PRELIMINARY HYDROLOGY STUDY

FOR

CORONA STATION DEVELOPMENT

Petaluma, California

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Prepared:
November 30, 2018

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1. INTRODUCTION

This Preliminary Hydrology Study (Study) examines and compares the pre- and post-project peak flows for the Corona Station Development located at the intersection of North McDowell Boulevard and Corona Road in Petaluma, California.

2. PRE-PROJECT CONDITIONS

The Corona Station Development is located at the southeast corner of the intersection of North McDowell Boulevard and Corona Road in Petaluma, California. The Assessor's Parcel Number of the project property is 137-061-19.

The 6.75 acre project site is situated in an area of Petaluma that is comprised of a combination of residential, commercial, industrial and rural development. The project site is triangular in shape and bounded to the northwest by Corona Road and commercial property, and to the southwest by North McDowell Boulevard and commercial and residential property. To the east and southeast the project site is bounded by the SMART railroad and rural and residential property. Corona Creek is adjacent to the property at the southern tip of the site.

The site is mostly vacant with temporary outdoor operations for a trucking company located on the southern portion of the site. Largely, the site is covered by compacted gravel for parking, storage and staging vehicles and materials. A few buildings were located on the site but were removed in 2018 to facilitate cleanup of contaminated soil within the site. Vegetated areas, largely of grass, are limited to strips of land adjacent to Corona Road, North McDowell Boulevard, at the southern tip of the site adjacent to the railroad and the Corona Creek corridor, along the southern edge of the site.

The terrain of the project site is flat with a 0.5% slope across the property from the higher elevations in the north to the lower elevations in the south. Approximately 0.17 acres of the site drains to the east into the ditch within the railroad right-of-way and running parallel to the railroad. The railroad ditch flows to the south into Corona Creek. Approximately 0.82 acres of the site drains to the curb and gutter in Corona Road and is intercepted by the storm drain system in Corona Road. This system discharges into a drainage ditch on the opposite side of Corona Road from the project site. After passing under North McDowell Boulevard through a culvert, the drainage ditch continues to the southwest along Corona Road. At Highway 101, runoff from the drainage ditch is intercepted by an underground storm drain system which conveys and discharges runoff into the Petaluma River on the north side of Corona Road.

Runoff from the remainder of the site is intercepted by a storm drain system in North McDowell Boulevard which flows south along North McDowell Boulevard and discharges into a culvert under North McDowell Boulevard for Corona Creek. After exiting the culvert under North McDowell Boulevard, Corona Creek then flows through open channels to the eastern edge of Highway 101 where it is intercepted and then conveyed by culvert to the

west side of Highway 101. After being discharged to the west side of Highway 101, Corona Creek continues as an open channel until it discharges into the Petaluma River.

3. POST-PROJECT CONDITIONS

The proposed project is comprised of a combination of single-family residences and multi-family housing in the mid- and southern portion of the site and sets aside the northern portion of the property directly abutting Corona Road and the SMART property along the railroad line to accommodate a future SMART railroad station and parking lot. A majority of the site will be covered by surfaces such as pavement and buildings. Landscape areas are proposed adjacent to the SMART railroad and along North McDowell Boulevard, in front of the houses and in numerous locations throughout the development, along walkways and to provide common open space areas. Bioretention planters and ponds are interspersed throughout the housing areas to treat runoff from roofs and pavement. Runoff from a majority of the project site will be intercepted by proposed storm drain pipe networks connected to the existing storm drain system in North McDowell Boulevard. Runoff from a small portion of the project site will continue to flow into the ditch next to the railroad and into Corona Creek.

4. ANALYSIS

4.1 Criteria

The Pre- and Post-Project peak flows were determined using the methodology contained within the Sonoma County Water Agency's (SCWA) Flood Control Design Criteria, dated 1983. Pre- and Post-Project peak flows rates were determined for the 10- and 100-year storm recurrence intervals.

4.2 Hydrology

a. Rational Method: The Rational Method was utilized to calculate design peak discharge in accordance with SCWA's Flood Control Design Criteria. The Rational method is based on the following formula:

$$Q=CIAK$$

Where: Q = Peak Flow Rate (cubic feet per second, cfs)
C = Runoff Coefficients
I = Rainfall Intensity (inches per hour, in/hr)
A = Tributary Area (acres, ac)
K = K-factor from Plate B-4 of the SCWA Flood Control Design Criteria (dimensionless)

b. Time of Concentration: Minimum times of concentration were applied according to the acreage of areas contributing to initial flows in the drainage areas. The

following minimum times of concentration are taken from the SCWA Flood Control Design Criteria manual:

Table 4.1 – Time of Concentration

Time of Concentration	Tributary Area
7 minutes	Commercial or similar areas
10 minutes	Areas smaller than ½ acre
15 minutes	Areas between ½ and 2 acres

Velocities for pipe flow were determined using the Hydraflow Express computer program distributed by Autodesk which calculates normal depth in open channel flow regimes by the use of Manning's Formula.

c. Rainfall Intensity: Intensities for the 10-year and the 100-year storm frequency events were determined from Plate B-2 of the SCWA Flood Control Design Criteria.

d. Runoff Coefficient: Following the SCWA's criteria within Plate No. B-1, runoff coefficients were set at 0.90 for Commercial, Industrial & Multiple Residential Areas. Where vegetated area of the Drainage Areas examined for this study exceeded 20%, weighted runoff coefficients were calculated.

e. Detention: Detention was modeled using the Hydraflow Hydrographs computer program distributed by Autodesk. The Hydrographs program developed hydrographs for the 10-year frequency storm event based on peak flows determined by the Rational Method.

5. RESULTS

Table 5.1 – Tributary Areas, Pre- vs. Post Project[1]

Drainage Area	Pre-Project Tributary Area (ac)	C-Factor	Post-Project Tributary Area (ac)	C-Factor
1	2.79	0.79	2.44	0.90
2	1.33	0.90	2.53	0.90
3	1.67	0.90	1.30	0.90
4	0.82	0.90	0.27	0.90
5	0.17	0.44	0.24	0.44

1. See Appendix 7.3 for calculations.

Table 5.2 – Peak Discharge Calculations[2]

Drainage Area	Pre-Project Q10 (cfs)	Post-Project Q10 (cfs)	Pre-Project Q100 (cfs)	Post-Project Q100 (cfs)
1	3.22	3.14	4.52	4.39
2	1.75	1.72[3]	2.45	4.51[5]
3	2.20	1.71	3.08	2.40
4	1.08	0.53	1.51	0.74
5	0.14	0.19[4]	0.19	0.27[4]

2. See Appendix 7.3 for calculations.
3. Peak flow as a result of incorporating detention within the proposed storm drain system. Without detention, Drainage Area 2 Post-Project peak flow is Q10 = 3.21cfs
4. The increase in peak flow from Area 5 can be mitigated to at or below pre-project conditions by grading the land so that the post-project area of Drainage Area 5 matches the pre-project area of Drainage Area 5. See page 17/17 of the Post-Project Calculations of Appendix 7.3.
5. This occurs during a 100-year event, for which a majority of the site is projected to be inundated by floodwater. See FEMA National Flood Hazard Layer FIRMette in Appendix 8.

6. CONCLUSIONS

The calculations of this Preliminary Hydrology Study show that impacts, due to changes in the peak flow of runoff to the analyzed points of concentration around the Corona Station Development, are less than significant or can be mitigated to be less than significant.

Of the five points of concentration around the project site, three locations will have a decrease in peak runoff due to a decrease in tributary drainage area contributing runoff to the point of concentration. The three locations are Drainage Area 1, Drainage Area 3 and Drainage Area 4 (see Table 5.2, above).

The remaining two locations, Drainage Area 2 and Drainage Area 5, have increases in peak flow, largely due to an increase in tributary drainage area, however, the increases in peak flow can be mitigated to at or below pre-project conditions. Increases in peak flow from Drainage Area 2 can be mitigated to at or below pre-project conditions by providing volume and constrictions within the proposed storm drain system to detain and slow the release of runoff from the site. Increases in peak flow from Drainage Area 5 can be mitigated to at or

below pre-project conditions by grading the site so that the footprint of Drainage Area 5 is the same between pre- and post-project conditions (see Table 5.2, above).

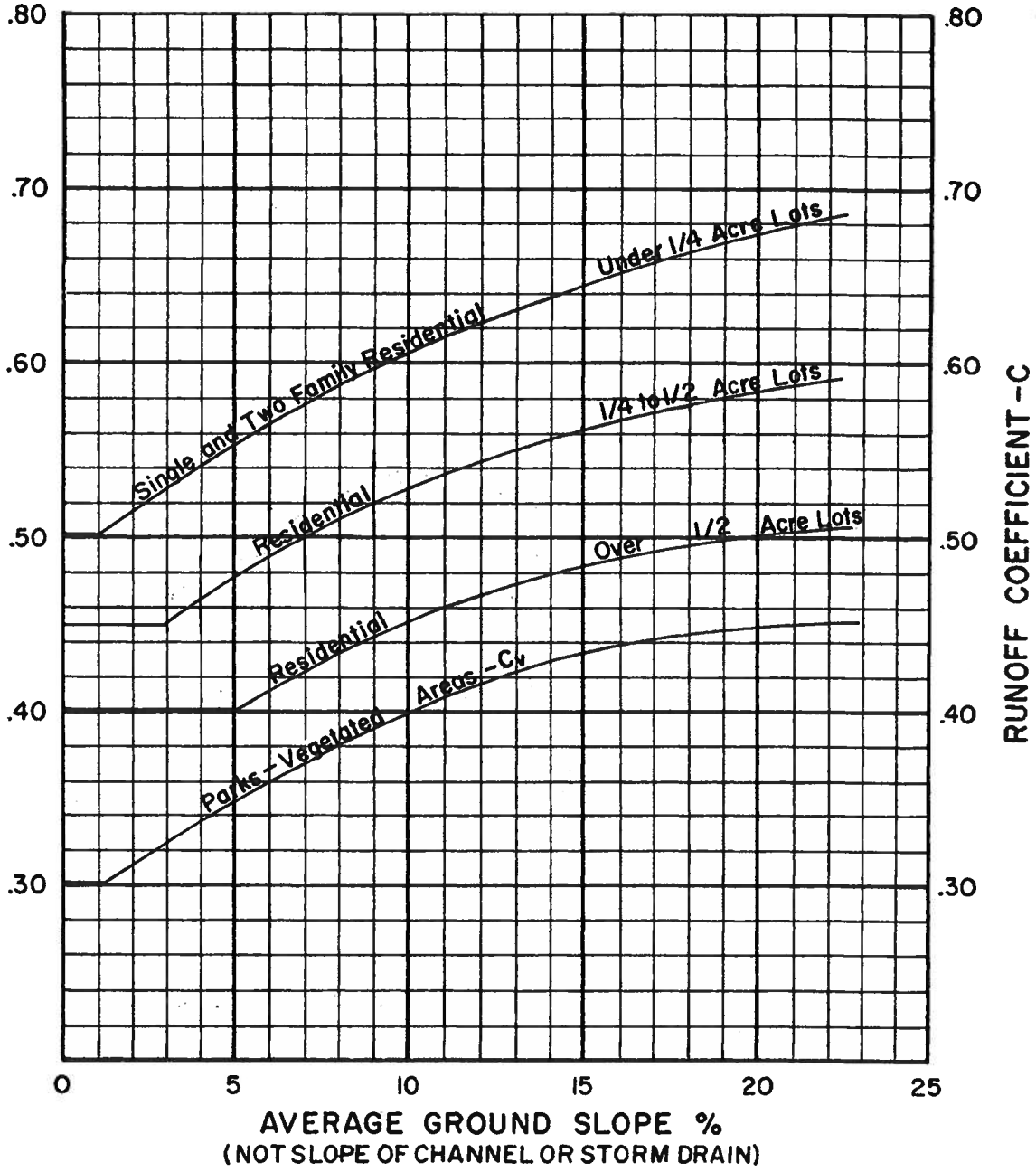
As is evident from the preceding study, the Corona Station Development project in Petaluma can be constructed so that impacts due to peak flows from the site are less than significant or can be mitigated to be less than significant.

As plans progress to a level commensurate for construction, analysis of the project should be provided in a Final Hydrology and Hydraulic Study to confirm that the proposed combination of site grading, routing of onsite storm water pipe facilities and storm water treatment systems continue to mitigate increases in calculated peak flows to the individual points of concentration around the site, to at or below pre-project conditions.

7.0 APPENDICES

Appendix 7.1 – Runoff Coefficients

RUNOFF COEFFICIENTS FOR RATIONAL FORMULA



NOTE: Commercial, Industrial & Multiple Residential Areas

$C_p = 0.9$ (Based on paving, roofs, etc.)

When vegetated area exceeds 20% of total, C_v from vegetated curve may be used to reduce above C_p as follows:

$$C_T = C_v \frac{A_v}{A_T} + C_p \frac{A_p}{A_T}$$

SONOMA COUNTY WATER AGENCY

118-2
7/64

PLATE No. B-1

Figure 819.2A

Runoff Coefficients for Undeveloped Areas

Watershed Types

	Extreme	High	Normal	Low
Relief	.28 -.35 Steep, rugged terrain with average slopes above 30%	.20 -.28 Hilly, with average slopes of 10 to 30%	.14 -.20 Rolling, with average slopes of 5 to 10%	.08-.14 Relatively flat land, with average slopes of 0 to 5%
Soil Infiltration	.12-.16 No effective soil cover, either rock or thin soil mantle of negligible infiltration capacity	.08 -.12 Slow to take up water, clay or shallow loam soils of low infiltration capacity, imperfectly or poorly drained	.06 -.08 Normal; well drained light or medium textured soils, sandy loams, silt and silt loams	.04 -.06 High; deep sand or other soil that takes up water readily, very light well drained soils
Vegetal Cover	.12-.16 No effective plant cover, bare or very sparse cover	.08 -.12 Poor to fair; clean cultivation crops, or poor natural cover, less than 20% of drainage area over good cover	.06 -.08 Fair to good; about 50% of area in good grassland or woodland, not more than 50% of area in cultivated crops	.04 -.06 Good to excellent; about 90% of drainage area in good grassland, woodland or equivalent cover
Surface Storage	.10 .12 Negligible surface depression few and shallow; drainageways steep and small, no marshes	.08 -.10 Low; well defined system of small drainageways; no ponds or marshes	.06 -.08 Normal; considerable surface depression storage; lakes and pond marshes	.04 -.06 High; surface storage, high; drainage system not sharply defined; large floodplain storage or large number of ponds or marshes
Given	An undeveloped watershed consisting of; 1) rolling terrain with average slopes of 5%, 2) clay type soils, 3) good grassland area, and 4) normal surface depressions.		Solution: Relief 0.14 Soil Infiltration 0.08 Vegetal Cover 0.04 Surface Storage 0.06 C = 0.32	
Find	The runoff coefficient, C, for the above watershed.			

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Undeveloped Area Runoff Coefficient, C_v

From Figure 819.2A

Runoff Coefficients for Undeveloped Areas

Caltrans, July 1, 2015, Highway Design Manual

C_v :

Relief	0.08
Soil Infiltration	0.12
Vegetal Cover	0.12
+ Surface Storage	0.12

C_v = 0.44

pre- & post- project

Appendix 7.2 – Precipitation, K-Factor and Intensity-Duration-Frequency Data

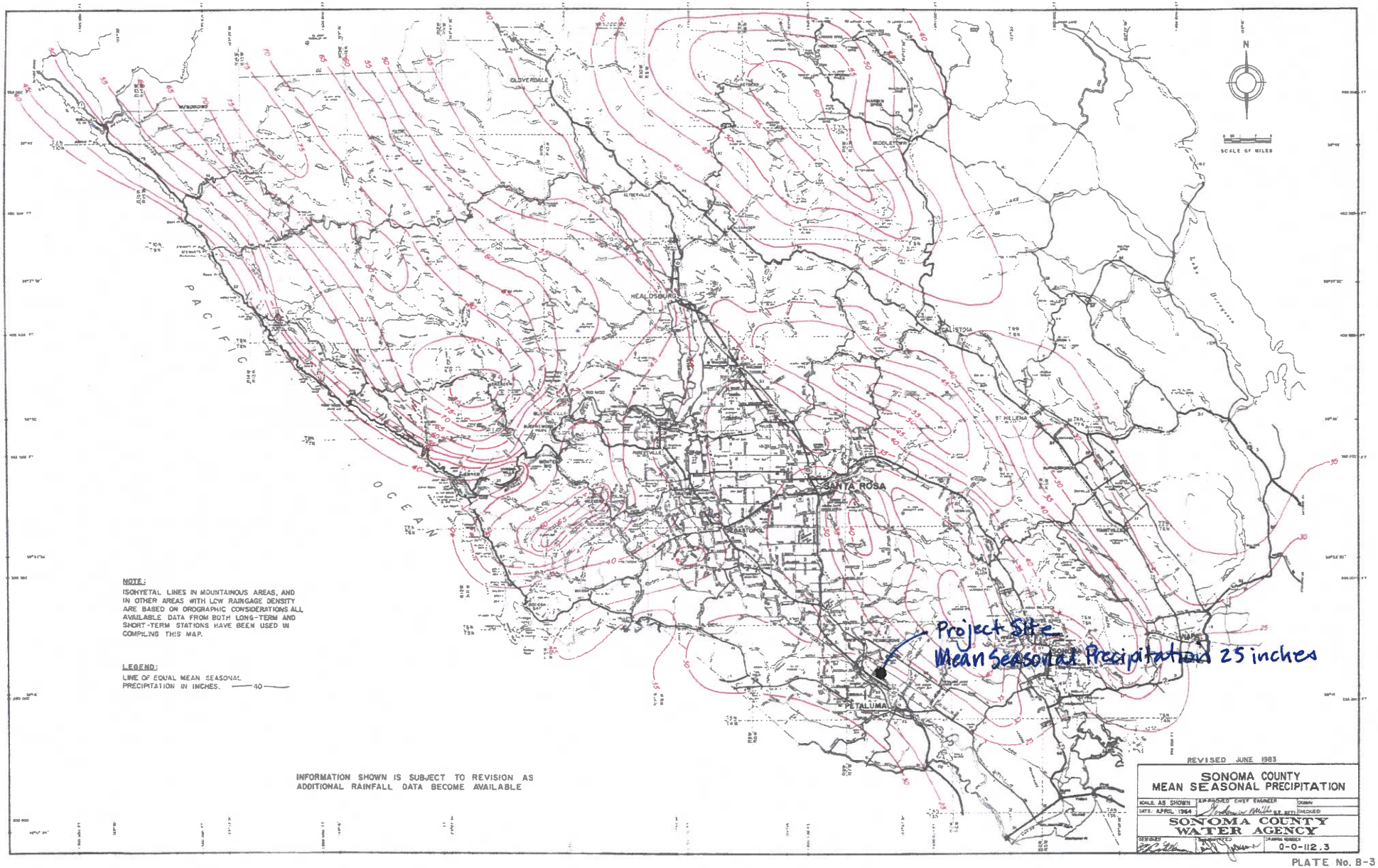
N
SCALE OF MILES
PACIFIC
OCEAN
SANTA ROSA
PETALUMA
HEALDSBURG
GLOVERDALE
CALISTOGA
ST HELENA
Project Site
Mean Seasonal Precipitation 25 inches
NOTE:
ISOHYETAL LINES IN MOUNTAINOUS AREAS, AND IN OTHER AREAS WITH LOW RAINGAGE DENSITY ARE BASED ON OROGRAPHIC CONSIDERATIONS ALL AVAILABLE DATA FROM BOTH LONG-TERM AND SHORT-TERM STATIONS HAVE BEEN USED IN COMPILING THIS MAP.
LEGEND:
LINE OF EQUAL MEAN SEASONAL PRECIPITATION IN INCHES. —40—
INFORMATION SHOWN IS SUBJECT TO REVISION AS ADDITIONAL RAINFALL DATA BECOME AVAILABLE
REVISED JUNE 1983
SONOMA COUNTY
MEAN SEASONAL PRECIPITATION
SCALE AS SHOWN
DATE APRIL 1964
APPROVED CHIEF ENGINEER
DRAWN
CHECKED
SONOMA COUNTY
WATER AGENCY
DESIGNED
TRACED
DRAWING NUMBER
0-0-112.3

PLATE No. B-3

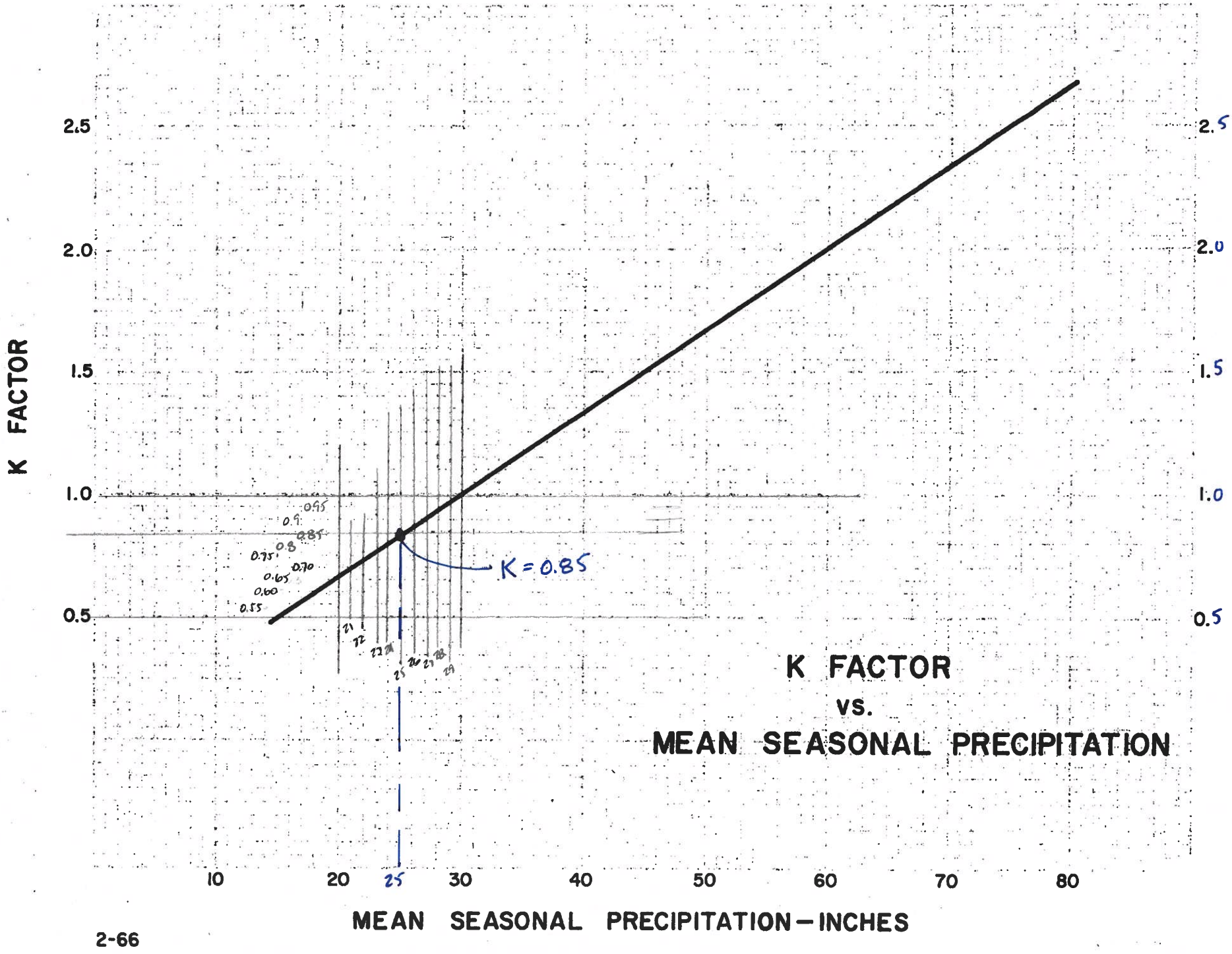

PLATE No. B-4

2-66

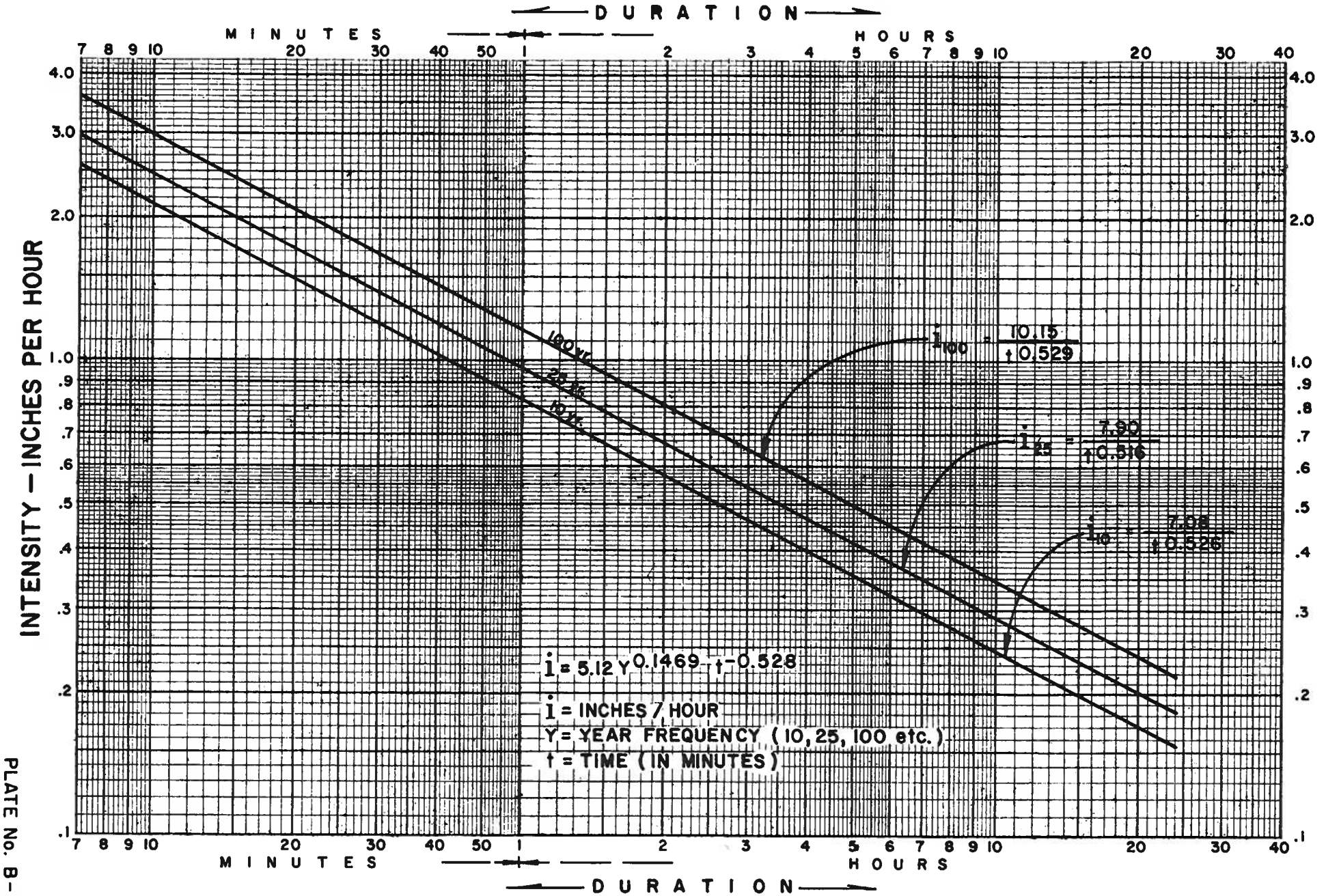

PLATE No. B-2

NOTE: THE INFORMATION SHOWN IS SUBJECT TO ANNUAL REVISION AS ADDITIONAL RAINFALL DATA BECOMES AVAILABLE

RAINFALL INTENSITY vs DURATION

Appendix 7.3 – Hydrology Calculations
(10- and 100-Year Storm Events)

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CLIENT _____ SUBJECT Preliminary Hydrology CHK'D _____ DATE _____

Pre-Project Condition

Calculations

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SHEET NO. 1/3

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CLIENT _____ SUBJECT Preliminary Hydrology CHK'D _____ DATE _____

Pre-Project Conditions

Drainage Areas:

Drainage Area Designation	Area (sf)	Area (Ac)	Pervious Area (sf)	% Perviousness	C
①	121,473.43	2.79	27875.51	22.9%	see C_{W_1}
②	58083.84	1.33	6280.06	10.8% *	0.90
③	72753.82	1.67	7320.76	10.1% *	0.90
④	35875.36	0.82	5180.80	14.4% *	0.90
⑤	7451.28	0.17	7451.28	100%	see C_{W_5}

* Per Plate No. B-1, Sonoma County Water Agency Flood Control Design Criteria
C = 0.9 for Commercial & Industrial Areas

C_{W_1}: Per Plate No. B-1, Sonoma Co. Water Agency, when vegetated area >20%

$$C_{W_1} = C_V \frac{A_V}{A_T} + C_P \frac{A_P}{A_T}$$

$C_V = 0.44$ (Figure 819.2A Caltrans Highway Design Manual)

$$C_{W_1} = (0.44)\left(\frac{27875.51}{121,473.43}\right) + (0.9)\left(\frac{93597.92}{121473.43}\right)$$

$\boxed{C_{W_1} = 0.79 \quad \text{pre-project}}$

C_{W_5}: $C_{W_5} = C_V \frac{A_V}{A_T} + C_P \frac{A_P}{A_T}$ $\quad C_V = 0.44$

$$C_{W_5} = (0.44)\left(\frac{7451.28}{7451.28}\right) + (0.90)\left(\frac{0}{7451.28}\right)$$

$\boxed{C_{W_5} = 0.44 \quad \text{pre-project}}$

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SHEET NO. 2/3

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CLIENT _____ SUBJECT Preliminary Hydrology CHK'D _____ DATE _____

Pre-Project Conditions

Time of Concentration for Areas ①, ②, ③ & ④:

T_c = 15 min (areas ½ acre to 2 acres, SCWA Flood Control Design Criteria)

Intensity for Areas ①, ②, ③ & ④: (Plate B-2 SCWA FCDC)

$I_{10yr,15min} = 5.12\,(10)^{0.1469}\,(15)^{-0.528} = 1.72$ in/hr

$I_{100yr,15min} = 5.12\,(100)^{0.1469}\,(15)^{-0.528} = 2.41$ in/hr

Rational Method Areas ①, ②, ③ & ④:

$Q = CIAK$ $K = 0.85$ (Plate B-4, SCWA FCDC)

Area ①

$Q_{10_①} = (0.79)(1.72\ in/hr)(2.79\ Ac)(0.85) = 3.22$ cfs $= Q_{10_①}$

$Q_{100_①} = (0.79)(2.41\ in/hr)(2.79\ Ac)(0.85) = 4.52$ cfs $= Q_{100_①}$

Pre-Project — Area 1

Area ②

$Q_{10_②} = (0.9)(1.72\ in/hr)(1.33\ Ac)(0.85) = 1.75$ cfs $= Q_{10_②}$

$Q_{100_②} = (0.9)(2.41\ in/hr)(1.33\ Ac)(0.85) = 2.45$ cfs $= Q_{100_②}$

Pre-Project — Area 2

Area ③

$Q_{10_③} = (0.9)(1.72\ in/hr)(1.67\ Ac)(0.85) = 2.20$ cfs $= Q_{10_③}$

$Q_{100_③} = (0.9)(2.41\ in/hr)(1.67\ Ac)(0.85) = 3.08$ cfs $= Q_{100_③}$

Pre-Project — Area 3

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Pre-Project Conditions cont'd:

Rational Method Areas ①, ②, ③ & ④ cont'd:

Area ④

$Q_{10④} = (0.9)(1.72\ in/hr)(0.82\ Ac)(0.85) = 1.08\ cfs = Q_{10④}$

$Q_{100④} = (0.9)(2.41\ in/hr)(0.82\ Ac)(0.85) = 1.51\ cfs = Q_{100④}$

Pre-Project

Area 4

Time of Concentration for Area ⑤:

$T_c = 10\ min$ (lots smaller than ½ acre, SCWA FCDC)

Intensity for Area ⑤:

$I_{10yr,10min} = 5.12\ (10)^{0.1469}\ (10)^{-0.528} = 2.13\ in/hr$

$I_{100yr,10min} = 5.12\ (100)^{0.1469}\ (10)^{-0.528} = 2.99\ in/hr$

Rational Method for Area ⑤:

$Q_{10⑤} = (0.44)(2.13\ in/hr)(0.17\ Ac)(0.85) = 0.14\ cfs = Q_{10⑤}$

$Q_{100⑤} = (0.44)(2.99\ in/hr)(0.17\ Ac)(0.85) = 0.19\ cfs = Q_{100⑤}$

Pre-Project

Area 5

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Post-Project Condition Calculations

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CLIENT _____ SUBJECT Preliminary Hydrology CHK'D _____ DATE _____

Post-Project Conditions

Drainage Areas:

Drainage Area Designation	Area (sf)	Area (Ac)	Pervious Area (sf)	% Perviousness	C
①	106387.46	2.44	*	< 20%	0.90
②	110371.69	2.53	*	< 20%	0.90
③	56595.47	1.30	*	< 20%	0.90
④	11929.56	0.27	*	< 20%	0.90
⑤	10211.38	0.23	CALTRANS HWY DESIGN MANUAL	100%	0.44

* Per Plate No. B-1, Sonoma County Water Agency Flood Control Design Criteria C = 0.9 for Multiple Residential Areas.

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Post-Project Conditions cont'd:

Find Q_{10} & Q_{100} for Area ①:

Per Sonoma County Water Agency Flood Control Design Criteria

Q is per the Rational Method.

$Q = C\ I\ A\ K$ $\quad K = 0.85$

(per Plate No. B-4 of the SCWA Flood Control Design Criteria)

From Point A to Point B:

Sub-area = 1.47 acres

$C = 0.90$

time of concentration = t_o = 15 minutes (areas ½ acre to 2 acres) SCWA Flood Control Design Criteria

Intensity (Plate B-2 SCWA FCDC)

$I_{10yr\,15min} = 5.12\,(10)^{0.1469}\,(15)^{-0.528} = 1.72$ in/hr

$I_{100yr\,15min} = 5.12\,(100)^{0.1469}\,(15)^{-0.528} = 2.41$ in/hr

At Point B:

$Q_{B10} = (0.9)(1.72\ in/hr)(1.47\ Ac)(0.85) = 1.93$ cfs

$Q_{B100} = (0.9)(2.41\ in/hr)(1.47\ Ac)(0.85) = 2.71$ cfs

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Post-Project Conditions cont'd:

Find Q_{10} & Q_{100} for Area D, cont'd:

From Point B to Point C: path length = 205 LF
path type = 24" pipe assume n=0.018

$$\text{slope} = \frac{28.30 - 26.37}{205} = 0.0094 \text{ ft/ft}$$

If pipe is flowing full, $v = 5.04$ ft/s (calculated using Hydraflow Express)

$$t_{t_{B-C}} = 205 \text{ LF} \left(\frac{1 \text{ sec}}{5.04 \text{ ft}}\right)\left(\frac{1 \text{ min}}{60 \text{ sec}}\right) = 0.7 \text{ min}$$

$$T_c = t_o + t_{t_{B-C}} = 15 \text{ min} + 0.7 \text{ min} = 15.7 \text{ min}$$

$T_c = 15.7$ min = time of concentration at Point C

Intensity

$$I_{10yr,\,15.7min} = 5.12\,(10)^{0.1469}\,(15.7)^{-0.528} = 1.68 \text{ in/hr}$$

$$I_{100yr,\,15.7min} = 5.12\,(100)^{0.1469}\,(15.7)^{-0.528} = 2.35 \text{ in/hr}$$

At Point C:

$$Q_{C_{10}} = (0.9)(1.68 \text{ in/hr})(2.44 \text{ Ac})(0.85) = 3.14 \text{ cfs}$$

$$Q_{C_{100}} = (0.9)(2.35 \text{ in/hr})(2.44 \text{ Ac})(0.85) = 4.39 \text{ cfs}$$

Area 1
Point of Concentration C
Post-Project
$Q_{C10} = 3.14$ cfs
$Q_{C,100} = 4.39$ cfs

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CLIENT _____ SUBJECT Preliminary Hydrology CHK'D _____ DATE _____

Post-Project Conditions cont'd:

Find Q_{10} & Q_{100} for Area ②:

$Q = C I A K$ $\quad K = 0.85$ (Plate No. B-4 SCWA FCDC)

From Point D to Point E:

Sub-area = 1.65 Acres

$C = 0.90$

time of concentration = t_o = 15 minutes (areas 1/2 acre to 2 acres SCWA FCDC)

Intensity (Plate B-2 SCWA FCDC)

$I_{10yr\ 15min} = 1.72$ in/hr
$I_{100yr\ 15min} = 2.41$ in/hr
} (see Area ①)

At Point E:

$Q_{E_{10}} = (0.9)(1.72\ in/hr)(1.65)(0.85) = 2.17$ cfs

$Q_{E_{100}} = (0.9)(2.41\ in/hr)(1.65)(0.85) = 3.04$ cfs

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Post-Project Conditions cont'd:

Find Q_{10} & Q_{100} for Area (2) cont'd:

From Point E to Point F: path length = 113 LF

path type = 18" pipe assume n=0.018

slope = 0.002 ft/ft

if pipe is flowing full, v = 1.92 ft/s (calculated using Hydraflow Express)

$t_{tE-F} = 113\ LF \left(\frac{1\ sec}{1.92\ ft}\right)\left(\frac{1\ min}{60\ sec}\right) = 1.0\ min$

$T_F = t_o + t_{tE-F} = 15\ min + 1.0\ min = 16.0\ min$
time of concentration at point F

Intensity

$I_{10\ yr\ 16\ min} = 5.12\ (10)^{0.1469}\ (16)^{-0.528} = 1.66\ in/hr$

$I_{100\ yr,\ 16\ min} = 5.12\ (100)^{0.1469}\ (16)^{-0.528} = 2.33\ in/hr$

At Point F:

$Q_{F10} = (0.9)(1.66\ in/hr)(2.53 A_c)(0.85) = 3.21\ cfs$

$Q_{F100} = (0.9)(2.33\ in/hr)(2.53 A_c)(0.85) = 4.51\ cfs$

Area 2

Point of Concentration F — $Q_{F10} = 3.21\ cfs$ ← See Page 9 & 12 of this Section for mitigation by detention within storm drain system.

Post-Project — $Q_{F100} = 4.51\ cfs$

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Post-Project Conditions cont'd:

Find Q_{10} & Q_{100} for Area ③:

$Q = CIAK$ $\quad K = 0.85$ (SCWA FCDC)

Area = 1.30 Ac

$C = 0.90$

$t_o = 15$ min (areas ½ acre to 2 acres, SCWA FCDC)

$I_{10,15} = 1.72$ in/hr
$I_{100,15} = 2.41$ in/hr
} see Area ① calculations

At Point of Concentration for Area 3:

$Q_{10_③} = CIAK = (0.90)(1.72\ in/hr)(1.30\ Ac)(0.85) = 1.71$ cfs

$Q_{100_③} = CIAK = (0.90)(2.41\ in/hr)(1.30\ Ac)(0.85) = 2.40$ cfs

Area 3	$Q_{10_③}$ =	1.71 cfs
Post-Project	$Q_{100_③}$ =	2.40 cfs

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Post-Project Conditions cont'd:

Find Q_{10} & Q_{100} for Area ④:

$Q = CIAK$ $K = 0.85$ (SCWA FCDC)

Area = 0.27 Ac

$C = 0.90$

$t_o = 7$ min (commercial & similar areas, SCWA FCDC)

Intensity:

$I_{10, 7min} = 5.12(10)^{0.1469}(7)^{-0.528} = 2.57$ in/hr

$I_{100, 7min} = 5.12(100)^{0.1469}(7)^{-0.528} = 3.60$ in/hr

At Point of Concentration for Area 4:

$Q_{10④} = CIAK = (0.9)(2.57 \text{ in/hr})(0.27 \text{ Ac})(0.85) = 0.53$ cfs

$Q_{100④} = CIAK = (0.9)(3.60 \text{ in/hr})(0.27 \text{ Ac})(0.85) = 0.74$ cfs

Area 4	$Q_{10④} = 0.53$ cfs
Post-Project	$Q_{100④} = 0.74$ cfs

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Post-Project Conditions cont'd:

Find Q_{10} & Q_{100} for Area (5):

$Q = CIAK$ $K = 0.85$ (SCWA FCDC)

Area = 0.24 Ac

$C = 0.44$

$t_o = 10$ min (lots smaller than 1/2 acre, SCWA FCDC)

Intensity:

$I_{10,10min} = 5.12\,(10)^{0.1469}(10)^{-0.528} = 2.13$ in/hr

$I_{100,10min} = 5.12\,(100)^{0.1469}(10)^{-0.528} = 2.99$ in/hr

At Point of Concentration for Area 5:

$Q_{10(5)} = CIAK = (0.44)(2.13\text{ in/hr})(0.24\text{ Ac})(0.85) = 0.19$ cfs

$Q_{100(5)} = CIAK = (0.44)(2.99\text{ in/hr})(0.24\text{ Ac})(0.85) = 0.27$ cfs

Area 5	$Q_{10(5)}$ =	0.19 cfs
Post-Project	$Q_{100(5)}$ =	0.27 cfs

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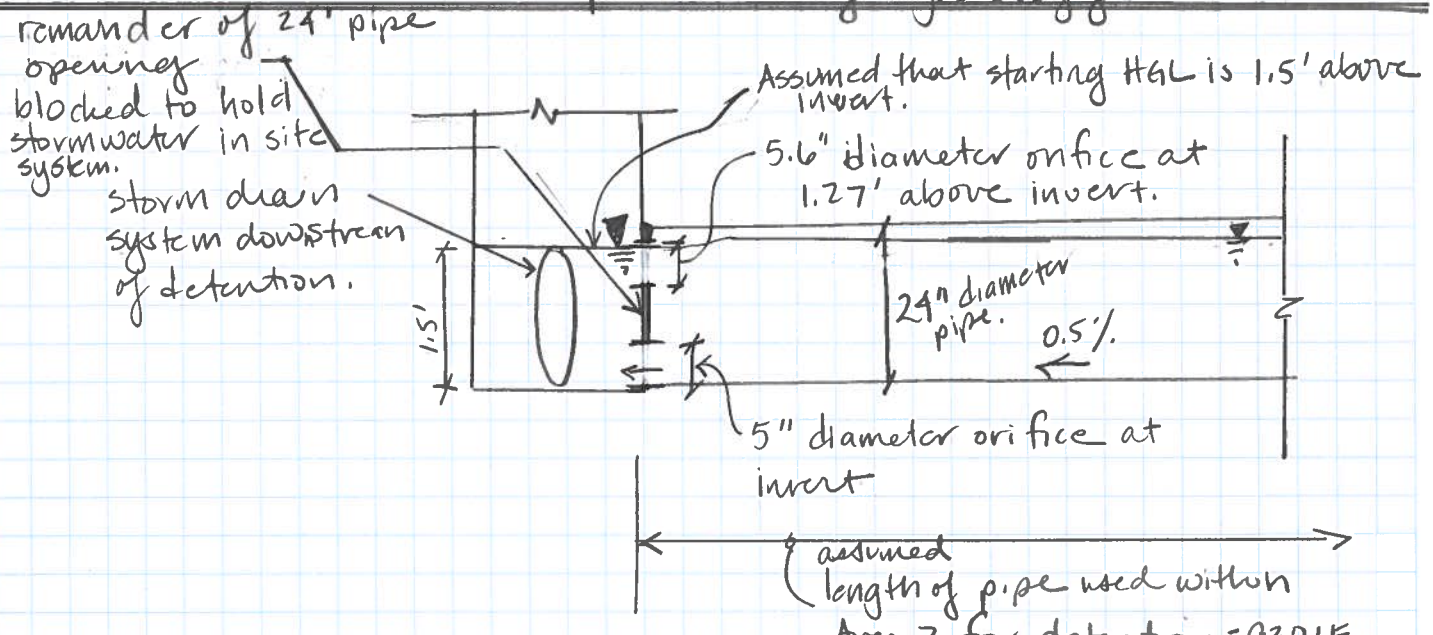
Post-Project Conditions cont'd:

For Area 2: Can post-project peak runoff, Q_{F10} be mitigated to at or below pre-project conditions?

① Create detention within proposed site storm drain within Area 2.

- 24" diameter pipe at 0.5% slope
- minimum 930 LF length (note Hydrographs program includes 3 barrels at 310 LF, each to model 930 LF of pipe)
- orifices detaining runoff have the following configuration (assumed for purposes of preliminary hydrology



Area 2 Detention Diagram NTS

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Hydraflow Hydrographs Output

Detention model for Area 2

Hydrograph Report

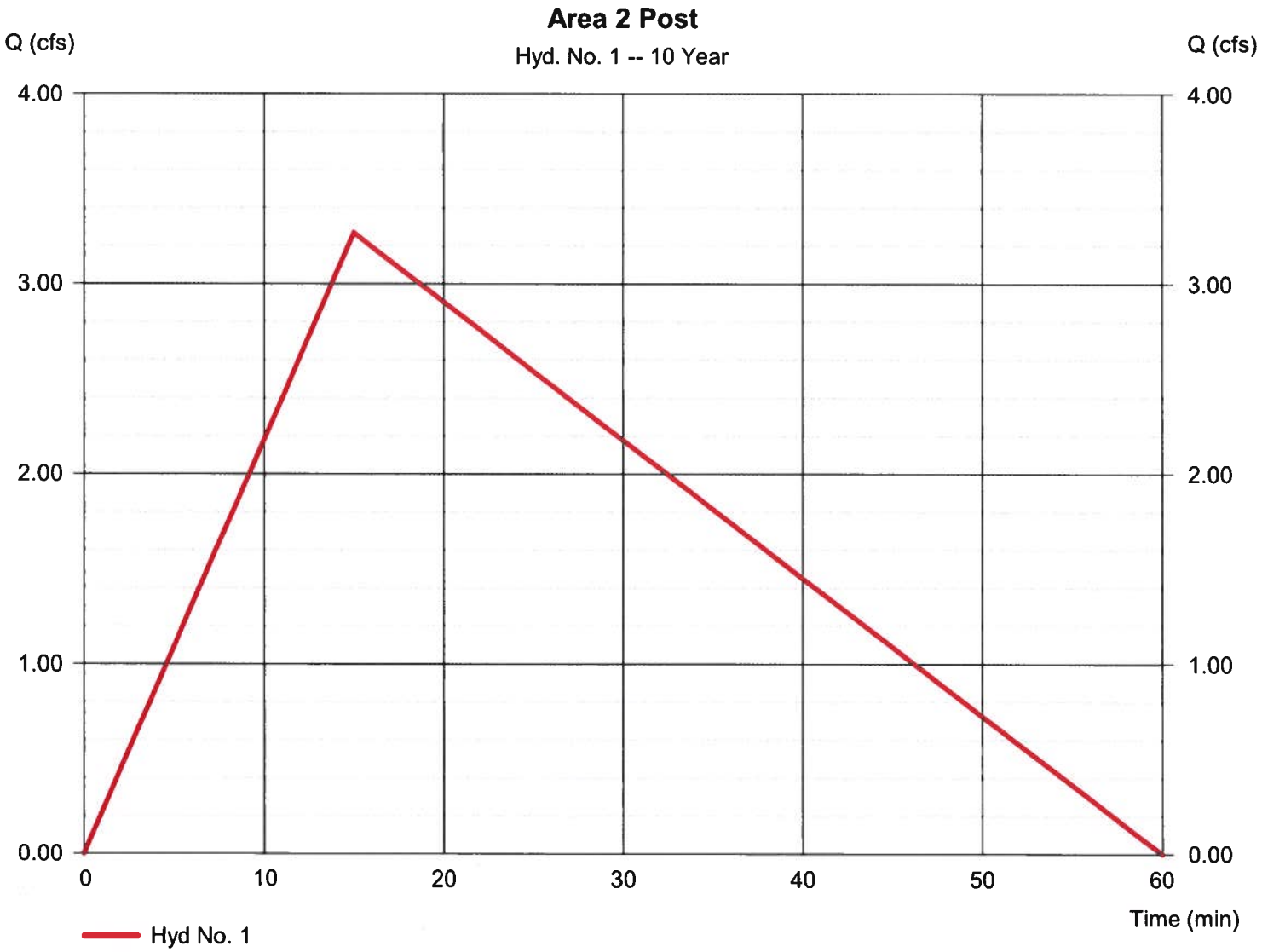
Hydraflow Hydrographs Extension for Autodesk® Civil 3D® 2019 by Autodesk, Inc. v2020

Friday, 11 / 30 / 2018

Hyd. No. 1

Area 2 Post

Hydrograph type	= Rational	Peak discharge	= 3.269 cfs
Storm frequency	= 10 yrs	Time to peak	= 15 min
Time interval	= 1 min	Hyd. volume	= 5,884 cuft
Drainage area	= 2.530 ac	Runoff coeff.	= 0.9
Intensity	= 1.436 in/hr	Tc by User	= 15.00 min
IDF Curve	= Petaluma-Corona-hydrographs.idf	Rec limb fact	= 1/3



Hydrograph Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® 2019 by Autodesk, Inc. v2020 Friday, 11 / 30 / 2018

Hyd. No. 2

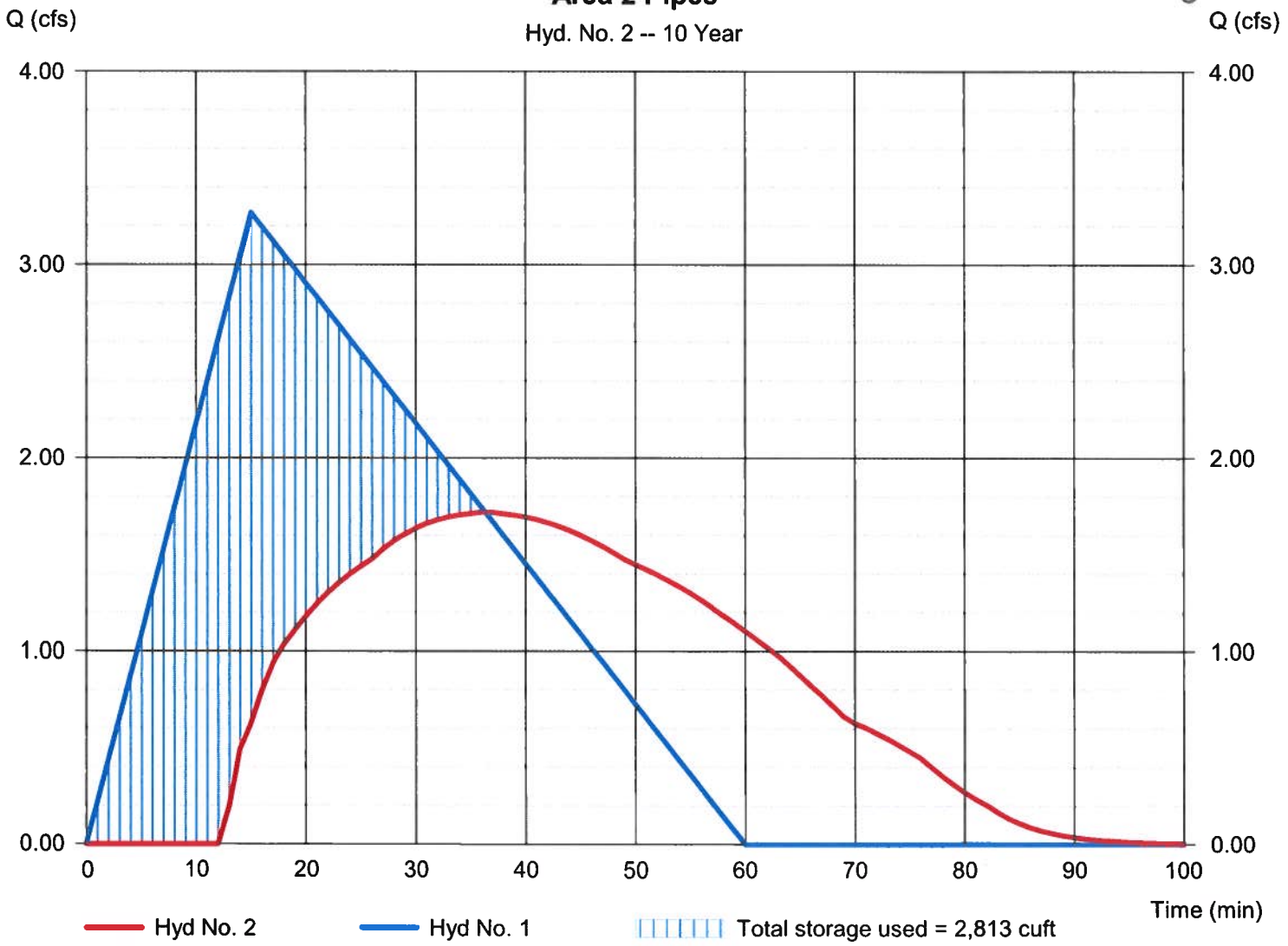
Area 2 Pipes

Hydrograph type	= Reservoir	Peak discharge	= 1.720 cfs ← Q_{F10}
Storm frequency	= 10 yrs	Time to peak	= 36 min
Time interval	= 1 min	Hyd. volume	= 4,840 cuft
Inflow hyd. No.	= 1 - Area 2 Post	Max. Elevation	= 31.48 ft
Reservoir name	= Storm Drain Pond	Max. Storage	= 2,813 cuft

Storage Indication method used.

10-year storm frequency event

Q_{F10} = 1.72 cfs (mitigated using detention within proposed site storm drain system)



Hydrograph Report

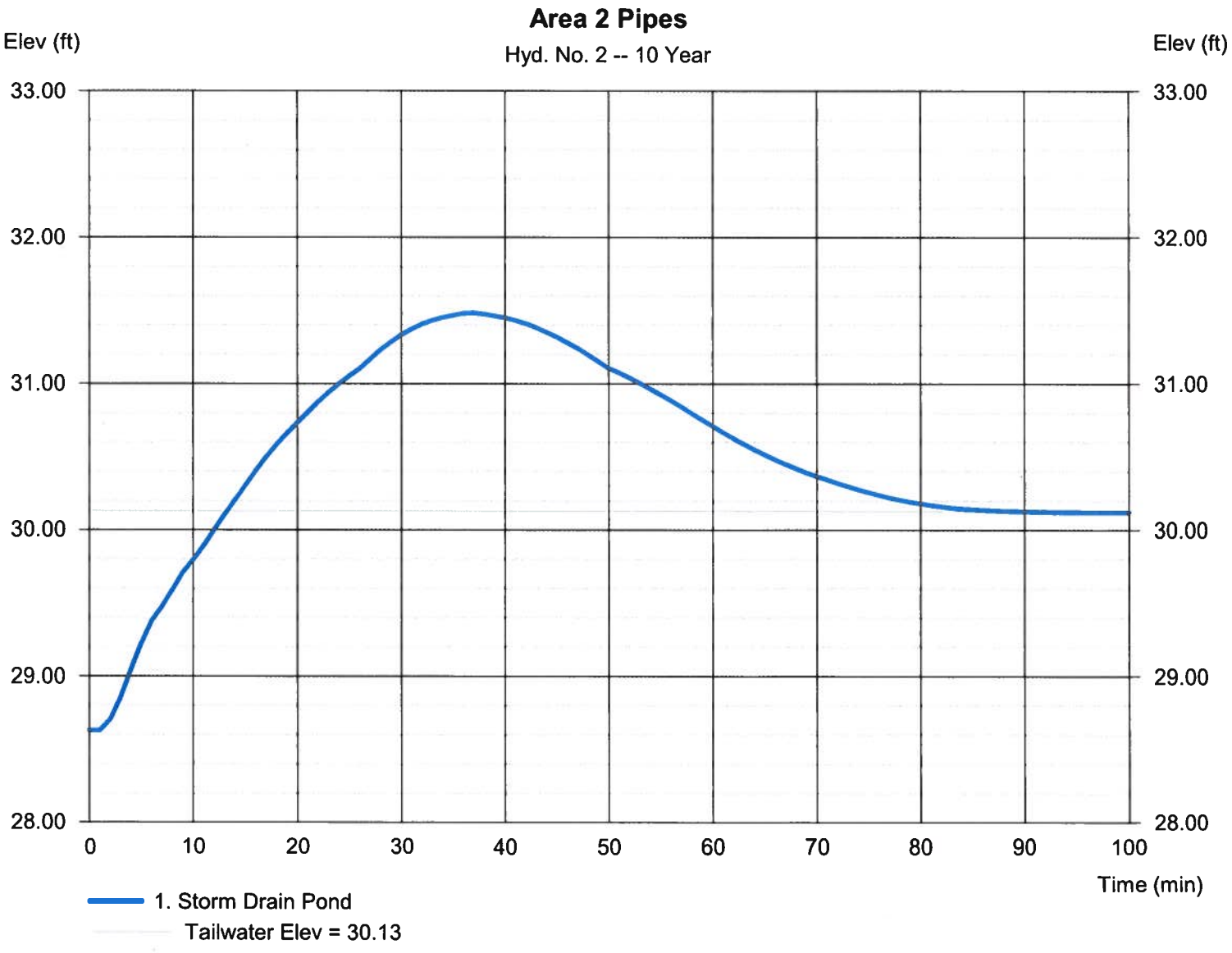
Hydraflow Hydrographs Extension for Autodesk® Civil 3D® 2019 by Autodesk, Inc. v2020 — Friday, 11 / 30 / 2018

Hyd. No. 2

Area 2 Pipes

Hydrograph type	= Reservoir	Peak discharge	= 1.720 cfs
Storm frequency	= 10 yrs	Time to peak	= 36 min
Time interval	= 1 min	Hyd. volume	= 4,840 cuft
Inflow hyd. No.	= 1 - Area 2 Post	Max. Elevation	= 31.48 ft
Reservoir name	= Storm Drain Pond	Max. Storage	= 2,813 cuft

Storage Indication method used.



Pond Report

Hydraflow Hydrographs Extension for Autodesk® Civil 3D® 2019 by Autodesk, Inc. v2020 — Friday, 11 / 30 / 2018

Pond No. 1 - Storm Drain Pond

Pond Data

UG Chambers -Invert elev. = 28.63 ft, Rise x Span = 2.00 x 2.00 ft, Barrel Len = 310.00 ft, No. Barrels = 3, Slope = 0.50%, Headers = Yes

Stage / Storage Table

Stage (ft)	Elevation (ft)	Contour area (sqft)	Incr. Storage (cuft)	Total storage (cuft)
0.00	28.63	n/a	0	0
0.35	28.98	n/a	61	61
0.71	29.34	n/a	102	163
1.06	29.69	n/a	289	452
1.42	30.05	n/a	480	932
1.77	30.40	n/a	554	1,487
2.13	30.76	n/a	554	2,041
2.48	31.11	n/a	480	2,521
2.84	31.47	n/a	289	2,810
3.19	31.82	n/a	101	2,911
3.55	32.18	n/a	61	2,973

Culvert / Orifice Structures

	[A]	[B]	[C]	[PrfRsr]
Rise (in)	= 5.00	5.60	0.00	0.00
Span (in)	= 5.00	5.60	0.00	0.00
No. Barrels	= 1	1	1	0
Invert El. (ft)	= 28.63	29.90	0.00	0.00
Length (ft)	= 5.00	5.00	0.00	0.00
Slope (%)	= 2.00	2.00	0.00	n/a
N-Value	= .013	.013	.013	n/a
Orifice Coeff.	= 0.60	0.60	0.60	0.60
Multi-Stage	= n/a	No	No	No

Weir Structures

	[A]	[B]	[C]	[D]
Crest Len (ft)	= 0.00	0.00	0.00	0.00
Crest El. (ft)	= 0.00	0.00	0.00	0.00
Weir Coeff.	= 3.33	3.33	3.33	3.33
Weir Type	= ---	---	---	---
Multi-Stage	= No	No	No	No

Exfil.(in/hr) = 0.000 (by Contour)

TW Elev. (ft) = 30.13

Note: Culvert/Orifice outflows are analyzed under inlet (ic) and outlet (oc) control. Weir risers checked for orifice conditions (ic) and submergence (s).

Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
0.00	0	28.63	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.04	6	28.67	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.07	12	28.70	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.11	18	28.74	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.14	25	28.77	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.18	31	28.81	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.21	37	28.84	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.25	43	28.88	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.28	49	28.91	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.32	55	28.95	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.35	61	28.98	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.39	72	29.02	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.43	82	29.06	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.46	92	29.09	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.50	102	29.13	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.53	112	29.16	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.57	122	29.20	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.60	133	29.23	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.64	143	29.27	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.67	153	29.30	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.71	163	29.34	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.75	192	29.38	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.78	221	29.41	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.82	250	29.45	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.85	279	29.48	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.89	307	29.52	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.92	336	29.55	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.96	365	29.59	0.00	0.00	---	---	---	---	---	---	---	---	0.000
0.99	394	29.62	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.03	423	29.66	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.06	452	29.69	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.10	500	29.73	0.00	0.00	---	---	---	---	---	---	---	---	0.000

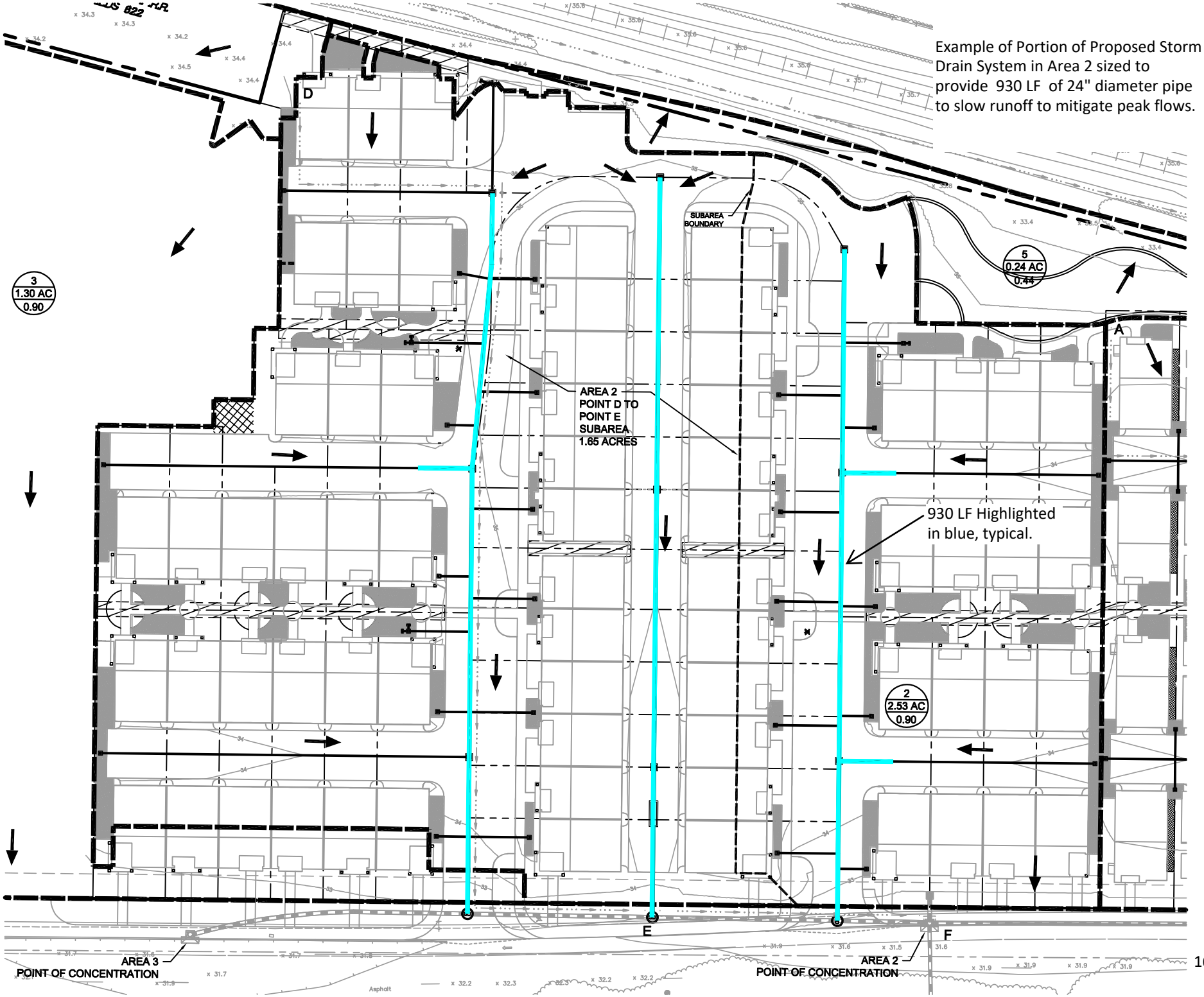
Continues on next page...

Storm Drain Pond

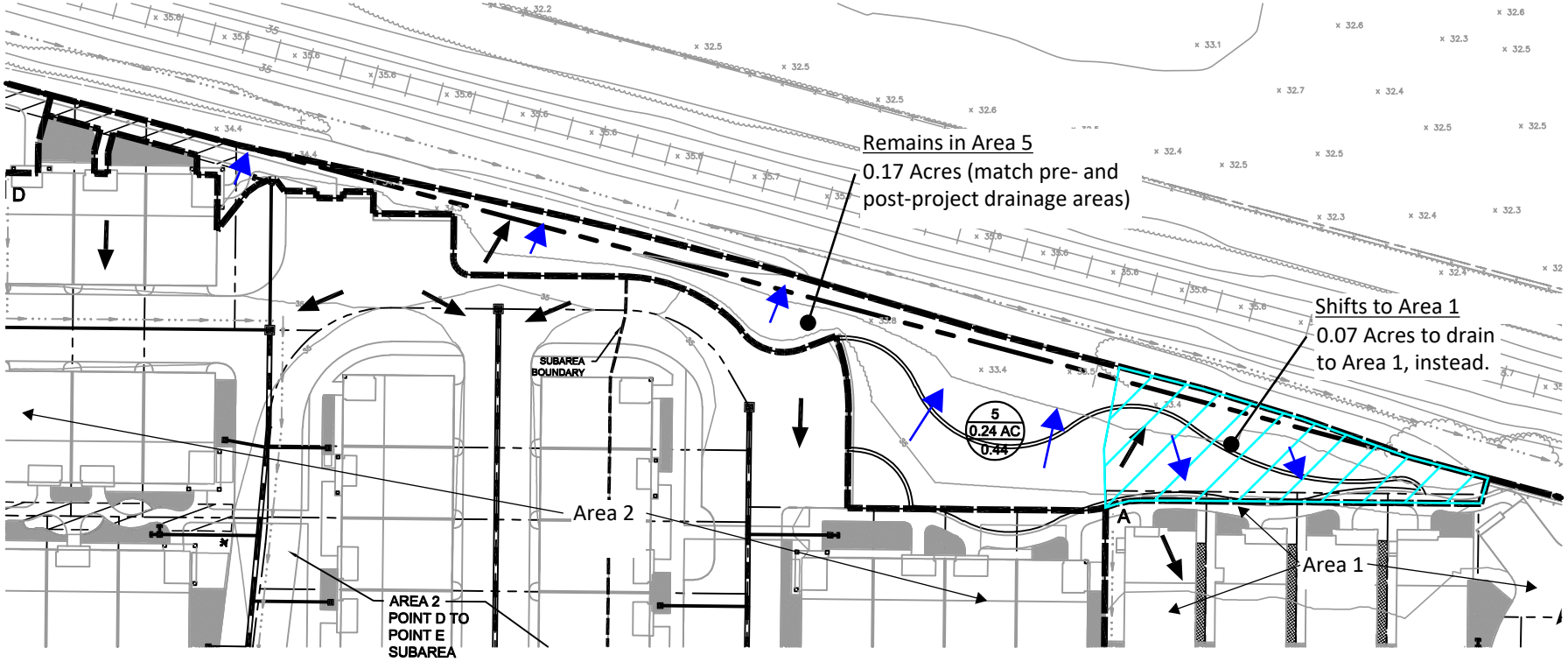
Stage / Storage / Discharge Table

Stage ft	Storage cuft	Elevation ft	Clv A cfs	Clv B cfs	Clv C cfs	PrfRsr cfs	Wr A cfs	Wr B cfs	Wr C cfs	Wr D cfs	Exfil cfs	User cfs	Total cfs
1.14	548	29.77	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.17	596	29.80	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.21	644	29.84	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.24	692	29.87	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.28	740	29.91	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.31	788	29.94	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.35	836	29.98	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.38	884	30.01	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.42	932	30.05	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.46	988	30.09	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.49	1,043	30.12	0.00	0.00	---	---	---	---	---	---	---	---	0.000
1.53	1,099	30.16	0.11 ic	0.09 oc	---	---	---	---	---	---	---	---	0.198
1.56	1,154	30.19	0.16 ic	0.16 oc	---	---	---	---	---	---	---	---	0.328
1.60	1,209	30.23	0.20 ic	0.24 oc	---	---	---	---	---	---	---	---	0.442
1.63	1,265	30.26	0.24 ic	0.27 oc	---	---	---	---	---	---	---	---	0.507
1.67	1,320	30.30	0.27 ic	0.29 oc	---	---	---	---	---	---	---	---	0.561
1.70	1,376	30.33	0.30 ic	0.31 oc	---	---	---	---	---	---	---	---	0.606
1.74	1,431	30.37	0.32 ic	0.32 oc	---	---	---	---	---	---	---	---	0.638
1.77	1,487	30.40	0.34 ic	0.37 oc	---	---	---	---	---	---	---	---	0.712
1.81	1,542	30.44	0.37 ic	0.41 oc	---	---	---	---	---	---	---	---	0.778
1.85	1,597	30.48	0.39 ic	0.45 oc	---	---	---	---	---	---	---	---	0.839
1.88	1,653	30.51	0.41 ic	0.49 oc	---	---	---	---	---	---	---	---	0.895
1.92	1,708	30.55	0.42 ic	0.52 oc	---	---	---	---	---	---	---	---	0.947
1.95	1,764	30.58	0.44 ic	0.55 ic	---	---	---	---	---	---	---	---	0.993
1.99	1,819	30.62	0.46 ic	0.57 ic	---	---	---	---	---	---	---	---	1.032
2.02	1,874	30.65	0.47 ic	0.59 ic	---	---	---	---	---	---	---	---	1.069
2.06	1,930	30.69	0.49 ic	0.61 ic	---	---	---	---	---	---	---	---	1.105
2.09	1,985	30.72	0.51 ic	0.63 ic	---	---	---	---	---	---	---	---	1.139
2.13	2,041	30.76	0.52 ic	0.65 ic	---	---	---	---	---	---	---	---	1.173
2.17	2,089	30.80	0.54 ic	0.67 ic	---	---	---	---	---	---	---	---	1.206
2.20	2,137	30.83	0.55 ic	0.69 ic	---	---	---	---	---	---	---	---	1.237
2.24	2,185	30.87	0.56 ic	0.71 ic	---	---	---	---	---	---	---	---	1.268
2.27	2,233	30.90	0.58 ic	0.72 ic	---	---	---	---	---	---	---	---	1.299
2.31	2,281	30.94	0.59 ic	0.74 ic	---	---	---	---	---	---	---	---	1.328
2.34	2,329	30.97	0.60 ic	0.75 ic	---	---	---	---	---	---	---	---	1.357
2.38	2,377	31.01	0.62 ic	0.77 ic	---	---	---	---	---	---	---	---	1.386
2.41	2,425	31.04	0.63 ic	0.79 ic	---	---	---	---	---	---	---	---	1.413
2.45	2,473	31.08	0.64 ic	0.80 ic	---	---	---	---	---	---	---	---	1.441
2.48	2,521	31.11	0.65 ic	0.82 ic	---	---	---	---	---	---	---	---	1.467
2.52	2,550	31.15	0.66 ic	0.83 ic	---	---	---	---	---	---	---	---	1.494
2.56	2,579	31.19	0.67 ic	0.84 ic	---	---	---	---	---	---	---	---	1.519
2.59	2,608	31.22	0.69 ic	0.86 ic	---	---	---	---	---	---	---	---	1.545
2.63	2,636	31.26	0.70 ic	0.87 ic	---	---	---	---	---	---	---	---	1.570
2.66	2,665	31.29	0.71 ic	0.89 ic	---	---	---	---	---	---	---	---	1.594
2.70	2,694	31.33	0.72 ic	0.90 ic	---	---	---	---	---	---	---	---	1.619
2.73	2,723	31.36	0.73 ic	0.91 ic	---	---	---	---	---	---	---	---	1.642
2.77	2,752	31.40	0.74 ic	0.93 ic	---	---	---	---	---	---	---	---	1.666
2.80	2,781	31.43	0.75 ic	0.94 ic	---	---	---	---	---	---	---	---	1.689
2.84	2,810	31.47	0.76 ic	0.95 ic	---	---	---	---	---	---	---	---	1.712
2.88	2,820	31.51	0.77 ic	0.96 ic	---	---	---	---	---	---	---	---	1.735
2.91	2,830	31.54	0.78 ic	0.98 ic	---	---	---	---	---	---	---	---	1.757
2.95	2,840	31.58	0.79 ic	0.99 ic	---	---	---	---	---	---	---	---	1.779
2.98	2,850	31.61	0.80 ic	1.00 ic	---	---	---	---	---	---	---	---	1.800
3.02	2,860	31.65	0.81 ic	1.01 ic	---	---	---	---	---	---	---	---	1.822
3.05	2,871	31.68	0.82 ic	1.03 ic	---	---	---	---	---	---	---	---	1.843
3.09	2,881	31.72	0.83 ic	1.04 ic	---	---	---	---	---	---	---	---	1.864
3.12	2,891	31.75	0.84 ic	1.05 ic	---	---	---	---	---	---	---	---	1.885
3.16	2,901	31.79	0.85 ic	1.06 ic	---	---	---	---	---	---	---	---	1.905
3.19	2,911	31.82	0.85 ic	1.07 ic	---	---	---	---	---	---	---	---	1.926
3.23	2,917	31.86	0.86 ic	1.08 ic	---	---	---	---	---	---	---	---	1.946
3.27	2,923	31.90	0.87 ic	1.09 ic	---	---	---	---	---	---	---	---	1.966
3.30	2,930	31.93	0.88 ic	1.10 ic	---	---	---	---	---	---	---	---	1.985
3.34	2,936	31.97	0.89 ic	1.12 ic	---	---	---	---	---	---	---	---	2.005
3.37	2,942	32.00	0.90 ic	1.13 ic	---	---	---	---	---	---	---	---	2.024
3.41	2,948	32.04	0.91 ic	1.14 ic	---	---	---	---	---	---	---	---	2.043
3.44	2,954	32.07	0.92 ic	1.15 ic	---	---	---	---	---	---	---	---	2.062
3.48	2,960	32.11	0.92 ic	1.16 ic	---	---	---	---	---	---	---	---	2.081
3.51	2,966	32.14	0.93 ic	1.17 ic	---	---	---	---	---	---	---	---	2.100
3.55	2,973	32.18	0.94 ic	1.18 ic	---	---	---	---	---	---	---	---	2.118

...End


Example of Portion of Proposed Storm Drain System in Area 2 sized to provide 930 LF of 24" diameter pipe to slow runoff to mitigate peak flows.
D
SUBAREA BOUNDARY
5
0.24 AC
0.44
3
1.30 AC
0.90
A
AREA 2
POINT D TO
POINT E
SUBAREA
1.65 ACRES
930 LF Highlighted in blue, typical.
2
2.53 AC
0.90
E
F
AREA 3
POINT OF CONCENTRATION
AREA 2
POINT OF CONCENTRATION

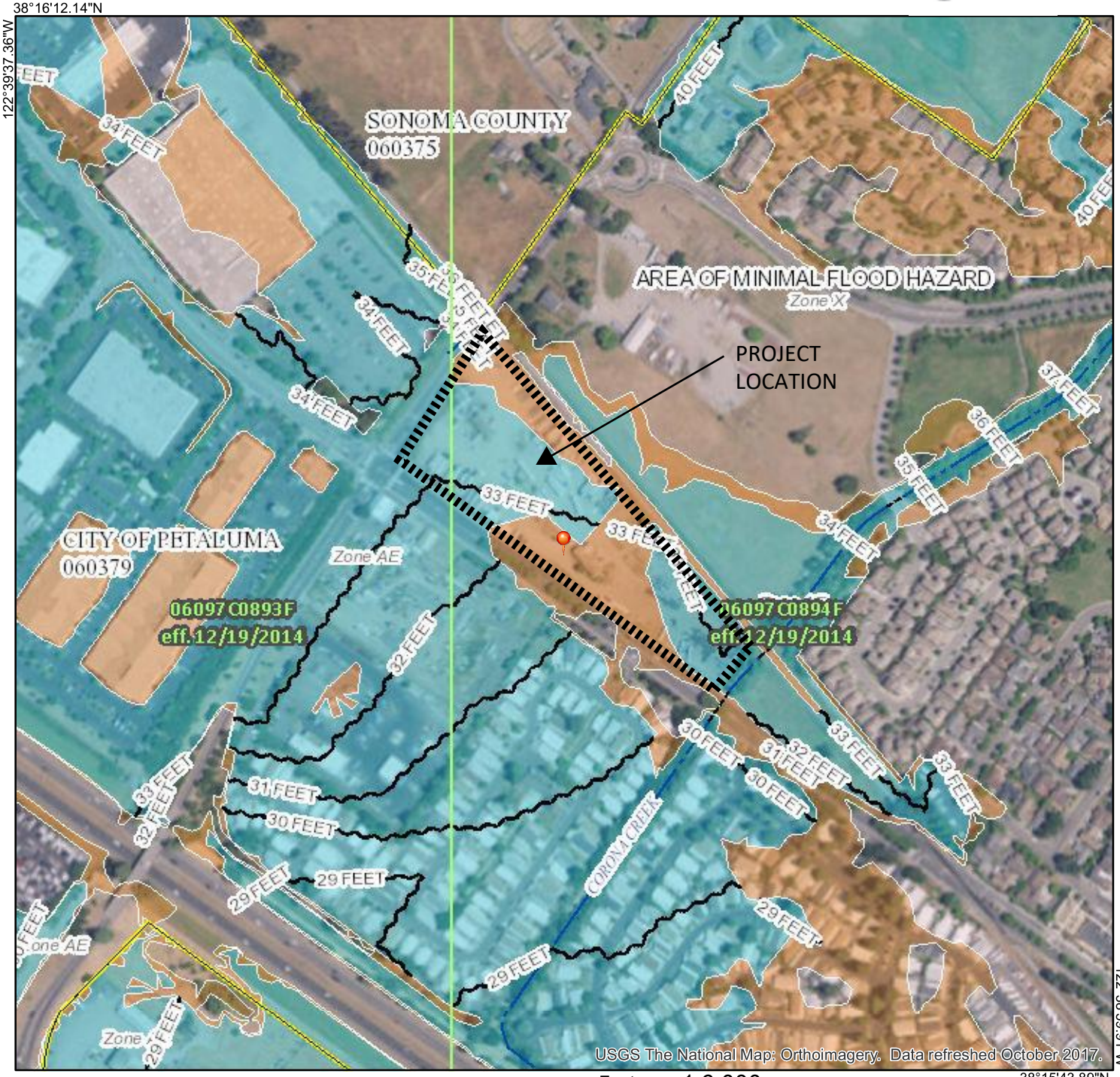
Example of portion of Area 5 graded to drain to Area 1, instead, in order to match pre- and post-project peak flow.



8.0 EXHIBITS

National Flood Hazard Layer FIRMette

FEMA



Legend

SEE FIS REPORT FOR DETAILED LEGEND AND INDEX MAP FOR FIRM PANEL LAYOUT

- **SPECIAL FLOOD HAZARD AREAS**
  - Without Base Flood Elevation (BFE) *Zone A, V, A99*
  - With BFE or Depth *Zone AE, AO, AH, VE, AR*
  - Regulatory Floodway
- **OTHER AREAS OF FLOOD HAZARD**
  - 0.2% Annual Chance Flood Hazard, Areas of 1% annual chance flood with average depth less than one foot or with drainage areas of less than one square mile *Zone X*
  - Future Conditions 1% Annual Chance Flood Hazard *Zone X*
  - Area with Reduced Flood Risk due to Levee. See Notes. *Zone X*
  - Area with Flood Risk due to Levee *Zone D*
- **OTHER AREAS**
  - NO SCREEN Area of Minimal Flood Hazard *Zone X*
  - Effective LOMRs
  - Area of Undetermined Flood Hazard *Zone D*
- **GENERAL STRUCTURES**
  - Channel, Culvert, or Storm Sewer
  - Levee, Dike, or Floodwall
- **OTHER FEATURES**
  - 20.2 / 17.5 Cross Sections with 1% Annual Chance Water Surface Elevation
  - Coastal Transect
  - Base Flood Elevation Line (BFE)
  - Limit of Study
  - Jurisdiction Boundary
  - Coastal Transect Baseline
  - Profile Baseline
  - Hydrographic Feature
- **MAP PANELS**
  - Digital Data Available
  - No Digital Data Available
  - Unmapped

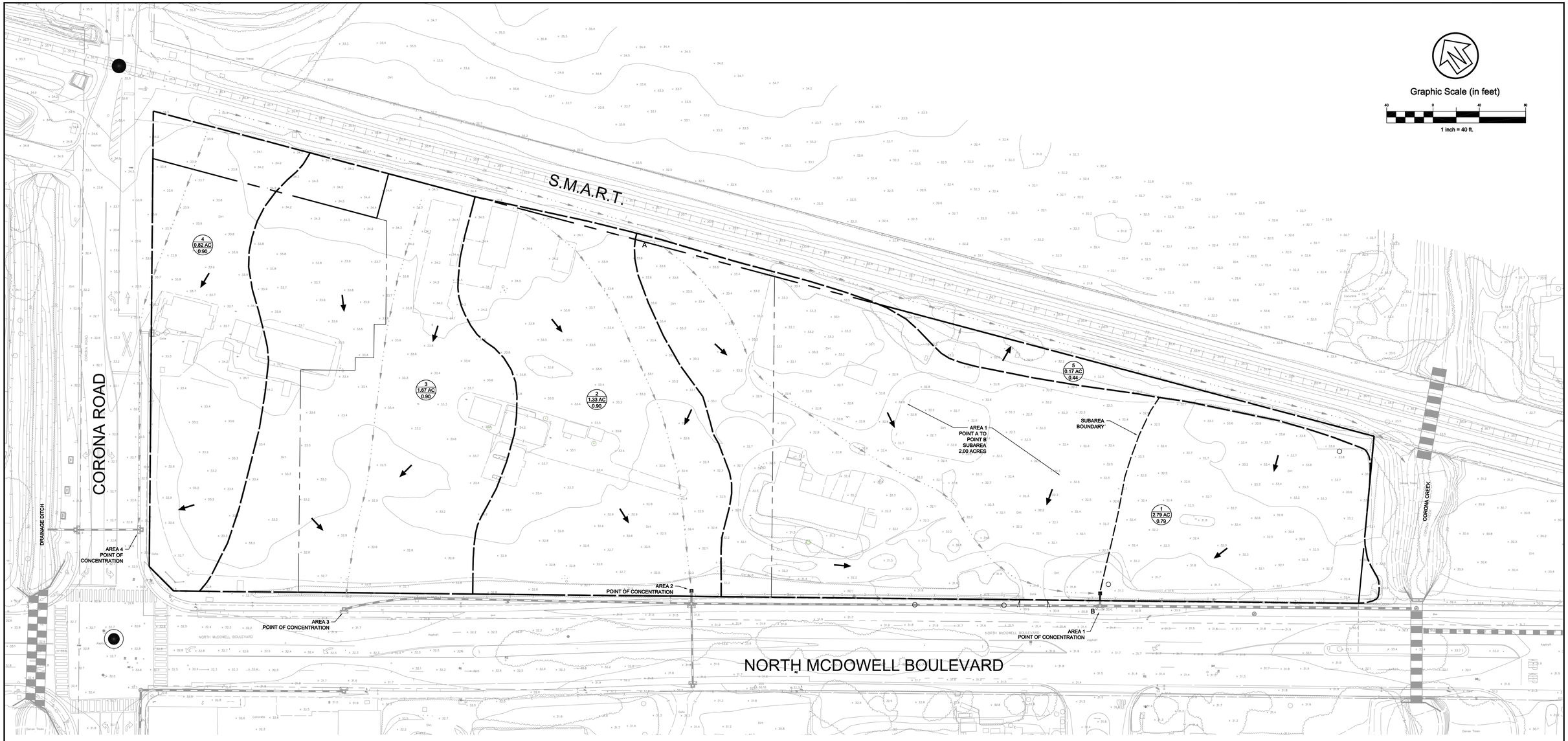
N

The pin displayed on the map is an approximate point selected by the user and does not represent an authoritative property location.

This map complies with FEMA's standards for the use of digital flood maps if it is not void as described below. The basemap shown complies with FEMA's basemap accuracy standards

The flood hazard information is derived directly from the authoritative NFHL web services provided by FEMA. This map was exported on 11/29/2018 at 7:24:55 PM and does not reflect changes or amendments subsequent to this date and time. The NFHL and effective information may change or become superseded by new data over time.

This map image is void if the one or more of the following map elements do not appear: basemap imagery, flood zone labels, legend, scale bar, map creation date, community identifiers, FIRM panel number, and FIRM effective date. Map images for unmapped and unmodernized areas cannot be used for regulatory purposes.



HYDROLOGY LEGEND

- # / XXX AC / C — DRAINAGE SUB-AREA DESIGNATION; SUB-AREA IN ACRES; RUNOFF COEFFICIENT
- OVERLAND FLOW DIRECTION
- DRAINAGE AREA BOUNDARY
- DRAINAGE SUB-AREA BOUNDRY
- DRAINAGE PATH

Rev	Date	Description	Designed	Drawn	Checked
-	09/06/2018	PROGRESS PLOT TO PROJECT TEAM		JLW	WFL

CSW | ST2
CSW/Stuber-Stroeh Engineering Group, Inc.
Civil & Structural Engineers | Surveying & Mapping | Environmental Planning
Land Planning | Construction Management
45 Leveroni Court
Novato, CA 94949
tel: 415.883.9850
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http://www.cswst2.com

City	Petaluma
County	Sonoma
State	California

CORONA STATION DEVELOPMENT

HYDROLOGY MAP - PRE PROJECT CONDITIONS

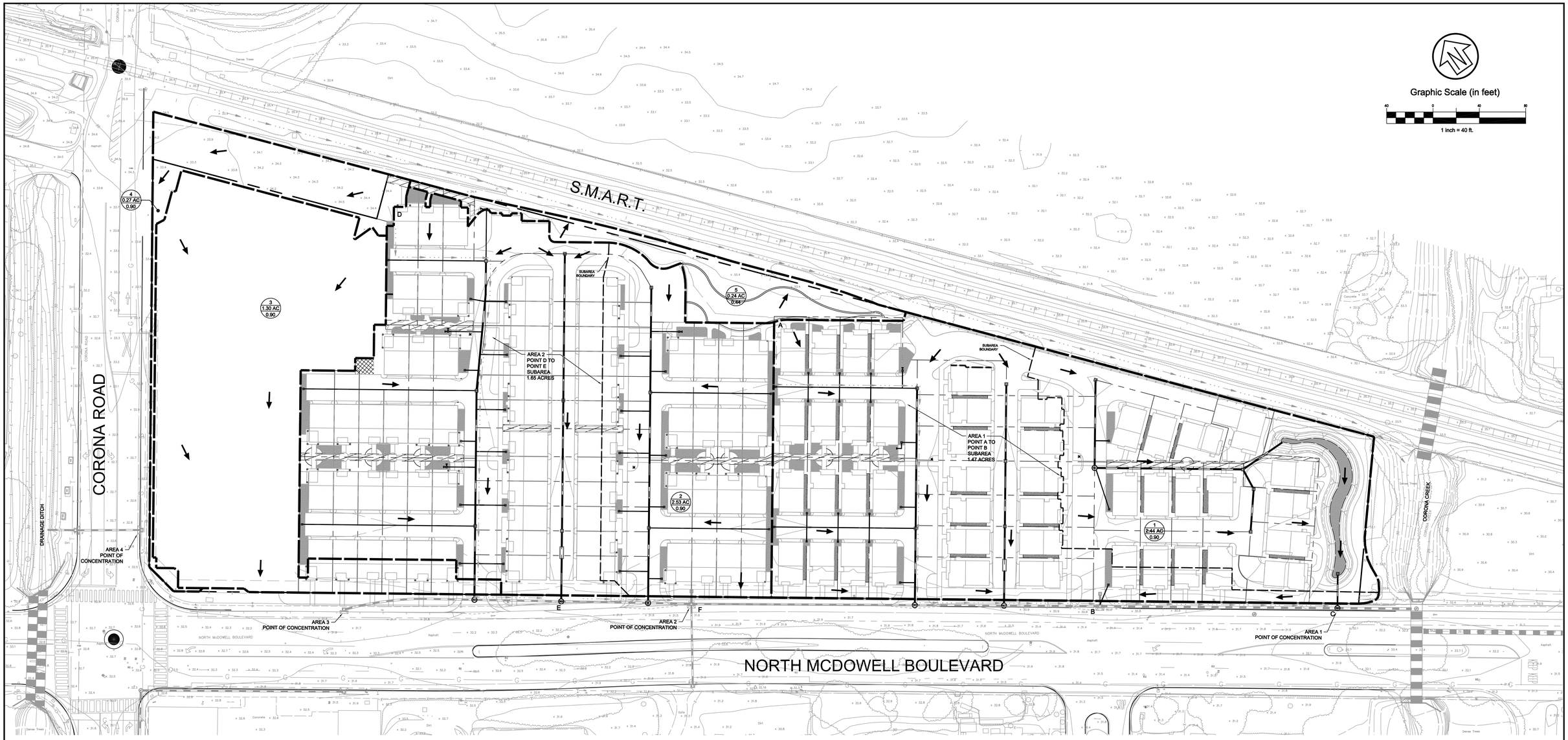
LOMAS PARTNERS, LLC - APN 137-061-19

Prepared Under the Direction of:

Sheet
H1.0

Scale:	1" = 40'
Date:	09/04/2018
Project Number:	5.1498.01
Plan File:	XX

P:\05\5149\00\DWG\Sheet_Drawings\Design Development\H1.0 Hydrology Map Pre Project.dwg 11/08/2018 - 10:07 AM rsavik 1:1.5842



HYDROLOGY LEGEND

- # / XXX AC / C — DRAINAGE SUB-AREA DESIGNATION; SUB-AREA IN ACRES; RUNOFF COEFFICIENT
- OVERLAND FLOW DIRECTION
- DRAINAGE AREA BOUNDARY
- DRAINAGE SUB-AREA BOUNDRY
- DRAINAGE PATH

Rev	Date	Description	Designed	Drawn	Checked
-	11/26/2018	INITIAL CITY SUBMITTAL	SAS	SAS	WFL

CSW | ST2
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tel: 415.883.9850
fax: 415.883.9835
http://www.cswst2.com

City: Petaluma
County: Sonoma
State: California

CORONA STATION DEVELOPMENT

HYDROLOGY MAP - POST PROJECT CONDITIONS

LOMAS PARTNERS, LLC - APN 137-061-19

Prepared Under the Direction of:

Sheet H1.1

Scale: 1" = 40'
Date: 11/26/2018
Project Number: 5.1498.01
Plan File: D-5517-