INFORMATION HANDOUT

For Contract No. 01-0B5204
At 01-Men-128-39.5

Identified by
Project ID 0112000135

MATERIALS INFORMATION

Geotechnical Design Report for Shoulder Failure at PM 39.5 dated February 19, 2015

Water Source Information

Beebe Creek Slip and Slide Drainage Report dated May 21, 2014.

Memorandum

Flex your power!
Be energy efficient!

To: MR. Steven Blair
Bridge Design Branch 13, Chief
Office of Bridge Design – West
Division of Engineering Services

Date: February 19, 2015

Attention: Sameh Hegazi

File: 04-MEN-128-PM 39.5
01-0B5201
Shoulder Failure

From: VAHID KHATAOKHOTAN
Transportation Engineer
Office of Geotechnical Design – West
Geotechnical Services
Division of Engineering Services

For HOOSHMAND NIKOUI
Chief, Branch A
Office of Geotechnical Design – West
Geotechnical Services
Division of Engineering Services

MATTHEW GAFFNEY MG
Engineering Geologist
Office of Geotechnical Design – West
Geotechnical Services
Division of Engineering Services

Subject : Geotechnical Design Report for Shoulder Failure at PM 39.5

This memorandum presents our geotechnical recommendations for the above referenced project. The recommendations are based on the results from subsurface explorations, previously prepared memorandums, and installed monitoring devices within the limits of the project.

BACKGROUND

Per your request in February 14, 2013, this office has investigated shoulder failure on Eastbound Route 128 at Postmiles 39.5 between cities of Yorkville and Booneville, in Mendecino County. At this location, I-128 is a two-lane highway built on fill within the problem area. This location, about 275 ft in total length, has suffered several slope failures in the past few years. Subsequent repairs, such as construction of a temporary Geosynthetic Reinforced Embankment (GRE) has kept the highway operational in this area.

SCOPE OF WORK

Work performed for preparing the foundation report includes field mapping and drilling a total of two bore holes and installing slope inclinometers/piezometers for monitoring. The current project consists of constructing earth retaining systems to permanently repair the slope failures at this location (see Figure 1).

SITE GEOLOGY

Regional Geology

The project site is located within the California Coast Ranges geomorphic province. This province formed after the Farllon Plate subducted under the North American Plate and the San Andreas Fault, along with a series of parallel faults, one of which is the Maacama fault zone, were formed.

Site Geology

At the project site, Quaternary alluvium deposits and Quaternary landslide deposits overlie the bedrock that consists of the Franciscan Complex to the north, and the Coastal Belt Franciscan formation to the south. The Coastal Belt Franciscan consists of marine sandstone, shale and conglomerate, whereas the Franciscan Complex is mélange terrain. These mélange deposits coincide with the Coastal Belt thrust fault that is mapped in close proximity. Geology is presented in Figure 2.

Existing Conditions

The site is on the western edge of a dormant landslide complex that is three miles long by one mile wide. This slide complex flowed in the southwest direction, towards SR 128 and bordered by Beebe Creek to the west and Dry Creek to the east. The current embankment failure is taking place at a Geogrid Reinforced Embankment (GRE). The GRE was placed to repair a landslide that was caused by Beebe Creek undercutting the slope destabilizing the roadway. The slide is approximately 160 feet wide. The slide flowed a distance of 100 feet and cross the creek. Within the slide's footprint there are a couple of smaller slides that are continuing to destabilize the slope.

Groundwater

At PM 39.5, groundwater was measured to be about 16.5 ft from the surface, in boring R-12-001 boring R-13-001 respectively. Groundwater has been measured in the past few years and it has been measured in both bore holes to be in the range of 16 to 17 ft below ground surface. However, groundwater levels are subject to fluctuations as seasonal precipitation in and around the creek.

Seismicity

Faulting and Seismicity

The controlling fault for the project is Maacama fault zone. Fault data is presented in Table 1, and fault location is presented in Figure 6. According to the Alquist-Priolo Earthquake Fault Zone Maps, there are no faults within the limits of the project site, so surface rupture is not an issue.

FAULT	Fault No.	Distance (Miles)	Fault Type	Maximum Magnitudee Earthquake	Peak Ground Acceleration (560 m/s shear wave velocity)
Maacama fault zone (North section)	66	10.3	Right Lateral Strike Slip	7.4	0.22g
San Andreas (North Coast Section)	80	16.4	Right Lateral Strike Slip	8.0	0.19g
Maacama fault zone (South section)	92	12.3	Right Lateral Strike Slip	7.4	0.19g
Probabilistic Model USGS Seismic Hazard Map(2008) 975 Year Return Period, calculated at 560m/s					0.46g

Table 1: Seismic Data

Seismic Hazards

Potential seismic hazards in such an active region include primary surface rupture, seismic fault creep, and the secondary effects due to strong ground shaking. The following describes the hazards that may be encountered during either surface rupture or ground shaking and possible mitigation procedures to use during design and/or construction.

Primary Seismic Hazards

Surface rupture and fault creep: There are no active faults that cross the project limits, therefore, fault rupture and fault creep are not considered to pose hazard to the project.

Ground shaking: The potential for strong ground shaking is low in the project area and will have minimal effects on design.

Secondary Seismic Hazards

Liquefaction: The subsurface sampling revealed that the soils foundation at the site have a low potential for liquefaction.

Flooding: Contact District 1 Hydraulics Branch to address the flooding potential at this location.

SUBSURFACE SOIL CONDITIONS

Subsurface investigations were performed at two different occasions, one in 2011 and the other in 2012. The subsurface investigation consisted of two vertical borings at the site (see Figure 5). In-situ Standard Penetration Test (SPT) blow counts were recorded at 5-foot intervals to evaluate the density/consistency of the on-site soils. In addition to soil, rock was encountered during drilling, thus coring methods were used.

At PM39.5, borehole R-12-001 was advanced to a depth of 60ft. The subsurface soil encountered in this boring consisted of loose silty sand up to about 5ft depth. Below the sand layer, a 25ft thick stiff sandy clay layer was encountered. The remainder of the borehole, from 30 to 60ft, moderately soft to moderately hard sandstone was observed. Other borehole, R-13-001, was advanced to a depth of 39ft. The subsurface soil encountered in this boring consisted of medium to very dense sandy layer present up to about 26ft depth. The remainder of the borehole, from 26 to 39ft, hard shale and sandstone were encountered. Log of Test Borings will be provided later.

FOUNDATION RECOMMENDATIONS

Based on the submitted plans and cross-sections, we recommend constructing a 270 ft long CIDH soldier pile without lagging between Station 91+20 and Station 93+90 (see Figure 5, Preliminary General Plan Submitted by Structure Design). The proposed wall should be designed as a 10 ft high wall with maximum of pile spacing 4 ft center to center. Office of Structures Design will determine exact location of the wall.

We recommend that the proposed soldier pile wall be designed for the following:

Earth Pressures

For *Active pressure* against the wall, use the following:

- For depth of 0 to 10 ft, internal friction angle ϕ =30°, C=1500 psf and soil moist unit weight γ= 120 lb/ft^3.
- For depth of 10 to 50 ft, internal friction angle ϕ=34°, C=0 and soil moist unit weight γ= 125 lb/ft^3.
- For earth pressure distribution, use a triangular pressure distribution.
- A rectangular pressure diagram from top of the wall to a depth of 10 ft for traffic surcharge equivalent to 2 ft of fill.
- The wall shall be capable of resisting an additional seismic uniform earth pressure estimated to be equal to 10H psf.

For *passive pressure* against the soldier piles, use the following input:

- From depth of 10 ft (dredge line) to 50 ft, internal friction angle ϕ =34°, C=0 and soil moist unit weight γ= 125 lb/ft^3.

CONSTRUCTION CONSIDERATIONS

- Because of the existing groundwater, the contractor should be prepared for dewatering during drilling holes for CIDH piles.
- Minor caving of the drilled holes is anticipated. Use of casing may also be needed due to sandy nature of the soil.
- The contractor may encounter difficulties during drilling for the soldier beam piles.

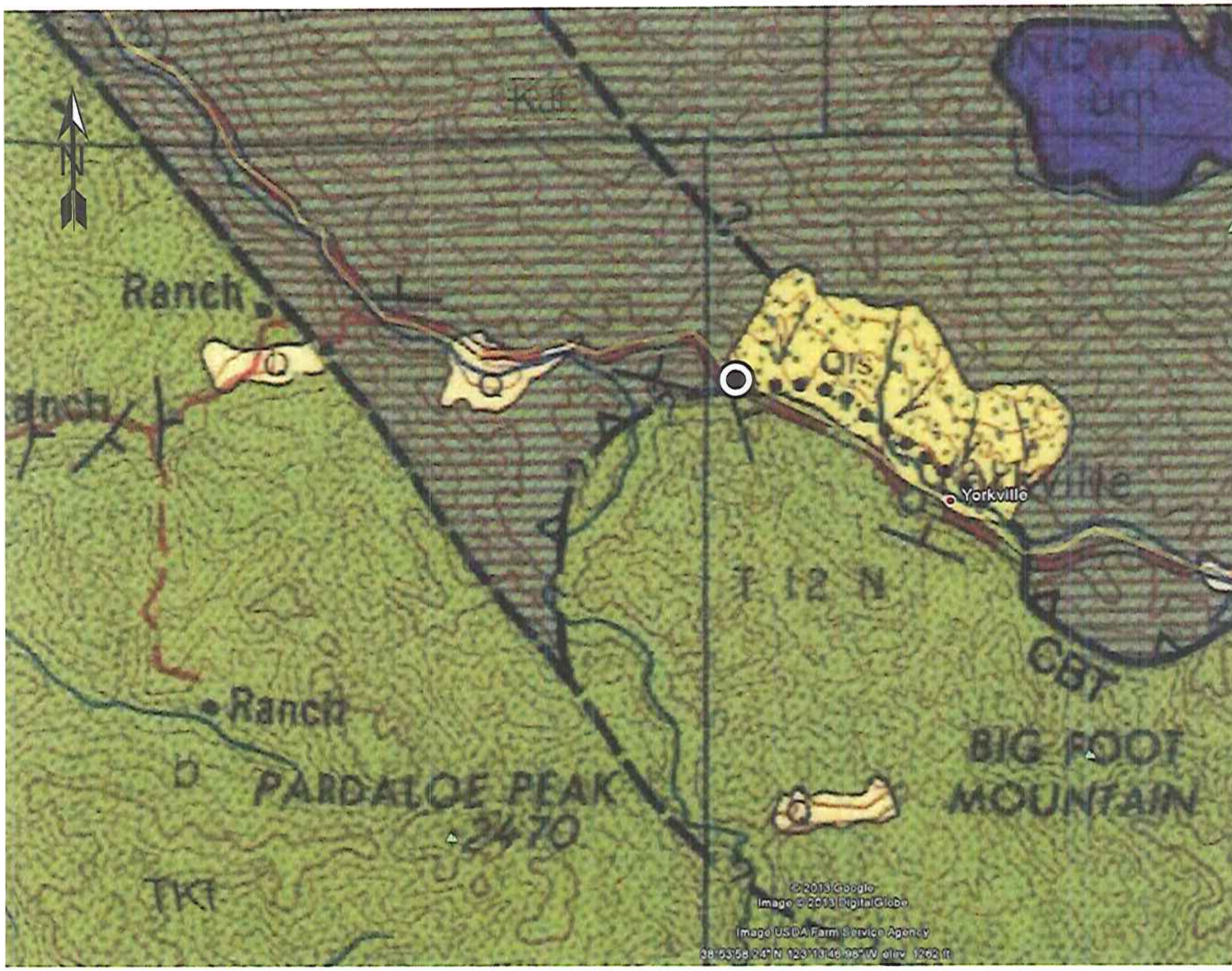
Any questions regarding the above recommendations should be directed to Vahid Khataokhotan at (510)622-1729, or Hooshmand Nikoui (510)286-4811, of the Office of Geotechnical Design-West.

c: TPokrywka, HNikoui, Daily File
Project Manager

REGISTERED PROFESSIONAL ENGINEER
VAHID KHATA-O-KHOTAN
No. 66980
Exp. 09/16
CIVIL
STATE OF CALIFORNIA

PROFESSIONAL GEOLOGIST
MATTHEW J. GAFFNEY
No. 8045
6/30/16
STATE OF CALIFORNIA

SCALE 0 — 200ft	Caltrans	DIVISION OF ENGINEERING SERVICES GEOTECHNICAL SERVICES GEOTECHNICAL DESIGN - WEST – BRANCH B	LOCATION MAP 04-MEN-128 0112000135 PM. 39.5 JUNE 2013 FIGURE 1



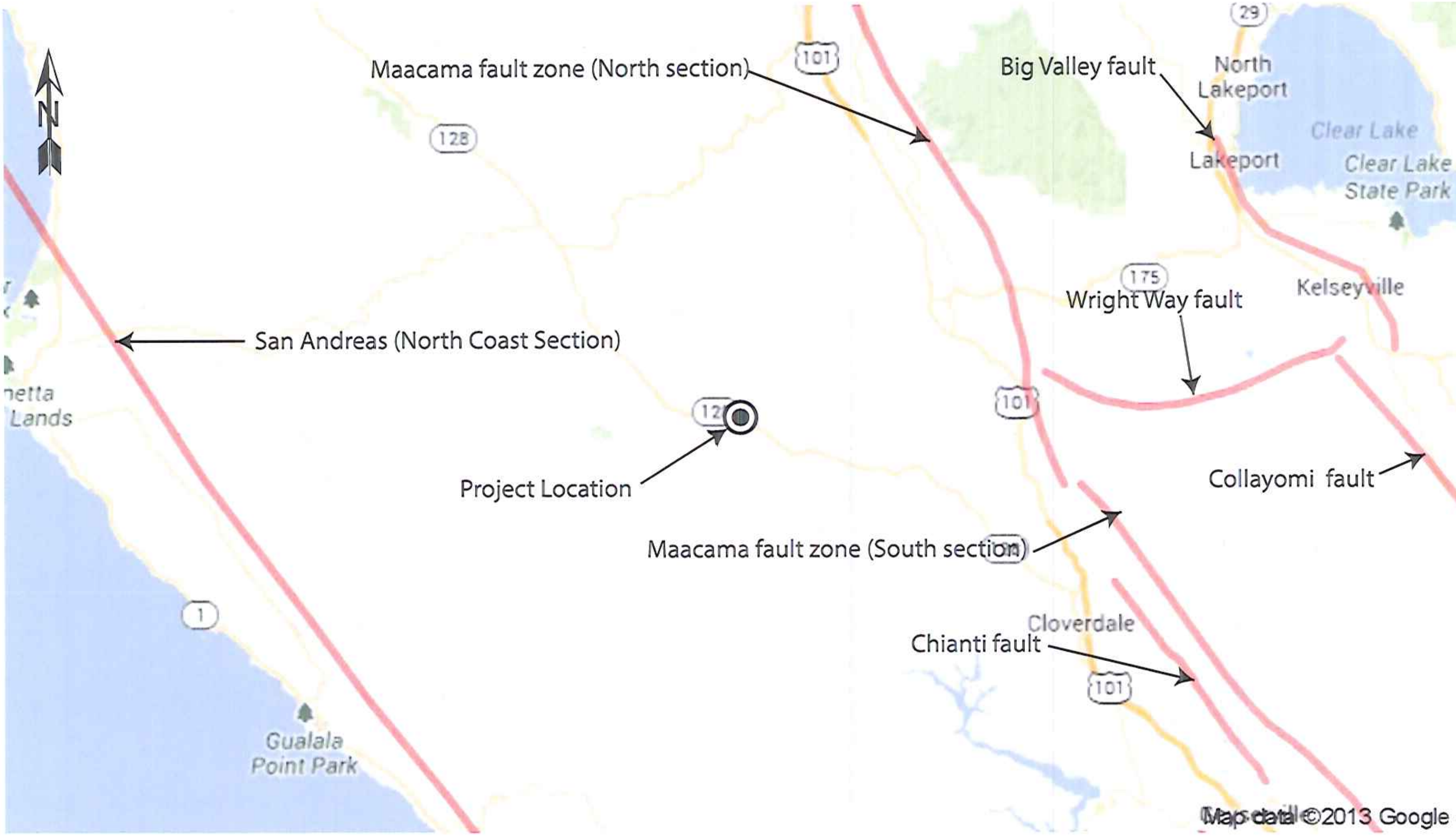
Explanation

Quaternary

Holocene

Symbol	Description
Q	Alluvium (Holocene)
Qls	Lanslide deposits (Holocene)
TKl	Coastal Belt Franciscan (Marine sandstone, shale and conglomerate)
KJl (ss, ch, gs, mg)	Franciscan Complex (Jurassic) melange terraine
um	Ultramfic rocks - Peridotite (Jurassic) - partly to completely serpentinized
◉	Project Location

SCALE 0 — 10 miles	Caltrans	DIVISION OF ENGINEERING SERVICES GEOTECHNICAL SERVICES GEOTECHNICAL DESIGN - WEST – BRANCH B	GEOLOGY MAP 04-MEN-128 0112000135 PM. 39.5 JUNE 2013 FIGURE 2



SCALE 0 — 10 miles		DIVISION OF ENGINEERING SERVICES GEOTECHNICAL SERVICES GEOTECHNICAL DESIGN - WEST – BRANCH B	REGIONAL FAULT MAP 04-MEN-128 0112000135 PM. 39.5 FEBRUARY 2015 FIGURE 3

SCALE 0 — 200ft	Caltrans	**DIVISION OF ENGINEERING SERVICES** GEOTECHNICAL SERVICES GEOTECHNICAL DESIGN - WEST – BRANCH B	**LOCATION MAP** **04-MEN-128** **0112000135** **PM. 39.5** **FEBRUARY 2015** **FIGURE 4**

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET No.	TOTAL SHEETS
01	Men	128			

REGISTERED CIVIL ENGINEER — X DATE

PLANS APPROVAL DATE

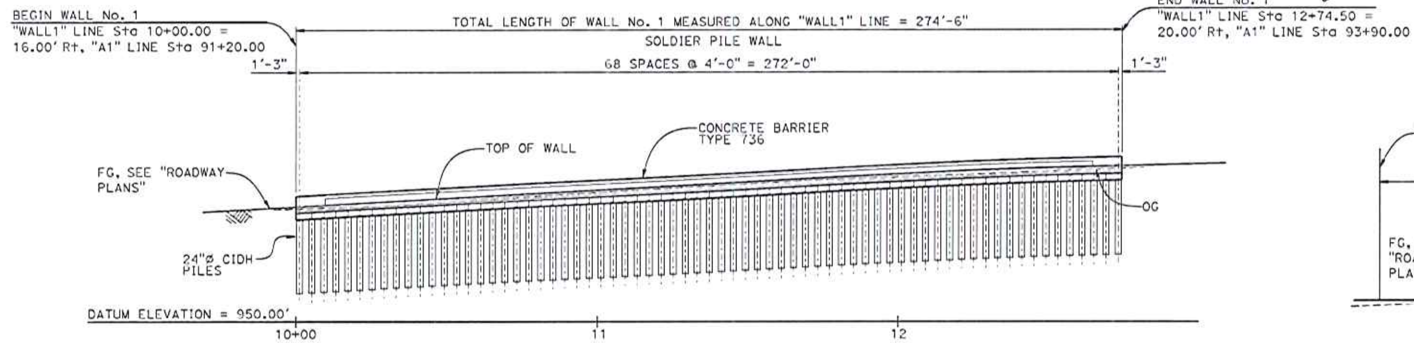
The State of California or its officers or agents shall not be responsible for the accuracy or completeness of scanned copies of this plan sheet.

REGISTERED PROFESSIONAL ENGINEER — SAMEH HEGAZI — No. C64899 — Exp. X — CIVIL — STATE OF CALIFORNIA

DRAFT COPY

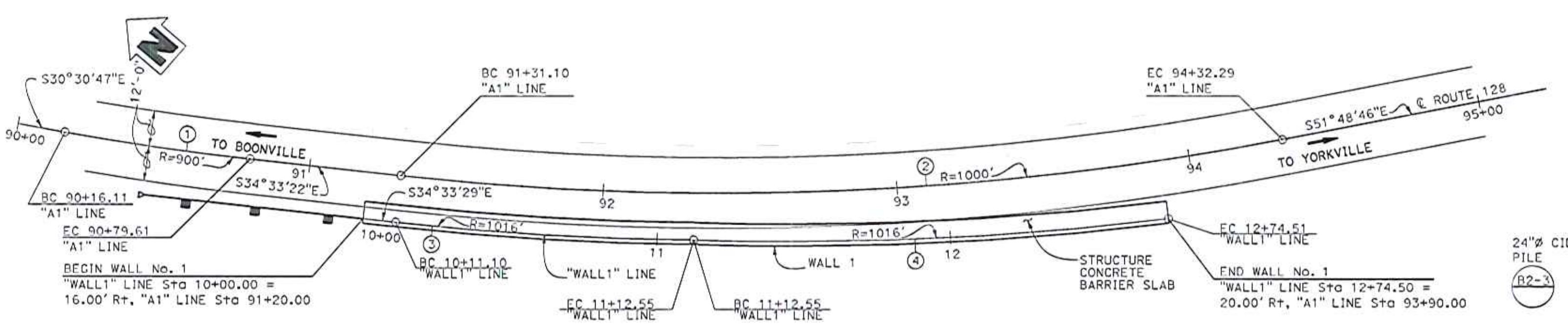
NOTES:

1. For Top of Wall and Finished Grade elevation, see "ROADWAY PLANS".
2. The Contractor shall field locate all utilities before drilling.



DEVELOPED ELEVATION

1" = 20'-0"

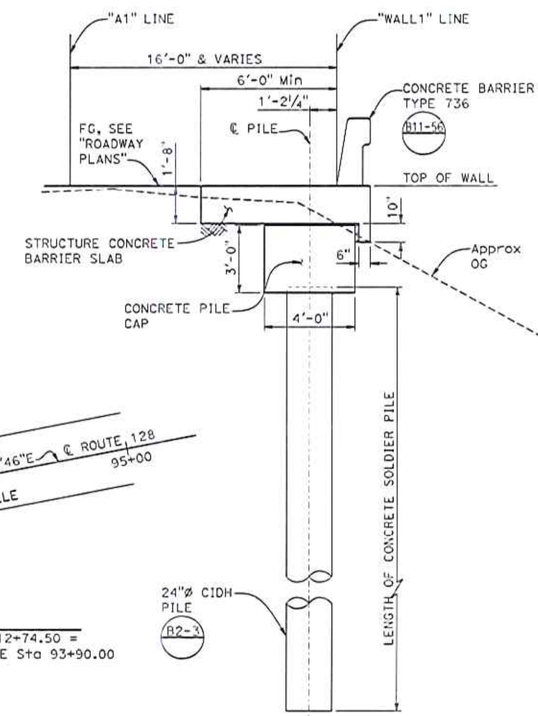


CURVE DATA

No.	R	Δ	T	L
"A1" ①	900.00'	04°02'33"	31.76'	63.50'
"A1" ②	1000.00'	17°15'25"	151.74'	301.19'
"WALL1" ③	1016.00'	05°43'16"	50.77'	101.45'
"WALL1" ④	1016.00'	09°08'02"	81.15'	161.97'

PLAN

1" = 20'-0"



TYPICAL SECTION

⅜" = 1'-0"

NOTE:
THE CONTRACTOR SHALL VERIFY ALL CONTROLLING FIELD DIMENSIONS BEFORE ORDERING OR FABRICATING ANY MATERIAL.

	BY	CHECKED		BY	CHECKED
DESIGN	Sameh Hegazi	Bichvan Thach	LOAD & RESISTANCE FACTOR DESIGN	LIVE LOADING: HL93 W/"LOW-BOY" PERMIT DESIGN VEHICLE	
DETAILS	Carlo Cancino/TK	X	LAYOUT	X	X
QUANTITIES	X	X	SPECIFICATIONS	X	PLANS AND SPECS COMPARED X

BRIAN MORI
DESIGN ENGINEER

STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

DIVISION OF ENGINEERING SERVICES
STRUCTURE DESIGN
DESIGN BRANCH 8

BRIDGE NO. 10E0033
POST MILE 39.5/39.8

BEEBE CREEK STORM DAMAGE SLOPE PROTECTION
BEEBE CREEK SOLDIER PILE WALL NO. 1
GENERAL PLAN

ORIGINAL SCALE IN INCHES FOR REDUCED PLANS 0 1 2 3

UNIT: 3593
PROJECT NUMBER & PHASE: 0112000135 1
CONTRACT NO.: 01-0B5201

DISREGARD PRINTS BEARING EARLIER REVISION DATES
REVISION DATES: 09-29-14, 09-29-14, 09-01-14
SHEET 1 OF X

STRUCTURES DESIGN GENERAL PLAN SHEET (ENGLISH) (REV.09-01-10)
FILE => 10e0033-a-gp-20140915-1.dgn
USERNAME => s134255 DATE PLOTTED => 15-SEP-2014 TIME PLOTTED => 15:21

Figure 5

Johnson, Nicki@DOT

From: Rob Scates <rscates@ci.healdsburg.ca.us>
Sent: Thursday, February 18, 2016 1:28 PM
To: Johnson, Nicki@DOT
Subject: RE: Water Availability for Caltrans Construction Project (01-0B520)

Follow Up Flag: Follow up
Flag Status: Flagged

Nicki,

I think your project would be able to use our non-potable recycled water. Although the distance is considerable, if the contractor decides to haul the water I will need to arrange a meeting with them to issue a permit prior to the use of recycled water. It is easy and free. Several guidelines would have to be followed, including no discharge to storm drains or creeks, no drinking, etc. The permit has all of the details. I would be able to provide as much water as you need, you would only be limited by how fast they could get it to you.
Please let me know if you need any further information.

Thank you,

ROB SCATES | Water/Wastewater Operations Superintendent
City of Healdsburg Municipal Utilities Department
401 Grove St. Healdsburg, CA 95448
707.431.3346 | rscates@ci.healdsburg.ca.us

From: Johnson, Nicki@DOT [mailto:Nicki.Johnson@dot.ca.gov]
Sent: Thursday, February 18, 2016 12:20 PM
To: Rob Scates
Subject: Water Availability for Caltrans Construction Project (01-0B520)

Rob,
Thank you for talking with me earlier in regards to the Route 128 project just north of Yorkville. If allowed by the city, the contractor may consider Healdsburg as a non-potable water source option for this project. Attached you'll find a letter with a project description, a location map, and water use estimate. Please feel free to contact me if you should have any questions.

Thank you,

Nicki Johnson
PLA #5213, CPESC, QSD/QSP
Caltrans - District 3
Landscape Architecture, Storm Water
(530) 741-4012

Johnson, Nicki@DOT

From:	Tammy Omundson <tomundson@ci.cloverdale.ca.us>
Sent:	Thursday, February 11, 2016 2:29 PM
To:	Johnson, Nicki@DOT
Subject:	RE: Water Availability for Caltrans Construction Project (01-0B520)

Hi Nicki,
I received your email and we are able to accommodate your request although it would be filled with potable water. We do not offer any non-potable water. We would be able to provide a hydrant meter however the nearest hydrant would be within Cloverdale city limits.
Please let me know if you have any further questions.
Thank you,
Tammy

CITY OF CLOVERDALE
Tammy Omundson
124 N. Cloverdale Blvd
Cloverdale, CA 95425
707.894.1714
tomundson@ci.cloverdale.ca.us

From: Johnson, Nicki@DOT [mailto:Nicki.Johnson@dot.ca.gov]
Sent: Wednesday, February 10, 2016 2:35 PM
To: Customer Service <customerservice@ci.cloverdale.ca.us>
Subject: Water Availability for Caltrans Construction Project (01-0B520)

Dear Ms. Omundson,

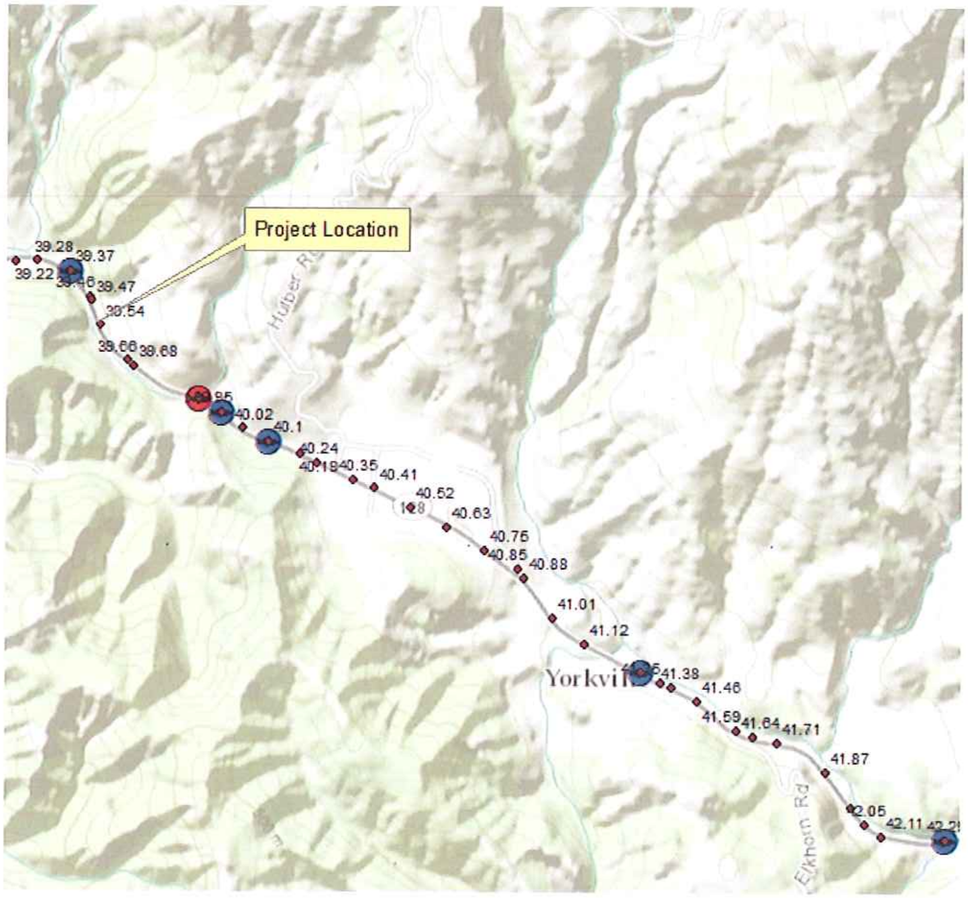
Caltrans will be advertising a contract to construct a project just north of Yorkville on State Route 128 and would like to know whether there will be a sufficient quantity of non-potable / potable water for use for construction. Attached is a letter with project information and a vicinity map. Please feel free to respond via email.

Thank you,

Nicki Johnson
PLA #5213, CPESC, QSD/QSP
Caltrans - District 3
Landscape Architecture, Storm Water
(530) 741-4012

Men 128 PM 39.8/39.8
Beebe Creek Slip and Slide
Drainage Report
01-0B520
5/21/2014

DRAINAGE REPORT



In Mendocino County on Route 128
Between PM 39.5 and 39.8
6/13/14

Men 128 PM 39.8/39.8
Beebe Creek Slip and Slide
Drainage Report
01-0B520
5/21/2014

This Drainage Report has been prepared under the direction of the following registered civil engineer. The registered civil engineer attests to the technical information contained herein and the engineering data upon which recommendations, conclusions, and decisions are based.

Glenn Hurlburt
REGISTERED CIVIL ENGINEER

6/12/2014
DATE

PROJECT DESCRIPTION

This project proposes to stabilize the roadway segment at two sections along Highway 128 in Mendocino County at PM 39.5 and PM 39.8 that experience roadway failure by constructing a soldier pile wall and Drilled Pier Tie-back/ Slope Stressing. The project also includes some drainage work, roadway reconstruction, installing a safety barrier, and placing thermoplastic traffic stripes.

CLIMATOLOGICAL INFORMATION

The climatological station with annual precipitation information maintained by the Western Regional Climate Center is Boonville HMS, California (040973). The average rainfall for this area is estimated at 38" per year.

HYDROLOGY/HYDRAULICS

There are 3 drainage facilities within the project limits, but work will only be performed on the 24" culvert at PM 39.54. None of the culverts fall within the proposed wall limits. Hydraulic calculations were performed for the culvert at PM 39.54 which drains approximately 15 acres and are attached.

FLOODPLAIN INFORMATION

The proposed project lies approximately 1.2 miles west of Yorkville, on Route 128 in Mendocino County. The project limits lie within Federal Emergency Management Agency (FEMA) mapped area and is shown on the 06045C1850F Flood Insurance Rate Map (FIRMette, Attached Figure 1). The project location is designated as Zone D which is defined as, "Areas where there are possible but undetermined flood hazards". The proposed construction activities are not expected to have any significant adverse floodplain impacts.

STORM WATER

A separate Storm Water Data Report (Short Form) has been completed for the project. Temporary Construction BMPs will be deployed under a contractor prepared WPCP.
Bees Item that will be part of the contract includes:

- Construction Site Management
- Prepare Water Pollution Control Program
- Prepare Storm Water Pollution Prevention Plan
- Rain Event Action Plan
- Storm Water Annual Report

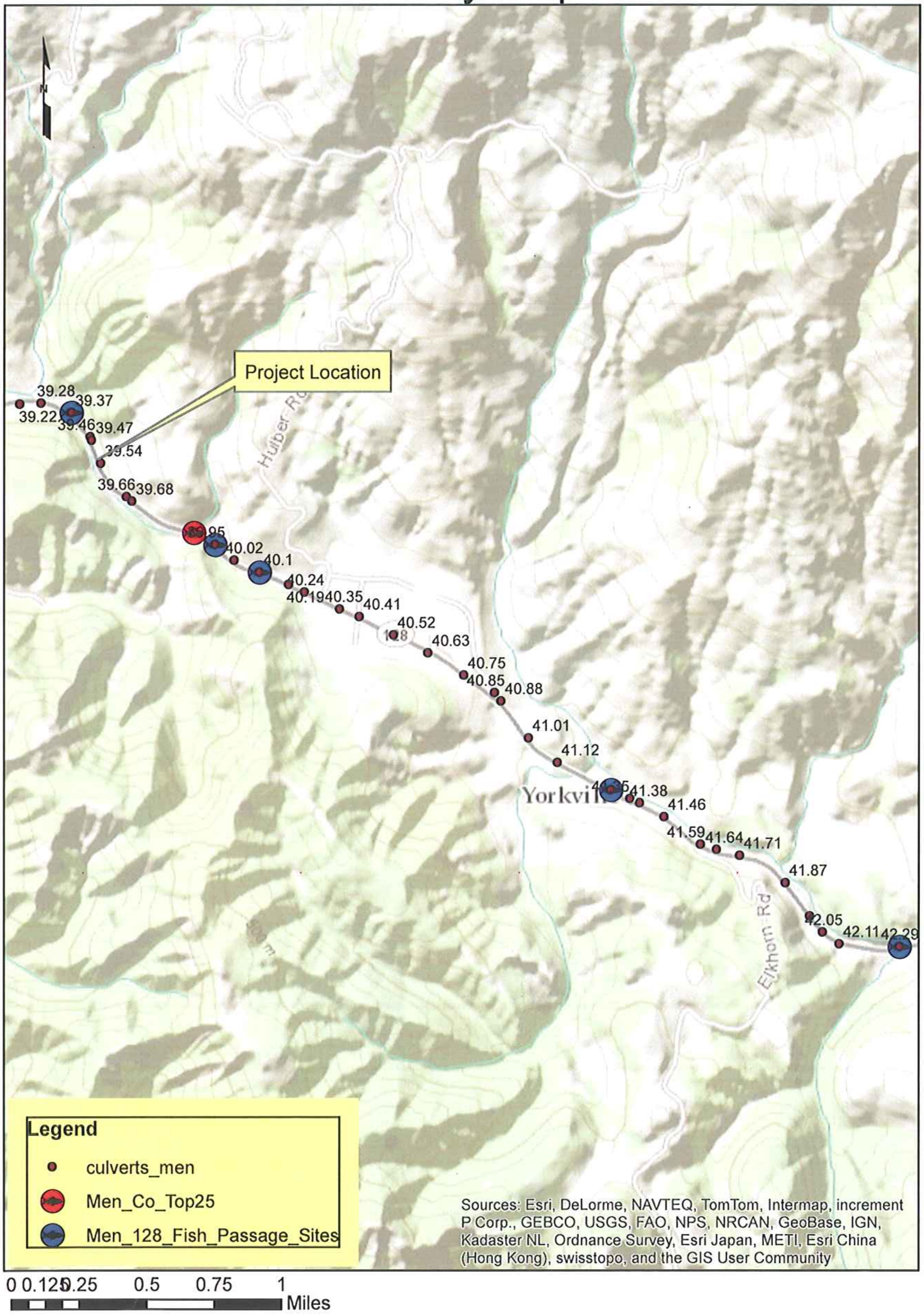
CONCLUSIONS AND RECOMMENDATIONS

Calculations indicate that the existing 24" cross culvert is adequate in size for passing the 100yr storm but is in poor condition. It is recommended to replace the culvert with a 24" diameter APC and place RSP at the outlet.

Attachments:
- Vicinity Map
- Drainage Plan Sheets
- FERS
- Drainage Calculations

MEN128 PM 39.5/39.
Beebe Creek Slip and Slid
01-0B52

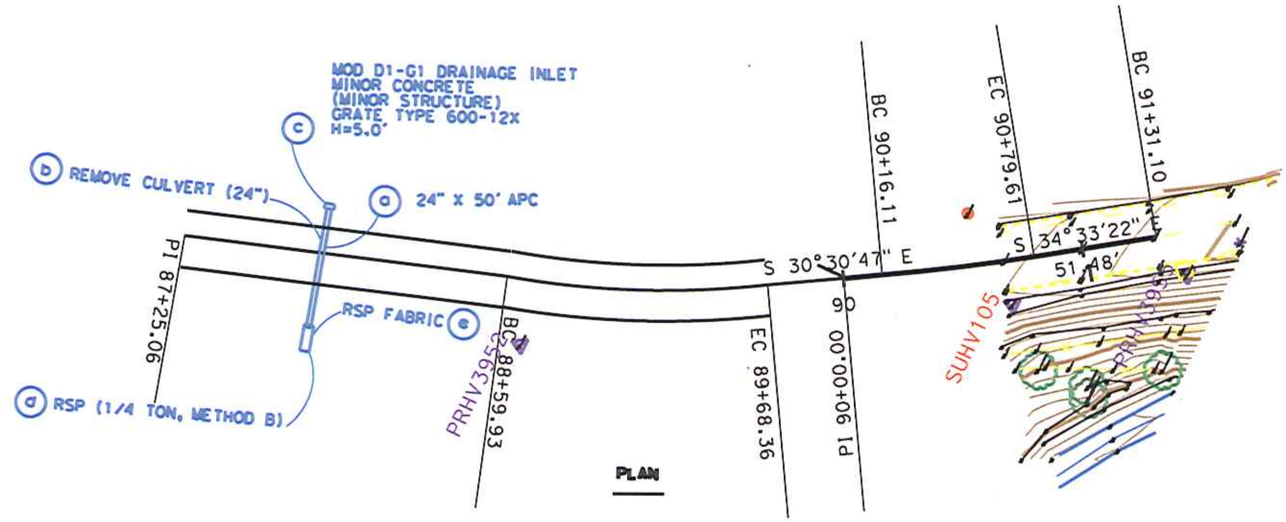
Vicinity Map



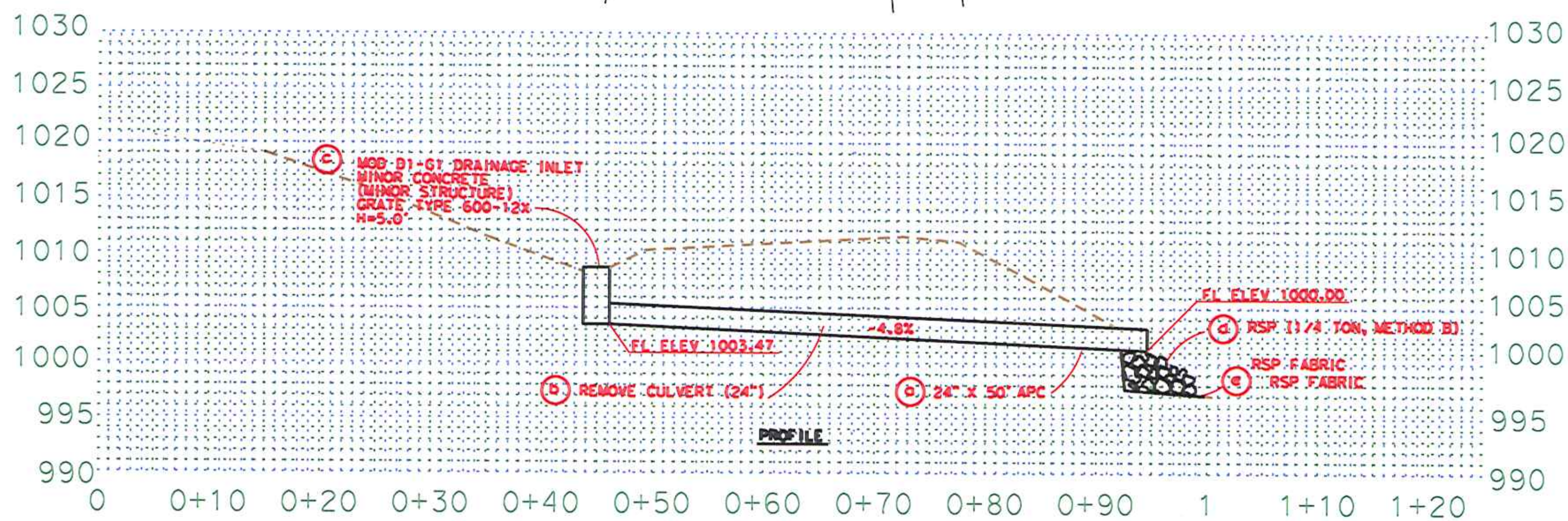
DRAINAGE SYSTEM No. 1

"A" 87+36.52 PM 39.54

SCALE: 1"=50'



PLAN



PROFILE

DIST	COUNTY	ROUTE	POST MILES TOTAL PROJECT	SHEET NO.	TOTAL SHEETS

REGISTERED CIVIL ENGINEER 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.

DRAFT

REVISED BY | DATE REVISED | CALCULATED-DESIGNED BY | CHECKED BY | FUNCTIONAL SUPERVISOR

STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION

BORDER LAST REVISED 7/2/2010 | USERNAME => USER | DGN FILE => REQUEST | RELATIVE BORDER SCALE IS IN INCHES 0 1 2 3 | UNIT 0000 | PROJECT NUMBER & PHASE 00000000001

DATE PLOTTED => DATE | TIME PLOTTED => TIME | LAST REVISION 00-00-00

FLOODPLAIN EVALUATION REPORT SUMMARY

Dist. 01 **Co.** Men **Rte.** 128 **P.M.** 39.5/39.8
Project No.: 01-0B520 **Bridge No.** N/A

Limits:
This project proposes to stabilize the roadway segment at two sections along Highway 128 in Mendocino County at PM 39.5 and PM 39.8 that experience roadway failure by constructing soldier pile wall and Drilled Pier Tie-back/ Slope Stressing. It includes some drainage work, roadway work, safety barrier, and thermoplastic traffic stripes.

Floodplain Description:
The proposed project lies approximately 1.2 miles west of Yorkville, on Route 128 in Mendocino County. The project limits lie within Federal Emergency Management Agency (FEMA) mapped area and is shown on the 06045C1850F Flood Insurance Rate Map (FIRMette, Attached Figure 1). The project location is designated as Zone D which is defined as, "Areas where there are possible but undetermined flood hazards". The proposed construction activities are not expected to have any significant adverse floodplain impacts.

		No	Yes
1.	Is the proposed action a longitudinal encroachment of the base floodplain?	x	
2.	Are the risks associated with the implementation of the proposed action significant?	x	
3.	Will the proposed action support probable incompatible floodplain development?	x	
4.	Are there any significant impacts on natural and beneficial floodplain values?	x	
5.	Routine construction procedures are required to minimize impacts on the floodplain. Are there any special mitigation measures necessary to minimize impacts or restore and preserve natural and beneficial floodplain values? If yes, explain.	x	
6.	Does the proposed action constitute a significant floodplain encroachment as defined in 23 CFR, Section 650.105(q).	x	
7.	Are Floodplain Hydraulic Studies that document the above answers on file? If not explain.		x

PREPARED BY:

[signature]
Signature - Dist. Hydraulic Engineer

6/12/2014
Date

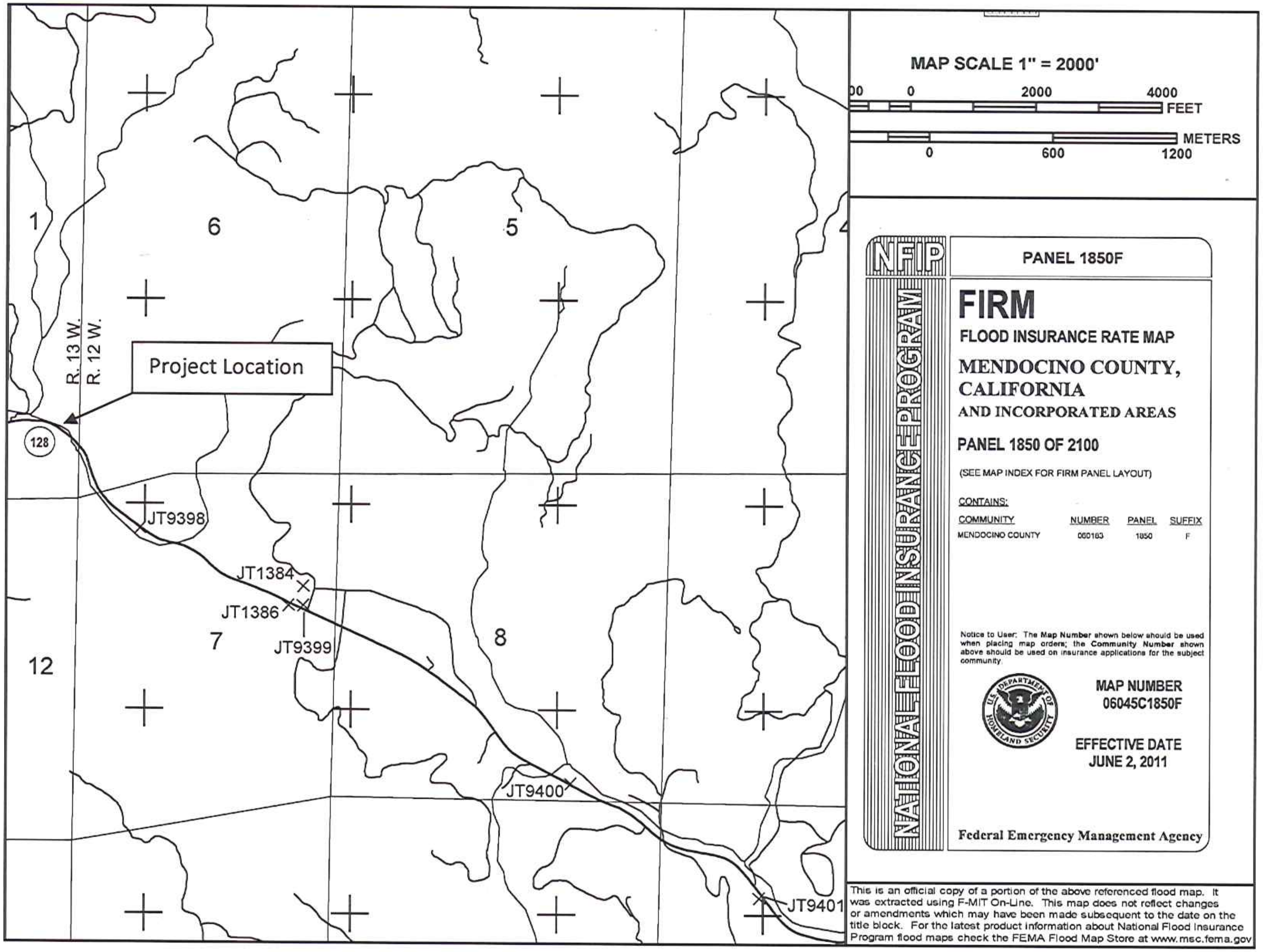
REGISTERED PROFESSIONAL ENGINEER
GLENN G. HURLBURT
68303
EXP. 5/30/15
CIVIL
STATE OF CALIFORNIA

Signature - Dist. Environmental Branch Chief

Date

Signature - Dist. Project Engineer

Date



NFIP

NATIONAL FLOOD INSURANCE PROGRAM

PANEL 1850F

FIRM

FLOOD INSURANCE RATE MAP

MENDOCINO COUNTY, CALIFORNIA

AND INCORPORATED AREAS

PANEL 1850 OF 2100

(SEE MAP INDEX FOR FIRM PANEL LAYOUT)

CONTAINS:

COMMUNITY	NUMBER	PANEL	SUFFIX
MENDOCINO COUNTY	060183	1850	F

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

MAP NUMBER
06045C1850F

EFFECTIVE DATE
JUNE 2, 2011

Federal Emergency Management Agency

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

Culvert Calculator for Inlet Control with Pipe Flow Depth and Velocity

Calculated by: Glenn Hurlburt
Date: 22-May-14

Men-128, PM 39.54, Beebe Cr. Storm Damage, EA 01-0B520

Inlet Control Calculations (Form 1 of the Unsubmerged Condition Equation)			**Pipe Hydraulic Calculations**		
	D = 24 in			S = 5.00%	
	RCP - groove end with headwall:	CMP with square headwall:		RCP - groove end with headwall:	CMP with square headwall:
For HW/D =	*1.00*		n_{full}:	0.024	0.010
HW =	*2.0 ft*		Q_{max}:	28.8 cfs	69.1 cfs
approx. Q =	*13.3 cfs*	*12.7 cfs*	V_{max}:	9.4 fps	22.4 fps
Q_{10} =	12.53 cfs			12.53 cfs	12.53 cfs
$Q/(A*D^{0.5})$ =	2.82				
Vc = 5.9 fps	Yc = 1.27 ft		%Full:	54%	34%
			Yn:	1.07 ft	0.67 ft
HW/D =	0.90	0.95	V:	7.3 fps	13.5 fps
HW =	1.80 ft	1.89 ft	n_{adj}:	0.0296	0.0128
Q_{25} =	16.57 cfs			16.57 cfs	16.57 cfs
$Q/(A*D^{0.5})$ =	3.73				
Vc = 6.7 fps	Yc = 1.47 ft		%Full:	63%	39%
			Yn:	1.25 ft	0.78 ft
HW/D =	1.13	1.21	V:	8.0 fps	14.6 fps
HW =	2.26 ft	2.41 ft	n_{adj}:	0.0285	0.0127
Q_{50} =	20.40 cfs			20.40 cfs	20.40 cfs
$Q/(A*D^{0.5})$ =	4.59				
Vc = 7.5 fps	Yc = 1.62 ft		%Full:	71%	43%
			Yn:	1.42 ft	0.87 ft
HW/D =	1.35	1.49	V:	8.6 fps	15.6 fps
HW =	2.71 ft	2.98 ft	n_{adj}:	0.0275	0.0126
Q_{100} =	23.61 cfs			23.61 cfs	23.61 cfs
$Q/(A*D^{0.5})$ =	5.31				
Vc = 8.2 fps	Yc = 1.72 ft		%Full:	78%	47%
			Yn:	1.56 ft	0.94 ft
HW/D =	1.56	1.76	V:	9.0 fps	16.2 fps
HW =	3.13 ft	3.52 ft	n_{adj}:	0.0266	0.0126

Constants: (Form 1)					
	RCP - groove end with headwall:	K = 0.0018	M = 2	c = 0.0292	Y = 0.74
	CMP with square headwall:	K = 0.0078	M = 2	c = 0.0379	Y = 0.69

Spreadsheet by: Fernando Manzanera, Caltrans District 1 Hydraulics, April 2014

Notes:
- This sheet calculates: the approximate discharges for the HW/D =1 condition (HDM 821.3) for Q_{10}. Also calculates the hydraulic parameters with the Manning's equation for partial flow for four different discharges and two different pipes.
- Uses the equations for submerged and unsubmerged (Form 1) conditions. At the transition, it uses the unsubmerged equation up to $Q/AD^{0.5}$ = 3.25, the submerged when it's over 3.85, and an interpolation when in-between.
- Uses the n_{full} partial flow correction for normal depth in pipes (T.R.Camp, 1946), Culvertmaster does not adjust this.
- The maximum discharge occurs at 96.4% full, and the maximum water velocity occurs at 92.0% full.

References:
- HDS-5, Appendix A, Constants for Inlet Control Equations for Charts 1 & 2, April 2012.
- Camp, T.R., "Design of Sewers to Facilitate Flow", Sewage Works Journal, 1946.
- Steel, E.W. & McGhee, T.J., *Water Supply and Sewerage* , McGraw-Hill Book Company, 1979.

BOONVILLE HMS, CALIFORNIA (040973)

Period of Record Monthly Climate Summary

Period of Record : 5/ 1/1959 to 6/30/1977

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)					Insuff icient Data								
Average Min. Temperature (F)					Insuff icient Data								
Average Total Precipitation (in.)	8.14	5.16	5.34	2.58	0.62	0.16	0.05	0.26	0.38	2.16	5.55	7.49	37.88
Average Total SnowFall (in.)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Percent of possible observations for period of record.
Max. Temp.: 0.6% Min. Temp.: 0.6% Precipitation: 99% Snowfall: 98.4% Snow Depth: 98.4%
Check Station Metadata or Metadata graphics for more detail about data completeness.

Western Regional Climate Center, wrcc@dri.edu

MEN 128 PM 39.54

RATIONAL METHOD MODEL WITH KINEMATIC WAVE, SHALLOW CONCENTRATED FLOW, AND ROUTING CAPABILITIES

PREPARED BY: Glenn Hurlburt
DATE: May 22, 2014

DESCRIPTION: MEN 128 STORM DAMAGE PM 39.54 10 YEAR BEEBE CR.

COORDINATES: 38.9122 -123.24 ELEVATION: 957

IDF Curves Parameters:

TR	RP(TR)	E(TR)
1	3.5585	-0.459
2	4.3846	-0.458
5	5.4466	-0.46
10	6.2465	-0.459
25	7.2761	-0.459
50	8.0605	-0.46
100	8.7787	-0.459
200	9.5193	-0.459
500	10.4660	-0.459
1000	11.1560	-0.458

Equations adjusted from the NOAA Atlas 14 Volume 6 for the 0 to 1 hour durations.

The IDF equation used is: **$Int = RP * Dur^E$**, where RP and E are regression analysis parameters.

Return Period for this Rational Method Calculation (years): 10

Minimum time of concentration to use (5 or 10 minutes): 5

INITIAL AREA: A-1 *MEN 128 PM 39.54*

	elevation (ft)				
Upstream node:	1289	Length L (ft):	50	C FACTOR (unadjusted for Tr or S):	0.2
		Initial Area (acres):	0.1	**C FACTOR (final):**	**0.44**
Downstream node:	1279	Overland Flow Roughness Coef. (*N*):	0.6	Slope S (ft/ft):	0.200

This module follows the Recursive Kinematic Wave Equation methodology to determine the time of concentration.

		At downstream node: I(in/hr) =	2.38
		Effective area (acres) =	0.10
Composite parameter $N * L/S^{0.5}$ should be < 100:	7	Tc(min) =	8.20
Average velocity through subarea (fps) =	0.10	**Qt(cfs) =**	**0.10**
Total area (acres) =	**0.10**	Ratio Q/At =	1.05

SHALLOW AREA: A-2 *MEN 128 PM 39.54*

	elevation (ft)				
Upstream node:	1279	Length L (ft):	100	C FACTOR (unadjusted for Tr nor S):	0.2
		Subarea Area (ac):	0.2	**C FACTOR (final):**	**0.44**
Downstream node:	1259	Intercept Coefficient k =	0.08	Slope S (ft/ft):	0.200
				Subarea time of concentration tc (min):	1.42

This module calculates the time of concentraton for the Shallow Concentrated Flow with the Upland Method.

		At downstream node: I(in/hr) =	2.21
		Accum. effective area (acres) =	0.30
		Tc(min) =	9.62
Average velocity through subarea (fps) =	1.17	**Qt(cfs) =**	**0.30**
Accumulated total area (acres) =	**0.30**	Ratio Q/At =	1.00

ROUTING MODULE: A-3 *MEN 128 PM 39.54*

	elevation				
Upstream node:	1259	Length L (ft):	1500	C FACTOR (unadjusted for Tr nor S):	0.2
		Subarea Area (ac):	14.5	**C FACTOR (final):**	**0.44**
Downstream node:	960			Slope S (ft/ft):	0.199

Corresponding subarea discharge Q=CIA: 12.23 — Subarea time of concentration tc (min): 3.24

Average Q to route through the subarea: **6.41** ← *Iterate until they are equal* — Overall basin slope: 0.199

At downstream node: I(in/hr) = 1.93

Type of conveyance: Trapezoidal Channel — Accum. effective area (acres) = 14.80

n = 0.035, b = 2 ft, z = 1.5, Dn = 0.33 ft, T = 3, Fr = 2.58 — Tc(min) = 12.86

V (fps) = 7.72, S (ft/ft) = 0.199, Q (cfs) = 6.41 — **Qt(cfs) = 12.53**

Accumulated total area (acres) = 14.8 — Ratio Q/At = 0.85

Program prepared by Fernando Manzanera, Caltrans District 1 Hydraulics, 11/03/2011

MEN 128 PM 39.54

RATIONAL METHOD MODEL WITH KINEMATIC WAVE, SHALLOW CONCENTRATED FLOW, AND ROUTING CAPABILITIES

PREPARED BY: Glenn Hurlburt
DATE: May 22, 2014

DESCRIPTION: MEN 128 STORM DAMAGE PM 39.54 10 YEAR BEEBE CR.

COORDINATES: 38.9122 -123.24 ELEVATION: 957

IDF Curves Parameters:

Equations adjusted from the NOAA Atlas 14 Volume 6 for the 0 to 1 hour durations.

TR	RP(TR)	E(TR)
1	3.5585	-0.459
2	4.3846	-0.458
5	5.4466	-0.46
10	6.2465	-0.459
25	7.2761	-0.459
50	8.0605	-0.46
100	8.7787	-0.459
200	9.5193	-0.459
500	10.4660	-0.459
1000	11.1560	-0.458

The IDF equation used is: **Int = RP * Dur ^{E}**, where RP and E are regression analysis parameters.

Return Period for this Rational Method Calculation (years): 25

Minimum time of concentration to use (5 or 10 minutes): 5

INITIAL AREA: A-1 — *MEN 128 PM 39.54*

elevation (ft)
Upstream node: 1289
Downstream node: 1279

Length L (ft): 50
Initial Area (acres): 0.1
Overland Flow Roughness Coef. (*N*): 0.6

C FACTOR (unadjusted for Tr or S): 0.2
C FACTOR (final): 0.48
Slope S (ft/ft): 0.200

This module follows the Recursive Kinematic Wave Equation methodology to determine the time of concentration.

Composite parameter $N*L/S^{0.5}$ should be < 100: 7
Average velocity through subarea (fps) = 0.11
Total area (acres) = 0.10

At downstream node: I(in/hr) = 2.87
Effective area (acres) = 0.10
Tc(min) = 7.61
Qt(cfs) = 0.14
Ratio Q/At = 1.39

SHALLOW AREA: A-2 — *MEN 128 PM 39.54*

elevation (ft)
Upstream node: 1279
Downstream node: 1259

Length L (ft): 100
Subarea Area (ac): 0.2
Intercept Coefficient k = 0.08

C FACTOR (unadjusted for Tr nor S): 0.2
C FACTOR (final): 0.48
Slope S (ft/ft): 0.200
Subarea time of concentration tc (min): 1.42

This module calculates the time of concentraton for the Shallow Concentrated Flow with the Upland Method.

At downstream node: I(in/hr) = 2.65
Accum. effective area (acres) = 0.30
Tc(min) = 9.03
Qt(cfs) = 0.40
Ratio Q/At = 1.32

Average velocity through subarea (fps) = 1.17
Accumulated total area (acres) = 0.30

ROUTING MODULE: A-3 — *MEN 128 PM 39.54*

elevation
Upstream node: 1259
Downstream node: 960

Length L (ft): 1500
Subarea Area (ac): 14.5

C FACTOR (unadjusted for Tr nor S): 0.2
C FACTOR (final): 0.48
Slope S (ft/ft): 0.199
Subarea time of concentration tc (min): 2.97
Overall basin slope: 0.199
At downstream node: I(in/hr) = 2.33
Accum. effective area (acres) = 14.80
Tc(min) = 12.00
Qt(cfs) = 16.57
Ratio Q/At = 1.12

Corresponding subarea discharge Q=CIA: 16.17
Average Q to route through the subarea: **8.48** ← *Iterate until they are equal*

Type of conveyance: Trapezoidal Channel
n = 0.035, b = 2 ft, z = 1.5, Dn = 0.39 ft, T = 3.17, Fr = 2.63
V (fps) = 8.42, S (ft/ft) = 0.199, Q (cfs) = 8.48

Accumulated total area (acres) = 14.8

Program prepared by Fernando Manzanera, Caltrans District 1 Hydraulics, 11/03/2011

MEN 128 PM 39.54

RATIONAL METHOD MODEL WITH KINEMATIC WAVE, SHALLOW CONCENTRATED FLOW, AND ROUTING CAPABILITIES

PREPARED BY: Glenn Hurlburt
DATE: May 22, 2014

DESCRIPTION: MEN 128 STORM DAMAGE PM 39.54 10 YEAR BEEBE CR.

COORDINATES: 38.9122 -123.24 ELEVATION: 957

IDF Curves Parameters:

TR	RP(TR)	E(TR)
1	3.5585	-0.459
2	4.3846	-0.458
5	5.4466	-0.46
10	6.2465	-0.459
25	7.2761	-0.459
50	8.0605	-0.46
100	8.7787	-0.459
200	9.5193	-0.459
500	10.4660	-0.459
1000	11.1560	-0.458

Equations adjusted from the NOAA Atlas 14 Volume 6 for the 0 to 1 hour durations.

The IDF equation used is: **Int = RP * Dur^{E}**, where RP and E are regression analysis parameters.

Return Period for this Rational Method Calculation (years): 50

Minimum time of concentration to use (5 or 10 minutes): 5

INITIAL AREA: A-1 — *MEN 128 PM 39.54*

	elevation (ft)				
		Length L (ft):	50	C FACTOR (unadjusted for Tr or S):	0.2
Upstream node:	1289	Initial Area (acres):	0.1	**C FACTOR (final):**	**0.53**
Downstream node:	1279	Overland Flow Roughness Coef. (N):	0.6	Slope S (ft/ft):	0.200

This module follows the Recursive Kinematic Wave Equation methodology to determine the time of concentration.

		At downstream node: I(in/hr) =	3.24
		Effective area (acres) =	0.10
Composite parameter $N*L/S^{0.5}$ should be < 100:	7	Tc(min) =	7.25
Average velocity through subarea (fps) =	0.11	**Qt(cfs) =**	**0.17**
Total area (acres) =	**0.10**	Ratio Q/At =	1.71

SHALLOW AREA: A-2 — *MEN 128 PM 39.54*

	elevation (ft)				
		Length L (ft):	100	C FACTOR (unadjusted for Tr nor S):	0.2
Upstream node:	1279	Subarea Area (ac):	0.2	**C FACTOR (final):**	**0.53**
Downstream node:	1259	Intercept Coefficient k =	0.08	Slope S (ft/ft):	0.200
				Subarea time of concentration tc (min):	1.42

This module calculates the time of concentraton for the Shallow Concentrated Flow with the Upland Method.

		At downstream node: I(in/hr) =	2.98
		Accum. effective area (acres) =	0.30
		Tc(min) =	8.67
Average velocity through subarea (fps) =	1.17	**Qt(cfs) =**	**0.49**
Accumulated total area (acres) =	**0.30**	Ratio Q/At =	1.62

ROUTING MODULE: A-3 — *MEN 128 PM 39.54*

	elevation				
		Length L (ft):	1500	C FACTOR (unadjusted for Tr nor S):	0.2
Upstream node:	1259	Subarea Area (ac):	14.5	**C FACTOR (final):**	**0.52**
Downstream node:	960			Slope S (ft/ft):	0.199

Corresponding subarea discharge Q=CIA: 19.92

Average Q to route through the subarea: **10.45** ← *Iterate until they are equal*

Type of conveyance: Trapezoidal Channel

n = 0.035, b = 2 ft, z = 1.5, Dn = 0.44 ft, T = 3.31, Fr = 2.67

V (fps) = 8.97, S (ft/ft) = 0.199, Q (cfs) = 10.44

Accumulated total area (acres) = **14.8**

Subarea time of concentration tc (min):	2.79
Overall basin slope:	0.199
At downstream node: I(in/hr) =	2.63
Accum. effective area (acres) =	14.80
Tc(min) =	11.46
Qt(cfs) =	**20.40**
Ratio Q/At =	1.38

Program prepared by Fernando Manzanera, Caltrans District 1 Hydraulics, 11/03/2011

MEN 128 PM 39.54

RATIONAL METHOD MODEL WITH KINEMATIC WAVE, SHALLOW CONCENTRATED FLOW, AND ROUTING CAPABILITIES

PREPARED BY: Glenn Hurlburt
DATE: May 22, 2014

DESCRIPTION: MEN 128 STORM DAMAGE PM 39.54 10 YEAR BEEBE CR.

COORDINATES: 38.9122 -123.24 ELEVATION: 957

IDF Curves Parameters:

TR	RP(TR)	E(TR)
1	3.5585	-0.459
2	4.3846	-0.458
5	5.4466	-0.46
10	6.2465	-0.459
25	7.2761	-0.459
50	8.0605	-0.46
100	8.7787	-0.459
200	9.5193	-0.459
500	10.4660	-0.459
1000	11.1560	-0.458

Equations adjusted from the NOAA Atlas 14 Volume 6 for the 0 to 1 hour durations.

The IDF equation used is: **Int = RP * Dur ^{E}**, where RP and E are regression analysis parameters.

Return Period for this Rational Method Calculation (years): 100

Minimum time of concentration to use (5 or 10 minutes): 5

INITIAL AREA: A-1 *MEN 128 PM 39.54*

	elevation (ft)				
Upstream node:	1289	Length L (ft):	50	C FACTOR (unadjusted for Tr or S):	0.2
Downstream node:	1279	Initial Area (acres):	0.1	**C FACTOR (final):**	**0.55**
		Overland Flow Roughness Coef. (N):	0.6	Slope S (ft/ft):	0.200

This module follows the Recursive Kinematic Wave Equation methodology to determine the time of concentration.

		At downstream node: I(in/hr) =	3.61
		Effective area (acres) =	0.10
Composite parameter N*L/S$^{0.5}$ should be < 100:	7	Tc(min) =	6.94
Average velocity through subarea (fps) =	0.12	**Qt(cfs) =**	**0.20**
Total area (acres) =	**0.10**	Ratio Q/At =	1.98

SHALLOW AREA: A-2 *MEN 128 PM 39.54*

	elevation (ft)				
Upstream node:	1279	Length L (ft):	100	C FACTOR (unadjusted for Tr nor S):	0.2
Downstream node:	1259	Subarea Area (ac):	0.2	**C FACTOR (final):**	**0.55**
		Intercept Coefficient k =	0.08	Slope S (ft/ft):	0.200
				Subarea time of concentration tc (min):	1.42

This module calculates the time of concentraton for the Shallow Concentrated Flow with the Upland Method.

		At downstream node: I(in/hr) =	3.31
		Accum. effective area (acres) =	0.30
		Tc(min) =	8.36
Average velocity through subarea (fps) =	1.17	**Qt(cfs) =**	**0.56**
Accumulated total area (acres) =	**0.30**	Ratio Q/At =	1.88

ROUTING MODULE: A-3 *MEN 128 PM 39.54*

	elevation				
Upstream node:	1259	Length L (ft):	1500	C FACTOR (unadjusted for Tr nor S):	0.2
Downstream node:	960	Subarea Area (ac):	14.5	**C FACTOR (final):**	**0.55**
				Slope S (ft/ft):	0.199

Corresponding subarea discharge Q=CIA: 23.05

Average Q to route through the subarea: **12.09** ← *Iterate until they are equal*

Type of conveyance: Trapezoidal Channel
n = 0.035, b = 2 ft, z = 1.5, Dn = 0.48 ft, T = 3.43, Fr = 2.69
V (fps) = 9.37, S (ft/ft) = 0.199, Q (cfs) = 12.08

Accumulated total area (acres) = **14.8**

Subarea time of concentration tc (min):	2.67
Overall basin slope:	0.199
At downstream node: I(in/hr) =	2.92
Accum. effective area (acres) =	14.80
Tc(min) =	11.03
Qt(cfs) =	**23.61**
Ratio Q/At =	1.60

Program prepared by Fernando Manzanera, Caltrans District 1 Hydraulics, 11/03/2011

Intensity-Duration-Frequency Curves (0 to 60 minutes)
Equations adjusted from NOAA Atlas 14 Volume 6

The equation used is: **Int = RP * Dur ^{E}**,
where RP and E are parameters adjusted from the NOAA tables

Calculated by: Glenn Hurlburt
Date: 5/21/2014

Project site information:

Description MEN-128 PM39.5/39.8 Beebe Creek Slip and Slide

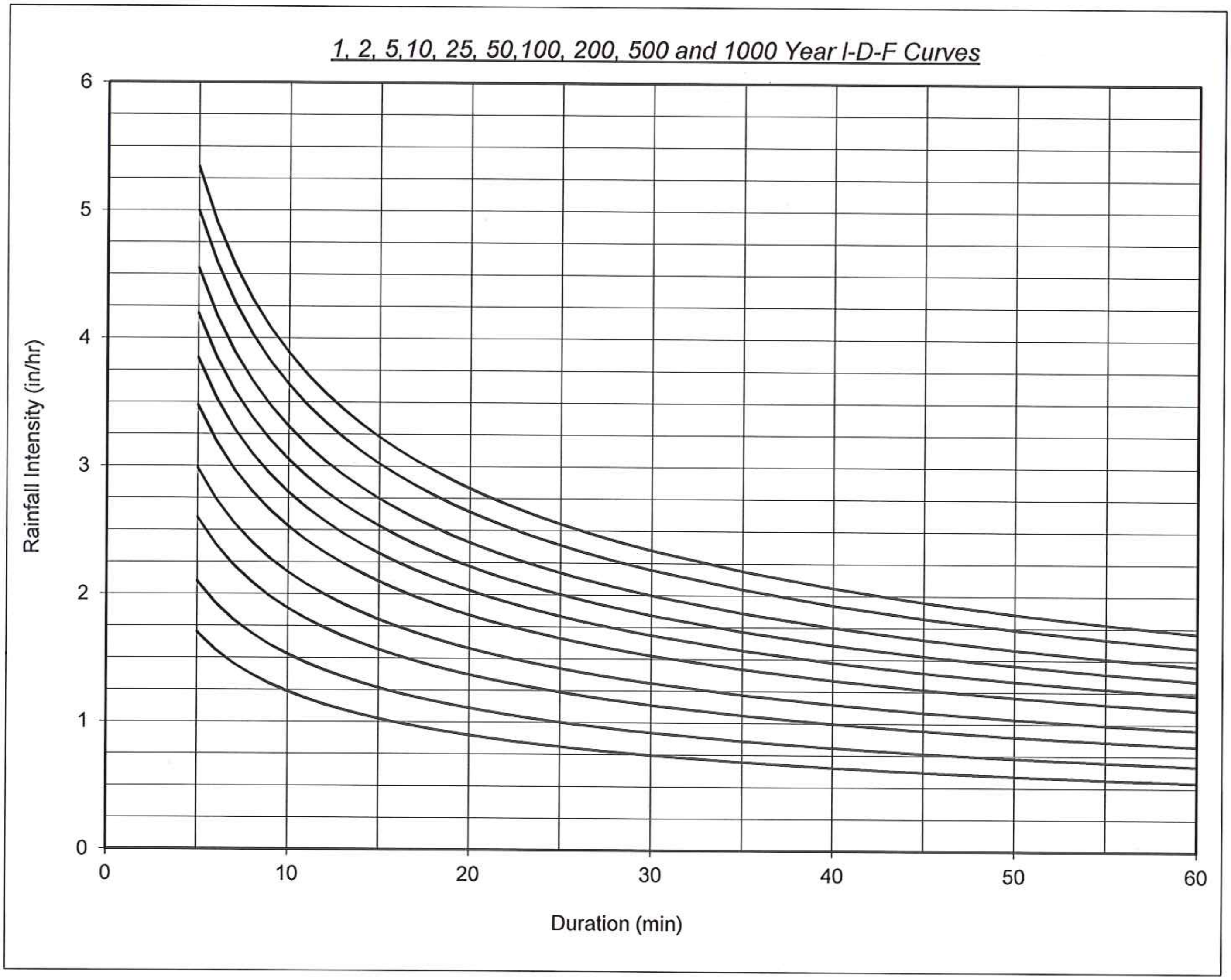
Latitude:	38.9122 deg,	(38 deg, 54 min, 43.9 sec)
Longitude:	123.2450 deg,	(123 deg, 14 min, 42.0 sec)

Elevation: 957 ft
Datum: NAD 83
PDS Data Series

Regression Parameters

	TR = 1	TR = 2	TR = 5	TR = 10	TR = 25	TR = 50	TR=100	TR=200	TR=500	TR=1000
RP:	3.5585	4.3846	5.4466	6.2465	7.2761	8.0605	8.7787	9.5193	10.4660	11.1560
E:	-0.4590	-0.4580	-0.4600	-0.4590	-0.4590	-0.4600	-0.4590	-0.4590	-0.4590	-0.4580
10-min error:	0.01 in/hr	0.01 in/hr	0.02 in/hr	0.02 in/hr	0.03 in/hr	0.03 in/hr	0.03 in/hr	0.03 in/hr	0.03 in/hr	0.03 in/hr

The resulting 10-year, 10-minutes intensity is: 2.17 in/hr
the 25-year, 10 minutes intensity is: 2.53 in/hr
and the 100-year, 10 minutes intensity is: 3.05 in/hr



- Underlined values are input data.

Intensity-Duration-Frequency Table (0 to 60 minutes)
Equations adjusted from NOAA Atlas 14 Volume 6

MEN-128 PM39.5/39.8 Beebe Creek Slip and Slide

Coordinates: 38.9122 deg, 123.2450 deg

Elevation: 957 ft
PDS Data Series, Datum: NAD 83

Calculated by: Glenn Hurlburt
May 21, 2014

Duration (min)	TR = 1 (in/hr)	TR = 2 (in/hr)	TR = 5 (in/hr)	TR = 10 (in/hr)	TR = 25 (in/hr)	TR = 50 (in/hr)	TR=100 (in/hr)	TR=200 (in/hr)	TR=500 (in/hr)	TR=1000 (in/hr)
5	**1.70**	**2.10**	**2.60**	**2.98**	**3.48**	**3.84**	**4.19**	**4.55**	**5.00**	**5.34**
6	1.56	1.93	2.39	2.74	3.20	3.54	3.86	4.18	4.60	4.91
7	1.46	1.80	2.23	2.56	2.98	3.29	3.59	3.90	4.28	4.58
8	1.37	1.69	2.09	2.41	2.80	3.10	3.38	3.67	4.03	4.30
9	1.30	1.60	1.98	2.28	2.65	2.93	3.20	3.47	3.82	4.08
10	**1.24**	**1.53**	**1.89**	**2.17**	**2.53**	**2.79**	**3.05**	**3.31**	**3.64**	**3.89**
11	1.18	1.46	1.81	2.08	2.42	2.67	2.92	3.17	3.48	3.72
12	1.14	1.40	1.74	2.00	2.33	2.57	2.81	3.04	3.35	3.57
13	1.10	1.35	1.67	1.92	2.24	2.48	2.70	2.93	3.22	3.45
14	1.06	1.31	1.62	1.86	2.17	2.39	2.61	2.83	3.12	3.33
15	1.03	1.27	1.57	1.80	2.10	2.32	2.53	2.75	3.02	3.23
16	1.00	1.23	1.52	1.75	2.04	2.25	2.46	2.67	2.93	3.13
17	0.97	1.20	1.48	1.70	1.98	2.19	2.39	2.59	2.85	3.05
18	0.94	1.17	1.44	1.66	1.93	2.13	2.33	2.53	2.78	2.97
19	0.92	1.14	1.41	1.62	1.88	2.08	2.27	2.46	2.71	2.90
20	0.90	1.11	1.37	1.58	1.84	2.03	2.22	2.41	2.65	2.83
21	0.88	1.09	1.34	1.54	1.80	1.99	2.17	2.35	2.59	2.77
22	0.86	1.06	1.31	1.51	1.76	1.94	2.12	2.30	2.53	2.71
23	0.84	1.04	1.29	1.48	1.73	1.91	2.08	2.26	2.48	2.65
24	0.83	1.02	1.26	1.45	1.69	1.87	2.04	2.21	2.43	2.60
25	0.81	1.00	1.24	1.43	1.66	1.83	2.00	2.17	2.39	2.55
26	0.80	0.99	1.22	1.40	1.63	1.80	1.97	2.13	2.35	2.51
27	0.78	0.97	1.20	1.38	1.60	1.77	1.93	2.10	2.31	2.47
28	0.77	0.95	1.18	1.35	1.58	1.74	1.90	2.06	2.27	2.42
29	0.76	0.94	1.16	1.33	1.55	1.71	1.87	2.03	2.23	2.39
30	0.75	0.92	1.14	1.31	1.53	1.69	1.84	2.00	2.20	2.35
35	0.70	0.86	1.06	1.22	1.42	1.57	1.72	1.86	2.05	2.19
40	0.65	0.81	1.00	1.15	1.34	1.48	1.61	1.75	1.93	2.06
45	0.62	0.77	0.95	1.09	1.27	1.40	1.53	1.66	1.82	1.95
50	0.59	0.73	0.90	1.04	1.21	1.33	1.46	1.58	1.74	1.86
55	0.57	0.70	0.86	0.99	1.16	1.28	1.40	1.51	1.66	1.78
60	**0.54**	**0.67**	**0.83**	**0.95**	**1.11**	**1.23**	**1.34**	**1.45**	**1.60**	**1.71**

- Spreadsheet developed by Fernando Manzanera (Caltrans District 1 Hydraulics, 10/12/11).