Appendix G. Hydrology and Hydraulics Report

February 2024

Last Chance Grade Permanent Restoration Project
Hydrology and Hydraulics Study Report

Submittal #SUB080

June 2023

EA# 01-0F280
Project EFIS# 0115000099
Del Norte County, U.S. 101,
PM 12.7/16.5

Caltrans

LAST CHANCE GRADE

Hydrology and Hydraulics Study Report

for the

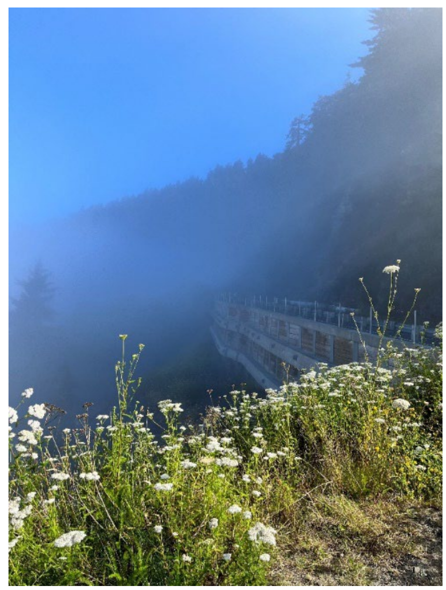
LAST CHANCE GRADE

PERMANENT RESTORATION PROJECT

U.S. Highway 101 (01-DN-101)

from Post Miles 12.7 to 16.5

in Del Norte County, California



June 2023

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CALIFORNIA DEPARTMENT OF TRANSPORTATION

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HYDROLOGY AND HYDRAULICS STUDY REPORT

LAST CHANCE GRADE

PERMANENT RESTORATION PROJECT

U.S. HIGHWAY 101

01-DN-101 POST MILES 12.7 TO 16.5

EFIS 0115000099 / EA 01-0F280

June 2023

STATE OF CALIFORNIA
Department of Transportation

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Executive Summary

The Last Chance Grade Permanent Restoration Project (Project) is located on a section of U.S. Highway 101 (U.S. 101) known as Last Chance Grade (LCG), south of Crescent City in Del Norte County, California. The California Department of Transportation (Caltrans) proposes this Project to develop a long-term solution to the instability and potential roadway failure at LCG. The Project considers alternatives that provide a more reliable connection, reduce maintenance costs, and protect the economy, natural resources, and cultural landscapes. Under consideration are two build alternatives (Alternative F and Alternative X) and a no-build alternative.

Alternative X would involve reengineering a 1.6-mile-long section of the existing highway to minimize the risk of landslides. Main Project components would include an underground drainage system, a series of retaining walls, and strategic eastward retreats.

Alternative F would involve constructing a 6,000-foot (1.1-mile) tunnel to the east of the existing highway to avoid the most intense areas of known landslides and geologic instability. Main Project components would include a tunnel and its portals, a bridge, and an Operations Maintenance Center.

Geotechnical investigations would be needed for both Alternative X and Alternative F to inform Project design.

Under the no-build alternative, no work would be done on the existing highway; existing conditions would persist, including the continuation of emergency repairs and enhanced maintenance.

The purpose of this *Hydrology and Hydraulics Study Report* is to document the existing drainage conditions and provide preliminary recommended drainage improvements to route or collect on-site and off-site stormwater runoff and to discharge the flows to existing cross culvert outfalls for the Project Approval and Environmental Document (PA/ED) phase of the Project.

The Project is under the jurisdiction of the North Coast Regional Water Quality Control Board (RWQCB) and is, therefore, subject to the *Water Quality Control Plan for the North Coast Region* (Basin Plan). Because the Project discharges to the Pacific Ocean, it is also subject to the State Water Resources Control Board's *Water Quality Control Plan Ocean Waters of California* (Ocean Plan).

Various aquatic resources, including wetlands and other waters, are present within the Project Environmental Study Limits (ESL). Details on the features within the ESL and a 100-foot buffer are reported in the Project's *Federal Aquatic Resources Delineation* and *State Aquatic Resources Delineation* (Federal and State ARDs). Streams within this area drain either directly to the Pacific Ocean or indirectly through tributary systems and Wilson Creek.

The Project ESL is located within the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map 06015C0365F (Panel 365 of 675) and 06015C0455F (Panel 455 of 675) for Del Norte County, California, and incorporated areas, revised on August 2, 2017. The effective

Flood Insurance Study for Del Norte County, California, and incorporated areas associated with the Project is 06015CV000C (revised by FEMA on August 2, 2017). FEMA documents indicate that both Alternative X and Alternative F are located primarily within FEMA Zone D, which is defined as having possible but undetermined flood hazards because no flood hazard analyses have been conducted for these areas. While a portion of the ESL is within FEMA Zone X, no work on either alternative is proposed for this portion of the ESL.

The adjacent coast is within the Zone VE floodplain. Zone VE floodplains are coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. The base flood elevation (BFE) derived from detailed analyses is shown at selected intervals within these zones. The BFE of the Zone VE floodplain adjacent to the Project site is 19 feet NAVD 88. The Project area is adjacent to Wilson Creek, which is within a Zone A floodplain, and Zone A floodplains are considered special flood hazard areas with a 1% annual chance of flooding. Because detailed analyses are not performed for such areas, no depths or BFEs are shown within these zones. However, there would be no Project work within a Zone A floodplain.

The Project is located within Caltrans' right-of-way; thus, the drainage design for the Project will be based on procedures presented in the updated seventh edition of the Caltrans' *Highway Design Manual* (HDM) and the Federal Highway Administration's (FHWA) *Hydraulic Engineering Circular Number 22* (HEC-22), a publication for highway pavement drainage. The cross culvert drainage systems will be evaluated using Autodesk's Hydraflow Storm Sewers software. Calculations are likely to be provided in the design phase. The cross culvert drainage systems are likely to be evaluated with a starting tailwater to ensure the hydraulic grade line is contained within the cross culvert during the 10-year storm event and does not cause the headwater elevation to rise above the inlet top of the culvert during the 100-year storm event. The longitudinal systems would be evaluated using the 25-year storm event.

The overall existing drainage patterns would be maintained. The Project alternatives are anticipated to impact off-site run-on. Therefore, preliminary off-site analysis was done for the PA/ED phase of the Project to assess pre-Project and post-Project flows. Due to the large off-site watershed, a detailed time of concentration was performed assessing sheet flow, shallow concentrated flow, and concentrated flow. The hydrology done is preliminary and is likely to be refined in the Plans, Estimates, and Specifications phase.

Per Caltrans' Water Quality Planning Tool, the Redwood National and State Parks provide 35.9 miles of shoreline for the Redwood National Park's Areas of Special Biological Significance (ASBS). Currently, there are two ASBS discharge points identified within the Project ESL, RED014 and RED015 (located at PMs 14.65 and 14.56, respectively), that may be impacted by Project activities.

The Project includes retaining wall improvements, which might require the need for additional inlet improvements. Grate interception, bypass, and gutter spread calculations were based on formulas and procedures from FHWA's HEC-22. The goal of the preliminary drainage design is to limit the width of flooding during the design storm to within the roadway shoulder and to keep bypass flow that crosses over traveled lanes under 0.1 cubic feet per second. The goal is also to ensure that flows collected along the shoulder do not overtop the adjacent barriers or dikes that are meant to contain the flow. A drainage inlet is required to be proposed at roadway low points, where there would be a dike, retaining wall, or barrier. Flanking inlets are required to be proposed approximately 20 to 30 feet from every low-point inlet. For all proposed roadside ditches and bioretention areas with concentrated flow, preliminary ditch calculations were performed using the Manning's equation.

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Acronyms

ABS	acrylonitrile butadiene styrene
ac	acre
ASBS	Areas of Special Biological Significance
Basin Plan	*Water Quality Control Plan for the North Coast Region*
BFE	base flood elevation
CA	California
Caltrans	California Department of Transportation
CCC	California Coastal Commission
cfs	cubic feet per second
CMP	corrugated metal pipe
CPP	corrugated plastic pipe
ESL	Environmental Study Limits
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
ft	feet
fps	feet per second
ft/ft	feet per feet
HA	hydrologic area
HDM	*Highway Design Manual*
HDPE	high-density polyethylene
HGL	hydraulic grade line
in.	inch
in./hr	inches per hour
LCG	Last Chance Grade
min	minute
NAVD 88	North American Vertical Datum of 1988
NOAA	National Oceanic and Atmospheric Administration
Ocean Plan	*Water Quality Control Plan Ocean Waters of California*
PA/ED	Project Approval and Environmental Document
Project	Last Chance Grade Permanent Restoration Project
PS&E	Plans, Specifications, and Estimates
PM	post mile
RSP	rock slope protection
RWQCB	Regional Water Quality Control Board
SWRCB	State Water Resources Control Board
U.S. 101	U.S. Highway 101
USGS	United States Geological Survey
WQAR	*Water Quality Assessment Report*

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CHAPTER 1 INTRODUCTION

1.1 Proposed Project

The proposed Last Chance Grade Permanent Restoration Project (Project) is located on a section of U.S. Highway 101 (U.S. 101) known as Last Chance Grade (LCG) in southern Del Norte County, California (CA). It is approximately 10 miles south of Crescent City, from post mile (PM) 12.7 to PM 16.5.

1.2 Project Purpose

The purpose of the Project is to develop a long-term solution to the instability and potential roadway failure at LCG. The project considers alternatives that provide a more reliable connection, reduce maintenance costs, and protect the economy, natural resources, and cultural landscapes.

A long-term sustainable solution at LCG is needed to address:

- Economic ramifications of a long-term failure and closure
- Risk of delay/detour to the traveling public
- Increasing maintenance and emergency project costs
- Increase in frequency and severity of large storm events caused by climate change

Refer to Figure 1 for the Project Location Map (Caltrans, 2023a).

1.3 Project Alternatives

The Project proposes two build alternatives—Alternative X and Alternative F—in addition to the no-build alternative. Refer to Figure 2 for an overview of the Project build alternatives (Caltrans, 2023a).

Alternative X would involve reengineering a 1.6-mile-long section of the existing highway to minimize the risk of landslides. Main Project components would include an underground drainage system, a series of retaining walls, and strategic eastward retreats.

Alternative F would involve constructing a 6,000-foot (1.1-mile) tunnel to the east of the existing highway to avoid the most intense areas of known landslides and geologic instability. Main Project components would include a tunnel and its portals, a bridge, and an Operations Maintenance Center.

Geotechnical investigations would be needed for both Alternative X and Alternative F to inform Project design.

Under the no-build alternative, no work would be done on the existing highway; existing conditions would persist, including the continuation of emergency repairs and enhanced maintenance.

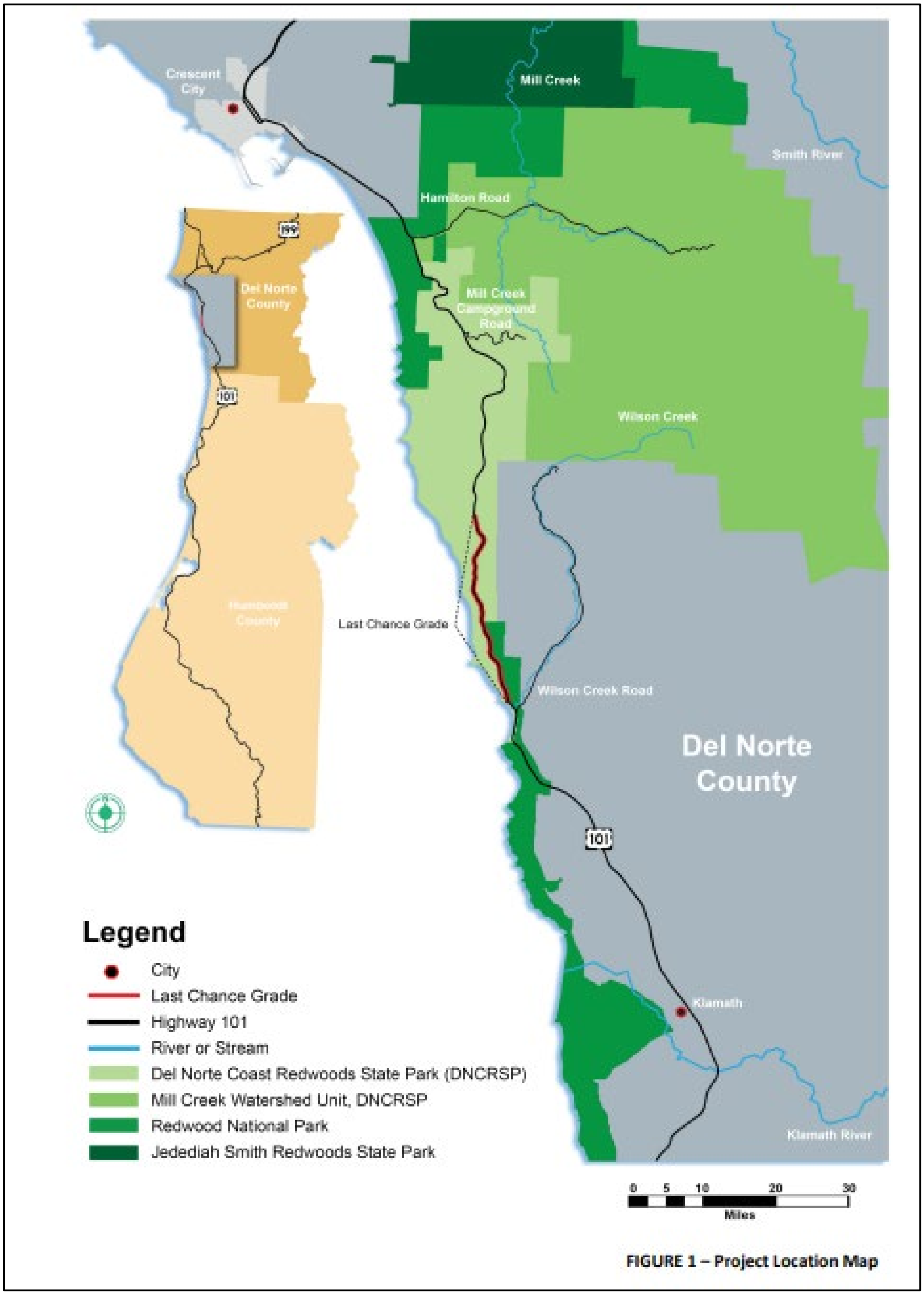

Figure 1. Project Location Map

Source: Caltrans, 2023a

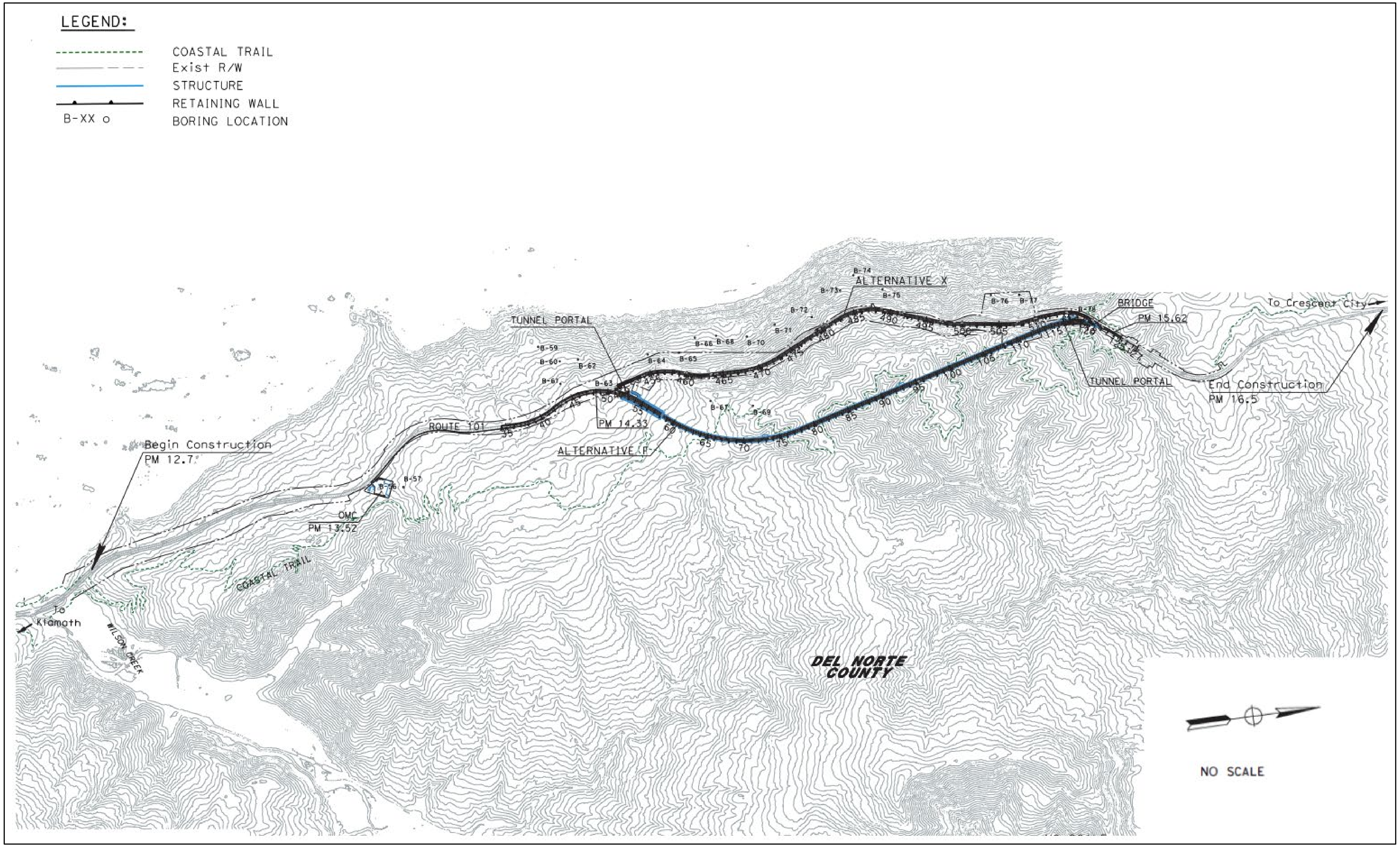

Figure 2. Project Alternatives Overview

Source: Caltrans, 2023a

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1.4 Reference Documents

1.4.1 Preliminary Layout Sheet

Project Approval and Environmental Document (PA/ED) *Project Plans* (Caltrans, 2023b) was provided by Caltrans on February 7, 2023. Refer to Appendix A for the Preliminary Layout sheets.

1.4.2 Geographical References

Project topographic maps with a contour interval of 1 foot were generated by Caltrans; the 48 topographic survey files, *0121327e0501* through *0121327e0547*, were compiled in digital terrain model, MicroStation DGN, and AutoCAD DWG formats by Caltrans (2021). The vertical datum of the Project is North American Vertical Datum of 1988 (NAVD 88).

1.5 Agencies and Organizations

1.5.1 State Water Resources Control Board

This Project would discharge to coastal watersheds within one mile of the Pacific Ocean, and, as such, the Project is subject to the State Water Resources Control Board's (SWRCB) *Water Quality Control Plan Ocean Waters of California* (Ocean Plan) (2019). The Ocean Plan also includes implementation provisions for Areas of Special Biological Significance (ASBS) designated by the SWRCB as requiring special protection of species or biological communities to the extent that maintenance of natural water quality is assured. Detailed discussions on the ASBS implementation provisions can be found in the Project's *Water Quality Assessment Report* (WQAR) (Caltrans, 2023c).

1.5.2 Regional Water Quality Control Board

The Project is located within the jurisdictions of Caltrans District 1 and the North Coast Regional Water Quality Control Board (RWQCB), Region 1. The *Water Quality Control Plan for the North Coast Region* (Basin Plan) (North Coast RWQCB, 2018) states the goals and policies, beneficial uses, and water quality objectives that apply to the water bodies throughout the North Coast region, which includes the Project Environmental Study Limits (ESL). See the Project's WQAR (Caltrans, 2023c) for all beneficial uses and water quality objectives that apply to the Project's receiving water bodies.

1.5.3 California Coastal Commission

The California Coastal Commission (CCC) plans and regulates the use of land and water in the coastal zone. The CCC's planning and regulatory responsibilities fall under the California Coastal Act, which mandates the protection of public access and recreation along the coast as well as the protection of coastal habitats and other sensitive resources and provides priority visitor-serving and coastal-dependent or coastal-related development while simultaneously minimizing risks from coastal hazards. Detailed discussions on CCC permit requirements can be found in the Project's WQAR (Caltrans, 2023c).

1.6 Creeks, Streams, River Crossings

Various aquatic resources, including wetlands and other waters, are present within the Project ESL. Details on the features within the ESL and a 100-foot buffer are reported in the Project's *Federal Aquatic Resources Delineation* and *State Aquatic Resources Delineation* (Federal and State ARDs) (Caltrans, 2023d and 2023e). Streams within this area drain either directly to the Pacific Ocean or indirectly through tributary systems and Wilson Creek.

1.7 Floodplains

The Project ESL is located within the Federal Emergency Management Agency (FEMA) Flood Insurance Rate Map 06015C0365F (Panel 365 of 675) (FEMA, 2017a) and 06015C0455F (Panel 455 of 675) (FEMA, 2017b) for Del Norte County, California, and incorporated areas, revised on August 2, 2017. The effective Flood Insurance Study for Del Norte County, California, and incorporated areas associated with the Project is 06015CV000C (revised by FEMA on August 2, 2017) (FEMA, 2017c). FEMA documents indicate that both Alternative X and Alternative F are located primarily within FEMA Zone D, which is defined as having possible but undetermined flood hazards because no flood hazard analyses have been conducted for these areas. While a portion of the ESL is within FEMA Zone X, no work on either alternative is proposed for this portion of the ESL (see Figure 3).

The adjacent coast is within the Zone VE floodplain. Zone VE floodplains are coastal areas with a 1% or greater chance of flooding and an additional hazard associated with storm waves. The base flood elevation (BFE) derived from detailed analyses is shown at selected intervals within these zones. The BFE of the Zone VE floodplain adjacent to the Project site is 19 feet NAVD 88. The Project area is adjacent to Wilson Creek, which is within a Zone A floodplain, and Zone A floodplains are considered special flood hazard areas with a 1% annual chance of flooding. Because detailed analyses are not performed for such areas, no depths or BFEs are shown within these zones. However, there would be no Project work within a Zone A floodplain.

Refer to the Project's *Location Hydraulic Study/Floodplain Evaluation Report* (Caltrans, 2023f) for further information regarding floodplains. Refer to Figure 3 for the floodplain map.

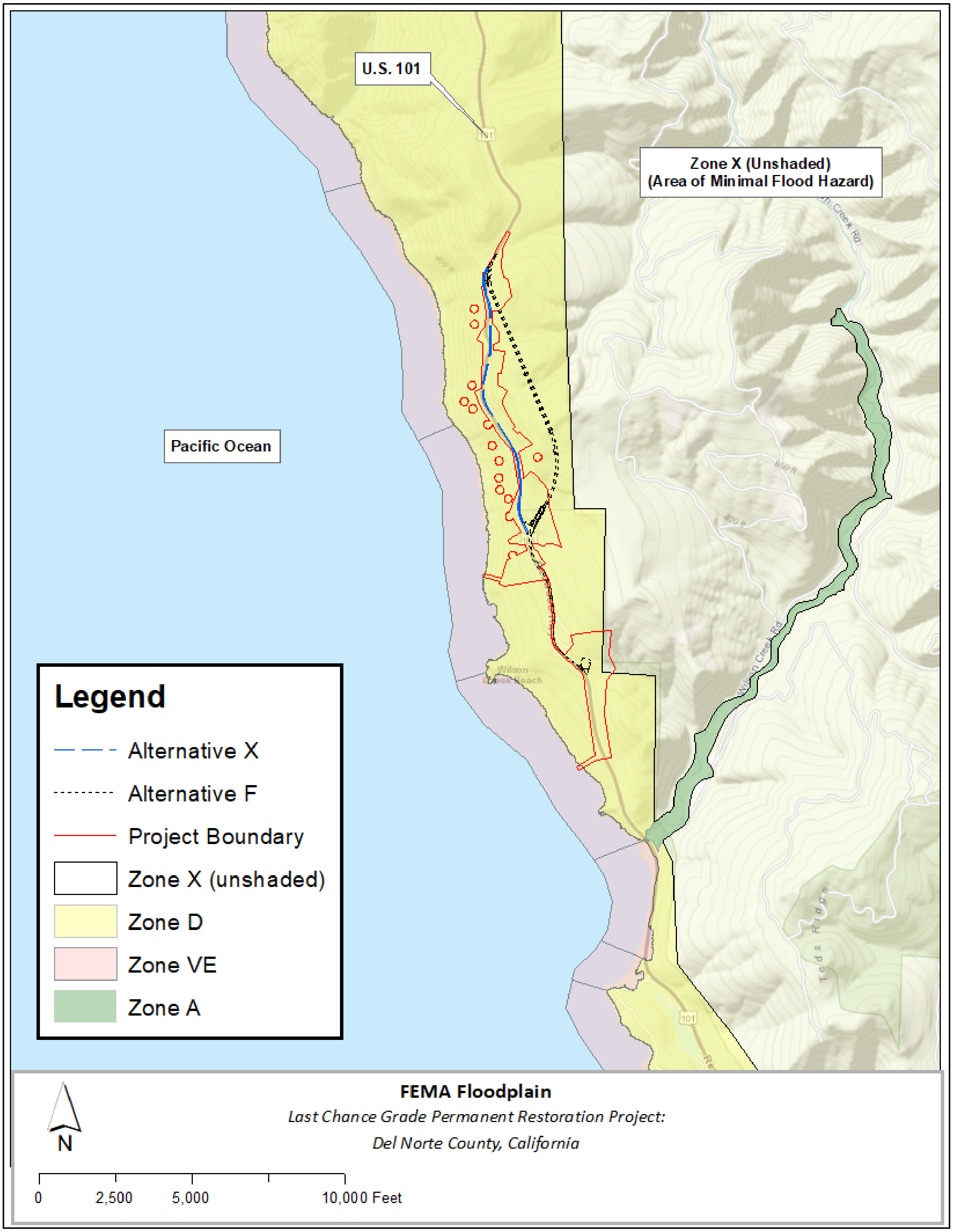

Figure 3. Floodplain Map

Source: FEMA, 2017a and 2017b

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CHAPTER 2 HYDROLOGY

2.1 Off-Site

2.1.1 Watershed Map with Contours and Delineated Shed Boundaries

Off-site watersheds were delineated for the existing condition and proposed condition per alternatives. Watershed maps for off-site areas that drain to the Project site are provided in Appendix B.

2.1.2 Basin Characteristics Used for Runoff Determination

All proposed drainage improvements are within Caltrans' right-of-way, and, therefore, the drainage analysis is performed following the procedures in Caltrans' *Highway Design Manual* (HDM) (Caltrans, 2020).

Table 1 lists the selected relevant HDM sections pertinent to the hydrology of the drainage design.

Table 1. Hydrology Standards

Criteria	Section
Table 819.5A Summary of Methods for Estimating Design Discharge – Rational Method	819
Estimating Design Discharge – Empirical Methods	819.2

Source: Caltrans, 2020

2.1.3 Rainfall Data (Appropriate Gage and Intensities)

Based on the guidelines presented in Chapter 830, Table 831.3, of the HDM (Caltrans, 2020), the 10-year and 100-year design storm will be used for cross culvert systems conveying off-site run-on.

Intensity-duration-frequency curves and rainfall intensities were obtained from the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 website (NOAA, 2022). The NOAA precipitation intensities that are used for this Project are supplied in Appendix C.

2.1.4 Point of Concentration and Outfalls

The existing drainage of the Project consists of roadside ditches, sheet flow, drainage inlets, cross culverts, overside drains, and longitudinal systems.

The Project area features mountainous terrain, sloping from east to west towards the Pacific Ocean. U.S. 101 within the Project ESL slopes uphill from elevation 197 feet NAVD 88 to 920 feet NAVD 88 (Caltrans, 2021).

There are 40 existing cross culvert outfalls located throughout the Project ESL. Refer to Table 2 for a list of cross culverts. The points of concentration for the Project are defined at the upstream end of the cross culverts. The outfalls are defined at the points of discharge of the cross culverts.

Per Caltrans' Water Quality Planning Tool (2022a), the Redwood National and State Parks provide 35.9 miles of shoreline for the Redwood National Park ASBS. Currently, there are two ASBS discharge points identified within the Project ESL, RED014 and RED015 (located at PMs 14.65 and 14.56, respectively), that may be impacted by Project activities. Refer to the Project's WQAR (Caltrans, 2023c) for more information on the ASBS.

Table 2. Existing Cross Culverts

Existing Cross Culvert Facility	Post Miles	Approximate Station "Exist"	Type	ASBS Discharge Point
Culvert	12.70	371+00	Unknown Diameter	RED023
18" Culvert	13.03	386+46.67	18" Diameter	N/A
24" Culvert	13.12	391+20.22	24" Diameter	N/A
24" CPP and 10" CPP with inlet	13.17	393+98.72	24" and 10" Diameter	N/A
24" CPP with inlet	13.24	397+49.83	24" Diameter	RED017A
18" CPP [1]	13.26	398+50.28	18" Diameter	N/A
12" CPP with inlet	13.31	401+23.99	12" Diameter	RED018A
24" CMP	13.36	404+14.78	24" Diameter	N/A
24" CSP with inlet	13.42	407+11.41	24" Diameter	N/A
24" CPP with inlet	13.51	412+04.40	24" Diameter	N/A
24" CSP with inlet	13.57	415+40.15	24" Diameter	N/A
24" CMP with inlet	13.62	418+18.04	24" Diameter	N/A
18" CMP with inlet	13.67	420+91.65	18" Diameter	N/A
24" CMP with inlet	13.73	424+39.07	24" Diameter	N/A
24" CMP with inlet	13.84	429+10.97	24" Diameter	N/A
24" CMP with inlet	13.87	431+32.04	24" Diameter	N/A
24" CMP with inlet	13.97	437+02.00	24" Diameter	N/A
18" CMP with inlet (Survey noted outfall could not be found)	14.04	441+02.65	18" Diameter	N/A
18" CMP with inlet	14.08	442+35.15	18" Diameter	N/A
30" CMP	14.22	448+86	30" Diameter	N/A
S 15 C 1 [2] Unlined Swale	14.28	451+50	Unknown Diameter	N/A
S 17 C 1 [2]	14.28	451+50	Unknown Diameter	N/A
24" CPP with inlet	14.35	455+66.05	24" Diameter	N/A
6" CMP (on-site)	14.46	461+22.92	6" Diameter	N/A
24" CMP with inlet	14.56	466+49.85	24" Diameter	RED015
24" CMP with inlet	14.65	471+53.37	24" Diameter	RED014

Existing Cross Culvert Facility	Post Miles	Approximate Station "Exist"	Type	ASBS Discharge Point
24" CMP with inlet	14.73	475+59.79	24" Diameter	N/A
18" CMP with inlet	14.75	477+25.00	18" Diameter	N/A
21" ABS with inlet	14.88	483+86.79	21" Diameter	N/A
18" HDPE with inlet	14.96	488+39.41	18" Diameter	N/A
18" CMP with inlet	15.02	492+07.84	18" Diameter	N/A
24" CMP with inlet	15.03	492+84.69	24" Diameter	N/A
24" CMP with inlet	15.06	494+38.66	24" Diameter	N/A
18" CMP with inlet	15.15	498+75.71	18" Diameter	N/A
18" HDPE with inlet	15.31	507+85.74	18" Diameter	N/A
18" CMP with inlet	15.38	511+55.39	18" Diameter	N/A
24" HDPE with headwall	15.54	519+27.01	24' Diameter	N/A
24" HDPE with headwall	15.60	522+44.92	24" Diameter	N/A
30" CMP with headwall	15.65	524+91.46	30" Diameter	N/A
36" Steel with headwall	15.76	528+86.81	36" Diameter	N/A

Note: CMP=corrugated metal pipe; CPP=corrugated plastic pipe, ABS= acrylonitrile butadiene styrene; HDPE=high-density polyethylene
1 On-site Longitudinal Culvert that does not convey off-site flow
2 The label is shown on the Federal and State ARDs (Caltrans, 2023d and 2023e)

Source: Caltrans, 2022b and 2016

For Alternative F, drainage improvements would be needed to route Project flows adjacent to the tunnel entrances locally to the Project's best management practices (BMPs). Some challenges include draining in the reverse slope direction and BMP locations located on the high side of the road. The BMP locations and drainage additions are likely to be further refined and optimized in the Plans, Specifications, and Estimates (PS&E) phase.

2.1.5 Time of Concentration Calculations

For the off-site runoff flows, the time of concentration is calculated for sheet flow and shallow concentrated flow for the watershed delineated.

2.1.5.1 Sheet Flow Travel Time

In unpaved areas, sheet flow was assumed to occur for a maximum length of 90 ft. After 90 ft, flow is expected to collect into shallow concentrated flow.

Calculation of the sheet flow travel time follows the methods presented in the HDM (Caltrans, 2020) as follows:

$$T_t = \frac{(0.42 * L^{\frac{4}{5}} * n^{\frac{4}{5}})}{P_2^{\frac{1}{2}} S^{\frac{2}{5}}}$$

Where:

T_t = travel time (hour)
L = length of flow path (ft)
n = Manning's roughness coefficient for sheet flow
P_2 = 2-year, 24-hour rainfall depth (inches [in.])
S = slope of flow path (feet per feet [ft/ft])

Assumptions:
The Manning's *n* value used in calculations for off-site watershed sheet flow was 0.8 for dense underbrush, per the HDM (Caltrans, 2020). The 2-year, 24-hour rainfall depth used was 5.71 in., per the NOAA Atlas 14 (NOAA, 2022). Refer to Appendix C for the NOAA 2-year, 24-hour depth.

2.1.5.2 Shallow Concentrated Flow Travel Time

The runoff was assumed to be shallow concentrated flow from the point at which sheet flow ended to the point where it reached a ditch or gutter along the side of the road, unless there was a stream shown in the United States Geological Survey (USGS) topographic map (as indicated by a blue line). In that case, shallow concentrated flow was assumed to end at the start of that line.

The shallow concentrated flow velocity for the Rational Method was calculated using the following equation (Caltrans, 2020):

$$V = 3.28kS^{1/2}$$

Where:

V = velocity (feet per second [fps])
k = intercept coefficient for shallow concentrated flow
S = slope (percent)

Assumptions:
Per the HDM (2020), the coefficient k for forest with heavy ground litter land cover is 0.076. This coefficient was used to calculate the shallow concentrated flow travel time.

The travel time was calculated using the following equation:

$$T_t = \frac{L}{60V}$$

Where:

T_t = travel time (minute [min])
L = length of flow path (ft)
V = velocity (fps)

2.1.5.3 Channel Flow Travel Time

Open channel flow was assumed for locations defined as a stream on the USGS topographic map and for roadside ditches.

The open channel flow velocity was calculated using the Manning's equation:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

Where:

V = mean velocity (fps)
n = Manning's coefficient of roughness for open channel flow
R = hydraulic radius (feet) = flow area/wetted perimeter
S = channel slope (ft/ft)

All the roadside ditches were shallow according to the design files (Caltrans, 2021); thus, they were assumed to be under shallow concentrated flow.

The summary of parameters used to calculate shallow concentrated flow travel time and the resulting travel time are shown in Table 3. The times of concentration were calculated per Caltrans' HDM criteria (2020).

Table 3. Summary of Time of Concentration

Drainage System ID	Description	Post Miles	Approximate Station "Exist"	Time of Concentration (min)		
				Sheet Flow	Shallow Concentrated	Total
18" Culvert	18" Diameter	13.03	386+46.67	43.3	31.5	74.8
24" Culvert	24" Diameter	13.12	391+20.22	29.3	13.3	42.6
24" CPP and 10" CPP with inlet	24" and 10" Diameter	13.17	393+98.72	29.3	9.6	38.9
24" CPP with inlet	24" Diameter	13.24	397+49.83	31.0	15.1	46.1
18" CPP	18" Diameter	13.26	398+50.28	0.0	0.0	5.0
24" CPP with inlet	24" Diameter	13.31	401+23.99	0.0	0.0	5.0
24" CMP	24" Diameter	13.36	404+14.78	34.2	13.6	47.8

Drainage System ID	Description	Post Miles	Approximate Station "Exist"	Time of Concentration (min)		
				Sheet Flow	Shallow Concentrated	Total
24" CSP with inlet	24" Diameter	13.42	407+11.41	39.9	20.8	60.7
24" CSP with inlet	24" Diameter	13.51	412+04.40	44.7	20.9	65.6
24" CSP with inlet	24" Diameter	13.57	415+40.15	52.6	7.9	60.5
24" CSP with inlet	24" Diameter	13.62	418+18.04	38.9	6.4	45.3
18" CMP with inlet	18" Diameter	13.67	420+91.65	73.2	39.9	113.1
24" CMP with inlet	24" Diameter	13.73	424+39.07	73.2	20.3	93.5
24" CMP with inlet	24" Diameter	13.84	429+10.97	73.2	13.2	86.4
24" CMP with inlet	24" Diameter	13.87	431+32.04	63.5	21.1	84.6
24" CMP with inlet	24" Diameter	13.97	437+02.00	36.5	38.7	75.2
18" CMP with inlet	18" Diameter	14.04	441+02.65	61.1	20.8	81.9
18" CMP with inlet	18" Diameter	14.08	442+35.15	63.5	18.5	82.0
30" CMP	Unknown Diameter	14.22	448+86	51.3	41.3	92.6
S 15 C 1	Unknown Diameter	14.28	451+50	51.3	39.9	91.2
S 17 C 1	Unknown Diameter	14.28	451+50	61.1	13.5	74.6
24" CPP with inlet	24" Diameter	14.35	455+66.05	25.9	8.0	33.9
6" CMP (on-site)	6" Diameter	14.46	461+22.92	0.0	0.0	5.0
24" CMP with inlet	24" Diameter	14.56	466+49.85	39.9	8.7	48.5
24" CMP with inlet	24" Diameter	14.65	471+53.37	32.1	1.2	33.2
24" CMP with inlet	24" Diameter	14.73	475+59.79	34.2	7.9	42.0
18" CMP with inlet	18" Diameter	14.75	477+25.00	50.2	11.4	61.6
21" ABS with inlet	21" Diameter	14.88	483+86.79	41.5	8.7	50.2
18" HDPE with inlet	18" Diameter	14.96	488+39.41	34.5	7.0	41.5
18" CMP with inlet	18" Diameter	15.02	492+07.84	38.9	5.8	44.7
24" CMP with inlet	24" Diameter	15.03	492+84.69	33.3	6.4	39.7

Drainage System ID	Description	Post Miles	Approximate Station "Exist"	Time of Concentration (min)		
				Sheet Flow	Shallow Concentrated	Total
24" CMP with inlet	24" Diameter	15.06	494+38.66	32.1	2.9	35.0
18" CMP with inlet	18" Diameter	15.15	498+75.71	40.9	5.7	46.6
18" HDPE with inlet	18" Diameter	15.31	507+85.74	47.2	4.5	51.6
18" CMP with inlet	18" Diameter	15.38	511+55.39	50.2	13.5	63.7
24" HDPE with headwall	24' Diameter	15.54	519+27.01	52.6	7.0	59.6
24" HDPE with headwall	24" Diameter	15.60	522+44.92	52.6	7.8	60.4
30" CMP with headwall	30" Diameter	15.65	524+91.46	44.0	3.1	47.1
36" STEEL with headwall	36" Diameter	15.76	528+86.81	83.7	36.9	120.7

2.1.6 Design Discharge

For Caltrans criteria, design discharge was calculated using the Rational Method for the off-site watersheds below 320 acres (ac). The discharge calculations are described below.

The equation for the Rational Method is:

$$Q = CiA$$

Where:

Q = design discharge (cubic ft per second [cfs])
C = runoff coefficient for Rational Method including design storm frequency factor (1.0 for 10-year storm, 1.1 for 25-year storm, and 1.25 for 100-year storm)
i = average rainfall intensity for the selected frequency and for a duration equal to the time of concentration (inches per hour [in./hr])
A = drainage area (ac)

Preliminary pre-Project and post-Project 10-year and 100-year storm event design discharge was calculated for all watersheds discharging to the existing cross culverts. Refer to Appendix D for a summary of design discharges and the change in flows for Alternative X and Alternative F.

2.2 On-Site

2.2.1 Watershed Maps with Delineated Boundaries and Nomenclature

On-site watersheds were delineated for the existing condition and proposed condition per alternatives. Watershed maps for on-site areas that drain to the Project site are provided in

Appendix B. Watersheds were named by the post mile corresponding to the existing cross culvert.

2.2.2 Recurrence Interval Selected and Justification

Based on the guidelines presented in Chapter 830, Table 831.3, of the HDM (Caltrans, 2020), the 25-year design storm will be used for the on-site drainage design.

The NOAA precipitation intensities that are used for this Project are supplied in Appendix C.

2.2.3 Time of Concentration Calculations

A 5-minute time of concentration is used to calculate the on-site runoff flows within the Project ESL. The 25-year, 5-minute time of concentration is 4.57 in./hr. For systems connecting to other drainage systems, the times should accumulate with all pipe connections.

2.2.4 Design Discharge

For Caltrans criteria, design discharge was calculated using the Rational Method. The discharge calculations are described below.

The equation for the Rational Method is:

$$Q = CiA$$

Where:

Q = design discharge (cfs)
C = runoff coefficient for Rational Method including design storm frequency factor (1.0 for 10-year storm, 1.1 for 25-year storm, and 1.25 for 100-year storm)
i = average rainfall intensity for the selected frequency and for a duration equal to the time of concentration (in./hr)
A = drainage area (ac)

Refer to Appendix D for a summary of design discharges and the change in flows for both Alternative X and Alternative F.

CHAPTER 3 HYDRAULICS

3.1 Off-Site

3.1.1 Drainage System Number Referenced to Appropriate Watershed Designation

Off-site watersheds were delineated for the existing condition and proposed condition per alternatives. Watersheds were named by the post mile corresponding to the existing cross culvert. Watershed maps for off-site areas that drain to the Project site and the respective labels are provided in Appendix B.

3.1.2 System Controls

The drainage analysis for the existing cross culverts is performed following the procedures in Caltrans' HDM (2020). See below for a summary of the design criteria for hydraulic calculations that should be referenced for this Project due to proposed drainage improvements involving cross culvert sizing.

Table 4 summarizes some of the pertinent Caltrans' drainage design criteria that are applicable to the Project.

Table 4. Caltrans' Drainage Design Flow Criteria

Criteria Type	Design Flow	Criteria
Cross Culvert Hydraulics	100-year	HGL without rising above an elevation that would cause objectionable backwater depths or outlet velocities
	10-year	HGL without causing the headwater elevation to rise above the inlet top of the culvert

Note: HGL = hydraulic grade line

Source: Caltrans, 2020

The cross culvert drainage systems are likely to be evaluated using Autodesk's Hydraflow Storm Sewers software (2018). Calculations are likely to be provided in the design phase. The tailwater for each cross culvert drainage system depends on the type of outfall that is downstream of the system. In areas where the pipe free outfall or pipes that are steep, a normal depth is used as the tailwater condition.

3.1.3 Available Headwater

The cross culvert drainage systems is evaluated with a starting tailwater to ensure the hydraulic grade line be contained within the cross culvert during the 10-year storm event and not cause the headwater elevation to rise above the inlet top of the culvert during the 100-year storm event (Caltrans, 2020).

3.1.4 Analysis of Hydraulically Efficient Materials

The hydraulic grade line analyses for new pipe improvements are likely to be based on proposed drainage layouts and profiles during the PS&E phase. The *n* value for alternative pipe culverts is 0.024, and that for reinforced concrete pipes is 0.013.

3.1.5 Inlet and Outlet Treatment

3.1.5.1 Energy Dissipation Requirements

Rock slope protection (RSP) is recommended as an erosion countermeasure to protect ditches or at culvert entrances and exits. The FHWA "Hydraulic Design of Energy Dissipators for Culverts and Channels" in *Hydraulic Engineering Circular No. 14* includes equation 10.4 (shown below) (FHWA, 2006), an equation to estimate the rock size necessary to address erosion potential. As more detailed survey information is made available at the PS&E phase, the detailed design of the RSP rock sizes is likely to be provided for the outfalls of proposed culverts. These calculations will be done in the PS&E phase.

$$D_{50} = 0.2D\left(\frac{Q}{(\sqrt{g})D^{2.5}}\right)^{4/3}\left(\frac{D}{TW}\right)$$

Where:

D_{50} = median stone diameter (ft)
D = culvert diameter (ft)
Q = design discharge (cfs)
g = gravitational acceleration (32.2 fps^2)
TW = tailwater depth (ft)

The design discharge is calculated using the following equation:

$$Q = VA$$

Where:

V = culvert exit velocity (fps)
A = cross-sectional area of culvert (square ft)

3.2 On-Site

3.2.1 System Control

The 25-year design storm is modeled for all the on-site, proposed longitudinal drainage systems to ensure that they are sized to convey the anticipated flow. The tailwater for each proposed drainage system depends on the type of outfall that is downstream of the system. In areas where the proposed systems discharge to a ditch or swale, the hydraulic grade line calculated for those ditches or swales is used as the tailwater elevation for those proposed drainage systems. In areas where the pipe free outfall or pipes that are steep, a normal depth is used as the tailwater condition.

Table 5 and Table 6 present the hydraulic criteria specified by Caltrans' HDM (2020).

Table 5. Selected HDM Hydraulics Criteria

Criteria	Section
Maximum allowable flow spread width (shoulder or parking lane width)	831.3
Minimum allowable pipe diameter under roadbed (18 in.)	838.4
Manning's coefficient estimation method	852.1

Source: Caltrans, 2020

Table 6. Caltrans' Drainage Design Flow Criteria

Criteria Type	Design Flow	Criteria
Inlet capacity	25-year	Flow width contained within the shoulder; flow depth less than the adjacent dike height
Crossover flow	25-year	Less than or equal to 0.1 cfs
On-site culvert hydraulics	25-year	Hydraulic grade line at least 0.75 ft below the top of grate or top of cover
	Half full	Pipe slope and roughness such that the flow velocity would equal or exceed 3 fps when flowing half full

Source: Caltrans, 2020

3.2.2 Gutter Spread and Capacity Calculations

Grate interception, bypass, and gutter spread calculations were based on formulas and procedures from FHWA's *Hydrologic Engineering Circular-22* (2001). The goal of the proposed drainage design is to limit the width of flooding during the design storm to within the roadway shoulder and to keep bypass flow that crosses over traveled lanes under 0.1 cfs. The goal is also to ensure that flows collected along the shoulder do not overtop the adjacent barriers or dikes that are meant to contain the flow. A drainage inlet is required to be proposed at roadway low points where there would be a dike, retaining wall, or barrier. Flanking inlets are required to be proposed approximately 20 to 30 ft from every low-point inlet. These calculations are likely to be done in the PS&E phase.

3.2.3 Hydraulic Grade Line for Networks

The hydraulic grade line analyses for new pipe improvements are likely to be based on proposed drainage layouts and profiles during the PS&E phase. The *n* value for proposed pipes is 0.024 for alternative pipe culverts and 0.013 for reinforced concrete pipes.

The 25-year design storm will be modeled for all the proposed drainage systems to ensure that they are sized to convey the anticipated flow. Downstream controls for each proposed drainage system depend on the type of outfall that is downstream of the system. In areas where the proposed systems discharge to a ditch or swale, the hydraulic grade line calculated for those ditches or swales will be used as the tailwater elevation for those proposed drainage systems. In areas where the pipe free outfall or pipes that are steep, a normal depth is used as the tailwater condition.

3.2.4 Summary of Design Discharges

Refer to Appendix D for a summary of the design discharges.

CHAPTER 4 OPEN CHANNEL

For all proposed roadside ditches and bioretention areas with concentrated flow, preliminary ditch calculations are performed using the Manning's equation. See below for the Manning's equation.

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

Where:

V = Manning's velocity (fps)
n = Manning's coefficient
R = hydraulic radius (ft)
S = longitudinal slope (ft/ft)

The design discharge is calculated using the following equation:

$$Q = VA$$

Where:

V = culvert exit velocity (fps)
A = cross-sectional area of channel flow (square ft)

Refer to Appendix E for the open channel, ditch capacity calculations.

Per Table 865.2 of the HDM (Caltrans, 2020), the permissible velocities for the roadside unlined ditches are 3.75 fps, and the permissible shear stress is 2.75 pounds per square foot, due to the soils being silt and lean clay. Refer to the Project's *Geotechnical Data Report – Final* (Caltrans, 2022c) for further information on the Project's soils. This permissible shear stress and velocity criterion was also verified by performing ditch calculations using the Manning's equation. See Appendix E for predicted velocities and the shear stresses of each treatment BMP location.

The following equation was used to determine the maximum shear stress along the ditch flowline.

$$\tau_d = \gamma d S * (\mathrm{SF})$$

Where:

τ_d = shear stress at maximum depth (pound per square foot)
γ = specific weight of water = 62.4 pound per cubic foot
d = maximum depth of flow in ditch (ft)
S = slope of ditch (ft/ft)
SF = safety factor = 1

Assumptions:

The typical dimensions for roadside, unlined ditches and bioretention areas are:

- Maximum 2:1 side-slope
- Typical 4:1 fore-slope, 2:1 back-slope for bioretention areas
- Minimum longitudinal slope of 0.003 ft/ft
- Manning's *n* of 0.05

The typical dimensions for roadside, lined ditches are:

- Maximum 2:1 side-slope
- Minimum longitudinal slope of 0.003 ft/ft
- Manning's *n* of 0.013

CHAPTER 5 IMPACTED DRAINAGE SYSTEMS

The following sections present potential permanent drainage impacts to the existing drainage systems anticipated from the Project activities. The goal of the Project's preliminary drainage design is to maintain existing drainage patterns. Refer to Appendix F for the *Alternative F Bridge Technical Memorandum* (Caltrans, 2023g).

5.1 Impacted Off-Site Drainage Systems

Stormwater runoff from the adjacent hillside would be collected via retaining wall inlets to cross culverts to maintain existing drainage patterns. Existing cross culvert outfalls would be maintained. Upstream existing drainage structures of the cross culverts may need to be removed, replaced, extended, or adjusted on the basis of Project alternatives.

Much of U.S. 101 within the Project ESL is surrounded by hills or mountainous areas; therefore, existing cross culverts may need to be modified, or new cross culverts may be necessary to direct flows that cross the roadway.

Alternative X would realign the existing U.S. 101 corridor and include new retaining walls. Existing cross culverts would need to be extended, modified, adjusted, or replaced. Alternative F includes a new tunnel alignment for the U.S. 101 corridor. Existing cross culverts adjacent to the two tunnel entrances would need to be extended, modified, adjusted, or replaced. Due to the new roadway and bridge structure at the northern portal, a preliminary 24-inch diameter culvert was proposed near the northern portal to convey off-site run-on to Stream 21. The analysis of this culvert is likely to be provided in the PS&E phase.

Proposed drainage improvements include new roadway drainage inlets, new culverts, retaining wall drainage, or modification of existing drainage facilities to collect and convey the adjacent off-site runoff draining toward the Project while maintaining the overall existing drainage patterns.

5.2 Impacted On-Site Drainage Systems

Stormwater runoff from the roadways within the Project ESL would sheet flow to roadway drainage inlets where there would be new curbs or retaining walls.

Alternative X would realign the existing U.S. 101 corridor and include new retaining walls. Proposed drainage improvements include new roadway drainage inlets, storm drainpipes, adjacent to retaining walls, and potential stormwater BMPs to collect roadway runoff to convey to existing outfalls.

Alternative F would reroute the existing U.S. 101 corridor entirely to a new tunnel alignment. Proposed drainage improvements include stormwater treatment BMPs, retaining wall inlets, and new roadway drainage inlets and storm drainpipes adjacent to the tunnel portals to effectively convey additional runoff generated by the alternative while maintaining the overall existing drainage patterns.

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CHAPTER 6 STORMWATER BEST MANAGEMENT PRACTICE

Detailed discussions of the proposed construction site and permanent BMPs can be found in the Project's *Storm Water Data Report* (Caltrans, 2023h). There are three preliminary BMPs and infiltration trenches within the Project ESL to meet the treatment goals.

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CHAPTER 7 REFERENCES

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Appendix A Preliminary Layouts

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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		

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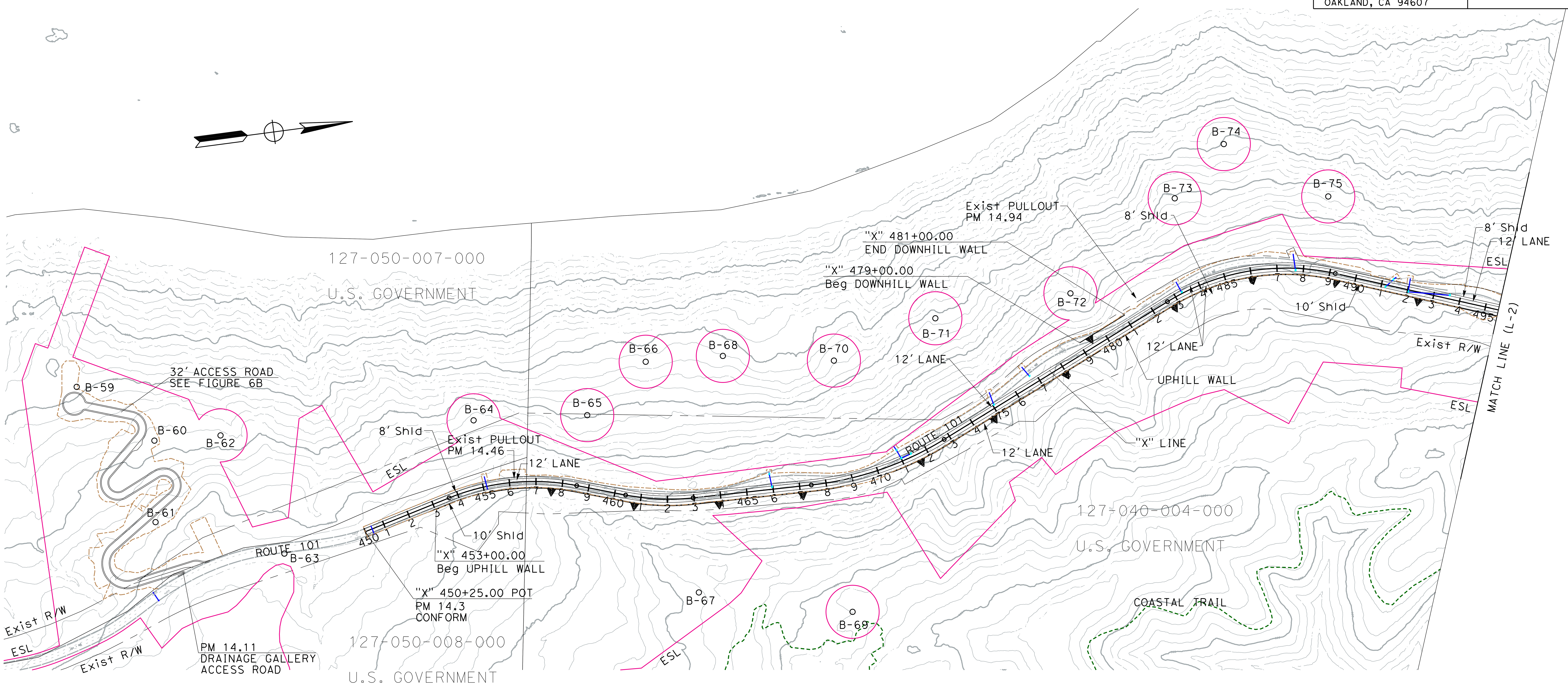
- Exist R/W
- STRUCTURE
- RETAINING WALL
- B-XX ○ BORING LOCATION



LAYOUT

ALTERNATIVE X

SCALE: 1" = 200'

L-1

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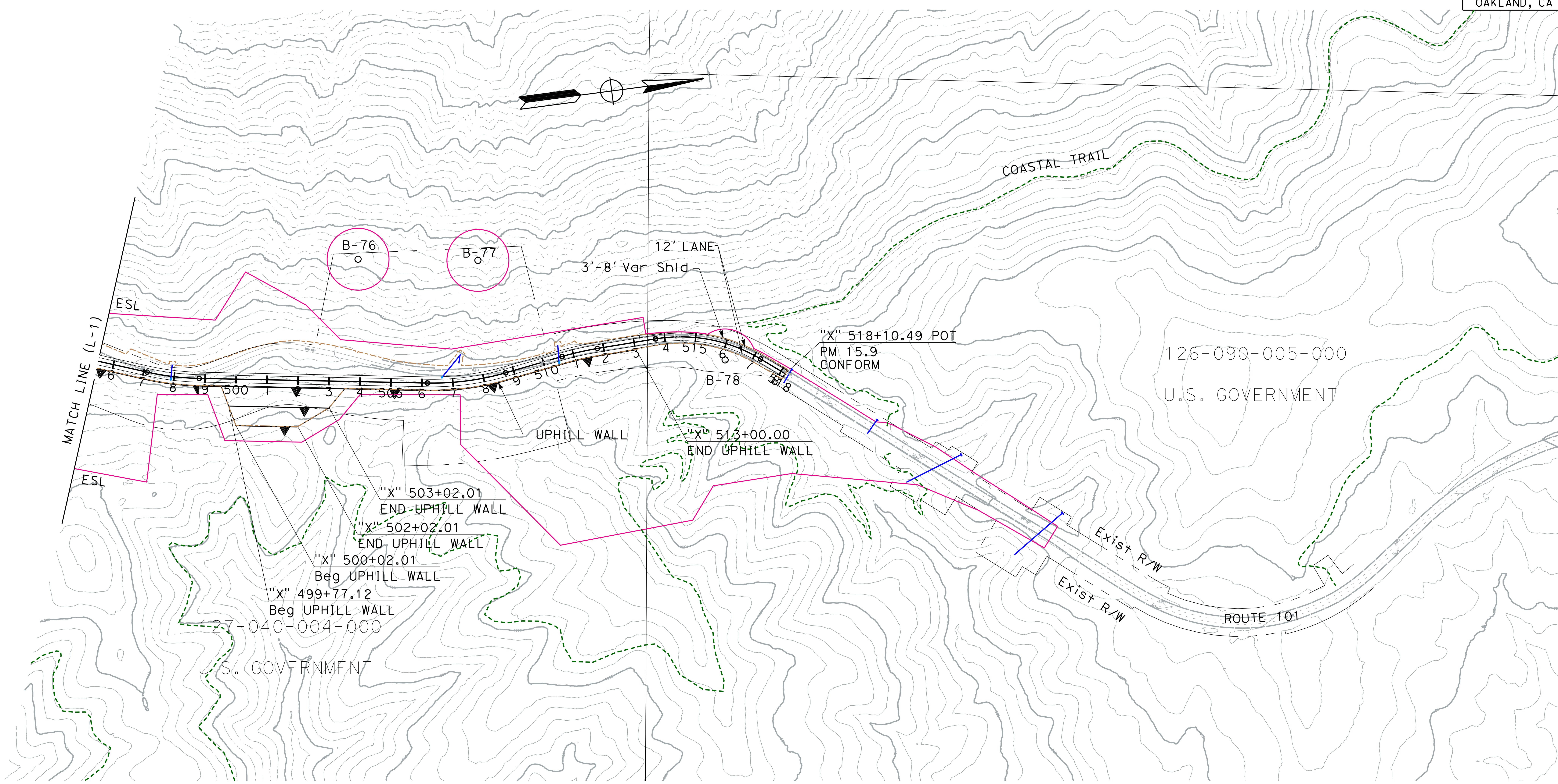
- STRUCTURE
- RETAINING WALL
- B-XX o BORING LOCATION



LAYOUT
ALTERNATIVE X
SCALE: 1" = 200'
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01	DN	101	12.7/16.5		

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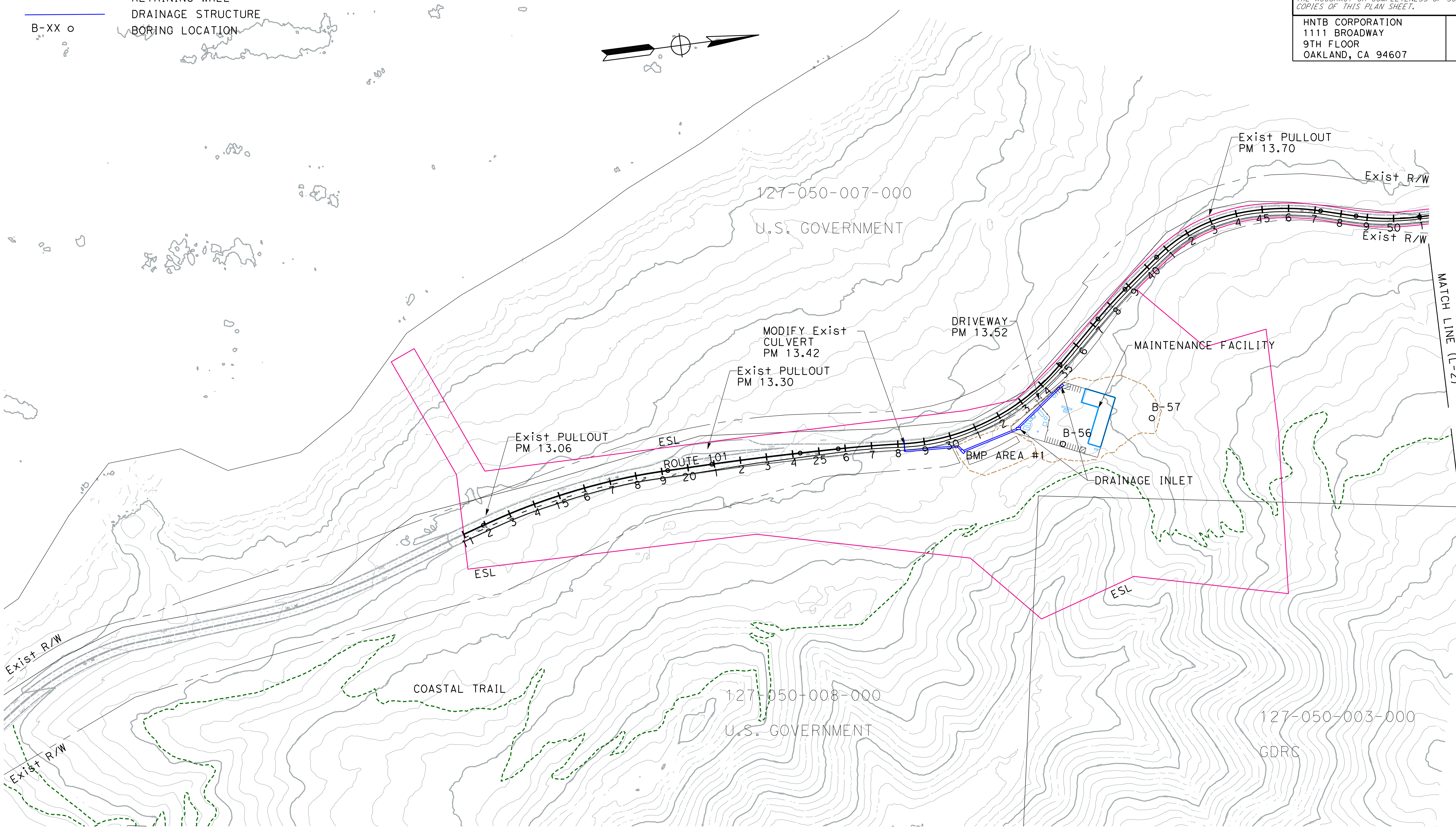
- STRUCTURE
- RETAINING WALL
- DRAINAGE STRUCTURE
- B-XX o BORING LOCATION



LAYOUT

ALTERNATIVE F

SCALE: 1" = 200'

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- STRUCTURE
- RETAINING WALL
- DRAINAGE STRUCTURE
- B-XX o BORING LOCATION

LAYOUT
ALTERNATIVE F
SCALE: 1" = 200'
L-2

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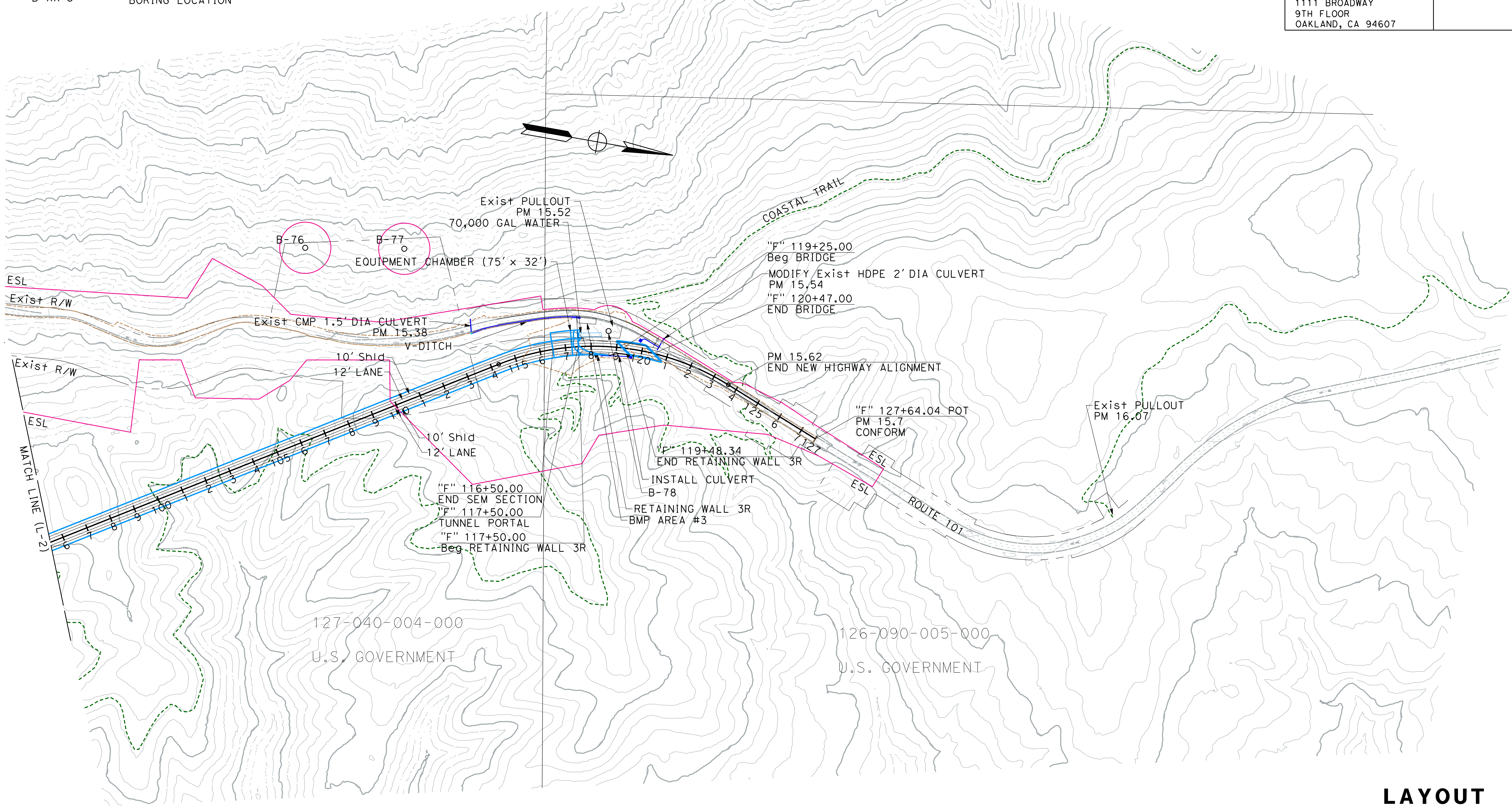
- RETAINING WALL
- DRAINAGE STRUCTURE
- B-XX ○ BORING LOCATION



LAYOUT

ALTERNATIVE F

SCALE: 1" = 200′

L-3

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Appendix B Watershed Maps

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Appendix B.1 Watershed Maps (Existing Condition)

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01	DN	101	12.7/16.5		???

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XX-XX-XX

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NOTE:

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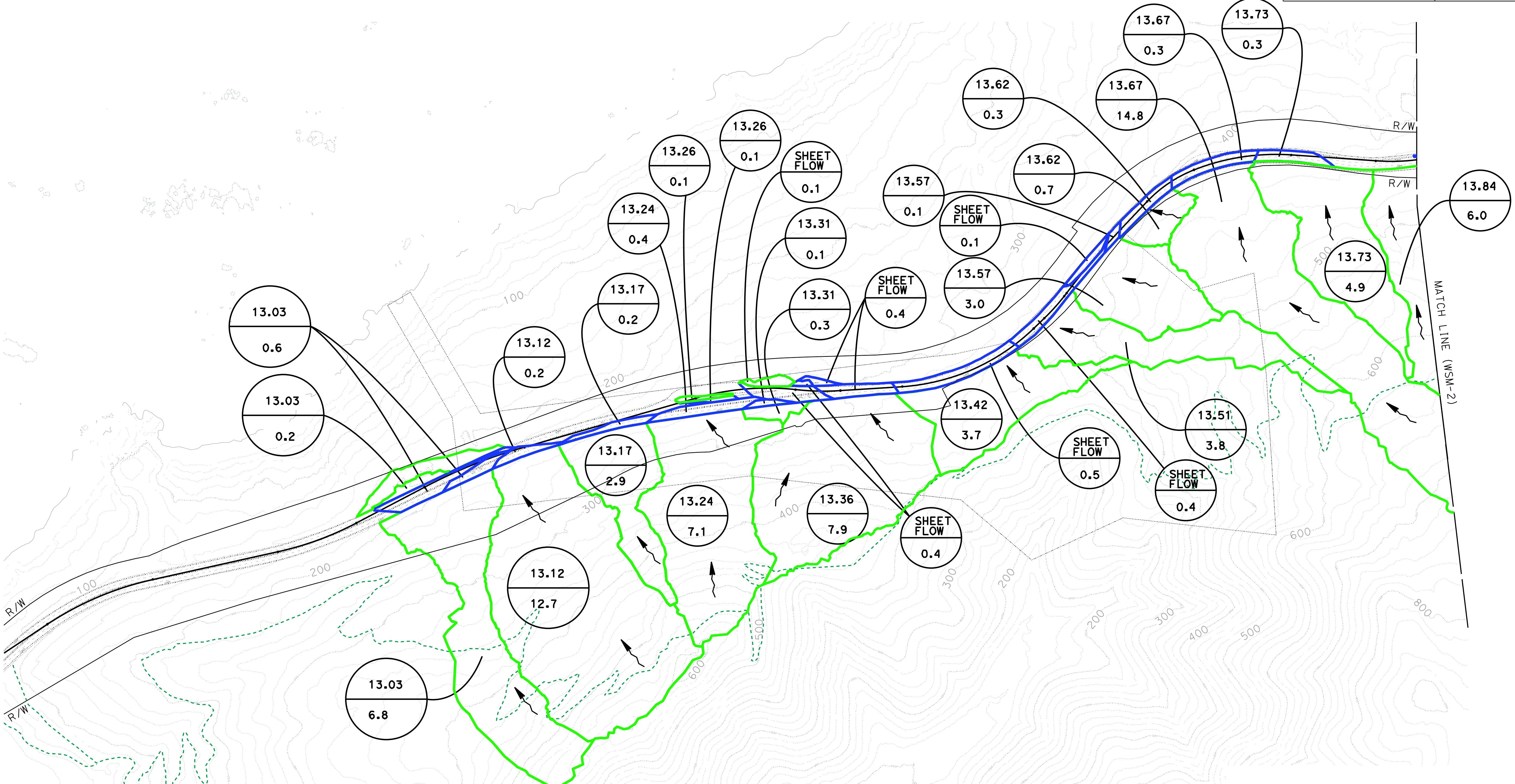
LEGEND:

IMPERVIOUS WATERSHED

PERVIOUS WATERSHED

POST MILE / AREA



SEE OFF-SITE WSM 1

WATERSHED MAP

Exist Condition

SCALE: 1" = 200' **WSM-1**

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CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

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Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

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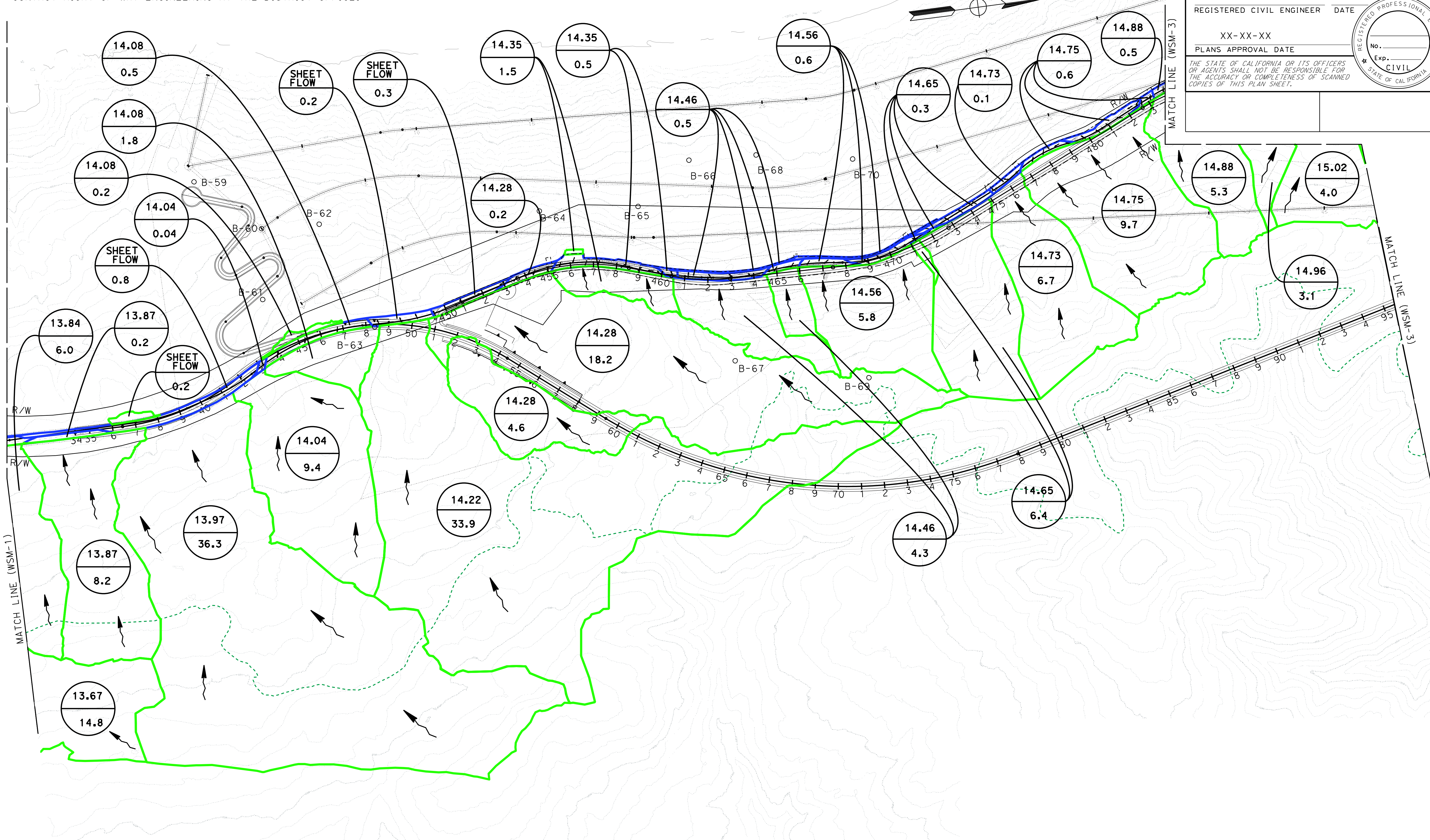

WATERSHED MAP

Exist Condition

SCALE: 1" = 200' **WSM-2**

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DATE REVISED

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TIME PLOTTED => 14:50

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UNIT 0000
PROJECT NUMBER & PHASE 0115000099

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

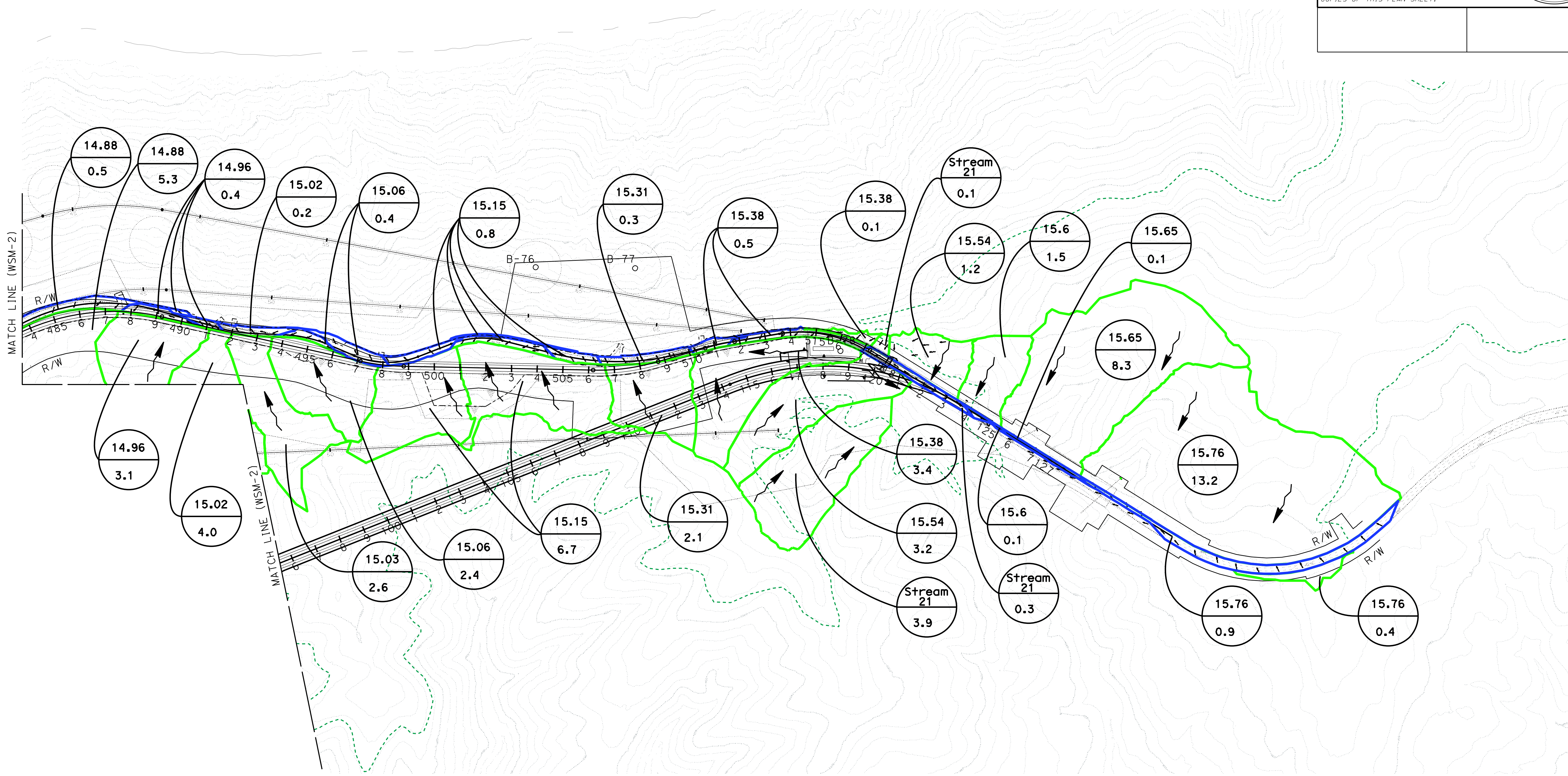
PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.



WATERSHED MAP

Exist Condition

SCALE: 1" = 200' **WSM-3**

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

LAST REVISION 10-14-22

DATE PLOTTED => 01-MAR-2023

TIME PLOTTED => 14:51

BORDER LAST REVISED 7/2/2010

USERNAME => JFAN

DGN FILE => 0115000099_WSM Exist 003.dgn

RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3

UNIT 0000

PROJECT NUMBER & PHASE 0115000099

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Appendix B.2 Watershed Maps (Proposed Condition)

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

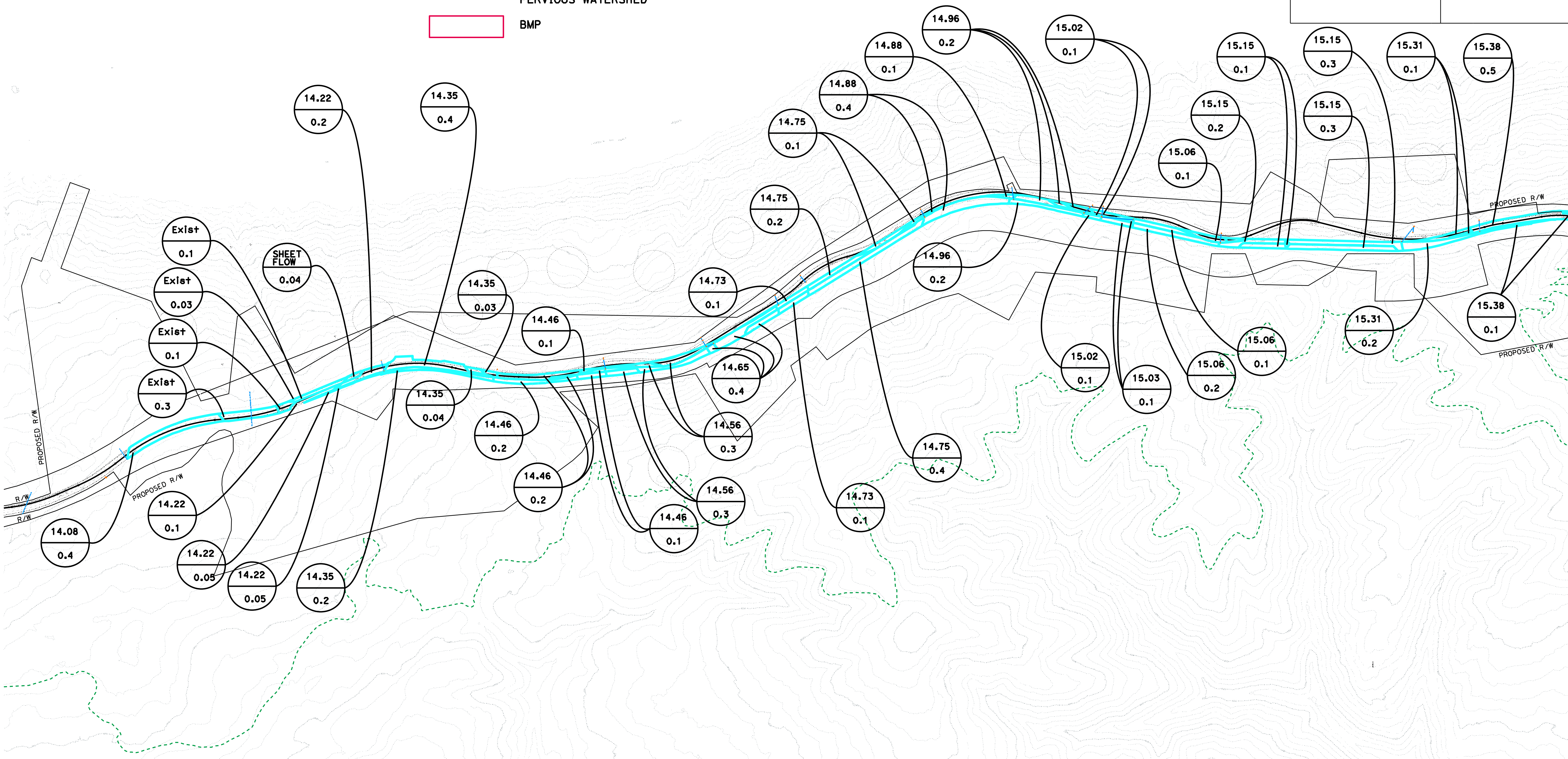
REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

NOTE:

1. FOR ACCURATE RIGHT OF WAY AND ACCESS DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.
2. WATERSHEDS WERE DELINEATED PER PRELIMINARY TYPICAL CROSS SECTIONS AND TO BE REFINED IN DESIGN PHASE.

LEGEND:

- POST ON-SITE IMPERVIOUS WATERSHED
- POST ON-SITE PERVIOUS WATERSHED
- POST OFF-SITE - ALTERNATIVE X PERVIOUS WATERSHED
- POST OFF-SITE - ALTERNATIVE F PERVIOUS WATERSHED
- BMP
- DRAINAGE FLOW PATH
- DRAINAGE SYSTEM / DRAINAGE AREA (ac)
- DRAINAGE CULVERT



WATERSHED MAP

ALTERNATIVE X - IMPERVIOUS

SCALE: 1" = 250' **WSM-1**

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

DATE PLOTTED => 01-MAR-2023
TIME PLOTTED => 14:57

LAST REVISION 10-14-22

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA,
CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

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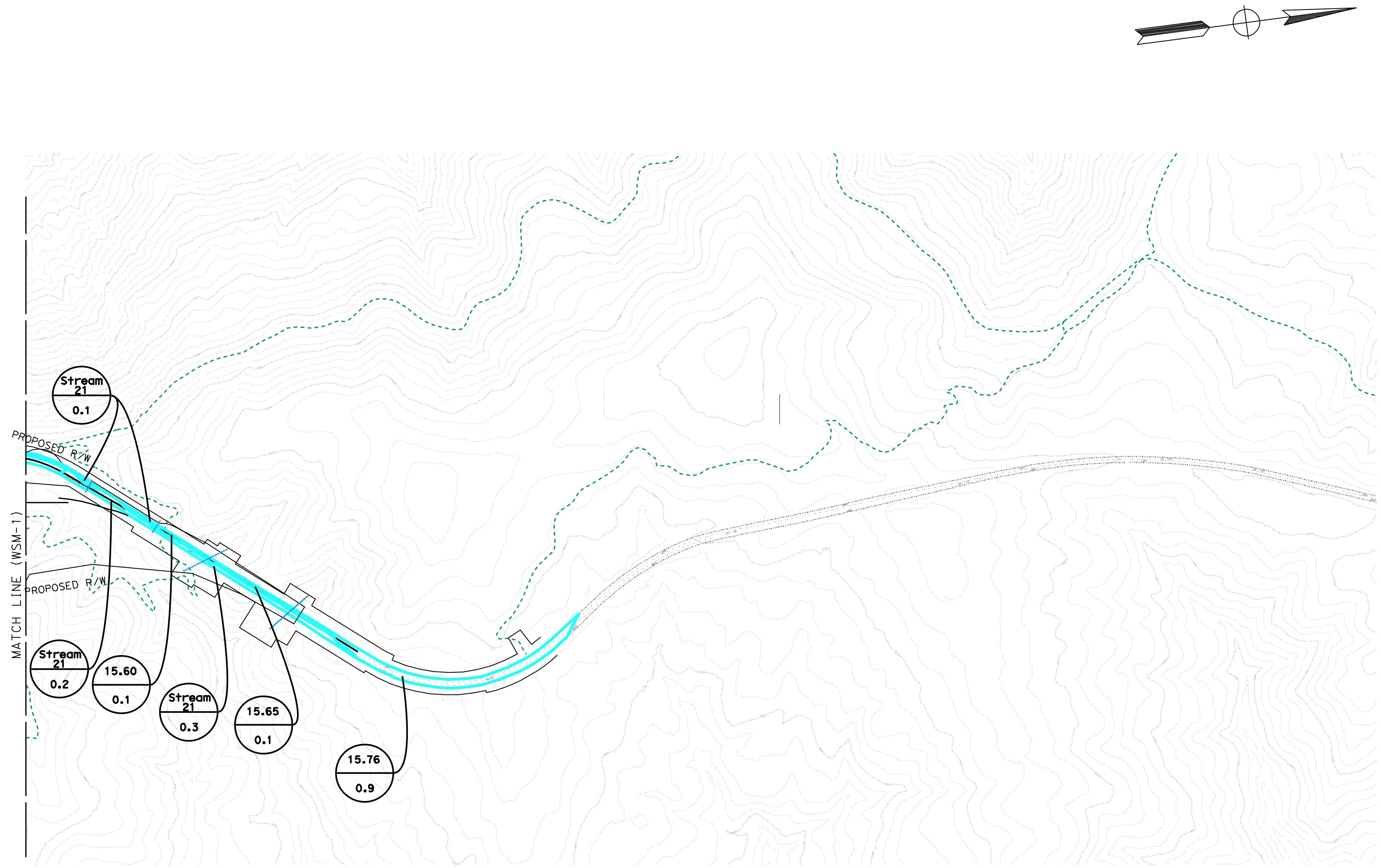
REGISTERED PROFESSIONAL ENGINEER
No.
Exp.
CIVIL
STATE OF CALIFORNIA



STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

WATERSHED MAP

ALTERNATIVE X - IMPERVIOUS

SCALE: 1" = 250' **WSM-2**

LAST REVISION 10-14-22

DATE PLOTTED => 01-MAR-2023
TIME PLOTTED => 14:57

BORDER LAST REVISED 7/2/2010

USERNAME => JFAN
DGN FILE => 0115000099_WSM X_Impervious 002.dgn

RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3

UNIT 0000

PROJECT NUMBER & PHASE 0115000099

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

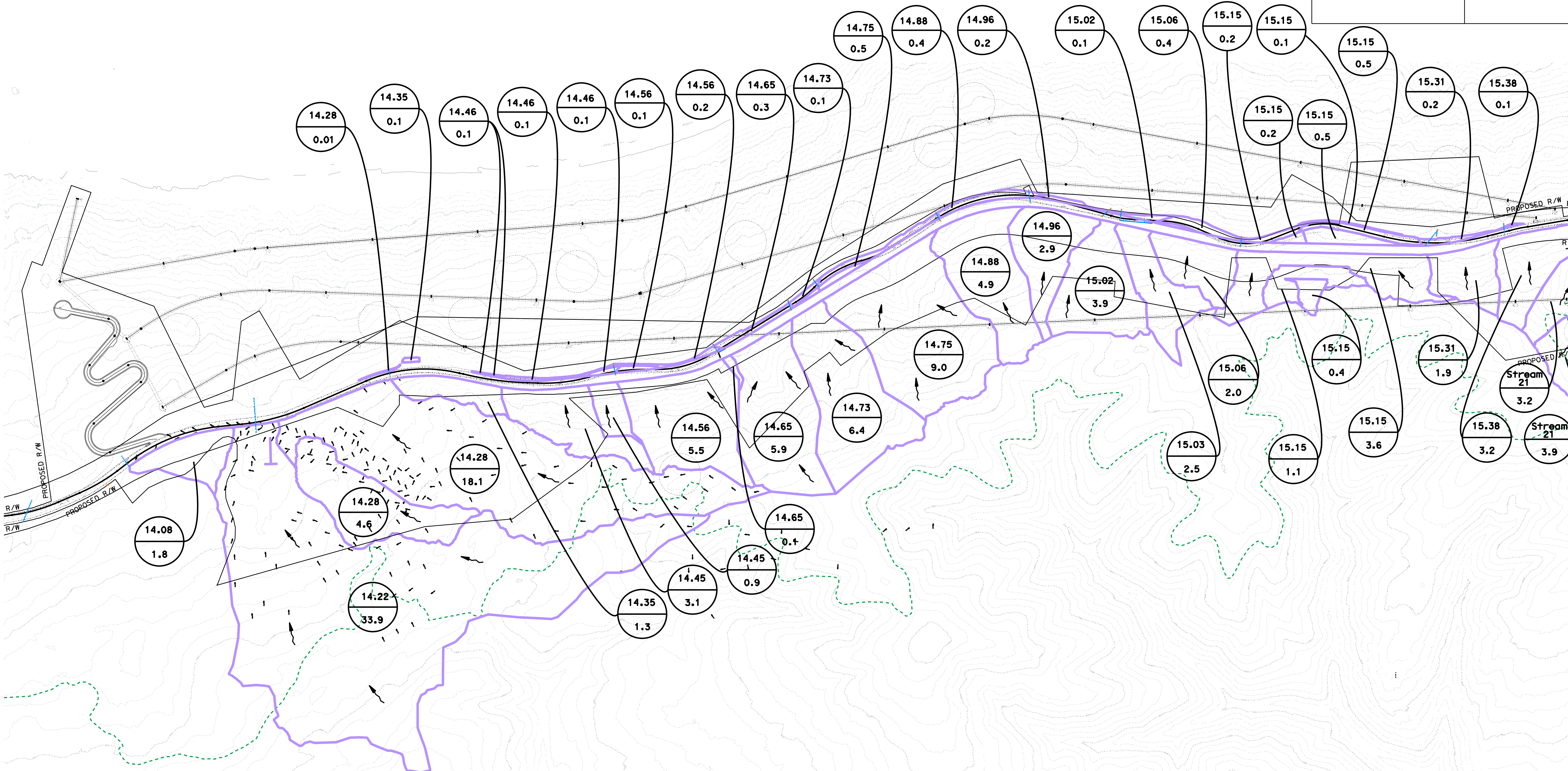
REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.



WATERSHED MAP

ALTERNATIVE X - PERVIOUS

SCALE: 1" = 250' **WSM-3**

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

LAST REVISION 10-14-22

DATE PLOTTED => 01-MAR-2023

TIME PLOTTED => 14:57

BORDER LAST REVISED 7/2/2010

USERNAME => JFAN

DGN FILE => 0115000099_WSM X_Pervious 003.dgn

RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3

UNIT 0000

PROJECT NUMBER & PHASE 0115000099

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

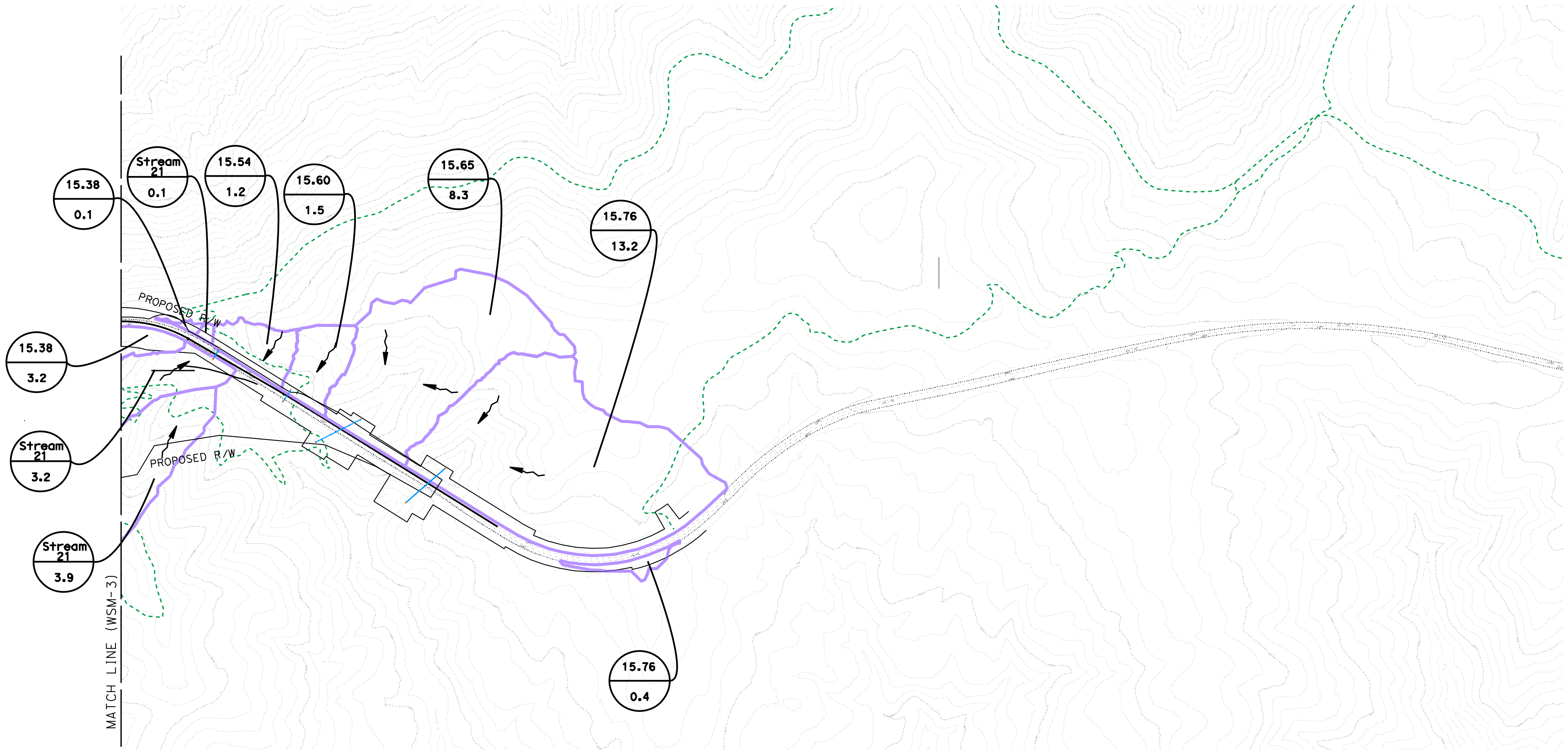
REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA



STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

WATERSHED MAP

ALTERNATIVE X - PERVIOUS

SCALE: 1" = 250' **WSM-4**

LAST REVISION 10-14-22 DATE PLOTTED => 01-MAR-2023 TIME PLOTTED => 14:58

BORDER LAST REVISED 7/2/2010

USERNAME => JFAN
DGN FILE => 0115000099_WSM X_Pervious 004.dgn

RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3

UNIT 0000

PROJECT NUMBER & PHASE 0115000099

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA,
CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

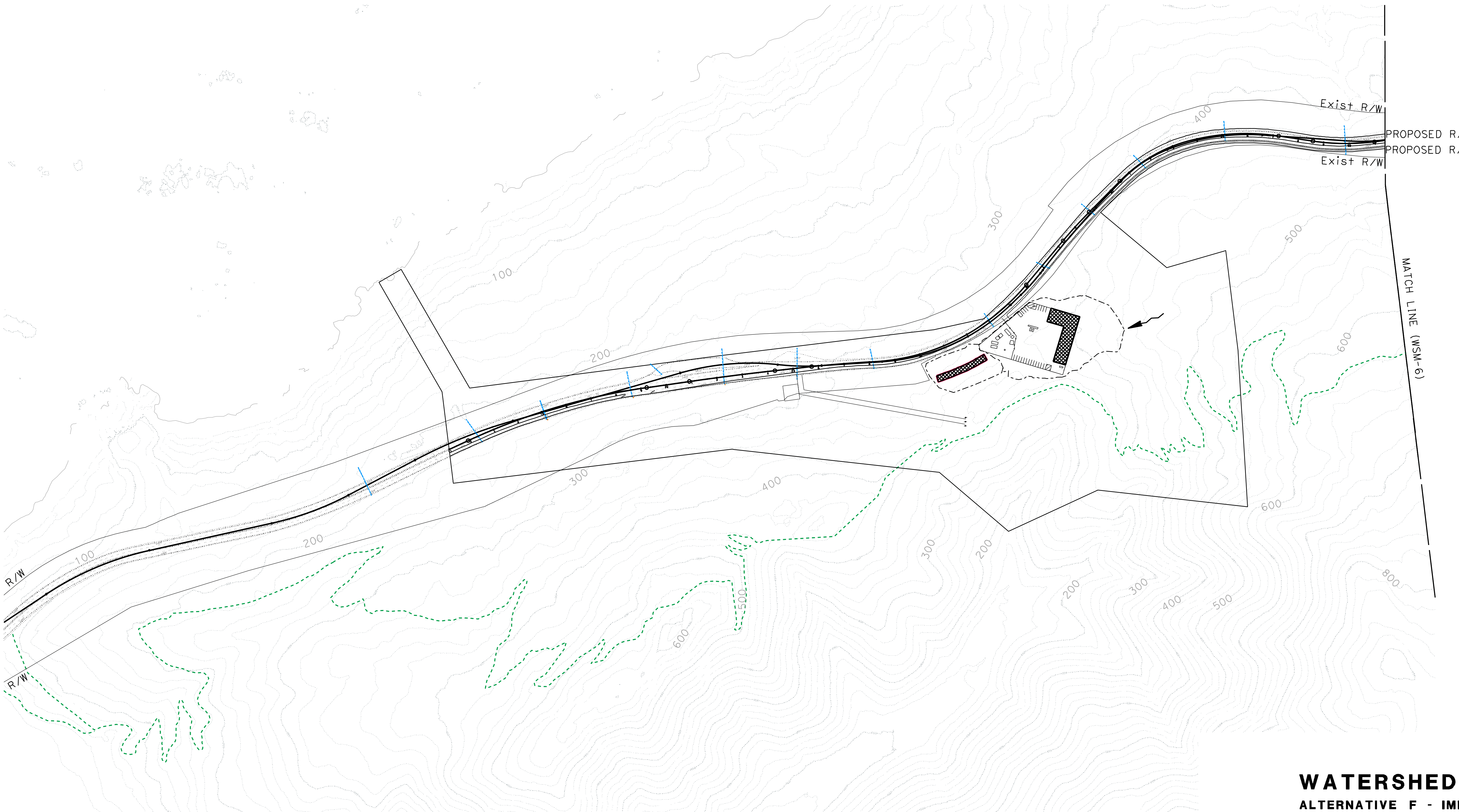
REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA



STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

WATERSHED MAP

ALTERNATIVE F - IMPERVIOUS

SCALE: 1" = 200' **WSM-5**

LAST REVISION 10-14-22

DATE PLOTTED => 01-MAR-2023
TIME PLOTTED => 14:51

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA,
CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

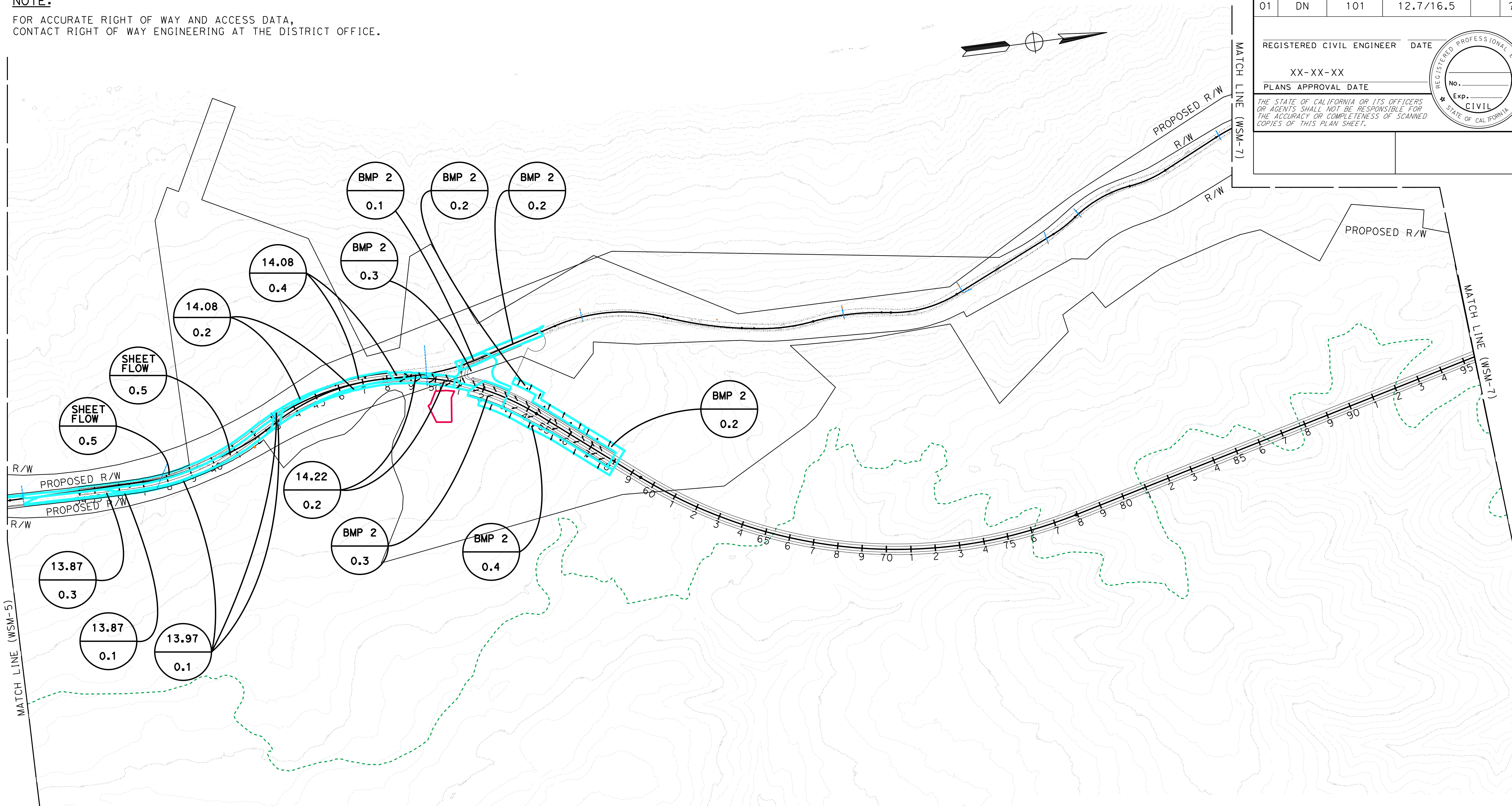
REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA



STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

WATERSHED MAP

ALTERNATIVE F - IMPERVIOUS

SCALE: 1" = 200' **WSM-6**

LAST REVISION 10-14-22 DATE PLOTTED => 01-MAR-2023 TIME PLOTTED => 14:52

NOTE:
FOR ACCURATE RIGHT OF WAY AND ACCESS DATA,
CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

REGISTERED CIVIL ENGINEER DATE

XX-XX-XX
PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA

WATERSHED MAP
ALTERNATIVE F - IMPERVIOUS
SCALE: 1" = 200' **WSM-7**

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION
Caltrans
CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA
CALCULATED-DESIGNED BY: DENNY ZHU
CHECKED BY: JIACHENG FAN
REVISED BY
DATE REVISED

LAST REVISION 10-14-22
DATE PLOTTED => 01-MAR-2023
TIME PLOTTED => 14:54

BORDER LAST REVISED 7/2/2010
USERNAME => JFAN
DGN FILE => 0115000099_WSM F_Impervious 007.dgn
RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3
UNIT 0000
PROJECT NUMBER & PHASE 0115000099

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA,
CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

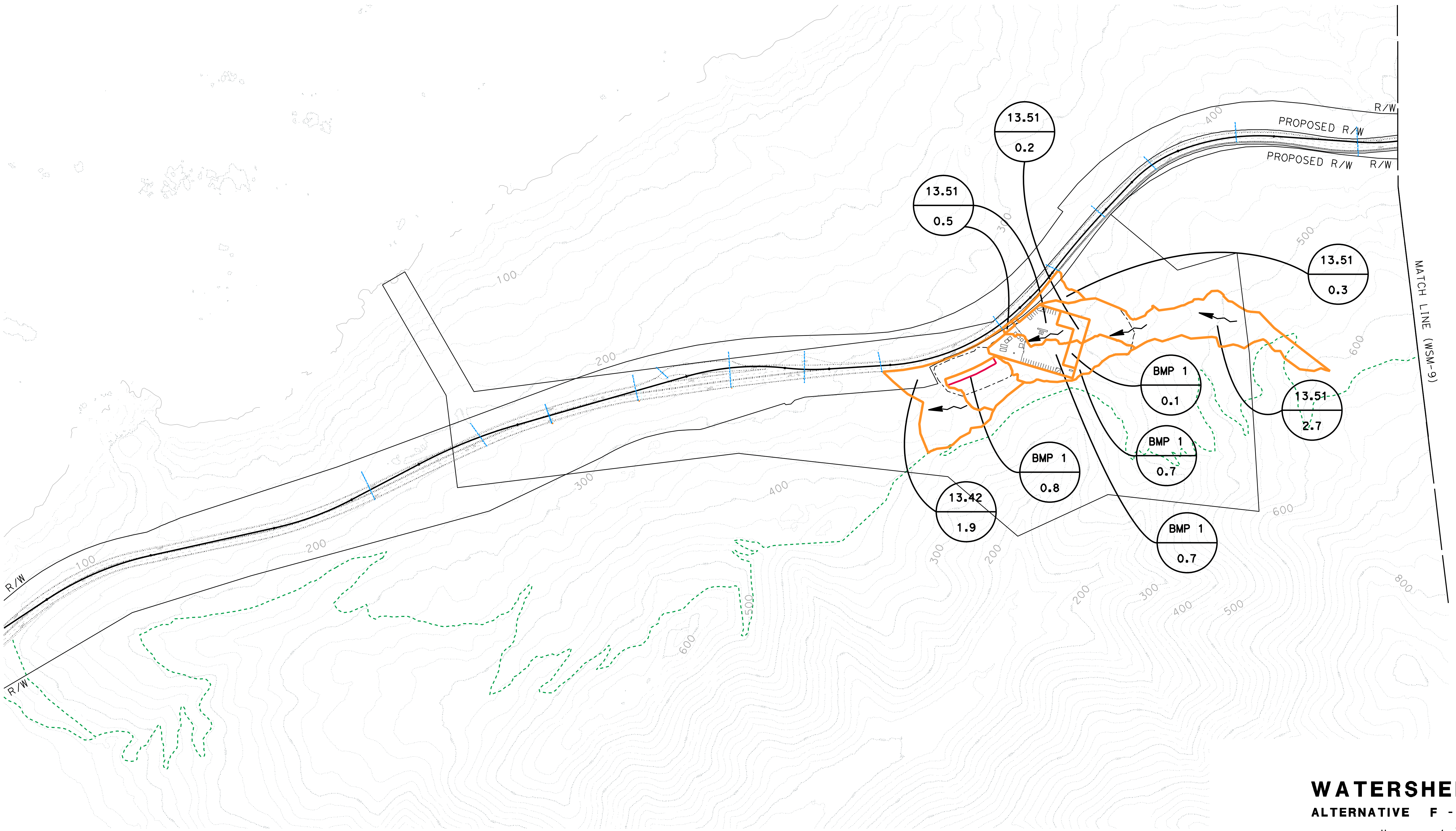
REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA



WATERSHED MAP

ALTERNATIVE F - PERVIOUS

SCALE: 1" = 200' **WSM-8**

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR ANALETTE OCHOA

CALCULATED-DESIGNED BY DENNY ZHU

CHECKED BY JIACHENG FAN

REVISED BY

DATE REVISED

LAST REVISION 10-14-22

DATE PLOTTED => 01-MAR-2023
TIME PLOTTED => 14:54

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA,
CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

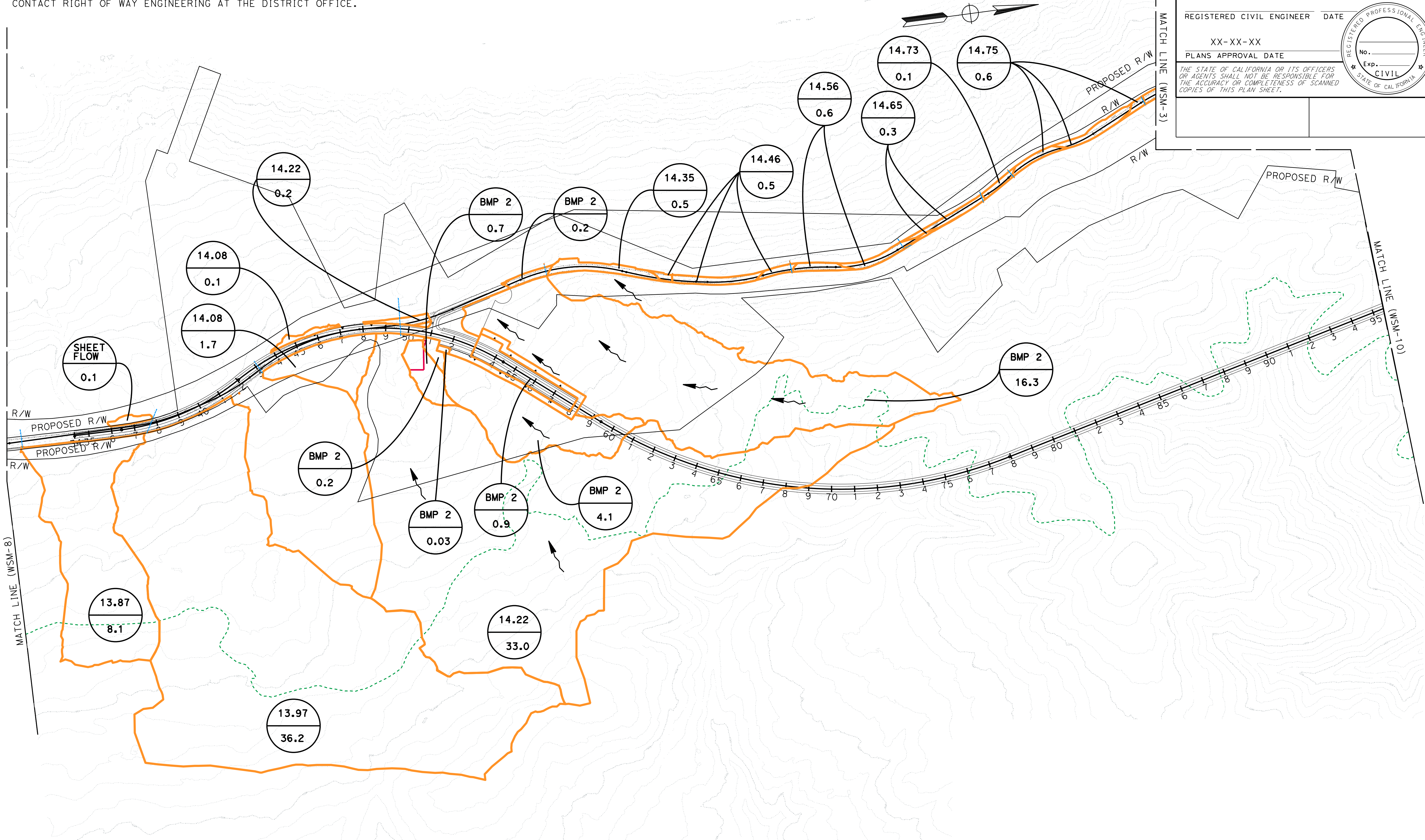
REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER
No.
Exp.
CIVIL
STATE OF CALIFORNIA



WATERSHED MAP

ALTERNATIVE F - PERVIOUS

SCALE: 1" = 200' **WSM-9**

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION

Caltrans

CONSULTANT FUNCTIONAL SUPERVISOR: ANALETTE OCHOA

CALCULATED-DESIGNED BY: DENNY ZHU

CHECKED BY: JIACHENG FAN

REVISED BY

DATE REVISED

LAST REVISION: 10-14-22

DATE PLOTTED => 01-MAR-2023
TIME PLOTTED => 14:55

BORDER LAST REVISED 7/2/2010

USERNAME => JFAN
DGN FILE => 0115000099_WSM F_Pervious 009.dgn

RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3

UNIT 0000

PROJECT NUMBER & PHASE 0115000099

NOTE:

FOR ACCURATE RIGHT OF WAY AND ACCESS DATA, CONTACT RIGHT OF WAY ENGINEERING AT THE DISTRICT OFFICE.

Dist	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	DN	101	12.7/16.5		???

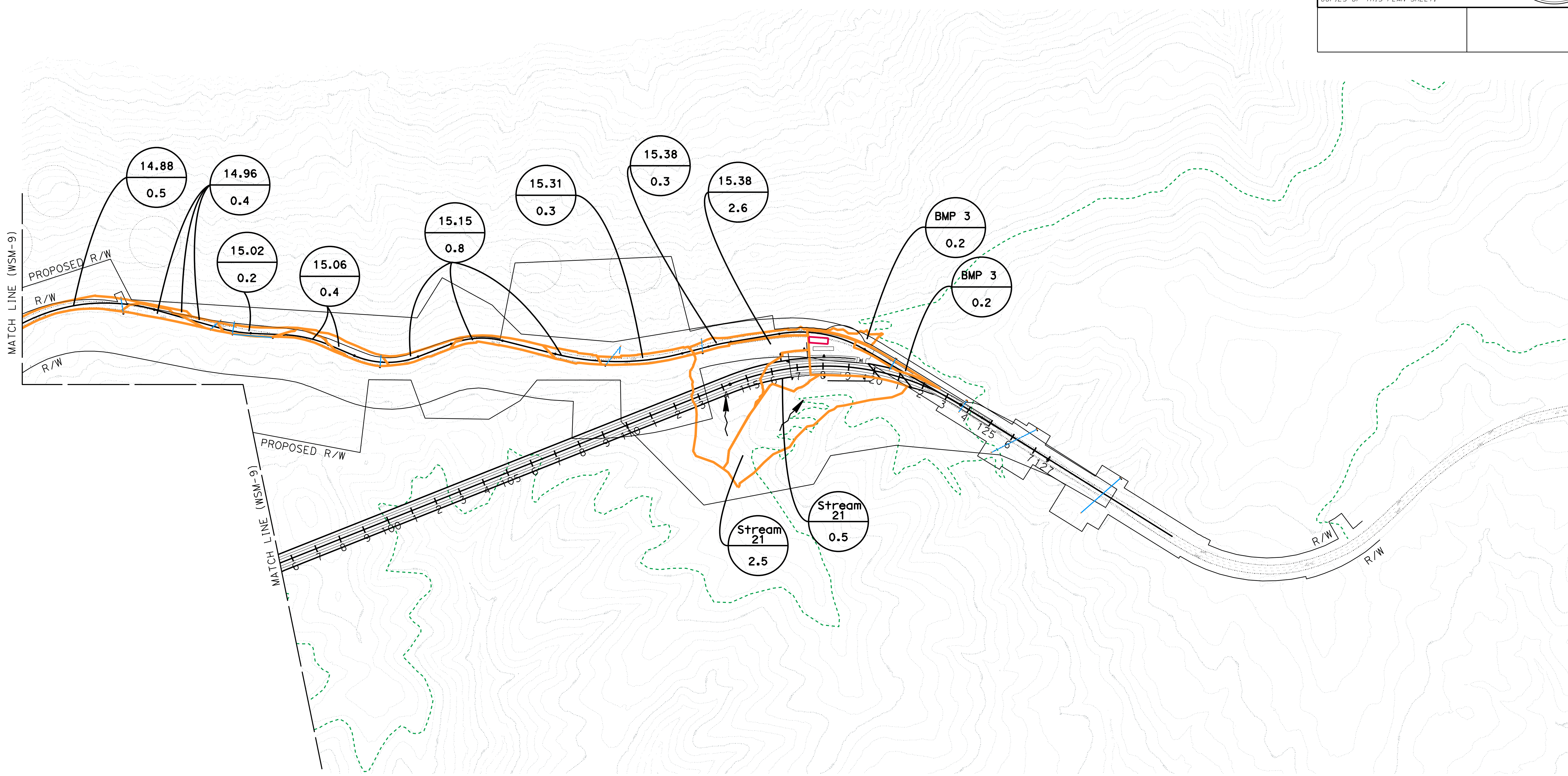
REGISTERED CIVIL ENGINEER DATE

XX-XX-XX

PLANS APPROVAL DATE

THE STATE OF CALIFORNIA OR ITS OFFICERS OR AGENTS SHALL NOT BE RESPONSIBLE FOR THE ACCURACY OR COMPLETENESS OF SCANNED COPIES OF THIS PLAN SHEET.

REGISTERED PROFESSIONAL ENGINEER No. Exp. CIVIL STATE OF CALIFORNIA



REVISED BY DATE REVISED

DENNY ZHU JIACHENG FAN

CALCULATED-DESIGNED BY CHECKED BY

CONSULTANT FUNCTIONAL SUPERVISOR ANALETTE OCHOA

STATE OF CALIFORNIA - DEPARTMENT OF TRANSPORTATION Caltrans

WATERSHED MAP

ALTERNATIVE F - PERVIOUS

SCALE: 1" = 200' **WSM-10**

LAST REVISION 10-14-22 DATE PLOTTED => 01-MAR-2023 TIME PLOTTED => 14:56

BORDER LAST REVISED 7/2/2010 USERNAME => JFAN DGN FILE => 0115000099_WSM F_Pervious 010.dgn RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3 UNIT 0000 PROJECT NUMBER & PHASE 0115000099

Appendix C Rainfall Precipitation Data

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NOAA Atlas 14, Volume 6, Version 2
Location name: Klamath, California, USA*
Latitude: 41.6469°, Longitude: -124.1122°
Elevation: 956.24 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**2.16** (1.88-2.51)	**2.66** (2.32-3.08)	**3.31** (2.87-3.85)	**3.84** (3.31-4.51)	**4.57** (3.79-5.58)	**5.15** (4.16-6.42)	**5.72** (4.51-7.34)	**6.32** (4.84-8.36)	**7.15** (5.22-9.91)	**7.80** (5.48-11.2)
10-min	**1.55** (1.35-1.80)	**1.91** (1.66-2.21)	**2.37** (2.06-2.76)	**2.75** (2.37-3.24)	**3.28** (2.72-4.00)	**3.68** (2.98-4.60)	**4.10** (3.23-5.26)	**4.54** (3.46-6.00)	**5.12** (3.74-7.10)	**5.59** (3.92-8.05)
15-min	**1.25** (1.09-1.45)	**1.54** (1.34-1.78)	**1.91** (1.66-2.23)	**2.22** (1.91-2.61)	**2.64** (2.19-3.22)	**2.97** (2.40-3.71)	**3.31** (2.60-4.24)	**3.66** (2.79-4.84)	**4.13** (3.02-5.72)	**4.51** (3.16-6.48)
30-min	**0.874** (0.762-1.01)	**1.07** (0.934-1.25)	**1.34** (1.16-1.56)	**1.55** (1.34-1.82)	**1.85** (1.53-2.25)	**2.08** (1.68-2.59)	**2.31** (1.82-2.96)	**2.55** (1.95-3.38)	**2.89** (2.11-4.00)	**3.15** (2.21-4.53)
60-min	**0.648** (0.565-0.751)	**0.796** (0.693-0.923)	**0.991** (0.860-1.15)	**1.15** (0.990-1.35)	**1.37** (1.14-1.67)	**1.54** (1.25-1.92)	**1.71** (1.35-2.20)	**1.89** (1.45-2.50)	**2.14** (1.56-2.96)	**2.34** (1.64-3.36)
2-hr	**0.498** (0.434-0.577)	**0.606** (0.527-0.702)	**0.747** (0.648-0.870)	**0.863** (0.742-1.01)	**1.02** (0.846-1.24)	**1.14** (0.925-1.43)	**1.27** (0.998-1.63)	**1.40** (1.07-1.85)	**1.57** (1.15-2.18)	**1.71** (1.20-2.46)
3-hr	**0.428** (0.373-0.496)	**0.518** (0.451-0.601)	**0.636** (0.552-0.740)	**0.732** (0.629-0.859)	**0.861** (0.714-1.05)	**0.961** (0.778-1.20)	**1.06** (0.837-1.36)	**1.17** (0.891-1.54)	**1.31** (0.954-1.81)	**1.42** (0.996-2.04)
6-hr	**0.332** (0.289-0.384)	**0.400** (0.349-0.465)	**0.489** (0.424-0.569)	**0.559** (0.481-0.657)	**0.653** (0.541-0.796)	**0.724** (0.586-0.903)	**0.795** (0.626-1.02)	**0.867** (0.662-1.15)	**0.962** (0.702-1.33)	**1.04** (0.727-1.49)
12-hr	**0.247** (0.215-0.286)	**0.303** (0.264-0.352)	**0.373** (0.324-0.434)	**0.427** (0.368-0.502)	**0.498** (0.412-0.606)	**0.549** (0.444-0.685)	**0.599** (0.471-0.768)	**0.648** (0.495-0.857)	**0.711** (0.519-0.985)	**0.759** (0.533-1.09)
24-hr	**0.190** (0.169-0.217)	**0.238** (0.212-0.272)	**0.296** (0.263-0.339)	**0.340** (0.300-0.393)	**0.396** (0.340-0.470)	**0.435** (0.367-0.526)	**0.473** (0.391-0.584)	**0.510** (0.411-0.645)	**0.556** (0.433-0.729)	**0.590** (0.445-0.797)
2-day	**0.131** (0.117-0.149)	**0.163** (0.146-0.187)	**0.202** (0.180-0.232)	**0.232** (0.205-0.268)	**0.270** (0.232-0.321)	**0.297** (0.250-0.359)	**0.322** (0.266-0.398)	**0.347** (0.280-0.439)	**0.379** (0.295-0.497)	**0.401** (0.303-0.543)
3-day	**0.101** (0.090-0.116)	**0.126** (0.112-0.144)	**0.155** (0.138-0.178)	**0.178** (0.157-0.206)	**0.207** (0.178-0.246)	**0.227** (0.192-0.275)	**0.247** (0.204-0.305)	**0.266** (0.215-0.337)	**0.290** (0.226-0.380)	**0.307** (0.232-0.416)
4-day	**0.086** (0.076-0.098)	**0.106** (0.095-0.122)	**0.131** (0.117-0.151)	**0.150** (0.133-0.174)	**0.174** (0.150-0.207)	**0.191** (0.161-0.231)	**0.207** (0.171-0.256)	**0.223** (0.180-0.282)	**0.243** (0.189-0.319)	**0.257** (0.194-0.348)
7-day	**0.062** (0.055-0.071)	**0.077** (0.068-0.088)	**0.094** (0.084-0.108)	**0.107** (0.095-0.124)	**0.124** (0.106-0.147)	**0.135** (0.114-0.164)	**0.146** (0.121-0.181)	**0.157** (0.126-0.198)	**0.170** (0.132-0.223)	**0.179** (0.135-0.242)
10-day	**0.051** (0.046-0.058)	**0.063** (0.056-0.072)	**0.077** (0.069-0.088)	**0.087** (0.077-0.101)	**0.100** (0.086-0.119)	**0.109** (0.092-0.132)	**0.118** (0.097-0.145)	**0.126** (0.101-0.159)	**0.136** (0.106-0.178)	**0.143** (0.108-0.193)
20-day	**0.035** (0.031-0.040)	**0.043** (0.038-0.049)	**0.052** (0.046-0.059)	**0.058** (0.052-0.067)	**0.066** (0.057-0.079)	**0.072** (0.061-0.087)	**0.077** (0.064-0.095)	**0.082** (0.066-0.103)	**0.087** (0.068-0.114)	**0.091** (0.069-0.123)
30-day	**0.029** (0.026-0.034)	**0.036** (0.032-0.041)	**0.043** (0.038-0.049)	**0.048** (0.043-0.056)	**0.055** (0.047-0.065)	**0.059** (0.050-0.071)	**0.063** (0.052-0.078)	**0.066** (0.054-0.084)	**0.071** (0.055-0.093)	**0.074** (0.056-0.099)
45-day	**0.025** (0.023-0.029)	**0.031** (0.027-0.035)	**0.036** (0.032-0.042)	**0.041** (0.036-0.047)	**0.046** (0.039-0.054)	**0.049** (0.041-0.059)	**0.052** (0.043-0.064)	**0.055** (0.044-0.069)	**0.058** (0.045-0.076)	**0.060** (0.045-0.081)
60-day	**0.023** (0.020-0.026)	**0.027** (0.024-0.031)	**0.032** (0.029-0.037)	**0.036** (0.032-0.042)	**0.040** (0.034-0.048)	**0.043** (0.036-0.052)	**0.045** (0.037-0.056)	**0.047** (0.038-0.060)	**0.050** (0.039-0.066)	**0.052** (0.039-0.070)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

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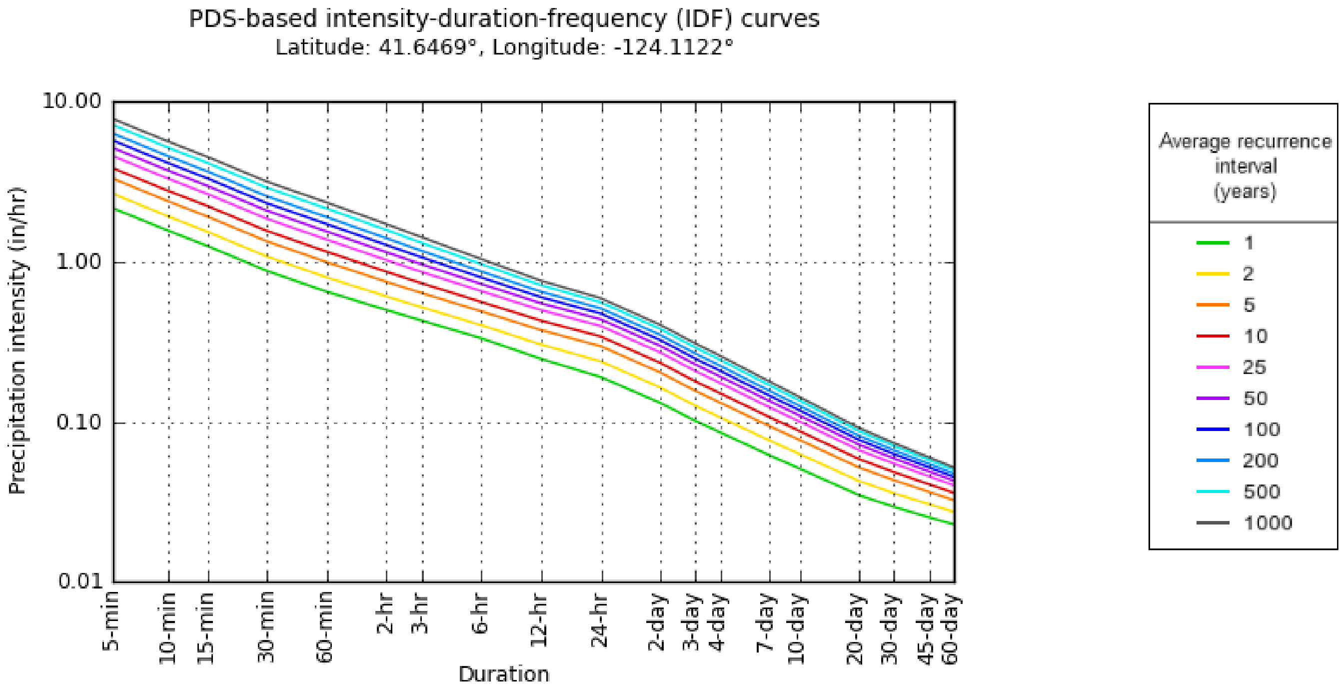
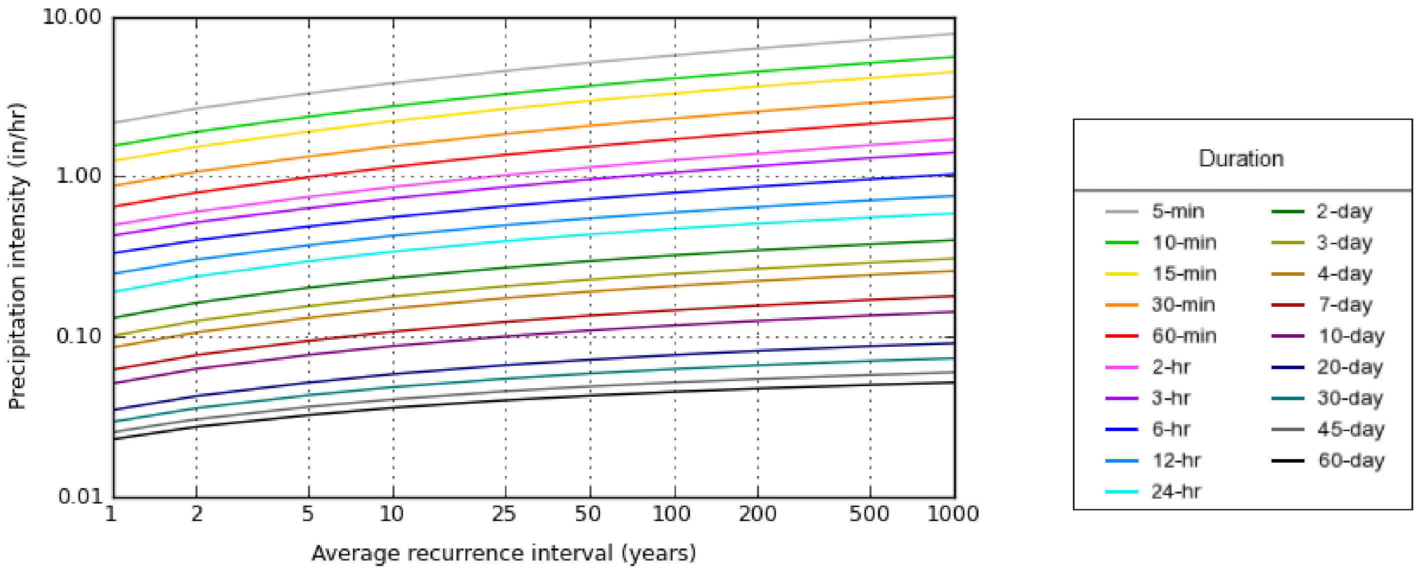
PF graphical





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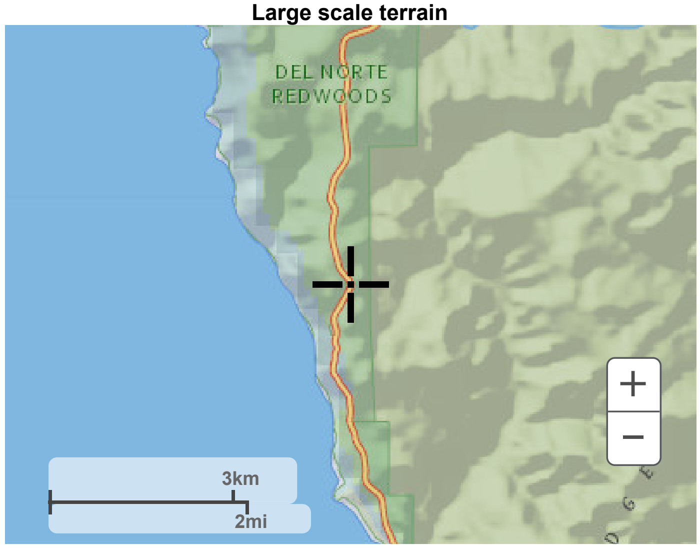
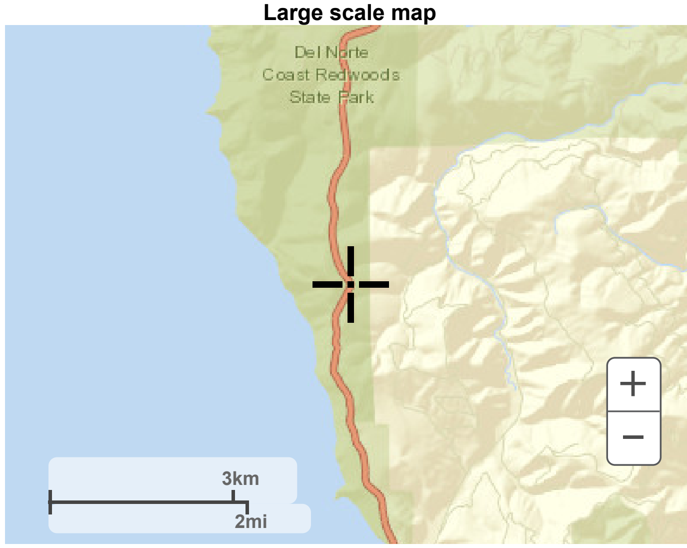
Maps & aerials

Small scale terrain

Large scale terrain



Large scale map



Large scale aerial

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Questions?: HDSC.Questions@noaa.gov

NOAA Atlas 14, Volume 6, Version 2
Location name: Klamath, California, USA*
Latitude: 41.6469°, Longitude: -124.1122°
Elevation: 956.24 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.180** (0.157-0.209)	**0.222** (0.193-0.257)	**0.276** (0.239-0.321)	**0.320** (0.276-0.376)	**0.381** (0.316-0.465)	**0.429** (0.347-0.535)	**0.477** (0.376-0.612)	**0.527** (0.403-0.697)	**0.596** (0.435-0.826)	**0.650** (0.457-0.935)
10-min	**0.259** (0.225-0.300)	**0.318** (0.277-0.369)	**0.395** (0.343-0.460)	**0.459** (0.395-0.540)	**0.547** (0.453-0.667)	**0.614** (0.497-0.767)	**0.684** (0.539-0.877)	**0.756** (0.577-1.00)	**0.854** (0.623-1.18)	**0.932** (0.654-1.34)
15-min	**0.313** (0.273-0.362)	**0.384** (0.334-0.446)	**0.478** (0.415-0.557)	**0.556** (0.478-0.652)	**0.661** (0.548-0.806)	**0.743** (0.601-0.927)	**0.827** (0.651-1.06)	**0.914** (0.698-1.21)	**1.03** (0.754-1.43)	**1.13** (0.791-1.62)
30-min	**0.437** (0.381-0.506)	**0.537** (0.467-0.623)	**0.668** (0.580-0.778)	**0.776** (0.668-0.912)	**0.924** (0.765-1.13)	**1.04** (0.840-1.30)	**1.16** (0.910-1.48)	**1.28** (0.975-1.69)	**1.44** (1.05-2.00)	**1.58** (1.11-2.27)
60-min	**0.648** (0.565-0.751)	**0.796** (0.693-0.923)	**0.991** (0.860-1.15)	**1.15** (0.990-1.35)	**1.37** (1.14-1.67)	**1.54** (1.25-1.92)	**1.71** (1.35-2.20)	**1.89** (1.45-2.50)	**2.14** (1.56-2.96)	**2.34** (1.64-3.36)
2-hr	**0.996** (0.868-1.15)	**1.21** (1.05-1.41)	**1.49** (1.30-1.74)	**1.73** (1.48-2.03)	**2.04** (1.69-2.49)	**2.29** (1.85-2.85)	**2.53** (2.00-3.25)	**2.79** (2.13-3.69)	**3.15** (2.29-4.36)	**3.42** (2.40-4.92)
3-hr	**1.29** (1.12-1.49)	**1.56** (1.36-1.81)	**1.91** (1.66-2.22)	**2.20** (1.89-2.58)	**2.59** (2.14-3.15)	**2.89** (2.34-3.60)	**3.19** (2.51-4.09)	**3.50** (2.68-4.63)	**3.93** (2.87-5.44)	**4.26** (2.99-6.13)
6-hr	**1.99** (1.73-2.30)	**2.40** (2.09-2.78)	**2.93** (2.54-3.41)	**3.35** (2.88-3.93)	**3.91** (3.24-4.77)	**4.34** (3.51-5.41)	**4.76** (3.75-6.10)	**5.19** (3.96-6.86)	**5.76** (4.20-7.98)	**6.20** (4.36-8.92)
12-hr	**2.97** (2.59-3.44)	**3.65** (3.18-4.24)	**4.49** (3.90-5.23)	**5.15** (4.43-6.05)	**5.99** (4.97-7.31)	**6.61** (5.35-8.25)	**7.21** (5.68-9.25)	**7.80** (5.96-10.3)	**8.57** (6.25-11.9)	**9.14** (6.42-13.1)
24-hr	**4.56** (4.07-5.21)	**5.71** (5.09-6.53)	**7.10** (6.32-8.14)	**8.16** (7.21-9.42)	**9.49** (8.15-11.3)	**10.4** (8.81-12.6)	**11.4** (9.38-14.0)	**12.2** (9.87-15.5)	**13.3** (10.4-17.5)	**14.1** (10.7-19.1)
2-day	**6.28** (5.61-7.18)	**7.83** (6.99-8.96)	**9.72** (8.65-11.1)	**11.2** (9.86-12.9)	**13.0** (11.1-15.4)	**14.2** (12.0-17.2)	**15.5** (12.8-19.1)	**16.7** (13.4-21.1)	**18.2** (14.1-23.8)	**19.3** (14.6-26.0)
3-day	**7.28** (6.50-8.32)	**9.05** (8.07-10.4)	**11.2** (9.96-12.8)	**12.8** (11.3-14.8)	**14.9** (12.8-17.7)	**16.4** (13.8-19.8)	**17.8** (14.7-22.0)	**19.2** (15.4-24.2)	**20.9** (16.2-27.4)	**22.1** (16.7-29.9)
4-day	**8.23** (7.34-9.40)	**10.2** (9.10-11.7)	**12.6** (11.2-14.5)	**14.4** (12.7-16.7)	**16.7** (14.4-19.9)	**18.4** (15.5-22.2)	**19.9** (16.5-24.6)	**21.4** (17.3-27.1)	**23.3** (18.2-30.6)	**24.7** (18.7-33.4)
7-day	**10.4** (9.32-11.9)	**12.9** (11.5-14.8)	**15.8** (14.1-18.2)	**18.1** (16.0-20.9)	**20.8** (17.9-24.7)	**22.8** (19.2-27.5)	**24.6** (20.3-30.4)	**26.3** (21.2-33.3)	**28.5** (22.2-37.4)	**30.1** (22.7-40.7)
10-day	**12.2** (10.9-14.0)	**15.1** (13.5-17.3)	**18.5** (16.4-21.2)	**21.0** (18.5-24.2)	**24.1** (20.7-28.6)	**26.2** (22.1-31.7)	**28.3** (23.4-34.9)	**30.2** (24.4-38.2)	**32.6** (25.3-42.7)	**34.3** (25.9-46.3)
20-day	**16.7** (14.9-19.1)	**20.5** (18.3-23.4)	**24.8** (22.1-28.5)	**28.0** (24.8-32.4)	**31.9** (27.4-37.9)	**34.5** (29.1-41.7)	**36.9** (30.5-45.6)	**39.2** (31.6-49.6)	**41.9** (32.6-55.0)	**43.8** (33.1-59.2)
30-day	**21.2** (18.9-24.2)	**25.8** (23.0-29.5)	**31.1** (27.7-35.6)	**34.9** (30.8-40.3)	**39.4** (33.9-46.8)	**42.5** (35.8-51.4)	**45.2** (37.4-55.9)	**47.8** (38.5-60.5)	**50.9** (39.6-66.7)	**53.0** (40.0-71.6)
45-day	**27.3** (24.4-31.3)	**33.0** (29.4-37.7)	**39.4** (35.0-45.2)	**43.9** (38.8-50.7)	**49.3** (42.3-58.5)	**52.8** (44.5-63.9)	**56.0** (46.3-69.1)	**58.9** (47.5-74.5)	**62.3** (48.5-81.7)	**64.7** (48.8-87.4)
60-day	**32.9** (29.4-37.6)	**39.4** (35.2-45.1)	**46.7** (41.5-53.5)	**51.8** (45.8-59.8)	**57.8** (49.6-68.6)	**61.7** (52.0-74.6)	**65.2** (53.8-80.5)	**68.3** (55.1-86.5)	**72.0** (56.0-94.5)	**74.5** (56.3-101)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

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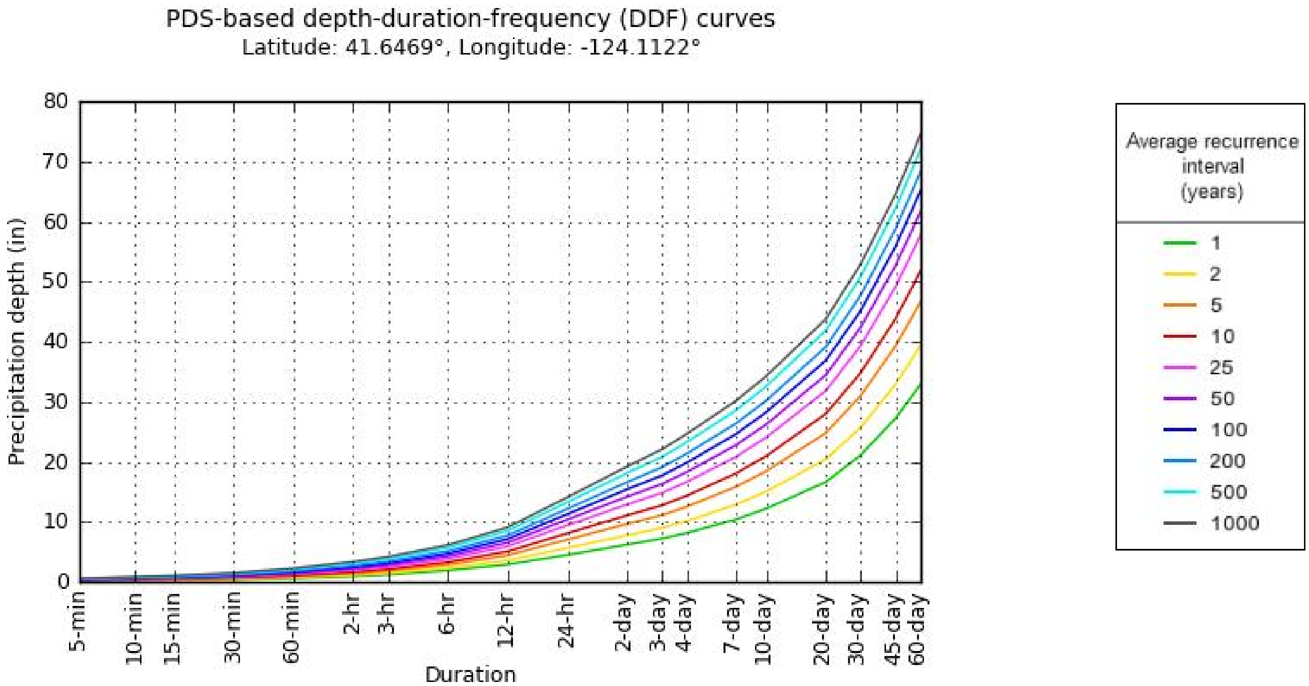
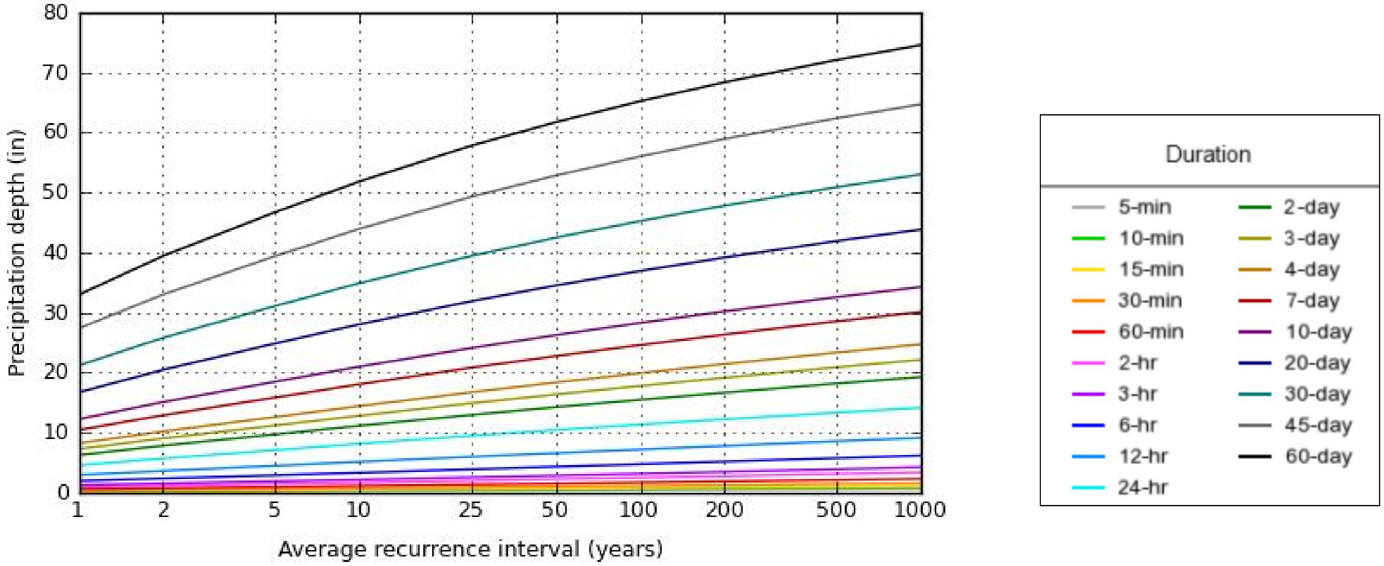
PF graphical





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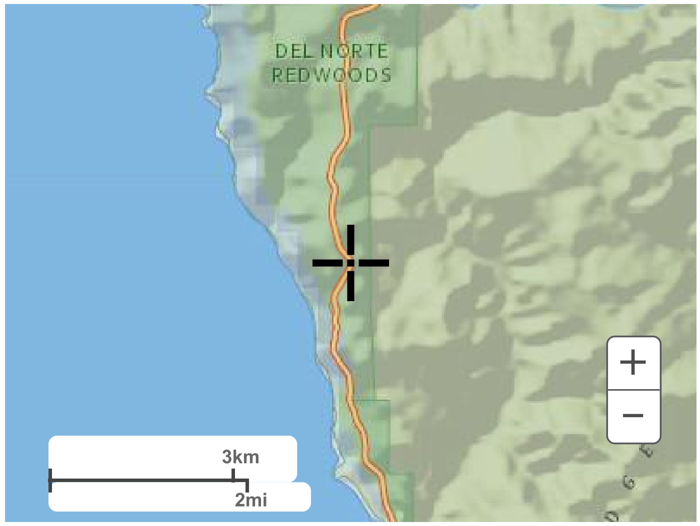
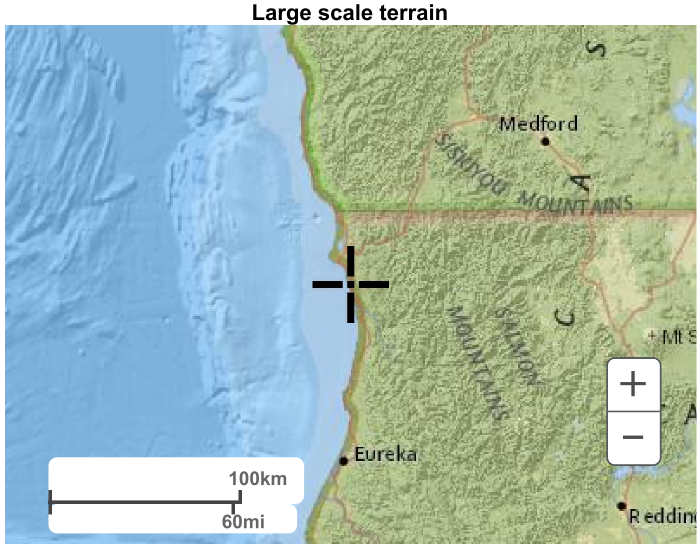
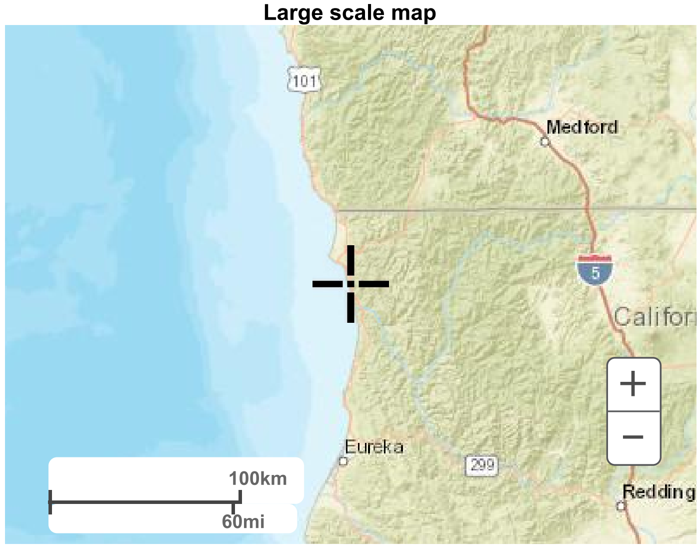


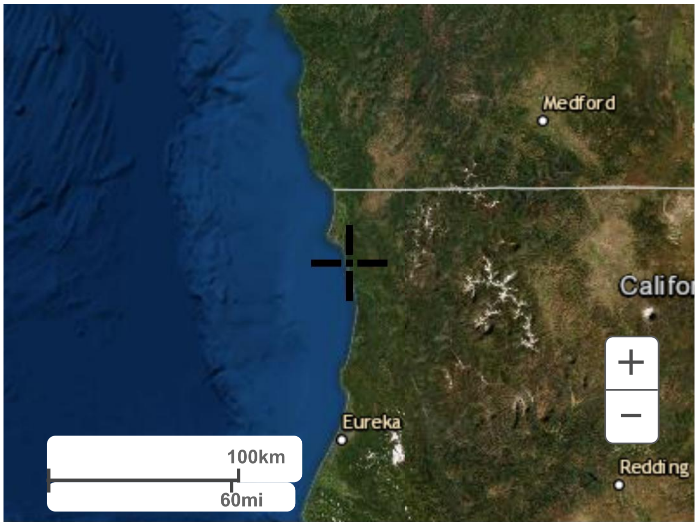
Large scale terrain



Large scale map



Large scale aerial



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Appendix D Summary of Design Discharge

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Drainage System ID	Description	Post Miles	Existing Hydrology									Pre-Project Flow		Alternative X Hydrology								Alternative X Post-Project Flow		Alternative F Hydrology									Alternative F Post-Project Flow		Notes
			Tc	off-site A	on-site Imp A	on-site Perv A	Total A	C10	C100	i10	i100	Q10	Q100	off-site A	on-site Imp A	on-site Perv A [1]	Total A	C10	C100	i10	i100	Q10	Q100	off-site A	on-site A	on-site Perv A [1]	Total A	Tc	C10	C100	i10	i100	Q10	Q100	
			(min)	(ac)	(ac)	(ac)	(ac)			(in./hr)	(in./hr)	(cfs)	(cfs)	(ac)	(ac)	(ac)	(ac)			(in./hr)	(in./hr)	(cfs)	(cfs)	(ac)	(ac)	(ac)	(ac)	(min)			(in./hr)	(in./hr)	(cfs)	(cfs)	
18" Culvert	18" Diameter	13.03	74.8	6.8	0.6	0.2	7.6	0.67	0.84	1.01	1.51	5.2	9.6	6.8	0.6	0.2	7.6	NA	NA	NA	NA	NA	NA	6.8	0.6	0.2	7.6	NA	NA	NA	NA	NA	NA	NA	
24" Culvert	24" Diameter	13.12	42.6	12.7	0.2	0.0	12.9	0.67	0.84	1.34	1.99	11.6	21.5	12.7	0.2	0.0	12.9	NA	NA	NA	NA	NA	NA	12.7	0.2	0.0	12.9	NA	NA	NA	NA	NA	NA	NA	
24" CPP and 10" CPP with inlet	24" and 10" Diameter	13.17	38.9	2.9	0.2	0.0	3.1	0.67	0.84	1.40	2.08	2.9	5.4	2.9	0.2	0.0	3.1	NA	NA	NA	NA	NA	NA	2.9	0.2	0.0	3.1	NA	NA	NA	NA	NA	NA	NA	
24" CPP with inlet	24" Diameter	13.24	46.1	7.1	0.4	0.0	7.5	0.67	0.84	1.29	1.91	6.5	12.1	7.1	0.4	0.0	7.5	NA	NA	NA	NA	NA	NA	7.1	0.4	0.0	7.5	NA	NA	NA	NA	NA	NA	NA	
18" CPP (on-site)	18" Diameter	13.26	5.0	0.0	0.1	0.1	0.2	0.67	0.84	3.83	5.71	0.5	1.0	0.0	0.1	0.1	0.2	NA	NA	NA	NA	NA	NA	0.0	0.1	0.1	0.2	NA	NA	NA	NA	NA	NA	NA	
24" CPP with inlet	24" Diameter	13.31	5.0	0.3	0.1	0.0	0.4	0.67	0.84	3.83	5.71	0.9	1.7	0.3	0.1	0.0	0.4	NA	NA	NA	NA	NA	NA	0.3	0.1	0.0	0.4	NA	NA	NA	NA	NA	NA	NA	
24" CMP	24" Diameter	13.36	47.8	7.9	0.0	0.0	7.9	0.67	0.84	1.26	1.88	6.7	12.5	7.9	0.0	0.0	7.9	NA	NA	NA	NA	NA	NA	7.9	0.0	0.0	7.9	NA	NA	NA	NA	NA	NA	NA	
24" CSP with inlet	24" Diameter	13.42	60.6	3.7	0.0	0.0	3.7	0.67	0.84	1.12	1.67	2.8	5.2	3.7	0.0	0.0	3.7	NA	NA	NA	NA	NA	NA	1.9	0.0	2.3	4.2	NA	0.7	0.8	1.1	1.7	3.2	5.9	Alt F BMP 1 outfall
24" CSP with inlet	24" Diameter	13.51	65.6	3.8	0.0	0.0	3.8	0.67	0.84	1.08	1.61	2.8	5.1	3.8	0.0	0.0	3.8	NA	NA	NA	NA	NA	NA	3.0	0.0	0.7	3.7	NA	0.7	0.8	1.1	1.6	2.7	5.0	
24" CSP with inlet	24" Diameter	13.57	60.5	3.0	0.1	0.0	3.1	0.67	0.84	1.13	1.67	2.3	4.3	3.0	0.1	0.0	3.1	NA	NA	NA	NA	NA	NA	3.0	0.1	0.0	3.1	NA	NA	NA	NA	NA	NA	NA	
24" CSP with inlet	24" Diameter	13.62	45.3	0.7	0.3	0.0	1.0	0.67	0.84	1.30	1.93	0.9	1.7	0.7	0.3	0.0	1.0	NA	NA	NA	NA	NA	NA	0.7	0.3	0.0	1.0	NA	NA	NA	NA	NA	NA	NA	
18" CMP with inlet	18" Diameter	13.67	113.1	14.8	0.3	0.0	15.1	0.67	0.84	0.83	1.23	8.4	15.5	14.8	0.3	0.0	15.1	NA	NA	NA	NA	NA	NA	14.8	0.3	0.0	15.1	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	13.73	93.5	4.9	0.3	0.0	5.2	0.67	0.84	0.91	1.35	3.2	5.9	4.9	0.3	0.0	5.2	NA	NA	NA	NA	NA	NA	4.9	0.3	0.0	5.2	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	13.84	86.4	6.0	0.0	0.0	6.0	0.67	0.84	0.94	1.40	3.8	7.1	6.0	0.0	0.0	6.0	NA	NA	NA	NA	NA	NA	6.0	0.0	0.0	6.0	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	13.87	84.6	8.2	0.2	0.0	8.4	0.67	0.84	0.95	1.42	5.4	10.0	8.2	0.2	0.0	8.4	NA	NA	NA	NA	NA	NA	8.1	0.4	0.0	8.5	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	13.97	75.2	36.3	0.0	0.0	36.3	0.67	0.84	1.01	1.50	24.6	45.7	36.3	0.0	0.0	36.3	NA	NA	NA	NA	NA	NA	36.2	0.1	0.0	36.3	NA	NA	NA	NA	NA	NA	NA	
18" CMP with inlet	18" Diameter	14.04	81.9	9.4	0.0	0.0	9.4	0.67	0.84	0.97	1.44	6.1	11.4	9.4	0.0	0.0	9.4	NA	NA	NA	NA	NA	NA	9.4	0.1	0.0	9.4	NA	NA	NA	NA	NA	NA	NA	
18" CMP with inlet	18" Diameter	14.08	82.0	1.8	0.5	0.2	2.5	0.67	0.84	0.97	1.44	1.6	3.0	1.8	0.5	0.2	2.5	NA	NA	NA	NA	NA	NA	1.7	0.6	0.1	2.4	NA	NA	NA	NA	NA	NA	NA	
30" CMP	30" Diameter	14.22	92.6	33.9	0.0	0.0	33.9	0.67	0.84	0.91	1.36	21.0	39.0	33.9	0.4	0.0	34.3	NA	NA	NA	NA	NA	NA	33.0	1.9	22.4	73.6	95.1	0.7	0.8	0.9	1.3	44.7	82.9	Alt F BMP 2 outfall Include Watershed Area from Pm 14.28 However, the downstream STREAM will see the same watershed. Drainage Improvements to be refined in PS&E to divorce off-site runon
Existing Unlined Swale S 15 C 1 per ARDR	Existing Unlined Swale to Unknown Culvert Diameter	14.28	91.2	18.2	0.2	0.0	18.4	0.67	0.84	0.92	1.37	11.4	21.1	18.1	0.4	0.0	18.5	0.67	0.84	0.9	1.4	11.4	21.1	16.3	0.0	0.0	16.3	NA	0.7	0.8	0.9	1.4	10.0	18.7	Potential culvert removal in Alt F. 16.3 ac off-site watershed added to 14.22 30" CMP. Design to be refined in PS&E.
S 17 C1 per ARDR	S 17 C1	14.28	74.6	4.6	0.0	0.0	4.6	0.67	0.84	1.02	1.51	3.1	5.8	4.6	0.0	0.0	4.6	0.67	0.84	1.0	1.5	3.1	5.8	0.0	0.0	0.0	0.0	NA	0.7	0.8	1.0	1.5	0.0	0.0	Potential culvert removal in Alt F
24" CPP with inlet	24" Diameter	14.35	33.9	1.5	0.5	0.0	2.0	0.67	0.84	1.49	2.22	1.9	3.5	1.3	0.6	0.1	2.0	0.67	0.84	1.5	2.2	1.9	3.5	1.5	0.5	0.5	2.5	NA	0.7	0.8	1.5	2.2	2.0	3.7	
6" CMP (on-site)	6" Diameter	14.46	5.0	4.3	0.5	0.0	4.8	0.67	0.84	3.83	5.71	12.4	23.2	4.0	0.6	0.3	4.9	0.67	0.84	3.8	5.7	12.4	23.2	4.3	0.0	0.5	4.8	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	14.56	48.5	5.8	0.6	0.0	6.4	0.67	0.84	1.25	1.86	5.4	10.0	5.5	0.6	0.3	6.4	0.67	0.84	1.3	1.9	5.4	10.0	5.8	0.0	0.6	6.4	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	14.65	33.2	6.4	0.3	0.0	6.7	0.67	0.84	1.51	2.25	6.8	12.6	6.0	0.4	0.3	6.7	0.67	0.84	1.5	2.2	6.8	12.6	6.4	0.0	0.3	6.7	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	14.73	42.0	6.7	0.1	0.0	6.8	0.67	0.84	1.35	2.00	6.0	11.2	6.4	0.2	0.1	6.7	0.67	0.84	1.3	2.0	6.0	11.2	6.7	0.0	0.1	6.8	NA	NA	NA	NA	NA	NA	NA	
18" CMP with inlet	18" Diameter	14.75	61.6	9.7	0.6	0.0	10.3	0.67	0.84	1.12	1.66	7.6	14.2	9.0	0.7	0.5	10.2	0.67	0.84	1.1	1.7	7.6	14.2	9.7	0.0	0.6	10.3	NA	NA	NA	NA	NA	NA	NA	
21" ABS with inlet	21" Diameter	14.88	50.2	5.3	0.5	0.0	5.8	0.67	0.84	1.23	1.83	4.8	8.9	4.9	0.5	0.4	5.8	0.67	0.84	1.2	1.8	4.8	8.9	5.3	0.0	0.5	5.8	NA	NA	NA	NA	NA	NA	NA	
18" HDPE with inlet	18" Diameter	14.96	41.5	3.1	0.4	0.0	3.5	0.67	0.84	1.35	2.01	3.2	5.9	2.9	0.4	0.2	3.5	0.67	0.84	1.4	2.0	3.2	5.9	3.1	0.0	0.4	3.5	NA	NA	NA	NA	NA	NA	NA	
18" CMP with inlet	18" Diameter	15.02	44.7	4.0	0.2	0.0	4.2	0.67	0.84	1.31	1.94	3.7	6.8	3.9	0.2	0.1	4.2	0.67	0.84	1.3	1.9	3.7	6.8	4.0	0.0	0.2	4.2	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	15.03	39.7	2.6	0.0	0.0	2.6	0.67	0.84	1.38	2.06	2.4	4.5	2.5	0.1	0.0	2.6	0.67	0.84	1.4	2.1	2.4	4.5	2.6	0.0	0.0	2.6	NA	NA	NA	NA	NA	NA	NA	
24" CMP with inlet	24" Diameter	15.06	35.0	2.4	0.4	0.0	2.8	0.67	0.84	1.47	2.19	2.8	5.1	2.0	0.4	0.4	2.8	0.67	0.84	1.5	2.2	2.8	5.1	2.4	0.0	0.4	2.8	NA	NA	NA	NA	NA	NA	NA	
18" CMP with inlet	18" Diameter	15.15	46.6	6.7	0.8	0.0	7.5	0.67	0.84	1.28	1.90	6.4	11.9	5.1	0.9	1.5	7.5	0.67	0.84	1.3	1.9	6.4	11.9	6.7	0.0	0.8	7.5	NA	NA	NA	NA	NA	NA	NA	
18" HDPE with inlet	18" Diameter	15.31	51.6	2.1	0.3	0.0	2.4	0.67	0.84	1.22	1.81	2.0	3.6	1.9	0.3	0.2	2.4	0.67	0.84	1.2	1.8	2.0	3.6	2.1	0.0	0.3	2.4	NA	NA	NA	NA	NA	NA	NA	
18" CMP with inlet	18" Diameter	15.38	63.7	3.4	0.5	0.1	4.0	0.67	0.84	1.10	1.63	2.9	5.5	3.3	0.6	0.1	4.0	0.67	0.84	1.1	1.6	2.9	5.5	2.6	0.5	0.7	3.8	NA	0.7	0.8	1.1	1.6	2.6	4.8	Alt F BMP 3 Outfall
24" HDPE with headwall	24' Diameter	15.54	59.6	1.2	0.0	0.0	1.2	0.67	0.84	1.13	1.69	0.9	1.7	1.2	0.0	0.0	1.2	NA	NA	NA	NA	NA	NA	1.2	0.0	0.0	1.2	NA	0.7	0.8	1.1	1.7	0.9	1.7	
24" HDPE with headwall	24" Diameter	15.6	60.4	1.5	0.1	0.0	1.6	0.67	0.84	1.13	1.67	1.1	2.1	1.5	0.1	0.0	1.6	NA	NA	NA	NA	NA	NA	1.5	0.1	0.0	1.6	NA	NA	NA	NA	NA	NA	NA	
30" CMP with headwall	30" Diameter	15.65	47.1	8.3	0.1	0.0	8.4	0.67	0.84	1.27	1.89	7.1	13.2	8.3	0.1	0.0	8.4	NA	NA	NA	NA	NA	NA	8.3	0.1	0.0	8.4	NA	NA	NA	NA	NA	NA	NA	
36" STEEL with headwall	36" Diameter	15.76	120.7	13.6	0.9	0.0	14.5	0.67	0.84	0.80	1.19	7.8	14.4	13.6	0.9	0.0	14.5	NA	NA	NA	NA	NA	NA	13.6	0.9	0.0	14.5	NA	NA	NA	NA	NA	NA	NA	
NEW Culvert (Alt F)	Stream 21	Stream 21	0.0	3.2	0.0	0.0	3.2	0.40	0.50	3.83	5.71	4.9	10.0	3.2	0.0	0.0	3.2	NA	NA	NA	NA	NA	NA	2.5	0.8	0.5	3.8	NA	0.4	0.5	3.8	5.7	4.9	10.8	

Note:

1-This is post condition on-site pervious watershed; watershed to be refined in design phase

= Include Potential Pervious/ Landscape Area to be used for Stormwater BMP; TBD in PS&E phase

= No Improvements at PAED; Existing Watershed Unchanged. To be refined in PS&E phase.

= Preliminary improvement include removal of impervious of existing US101 route

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Appendix E Ditch Capacity Calculations

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Normal Depth Calculations for Channels using Manning's Equation
Post Mile: to

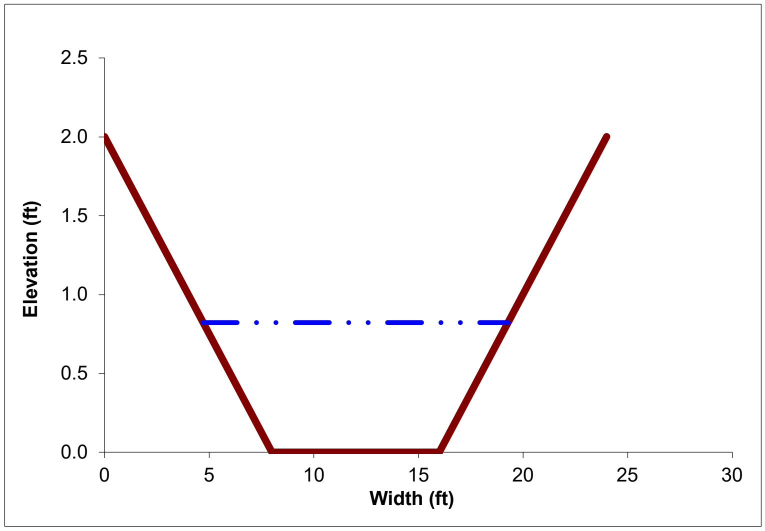
BIORETENTION
BMP 1

Input Values

Height	2	ft
Width	8	ft
Left Side Slope	4	:1 (h:v)
Right Side Slope	4	:1 (h:v)
Mannings	0.05	
Slope	0.0050	ft/ft
Design Flow	14.29	cfs

Normal Depth for Channel

Depth	0.822	ft
Cross Sectional Area	9.28	ft^2
Wetted Perimeter	14.78	ft
Hydraulic Radius, Rh	0.63	ft
Velocity	1.54	ft/s
Flow for 25-yr Storm	14.29	cfs
Goal Seek	0.00	



Length	206.80	ft
Intensity	4.57	in/hr

Time of Concentration (min) = 5.0

Tributary area for paved areas	
0	square feet
0.00	acre
1.00	C for paved areas

5 minute used conservatively
Consider divorcing off-site
pervious run-on in PS&E

Tributary area for unpaved areas	
182,952	square feet
4.17	acre
0.75	C for unpaved areas

Shear Stress at Maximum Depth:	0.26	lb/ft^2
Specific Weight of Water:	62.4	lb/ft^3
Maximum depth of flow in ditch:	0.82	ft
Slope:	0.0050	ft/ft
Safety Factor:	1	
Permissible Shear Stress For Alluvial Silt:	0.25	lb/ft^2
Permissible Velocity For Alluvial Silt	3.5	ft/s

Composite area	
182,952	square feet
4.17	acre
0.75	weighted C

Offsite watershed was considered; suggest divorcing off-site
pervious run-on in PS&E

Energy head (He)	0.9	ft
Required Freeboard	0.172	ft
Design Freeboard	1.18	ft
Passes Freeboard?	Yes	

Normal Depth Calculations for Channels using Manning's Equation
Post Mile: to

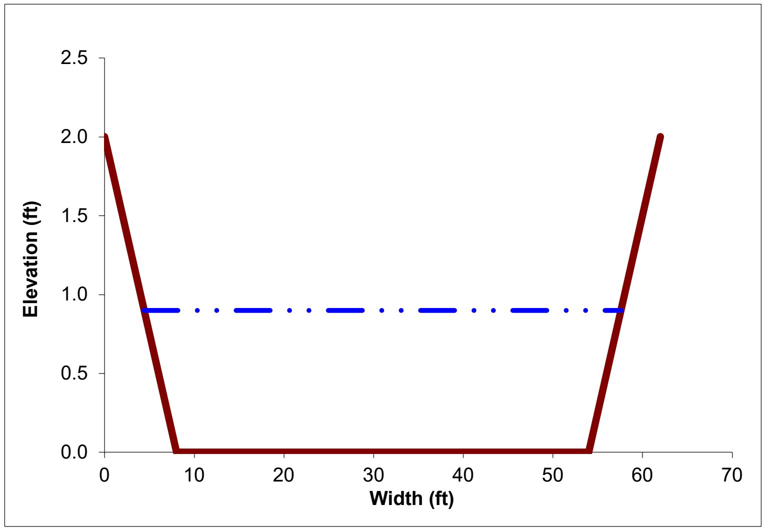
BIORETENTION
BMP 2

Input Values

Height	2	ft
Width	46	ft
Left Side Slope	4	:1 (h:v)
Right Side Slope	4	:1 (h:v)
Mannings	0.05	
Slope	0.0050	ft/ft
Design Flow	83.22	cfs

Normal Depth for Channel

Depth	0.900	ft
Cross Sectional Area	44.64	ft^2
Wetted Perimeter	53.42	ft
Hydraulic Radius, Rh	0.84	ft
Velocity	1.86	ft/s
Flow for 25-yr Storm	83.22	cfs
Goal Seek	0.00	



Length	127.00	ft
Intensity	4.57	in/hr

Time of Concentration (min) = 5.0

Tributary area for paved areas	
82,764	square feet
1.41	acre
1.00	C for paved areas

62-ft average top width per Preliminary Plan
Consider divorcing off-site
pervious run-on in PS&E

Tributary area for unpaved areas	
975,744	square feet
22.40	acre
0.75	C for unpaved areas

Shear Stress at Maximum Depth:	0.28	lb/ft^2
Specific Weight of Water:	62.4	lb/ft^3
Maximum depth of flow in ditch:	0.90	ft
Slope:	0.0050	ft/ft
Safety Factor:	1	
Permissible Shear Stress For Alluvial Silt:	0.25	lb/ft^2
Permissible Velocity For Alluvial Silt	3.5	ft/s

Composite area	
1,058,508	square feet
23.81	acre
0.76	weighted C

Offsite watershed was considered; suggest divorcing off-site
pervious run-on in PS&E

Energy head (He)	1.0	ft
Required Freeboard	0.191	ft
Design Freeboard	1.10	ft
Passes Freeboard?	Yes	

Normal Depth Calculations for Channels using Manning's Equation

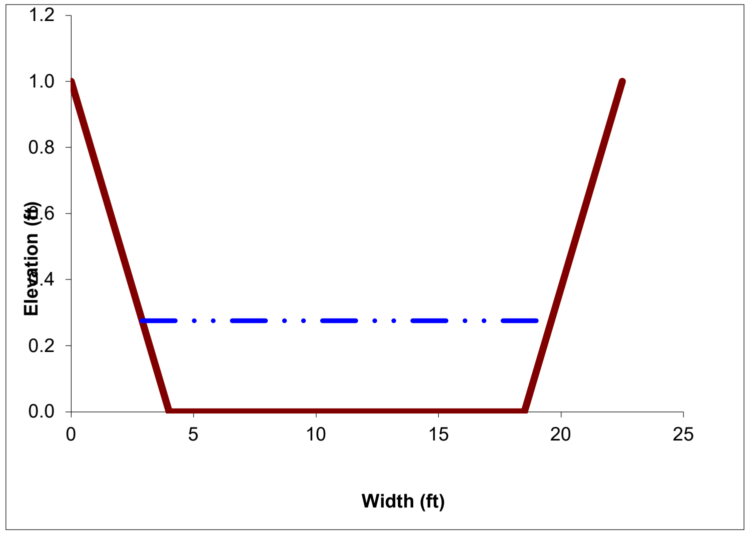
Post Mile: to

BIORETENTION

BMP 3

Input Values

Height	1	ft
Width	14.5	ft
Left Side Slope	4	:1 (h:v)
Right Side Slope	4	:1 (h:v)
Mannings	0.05	
Slope	0.0050	ft/ft
Design Flow	3.66	cfs



Normal Depth for Channel

Depth	0.276	ft
Cross Sectional Area	4.31	ft^2
Wetted Perimeter	16.78	ft
Hydraulic Radius, Rh	0.26	ft
Velocity	0.85	ft/s
Flow for 25-yr Storm	3.66	cfs
Goal Seek	0.00	

Length	72.30	ft
Intensity	4.57	in/hr

Time of Concentration (min) : 5.0

Tributary area for paved areas	
21,780	square feet
0.50	acre
1.00	C for paved areas

Tributary area for unpaved areas	
17,424	square feet
0.40	acre
0.75	C for unpaved areas

Composite area	
39,204	square feet
0.90	acre
0.89	weighted C

Energy head (He)	0.3	ft
Required Freeboard	0.057	ft
Design Freeboard	0.72	ft
Passes Freeboard?	Yes	

Shear Stress at Maximum Depth:	0.09	lb/ft^2
Specific Weight of Water:	62.4	lb/ft^3
Maximum depth of flow in ditch:	0.28	ft
Slope:	0.0050	ft/ft
Safety Factor:	1	
Permissible Shear Stress For Alluvial Silt:	0.25	lb/ft^2
Permissible Velocity For Alluvial Silt	3.5	ft/s

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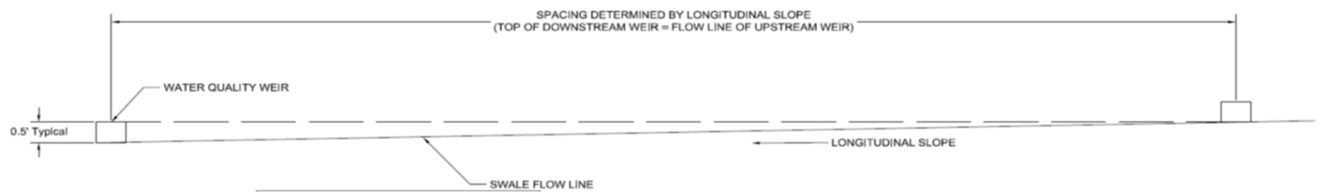
Summary of Biofiltraton Weir Caculation (25-Year Flow)

System Number	Ditch Depth [1]	Longitudinal Slope	Q_{25}	Weir Height[2]	Depth of Flow Above Weir/ Headloss due to Weir	Hydraulic Grade Line Depth (HGL)[3]	Normal Depth	Normal Depth Less than HGL due to Weir? [4]	Energy Head[5]	Required Freeboard[3]	Available Freeboard[6]
	(ft)	(ft/ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	Check?	(ft)	(ft)	(ft)
BMP 1	2	0.0050	14.29	0.5	0.50	1.00	0.82	YES	1.06	0.21	1.00
BMP 2	2	0.0050	83.22	0.5	0.62	1.12	0.90	YES	1.22	0.24	0.88
BMP 3	1	0.0050	3.66	0.5	0.15	0.65	0.28	YES	0.68	0.14	0.35

Notes:

1. Ditch Depth is ideal and pending the grading; assumes the most conservative option; Cross section is preliminary to be refined in PS&E
2. Calculation assumes blocked flow
3. Hydraulic Grade Line Depth = Weir Height + Depth of Flow Above Weir
4. Normal Depth Calculation based on the Manning's Equation
5. Energy head = $V^2/(2g)$
6. Available Freeboard = Ditch Depth - Hydraulic Grade Line Depth

Available Freeboard shown is for informational purposes. This bioswale capacity will be designed to account for the full 25-year design flow and headloss due to the weir per the trapezoidal weir equation, or the normal depth, whichever greater



BIORETENTION SWALE WITH WATER QUALITY WEIR
(TYPICAL PROFILE VIEW)

Flow Through Water Quality Weir

$$Q = \frac{2}{3} C_d b \sqrt{2g} \cdot H^{3/2}$$

Q	=	Flow	=		feet^3/sec
C_d	=	Discharge coefficient	=	0.63	
b	=	Width of weir	=		feet
g	=	Gravitational Acceleration	=	32.2	feet/sec^2
H	=	Depth of flow above weir	=		feet

$$H = \left(\frac{3Q}{2C_d b\sqrt{2g}}\right)^{2/3} = 0.445 \cdot \left(\frac{Q}{b}\right)^{2/3}$$

BMP 1 Downstream

Ditch Parameters

Right Side Slope	=	4	:1
Left Side Slope	=	4	:1
Bottom Width	=	8	feet
Ditch Depth	=	2	feet
Weir Height	=	0.5	feet

Q_{25}	=	25-year Design Flow	=	14.29	feet^3/sec
b	=	Width of weir	=	12	feet
H	=	Depth of flow above weir (Critical Depth)	=	0.500	feet
S	=	Longitudinal Slope	=	0.0050	feet/feet
A	=	Flow Area	=	7.00	feet^2
V	=	Velocity	=	2.04	feet/sec

Freeboard

Energy Head	=	1.06	feet
Required Freeboard	=	0.21	feet
Does Ditch Have Required Freeboard?	Yes		

Impervious Area (ac)	0
Pervious Area (ac)	4.17
Total Area (ac)	4.17
Runoff Coefficient, Impervious	1
Runoff Coefficient, Pervious	0.75
Weighted Runoff Coefficient	0.75
Rainfall Intensity (in/hr)	4.57

Flow Through Water Quality Weir

$$Q = \frac{2}{3} C_d b \sqrt{2g} \cdot h^{2/3}$$

Q	=	Flow	=		$feet^3/sec$
C_d	=	Discharge coefficient	=	0.63	
b	=	Width of weir	=		feet
g	=	Gravitational Acceleration	=	32.2	$feet/sec^2$
H	=	Depth of flow above weir	=		feet

$$H = \left(\frac{3Q}{2C_d b \sqrt{2g}}\right)^{2/3} = 0.445 \cdot \left(\frac{Q}{b}\right)^{2/3}$$

BMP 2

Ditch Parameters

Right Side Slope	=	4	:1
Left Side Slope	=	4	:1
Bottom Width	=	46	feet
Ditch Depth	=	2	feet
Weir Height	=	0.5	feet

Q_{25}	=	25-year Design Flow	=	83.22	$feet^3/sec$
b	=	Width of weir	=	50	feet
H	=	Depth of flow above weir (Critical Depth)	=	0.625	feet
S	=	Longitudinal Slope	=	0.0050	feet/feet
A	=	Flow Area	=	32.81	$feet^2$
V	=	Velocity	=	2.54	feet/sec

Freeboard

Energy Head	=	1.22	feet
Required Freeboard	=	0.24	feet
Does Ditch Have Required Freeboard?	Yes		

Impervious Area (ac)	1.41
Pervious Area (ac)	22.40
Total Area (ac)	23.81
Runoff Coefficient, Impervious	1
Runoff Coefficient, Pervious	0.75
Weighted Runoff Coefficient	0.76
Rainfall Intensity (in/hr)	4.57

Flow Through Water Quality Weir

$$Q = \frac{2}{3} C_d b \sqrt{2g} \cdot h^{2/3}$$

Q	=	Flow	=		$feet^3/sec$
C_d	=	Discharge coefficient	=	0.63	
b	=	Width of weir	=		feet
g	=	Gravitational Acceleration	=	32.2	$feet/sec^2$
H	=	Depth of flow above weir	=		feet

$$H = \left(\frac{3Q}{2C_d b\sqrt{2g}}\right)^{2/3} = 0.445 \cdot \left(\frac{Q}{b}\right)^{2/3}$$

BMP 3

Ditch Parameters

Right Side Slope	=	4	:1
Left Side Slope	=	4	:1
Bottom Width	=	14.5	feet
Ditch Depth	=	1	feet
Weir Height	=	0.5	feet

Q_{25}	=	25-year Design Flow	=	3.66	$feet^3/sec$
b	=	Width of weir	=	18.5	feet
H	=	Depth of flow above weir (Critical Depth)	=	0.151	feet
S	=	Longitudinal Slope	=	0.0050	feet/feet
A	=	Flow Area	=	2.88	$feet^2$
V	=	Velocity	=	1.27	feet/sec

Freeboard

Energy Head	=	0.68	feet
Required Freeboard	=	0.14	feet
Does Ditch Have Required Freeboard?	Yes		

Impervious Area (ac)	0.5
Pervious Area (ac)	0.4
Total Area (ac)	0.9
Runoff Coefficient, Impervious	1
Runoff Coefficient, Pervious	0.75
Weighted Runoff Coefficient	0.89
Rainfall Intensity (in/hr)	4.57

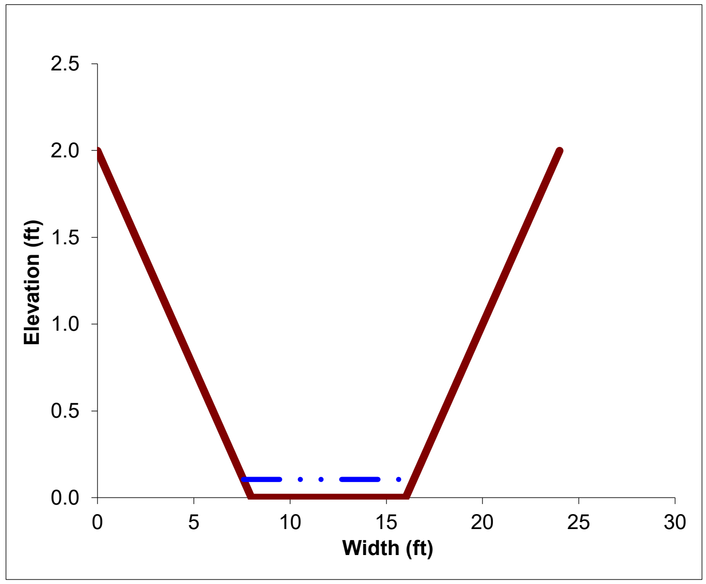
Normal Depth Calculations for Channels using Manning's Equation
Post Mile: to

BIORETENTION
BMP 1

.

Input Values

Height	2	ft
Width	8	ft
Left Side Slope	4	:1 (h:v)
Right Side Slope	4	:1 (h:v)
Mannings	0.24	
Slope	0.0050	ft/ft
Design Flow	0.08	cfs



Normal Depth for Channel

Depth	0.105	ft
Cross Sectional Area	0.89	ft^2
Wetted Perimeter	8.87	ft
Hydraulic Radius, Rh	0.10	ft
Velocity	0.09	ft/s
Flow for 25-yr Storm	0.08	cfs
Goal Seek	0.00	

Length	206.80	ft
Intensity	0.20	in/hr

Time of Concentration (min) = 5.0

Tributary area for paved areas	
0	square feet
0.00	acre
0.70	C for paved areas

Tributary area for unpaved areas	
182,952	square feet
4.17	acre
0.10	C for unpaved areas

Composite area	
182,952	square feet
4.17	acre
0.10	weighted C

Energy head (He)	0.1	ft
Required Freeboard	0.021	ft
Design Freeboard	1.89	ft
Passes Freeboard?	Yes	

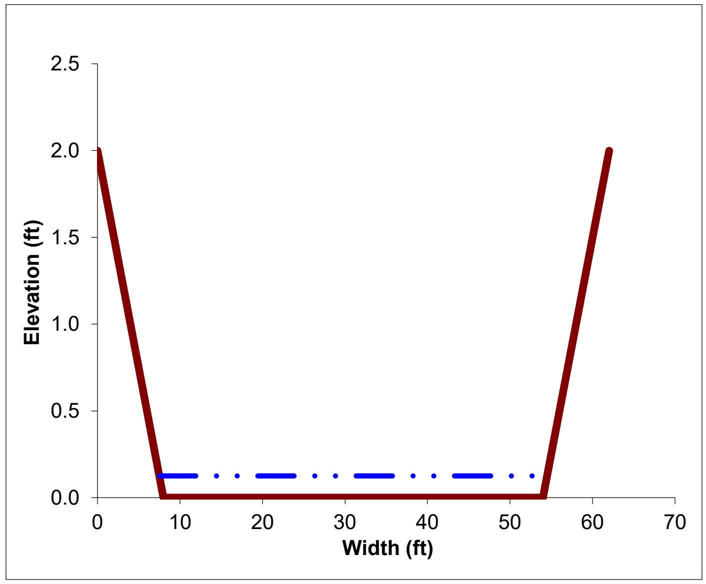
Normal Depth Calculations for Channels using Manning's Equation
Post Mile: to

BIORETENTION
BMP 2

.

Input Values

Height	2	ft
Width	46	ft
Left Side Slope	4	:1 (h:v)
Right Side Slope	4	:1 (h:v)
Mannings	0.24	
Slope	0.0050	ft/ft
Design Flow	0.65	cfs



Normal Depth for Channel

Depth	0.127	ft
Cross Sectional Area	5.89	ft^2
Wetted Perimeter	47.04	ft
Hydraulic Radius, Rh	0.13	ft
Velocity	0.11	ft/s
Flow for 25-yr Storm	0.65	cfs
Goal Seek	0.00	

Length	127.00	ft
Intensity	0.20	in/hr

Time of Concentration (min) = 5.0

62-ft average top width per Preliminary Plan

Tributary area for paved areas	
82,764	square feet
1.41	acre
0.70	C for paved areas

Tributary area for unpaved areas	
975,744	square feet
22.40	acre
0.10	C for unpaved areas

Composite area	
1,058,508	square feet
23.81	acre
0.14	weighted C

Energy head (He)	0.1	ft
Required Freeboard	0.025	ft
Design Freeboard	1.87	ft
Passes Freeboard?	Yes	

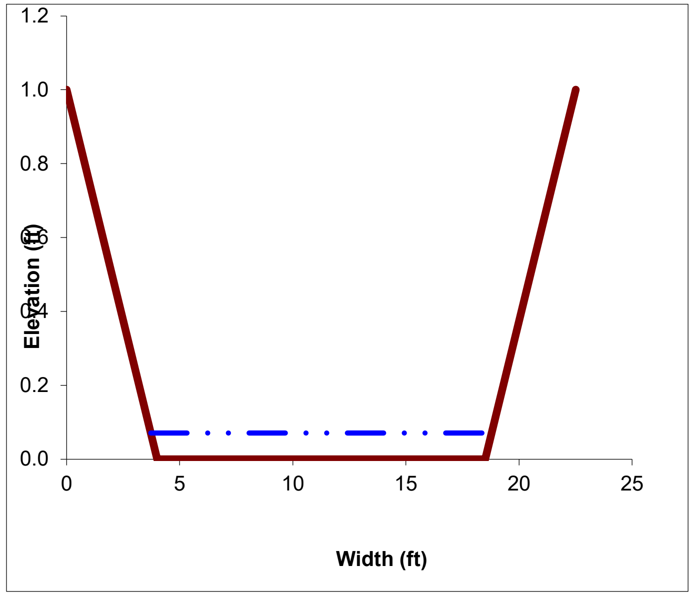
Last Chance Grade Restoration Project

Normal Depth Calculations for Channels using Manning's Equation
Post Mile: to

BIORETENTION
BMP 3

Input Values

Height	1	ft
Width	14.5	ft
Left Side Slope	4	:1 (h:v)
Right Side Slope	4	:1 (h:v)
Mannings	0.24	
Slope	0.0050	ft/ft
Design Flow	0.08	cfs



Normal Depth for Channel

Depth	0.071	ft
Cross Sectional Area	1.05	ft^2
Wetted Perimeter	15.09	ft
Hydraulic Radius, Rh	0.07	ft
Velocity	0.07	ft/s
Flow for 25-yr Storm	0.08	cfs
Goal Seek	0.00	

Length	72.30	ft
Intensity	0.20	in/hr

Time of Concentration (min) = 5.0

Tributary area for paved areas	
21,780	square feet
0.50	acre
0.70	C for paved areas

Tributary area for unpaved areas	
17,424	square feet
0.40	acre
0.10	C for unpaved areas

Composite area	
39,204	square feet
0.90	acre
0.43	weighted C

Energy head (He)	0.1	ft
Required Freeboard	0.014	ft
Design Freeboard	0.93	ft
Passes Freeboard?	Yes	

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Appendix F Alternative F Bridge Technical Memorandum

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Memorandum

Date: April 7, 2023

To: Karen Wang, Rodney Pimentel, and John Litzinger – HNTB

From: Analette Ochoa – WRECO

Project: Last Chance Grade Permanent Restoration Project

Subject: Preliminary Alternative F Bridge Water Surface Elevation and Freeboard Hydraulic Analysis (EA 01-0F280)

INTRODUCTION

The Last Chance Grade (LCG) Permanent Restoration Project is located on a section of U.S. Highway 101 (U.S. 101) known as Last Chance Grade in southern Del Norte County, California. It is approximately 10 miles south of Crescent City, between post miles (PM) 12.7 and 16.5 (Figure 1).

The purpose of the Project is to develop a long-term solution to the instability and potential roadway failure at LCG. The Project would consider alternatives that provide a more reliable connection, reduce maintenance costs, and protect the economy, natural resources, and cultural landscapes.

A long-term sustainable solution at LCG is needed to address:

- Economic ramifications of a long-term failure and closure
- Risk of delay/detour to the traveling public
- Increasing maintenance and emergency project costs
- Increases in the frequency and severity of large storm events caused by climate change

LCG is an area of geologic instability; there is a landslide complex that is approximately 3-miles-long with over 30 active landslides. This instability has required significant expenditures of tax dollars on emergency construction projects and maintenance activities to keep the highway open and safe. Between 1997 and 2021, landslide mitigation efforts, including retaining walls, drainage improvements, and roadway repairs cost more than $85 million. There is no foreseeable end to such expenditures, and effects of climate change may exacerbate conditions.

Other than U.S. 101, there are no viable routes between Crescent City and Klamath. Klamath is a community just south of LCG; many people routinely travel to and from Crescent City for work, school, or personal business. Typically, a one-way journey between the two communities would be about 22 miles, taking approximately 30-40 minutes. However, in the event of a closure, a 449-mile detour would be required, which would take approximately 8 hours (Figure 2).

Potential economic consequences of an emergency one-year closure of LCG include the loss of approximately 3,800 jobs and the reduction of business output by nearly half a billion dollars ($456 million) (Caltrans District 1, 2018). Such a closure would also lead to an estimated $236 million in travel costs to be collectively borne by individuals, businesses, and government institutions.

This *Memorandum* summarizes the preliminary hydrologic and hydraulic analysis to assist on the engineering design to verify the Alternative F Bridge Planning Study wetland crossings water surface elevation (WSE), WSE depth, and validate soffit elevations for ample freeboard for proposed Alternative F Bridge (Alignment "F" Line Station 119+25 to 120+47) for U.S. 101 LCG (EA 01-0F280). Due to limited creek crossing survey information at this time, this *Memorandum* is not intended for an environmental impact analysis and does not provide a detailed bridge hydraulic assessment.

Refer to Figure 1 for the Project Location Map and Figure 2 for the Regional Location and Detour Map.

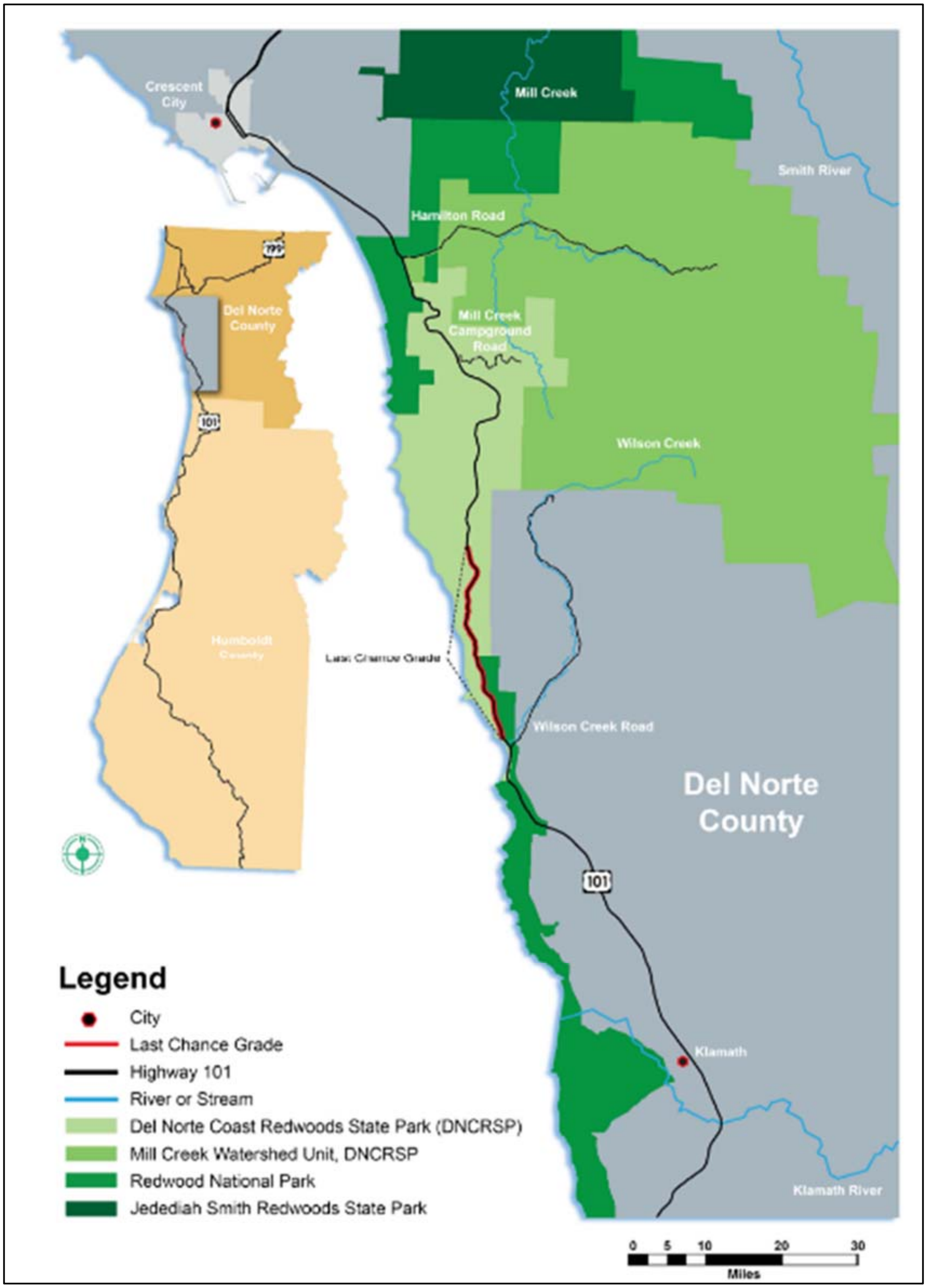

Figure 1. Project Location Map

Source: Caltrans, 2023a

Figure 2. Regional Location and Detour Route

Source: Caltrans, 2023a

Alternatives

There are three alternatives for this Project, which include two build alternatives—F and X—were developed to meet the purpose and need of the Project (Figure 3), as well as a no-build alternative. Both build alternatives would require geotechnical investigations.

Alternative F
Alternative F would involve constructing an approximately 6,000-foot-long (1.1-mile) tunnel to avoid the most intense area of known landslides and geologic instability, thereby avoiding the portion of U.S. 101 most prone to closure.

Alternative X
Alternative X would involve reengineering a 1.6-mile-long portion of the existing roadway. This alternative would include a series of retaining walls, underground drainage features, and strategic eastward retreats to minimize the risk of landslides.

No-Build Alternative
For the No-Build Alternative, no work would be done to the existing highway; existing conditions would persist, including the continuation of emergency repairs and enhanced maintenance.

Alternative F

Alternative F would involve constructing an approximately 6,000-foot (1.1-mile) tunnel to the east of the existing highway to avoid the most intense areas of known landslides and geologic instability.

This alternative would be between PM 13.42 and 15.7. Portions of the alternative are near sections of the California Coastal Trail. However, no work is proposed on the trail and it is anticipated the trail would remain accessible during construction.

Main components of this alternative include the construction of tunnel portals and the tunnel, a bridge, and an Operations Maintenance Center (OMC). Geotechnical investigations would be conducted to inform Project design.

From the south, Alternative F would diverge from the existing highway near the end of the existing truck climbing lane (PM 14.2), traveling approximately 800 feet towards the southern portal. The portal would open into a single, large diameter tunnel, which would be approximately 200 feet below ground for most of its length. The tunnel would exit the hillside just north of the existing slide. A bridge would be constructed at the northern portal to reconnect the new alignment to the existing highway. An OMC would be built south of the tunnel to facilitate tunnel operation and maintenance.

More details on these features and other Project components are included below.

Bridge
A bridge would be constructed to span a Wilson Creek tributary between the northern portal and where the new alignment merges with U.S. 101 to the north.

The single-span, pre-cast, concrete girder bridge would be approximately 150-feet-long and 48-feet-wide, with a single 12-foot-wide lane in each direction, and 10-foot-wide shoulders. The wider shoulders would improve access for bicyclists and pedestrians, and provide refuge for stranded vehicles. Furthermore, a separate 6-foot-wide path is proposed, which would allow southbound bicyclists and pedestrians an alternative access route around the bridge to the southbound pedestrian/bike lane in the tunnel (Figure 4).

The bridge abutment locations would be accessed by the existing highway from the north and through a staging area created for bridge construction and tunnel access located immediately to the south. The concrete abutments and associated wingwalls would be constructed on cast-in-drilled-hole (CIDH) pile foundations. A crane would place pre-cast concrete girders on the abutments, and falsework would be constructed using the girders as support. Rebar would be installed, the concrete deck would be cast, and see-through bridge rails installed. Rock Slope Protection (RSP) may be placed for bank stabilization.

The bridge deck would not contain drains (scuppers). Instead, water would be conveyed to the ends of the bridge via gravity and discharged to adjacent vegetated slopes or RSP. The layout of Alternative F Bridge is shown in Figure 4, and the planning study of Alternative F Bridge is shown in Figure 5.

Roadway Drainage

In addition to drainage features associated with the tunnel, bridge, and OMC described above, there would be changes to drainages at various other locations.

At the tunnel portals, bridge, and OMC, stormwater runoff would be captured and conveyed to existing drainages at PMs 14.08 and 14.35 for the south portal; at PM 15.38 for the north portal and bridge, and PM 13.42 for the OMC. Some culverts would be extended to accommodate roadway changes. In addition, new inlets and culverts would be installed near the south portal, the north portal, and the OMC, which would be connected to existing culverts. Culvert outfall locations would remain unchanged; any lengthening of existing culverts would occur to the east. RSP may be needed at the outlets.

A new culvert would be installed under the northern tunnel approach between the bridge and the northern portal; the culvert would be 24 inches in diameter or larger, and approximately 200-feet-long.

Best management practices (BMP), such as bioswales, may be implemented to offset impacts to water quality. Potential areas for bioswales or other BMPs have been identified near the northern and southern portals and the OMC.

Datum

The preliminary analysis references the North American Vertical Datum of 1988 (NAVD 88).

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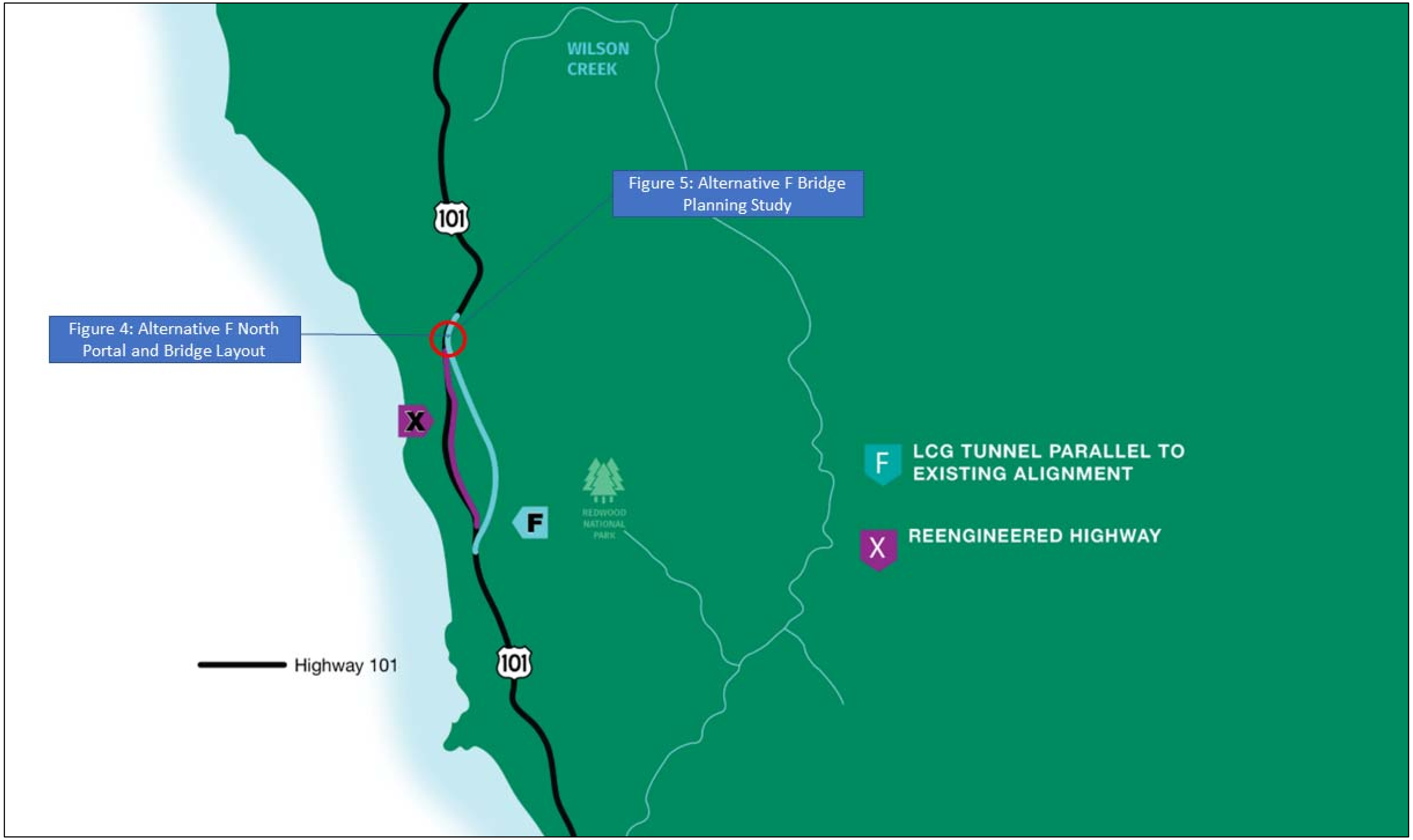

Figure 3. Build Alternatives Overview

Source: Caltrans, 2023a

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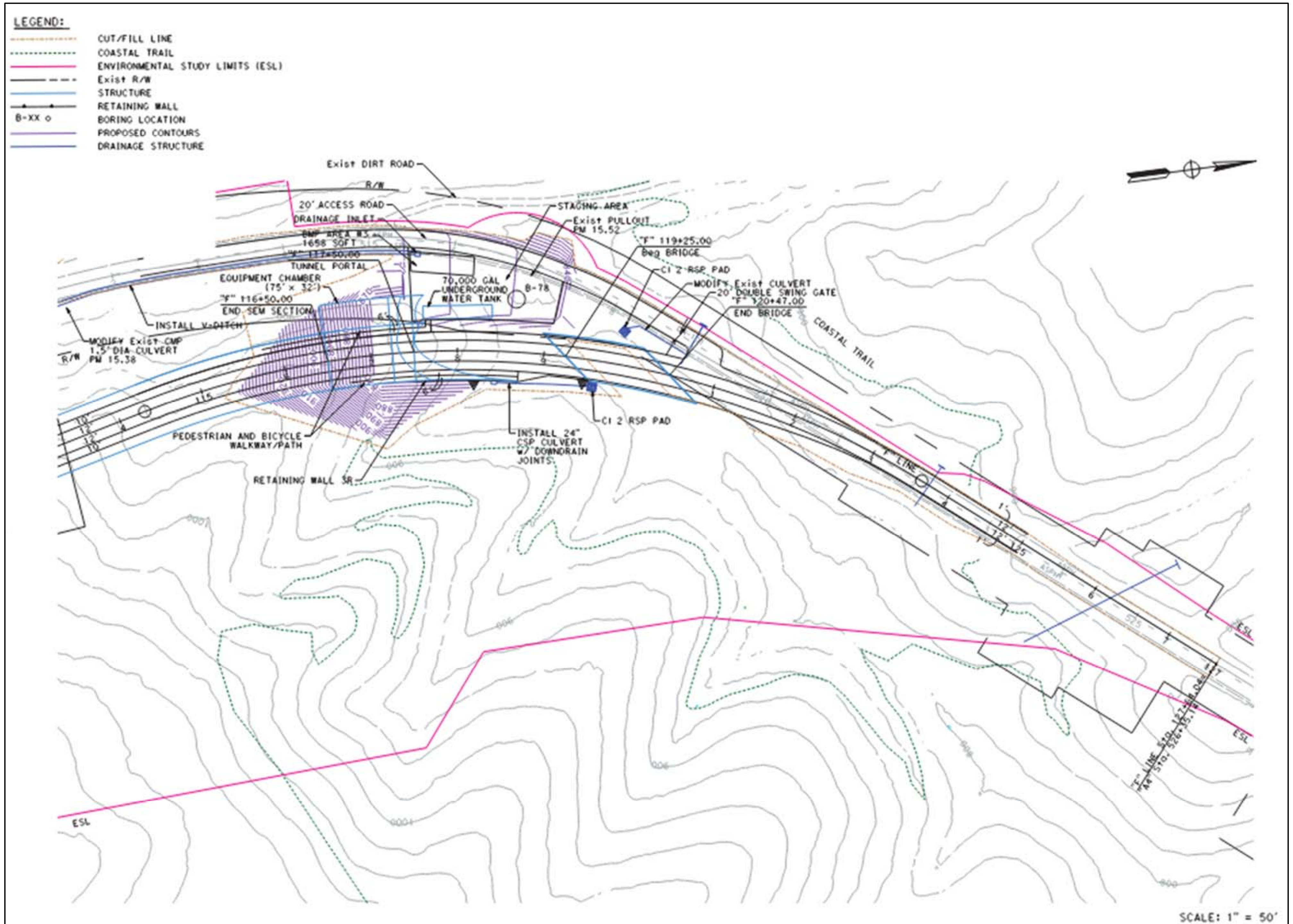

Figure 4. Alternative F North Portal and Bridge Layout

Source: Caltrans, 2023a

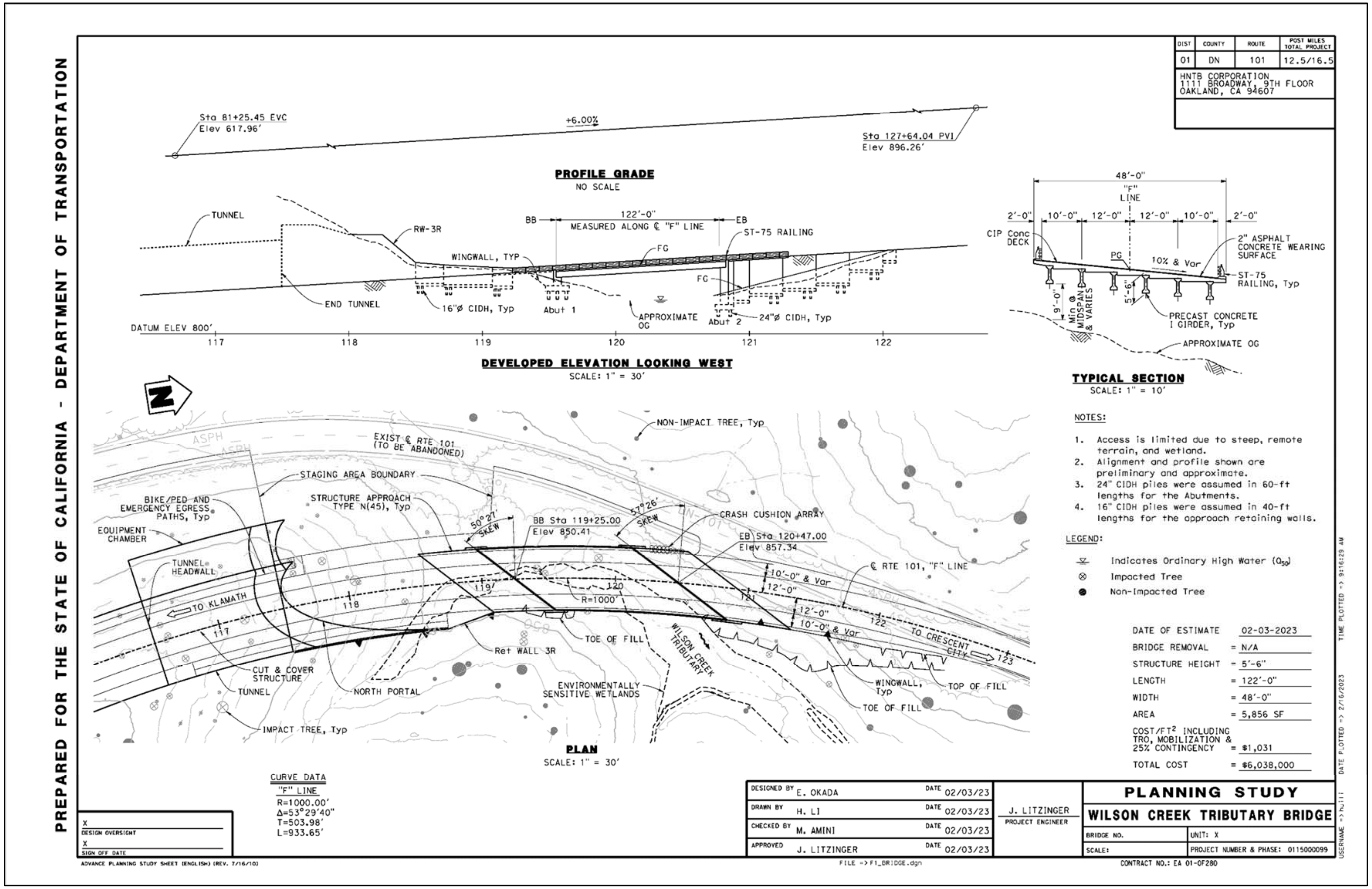

Figure 5. LCG Alternative F Bridge Planning Study

Source: Caltrans, 2023a

HYDRAULIC BRIDGE DESIGN CRITERIA

The following criteria are applicable to the Project area and are being considered in the development of alternative for the bridge.

Federal Highway Administration Standards

Bridges must be designed per the 2017 *California Amendments to the American Association of State Highways and Transportation Officials Load and Resistance Factor Design Bridge Design Specifications* (AASHTO LRFD BDS) (Caltrans, 2019). AASHTO LRFD BDS Section 2.6.3 defers to state requirements for hydraulic studies.

From *Memo to Designers 16-1 Hydraulic Design for Structures over Waterways* (Caltrans, 2017), the proposed bridge soffit should provide adequate freeboard to pass anticipated drift for the 50-year design flood, or to pass the 100-year base flood without freeboard, whichever is greater.

Caltrans Standards

From Chapter 820 of the Caltrans' *Highway Design Manual* (HDM) (2020), the criterion for the hydraulic design of bridges is that they are designed to pass the 2% probability of annual exceedance flow (50-year design discharge) with adequate freeboard to pass anticipated drift and debris. Two (2) feet of freeboard is commonly used in bridge designs. Alternatively, the bridge can also be designed to pass the 1% probability of annual exceedance flow (100-year design discharge, or base flood). No freeboard is added to the base flood.

PRELIMINARY HYDROLOGIC ANALYSIS

The following sub-sections describe the hydrologic data sources that were used to estimate the design flows for the Project area.

Hydrologic Design Methods

WRECO evaluated the hydrology for proposed Alternative F bridge area using the following references:

1. Project's survey imagery 2021 Light Detection and Ranging (LiDAR) (provided by Caltrans)
2. National Oceanic and Atmospheric Administration (NOAA) (2022) 2020 United States Geological Survey (USGS) Coastal National Elevation Database (CoNED) Topobathy DEM
3. NOAA Atlas 14, Volume 6, Version 2, Precipitation Frequency Data Server (PFDS) web application (2022)
4. Project's preliminary wetland delineation for Alternative F Bridge crossing (Caltrans, 2022)

Rainfall Data and Intensities

Precipitation data was collected using NOAA Atlas 14, Volume 6, Version 2, PFDS web application (2022). The rainfall data generated from NOAA's PFDS website is summarized in Table 1, and the full dataset can be found in the NOAA Atlas 14 Rainfall Intensity Attachment.

Table 1. NOAA Atlas 14 Intensity-Duration-Frequency Summary

DURATION	INTENSITY (INCHES/HOUR)	
	50-year	100-year
5 minutes	5.15	5.72
10 minutes	3.68	4.10
30 minutes	2.08	2.31
1 hour	1.54	1.71
2 hours	1.14	1.27
24 hours	0.45	0.47

Source: NOAA, 2022

Receiving Waterbodies

The southern end of Project drains to Wilson Creek near PM 12.0 on U.S. 101. Wetlands within the Alternative F proposed bridge crossing were provided by Caltrans in July 2022 (Caltrans, 2022). Figure 6 shows the wetlands within the vicinity of the Alternative F Bridge.

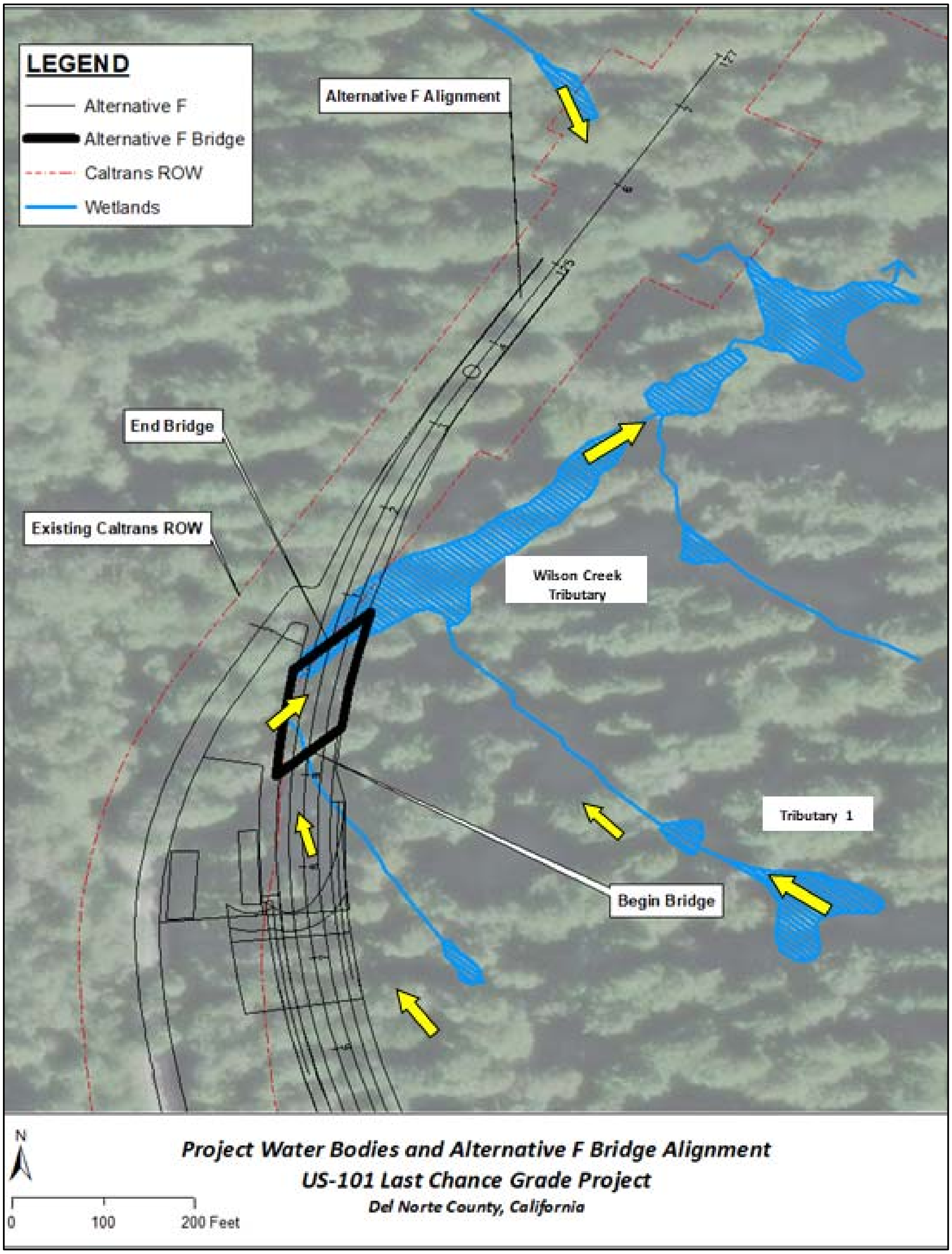

Figure 6. Project Water Bodies and Alternative F Bridge Alignment

Source: Caltrans, 2022

Design Watershed Drainage Area and Discharge

Federal Emergency Management Agency Flood Insurance Study

The effective Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for Del Norte County, California, and unincorporated areas did not provide hydrologic analysis or information on the wetlands or Wilson Creek. The effective FEMA FIS was not used to determine the peak flow rates for this analysis.

NOAA USGS Topobathy

The NOAA 2020 USGS Topobathy CoNED (USGS, 2022) and ESRI's ArcMap spatial analysis hydrology tool (2019) was used to determine the drainage area for the Alternative F proposed bridge wetland crossing.

Table 2 shows the watershed drainage areas and Figure 7 shows the watershed delineations of the wetlands. The Wilson Creek Tributary downstream of the confluence with Tributary 1 is the sum of both Wilson Creek Tributary upstream of Tributary 1's confluence and Tributary 1's watershed drainage area.

Table 2. Wetland Drainage Area for Alternative F

Wetlands	Watershed Drainage Area (acre)
Wilson Creek Tributary (Upstream of Tributary 1 Confluence)	37.4
Tributary 1	3.8
Wilson Creek Tributary (Downstream of Tributary 1 Confluence	41.2

Rational Method

Runoff for the wetland drainage areas was determined using the Rational Method, as per HDM Index 819.2 (1) criterion, with the following assumptions:

1. The rainfall is of equal intensity over the entire watershed.
2. The peak flow occurs when the entire watershed is contributing to the flow.

The formula used to calculate the runoff is below:

$$Q = C(f)CiA \qquad (1)$$

Where:

Q = Design discharge in cubic feet per second.
$C(f)$ = Frequency factor (1.0 for 10-year storm event; 1.1 for 25-year storm event).
C = Weighted runoff coefficient for the entire tributary area.
i = Average rainfall intensity in inches per hour for the selected frequency and for a duration equal to the time of concentration (5 minutes).
A = Tributary shed area in acres

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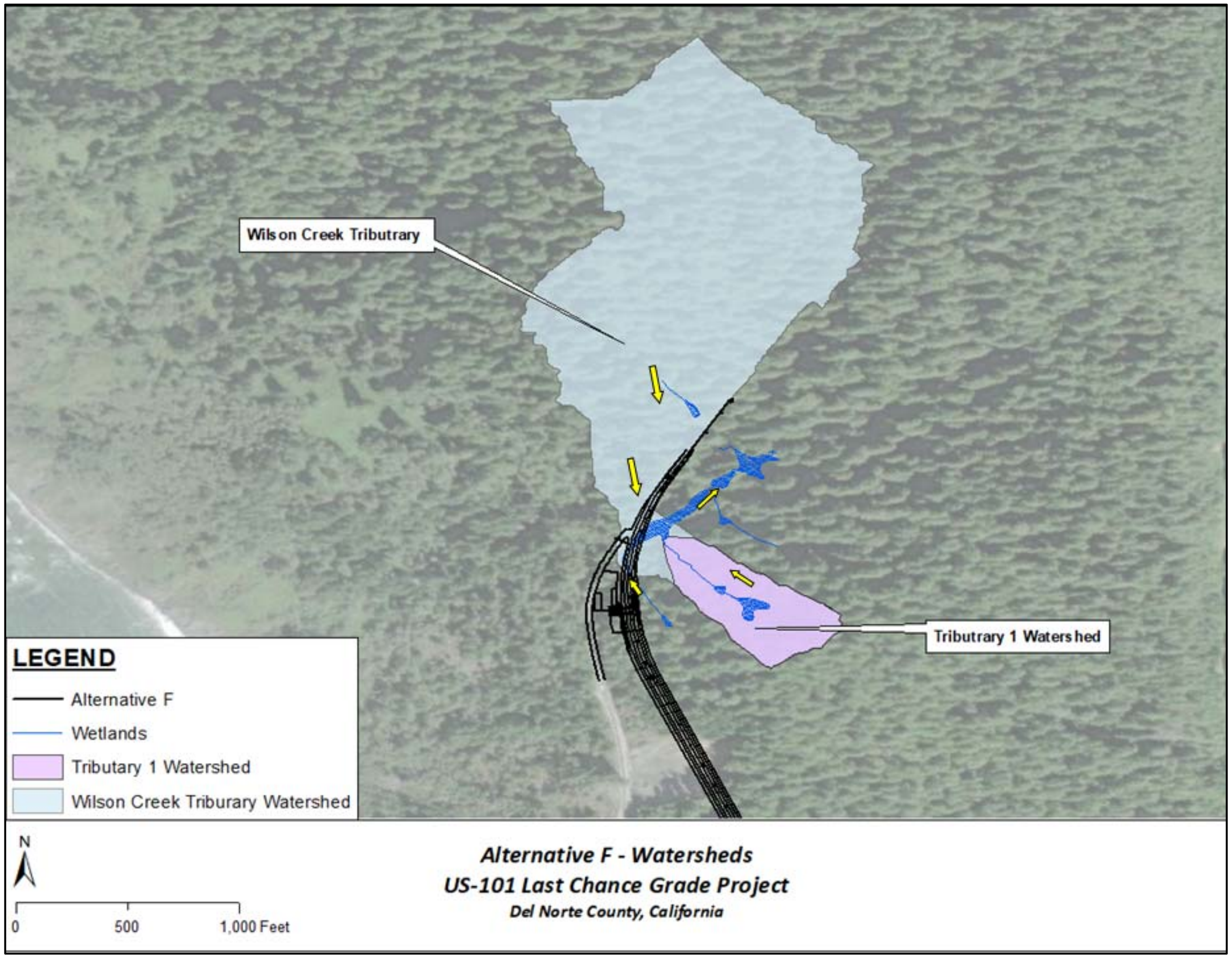

Figure 7. Alternative F Bridge Watersheds

Source: Caltrans, 2023b

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Runoff Coefficient

Runoff coefficient "*C*" in equation (1) represents the percent of water that will run off onto the ground surface during a storm. The remaining percent of precipitation is lost to infiltration, transpiration, evaporation, and depression storage.

Caltrans' HDM (2020) Figure 819.2A shows the runoff coefficient for undeveloped watershed types, the undeveloped watershed "*C*" value for the wetland areas within the proposed Alternative F bridge crossing was determined to be 0.5. Table 3 provides the calculation of "*C*".

Table 3. Runoff Coefficient Calculation

Undeveloped Watershed	Characteristic	Value
Relief	Hilly, with average slopes of 10 to 30%	0.20 – 0.28
Soil Infiltration	High; deep sand or other soil that takes up water readily; very light well drained soils	0.04 – 0.06
Vegetal Cover	Good to excellent; about 90% of drainage area in good grassland, woodland, or equivalent cover	0.04 – 0.06
Surface Storage	Negligible surface depression few and shallow; drainageways steep and small , no marshes	0.10 – 0.12
Total *C* value		0.38 – 0.52

Source: Caltrans, 2020

Design Discharge

The 100-year and 50-year design discharge for the wetlands within the proposed Alternative F bridge crossing are shown in Table 4.

Table 4. Wetland Design Discharge for Alternative F

Wetlands	Drainage Area (ac)	Design Discharge (cfs)	
		100-year	50-year
Wilson Creek Tributary (Upstream of Tributary 1 Confluence)	37.4	70	60
Tributary 1	3.8	10	7
Wilson Creek Tributary (Downstream of Tributary 1 Confluence)	41.2	80	70

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PRELIMINARY HYDRAULIC ANALYSIS

The preliminary hydraulics analysis of the proposed LCG Alternative F bridge crossing was performed using United States Army Corps of Engineers' (USACE) Hydrologic Engineering Center's River Analysis System (HEC-RAS) modeling software, Version 6.2.0. The inputs to the hydraulic model were based on NOAA 2020 USGS Topobathy CoNED, LCG LiDAR provided by Caltrans (2021), preliminary wetland delineations and *Alternative F Bridge Planning Study* provided by Caltrans, 2023b (Figure 5).

Due to limited elevation information from the LiDAR DEM and no creek crossing survey information being at this time, the preliminary proposed bridge model is based on the *Alternative F Bridge Planning Study* (Caltrans, 2023b) control points and available LiDAR for the Project site. The normal depth was used in the hydraulic model as the downstream boundary condition. Figure 8 shows the cross section locations of the model.

Further hydraulic analysis of proposed Alternative F bridge will be updated once survey information is available and the proposed roadway grading is available for Alternative F.

Model Boundary Conditions

The normal depth of the Wilson Creek Tributary was used in the hydraulic model as the downstream boundary condition.

Manning's Roughness Coefficients

Manning's roughness coefficients were used in the hydraulic model to estimate energy losses in the flow due to friction. A roughness coefficient of 0.045 was used to describe the channel and channel bank areas.

Expansion and Contraction Coefficients

Expansion and contraction coefficients were used in the hydraulic model to represent energy losses in the channel. An expansion coefficient of 0.3 and a contraction coefficient of 0.1 were used to represent the channel. These values represent a channel with gradual transitions between the cross sections. An expansion coefficient of 0.5 and a contraction coefficient of 0.3 were used to represent the channel in the vicinity of the structures. These values represent the flow interference caused by the structures.

Bridge Culvert Crossings

Due to limited information and the design of the culvert crossing along Alternative F bridge crossing, this preliminary hydraulic analysis assumes all proposed culvert crossing(s) will perpetuate existing flows and follow all design standards and criteria.

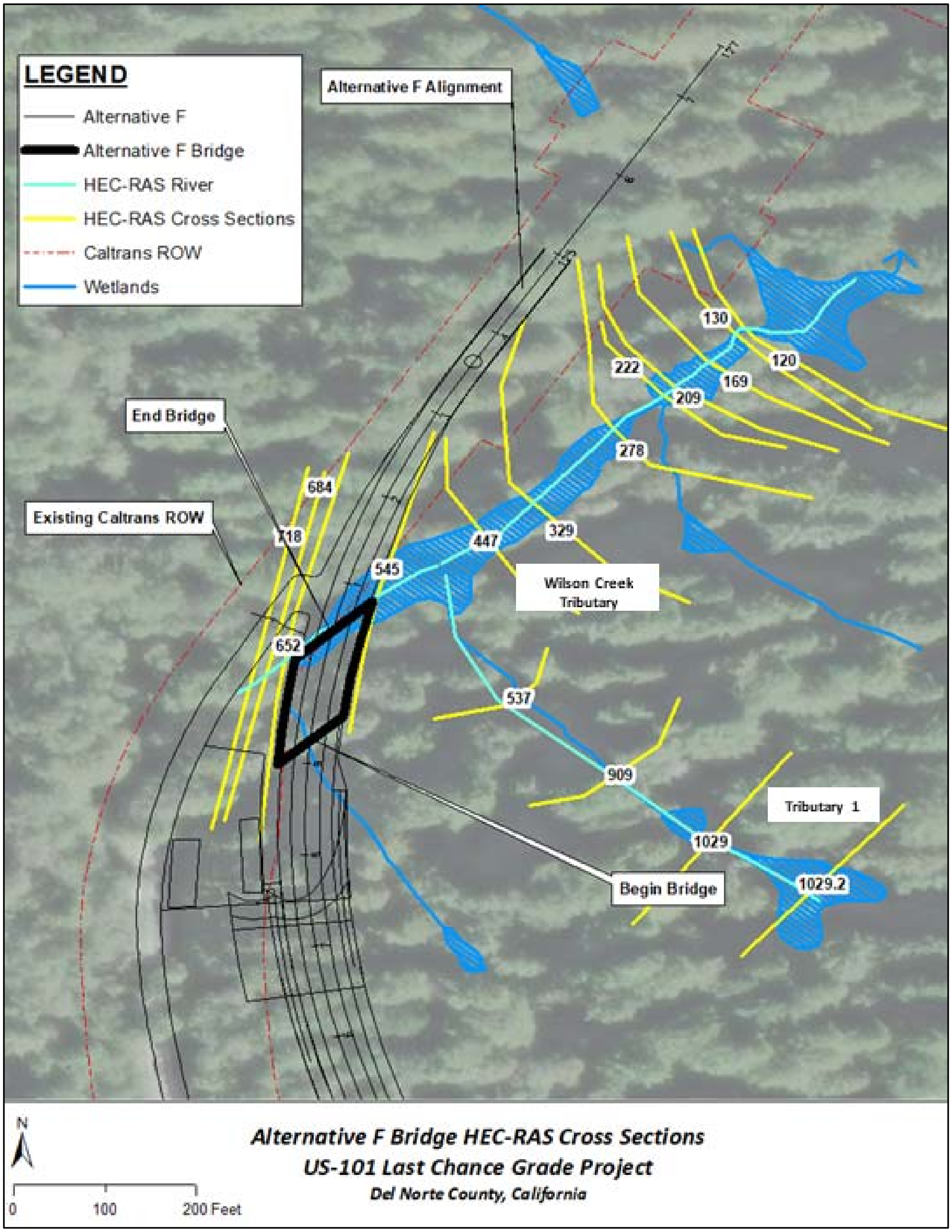

Figure 8. Alternative F Bridge HEC-RAS Cross Sections

Source: Caltrans, 2022b

Preliminary Hydraulic Model Results

The preliminary hydraulic model was developed to assist design and verify the *Alternative F Planning Study* (Caltrans, 2023b) crossing at the Wilson Creek Tributary's WSE and WSE depth, validate soffit elevation, and meet the freeboard criterion. The model was computed using a steady flow analysis. This section summarizes the results of the preliminary hydraulic model analysis for the existing and proposed conditions. The preliminary hydraulic model results can be found in the HEC-RAS Results for Proposed Condition Attachment.

Alternative F Bridge Water Surface Elevation

The 100-year and 50-year storm WSE for the Alternative F bridge at the Wilson Creek Tributary are presented in Table 5 and Table 6. The construction of the new abutments along the bridge would potentially increase the WSE due to a blockage of flow impacting the flow during the 50-year and 100-year storm event. Based on preliminary models, the preliminary existing and proposed conditions for the flow during the 100-year storm event show an increase upstream of 0.3 feet in WSE and no change in the downstream WSE. Based on preliminary models, the preliminary existing and proposed conditions during the 50-year storm event show an increase upstream of 0.3 feet in WSE and no change in the downstream WSE. Figure 9 through Figure 11 shows the proposed condition, Alternative F Bridge, downstream and upstream crossing. Figure 12 shows the profile of the 50-year and 100-year WSE.

Table 5. Alternative F Bridge Tributary 1 100-year Water Surface Elevations

River Station	Description/Distance from Existing Bridge Centerline (ft)	100-Year (10 cfs) Water Surface Elevation (ft NAVD 88)		Difference between Existing and Proposed Improvements
		Existing	Proposed	
652	Upstream of Alt. F Bridge and Tributary 1 crossing	833.2	833.5	0.3
545	Downstream of Alt. F Bridge and Tributary 1 crossing	823.5	823.4	0.0

Table 6. Alternative F Bridge Tributary 1 50-year Water Surface Elevations

River Station	Description/Distance from Existing Bridge Centerline (ft)	50-Year (7 cfs) Water Surface Elevation (ft NAVD 88)		Difference between Existing and Proposed Improvements
		Existing	Proposed	
652	Upstream of Proposed Alt. F Bridge and Tributary 1 crossing	833.1	833.4	0.2
545	Downstream of Proposed Alt. F Bridge and Tributary 1 crossing	824.3	824.3	0.0

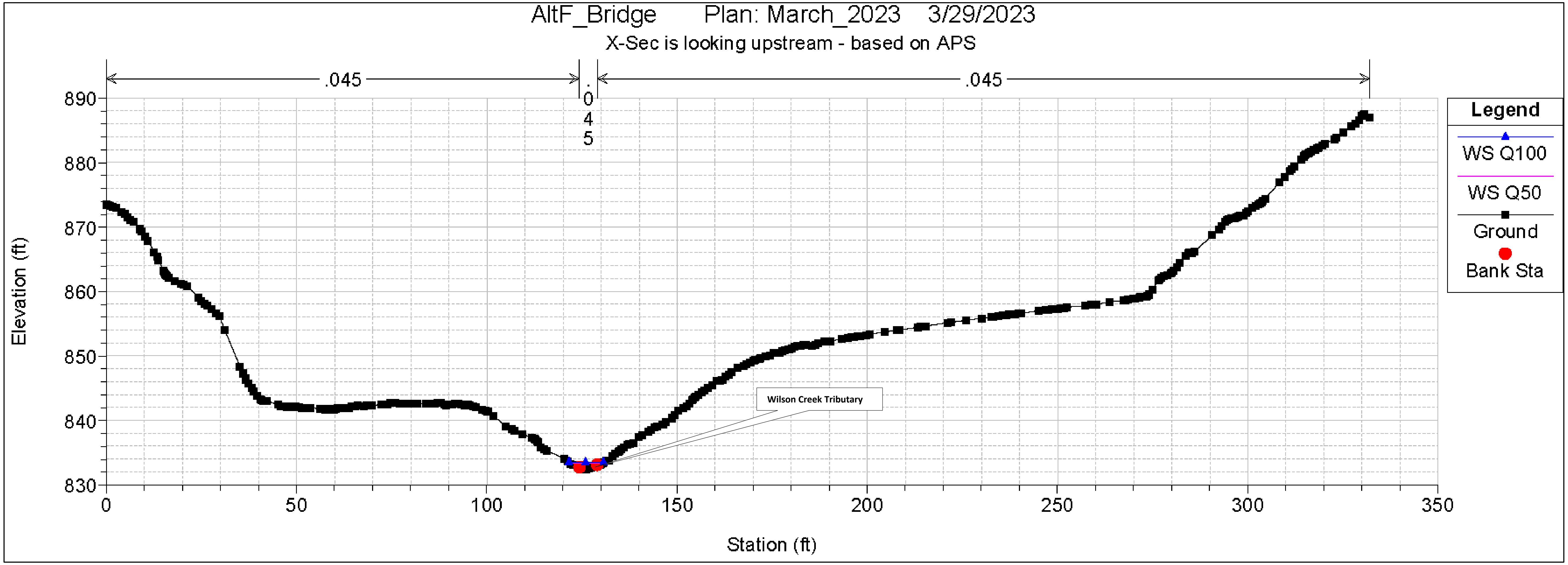

Figure 9. Upstream Face of Alternative F Bridge, Looking Upstream

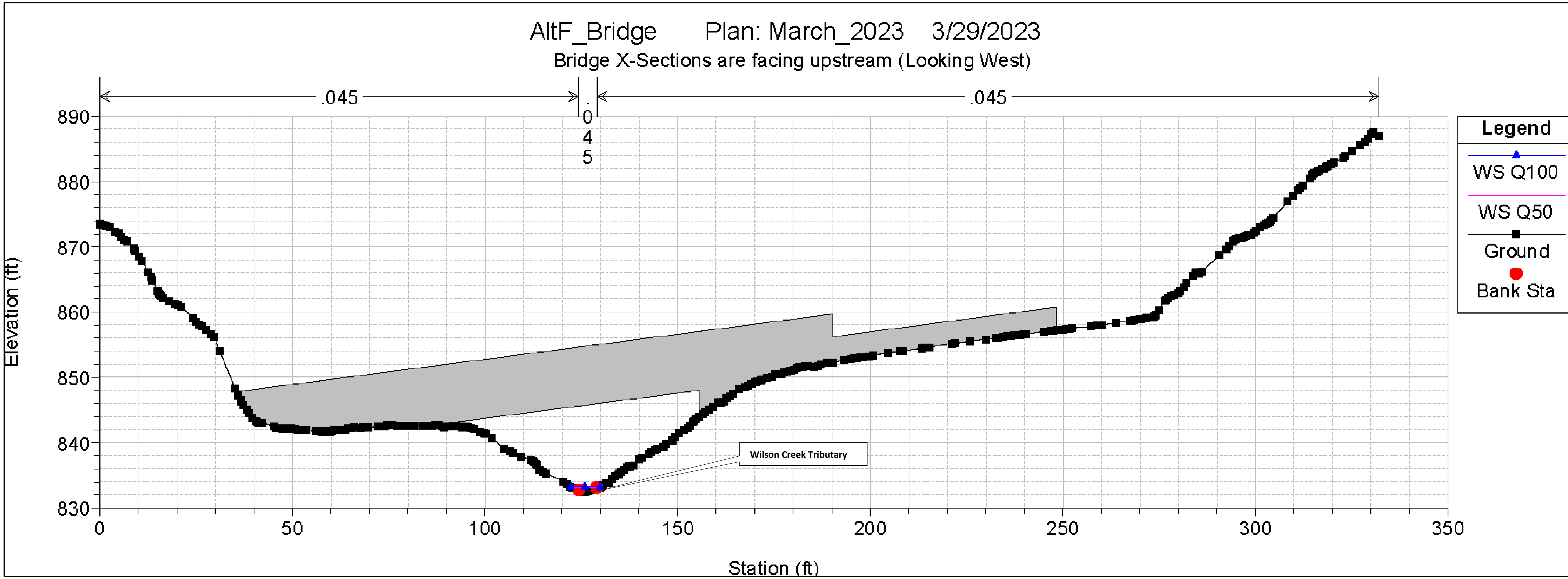

Figure 10. Upstream Face of Alternative F Bridge, Looking Upstream

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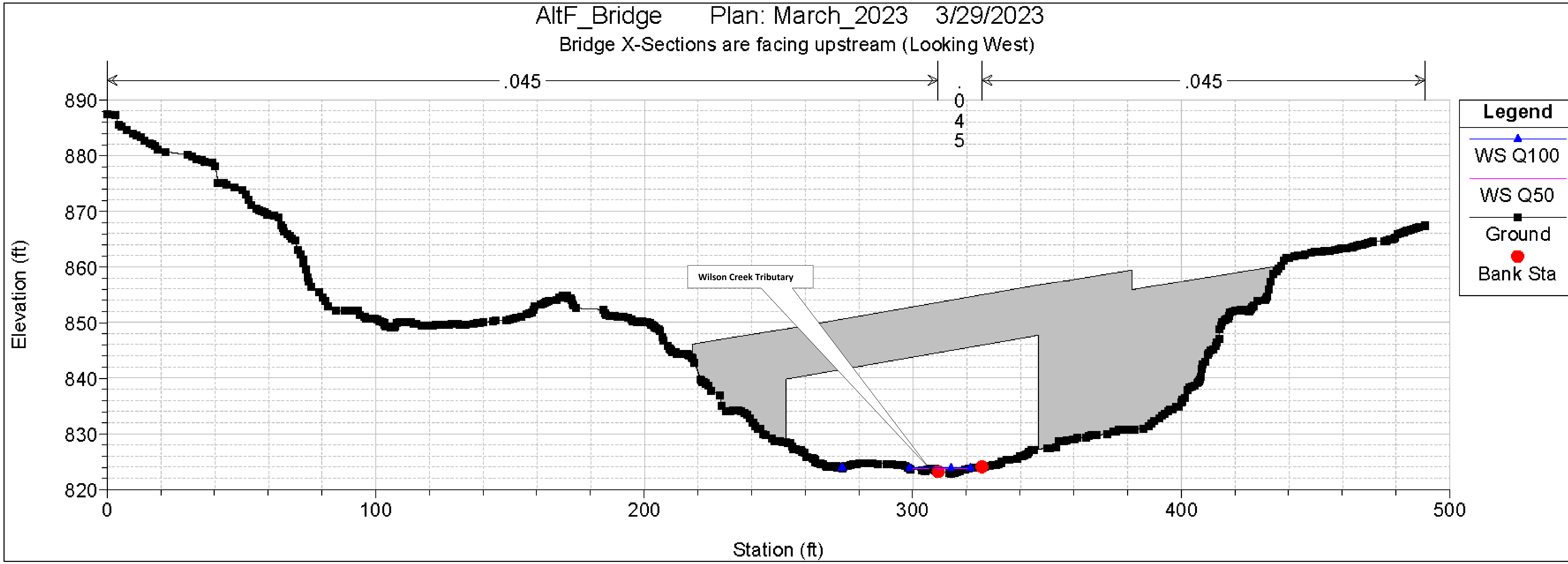

Figure 11. Downstream Face of Alternative F Bridge, Looking Upstream

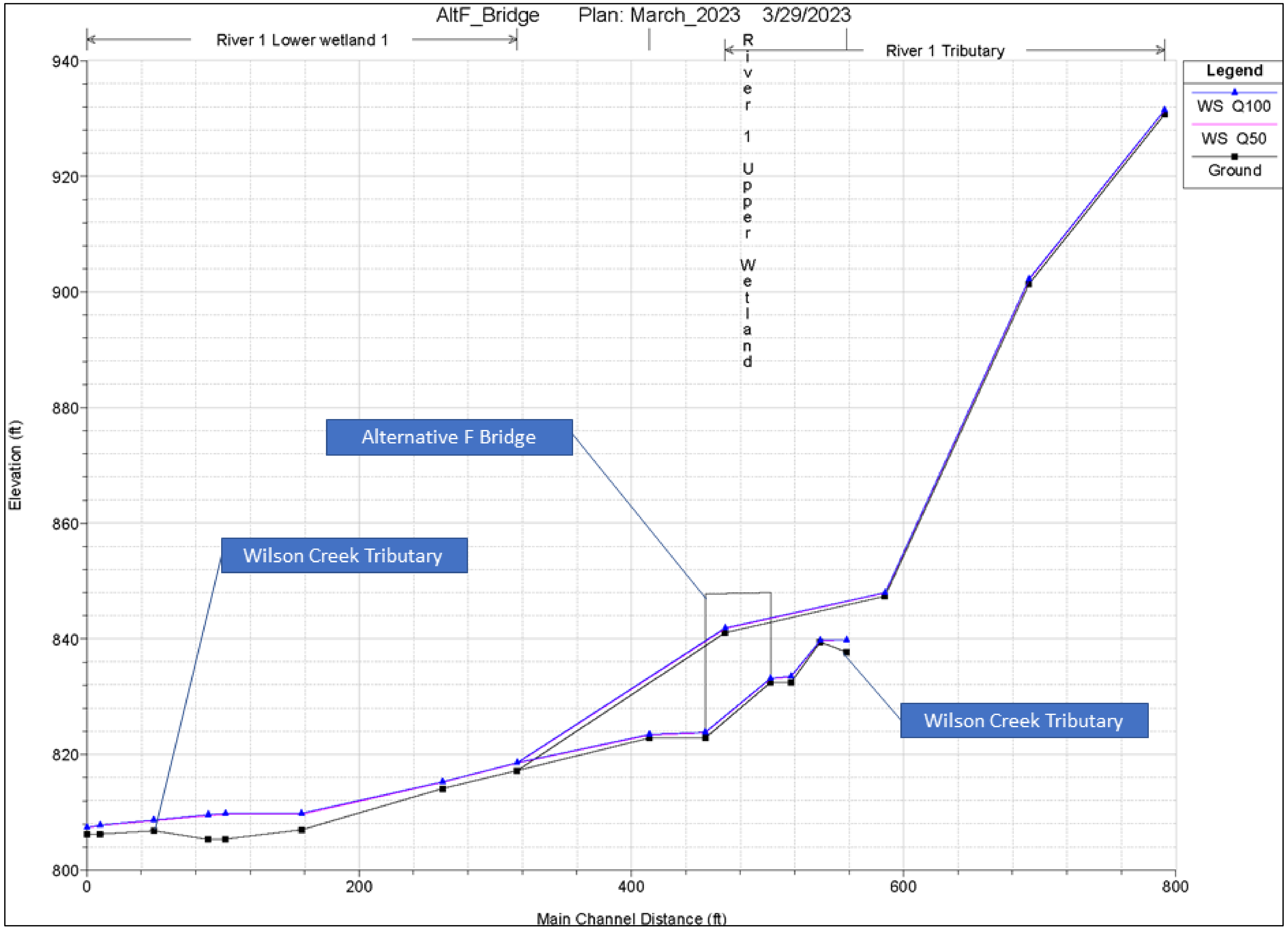

Figure 12. Alternative F Bridge 50- and 100-Year Water Surface Profile

Bridge Freeboard

Based on the preliminary bottom creek elevation provided by the Project site LiDAR imagery (Caltrans, 2022), WSE depth due to the Alternative F bridge was determined for Wilson Creek Tributary at the proposed upstream and downstream face was approximately 0.6 and 0.9 feet, respectively (Table 7), during the 50-year storm event. The proposed Alternative F bridge crossing at Wilson Creek Tributary has approximately 9.7 to 16.1 feet of freeboard during the 50-year storm event. The lowest soffit elevation for the proposed Alternative F bridge crossing was estimated to be 842.76 feet near Abutment 1 at the upstream face of the proposed bridge, and 839.4 feet at the downstream face near Abutment 1.

Table 7. Alternative F Bridge Q50 WSE Depth and Freeboard

Proposed Bridge	50-Year Storm Event		
	WSE (ft NAVD 88)	WSE Depth of Crossing (feet)	Freeboard (feet)
Upstream Face (Soffit Elevation: 842.76 ft)	833.5	0.6	9.7
Downstream Face (Soffit Elevation: 839.4 ft)	823.4	0.9	16.1

The WSE depth due to the proposed Alternative F bridge crossing was determined for the Wilson Creek Tributary at the proposed upstream and downstream face to be approximately 0.7 and 1.0 feet, respectively, during the 100-year storm event. During the 100-year storm, the available freeboard is shown in Table 8. Based on the preliminary analysis, the proposed Alternative F bridge has approximately 9.6 to 16.6 feet of freeboard.

Table 8. Alternative F Bridge Q100 WSE Depth and Freeboard

Proposed Bridge	100-Year Storm Event		
	WSE (ft NAVD 88)	WSE Depth of Crossing (feet)	Freeboard (feet)
Upstream Face (Soffit Elevation: 842.76 ft)	833.4	0.7	9.6
Downstream Face (Soffit Elevation: 839.4 ft)	823.4	1.0	16.6

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Walnut Creek, CA 94597
Phone: 925.465.2700
www.wreco.com

ATTACHMENTS

- NOAA Atlas 14 Rainfall Intensity
- HEC-RAS Results for Proposed Condition

NOAA Atlas 14, Volume 6, Version 2
Location name: Klamath, California, USA*
Latitude: 41.6469°, Longitude: -124.1122°
Elevation: 956.24 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**2.16** (1.88-2.51)	**2.66** (2.32-3.08)	**3.31** (2.87-3.85)	**3.84** (3.31-4.51)	**4.57** (3.79-5.58)	**5.15** (4.16-6.42)	**5.72** (4.51-7.34)	**6.32** (4.84-8.36)	**7.15** (5.22-9.91)	**7.80** (5.48-11.2)
10-min	**1.55** (1.35-1.80)	**1.91** (1.66-2.21)	**2.37** (2.06-2.76)	**2.75** (2.37-3.24)	**3.28** (2.72-4.00)	**3.68** (2.98-4.60)	**4.10** (3.23-5.26)	**4.54** (3.46-6.00)	**5.12** (3.74-7.10)	**5.59** (3.92-8.05)
15-min	**1.25** (1.09-1.45)	**1.54** (1.34-1.78)	**1.91** (1.66-2.23)	**2.22** (1.91-2.61)	**2.64** (2.19-3.22)	**2.97** (2.40-3.71)	**3.31** (2.60-4.24)	**3.66** (2.79-4.84)	**4.13** (3.02-5.72)	**4.51** (3.16-6.48)
30-min	**0.874** (0.762-1.01)	**1.07** (0.934-1.25)	**1.34** (1.16-1.56)	**1.55** (1.34-1.82)	**1.85** (1.53-2.25)	**2.08** (1.68-2.59)	**2.31** (1.82-2.96)	**2.55** (1.95-3.38)	**2.89** (2.11-4.00)	**3.15** (2.21-4.53)
60-min	**0.648** (0.565-0.751)	**0.796** (0.693-0.923)	**0.991** (0.860-1.15)	**1.15** (0.990-1.35)	**1.37** (1.14-1.67)	**1.54** (1.25-1.92)	**1.71** (1.35-2.20)	**1.89** (1.45-2.50)	**2.14** (1.56-2.96)	**2.34** (1.64-3.36)
2-hr	**0.498** (0.434-0.577)	**0.606** (0.527-0.702)	**0.747** (0.648-0.870)	**0.863** (0.742-1.01)	**1.02** (0.846-1.24)	**1.14** (0.925-1.43)	**1.27** (0.998-1.63)	**1.40** (1.07-1.85)	**1.57** (1.15-2.18)	**1.71** (1.20-2.46)
3-hr	**0.428** (0.373-0.496)	**0.518** (0.451-0.601)	**0.636** (0.552-0.740)	**0.732** (0.629-0.859)	**0.861** (0.714-1.05)	**0.961** (0.778-1.20)	**1.06** (0.837-1.36)	**1.17** (0.891-1.54)	**1.31** (0.954-1.81)	**1.42** (0.996-2.04)
6-hr	**0.332** (0.289-0.384)	**0.400** (0.349-0.465)	**0.489** (0.424-0.569)	**0.559** (0.481-0.657)	**0.653** (0.541-0.796)	**0.724** (0.586-0.903)	**0.795** (0.626-1.02)	**0.867** (0.662-1.15)	**0.962** (0.702-1.33)	**1.04** (0.727-1.49)
12-hr	**0.247** (0.215-0.286)	**0.303** (0.264-0.352)	**0.373** (0.324-0.434)	**0.427** (0.368-0.502)	**0.498** (0.412-0.606)	**0.549** (0.444-0.685)	**0.599** (0.471-0.768)	**0.648** (0.495-0.857)	**0.711** (0.519-0.985)	**0.759** (0.533-1.09)
24-hr	**0.190** (0.169-0.217)	**0.238** (0.212-0.272)	**0.296** (0.263-0.339)	**0.340** (0.300-0.393)	**0.396** (0.340-0.470)	**0.435** (0.367-0.526)	**0.473** (0.391-0.584)	**0.510** (0.411-0.645)	**0.556** (0.433-0.729)	**0.590** (0.445-0.797)
2-day	**0.131** (0.117-0.149)	**0.163** (0.146-0.187)	**0.202** (0.180-0.232)	**0.232** (0.205-0.268)	**0.270** (0.232-0.321)	**0.297** (0.250-0.359)	**0.322** (0.266-0.398)	**0.347** (0.280-0.439)	**0.379** (0.295-0.497)	**0.401** (0.303-0.543)
3-day	**0.101** (0.090-0.116)	**0.126** (0.112-0.144)	**0.155** (0.138-0.178)	**0.178** (0.157-0.206)	**0.207** (0.178-0.246)	**0.227** (0.192-0.275)	**0.247** (0.204-0.305)	**0.266** (0.215-0.337)	**0.290** (0.226-0.380)	**0.307** (0.232-0.416)
4-day	**0.086** (0.076-0.098)	**0.106** (0.095-0.122)	**0.131** (0.117-0.151)	**0.150** (0.133-0.174)	**0.174** (0.150-0.207)	**0.191** (0.161-0.231)	**0.207** (0.171-0.256)	**0.223** (0.180-0.282)	**0.243** (0.189-0.319)	**0.257** (0.194-0.348)
7-day	**0.062** (0.055-0.071)	**0.077** (0.068-0.088)	**0.094** (0.084-0.108)	**0.107** (0.095-0.124)	**0.124** (0.106-0.147)	**0.135** (0.114-0.164)	**0.146** (0.121-0.181)	**0.157** (0.126-0.198)	**0.170** (0.132-0.223)	**0.179** (0.135-0.242)
10-day	**0.051** (0.046-0.058)	**0.063** (0.056-0.072)	**0.077** (0.069-0.088)	**0.087** (0.077-0.101)	**0.100** (0.086-0.119)	**0.109** (0.092-0.132)	**0.118** (0.097-0.145)	**0.126** (0.101-0.159)	**0.136** (0.106-0.178)	**0.143** (0.108-0.193)
20-day	**0.035** (0.031-0.040)	**0.043** (0.038-0.049)	**0.052** (0.046-0.059)	**0.058** (0.052-0.067)	**0.066** (0.057-0.079)	**0.072** (0.061-0.087)	**0.077** (0.064-0.095)	**0.082** (0.066-0.103)	**0.087** (0.068-0.114)	**0.091** (0.069-0.123)
30-day	**0.029** (0.026-0.034)	**0.036** (0.032-0.041)	**0.043** (0.038-0.049)	**0.048** (0.043-0.056)	**0.055** (0.047-0.065)	**0.059** (0.050-0.071)	**0.063** (0.052-0.078)	**0.066** (0.054-0.084)	**0.071** (0.055-0.093)	**0.074** (0.056-0.099)
45-day	**0.025** (0.023-0.029)	**0.031** (0.027-0.035)	**0.036** (0.032-0.042)	**0.041** (0.036-0.047)	**0.046** (0.039-0.054)	**0.049** (0.041-0.059)	**0.052** (0.043-0.064)	**0.055** (0.044-0.069)	**0.058** (0.045-0.076)	**0.060** (0.045-0.081)
60-day	**0.023** (0.020-0.026)	**0.027** (0.024-0.031)	**0.032** (0.029-0.037)	**0.036** (0.032-0.042)	**0.040** (0.034-0.048)	**0.043** (0.036-0.052)	**0.045** (0.037-0.056)	**0.047** (0.038-0.060)	**0.050** (0.039-0.066)	**0.052** (0.039-0.070)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

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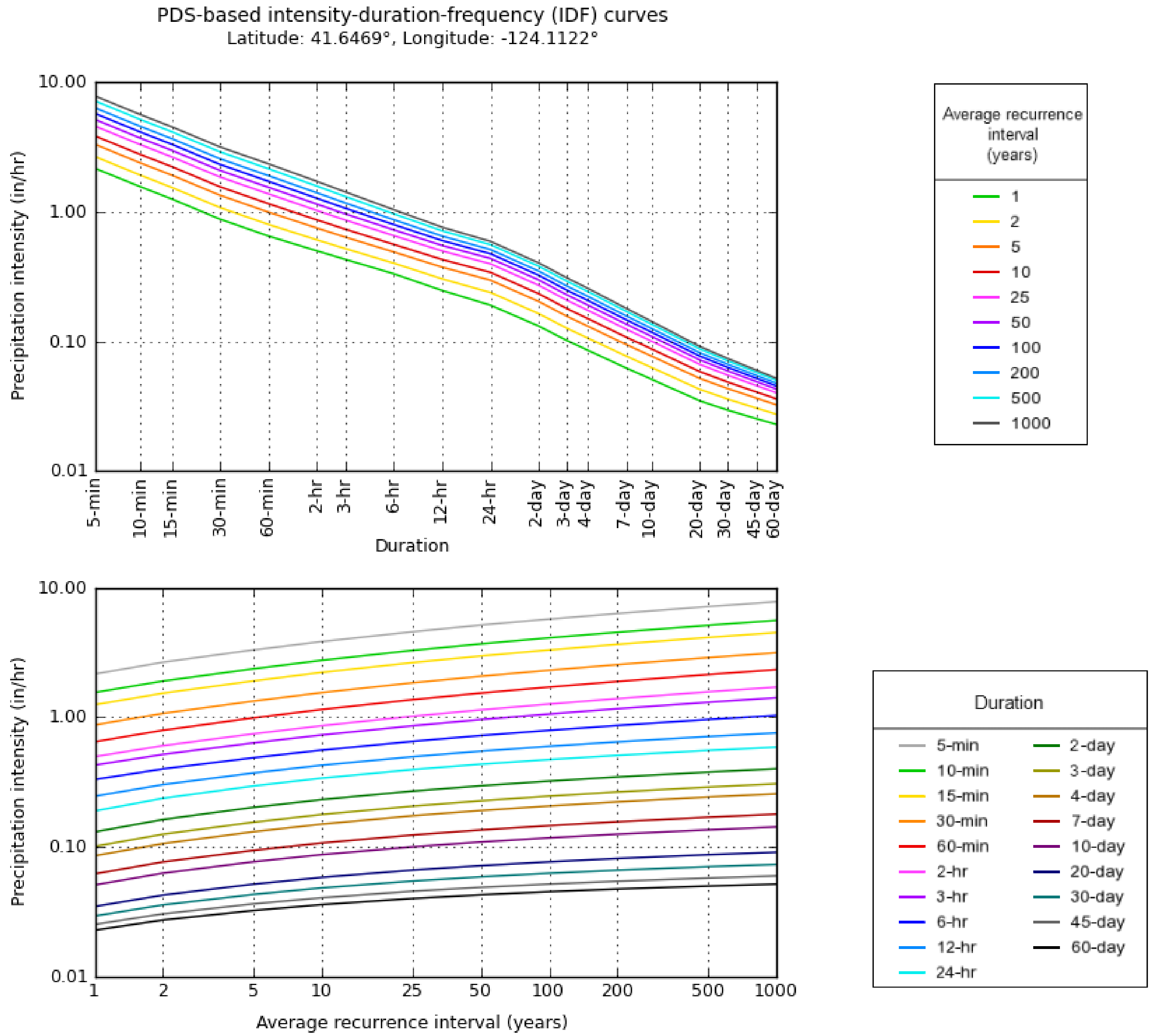
PF graphical



NOAA Atlas 14, Volume 6, Version 2 Created (GMT): Fri Feb 11 22:56:43 2022

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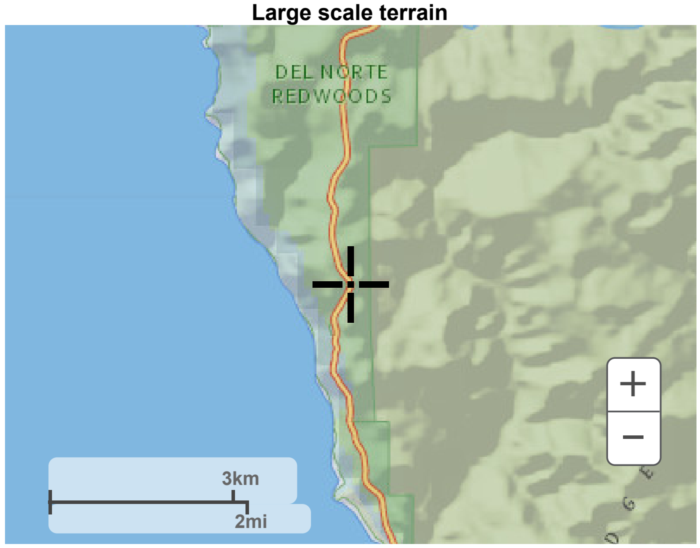
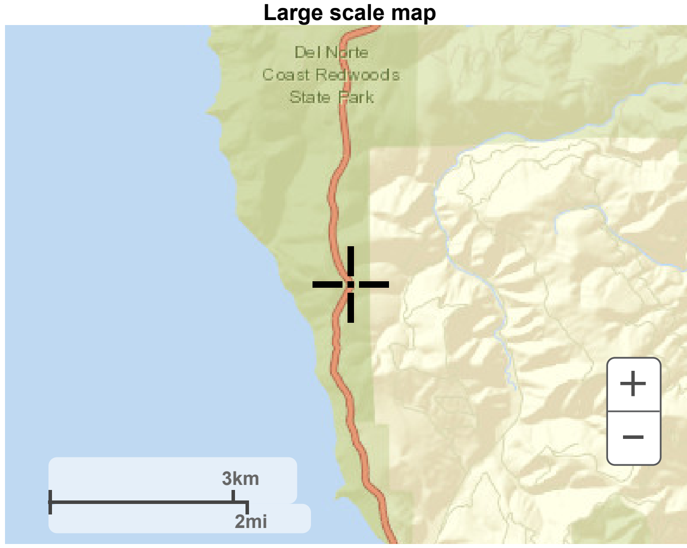
Maps & aerials

Small scale terrain

Large scale terrain



Large scale map



Large scale aerial

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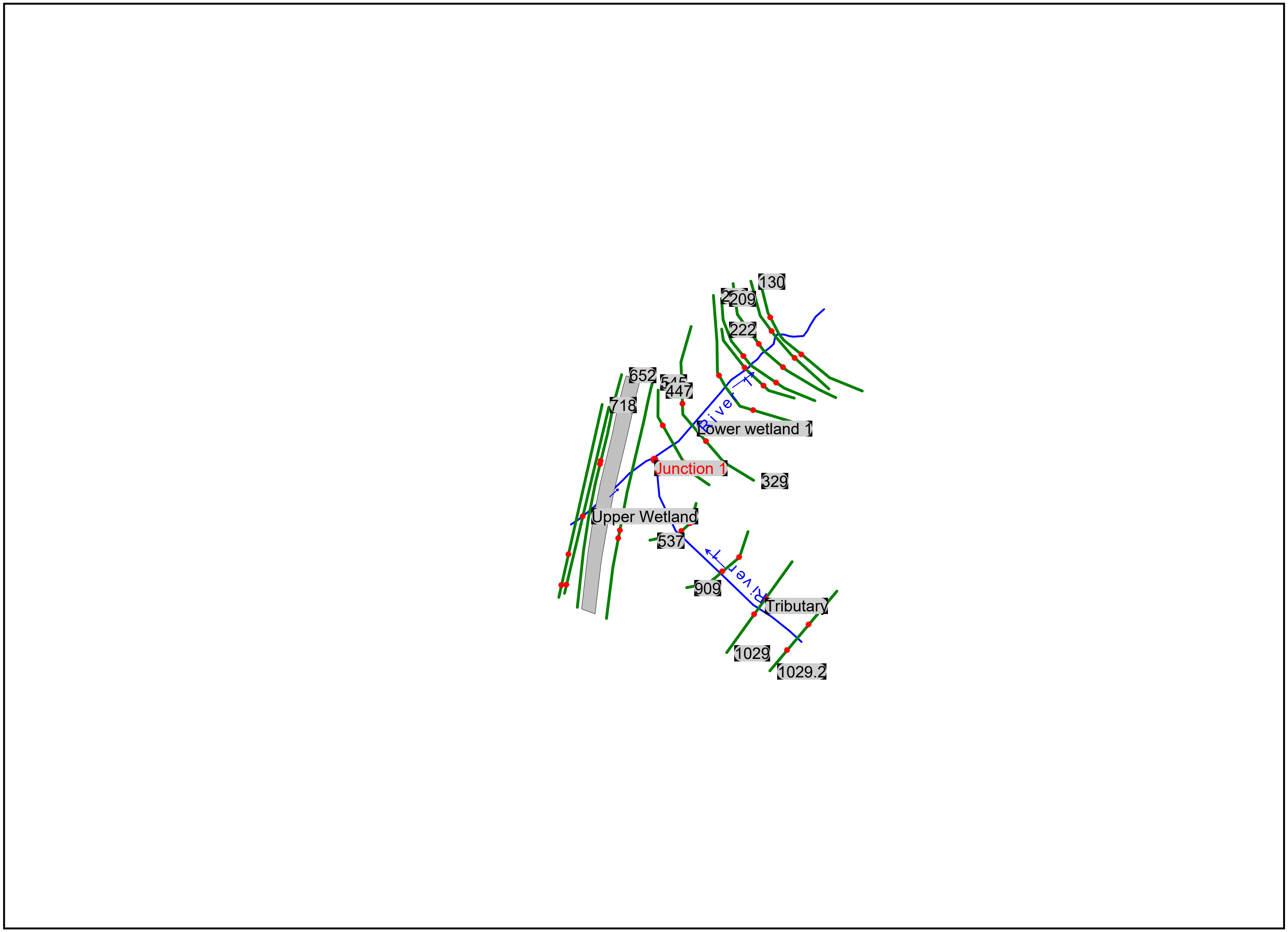
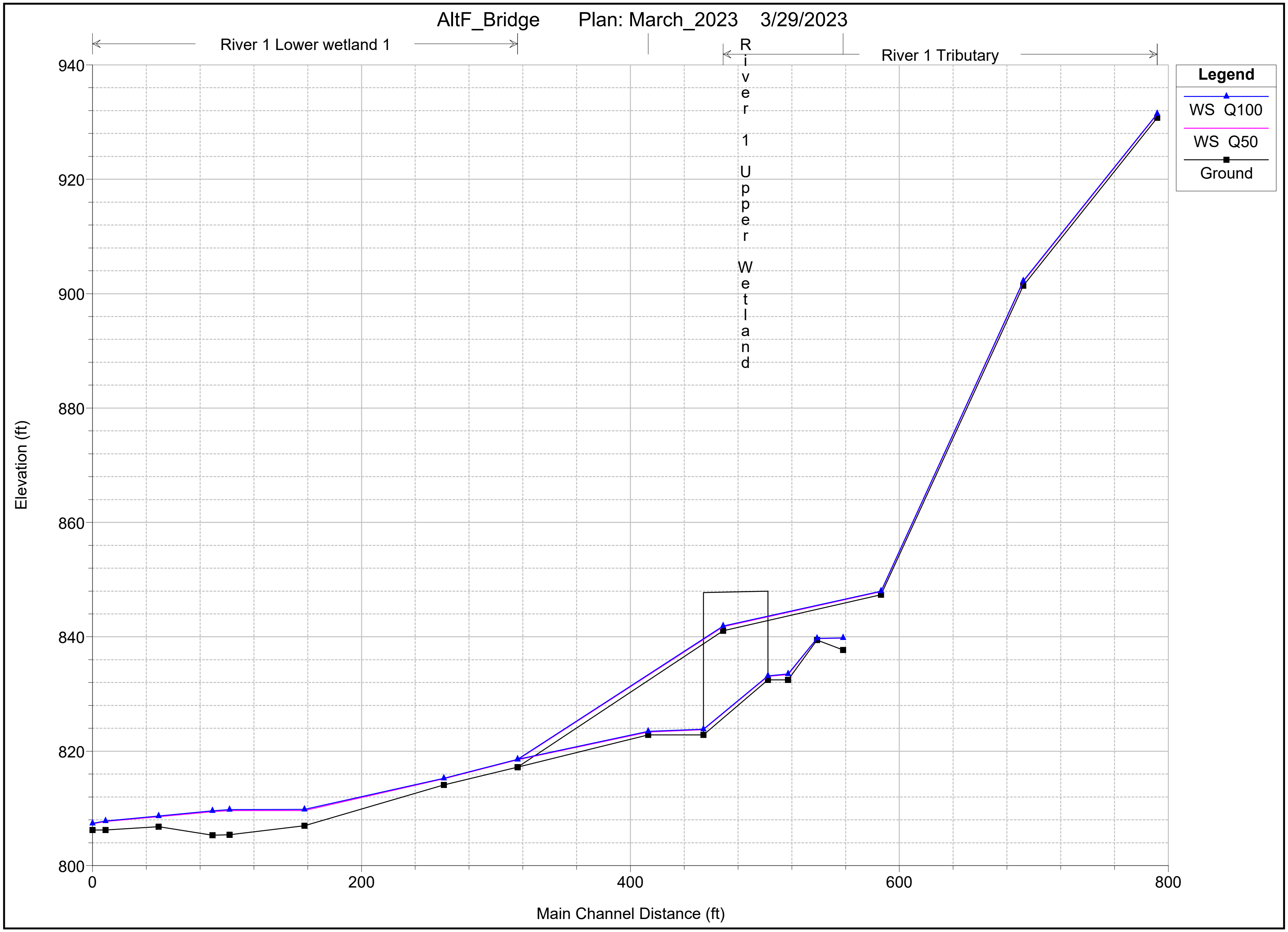

130
209
222
652
447
718
River 1
Lower wetland 1
Junction 1
329
Upper Wetland
537
River 1
909
Tributary
1029
1029.2

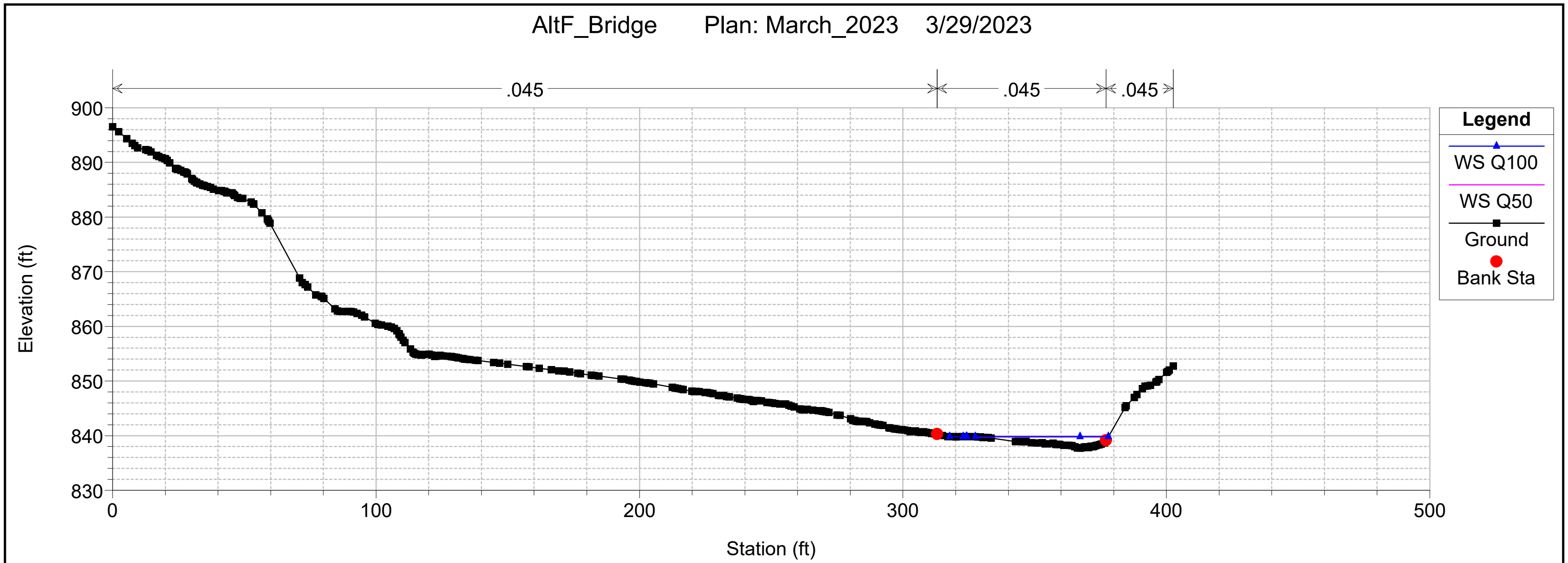

AltF_Bridge Plan: March_2023 3/29/2023
River 1 Lower wetland 1
River 1 Upper Wetland
River 1 Tributary
Legend
WS Q100
WS Q50
Ground
Elevation (ft)
940
920
900
880
860
840
820
800
0
200
400
600
800
Main Channel Distance (ft)

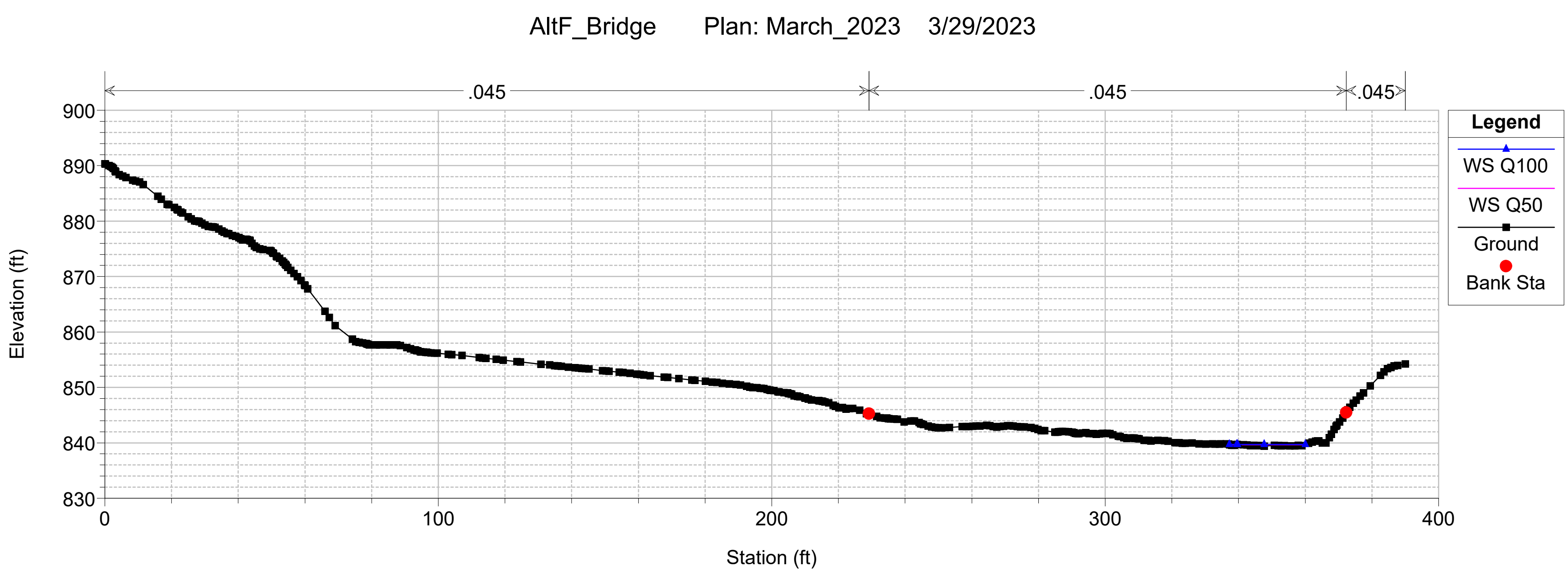
HEC-RAS Plan: March2023FG Profile: Q100

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Hydr Depth	Hydr Depth C	Length Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)	(ft)
Upper Wetland	718	Q100	10.00	837.70	839.82		839.82	0.000031	0.18	55.14	56.03	0.03	0.98	0.99	19.30
Upper Wetland	684	Q100	10.00	839.42	839.72	839.72	839.81	0.054256	2.45	4.07	22.51	1.02	0.18	0.18	21.60
Upper Wetland	652	Q100	10.00	832.49	833.51	833.19	833.57	0.005092	2.04	5.56	9.10	0.40	0.61	0.82	15.00
Upper Wetland	645 BR U	Q100	10.00	832.49	833.20	833.20	833.39	0.032447	3.73	2.92	7.60	0.92	0.38	0.51	48.00
Upper Wetland	645 BR D	Q100	10.00	822.83	823.86	823.46	823.88	0.002434	1.13	10.04	23.29	0.26	0.43	0.59	41.00
Upper Wetland	545	Q100	10.00	822.83	823.46	823.46	823.61	0.036599	3.17	3.31	11.90	0.93	0.28	0.36	97.22
Tributary	1029.2	Q100	10.00	930.74	931.45	931.45	931.59	0.046998	3.07	3.26	11.40	1.01	0.29	0.29	99.70
Tributary	1029	Q100	10.00	901.38	902.22	902.22	902.47	0.042060	4.03	2.48	5.05	1.01	0.49	0.49	105.80
Tributary	909	Q100	10.00	847.35	847.98	847.98	848.14	0.046724	3.12	3.21	10.97	1.02	0.29	0.29	117.30
Tributary	537	Q100	10.00	841.04	841.88	841.88	842.13	0.041831	4.02	2.49	5.07	1.01	0.49	0.49	152.96
Lower wetland 1	447	Q100	80.00	817.19	818.58	818.58	819.01	0.033439	5.26	15.21	18.20	1.01	0.84	0.84	54.80
Lower wetland 1	329	Q100	80.00	814.10	815.24	815.24	815.62	0.034708	4.91	16.28	22.25	1.01	0.73	0.73	103.60
Lower wetland 1	278	Q100	80.00	806.96	809.81		809.90	0.003092	2.35	34.01	22.53	0.34	1.51	1.51	55.70
Lower wetland 1	222	Q100	80.00	805.41	809.80		809.83	0.000412	1.22	65.84	24.64	0.13	2.67	2.67	12.70
Lower wetland 1	209	Q100	80.00	805.30	809.57		809.79	0.007077	3.76	21.26	8.97	0.43	2.37	2.37	40.10
Lower wetland 1	169	Q100	80.00	806.79	808.66	808.66	809.24	0.030928	6.11	13.10	11.44	1.01	1.14	1.14	39.40
Lower wetland 1	130	Q100	80.00	806.23	807.79		807.91	0.006992	2.83	28.30	27.05	0.49	1.05	1.05	9.70
Lower wetland 1	120	Q100	80.00	806.24	807.38	807.38	807.76	0.033656	4.92	16.25	22.03	1.01	0.74	0.74	

HEC-RAS Plan: March2023FG   Profile: Q50

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Hydr Depth	Hydr Depth C	Length Chnl
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(ft)	(ft)	(ft)
Upper Wetland	718	Q50	7.00	837.70	839.76		839.76	0.000016	0.14	51.93	49.56	0.02	1.05	1.06	19.30
Upper Wetland	684	Q50	7.00	839.42	839.67	839.67	839.75	0.054866	2.21	3.16	20.57	1.00	0.15	0.15	21.60
Upper Wetland	652	Q50	7.00	832.49	833.39	833.08	833.43	0.004647	1.75	4.48	8.61	0.37	0.52	0.70	15.00
Upper Wetland	645 BR U	Q50	7.00	832.49	833.08	833.08	833.26	0.039589	3.51	2.12	6.22	0.98	0.34	0.40	48.00
Upper Wetland	645 BR D	Q50	7.00	822.83	823.75	823.36	823.77	0.002143	1.01	7.73	18.77	0.24	0.41	0.55	41.00
Upper Wetland	545	Q50	7.00	822.83	823.37	823.37	823.51	0.046412	3.06	2.31	8.42	1.01	0.27	0.29	97.22
Tributary	1029.2	Q50	7.00	930.74	931.38	931.38	931.50	0.049921	2.79	2.51	10.58	1.01	0.24	0.24	99.70
Tributary	1029	Q50	7.00	901.38	902.09	902.09	902.31	0.043857	3.72	1.88	4.46	1.01	0.42	0.42	105.80
Tributary	909	Q50	7.00	847.35	847.91	847.91	848.04	0.046584	2.86	2.45	9.49	0.99	0.26	0.26	117.30
Tributary	537	Q50	7.00	841.04	841.76	841.76	841.97	0.044111	3.68	1.90	4.65	1.01	0.41	0.41	152.96
Lower wetland 1	447	Q50	70.00	817.19	818.50	818.50	818.90	0.034167	5.06	13.84	17.85	1.01	0.78	0.78	54.80
Lower wetland 1	329	Q50	70.00	814.10	815.18	815.18	815.52	0.034748	4.68	14.97	22.07	1.00	0.68	0.68	103.60
Lower wetland 1	278	Q50	70.00	806.96	809.63		809.71	0.003376	2.33	30.00	21.51	0.35	1.39	1.39	55.70
Lower wetland 1	222	Q50	70.00	805.41	809.63		809.65	0.000380	1.14	61.49	23.88	0.13	2.58	2.58	12.70
Lower wetland 1	209	Q50	70.00	805.30	809.42		809.62	0.006427	3.51	19.94	8.70	0.41	2.29	2.29	40.10
Lower wetland 1	169	Q50	70.00	806.79	808.54	808.54	809.09	0.031703	5.95	11.76	10.89	1.01	1.08	1.08	39.40
Lower wetland 1	130	Q50	70.00	806.23	807.70		807.82	0.006836	2.70	25.97	26.24	0.48	0.99	0.99	9.70
Lower wetland 1	120	Q50	70.00	806.24	807.31	807.31	807.66	0.034182	4.76	14.70	21.20	1.01	0.69	0.69	


AltF_Bridge Plan: March_2023 3/29/2023
.045
.045
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta
900
890
880
870
860
850
840
830
0
100
200
300
400
500


AltF_Bridge Plan: March_2023 3/29/2023
.045
.045
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta
900
890
880
870
860
850
840
830
0
100
200
300
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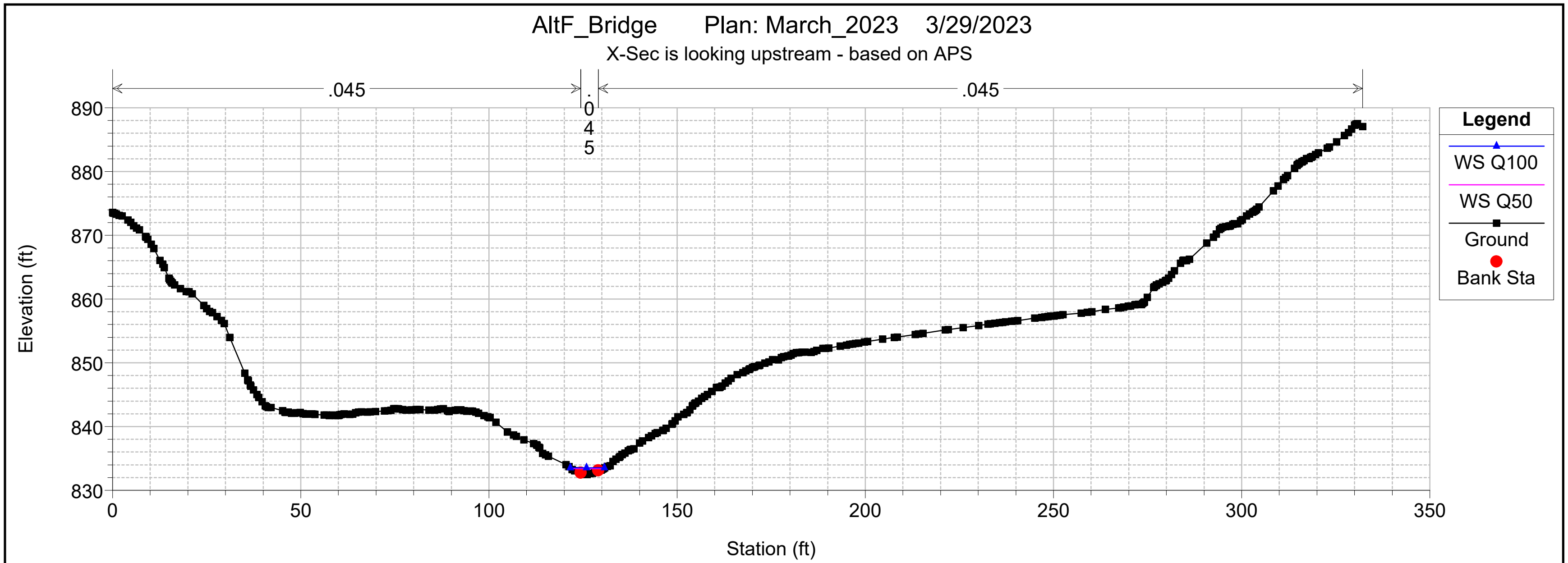
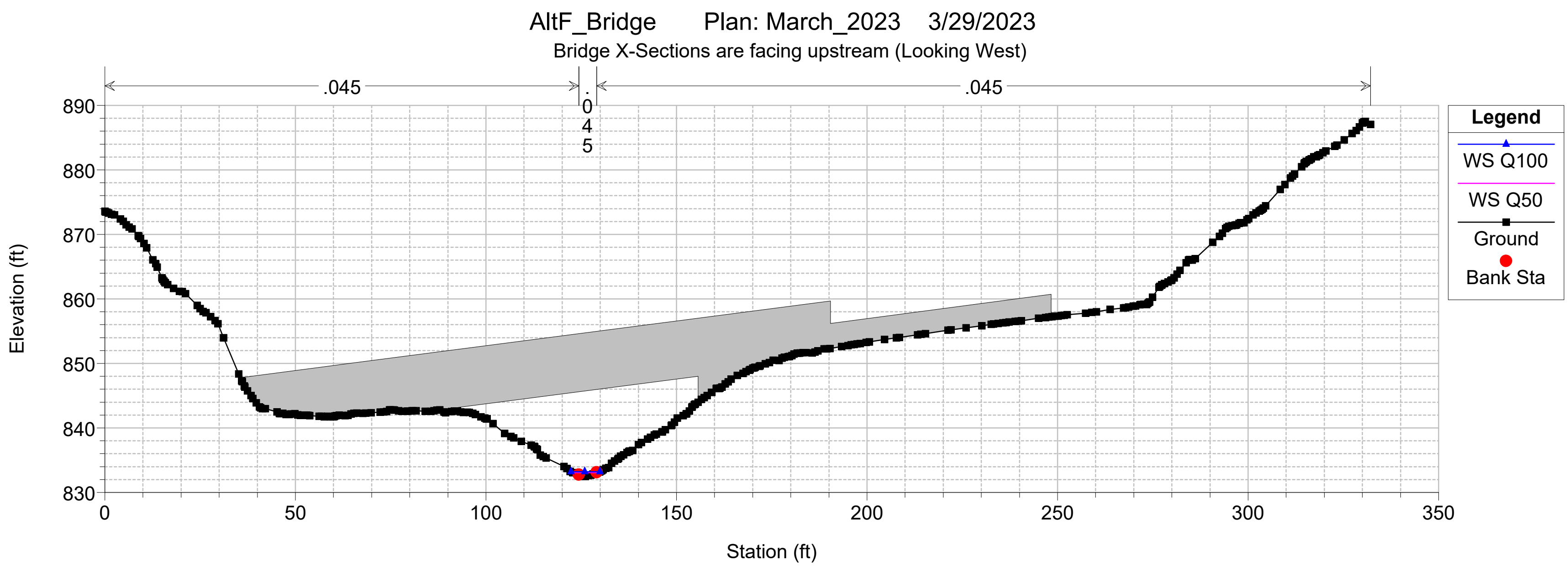
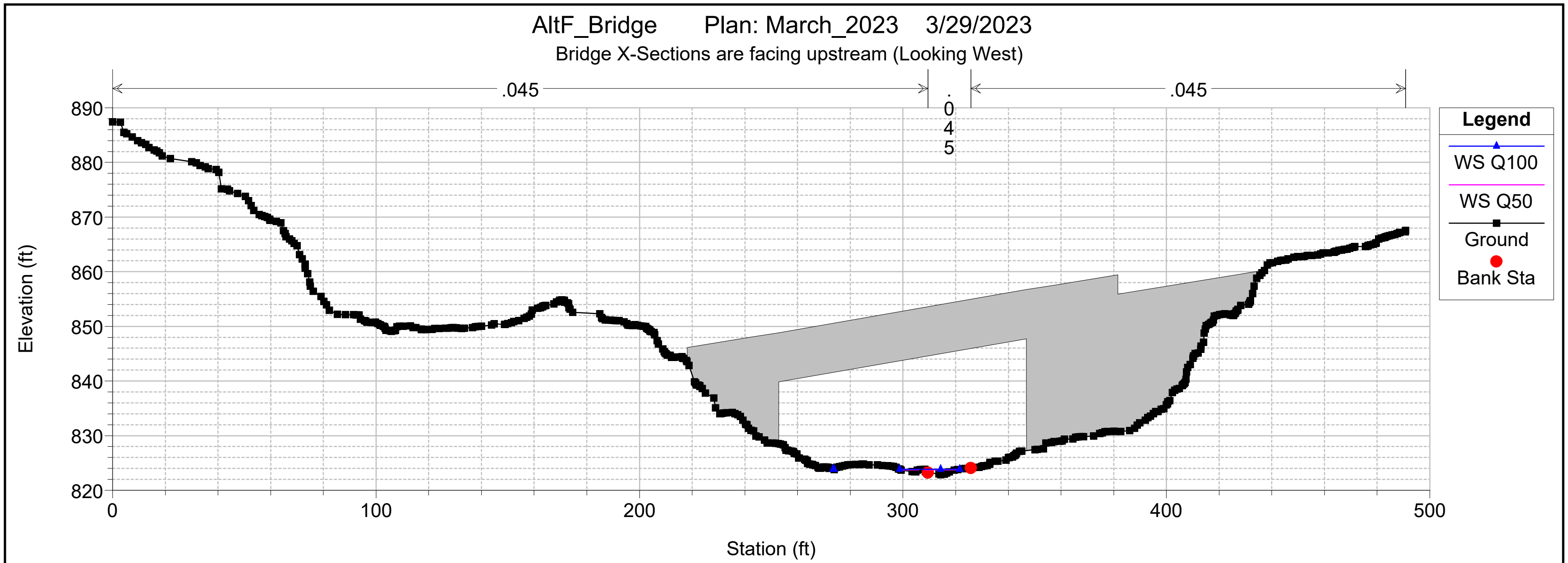


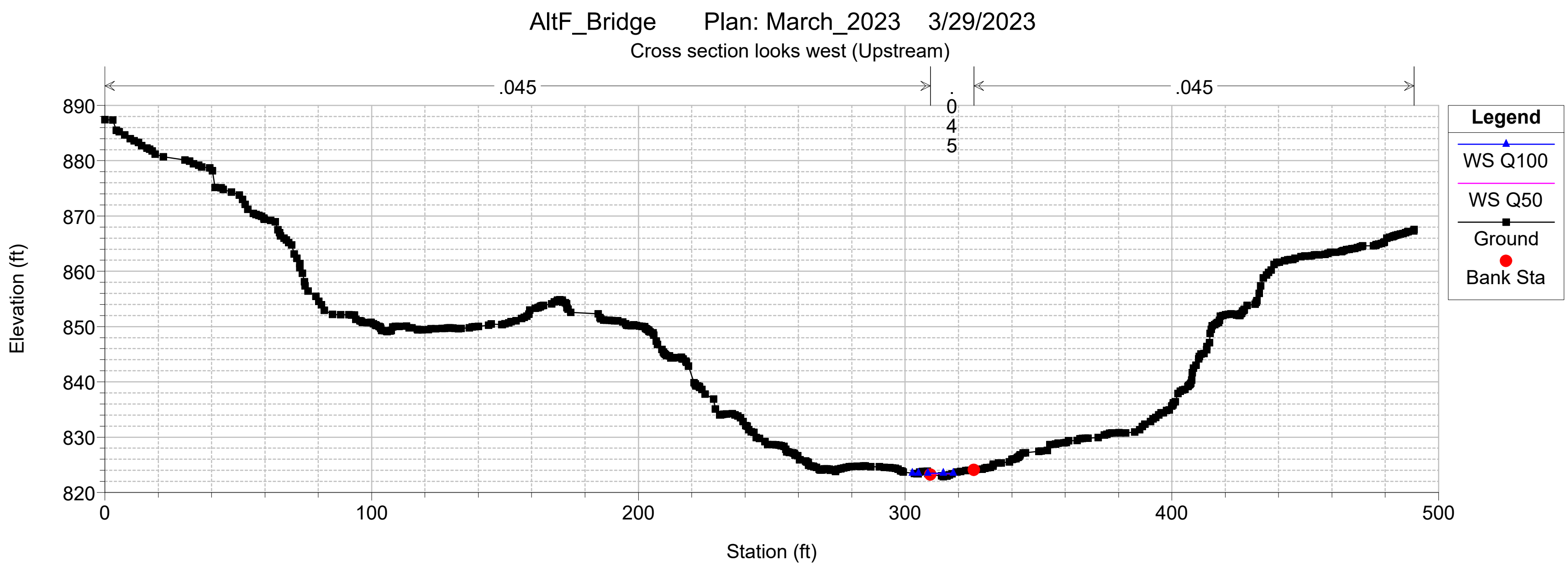
AltF_Bridge Plan: March_2023 3/29/2023
X-Sec is looking upstream - based on APS
.045
.045
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta



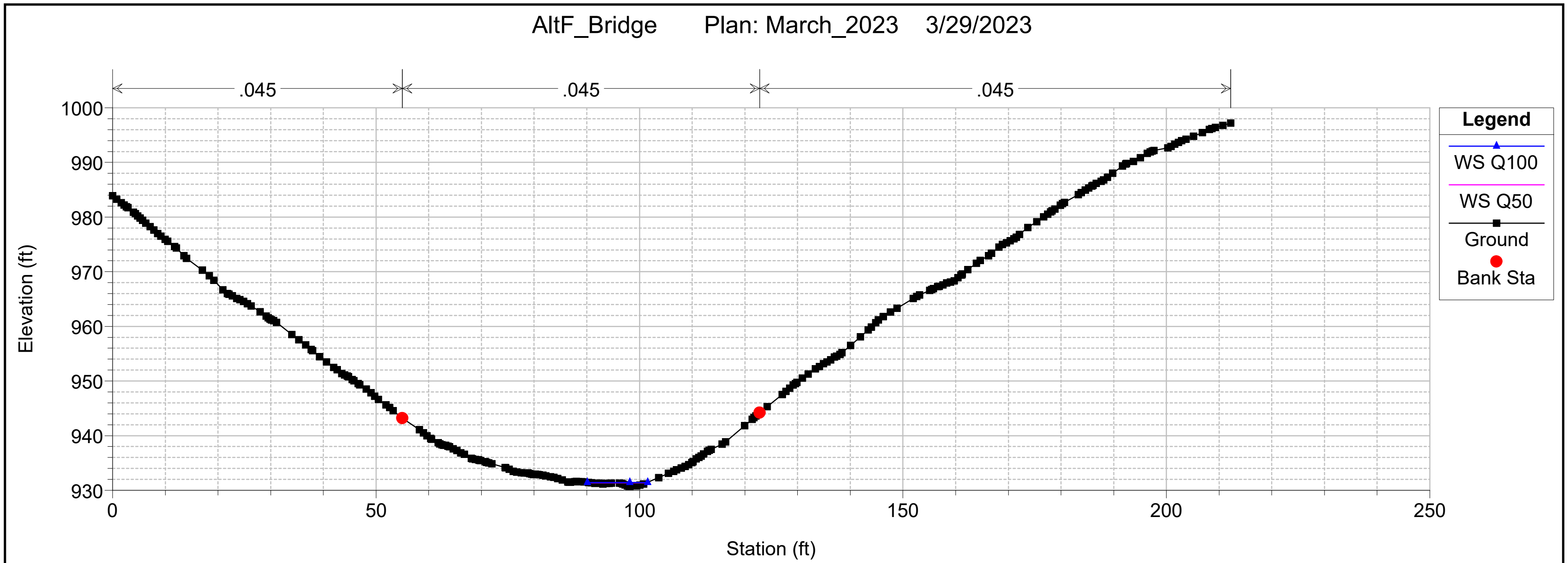
AltF_Bridge Plan: March_2023 3/29/2023
Bridge X-Sections are facing upstream (Looking West)
.045
.045
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta



AltF_Bridge Plan: March_2023 3/29/2023
Bridge X-Sections are facing upstream (Looking West)
.045
.045
.045
Legend
WS Q100
WS Q50
Ground
Bank Sta
Elevation (ft)
Station (ft)
890
880
870
860
850
840
830
820
0
100
200
300
400
500



AltF_Bridge Plan: March_2023 3/29/2023
Cross section looks west (Upstream)
.045
.045
.045
Legend
WS Q100
WS Q50
Ground
Bank Sta
Elevation (ft)
Station (ft)
890
880
870
860
850
840
830
820
0
100
200
300
400
500


AltF_Bridge Plan: March_2023 3/29/2023
.045
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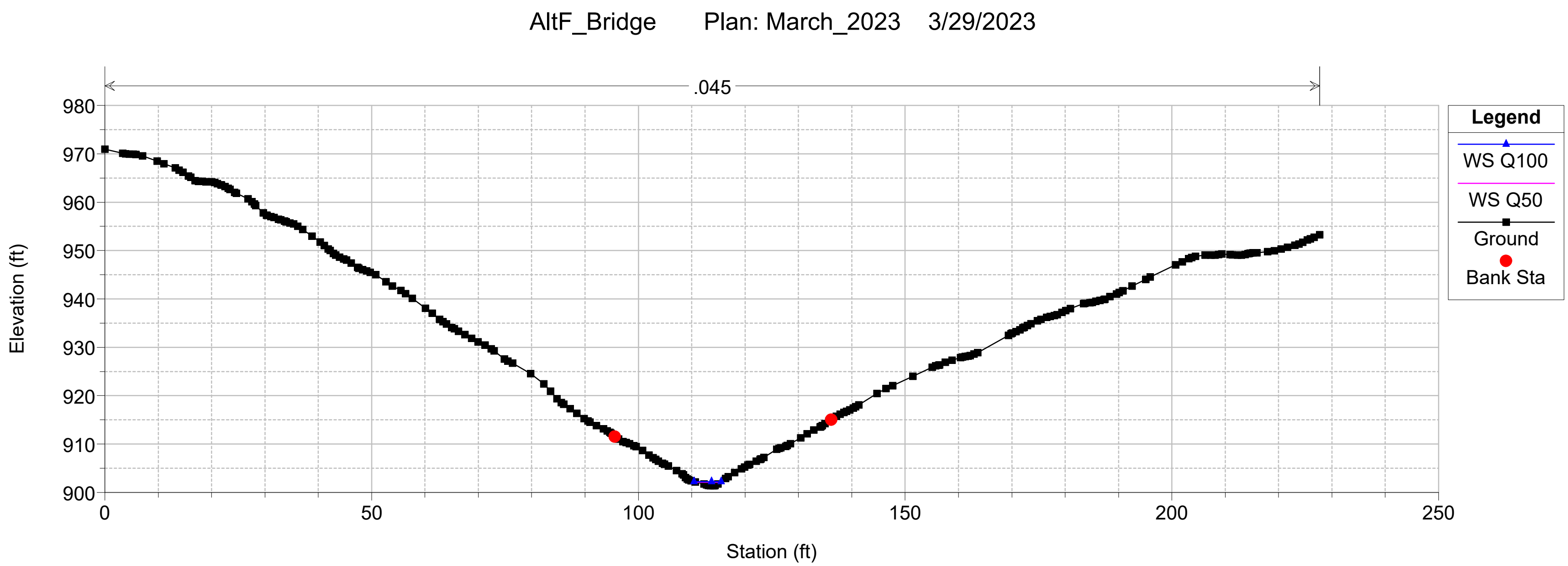
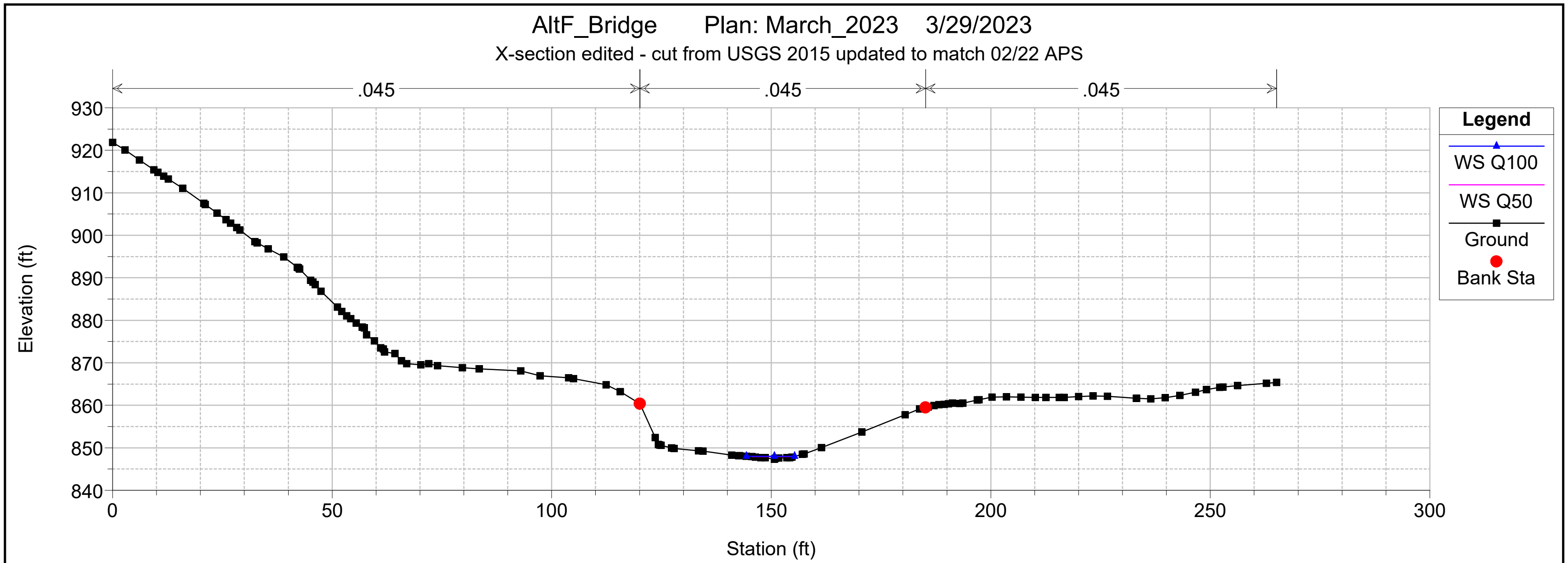
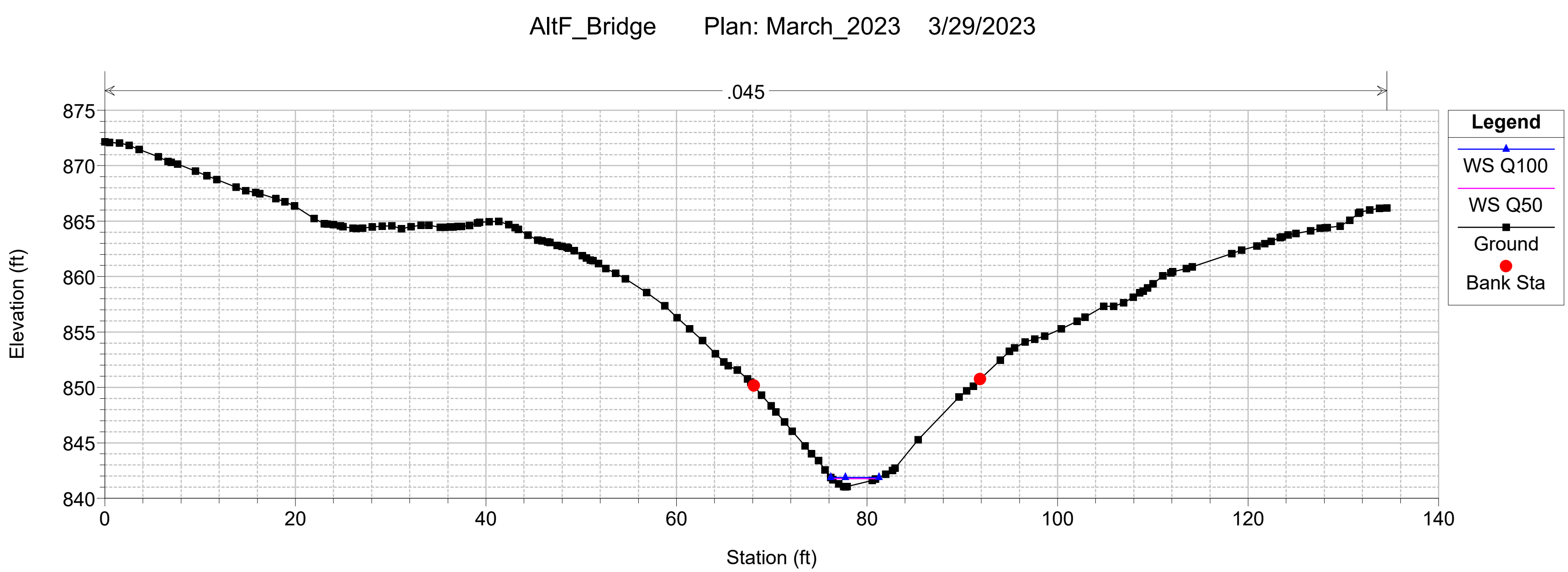
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta

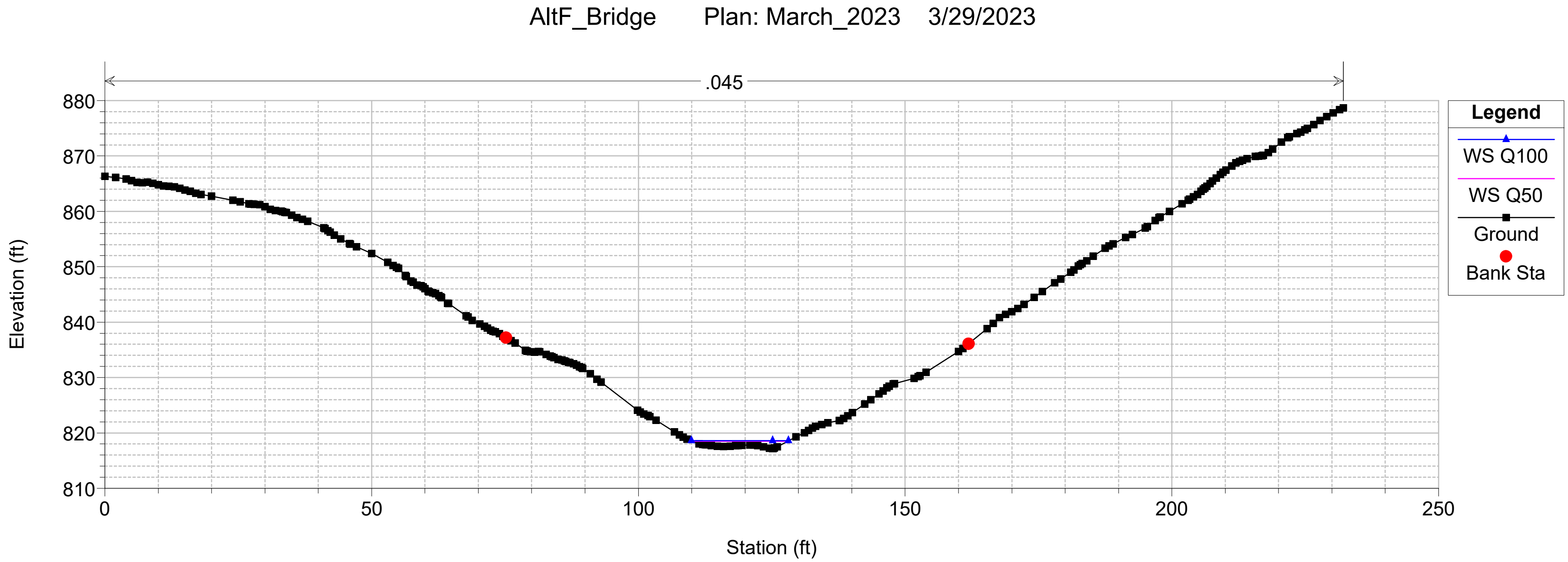

AltF_Bridge Plan: March_2023 3/29/2023
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta

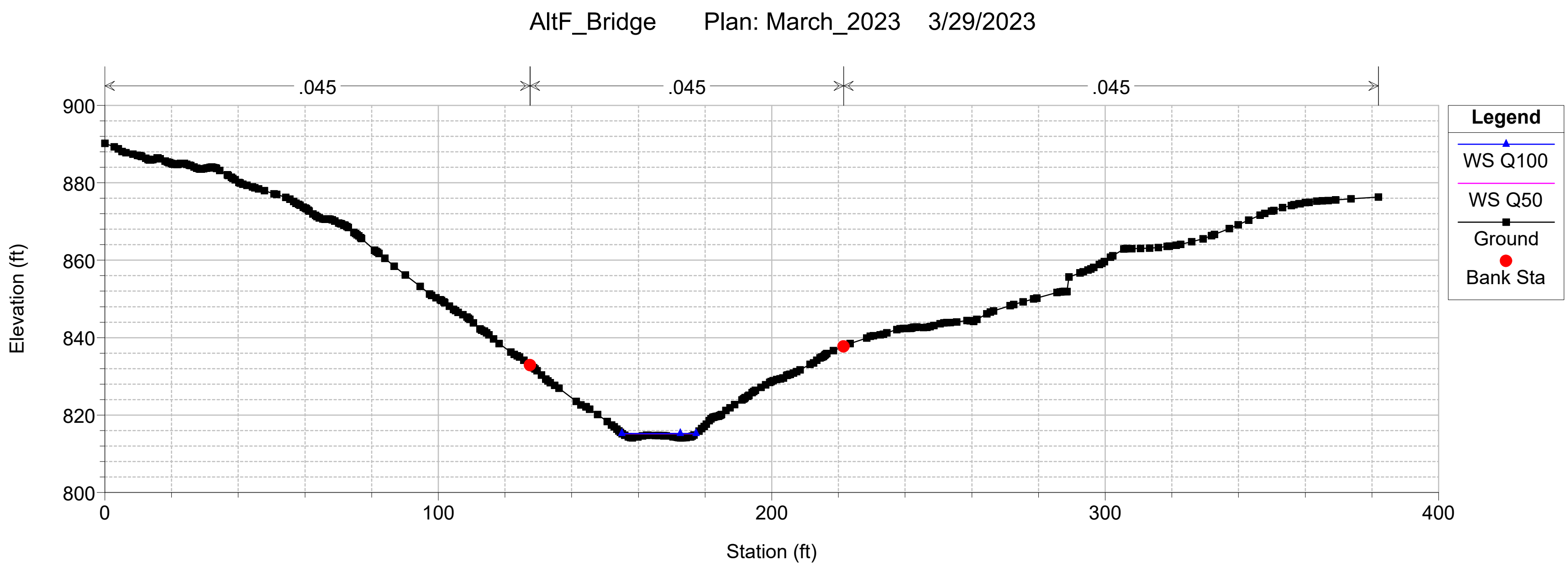


AltF_Bridge Plan: March_2023 3/29/2023
X-section edited - cut from USGS 2015 updated to match 02/22 APS
.045
.045
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta



AltF_Bridge Plan: March_2023 3/29/2023
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta


AltF_Bridge Plan: March_2023 3/29/2023
.045
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta
880
870
860
850
840
830
820
810
0
50
100
150
200
250


AltF_Bridge Plan: March_2023 3/29/2023
.045
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Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta
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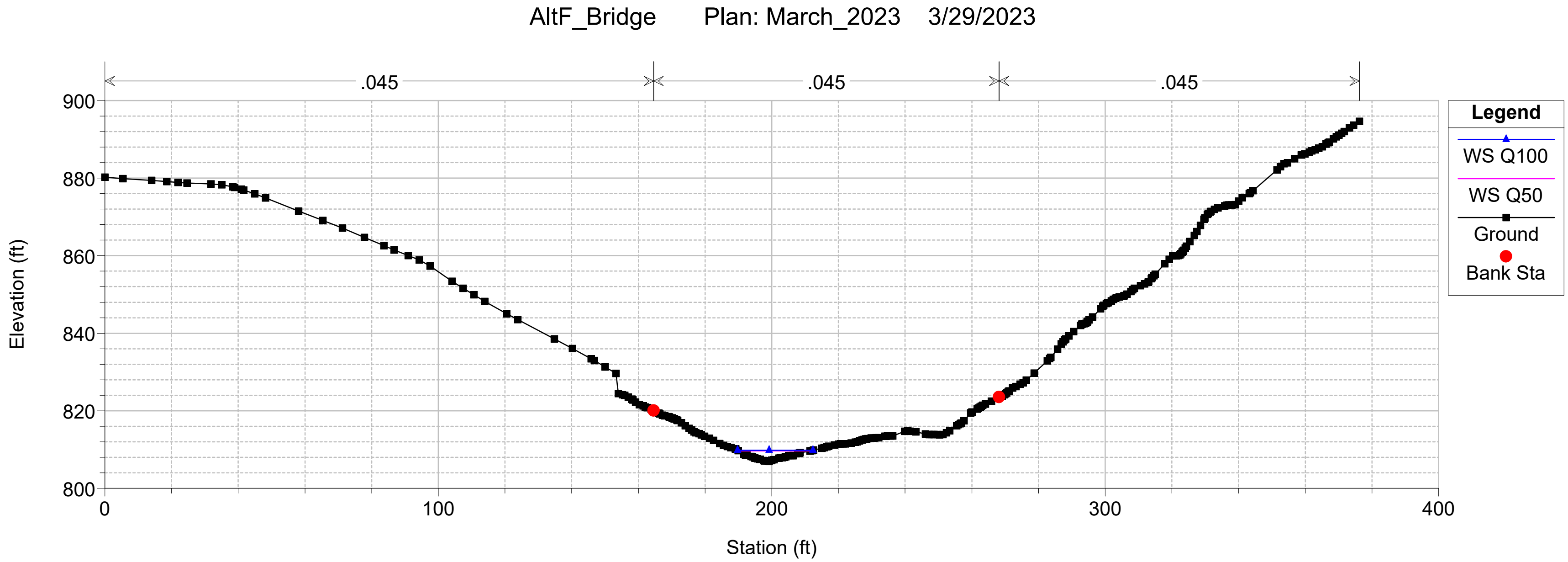
AltF_Bridge Plan: March_2023 3/29/2023
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Elevation (ft)
Station (ft)
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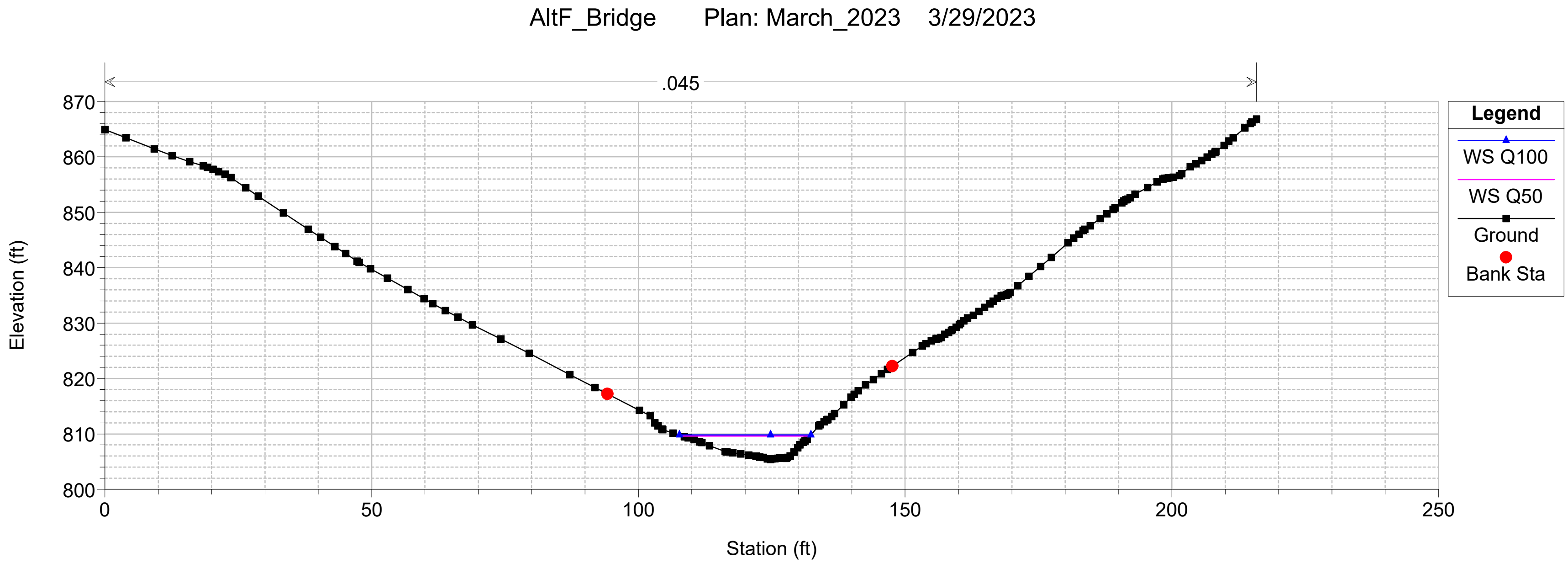
Legend
WS Q100
WS Q50
Ground
Bank Sta


AltF_Bridge Plan: March_2023 3/29/2023
.045
Elevation (ft)
Station (ft)
870
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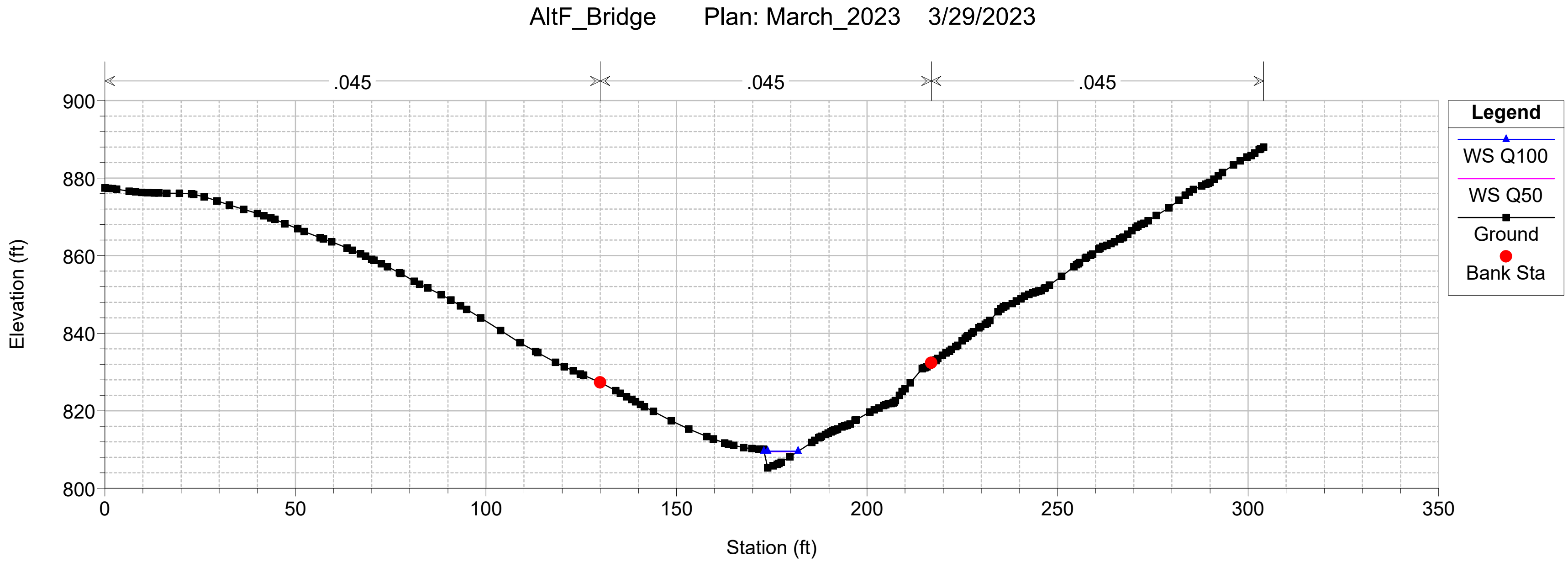
Legend
WS Q100
WS Q50
Ground
Bank Sta


AltF_Bridge Plan: March_2023 3/29/2023
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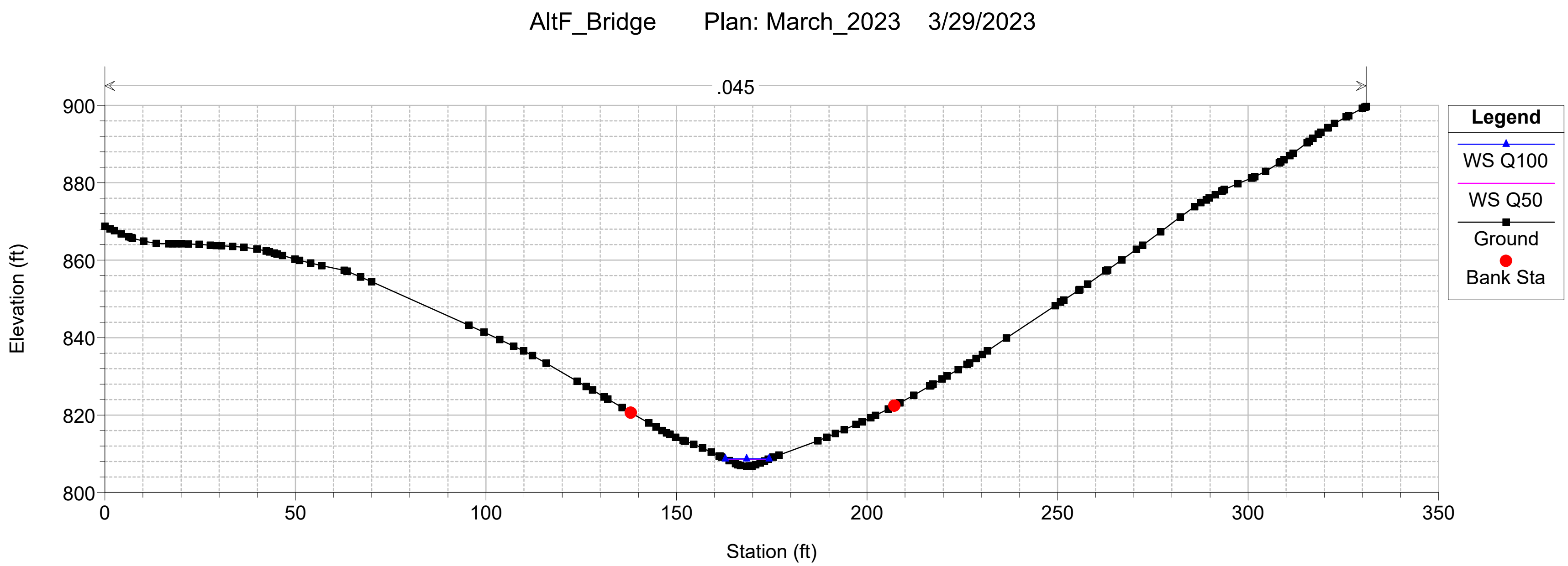
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta


AltF_Bridge Plan: March_2023 3/29/2023
.045
900
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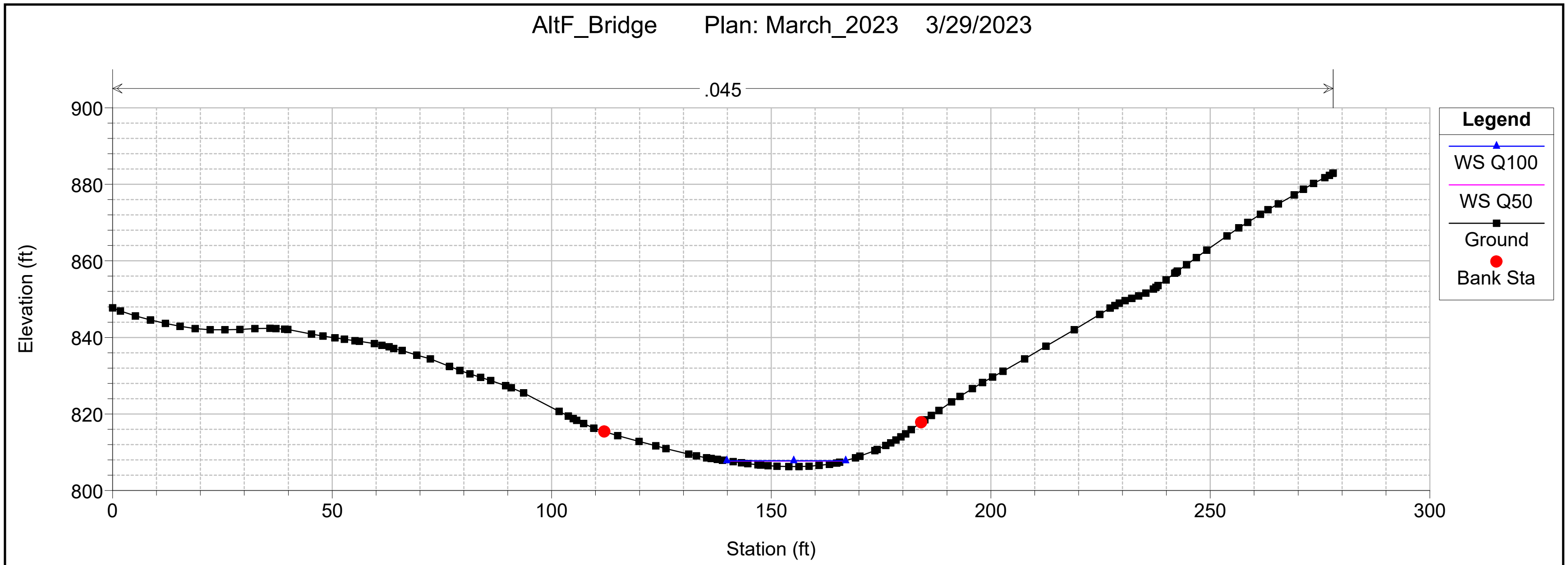
Elevation (ft)
Station (ft)
Legend
WS Q100
WS Q50
Ground
Bank Sta


AltF_Bridge Plan: March_2023 3/29/2023
.045
Elevation (ft)
Station (ft)
900
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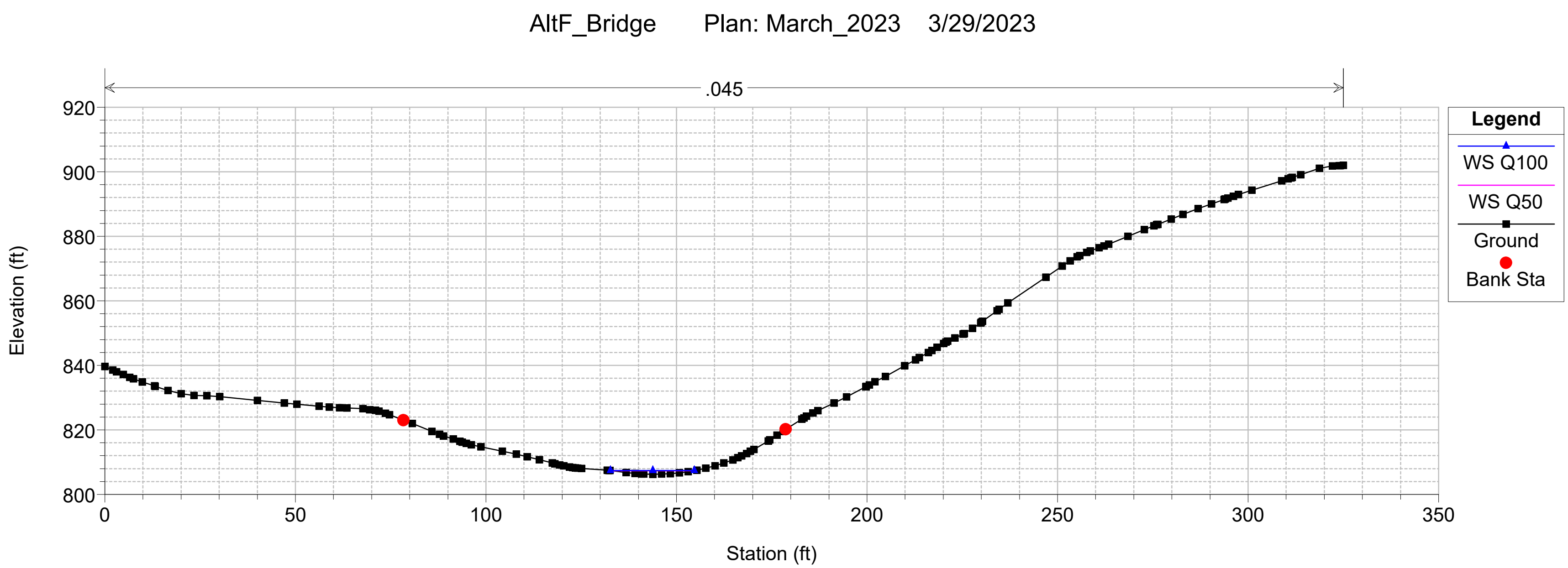
Legend
WS Q100
WS Q50
Ground
Bank Sta


AltF_Bridge Plan: March_2023 3/29/2023
.045
Elevation (ft)
Station (ft)
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300
350
Legend
WS Q100
WS Q50
Ground
Bank Sta