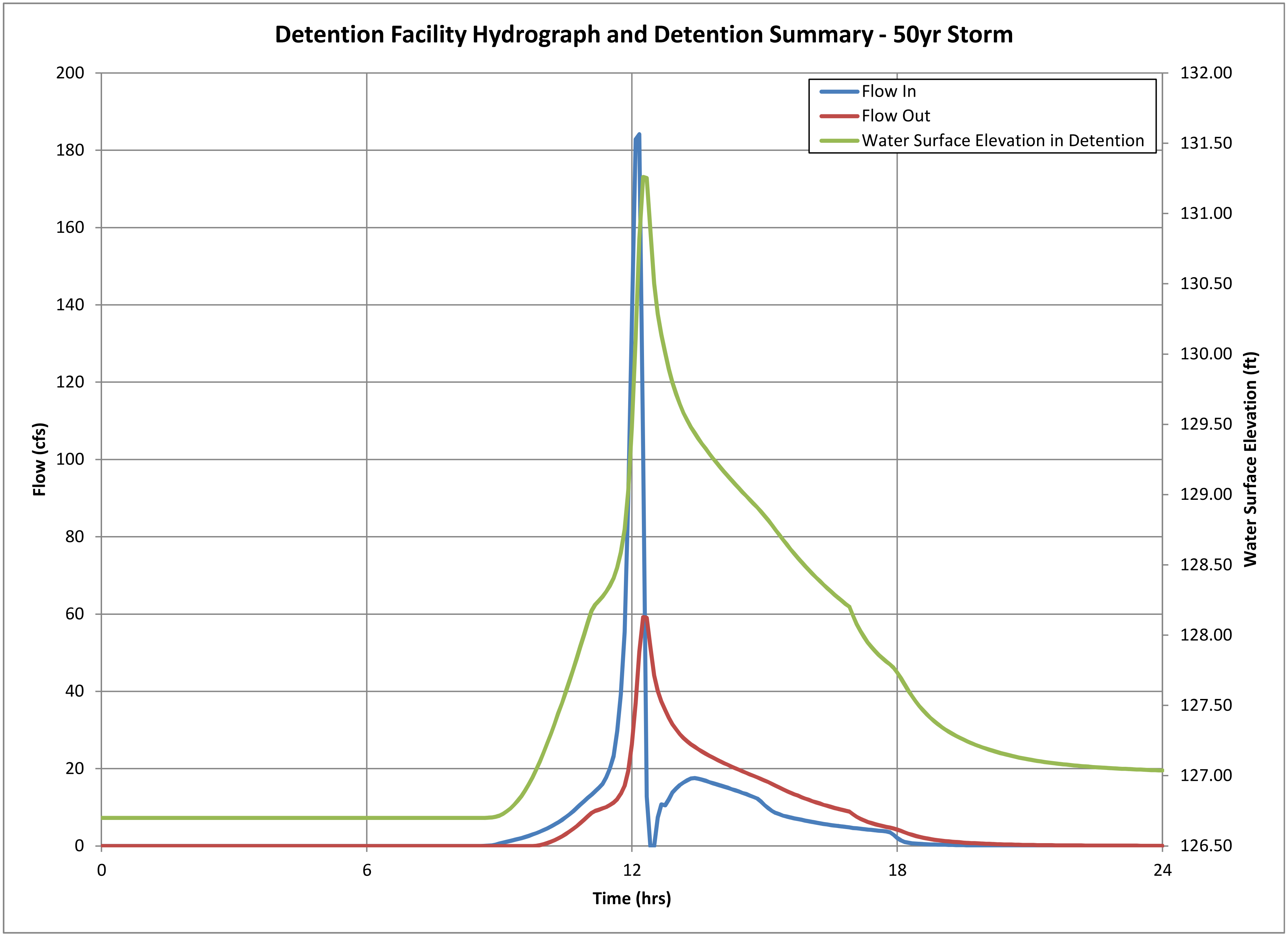
Runoff Hydrographs for Study Area, Cerro San Luis Channel, & Laguna Lake Discharge at Reach 4 - Proposed Conditions
2-yr
10-yr
25-yr
50-yr
100-yr
Flow (cfs)
2,500
2,000
1,500
1,000
500
0
0.00
6.00
12.00
18.00
24.00
Time (hrs)

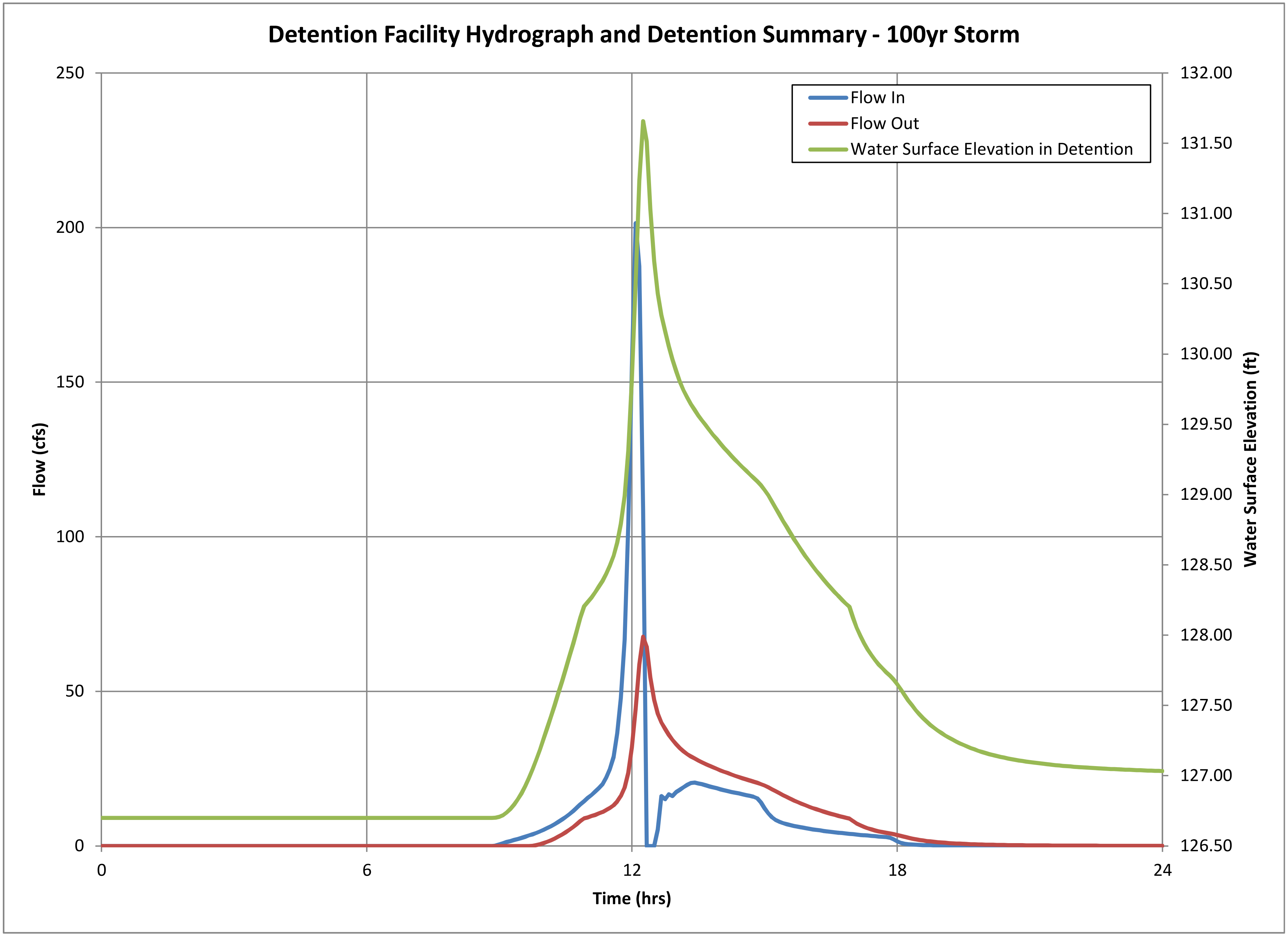

Detention Facility Hydrograph and Detention Summary - 2yr Storm
Flow In
Flow Out
Water Surface Elevation in Detention
Flow (cfs)
40
35
30
25
20
15
10
5
0
Water Surface Elevation (ft)
132.00
131.50
131.00
130.50
130.00
129.50
129.00
128.50
128.00
127.50
127.00
126.50
0
6
12
18
24
Time (hrs)


Detention Facility Hydrograph and Detention Summary - 10yr Storm
Flow In
Flow Out
Water Surface Elevation in Detention
Flow (cfs)
Water Surface Elevation (ft)
Time (hrs)
0
20
40
60
80
100
120
126.50
127.00
127.50
128.00
128.50
129.00
129.50
130.00
130.50
131.00
131.50
132.00
0
6
12
18
24



Detention Facility Hydrograph and Detention Summary - 25yr Storm
Flow In
Flow Out
Water Surface Elevation in Detention
Flow (cfs)
Water Surface Elevation (ft)
Time (hrs)
0
20
40
60
80
100
120
140
160
126.50
127.00
127.50
128.00
128.50
129.00
129.50
130.00
130.50
131.00
131.50
132.00
0
6
12
18
24


Detention Facility Hydrograph and Detention Summary - 50yr Storm
Flow In
Flow Out
Water Surface Elevation in Detention
Flow (cfs)
200
180
160
140
120
100
80
60
40
20
0
Water Surface Elevation (ft)
132.00
131.50
131.00
130.50
130.00
129.50
129.00
128.50
128.00
127.50
127.00
126.50
0
6
12
18
24
Time (hrs)



Detention Facility Hydrograph and Detention Summary - 100yr Storm
Flow In
Flow Out
Water Surface Elevation in Detention
Flow (cfs)
Water Surface Elevation (ft)
Time (hrs)
250
200
150
100
50
0
132.00
131.50
131.00
130.50
130.00
129.50
129.00
128.50
128.00
127.50
127.00
126.50
0
6
12
18
24

# Appendix D

*Miscellaneous Calculations*

1. Detention Intake Channel Calculation
2. Riprap Sizing at Storm Drain Outfalls

| PROJECT: San Luis Ranch | COMPUTED BY: STS | DATE: 6/21/2016 |
|---|---|---|
| SUBJECT: Detention Intake Channel Hydraulic Calcs | CHECKED BY: | SHT. 1 OF 4<br>PART: |

**CALCULATION COVER SHEET**

This spreadsheet contains calculations for water surface elevation, depth, and velocity in the intake channel from the diversion structure in Cerro San Luis Channel to the detention system.

These calculations are based on the assumption that the flow in the channel is gradually varied. The analysis starts at the downstream end of the channel with the water surface elevation equal to the water surface elevation in the detention system. Each subsequent section uses the depth calculated at the previous section as the starting depth for the current section. The calculation iterates at intervals in x direction along the length of the pipe to calculate the water surface profile. The Runge-Kutta 4th Order Method is used to approximate the solution of the governing differential equation for steady, gradually varied flow.

It appears that a maximum flow of about 202 cfs can be conveyed by the flat channel without significantly raising (0.003') the water surface elevation at the upstream end of the channel at the diversion intake.

A Mannings friction coefficient of 0.014 was assumed .

These calculations do not account for minor losses due to transitions, bends, fittings, etc.

Review Comments:

Revision History:

| Revision | Date: | Purpose | Checked By | Date |
|---|---|---|---|---|
| Original | | | | |
| rev 1 | | | | |
| rev 2 | | | | |
| rev 3 | | | | |

## Governing Equations

Steady, Gradually Varied Flow Equation

$$\frac{dy}{dx} = \frac{S_o - S_f}{1 - F_r^2}$$

*where:*

*y* = flow depth at location x

*x* = channel station or stream length location

$S_o$ = channel slope

$S_f$ = friction slope

$F_r$ = Froude Number

Ref: Mays, L.M. 2001. Water Resources Engineering. John Wiley & Sons, Inc. New York

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Friction Slope

The friction slope is calculated using the Manning's Equation

$$S_f = \left(\frac{Vn}{1.49R^{2/3}}\right)^2$$

*where:*

*V* = velocity

*n* = Manning roughness

*R* = Hydraulic Radius (A/P)

*A* = Wetted Area

*P* = Wetted Perimeter

Ref: Mays, L.M. 2001. Water Resources Engineering. John Wiley & Sons, Inc. New York

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Froude Number

The Froude Number is calcualted as follows:

$$F_r = \frac{V}{\sqrt{gy}}$$

Ref: Mays, L.M. 2001. Water Resources Engineering. John Wiley & Sons, Inc. New York

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Runge-Kutta 4th Order Method for Ordinary Differential Equations

The Runge-Kutta (RK) 4th Order Method is a numerical technique used to approximate the solutions of ordinary differential equations. This method obtains an approximate solution by iteration, while maintaining reasonable bounds on errors. In this calculation, the RK method is applied to the steady, gradually varied flow equation to solve for the water depth along the length of the pipe. The water depth at the upstream end of the pipe is specifed, and this boundary condition is used to calculate successive water depths along the length of the pipe at discrete intervals.

The RK equation used is as follows:

$$y_{i+1} = y_i + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)h$$

*where:*

$y_{i+1}$ = depth of water at next calculation step

$y_i$ = depth of water at current calculation step

*h* = $x_{i+1}$ - $x_i$, incremental change in x from current calculaiton step to next (Δx)

$x_{i+1}$ = location along flume at next calculation step

$x_i$ = location along flume at current calculation step

$k_1$ = $f(x_i, y_i)$

$k_2$ = $f(x_i + h/2, y_i + k_1 h/2)$

$k_3$ = $f(x_i + h/2, y_i + k_2 h/2)$

$k_4$ = $f(x_i + h, y_i + k_3 h)$

$$f(x_i, y_i) = \frac{S_{oi} - S_{fi}}{1 - F_{ri}^2}$$

So, the depth of water for the next calcuation step is calculated by the depth of water at the current calculation step, plus the Δx along the flume multiplied by the weighted average (calculated at 4 locations) of dy/dx.

**Gradually Varied Flow Calculations**

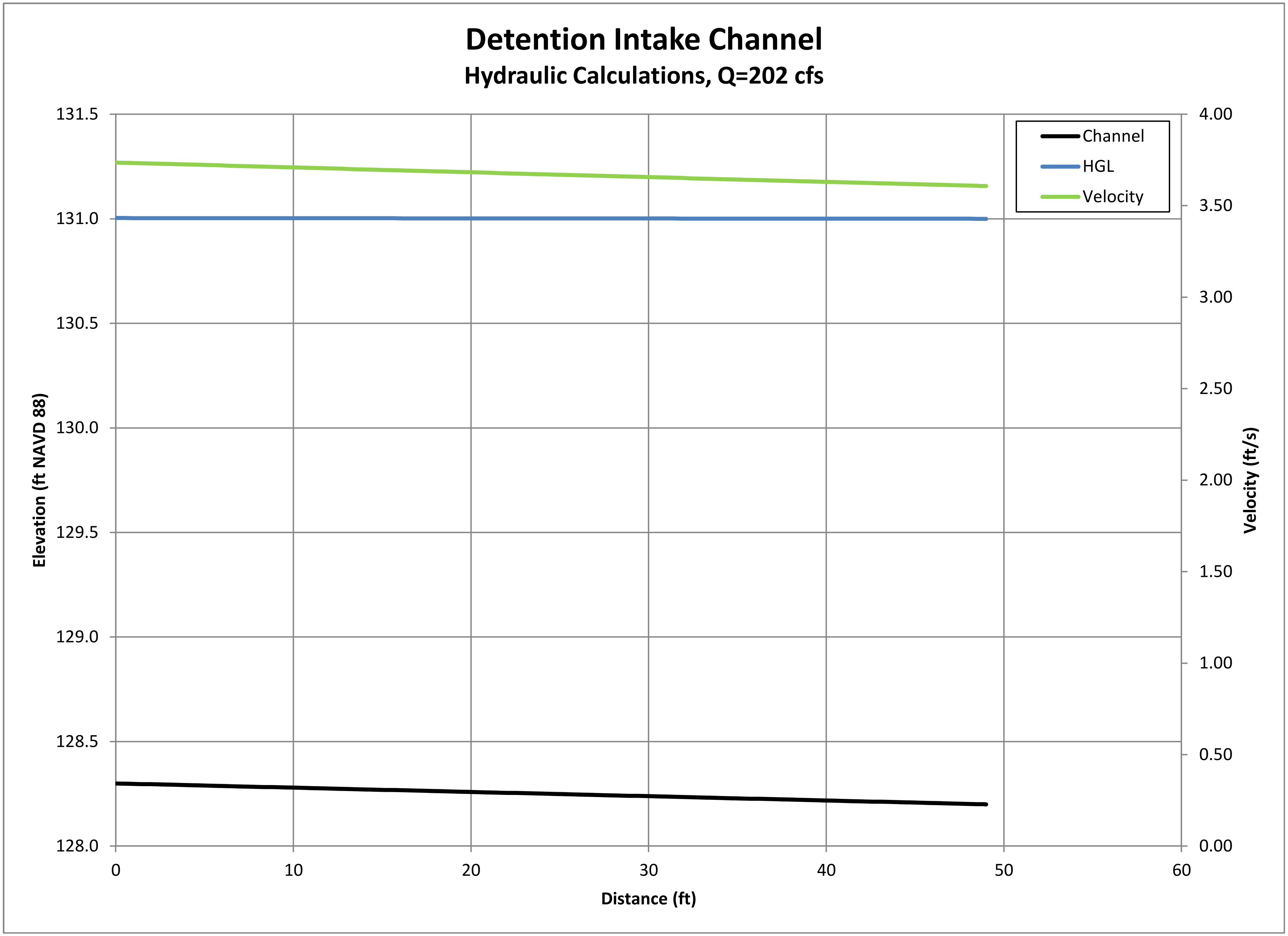
**Input**

| | | |
|---|---|---|
| Flow (cfs) | 202.00 | (100-yr peak inflow) |
| Downstream WSE (ft): | 131.00 | (Water surface elevation in detention system at 100-yr peak inflow) |

| Segment | Description | Width (ft) | Invert Elevation (ft) (NAVD 88) Upstream | Downstream | Length (ft) | Slope | Mannings n | *dx* (ft) |
|---|---|---|---|---|---|---|---|---|
| A | Intake Channel | 20.00 | 128.30 | 128.20 | 49 | 0.20% | 0.013 | 0.49 |

**Segment A**

| | | | | | | | *k₁ Calculations* | | | | | | | *k₂ Calculations* | | | | | | | | | *k₃ Calculations* | | | | | | | | | *k₄ Calculations* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Step Counter, *i* | Station, *x* (ft) | Flow, Q (cfs) | Invert Elevation (ft) | HGL (ft) | EGL (ft) | Depth, *y* (ft) | Area (ft²) | Velocity (ft/s) | Froude No. | *P* (ft) | *R* (ft) | $S_f$ | $dy/dx = k_1$ | $x_i+h/2$ | $y_i+k_1*hx/2$ | Area (ft²) | Velocity (ft/s) | Froude No. | *P* (ft) | *R* (ft) | $S_f$ | $dy/dx = k_2$ | $x_i+h/2$ | $y_i+k_2*h/2$ | Area (ft²) | Velocity (ft/s) | Froude No. | *P* (ft) | *R* (ft) | $S_f$ | $dy/dx = k_3$ | $x_i+h$ | $y_i+k_3*h$ | Area (ft²) | Velocity (ft/s) | Froude No. | *P* (ft) | *R* (ft) | $S_f$ | $dy/dx = k_4$ | $y_{i+1}$ |
| 1 | 0.000 | 202.00 | 128.300 | 131.003 | 131.220 | 2.703 | 54.066 | 3.74 | 0.40 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 0.490 | 202.00 | 128.299 | 131.003 | 131.220 | 2.704 | 54.086 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 0.245 | 2.704 | 54.076 | 3.74 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 0.245 | 2.704 | 54.076 | 3.74 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 0.000 | 2.703 | 54.066 | 3.74 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 2.703 |
| 3 | 0.980 | 202.00 | 128.298 | 131.003 | 131.220 | 2.705 | 54.105 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 0.735 | 2.705 | 54.095 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 0.735 | 2.705 | 54.095 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 0.490 | 2.704 | 54.086 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 2.704 |
| 4 | 1.470 | 202.00 | 128.297 | 131.003 | 131.220 | 2.706 | 54.124 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 1.225 | 2.706 | 54.115 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 1.225 | 2.706 | 54.115 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 0.980 | 2.705 | 54.105 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 2.705 |
| 5 | 1.960 | 202.00 | 128.296 | 131.003 | 131.219 | 2.707 | 54.144 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 1.715 | 2.707 | 54.134 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 1.715 | 2.707 | 54.134 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 1.470 | 2.706 | 54.124 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 2.706 |
| 6 | 2.450 | 202.00 | 128.295 | 131.003 | 131.219 | 2.708 | 54.163 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.205 | 2.708 | 54.153 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.205 | 2.708 | 54.153 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 1.960 | 2.707 | 54.144 | 3.73 | 0.40 | 25.41 | 2.13 | 0.0004 | 0.002 | 2.707 |
| 7 | 2.940 | 202.00 | 128.294 | 131.003 | 131.219 | 2.709 | 54.182 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.695 | 2.709 | 54.173 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.695 | 2.709 | 54.173 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.450 | 2.708 | 54.163 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.708 |
| 8 | 3.430 | 202.00 | 128.293 | 131.003 | 131.219 | 2.710 | 54.202 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 3.185 | 2.710 | 54.192 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 3.185 | 2.710 | 54.192 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.940 | 2.709 | 54.182 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.709 |
| 9 | 3.920 | 202.00 | 128.292 | 131.003 | 131.219 | 2.711 | 54.221 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 3.675 | 2.711 | 54.211 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 3.675 | 2.711 | 54.211 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 3.430 | 2.710 | 54.202 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.710 |
| 10 | 4.410 | 202.00 | 128.291 | 131.003 | 131.218 | 2.712 | 54.240 | 3.72 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 4.165 | 2.712 | 54.230 | 3.72 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 4.165 | 2.712 | 54.230 | 3.72 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 3.920 | 2.711 | 54.221 | 3.73 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.711 |
| 11 | 4.900 | 202.00 | 128.290 | 131.003 | 131.218 | 2.713 | 54.259 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 4.655 | 2.712 | 54.250 | 3.72 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 4.655 | 2.712 | 54.250 | 3.72 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 4.410 | 2.712 | 54.240 | 3.72 | 0.40 | 25.42 | 2.13 | 0.0004 | 0.002 | 2.712 |
| 12 | 5.390 | 202.00 | 128.289 | 131.003 | 131.218 | 2.714 | 54.279 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 5.145 | 2.713 | 54.269 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 5.145 | 2.713 | 54.269 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 4.900 | 2.713 | 54.259 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 2.713 |
| 13 | 5.880 | 202.00 | 128.288 | 131.003 | 131.218 | 2.715 | 54.298 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 5.635 | 2.714 | 54.288 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 5.635 | 2.714 | 54.288 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 5.390 | 2.714 | 54.279 | 3.72 | 0.40 | 25.43 | 2.13 | 0.0004 | 0.002 | 2.714 |
| 14 | 6.370 | 202.00 | 128.287 | 131.003 | 131.218 | 2.716 | 54.317 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 6.125 | 2.715 | 54.308 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 6.125 | 2.715 | 54.308 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 5.880 | 2.715 | 54.298 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 2.715 |
| 15 | 6.860 | 202.00 | 128.286 | 131.003 | 131.217 | 2.717 | 54.337 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 6.615 | 2.716 | 54.327 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 6.615 | 2.716 | 54.327 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 6.370 | 2.716 | 54.317 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 2.716 |
| 16 | 7.350 | 202.00 | 128.285 | 131.003 | 131.217 | 2.718 | 54.356 | 3.72 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 7.105 | 2.717 | 54.346 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 7.105 | 2.717 | 54.346 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 6.860 | 2.717 | 54.337 | 3.72 | 0.40 | 25.43 | 2.14 | 0.0004 | 0.002 | 2.717 |
| 17 | 7.840 | 202.00 | 128.284 | 131.003 | 131.217 | 2.719 | 54.375 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 7.595 | 2.718 | 54.366 | 3.72 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 7.595 | 2.718 | 54.366 | 3.72 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 7.350 | 2.718 | 54.356 | 3.72 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 2.718 |
| 18 | 8.330 | 202.00 | 128.283 | 131.003 | 131.217 | 2.720 | 54.395 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 8.085 | 2.719 | 54.385 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 8.085 | 2.719 | 54.385 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 7.840 | 2.719 | 54.375 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 2.719 |
| 19 | 8.820 | 202.00 | 128.282 | 131.003 | 131.217 | 2.721 | 54.414 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 8.575 | 2.720 | 54.404 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 8.575 | 2.720 | 54.404 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 8.330 | 2.720 | 54.395 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 2.720 |
| 20 | 9.310 | 202.00 | 128.281 | 131.003 | 131.216 | 2.722 | 54.433 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 9.065 | 2.721 | 54.424 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 9.065 | 2.721 | 54.424 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 8.820 | 2.721 | 54.414 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 2.721 |
| 21 | 9.800 | 202.00 | 128.280 | 131.003 | 131.216 | 2.723 | 54.452 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 9.555 | 2.722 | 54.443 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 9.555 | 2.722 | 54.443 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 9.310 | 2.722 | 54.433 | 3.71 | 0.40 | 25.44 | 2.14 | 0.0004 | 0.002 | 2.722 |
| 22 | 10.290 | 202.00 | 128.279 | 131.003 | 131.216 | 2.724 | 54.472 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 10.045 | 2.723 | 54.462 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 10.045 | 2.723 | 54.462 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 9.800 | 2.723 | 54.452 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 2.723 |
| 23 | 10.780 | 202.00 | 128.278 | 131.003 | 131.216 | 2.725 | 54.491 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 10.535 | 2.724 | 54.481 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 10.535 | 2.724 | 54.481 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 10.290 | 2.724 | 54.472 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 2.724 |
| 24 | 11.270 | 202.00 | 128.277 | 131.003 | 131.216 | 2.726 | 54.510 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 11.025 | 2.725 | 54.501 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 11.025 | 2.725 | 54.501 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 10.780 | 2.725 | 54.491 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 2.725 |
| 25 | 11.760 | 202.00 | 128.276 | 131.002 | 131.216 | 2.726 | 54.530 | 3.70 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 11.515 | 2.726 | 54.520 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 11.515 | 2.726 | 54.520 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 11.270 | 2.726 | 54.510 | 3.71 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 2.726 |
| 26 | 12.250 | 202.00 | 128.275 | 131.002 | 131.215 | 2.727 | 54.549 | 3.70 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 12.005 | 2.727 | 54.539 | 3.70 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 12.005 | 2.727 | 54.539 | 3.70 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 11.760 | 2.726 | 54.530 | 3.70 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 2.726 |
| 27 | 12.740 | 202.00 | 128.274 | 131.002 | 131.215 | 2.728 | 54.568 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 12.495 | 2.728 | 54.559 | 3.70 | 0.40 | 25.46 | 2.14 | 0.0004 | 0.002 | 12.495 | 2.728 | 54.559 | 3.70 | 0.40 | 25.46 | 2.14 | 0.0004 | 0.002 | 12.250 | 2.727 | 54.549 | 3.70 | 0.40 | 25.45 | 2.14 | 0.0004 | 0.002 | 2.727 |
| 28 | 13.230 | 202.00 | 128.273 | 131.002 | 131.215 | 2.729 | 54.588 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 12.985 | 2.729 | 54.578 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 12.985 | 2.729 | 54.578 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 12.740 | 2.728 | 54.568 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 2.728 |
| 29 | 13.720 | 202.00 | 128.272 | 131.002 | 131.215 | 2.730 | 54.607 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 13.475 | 2.730 | 54.597 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 13.475 | 2.730 | 54.597 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 13.230 | 2.729 | 54.588 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 2.729 |
| 30 | 14.210 | 202.00 | 128.271 | 131.002 | 131.215 | 2.731 | 54.626 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 13.965 | 2.731 | 54.617 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 13.965 | 2.731 | 54.617 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 13.720 | 2.730 | 54.607 | 3.70 | 0.39 | 25.46 | 2.14 | 0.0004 | 0.002 | 2.730 |
| 31 | 14.700 | 202.00 | 128.270 | 131.002 | 131.214 | 2.732 | 54.646 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 14.455 | 2.732 | 54.636 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 14.455 | 2.732 | 54.636 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 14.210 | 2.731 | 54.626 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 2.731 |
| 32 | 15.190 | 202.00 | 128.269 | 131.002 | 131.214 | 2.733 | 54.665 | 3.70 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 14.945 | 2.733 | 54.655 | 3.70 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 14.945 | 2.733 | 54.655 | 3.70 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 14.700 | 2.732 | 54.646 | 3.70 | 0.39 | 25.46 | 2.15 | 0.0004 | 0.002 | 2.732 |
| 33 | 15.680 | 202.00 | 128.268 | 131.002 | 131.214 | 2.734 | 54.684 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 15.435 | 2.734 | 54.675 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 15.435 | 2.734 | 54.675 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 15.190 | 2.733 | 54.665 | 3.70 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 2.733 |
| 34 | 16.170 | 202.00 | 128.267 | 131.002 | 131.214 | 2.735 | 54.704 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 15.925 | 2.735 | 54.694 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 15.925 | 2.735 | 54.694 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 15.680 | 2.734 | 54.684 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 2.734 |
| 35 | 16.660 | 202.00 | 128.266 | 131.002 | 131.214 | 2.736 | 54.723 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 16.415 | 2.736 | 54.713 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 16.415 | 2.736 | 54.713 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 16.170 | 2.735 | 54.704 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 2.735 |
| 36 | 17.150 | 202.00 | 128.265 | 131.002 | 131.214 | 2.737 | 54.742 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 16.905 | 2.737 | 54.733 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 16.905 | 2.737 | 54.733 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 16.660 | 2.736 | 54.723 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 2.736 |
| 37 | 17.640 | 202.00 | 128.264 | 131.002 | 131.213 | 2.738 | 54.762 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 17.395 | 2.738 | 54.752 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 17.395 | 2.738 | 54.752 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 17.150 | 2.737 | 54.742 | 3.69 | 0.39 | 25.47 | 2.15 | 0.0004 | 0.002 | 2.737 |
| 38 | 18.130 | 202.00 | 128.263 | 131.002 | 131.213 | 2.739 | 54.781 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 17.885 | 2.739 | 54.771 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 17.885 | 2.739 | 54.771 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 17.640 | 2.738 | 54.762 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 2.738 |
| 39 | 18.620 | 202.00 | 128.262 | 131.002 | 131.213 | 2.740 | 54.800 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 18.375 | 2.740 | 54.791 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 18.375 | 2.740 | 54.791 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 18.130 | 2.739 | 54.781 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 2.739 |
| 40 | 19.110 | 202.00 | 128.261 | 131.002 | 131.213 | 2.741 | 54.819 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 18.865 | 2.740 | 54.810 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 18.865 | 2.740 | 54.810 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 18.620 | 2.740 | 54.800 | 3.69 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 2.740 |
| 41 | 19.600 | 202.00 | 128.260 | 131.002 | 131.213 | 2.742 | 54.839 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 19.355 | 2.741 | 54.829 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 19.355 | 2.741 | 54.829 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 19.110 | 2.741 | 54.819 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 2.741 |
| 42 | 20.090 | 202.00 | 128.259 | 131.002 | 131.212 | 2.743 | 54.858 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 19.845 | 2.742 | 54.848 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 19.845 | 2.742 | 54.848 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 19.600 | 2.742 | 54.839 | 3.68 | 0.39 | 25.48 | 2.15 | 0.0004 | 0.002 | 2.742 |
| 43 | 20.580 | 202.00 | 128.258 | 131.002 | 131.212 | 2.744 | 54.877 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 20.335 | 2.743 | 54.868 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 20.335 | 2.743 | 54.868 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 20.090 | 2.743 | 54.858 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 2.743 |
| 44 | 21.070 | 202.00 | 128.257 | 131.002 | 131.212 | 2.745 | 54.897 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 20.825 | 2.744 | 54.887 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 20.825 | 2.744 | 54.887 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 20.580 | 2.744 | 54.877 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 2.744 |
| 45 | 21.560 | 202.00 | 128.256 | 131.002 | 131.212 | 2.746 | 54.916 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 21.315 | 2.745 | 54.906 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 21.315 | 2.745 | 54.906 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 21.070 | 2.745 | 54.897 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 2.745 |
| 46 | 22.050 | 202.00 | 128.255 | 131.002 | 131.212 | 2.747 | 54.935 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 21.805 | 2.746 | 54.926 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 21.805 | 2.746 | 54.926 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 21.560 | 2.746 | 54.916 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 2.746 |
| 47 | 22.540 | 202.00 | 128.254 | 131.002 | 131.212 | 2.748 | 54.955 | 3.68 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 22.295 | 2.747 | 54.945 | 3.68 | 0.39 | 25.49 | 2.16 | 0.0004 | 0.002 | 22.295 | 2.747 | 54.945 | 3.68 | 0.39 | 25.49 | 2.16 | 0.0004 | 0.002 | 22.050 | 2.747 | 54.935 | 3.68 | 0.39 | 25.49 | 2.15 | 0.0004 | 0.002 | 2.747 |
| 48 | 23.030 | 202.00 | 128.253 | 131.002 | 131.211 | 2.749 | 54.974 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 22.785 | 2.748 | 54.964 | 3.68 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 22.785 | 2.748 | 54.964 | 3.68 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 22.540 | 2.748 | 54.955 | 3.68 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 2.748 |
| 49 | 23.520 | 202.00 | 128.252 | 131.002 | 131.211 | 2.750 | 54.993 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 23.275 | 2.749 | 54.984 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 23.275 | 2.749 | 54.984 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 23.030 | 2.749 | 54.974 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 2.749 |
| 50 | 24.010 | 202.00 | 128.251 | 131.002 | 131.211 | 2.751 | 55.013 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 23.765 | 2.750 | 55.003 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 23.765 | 2.750 | 55.003 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 23.520 | 2.750 | 54.993 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 2.750 |
| 51 | 24.500 | 202.00 | 128.250 | 131.002 | 131.211 | 2.752 | 55.032 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 24.255 | 2.751 | 55.022 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 24.255 | 2.751 | 55.022 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 24.010 | 2.751 | 55.013 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 2.751 |
| 52 | 24.990 | 202.00 | 128.249 | 131.002 | 131.211 | 2.753 | 55.051 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 24.745 | 2.752 | 55.042 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 24.745 | 2.752 | 55.042 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 24.500 | 2.752 | 55.032 | 3.67 | 0.39 | 25.50 | 2.16 | 0.0004 | 0.002 | 2.752 |
| 53 | 25.480 | 202.00 | 128.248 | 131.002 | 131.210 | 2.754 | 55.071 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 25.235 | 2.753 | 55.061 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 25.235 | 2.753 | 55.061 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 24.990 | 2.753 | 55.051 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 2.753 |
| 54 | 25.970 | 202.00 | 128.247 | 131.001 | 131.210 | 2.755 | 55.090 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 25.725 | 2.754 | 55.080 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 25.725 | 2.754 | 55.080 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 25.480 | 2.754 | 55.071 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 2.754 |
| 55 | 26.460 | 202.00 | 128.246 | 131.001 | 131.210 | 2.756 | 55.109 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 26.215 | 2.755 | 55.100 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 26.215 | 2.755 | 55.100 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 25.970 | 2.755 | 55.090 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 2.755 |
| 56 | 26.950 | 202.00 | 128.245 | 131.001 | 131.210 | 2.756 | 55.129 | 3.66 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 26.705 | 2.756 | 55.119 | 3.66 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 26.705 | 2.756 | 55.119 | 3.66 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 26.460 | 2.755 | 55.109 | 3.67 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 2.755 |
| 57 | 27.440 | 202.00 | 128.244 | 131.001 | 131.210 | 2.757 | 55.148 | 3.66 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 27.195 | 2.757 | 55.138 | 3.66 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 27.195 | 2.757 | 55.138 | 3.66 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 26.950 | 2.756 | 55.129 | 3.66 | 0.39 | 25.51 | 2.16 | 0.0004 | 0.002 | 2.756 |
| 58 | 27.930 | 202.00 | 128.243 | 131.001 | 131.210 | 2.758 | 55.168 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 27.685 | 2.758 | 55.158 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 27.685 | 2.758 | 55.158 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 27.440 | 2.757 | 55.148 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 2.757 |
| 59 | 28.420 | 202.00 | 128.242 | 131.001 | 131.209 | 2.759 | 55.187 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 28.175 | 2.759 | 55.177 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 28.175 | 2.759 | 55.177 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 27.930 | 2.758 | 55.168 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 2.758 |
| 60 | 28.910 | 202.00 | 128.241 | 131.001 | 131.209 | 2.760 | 55.206 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 28.665 | 2.760 | 55.197 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 28.665 | 2.760 | 55.197 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 28.420 | 2.759 | 55.187 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 2.759 |
| 61 | 29.400 | 202.00 | 128.240 | 131.001 | 131.209 | 2.761 | 55.226 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 29.155 | 2.761 | 55.216 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 29.155 | 2.761 | 55.216 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 28.910 | 2.760 | 55.206 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 2.760 |
| 62 | 29.890 | 202.00 | 128.239 | 131.001 | 131.209 | 2.762 | 55.245 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 29.645 | 2.762 | 55.235 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 29.645 | 2.762 | 55.235 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 29.400 | 2.761 | 55.226 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 2.761 |
| 63 | 30.380 | 202.00 | 128.238 | 131.001 | 131.209 | 2.763 | 55.264 | 3.66 | 0.39 | 25.53 | 2.16 | 0.0004 | 0.002 | 30.135 | 2.763 | 55.255 | 3.66 | 0.39 | 25.53 | 2.16 | 0.0004 | 0.002 | 30.135 | 2.763 | 55.255 | 3.66 | 0.39 | 25.53 | 2.16 | 0.0004 | 0.002 | 29.890 | 2.762 | 55.245 | 3.66 | 0.39 | 25.52 | 2.16 | 0.0004 | 0.002 | 2.762 |
| 64 | 30.870 | 202.00 | 128.237 | 131.001 | 131.208 | 2.764 | 55.284 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 30.625 | 2.764 | 55.274 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 30.625 | 2.764 | 55.274 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 30.380 | 2.763 | 55.264 | 3.66 | 0.39 | 25.53 | 2.16 | 0.0004 | 0.002 | 2.763 |
| 65 | 31.360 | 202.00 | 128.236 | 131.001 | 131.208 | 2.765 | 55.303 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 31.115 | 2.765 | 55.293 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 31.115 | 2.765 | 55.293 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 30.870 | 2.764 | 55.284 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 2.764 |
| 66 | 31.850 | 202.00 | 128.235 | 131.001 | 131.208 | 2.766 | 55.322 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 31.605 | 2.766 | 55.313 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 31.605 | 2.766 | 55.313 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 31.360 | 2.765 | 55.303 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 2.765 |
| 67 | 32.340 | 202.00 | 128.234 | 131.001 | 131.208 | 2.767 | 55.342 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 32.095 | 2.767 | 55.332 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 32.095 | 2.767 | 55.332 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 31.850 | 2.766 | 55.322 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 2.766 |
| 68 | 32.830 | 202.00 | 128.233 | 131.001 | 131.208 | 2.768 | 55.361 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 32.585 | 2.768 | 55.351 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 32.585 | 2.768 | 55.351 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 32.340 | 2.767 | 55.342 | 3.65 | 0.39 | 25.53 | 2.17 | 0.0004 | 0.002 | 2.767 |
| 69 | 33.320 | 202.00 | 128.232 | 131.001 | 131.208 | 2.769 | 55.380 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 33.075 | 2.769 | 55.371 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 33.075 | 2.769 | 55.371 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 32.830 | 2.768 | 55.361 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 2.768 |
| 70 | 33.810 | 202.00 | 128.231 | 131.001 | 131.207 | 2.770 | 55.400 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 33.565 | 2.769 | 55.390 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 33.565 | 2.769 | 55.390 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 33.320 | 2.769 | 55.380 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 2.769 |
| 71 | 34.300 | 202.00 | 128.230 | 131.001 | 131.207 | 2.771 | 55.419 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 34.055 | 2.770 | 55.409 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 34.055 | 2.770 | 55.409 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 33.810 | 2.770 | 55.400 | 3.65 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 2.770 |
| 72 | 34.790 | 202.00 | 128.229 | 131.001 | 131.207 | 2.772 | 55.438 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 34.545 | 2.771 | 55.429 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 34.545 | 2.771 | 55.429 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 34.300 | 2.771 | 55.419 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 2.771 |
| 73 | 35.280 | 202.00 | 128.228 | 131.001 | 131.207 | 2.773 | 55.458 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 35.035 | 2.772 | 55.448 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 35.035 | 2.772 | 55.448 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 34.790 | 2.772 | 55.438 | 3.64 | 0.39 | 25.54 | 2.17 | 0.0004 | 0.002 | 2.772 |
| 74 | 35.770 | 202.00 | 128.227 | 131.001 | 131.207 | 2.774 | 55.477 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 35.525 | 2.773 | 55.467 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 35.525 | 2.773 | 55.467 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 35.280 | 2.773 | 55.458 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 2.773 |
| 75 | 36.260 | 202.00 | 128.226 | 131.001 | 131.207 | 2.775 | 55.496 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.015 | 2.774 | 55.487 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.015 | 2.774 | 55.487 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 35.770 | 2.774 | 55.477 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 2.774 |
| 76 | 36.750 | 202.00 | 128.225 | 131.001 | 131.206 | 2.776 | 55.516 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.505 | 2.775 | 55.506 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.505 | 2.775 | 55.506 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.260 | 2.775 | 55.496 | 3.64 | 0.39 | 25.55 | 2.17 | 0.0004 | 0.002 | 2.775 |
| 77 | 37.240 | 202.00 | 128.224 | 131.001 | 131.206 | 2.777 | 55.535 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.995 | 2.776 | 55.525 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.995 | 2.776 | 55.525 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 36.750 | 2.776 | 55.516 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 2.776 |
| 78 | 37.730 | 202.00 | 128.223 | 131.001 | 131.206 | 2.778 | 55.555 | 3.64 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 37.485 | 2.777 | 55.545 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 37.485 | 2.777 | 55.545 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 37.240 | 2.777 | 55.535 | 3.64 | 0.38 | 25.55 | 2.17 | 0.0004 | 0.002 | 2.777 |
| 79 | 38.220 | 202.00 | 128.222 | 131.001 | 131.206 | 2.779 | 55.574 | 3.63 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 37.975 | 2.778 | 55.564 | 3.64 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 37.975 | 2.778 | 55.564 | 3.64 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 37.730 | 2.778 | 55.555 | 3.64 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 2.778 |
| 80 | 38.710 | 202.00 | 128.221 | 131.001 | 131.206 | 2.780 | 55.593 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 38.465 | 2.779 | 55.584 | 3.63 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 38.465 | 2.779 | 55.584 | 3.63 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 38.220 | 2.779 | 55.574 | 3.63 | 0.38 | 25.56 | 2.17 | 0.0004 | 0.002 | 2.779 |
| 81 | 39.200 | 202.00 | 128.220 | 131.001 | 131.205 | 2.781 | 55.613 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 38.955 | 2.780 | 55.603 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 38.955 | 2.780 | 55.603 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 38.710 | 2.780 | 55.593 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 2.780 |
| 82 | 39.690 | 202.00 | 128.219 | 131.001 | 131.205 | 2.782 | 55.632 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 39.445 | 2.781 | 55.622 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 39.445 | 2.781 | 55.622 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 39.200 | 2.781 | 55.613 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 2.781 |
| 83 | 40.180 | 202.00 | 128.218 | 131.001 | 131.205 | 2.783 | 55.651 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 39.935 | 2.782 | 55.642 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 39.935 | 2.782 | 55.642 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 39.690 | 2.782 | 55.632 | 3.63 | 0.38 | 25.56 | 2.18 | 0.0004 | 0.002 | 2.782 |
| 84 | 40.670 | 202.00 | 128.217 | 131.001 | 131.205 | 2.784 | 55.671 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 40.425 | 2.783 | 55.661 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 40.425 | 2.783 | 55.661 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 40.180 | 2.783 | 55.651 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 2.783 |
| 85 | 41.160 | 202.00 | 128.216 | 131.001 | 131.205 | 2.785 | 55.690 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 40.915 | 2.784 | 55.680 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 40.915 | 2.784 | 55.680 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 40.670 | 2.784 | 55.671 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 2.784 |
| 86 | 41.650 | 202.00 | 128.215 | 131.000 | 131.205 | 2.785 | 55.709 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 41.405 | 2.785 | 55.700 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 41.405 | 2.785 | 55.700 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 41.160 | 2.785 | 55.690 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 2.785 |
| 87 | 42.140 | 202.00 | 128.214 | 131.000 | 131.204 | 2.786 | 55.729 | 3.62 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 41.895 | 2.786 | 55.719 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 41.895 | 2.786 | 55.719 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 41.650 | 2.785 | 55.709 | 3.63 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 2.785 |
| 88 | 42.630 | 202.00 | 128.213 | 131.000 | 131.204 | 2.787 | 55.748 | 3.62 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 42.385 | 2.787 | 55.738 | 3.62 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 42.385 | 2.787 | 55.738 | 3.62 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 42.140 | 2.786 | 55.729 | 3.62 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 2.786 |
| 89 | 43.120 | 202.00 | 128.212 | 131.000 | 131.204 | 2.788 | 55.768 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 42.875 | 2.788 | 55.758 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 42.875 | 2.788 | 55.758 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 42.630 | 2.787 | 55.748 | 3.62 | 0.38 | 25.57 | 2.18 | 0.0004 | 0.002 | 2.787 |
| 90 | 43.610 | 202.00 | 128.211 | 131.000 | 131.204 | 2.789 | 55.787 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 43.365 | 2.789 | 55.777 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 43.365 | 2.789 | 55.777 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 43.120 | 2.788 | 55.768 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 2.788 |
| 91 | 44.100 | 202.00 | 128.210 | 131.000 | 131.204 | 2.790 | 55.806 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 43.855 | 2.790 | 55.797 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 43.855 | 2.790 | 55.797 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 43.610 | 2.789 | 55.787 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 2.789 |
| 92 | 44.590 | 202.00 | 128.209 | 131.000 | 131.204 | 2.791 | 55.826 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 44.345 | 2.791 | 55.816 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 44.345 | 2.791 | 55.816 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 44.100 | 2.790 | 55.806 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 2.790 |
| 93 | 45.080 | 202.00 | 128.208 | 131.000 | 131.203 | 2.792 | 55.845 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 44.835 | 2.792 | 55.835 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 44.835 | 2.792 | 55.835 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 44.590 | 2.791 | 55.826 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 2.791 |
| 94 | 45.570 | 202.00 | 128.207 | 131.000 | 131.203 | 2.793 | 55.864 | 3.62 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 45.325 | 2.793 | 55.855 | 3.62 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 45.325 | 2.793 | 55.855 | 3.62 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 45.080 | 2.792 | 55.845 | 3.62 | 0.38 | 25.58 | 2.18 | 0.0004 | 0.002 | 2.792 |
| 95 | 46.060 | 202.00 | 128.206 | 131.000 | 131.203 | 2.794 | 55.884 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 45.815 | 2.794 | 55.874 | 3.62 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 45.815 | 2.794 | 55.874 | 3.62 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 45.570 | 2.793 | 55.864 | 3.62 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 2.793 |
| 96 | 46.550 | 202.00 | 128.205 | 131.000 | 131.203 | 2.795 | 55.903 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 46.305 | 2.795 | 55.893 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 46.305 | 2.795 | 55.893 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 46.060 | 2.794 | 55.884 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 2.794 |
| 97 | 47.040 | 202.00 | 128.204 | 131.000 | 131.203 | 2.796 | 55.922 | 3.61 | 0.38 | 25.59 | 2.19 | 0.0004 | 0.002 | 46.795 | 2.796 | 55.913 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 46.795 | 2.796 | 55.913 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 46.550 | 2.795 | 55.903 | 3.61 | 0.38 | 25.59 | 2.18 | 0.0004 | 0.002 | 2.795 |
| 98 | 47.530 | 202.00 | 128.203 | 131.000 | 131.203 | 2.797 | 55.942 | 3.61 | 0.38 | 25.59 | 2.19 | 0.0003 | 0.002 | 47.285 | 2.797 | 55.932 | 3.61 | 0.38 | 25.59 | 2.19 | 0.0004 | 0.002 | 47.285 | 2.797 | 55.932 | 3.61 | 0.38 | 25.59 | 2.19 | 0.0004 | 0.002 | 47.040 | 2.796 | 55.922 | 3.61 | 0.38 | 25.59 | 2.19 | 0.0004 | 0.002 | 2.796 |
| 99 | 48.020 | 202.00 | 128.202 | 131.000 | 131.202 | 2.798 | 55.961 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 47.775 | 2.798 | 55.952 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 47.775 | 2.798 | 55.952 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 47.530 | 2.797 | 55.942 | 3.61 | 0.38 | 25.59 | 2.19 | 0.0003 | 0.002 | 2.797 |
| 100 | 48.510 | 202.00 | 128.201 | 131.000 | 131.202 | 2.799 | 55.981 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.265 | 2.799 | 55.971 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.265 | 2.799 | 55.971 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.020 | 2.798 | 55.961 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.798 |
| 101 | 48.559 | 202.00 | 128.201 | 131.000 | 131.202 | 2.799 | 55.983 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.535 | 2.799 | 55.982 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.535 | 2.799 | 55.982 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.510 | 2.799 | 55.981 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.799 |
| 102 | 48.608 | 202.00 | 128.201 | 131.000 | 131.202 | 2.799 | 55.984 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.584 | 2.799 | 55.984 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.584 | 2.799 | 55.984 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.559 | 2.799 | 55.983 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.799 |
| 103 | 48.657 | 202.00 | 128.201 | 131.000 | 131.202 | 2.799 | 55.986 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.633 | 2.799 | 55.985 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.633 | 2.799 | 55.985 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.608 | 2.799 | 55.984 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.799 |
| 104 | 48.706 | 202.00 | 128.201 | 131.000 | 131.202 | 2.799 | 55.988 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.682 | 2.799 | 55.987 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.682 | 2.799 | 55.987 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.657 | 2.799 | 55.986 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.799 |
| 105 | 48.755 | 202.00 | 128.201 | 131.000 | 131.202 | 2.800 | 55.990 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.731 | 2.799 | 55.989 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.731 | 2.799 | 55.989 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.706 | 2.799 | 55.988 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.799 |
| 106 | 48.804 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 55.992 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.780 | 2.800 | 55.991 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.780 | 2.800 | 55.991 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.755 | 2.800 | 55.990 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 107 | 48.853 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 55.994 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.829 | 2.800 | 55.993 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.829 | 2.800 | 55.993 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.804 | 2.800 | 55.992 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 108 | 48.902 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 55.996 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.878 | 2.800 | 55.995 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.878 | 2.800 | 55.995 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.853 | 2.800 | 55.994 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 109 | 48.951 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 55.998 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.927 | 2.800 | 55.997 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.927 | 2.800 | 55.997 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.902 | 2.800 | 55.996 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 110 | 48.961 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 55.998 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.956 | 2.800 | 55.998 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.956 | 2.800 | 55.998 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.951 | 2.800 | 55.998 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 111 | 48.971 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.966 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.966 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.961 | 2.800 | 55.998 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 112 | 48.980 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.976 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.976 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.971 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 113 | 48.990 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 56.000 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.985 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.985 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.980 | 2.800 | 55.999 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |
| 113 | 49.000 | 202.00 | 128.200 | 131.000 | 131.202 | 2.800 | 56.000 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.995 | 2.800 | 56.000 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.995 | 2.800 | 56.000 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 48.990 | 2.800 | 56.000 | 3.61 | 0.38 | 25.60 | 2.19 | 0.0003 | 0.002 | 2.800 |


Detention Intake Channel
Hydraulic Calculations, Q=202 cfs
Channel
HGL
Velocity
131.5
131.0
130.5
130.0
129.5
129.0
128.5
128.0
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0
10
20
30
40
50
60
Elevation (ft NAVD 88)
Velocity (ft/s)
Distance (ft)

**Pipe and Riprap Sizes at Creek Outlets**

Updated: 8/11/2016

| | | | | | | | | | | Riprap Apron Dimensions* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Creek Outlet** | **Design Storm** | **Peak Design Flow (cfs)** | **Pipe Size (in)** | **Min Riprap D50 (in)** | **Min Riprap Class** | **Specified D50 (in)** | **Specified Riprap Class** | **Apron Lenth Multiplier** | **Apron Depth Multiplier** | **W1 (ft)** | **W2 (ft)** | **L (ft)** | **H (in)** |
| 1 | 100-YR | 11.5 | 24 | 3.05 | 1 | 6 | 2 | 4.00 | 3.30 | 6.0 | 11.3 | 8.0 | 19.8 |
| 2 | 100-YR | 18.4 | 24 | 5.73 | 2 | 6 | 2 | 4.00 | 3.30 | 6.0 | 11.3 | 8.0 | 19.8 |
| 3 | 100-yr | 67.2 | 42 | 8.71 | 3 | 10 | 3 | 5.00 | 2.40 | 10.5 | 22.2 | 17.5 | 24.0 |
| 4 | 100-YR | 152.7 | 54 | 14.47 | 5 | 20 | 5 | 7.00 | 2.00 | 13.5 | 34.5 | 31.5 | 40.0 |

*Riprap Apron Dimensions based on methods in FHWA HEC. No 14

# Appendix E

*Model for Diversion Structure & Detention Facility*

**Description of Model for Diversion Structure and Detention Facility**

**8/17/16**

**Introduction**

The proposed design for San Luis Ranch includes a diversion structure at the upstream end of Cerro San Luis Channel that diverts water from the channel to an underground detention system. The diverted water will be routed through the underground detention facility, through an outlet control structure, then into a pipe that discharges into Prefumo Creek.

Industry standard hydrologic modeling software, including HEC-HMS and Hydraflow Hydrographs Extension for AutoCAD Civil 3D, were explored to model the proposed diversion and detention facility, but they did not have the capacity to model a system with this complexity. HEC-HMS has the ability to model a diversion from a channel, but not the ability to account the water surface elevation in the downstream detention facility which affects the amount of water diverted. Hydraflow Hydrographs Extension for AutoCAD Civil 3D does not have the ability to model a diversion from a channel.

A custom numerical model was developed at part of this project to: (1) estimate the flow distribution at the diversion structure (how much flow stays in Cerro San Luis Channel and how much is diverted to the detention facility); and (2) estimate the routing of the diverted water through the detention facility (outflow and water surface elevation). The model was developed in Microsoft Excel.

**Calculations**

The model is based on a two-step process for performing all of the calculations. The first step in the process estimates the flow distribution at the diversion structure; the second step in the process involves the routing of flow through the detention facility. The calculations for each step are described below.

*Flow Distribution at Diversion Structure*

The first series of calculations in the model take the inflow at the upstream end of Cerro San Luis Channel from input hydrograph and calculate the distribution of that flow between Cerro San Luis Channel downstream of the diversion structure and flow into the detention facility. The model inputs for these calculations include:

1) hydrographs for Cerro San Luis Channel
2) diversion structure geometry
3) water surface elevation in the channel downstream of the diversion structure

4) water surface elevation in the detention facility
5) water surface elevation in the diversion structure forebay

Model inputs 1 and 2 are known values for all time steps. Model inputs 3 and 4 are taken from the solutions in the previous time step of the model. Model input 5, the water surface elevation in the diversion structure forebay, is the variable that the model solves for. In order to solve for the forebay water surface elevation, conservation of mass (continuity) was applied to the flow at the diversion structure, based on the following equation:

$$Q_{CU} = Q_{CD} + Q_{Din}$$

where:

$Q_{CU}$ = known flow into CSL Channel at upstream end of diversion structure from input hydrograph (cfs)
$Q_{CD}$ = flow out of the diversion structure into Cerro San Luis Channel (cfs)
$Q_D$ = flow into (positive value) or out of (negative value) detention facility from diversion structure (cfs)

Flow out of the diversion structure into Cerro San Luis Channel is modeled as weir flow. The flow over the weir in the diversion structure is calculated using the free-flow weir equation or submerged weir equation, depending on the downstream water surface elevation.

Flow into and out of the detention facility is modeled as weir flow (free-flow or submerged) or orifice flow, depending on the water surface elevations of the diversion structure forebay and the detention facility. The calculations account for flow from the detention facility back into the channel in the event that the water surface elevation in the channel drops below the water surface elevation in the detention facility.

The forebay water surface elevation cannot be solved for directly in the continuity equation above because it is a variable in $Q_{CD}$ and $Q_D$. An iterative numerical technique called the *secant method* was used to solve for the forebay water surface elevation at each time step. This is a method to find a numerical solution to the equation $f(x) = 0$ and is based on approximating the function with secant lines. Two initial approximations for the variable of interest, $x_0$ and $x_i$, are required. The equation for the subsequent estimates of $x$ is:

$$x_{i+1} = x_i - \frac{x_i - x_{i-1}}{y_i - y_{i-1}} y_i$$

The continuity equation for the diversion structure was rearranged to the following format so that the secant method could be applied to it:

$$y = f(x) = Q_{CU} - (Q_{CD} + Q_D) = 0$$

The variable $x$ is defined as follows:

$x$ = water surface elevation in diversion structure forebay (ft)

Ten iterations are included in the model. Conversion occurs when $y \approx 0$, which means conservation of mass (continuity) is achieved for the flow into and out of the diversion structure.

*Routing Flow through Diversion Structure*

The second series of calculations in the model estimate the routing of the flow though the detention facility. The model inputs for these calculations include:

1) detention facility geometry
2) outlet structure geometry
3) flow into or out of detention facility from diversion structure

Model inputs 1 and 2 are known values for all time steps. Model input 3 is calculated in the first series of calculations for each time step and input into the routing calculations.

The *level pool routing* procedure as presented in Chow et al., 1988 was used to generate outflow hydrographs and calculate the change in storage for the detention facility. This procedure assumes a horizontal water surface elevation in a reservoir, so the storage and discharge from the reservoir are functions of the water surface elevation of the reservoir. This method requires that a *storage-discharge function* be developed for the reservoir.

The *storage-discharge function* was developed for the detention facility by combining an *elevation-discharge function* and an *elevation-storage function* for the facility. The *elevation-discharge function* was developed by modeling the discharge from the outlet structure as weir flow through a Cipoletti weir. The calculation assumes free-flow over the weir as the flow in the downstream pipe is supercritical as currently designed, so it should not affect the flow over the weir. The *elevation-storage function* was developed using the detention facility geometry, including a rock layer at the bottom of the facility and the void space within the chambers.

The *level pool routing* procedure calculates the change in storage volume over a time step with the following equation:

$$S_{j+1} - S_j = \frac{I_j + I_{j+1}}{2}\Delta t - \frac{Q_j + Q_{j+1}}{2}\Delta t$$

where:

$S_{j+1}$ = storage at current time step (cf)
$S_j$ = storage at previous time step (cf)
$I_{j+1}$ = inflow at current time step (cfs)
$I_j$ = inflow at previous time step (cfs)
$Q_{j+1}$ = outflow at current time step (cfs)

$Q_j =$ outflow at previous time step (cfs)
$\Delta t =$ time interval (seconds)

This equation and the *storage-outfall function* are used in conjunction to solve for the outflow at the current time step. Once that is known, the change in storage volume can be computed. The cumulative total of the changes in storage volume was used calculate the total volume of water in the detention facility at each time step.

The water surface elevation in the detention facility was calculated at each time step using the total volume of water in the facility and the *elevation-storage function* for the facility.

**Model Inputs**

*Hydrographs for Cerro San Luis Channel*

Hydrographs for flow into the upstream end of Cerro San Luis Channel are required input for the model. Wallace Group has studied the hydrology for Cerro San Luis Channel and they provided the basis for the estimation of flows that are discharged into the upstream end of the channel. They used the City of San Luis Obispo's HEC-HMS model as a starting point for the analysis. The sub-basins within the City's model that contribute flow to Cerro San Luis Channel include the Madonna Inn and Lower Prefumo sub-basins. The Madonna Inn sub-basin is the area that contributes flow to the upstream end of the triple box culvert at Madonna Road. Wallace extracted from the Lower Prefumo sub-basin the area upstream of the San Luis Ranch project and designated it the Madonna Plaza sub-basin. Only a portion of the flow from the Madonna Plaza sub-basin contributes to Cerro San Luis Channel, as the remainder enters the project site at the north-east corner near Embassy Suites. Wallace estimated that 72% of the runoff from the Madonna Plaza sub-basin discharges into Cerro San Luis Channel.

Wallace provided hydrographs for the Madonna Inn and Madonna Plaza sub-basins for all of the design storms (2-, 10-, 25-, 50-, and 100-yr). Hydrographs for the flow into the upstream end of Cerro San Luis Channel were developed by combing the hydrograph from the Madonna Inn sub-basin and 72% of the hydrograph from the Madonna Plaza sub-basin. The resulting hydrographs for inflow into Cerro San Luis Channel for all of the design storms are shown in Appendix B.

*Diversion Structure Geometry*

The geometry for the diversion structure is required input for the model. The components include the elevation and length of the weir that spans the width of the diversion structure, and also the dimensions and elevation of the opening for the inlet into the detention facility. The inputs also include weir and orifice coefficients for these components.

*Detention Facility*

The geometry for the detention facility is required input for the model. The inputs include:

- bottom of rock elevation
- top of rock elevation
- rock area
- rock porosity
- top inside of concrete chamber elevation
- concrete chamber volume

The geometry for the outlet structure is required input into the model. The outlet structure was modeled as a Cipoletti weir. The required input includes:

- bottom width of weir
- weir invert elevation
- weir coefficient

*Elevation-Flow Table for Cerro San Luis Channel Downstream of Diversion Structure*

An elevation-flow table for Cerro San Luis Channel immediately downstream of the diversion structure is required input for the model. A table was developed based on data from Wallace Group's HEC-RAS model at station 15+50.

**Governing Equations for Hydraulic Calculations**

*Flow Over Unsubmerged Sharp-crested Rectangular Weir (Free-discharge)*

$$Q = C_w B H^{1.5}$$

where:

$Q =$ flow over weir (cfs)
$C_w =$ weir coefficient
$B =$ weir length (ft)
$H =$ upstream water height above the weir crest (ft)

*Flow Over Submerged Sharp-crested Rectangular Weir*

$$Q_{submerged} = Q_{unsubmerged}\left(1-\left(\frac{H_{downstream}}{H_{upstream}}\right)^{1.5}\right)^{0.385}$$

where:

$Q_{submerged}$ = flow over submerged weir (cfs)

$Q_{unsubmerged}$ = flow over unsubmerged weir (cfs

$H_{downstream}$ = downstream water height above the weir crest (ft)

$H_{upstream}$ = upstream water height above the weir crest (ft)

*Flow Over Unsubmerged Cipoletti Weir (Free-discharge)*

$$Q = C_w B H^{1.5}$$

where:

$Q$ = flow over weir (cfs)

$C_w$ = weir coefficient (≈3.367 for US customary units)

$B$ = length of horizontal portion of weir (ft)

$H$ = upstream water height above the weir crest (ft)

*Flow through an Orifice*

$$Q = CA\sqrt{2gH}$$

where:

$Q$ = flow through orifice (cfs)

$C$ = orifice coefficient

$A$ = open area of orfice (sf)

$H$ = upstream water height above centroid of orifice for free-discharge condition (ft)
upstream water height above downstream water height for submerged condition (ft)

$g$ = acceleration due to gravity (32.2 ft/s$^2$ for US customary units)

**References**

Chow, VT, Maidment, D.R., and Mays, L.W. 1988. *Applied Hydrology*. McGraw-Hill Book Company. Singapore.

**Diversion Structure and Detention Facility Routing Model**

Updated: 8/15/16

**Diversion Structure**

| In-channel Weir | | |
|---|---|---|
| Length: | 45.00 | ft |
| Weir Coeff: | 3.20 | |
| Elevation: | 128.50 | |

| Diversion Inlet | | |
|---|---|---|
| Orifice Inv. Elev.: | 129.00 | ft |
| Orifice Height: | 2.50 | ft |
| Orifice Length: | 13.50 | ft |
| Orifice Coeff: | 0.60 | |
| Weir Coeff: | 3.20 | |

**Outlet Structure (Cipoletti Weir)**

| | | |
|---|---|---|
| Bottom Width: | 2.00 | ft |
| Weir Invert Elev: | 127.00 | ft |
| Weir Coefficient: | 3.37 | |

**Detention Facility Parameters**

| | | |
|---|---|---|
| Bottom Rock Elev.: | 126.70 | ft |
| Top Rock Elev.: | 128.20 | ft |
| Rock Area: | 67,550 | sf |
| Rock Porosity: | 0.25 | |
| Rock Volume: | 25,331 | cf |
| Top Inside Chamber Elev.: | 131.70 | ft |
| Chamber Volume: | 210,070 | cf |

**Detention Facility Elevation-Volume Table**

| Elev. (ft) | Cumulative Volume (cf) |
|---|---|
| 126.70 | 0 |
| 128.20 | 25,331 |
| 131.70 | 235,401 |

## Rating Curve for Station 15+50

(Data from Wallace's HEC-RAS Model in emails dated 10/1/15 and 10/2/15)

| Flow (cfs) | WSE (ft) |
|---|---|
| 0.00 | 127.94 |
| 226.57 | 129.86 |
| 393.15 | 130.56 |
| 478.92 | 130.88 |
| 556.51 | 131.14 |
| 616.09 | 131.33 |