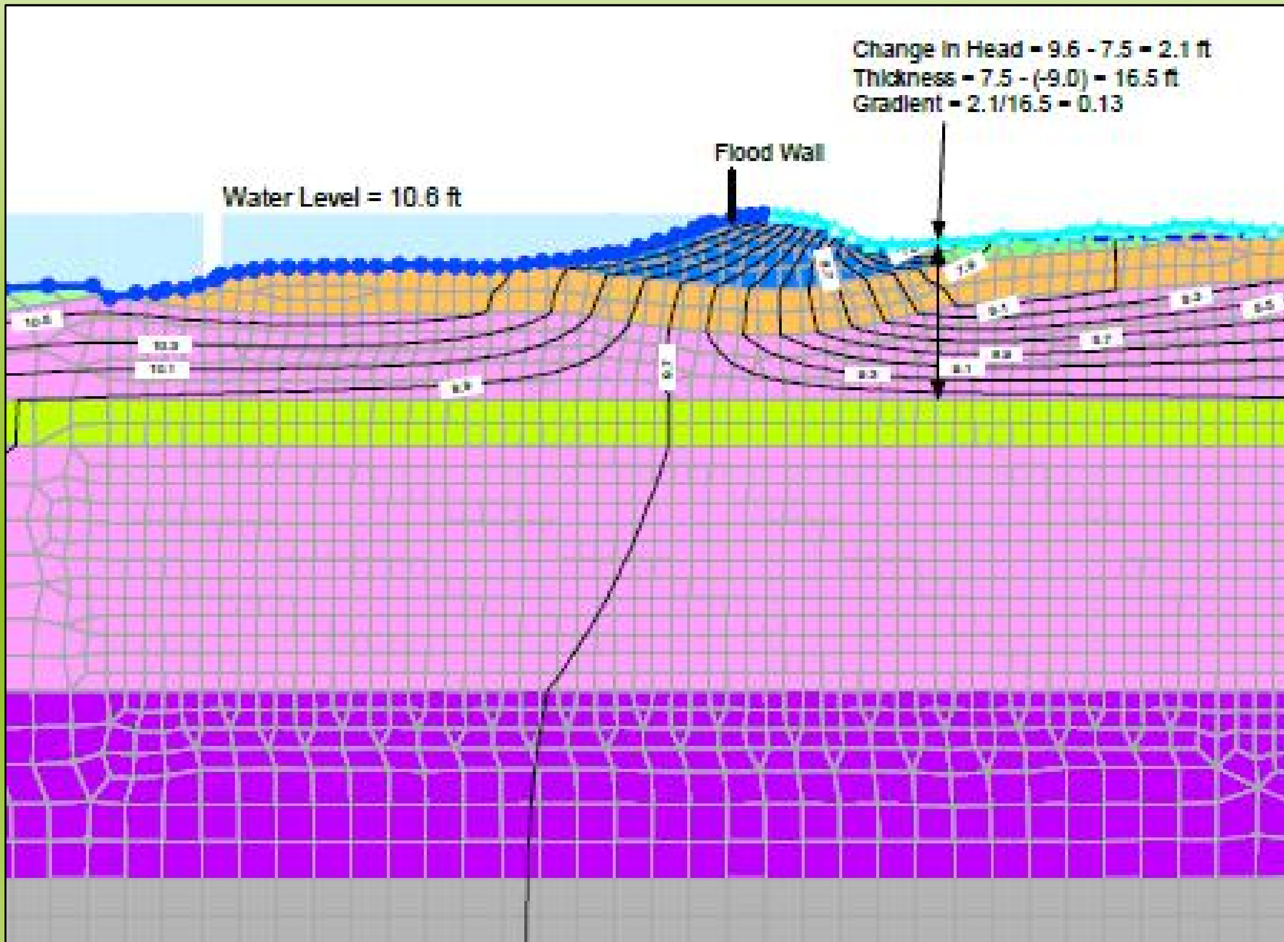
Geotechnical Evaluation Report

Corte Madera Creek Levee Evaluation
Marin County, California



SUBMITTED TO:

Marin County Flood Control and Water Conservation District
Mr. Felix Meneau, PE
Zone Engineer
3501 Civic Center Drive, Suite 304
San Rafael, CA 94903
FMeneau@marincounty.org

November 26, 2019

A3GEO

November 26, 2019

Marin County Flood Control and Water Conservation District
Mr. Felix Meneau, PE
Zone Engineer
Department of Public Works
3501 Civic Center Drive, Suite 304
San Rafael, CA 94903
FMeneau@marincounty.org

RE: FINAL Geotechnical Evaluation Report (GER)
Corte Madera Levee Evaluation
Marin County, California

Dear Mr. Meneau:

The attached Geotechnical Evaluation Report (GER) presents the final deliverable of A3GEO's Geotechnical Analysis Task (Task 4) for the Corte Madera Levee Evaluation Project. This work has been conducted in accordance with the Professional Services Agreement between Marin County Flood Control and Water Conservation District (County) and A3GEO dated January 9, 2018.

The Task 4 scope of work includes evaluating the current condition of the existing levees along Corte Madera Creek. This report provides a detailed description of the analytical reaches and representative cross sections selected for evaluation, a summary of the soil engineering properties developed for use in the geotechnical analyses, and a discussion of the current condition of the existing levees including embankment protection, seepage, slope stability, settlement and liquefaction/lateral spread potential.

The data presented in this report was developed in accordance with generally-accepted geotechnical and engineering principles and practices at the time that the report was prepared. Should you have questions about this Geotechnical Evaluation Report, please do not hesitate to call.

Yours very truly,

A3GEO, Inc.

Dona K Mann

Dona Mann, PE, GE
Principal Engineer
(415) 425-0247

REGISTERED PROFESSIONAL ENGINEER
DONA KELLY MANN
No 2901
Exp. 12/31/20
GEOTECHNICAL
STATE OF CALIFORNIA

Sarah K.

Sarah Khosravani, PE
Project Engineer
(650) 338-7205

REGISTERED PROFESSIONAL ENGINEER
SARAH KHOSRAVANI
C 87658
Exp. 09/30/2021
CIVIL
STATE OF CALIFORNIA

R. William Rudolph

R. William Rudolph, PE, GE
Senior Technical Advisor
(925) 899-7959

REGISTERED PROFESSIONAL ENGINEER
ROSS WILLIAM RUDOLPH
No. GE 000741
expires 12/31/20
GEOTECHNICAL
STATE OF CALIFORNIA

TABLE OF CONTENTS

Attachments:

1. INTRODUCTION

This Geotechnical Evaluation Report (GER) is the final deliverable of **Task 4, Geotechnical Analysis**, for the Corte Madera Creek (CMC) Levee Evaluation Project (Project). The Task 4 scope of work includes evaluating the current condition of the **existing levees along Corte Madera Creek** (Site Plan, Figure 1). The Project is administered by the Marin County Flood Control and Water Conservation District (MCFCWCD) and the Marin County Department of Public Works (MCDPW). Task 4 was completed by **A3GEO, Inc. (A3GEO)**, the prime consultant for the Project, and **Geosyntec Consultants, Inc. (Geosyntec)**, A3GEO's subconsultant. A3GEO's Professional Services Agreement with the MCFCWCD is dated 9 January 2018. Mr. Felix Meneau, Zone Engineer, is the MCDPW's designated Project Manager.

This GER specifically includes the following:

- A detailed description of the **analytical reaches and representative cross sections** selected for evaluation.
- A summary of the soil engineering properties developed for use in the geotechnical analyses.
- A discussion of the current condition of the existing levees including embankment protection, seepage, slope stability, settlement and preliminary liquefaction/lateral spread potential and resulting deformation.

Elevations referenced in this report correspond to the **North American Vertical Datum of 1988 (NAVD 88)** and are in feet. References to **"Left" and "Right" levees** are relative to an observer **looking downstream**.

2. ANALYTICAL REACHES AND REPRESENTATIVE CROSS SECTIONS

2.01 Summary

Three analytical reaches (designated as Reach A, B and C) were identified along the existing levees as shown on the Site Plan, Figure 1. Each analytical reach characterizes a portion of the existing levees with generally similar geometry, surrounding topography and subsurface conditions and is represented by a single Cross Section (designated Cross Section A-A', B-B' and C-C'). Stationing along the centerline of Corte Madera Creek (CMC Stationing) was developed by the County for previous projects and is used for reference in this report. Stationing along the centerline of Corte Madera Creek is identified on the Site Plan, Figure 1. The existing levees extend from about CMC Station 282+00 at Bon Air Bridge to CMC Station 319+00 at the upstream end of the earthen channel.

The scope of work for this study includes analyzing *three* cross sections; however, it should be noted that additional cross sections may need to be analyzed in the future in order to encompass all site conditions. The three reaches selected for this study are intended to represent the entire Existing Levee - Right Bank and Existing Levee - Left Bank. Analyzing the Existing Levee - Left Bank is particularly complex due to the fact that the existing levee has been modified since it was originally constructed and that a majority of length of the levee is adjacent to Creekside Marsh which is connected to Corte Madera Creek by open culverts. Currently, there are two sewer force mains in levee that run the entire length of the levee and each were constructed at different times. In addition, when the second force main was installed, a ground improvement program (utilizing compaction grouting) was implemented under the force main pipes. Additional information regarding the force main pipes and ground improvement program can be found in A3GEO's 2018 Existing Conditions Technical Memorandum.

Representative Cross Sections A-A', B-B' and C-C' were developed using a combination of the following resources: 1) 1968 USACE Corte Madera Creek (CMC) Channel Improvement Drawings which includes the USACE levee design drawings; 2) 2012 top of levee survey data collected from a previous Marin County project; 3) 2018 CLE-surveyed bathymetric survey data collected for this study; and 4) the subsurface profiles along the existing levees developed for this study in previous tasks.

Each Reach and representative Cross Section is discussed in more detail in the following sections. The stratigraphy within the cross sections is summarized in the following sections; however, the engineering characteristics of each material are discussed in more detail in Section 3.0, Material Properties.

2.02 Reach A / Cross Section A-A'

Reach A (highlighted in blue on the Site Plan, Figure 1) is approximately 2,050 feet long and is located along the Existing Levee - Right Bank. Reach A extends from approximately CMC Station 282+00 to 302+50. A3GEO CPT-2 and CPT-4 advanced for this study are located along Reach A. Reach A encompasses an area interpreted to have been developed (and filled) prior to the construction of the USACE levees. Based on our review of historic aerial photographs, historic topographic maps and the recent subsurface exploration conducted for this study, we interpret that Reach A includes a 5-foot-thick, gravelly fill layer (identified as General Fill) under the levee and over the marsh deposits. This gravelly, General Fill layer was not identified in the other Reaches evaluated for this study.

The representative cross section for Reach A is shown on Figure 2 (Cross Section A-A'). In Reach A, the existing levee sits on a 5-foot-thick layer of General Fill (SC/GC) overlying Upper and Lower Marsh Deposits. The Lower Marsh Deposits extend to approximately El. -60 feet and are underlain by dense to very dense Alluvium. Within the Upper Marsh Deposits, a 5-foot-thick layer of Sand is modeled 20 feet below the crest of the levee. A 5-foot-thick sand lens was encountered during our investigation in CPT-4, but was not found in CPT-2. On the waterside of the levee, significant sedimentation (identified as Channel Sedimentation) has accumulated at the bottom of CMC channel. The Channel Sedimentation profile was obtained from the bathymetric survey conducted for this study. On the landside of the levee, the levee toe is shown to be embedded by a thin layer of Uncompacted Fill. The presence of this material was approximated based on the 1968 USACE CMC Channel Improvement Drawings which call out placement of Uncompacted Fill between the levee and the developed properties to the southwest. For the purpose of the analyses for this study, the Uncompacted Fill is interpreted to have similar material properties as the General Fill. This interpretation will need to be verified during future studies.

2.03 Reach B / Cross Section B-B'

Reach B (highlighted in green on the Site Plan, Figure 1) is located along the Existing Levee - Right Bank and is approximately 480 feet long. Reach B extends from approximately CMC Station 302+50 to 307+30. A3GEO CPT-6 advanced for this study is located within Reach B. Reach B is adjacent to an existing marsh/wetland, in an area where the levee is interpreted to have been constructed directly on top the Marsh Deposits during its construction in 1968.

The representative cross section for Reach B is shown on Figure 3 (Cross Section B-B'). As shown, the existing levee with average height of 6 feet is underlain by a 45-foot-thick layer of Upper Marsh Deposits over a 20-foot-thick layer of Lower Marsh Deposits/Deep Clays over Alluvium/Bedrock. Two layers of clean Sand were encountered in CPT-6 within the Upper Marsh Deposits and are modeled in Reach B / Cross Section B-B'. The upper layer of Sand is 3-feet-thick and is 15 feet below the crest of the levee; the lower Sand layer is 5-feet-thick and is 23 feet below the crest of the levee. Similar to Reach A, Channel Sedimentation has accumulated at the bottom of CMC channel in Reach B. The Channel Sedimentation profile was obtained from the bathymetric survey conducted for this study. The geometry of the profile suggests that some erosion has occurred within the Upper Marsh Deposits between elevation 0 and +5 feet and that a thin layer of Channel Sedimentation has deposited at the toe of the levee.

On the landside of the levee, the levee toe is shown to be embedded by a layer of Undocumented Fill. According to USACE CMC Channel Improvement Drawings dated 1968, the wetlands on the landside of the levee were used as disposal area during construction of the CMC channel and existing levees. The Undocumented Fill is interpreted to have similar characteristics as the Upper Marsh Deposits which were excavated from CMC channel during construction in 1968. This interpretation will need to be verified during future studies.

2.04 Reach C / Cross Section C-C'

Reach C (highlighted in brown on the Site Plan, Figure 1) represents the entire Existing Levee - Left Bank and is approximately 3,500 feet long. Reach C extends from approximately CMC Station 284+00 to 319+00. Exploration and data previously collected by other consultants was used to characterize the conditions along Reach C. The land-side of the levee along Reach C is primarily marshland with meandering sloughs, and the levee itself contains two sewer force main pipes (30 and 36-inch-diameter) underlain by a 12-foot-wide by 22-foot-high zone of improved ground (i.e., compaction grouted soil). Additional information regarding the force main pipes and ground improvement program can be found in A3GEO's 2018 Existing Conditions Technical Memorandum.

As shown on the Site Plan, Figure 1, the upstream portion of Reach C, Station 319+00 to 308+00, is adjacent to McAllister Slough and Berens Slough, and the downstream portion of Reach C, Station 300+00 to 284+00, is adjacent to Creekside Marsh (Figure 1). These portions of Reach C are interpreted to have been constructed directly on top the Marsh Deposits during the levee construction in 1968. McAllister Slough is connected to Corte Madera Creek by three 36-inch-diameter HDPE culverts passing through the levee. At the time of our investigation, two of three culverts were capped. Berens Slough is connected to Corte Madera Creek by one 36-inch-diameter HDPE culvert passing through the levee. Wolfe Grade Creek, which runs along the western boundary of Creekside Marsh, is connected to Corte Madera Creek by four 72-inch CMP culverts passing through the levee.

The representative cross section for Reach C is shown on Figure 4 (Cross Section C-C'). Cross Section C-C' intersects McAllister and Berens Slough and is interpreted to represent the most problematic site conditions along Reach C. At Cross Section C-C', the centerlines of McAllister Slough and Berens Slough are approximately 20 feet and 130 feet inland from the landside toe of the levee, respectively. Figure 4 shows the existing levee with an average height of 7 feet underlain by a 20-foot-thick layer of Upper Marsh Deposits over a 36-foot-thick layer of Lower Marsh Deposits/Deep Clays over Alluvium/Bedrock. A 5-foot-thick layer of clean Sand was modeled 14 feet below the crest of the levee within the Upper Marsh Deposits. Isolated sand pockets (2 to 5-foot thick) were encountered at this approximate depth in CPTs previously conducted by others[1]. On the waterside of the levee (similar to Reach B), Channel Sedimentation is accumulated at the bottom of the channel and is also interpreted at the toe of the levee. The geometry of the profile suggests that some erosion has occurred within the Upper Marsh Deposits between elevation 0 and +5 feet.

[1] CPTs (spaced every 20 feet) were performed along the Existing Levee – Left Bank to evaluate liquefaction for the Ross Valley Sanitary Force Main project (DCM GeoEngineers, 2010).

3. ENGINEERING PROPERTIES

3.01 References

The Engineering properties developed for use in the geotechnical analyses were based on 1) data that was previously collected for numerous studies within the project area, 2) data collected for this study, and 3) various published references. The data collected from previous studies is summarized and discussed in detail in the following documents prepared by A3GEO for this study:

- A3GEO, Inc., 2019a, GIS Database (Final Revision) Submitted to Marin County on 8/27/2019.
- A3GEO, Inc., 2018, "Draft Existing Conditions Technical Memorandum, Corte Madera Creek Levee Evaluation, Marin County, California", dated August 31, 2018.

The data collected for this study is summarized and discussed in detail in the following document prepared by A3GEO for this study:

- A3GEO, Inc., 2019, "Draft Geotechnical Data Report, Corte Madera Creek Levee Evaluation, Marin County, California", dated March 8, 2019.

The following published documents (including, but necessarily limited to) were used as references to develop material properties for use in the analyses:

- U.S. Bureau of Reclamation (2011). "Chapter 8: Seepage." Design Standards No. 13; Embankment Dams, October.
- U.S. Army Corps of Engineers, Engineering and Design, Seepage Analysis and Control for Dams, Engineering Manual, EM 1110-2-1901, April 1993.
- U.S. Army Corps of Engineers, Engineering and Design, Slope Stability Engineering Manual, EM 1110-2-1902, October 2003.
- J. M. Duncan and S. G. Wright, "Soil Strength and Slope Stability," John Wiley & Sons, New York, 2014.

3.02 Properties

The material type [i.e., Unified Soil Classification System (USCS) designation] and average index testing results for each material used in the analyses (***with available data***) is summarized in the table below.

Material Type and Average Index Testing Results

Material	Material Type	Average Gradation (%)			Average Atterberg Limits		Average Water Content	Average Dry Density
		Gravel	Sand	-#200	Liquid Limit (LL)	Plasticity Index (PI)	(%)	(pcf)
Levee Fill	SC	28	44	28	32	14	10	110
General Fill	GC	45	38	17	Not Available	Not Available	13	115
Upper Marsh deposits	CH/CL	0	5	95	90	55	70	60
Sand and Gravel Layers	SW-SC-GW-GC	16	67	17	30	13	20	110
Lower Marsh Deposits / Deep Clays	CL/CH	3	17	80	35	15	27	100

Based on our current understanding of the existing site conditions, historic development and construction sequencing, the engineering properties for Sedimentation and Undocumented Fill were assumed to be similar to the Upper Marsh deposits and the engineering properties for Uncompacted Fill were assumed to be similar to the General Fill deposits.

The engineering properties for ¾-inch crushed rock, Caltrans Class 2 Aggregate Base, and the Compaction Grout Zone were based on published parameters and engineering judgment. The Compaction Grout Zone consist of discontinuous, low-slump grout bulbs which were intended to densify the soil, not construct an impermeable barrier. As a result, the grouted zone was not modeled as a seepage cutoff.

The following tables summarize the engineering properties developed for each material used in the analyses.

Engineering Material Properties

Material	Unit Weights		Estimated Design Strength Parameters				Permeabilities		
	Moist Density	Saturated Density	Undrained		Effective		Horizontal	Vertical	Kh/Kv
	(pcf)	(pcf)	Φ (˚)	C (psf)	Φ' (˚)	C' (psf)	(ft/day)	(ft/day)	
Levee Fill	120	125	0	1,200	32	150	0.0284	0.007	4
General Fill	125	130	36	0	36	0	0.284	0.142	2
Sedimentation	100	100	0	50	0	50	0.0284	0.019	1.5
Upper Marsh Deposits	100	110	0	Su/σ'=0.3	21	375	0.00284	0.0019	1.5
Sand Layers	125	130	0	35	0	35	2.84	0.7	4
Lower Marsh Deposits / Deep Clays	120	125	0	2,000	29	600	0.0284	0.007	4
Uncompacted Fill-Cross Section A-A'	110	125	36	0	36	0	0.284	0.142	2
Undocumented Fill-Cross Section B-B'	100	110	0	Su/σ'=0.3	21	375	0.00284	0.0019	1.5
¾" Crushed Rock Cross Section C-C'	120	120	32	0	32	0	8640	8640	1
Class 2 Aggregate Cross Section C-C'	150	150	40	0	40	0	864	432	2
Compaction Grout Zone Cross Section C-C'	135	135	36.5	0	36.5	0	0.0284	0.007	4

Consolidation Parameters

Material	Consolidation Parameters		
	Cce	Cre	Min OCR
Upper Marsh Deposits	0.57	0.09	1.1
Lower Marsh Deposits / Deep Clays	0.57	0.09	1.1
Undocumented Fill-Cross Section B-B'	0.24	0.07	2.5

4. GEOTECHNICAL ANALYSES

4.01 Seepage Analysis

4.01.1 Methodology

Seepage analyses assuming steady state flow conditions were performed for Cross Sections A-A', B-B' and C-C' for various water surface elevations (WSE) within Corte Madera Creek using the computer software program, SEEP/W (GEO-SLOPE, 2018). For each WSE analyzed, steady state phreatic surfaces and pore water pressures were developed and then used to calculate the average vertical hydraulic exit gradient across the blanket layer at the toe of the levee. The blanket layer is defined as the top stratum extending landward of the landside levee toe that has low vertical permeability in comparison to the horizontal permeability of deeper soils.

For Cross Section C-C', because high exit gradients could also develop at the adjacent landside channels (identified as Near and Far Channels, Figure 4); the average vertical hydraulic exit gradients were also calculated at each channel. For the purposes of this analysis, exit gradients were calculated considering both channels were full at time of high water event.

For each representative cross section (Cross Section A-A', B-B' and C-C'), a **Base Case and a Sensitivity Case** were analyzed. The **Base Case** for each section includes the interpreted stratigraphy as shown on Figures 2 through 4 and uses the engineering material properties presented in Section 3 of this report. The Base Case is judged to be a reasonable interpretation of the average conditions at each Reach, but it is based on limited data. The **Sensitivity Case** takes into account the uncertainty in the interpreted conditions and attempts to present a possible **"worst-case" scenario** based on our current understanding of the site conditions.

The **Sensitivity Case for Cross Section A-A'** modeled the lower half of the General Fill layer as having a higher permeability than the upper half. This consideration is postulated based on some of the existing subsurface data. **The Sensitivity Case for Cross Sections B-B' and C-C'** modeled a 3-foot-thick sand layer directly below levee. This consideration is postulated based on the geomorphic setting (marsh deposits with channels).

To envelop the existing and possible future WSEs of interest, analyses were performed to encompass WSEs ranging from 2.5 feet above to 2.5 feet below the original designed levee crest. For WSEs above the existing levee crest, a floodwall was modeled to retain the increased water height. From the results, plots of WSE vs. Vertical Hydraulic Exit Gradient were developed. The SEEP/W computer outputs and plots of WSE vs. Vertical Hydraulic Exit Gradient are included in Appendix A. The plots of WSE vs. Vertical Hydraulic Exit Gradient were then used to obtain the average vertical hydraulic exit gradients for Cross Sections A-A', B-B' and C-C' at the following relevant WSEs in Corte Madera Creek:

- The maximum WSE for the existing conditions (**10.1 feet;** 100-year Coastal Flood Event) (Stetson, 2018)
- The WSE at the **top of the existing levee** (elevations vary between 10.6 and 11.4 feet)
- The maximum WSE with proposed improvements in place (**11.6 to 11.7 feet;** 100-year Coastal Flood Event + 10-year storm event + Sea Level Rise) (Stetson, 2019; A3GEO, 2019b)

The results of the analyses are summarized in the following section.

4.01.2 Seepage Results

The average vertical hydraulic exit gradients resulting from the seepage analyses for Cross Sections A-A', B-B' and C-C' for the Base Case and Sensitivity Case at the WSEs discussed in the previous section of the report are tabulated below.

Average Vertical Hydraulic Exit Gradient

Section	Analysis Case	Water Surface Elevation (WSE) (ft)	Average Vertical Hydraulic Exit Gradient		
			At Toe of Levee		
A-A'	Base Case	10.1 (Max WSE for current Conditions)	0.11		
		11.3 (Top of the existing Levee)	0.15		
		11.6 (Max WSE after improvements)	0.17		
	Sensitivity Case	10.1 (Max WSE for current Conditions)	0.22		
		11.3 (Top of the existing Levee)	0.28		
		11.6 (Max WSE after improvements)	0.30		
B-B'	Base Case	10.1 (Max WSE for current Conditions)	0.09		
		10.6 (Top of the existing Levee)	0.11		
		11.6 (Max WSE after improvements)	0.15		
	Sensitivity Case	10.1 (Max WSE for current Conditions)	0.46		
		10.6 (Top of the existing Levee)	0.57		
		11.6 (Max WSE after improvements)	0.76		
Section	**Analysis Case**	**Water Surface Elevation (WSE) (ft)**	**Average Vertical Hydraulic Exit Gradient**		
			At Toe of Levee	**At Near Channel**	**At Far Channel**
C-C'	Base Case	10.1 (Max WSE for current Conditions)	0.11	0.17	0.3
		11.4 (Top of the existing Levee)	0.15	0.23	0.38
		11.7 (Max WSE after improvements)	0.16	0.24	0.39
	Sensitivity Case	10.1 (Max WSE for current Conditions)	0.77	1.77	N/A
		11.4 (Top of the existing Levee)	1.10	2.42	N/A
		11.7 (Max WSE after improvements)	1.12	2.46	N/A

Based on **USACE levee design criteria**, allowable exit gradients can be **no greater than 0.5 at the levee toe**. In the table above, calculated exit gradients at the levee toe that are greater than 0.5 are presented in red text. Although not explicit in USACE guidelines, an allowable exit gradient of **0.8 at 150 feet from the levee** may be considered a criterion as per the State of California Urban Levee Design Criteria (DWR, 2012). The Near Channel in Cross Section C-C' is about 20 feet from the levee toe and the Far Channel is about 130 feet from the levee toe; therefore, a **maximum allowable exit gradient of 0.5 is considered for the Near Channel** and a **maximum allowable exit gradient of 0.8 is considered for the Far Channel**. In the table above, calculated exit gradients at the Near Channel that are greater than 0.5 are presented in red text. Exit gradients at the Far Channel were less than 0.8.

In summary, the results show that all Reaches meet the USACE seepage criteria for all anticipated WSEs for the Base Case. If a sand layer exists directly below the levee, there may be localized areas that need remediation in order to meet USACE seepage criteria. Further evaluation would need to be performed in order to evaluate the presence of sand layers directly below the levee.

4.02 Slope Stability Analysis

4.02.1 Methodology

Static slope stability analyses were performed to evaluate the stability of the levee embankment and levee foundation for Cross Sections A-A', B-B' and C-C'. Analyses were conducted using the computer software program SLOPE/W (GEO-SLOPE, 2018) while employing the Spencer method (Spencer, 1967). The steady-state phreatic surfaces developed during the seepage analyses were used in the slope stability analyses.

For each representative cross section (Cross Section A-A', B-B' and C-C'), the same **Base Case** and **Sensitivity Case** were analyzed as completed for the seepage analyses. A detailed explanation of the Base Case and Sensitivity Case can be found in Section 4.01.1 of this report.

For each cross section, slope stability analyses were performed for **two loading conditions**:

1. **Rapid Drawdown**: The WSE in Corte Madera Creek (CMC) **drops 2.6 feet** from the top of the existing levee and the levee embankment **slope stability on the water-side of the levee is evaluated**. This scenario represents the maximum water surface elevation change over a 12 hour period during a 100-year riverine flood per Stetson Engineers.

2. **Steady-State:** The WSE in CMC is 2.5 feet above the design levee crest elevation and the levee embankment **slope stability on the land-side of the levee is evaluated**. It is important to note that per Stetson Engineers' hydraulic analyses for this study, the maximum anticipated water surface elevation in CMC, considering various flooding scenarios and potential improvements, is well below this arbitrary water level.

The SLOPE/W outputs are provided in Appendix B and the results of the analyses are summarized in the following section.

4.02.2 Slope Stability Results

The Factors of Safety (FS) calculated from the slope stability analyses are tabulated below.

Slope Stability Factors of Safety

Section	Analysis Case	Loading Condition	Slope Analyzed	Static Factor of Safety (FS)
A-A'	Base Case	Rapid drawdown	Water-side	5.41 → 3.42
		Steady State	Land-side	2.82
	Sensitivity Case	Rapid drawdown	Water-side	5.44 → 3.46
		Steady State	Land-side	2.70
B-B'	Base Case	Rapid drawdown	Water-side	6.34 → 4.41
		Steady State	Land-side	6.93
	Sensitivity Case	Rapid drawdown	Water-side	5.28 → 3.26
		Steady State	Land-side	4.36
C-C	Base Case	Rapid drawdown	Water-side	4.60 → 2.91
		Steady State	Land-side	3.16
	Sensitivity Case	Rapid drawdown	Water-side	3.09 → 2.22
		Steady State	Land-side	1.64

Based on the USACE guidelines, a minimum Factor of Safety (FS) of 1.4 is required on the landside and a minimum FS of 1.2 is required on the waterside. As displayed on the above table, the landside and waterside embankments of the existing levees in all three reaches are considered stable for both loading conditions.

4.03 Settlement Analysis

4.03.1 Methodology

Feasibility-level settlement analyses were performed to provide a rough estimation of settlement that may occur if earthen fill is placed to construct a levee raise each Reach. If earthen fill is used to accomplish a levee raise, fill would be placed both on the levee crest and on the levee slope or slopes (likely on the landside slope, so as to avoid decreasing channel capacity and adverse environmental impacts). Fill placed on the levee in this manner may induce settlement of the relatively soft soils underlying the levee. The subsurface conditions shown on Figures 2 through 4 (Cross Sections A-A', B-B' and C-C') were used in the analyses. The results of the analyses are summarized in the following section.

4.03.2 Settlement Analysis Results

The results of this analysis are tabulated below. The results indicate that settlement on the order of 0.5 to 6.5 inches may be expected for a levee raise of 1 to 3 feet. These values are feasibility-level values and would need to be refined during final design.

Settlement Estimates

Cross Section	Levee Raise (feet)	Consolidation Settlement (in)
A-A'	1	0.5
	3	2.5
B-B'	1	1.0
	3	6.3
C-C'	1	0.7
	3	4.4

4.04 Embankment Protection (Erosion) Analysis

4.04.1 Methodology

Embankment protection analysis was performed to evaluate the performance of the existing levee embankments against potential erosion. The channel flow velocity and shear stress at various CMC Stations for the 100-year Riverine Flood Event (combined with the mean higher high water (MHHW) tide) were provided by Stetson Engineers. In the analysis, the flow velocity was adjusted for the change in flow direction based on the channel width and the bend radius. The spreadsheet used to perform the erosion analyses is included in Appendix C and the results of the analyses are summarized in the following section.

4.04.2 Embankment Protection Results

Based on USACE guidelines, the maximum design velocity for the Levee Fill ranges from 4.5 to 5.5 feet per second (ft/s). This criterion was selected to account for the gradation of the Levee Fill and the existence of vegetation on the levee embankment. The results indicate that during the 100-year Riverine Flood Event, the flow velocities may exceed the allowable value at the bends in the river. These results are considered feasibility-level results and would need to be verified during design.

4.05 Preliminary Liquefaction Evaluation

4.05.1 Methodology

Liquefaction potential and resulting deformations (vertical settlement and lateral spreading) were preliminarily evaluated using the electronic CPT data collected during our 2018 field investigation for this study and commercially-available software CLiq (v.2.3.1.15) by Geologismiki. Youd et al., 2001 (i.e., NCEER, 1998) methodology was utilized for potential of liquefaction assessment; Zhang et al., 2002 methodology was used to calculate liquefaction-induced settlements; Zhang et al., 2004 methodology was used for lateral spreading estimations. In addition to the raw data, key inputs to the liquefaction analyses include earthquake magnitude (M_W), peak ground acceleration (PGA) and groundwater depth. We used the following values in our analyses:

Mw = 8.05: the mean characteristic magnitude for the rupture of the San Andreas fault (The Maximum Considered Earthquake, or MCE).

PGA = 0.53g: the geometric mean PGA (PGA_M) per ASCE 7-10.

In Situ Groundwater Depth = 5 feet below the ground surface.

Groundwater Depth during Seismic Event = 0 feet below the ground surface.

The CLiq outputs are provided in Appendix D and the results of the analyses are summarized in the following section.

4.05.2 Settlement and Lateral Spread Results

Preliminary liquefaction-induced vertical settlements and lateral spread estimates are summarized in the following table.

Liquefaction-Induced Deformations

Deformation	Cone Penetration Test ID		
	CPT-2	**CPT-4**	**CPT-6**
Vertical Settlement (inch)	0.9	1.4	2.4
Lateral Spread (feet)	1.4	1.7	4.4

These values should be considered feasibility-level estimates.

5. CONCLUSIONS

- Based on the current available data, the existing levees appear to meet the USACE seepage criteria for all anticipated WSEs.
- The presence of a high permeability layer directly beneath the levee significantly increases the average vertical hydraulic exit gradient, and in some cases, may cause the exit gradient to exceed the maximum USACE allowable gradient. Future studies should be performed to evaluate the presence of a high permeability layer directly beneath the levees in areas where insufficient data is available.
- In localized areas, if seepage is identified as a concern, construction of a cutoff wall (extended into the foundation soils) would likely mitigate seepage susceptibility. Supplemental analyses would be required to evaluate the required depth of seepage cutoff walls.

- Supplemental studies should be performed to confirm the engineering material properties of the Levee Fill, General Fill, Undocumented Fill, and Uncompacted Fill (and any other material not fully characterized).

- Slope stability does not appear to be a geotechnical concern for the existing levees along CMC. The landside and waterside embankments of the existing levees in all three reaches analyzed met USACE criteria for slope stability. Slope stability in reaches not analyzed in this study should be checked during future studies.

- Settlement is a geotechnical consideration if the levees along CMC are raised. Some minor settlement will occur if the levees are raised due to the added weight of the fill causing consolidation of the soft underlying clays; however, this can be accounted for during design by increasing the height of the levees to accommodate the estimated settlements. Impacts to underlying utilities and/or adjacent structures should also be considered during design.

- Embankment protection may be needed at the bends in the river to protect against the 100-year Riverine Flood Event. Further study should be performed to confirm.

- The liquefaction/lateral spread hazard is considered very high. During a strong earthquake, the existing levee may experience several inches of liquefaction-induced vertical settlement and several feet of lateral spread toward the center of Corte Madera Creek. Evaluation of seismic performance should be considered in future studies. The zone of improved ground (i.e., Compaction Grouted Zone) installed underneath the force main pipes in the Existing Levee – Left Bank should be considered in future studies; however, based on the available information, it is unclear that this zone could sufficiently mitigate a liquefaction and/or lateral spread hazard.

- Removing channel sedimentation in the future would have very little impact on the stability and seepage results.

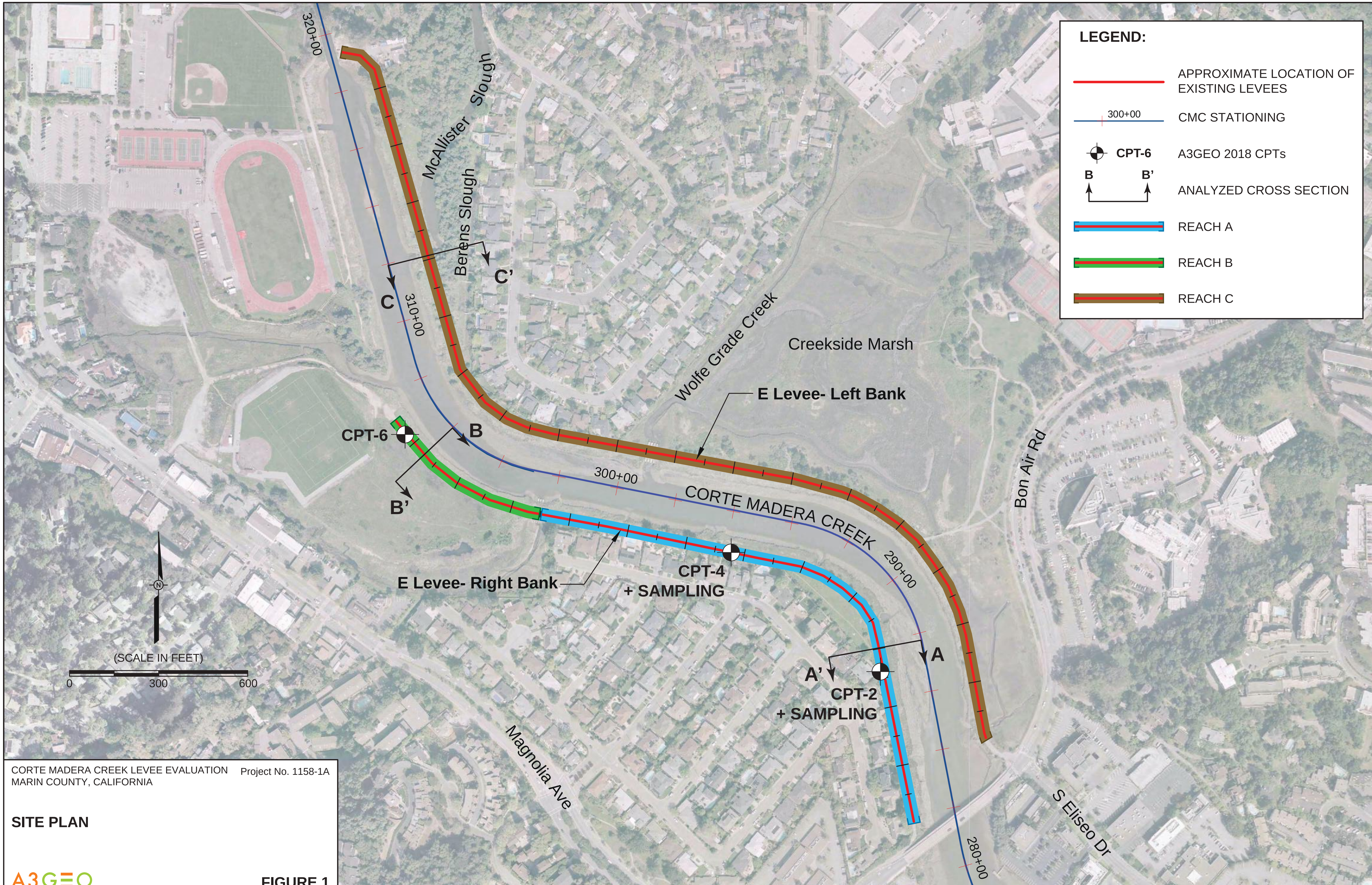
6. LIMITATIONS

This study is preliminary in nature and is not intended for design purposes. Further study, including but not necessarily limited to, subsurface exploration, laboratory testing and/or geotechnical analyses will be required to finalize the current condition of the existing levees along Corte Madera Creek.

This engineering report has been prepared for the exclusive use of Marin County Flood Control and Water Conservation District and their Consultants. The data and interpretations presented in this report were developed in accordance with generally-accepted geotechnical and engineering geologic principles and practices. No other warranty, expressed or implied, is made. The findings of this report are valid as of the present date. However, the passing of time will likely change the conditions due to natural processes or the works of man. In addition, due to legislation or the broadening of knowledge, changes in applicable or appropriate standards will occur. Accordingly, this report should not be relied upon after a period of three years without being reviewed by this office.

7. REFERENCES

- A3GEO, Inc., 2019a, GIS Database (Final Revision) Submitted to Marin County on 8/27/2019.
- A3GEO, Inc., 2019b, “Draft Remedial Alternatives Report, Corte Madera Creek Levee Evaluation, Marin County, California”, dated September 13, 2019.
- A3GEO, Inc., 2018, “Draft Existing Conditions Technical Memorandum, Corte Madera Creek Levee Evaluation, Marin County, California”, dated August 31, 2018.
- A3GEO, Inc., 2018, “Draft Geotechnical Data Report, Corte Madera Creek Levee Evaluation, Marin County, California”, dated March 8, 2019.
- ASCE/SEI 7-10, 2010, “Minimum Design Loads for Buildings and Other Structures,” American Society of Civil Engineers, Reston, Virginia.
- Brown and Caldwell, 2012, “Ross Valley Sanitary District - Record Drawing Plans for Kentfield Force Main Replacement Project, Segment 1A – Pipeline”, dated September 2012.
- CLE Engineering Inc., 2014, “Corte Madera Creek – Hydrographic Surveys, Marin County, California”,
- July 2014.
- CLE Engineering Inc., 2018, “Corte Madera Creek Bathymetric Survey, Marin County, California”,
- January 2018.
- DCM GeoEngineers, 2010, “Geotechnical Investigation Report, Sanitary District No.1 of Marin County Kentfield Force Main Replacement Project, Marin County, California”, dated February 2010.
- DCM GeoEngineers, 2010, “CPT-Liquefaction Evaluation Memorandums 1 to 9, Kentfield Force Main Replacement Project”, dated September to October 2010
- J. M. Duncan and S. G. Wright, “Soil Strength and Slope Stability,” John Wiley & Sons, New York, 2014.
- Robertson, P. K., 2009, “Performance Based Earthquake Design Using the CPT,” Keynote Lecture at International Conference on Performance-based design in Earthquake Geotechnical Engineering, IS Tokyo, Tsukuba, Japan.
- Robertson, P. K., 2009, “Discussion of CPT-based probabilistic soil characterization and classification,” by K. Onder Cetin and Cem Ozan., J. Geotech. Geoenviron. Eng., 135 1, 84–107.
- Robertson, P.K., 2009, “Interpretation of cone penetration tests – a unified approach”, Canadian Geotechnical Journal, Volume 46: 1337-1355, dated 2009.
- State of California Department of Water Resources (DWR), 2012, “Urban Levee Design Criteria,” May 2012.
- Stetson Engineers Inc., 2018, “Draft Existing Conditions Hydraulic Evaluation of the Corte Madera Creek Levees Report”, dated June 29, 2018.
- Stetson Engineers Inc., 2019, “Draft Project Conditions Hydraulic Evaluation of the Corte Madera Creek Levees Report”, dated June 17, 2019.
- Youd, T.L., and Idriss, I.M., 2001, “Liquefaction Resistance of Soils: Summary Report from the 1995 NCEER and 1998 NCEER/NSF Workshops on the Evaluation of Liquefaction Resistance for Soils,” in ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 127, No. 10, pp. 817-833, October 2001.
- US Army Corps of Engineers (USACE), 1968, “Log of Exploration Holes, Corte Madera Creek Channel Improvements, Marin County, California”, April 10, 1968.
- U.S. Army Corps of Engineers, Engineering and Design, Seepage Analysis and Control for Dams, Engineering Manual, EM 1110-2-1901, April 1993.
- U.S. Army Corps of Engineers, Engineering and Design, Slope Stability Engineering Manual, EM 1110-2-1902, October 2003.
- U.S. Bureau of Reclamation (2011). “Chapter 8: Seepage.” Design Standards No. 13; Embankment Dams, October.
- Youd, T.L. and Idriss, I.M., 2001, “Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils,” ASCE, Journal of Geotechnical and Geoenvironmental Engineering, April 2001.
- Zhang, G., Robertson, P.K., and Brachman, R.W.I., 2002, “Estimating Liquefaction-Induced Ground Settlements from CPT for Level Ground,” Can. Geotech. J., 39, pp. 1168-1180.
- Zhang, G., Robertson, P.K., and Brachman, R.W.I., 2004, “Estimating Liquefaction-Induced Lateral Displacements Using the Standard Penetration Test or Cone Penetration Test,” in ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 130, No. 8, pp. 861-871, August 1, 2004.



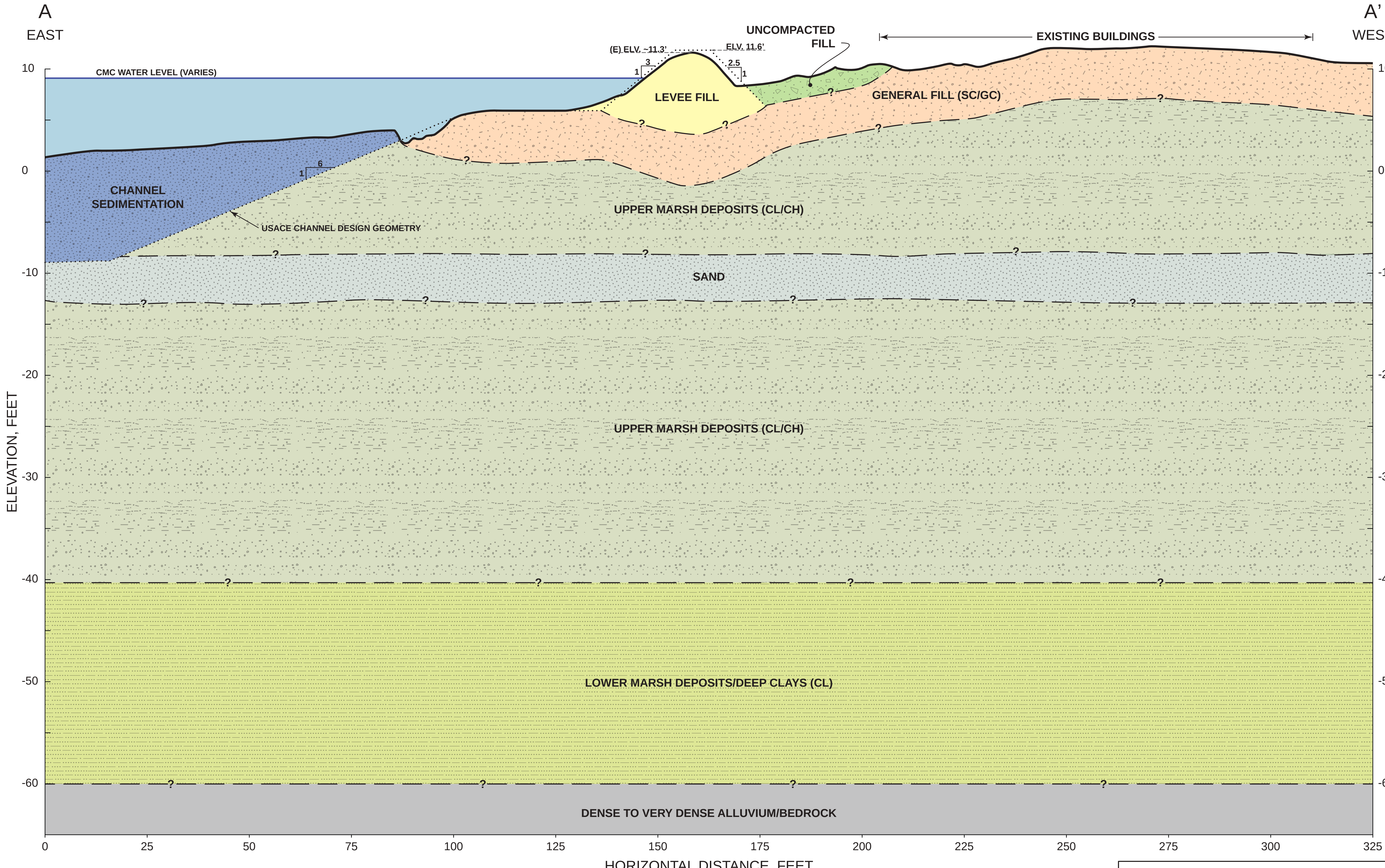
CORTE MADERA CREEK LEVEE EVALUATION
MARIN COUNTY, CALIFORNIA

Project No. 1158-1A

SITE PLAN

A3GEO

FIGURE 1



SCALE IN FEET

0 25 50 HORZ.

0 10 20 VERT.

Notes:

1. DOTTED LINES SHOW ORIGINAL AS-DESIGNED/CONSTRUCTED LEVEE AND CMC CHANNEL GEOMETRY BASED ON USACE 1968 DRAWINGS.
2. CONTINUOUS LINE SHOWS MOST RECENT TOPOGRAPHY ACCORDING TO 2012 STENTON-SURVEYED TOPOGRAPHIC DATA AND 2018 CLE-SURVEYED BATHYMETRIC DATA.
3. DASHED LINES SHOW APPROXIMATE STRATIFICATION ACCORDING TO A3GEO'S DEVELOPED SUBSURFACE PROFILE ALONG THE EXISTING LEVEE RIGHT BANK.

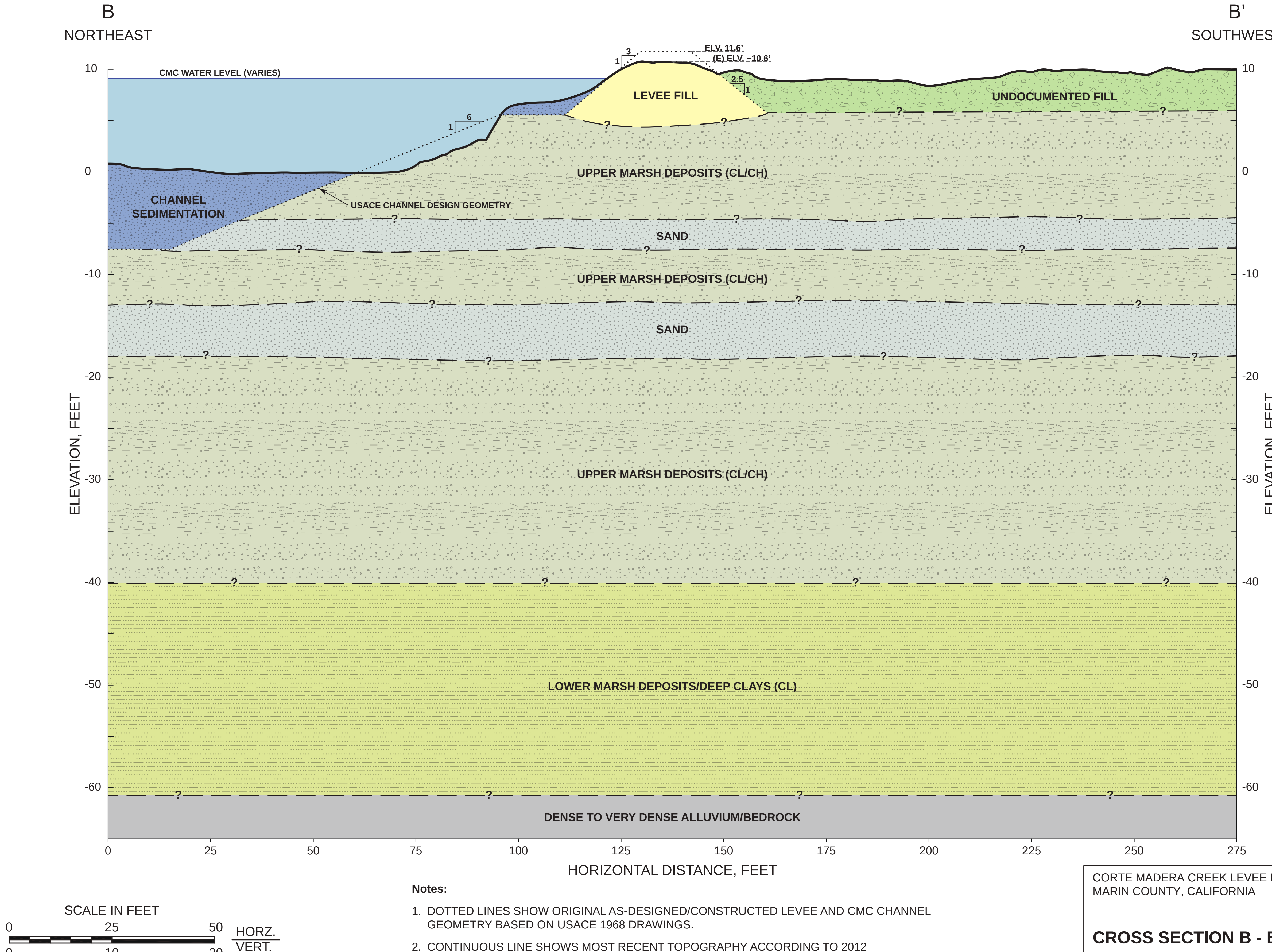
CORTE MADERA CREEK LEVEE EVALUATION Project No. 1158-1A
MARIN COUNTY, CALIFORNIA

CROSS SECTION A - A'

A3GEO

FIGURE 2

Date: 9/30/2019



Notes:

1. DOTTED LINES SHOW ORIGINAL AS-DESIGNED/CONSTRUCTED LEVEE AND CMC CHANNEL GEOMETRY BASED ON USACE 1968 DRAWINGS.
2. CONTINUOUS LINE SHOWS MOST RECENT TOPOGRAPHY ACCORDING TO 2012 STENTON-SURVEYED TOPOGRAPHIC DATA AND 2018 CLE-SURVEYED BATHYMETRIC DATA.
3. DASHED LINES SHOW APPROXIMATE STRATIFICATION ACCORDING TO A3GEO'S DEVELOPED SUBSURFACE PROFILE ALONG THE EXISTING LEVEE RIGHT BANK.

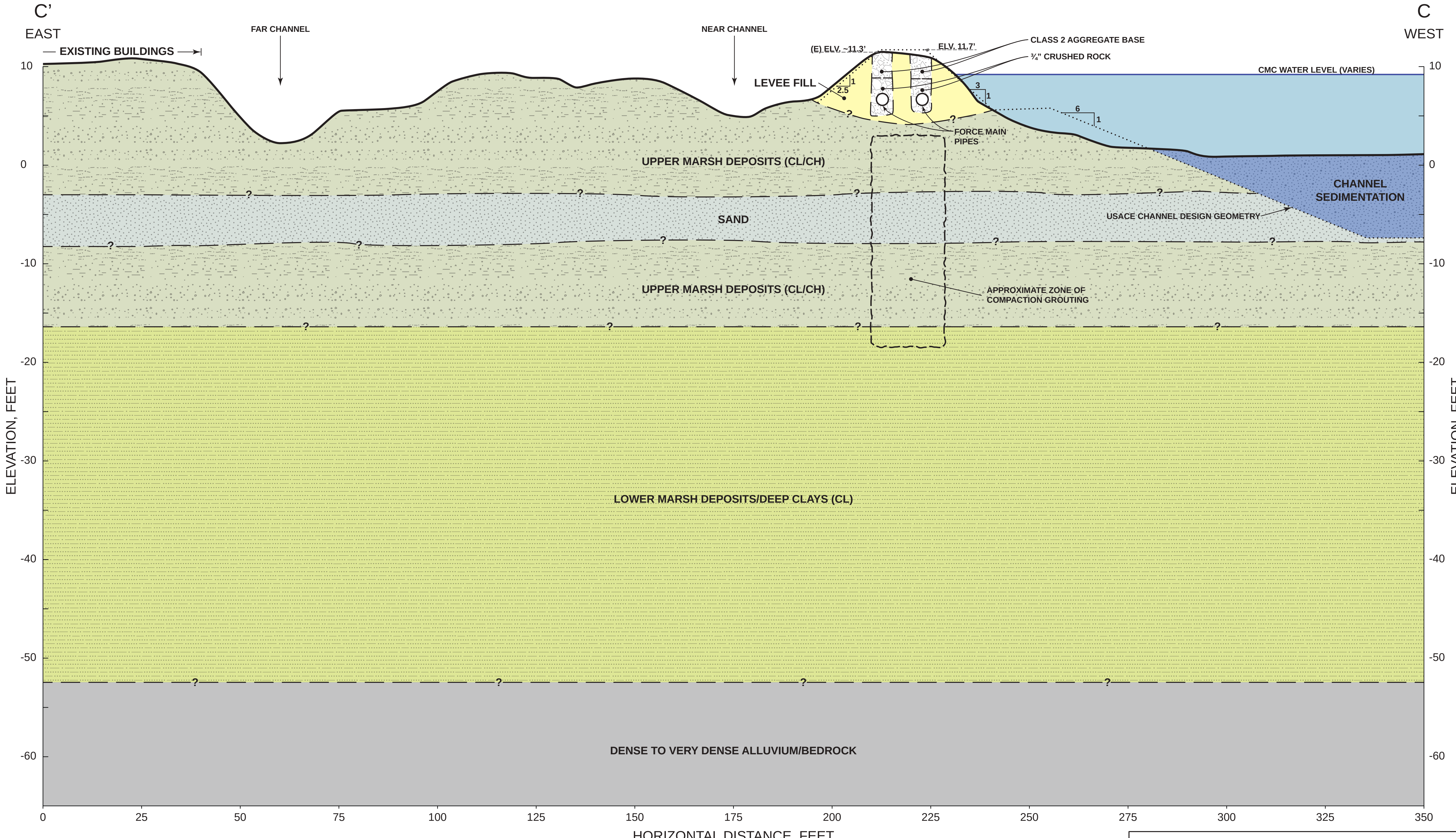
CORTE MADERA CREEK LEVEE EVALUATION Project No. 1158-1A
MARIN COUNTY, CALIFORNIA

CROSS SECTION B - B'

A3GEO

FIGURE 3

Date: 9/30/2019



SCALE IN FEET

0 25 50 HORZ.

0 10 20 VERT.

Notes:

1. DOTTED LINES SHOW ORIGINAL AS-DESIGNED/CONSTRUCTED LEVEE AND CMC CHANNEL GEOMETRY BASED ON USACE 1968 DRAWINGS.
2. CONTINUOUS LINE SHOWS MOST RECENT TOPOGRAPHY ACCORDING TO 2012 STENTON-SURVEYED TOPOGRAPHIC DATA AND 2018 CLE-SURVEYED BATHYMETRIC DATA.
3. DASHED LINES SHOW APPROXIMATE STRATIFICATION ACCORDING TO A3GEO'S DEVELOPED SUBSURFACE PROFILE ALONG THE EXISTING LEVEE RIGHT BANK.

CORTE MADERA CREEK LEVEE EVALUATION Project No. 1158-1A
MARIN COUNTY, CALIFORNIA

CROSS SECTION C - C'

A3GEO

FIGURE 4

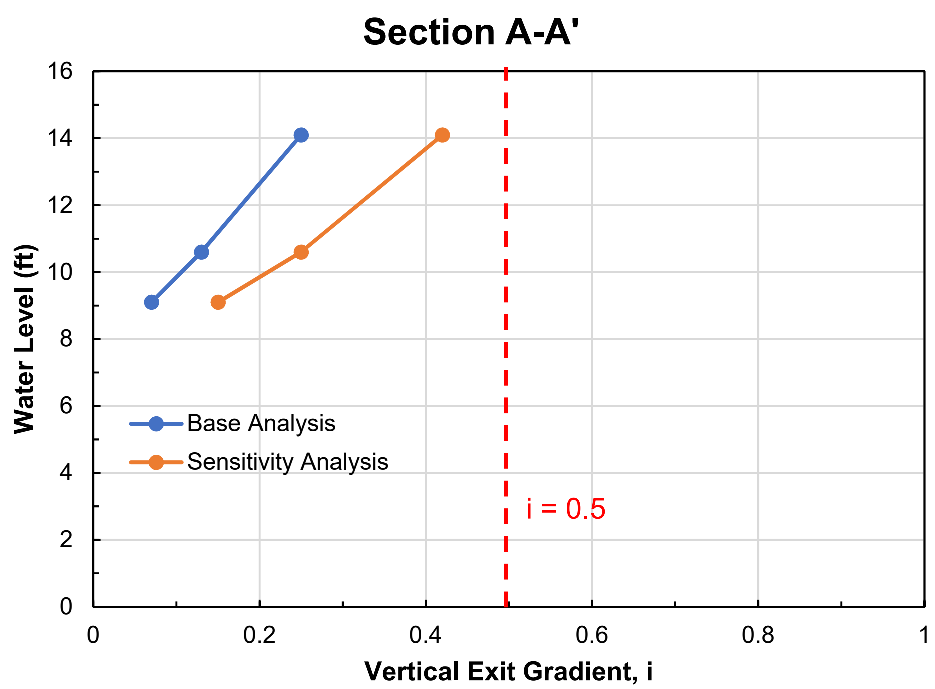
Date: 9/30/2019

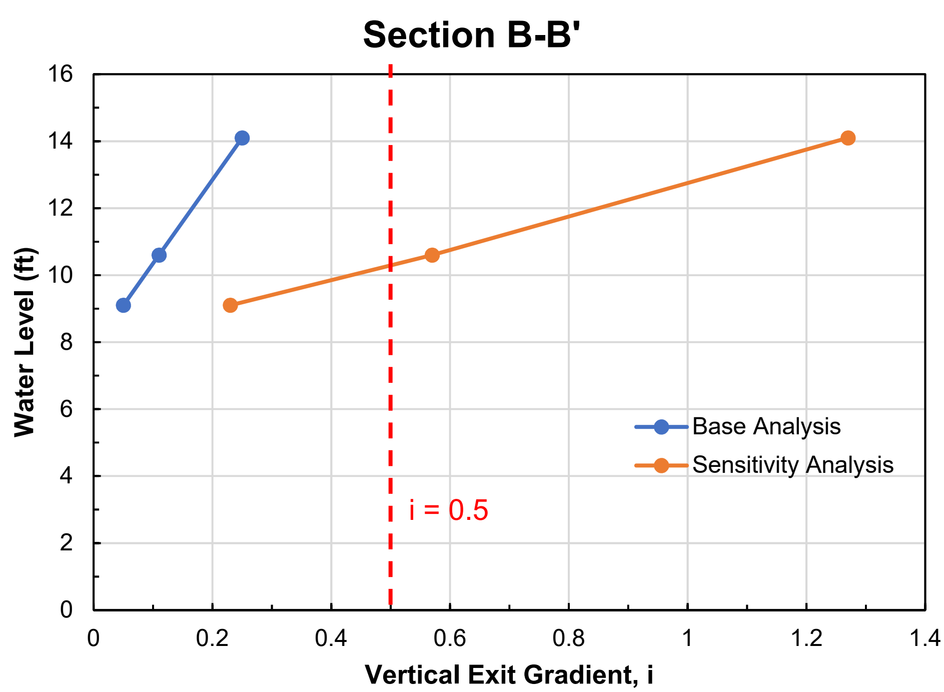
APPENDIX A

Seepage Analysis

Average Vertical Exit Gradient At Toe of Levee

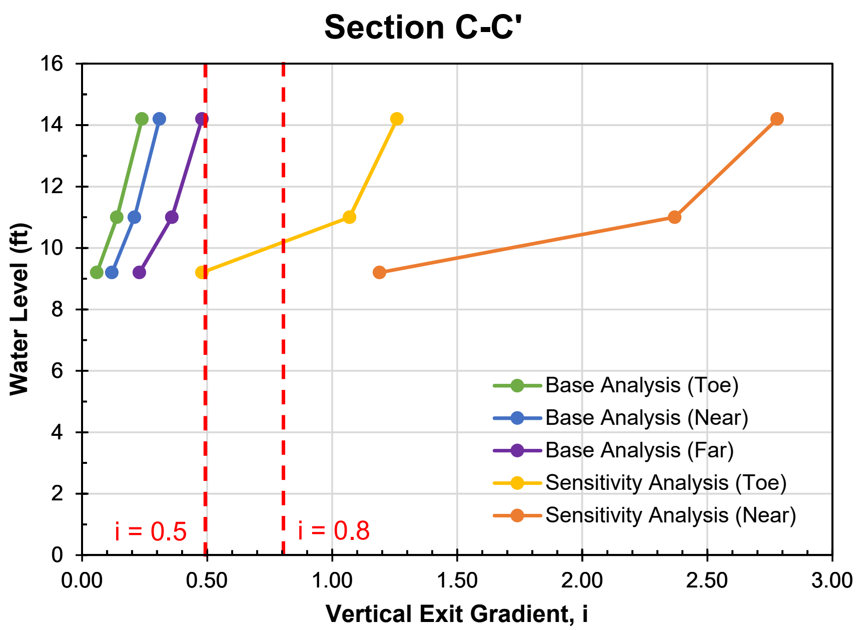
Water Level (ft)		Vertical Exit Gradient, i			
		Section A-A'		Section B-B'	
		Base Analysis	Sensitivity Analysis	Base Analysis	Sensitivity Analysis
9.1	2.5' Below Design	0.07	0.15	0.05	0.23
10.6	Existing	0.13	0.25	0.11	0.57
14.1	2.5' Above Design	0.25	0.42	0.25	1.27





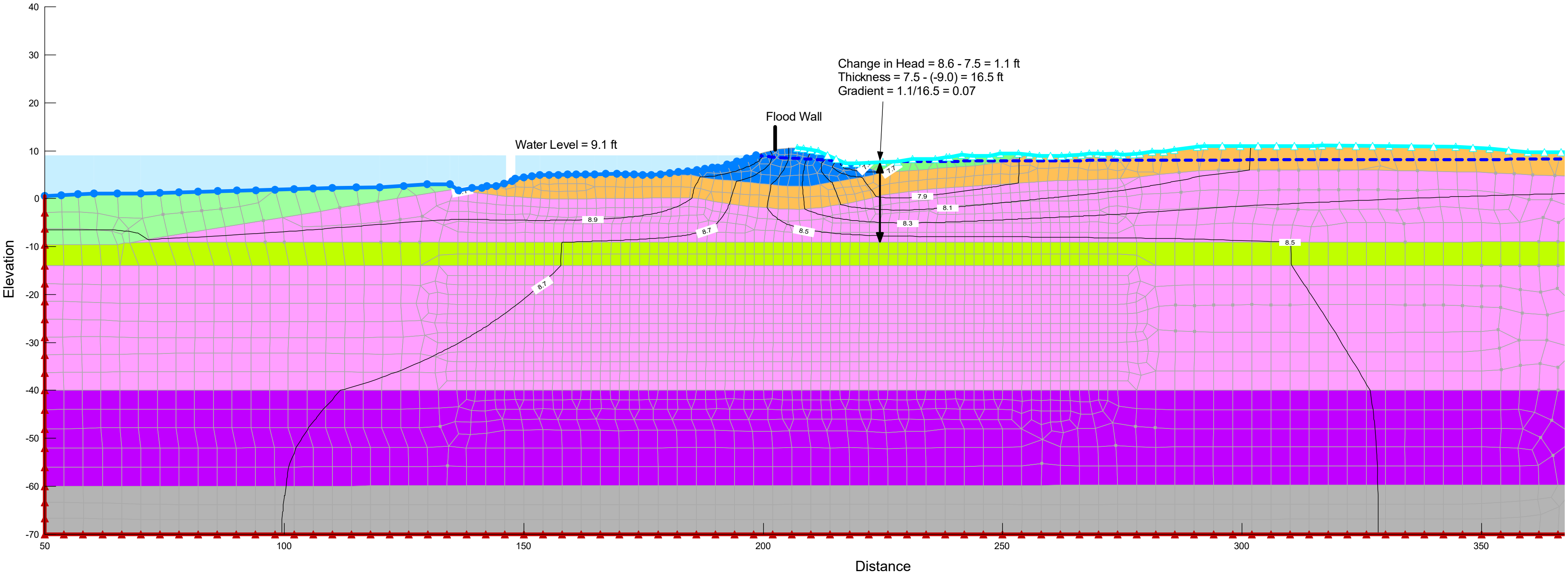
Average Vertical Exit Gradient (Section C-C')

		Vertical Exit Gradient, i					
Both Channels Filled		At Toe of Levee		At Near Channel		At Far Channel	
Water Level (ft)		Base Analysis	Sensitivity Analysis	Base Analysis	Sensitivity Analysis	Base Analysis	Sensitivity Analysis
9.2	2.5' Below Design	0.06	0.48	0.12	1.19	0.23	N/A
11.0	Existing	0.14	1.07	0.21	2.37	0.36	N/A
14.2	2.5' Above Design	0.24	1.26	0.31	2.78	0.48	N/A



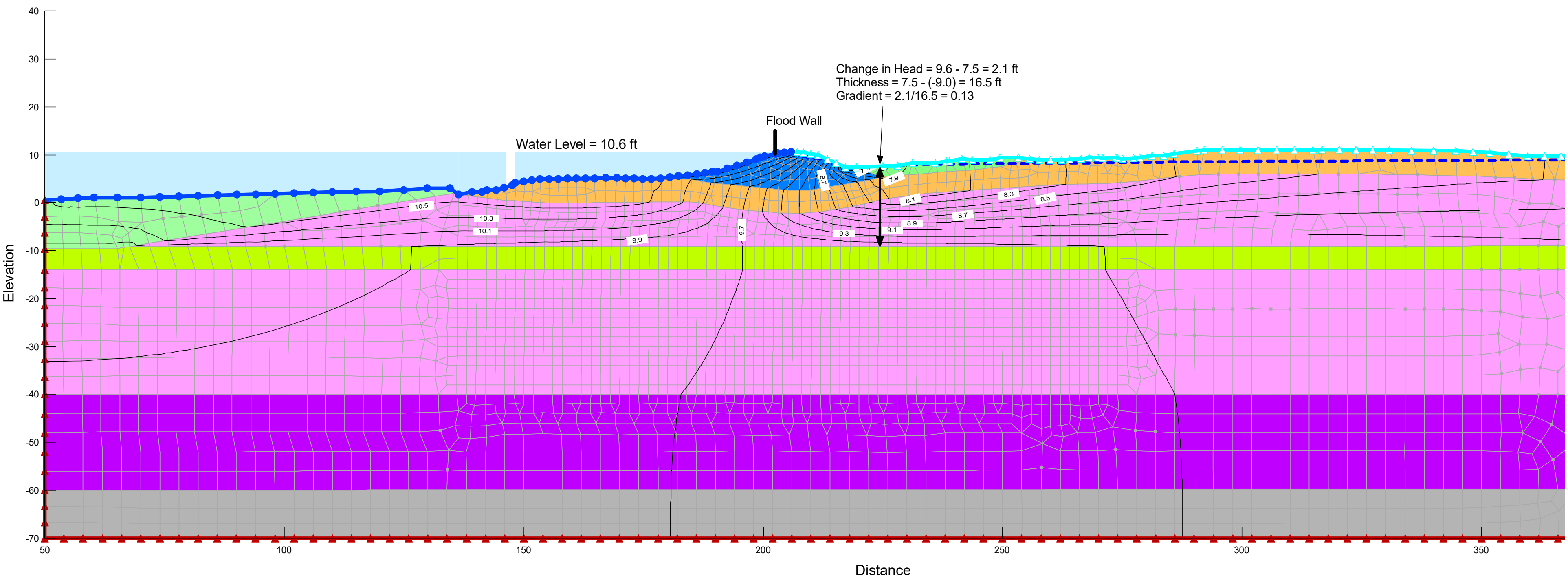
File Name: Corte Madera_Section AA'_2018.gsz
Title: Section AA'
Name: Water Elev. 9.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	10	0
	General Fill	Saturated Only	3.287e-06	0.5	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	63.5	0.6
	Undocumented Fill (A-A')	Saturated Only	3.287e-06	0.5	39.2	0
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	63.7	0.569



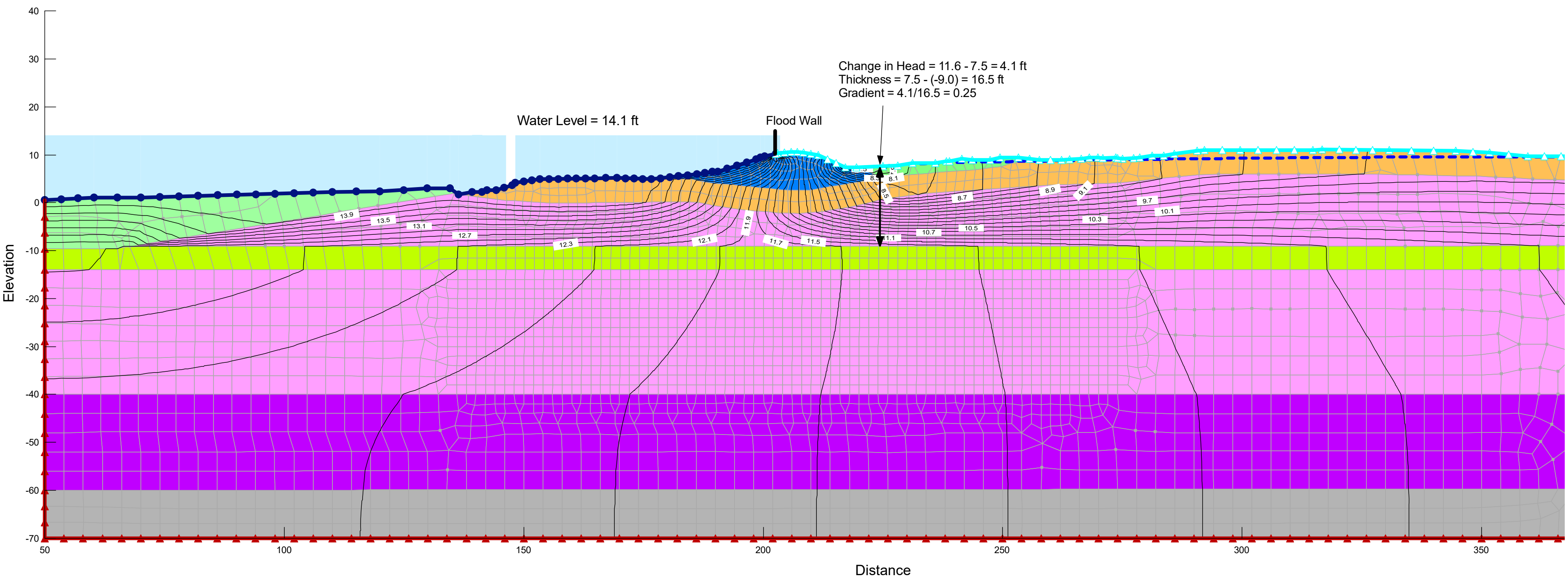
File Name: Corte Madera_Section AA'_2018.gsz
Title: Section AA'
Name: Water Elev. 10.6

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	10	0
	General Fill	Saturated Only	3.287e-06	0.5	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	63.5	0.6
	Undocumented Fill (A-A')	Saturated Only	3.287e-06	0.5	39.2	0
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	63.7	0.569



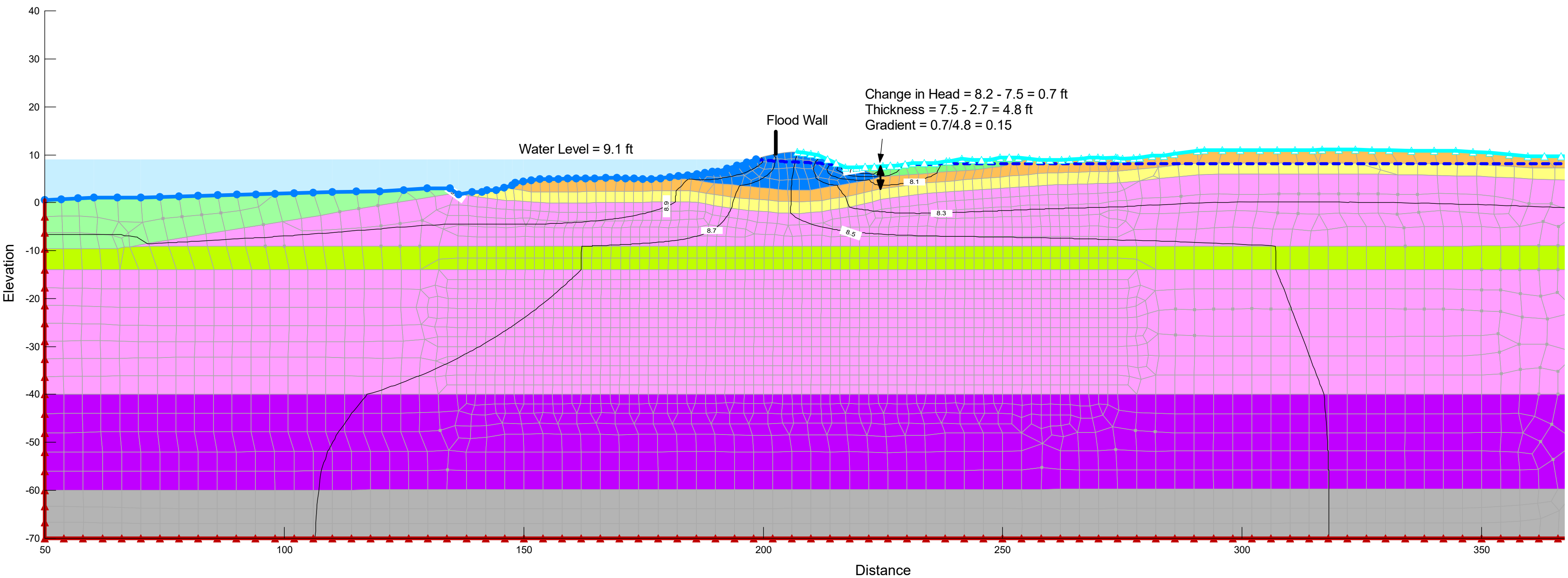
File Name: Corte Madera_Section AA'_2018.gsz
Title: Section AA'
Name: Water Elev. 14.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	10	0
	General Fill	Saturated Only	3.287e-06	0.5	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	63.5	0.6
	Undocumented Fill (A-A')	Saturated Only	3.287e-06	0.5	39.2	0
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	63.7	0.569



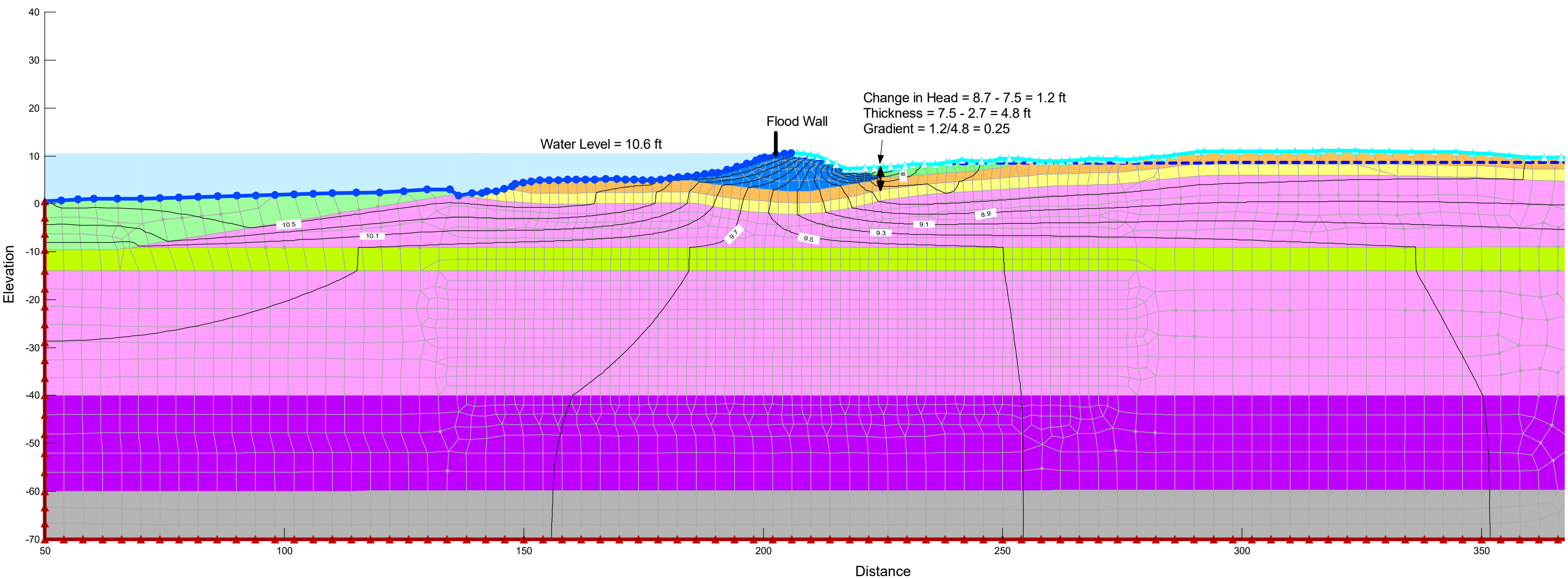
File Name: Corte Madera_Section AA'_Sensitivity_2018.gsz
Title: Section AA'
Name: Water Elev. 9.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	10	0
	General Fill	Saturated Only	3.287e-06	0.5	30.5	0
	General Fill_High K	Saturated Only	3.287e-05	0.5	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	63.5	0.6
	Undocumented Fill (A-A')	Saturated Only	3.287e-06	0.5	39.2	0
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	63.7	0.569



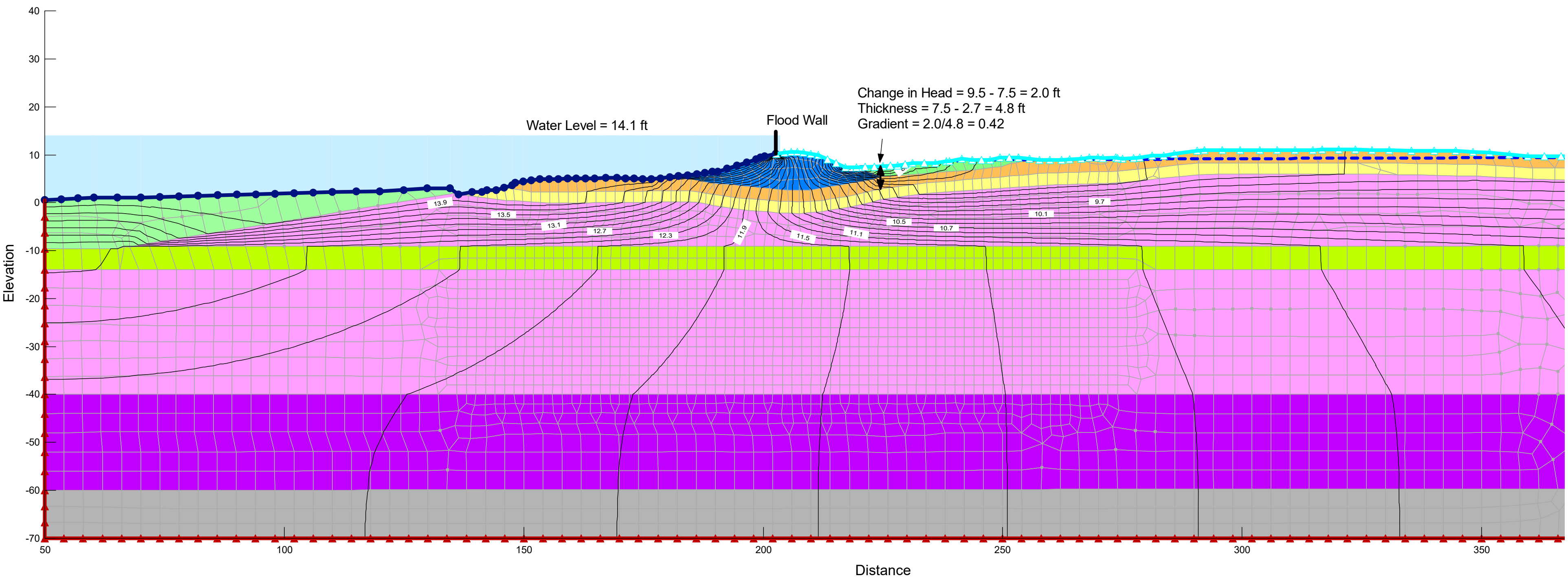
File Name: Corte Madera_Section AA'_Sensitivity_2018.gsz
Title: Section AA'
Name: Water Elev. 10.6

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	10	0
	General Fill	Saturated Only	3.287e-06	0.5	30.5	0
	General Fill_High K	Saturated Only	3.287e-05	0.5	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	63.5	0.6
	Undocumented Fill (A-A')	Saturated Only	3.287e-06	0.5	39.2	0
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	63.7	0.569



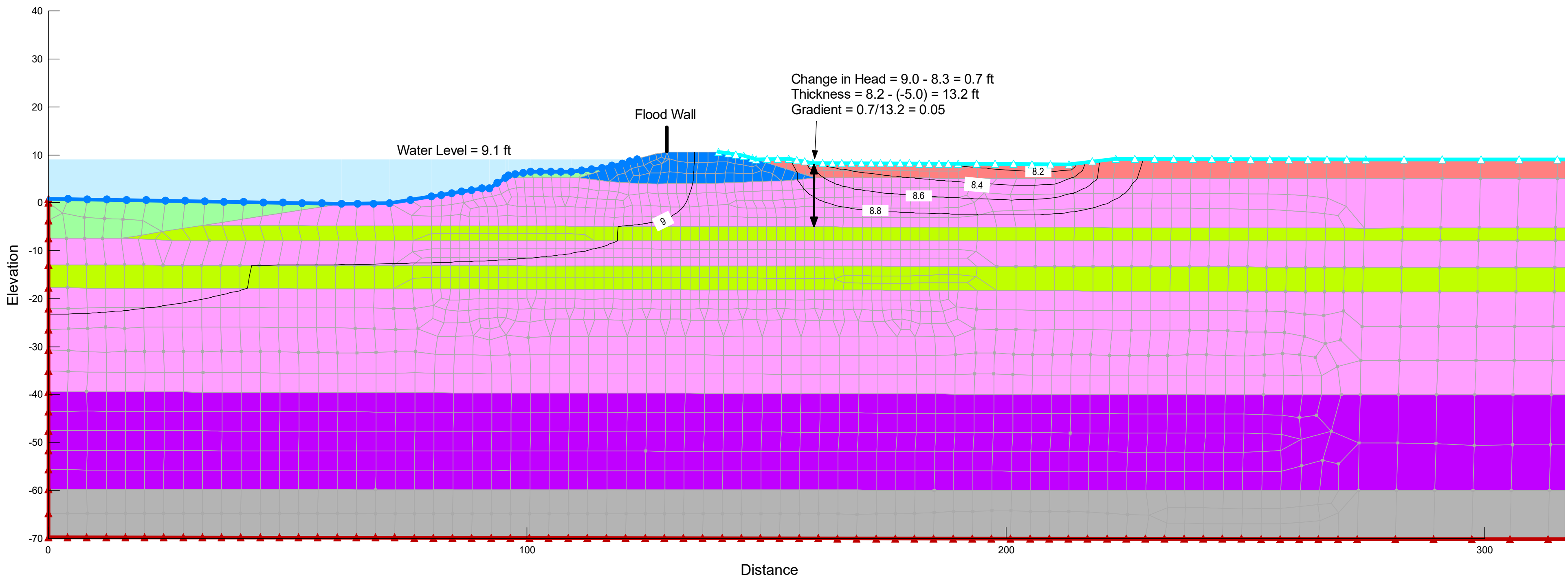
File Name: Corte Madera_Section AA'_Sensitivity_2018.gsz
Title: Section AA'
Name: Water Elev. 14.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	10	0
	General Fill	Saturated Only	3.287e-06	0.5	30.5	0
	General Fill_High K	Saturated Only	3.287e-05	0.5	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	63.5	0.6
	Undocumented Fill (A-A')	Saturated Only	3.287e-06	0.5	39.2	0
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	63.7	0.569



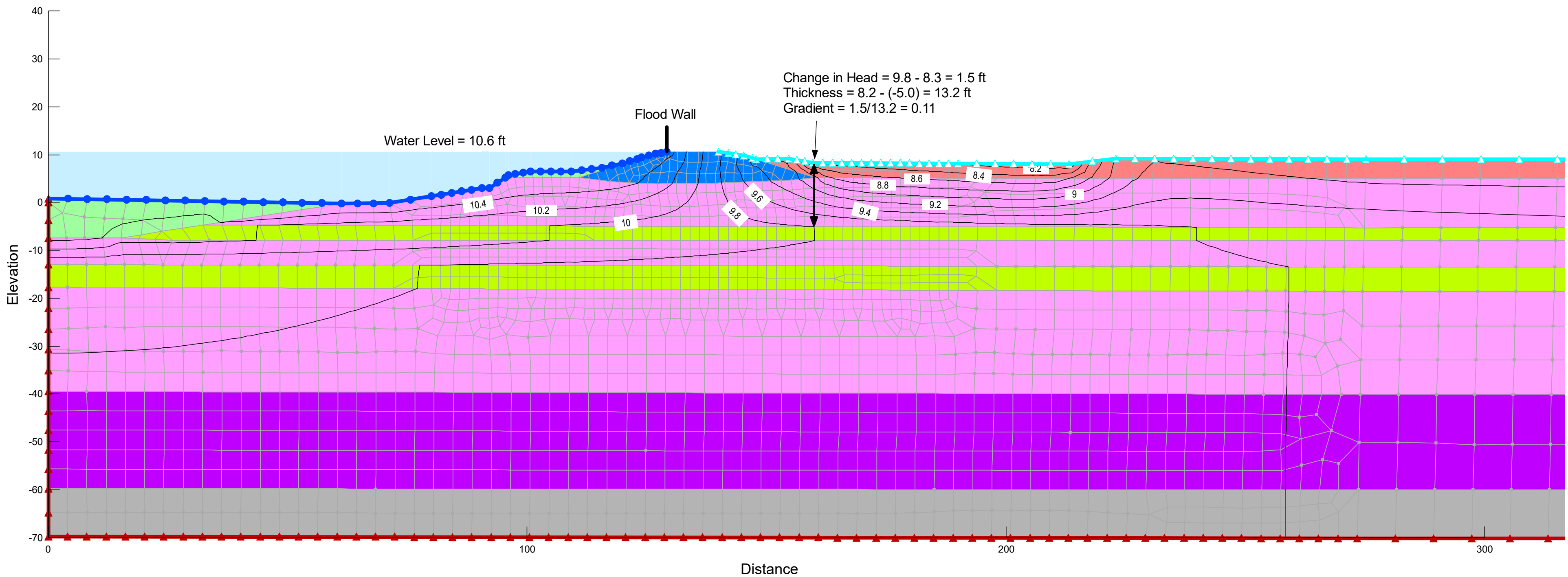
File Name: Corte Madera_Section BB'_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 9.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Undocumented Fill (B-B')	Saturated Only	3.287e-08	0.67	0	63.7	0.569
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



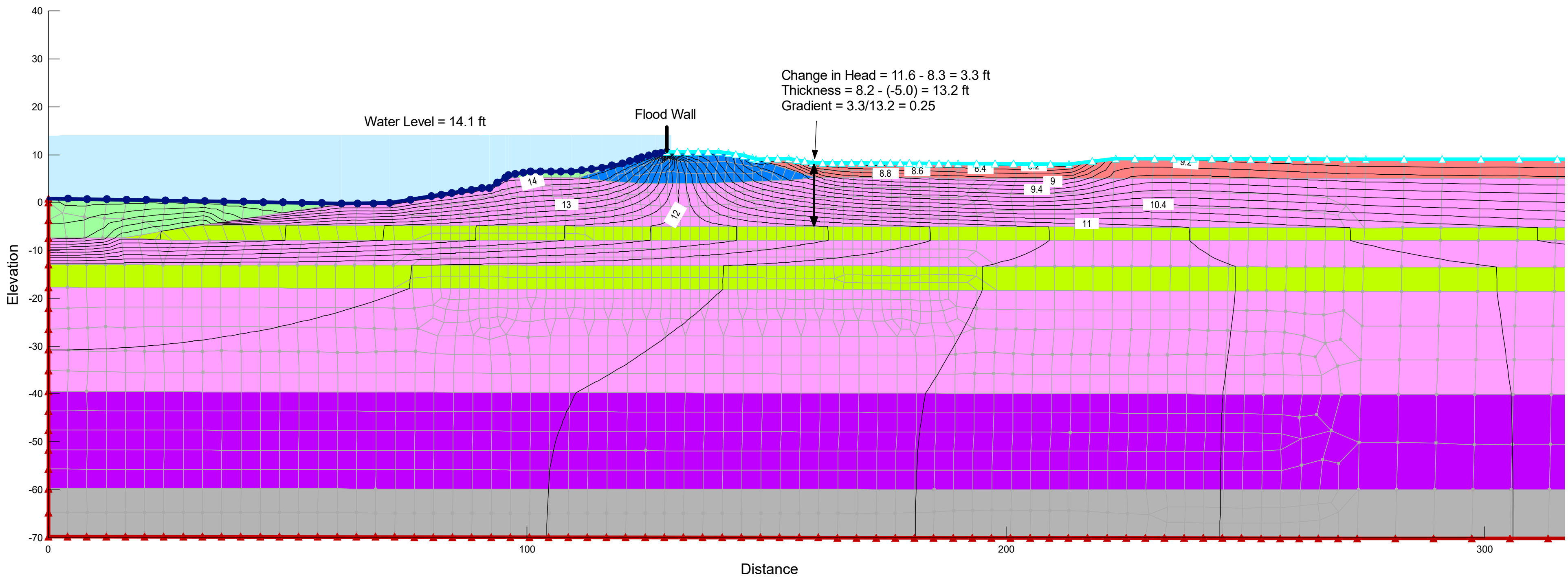
File Name: Corte Madera_Section BB'_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 10.6

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Undocumented Fill (B-B')	Saturated Only	3.287e-08	0.67	0	63.7	0.569
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



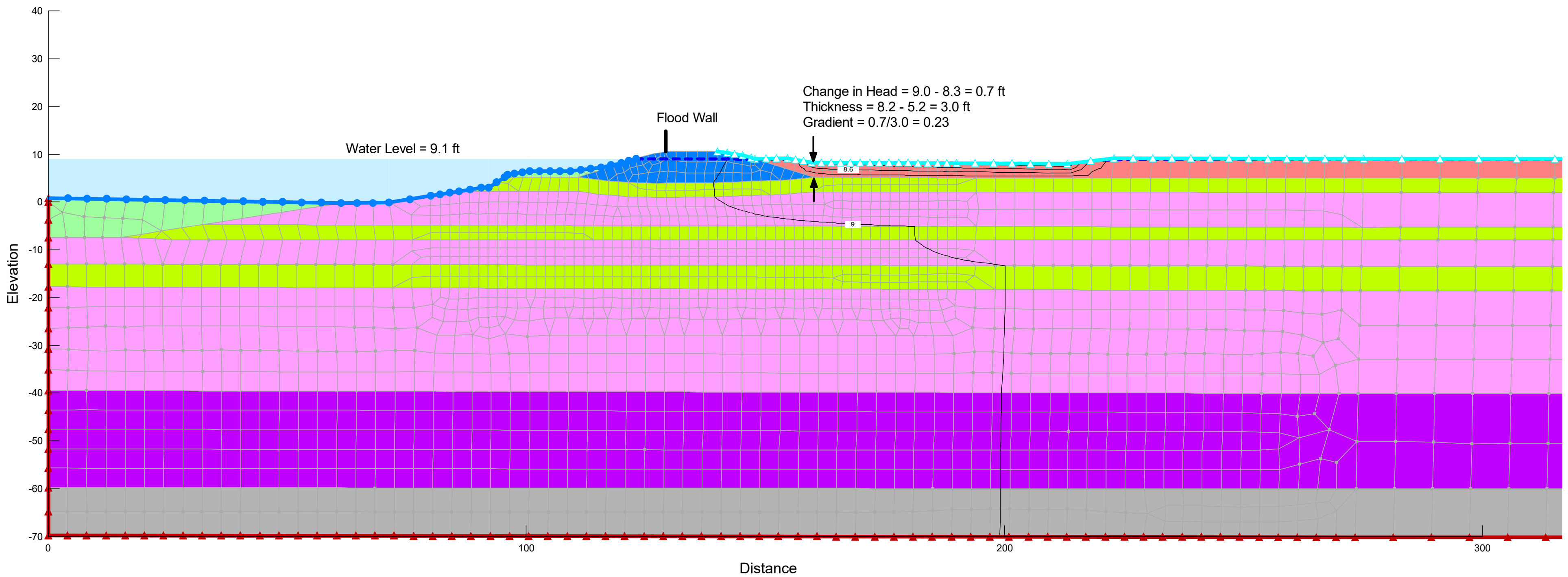
File Name: Corte Madera_Section BB'_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 14.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Undocumented Fill (B-B')	Saturated Only	3.287e-08	0.67	0	63.7	0.569
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



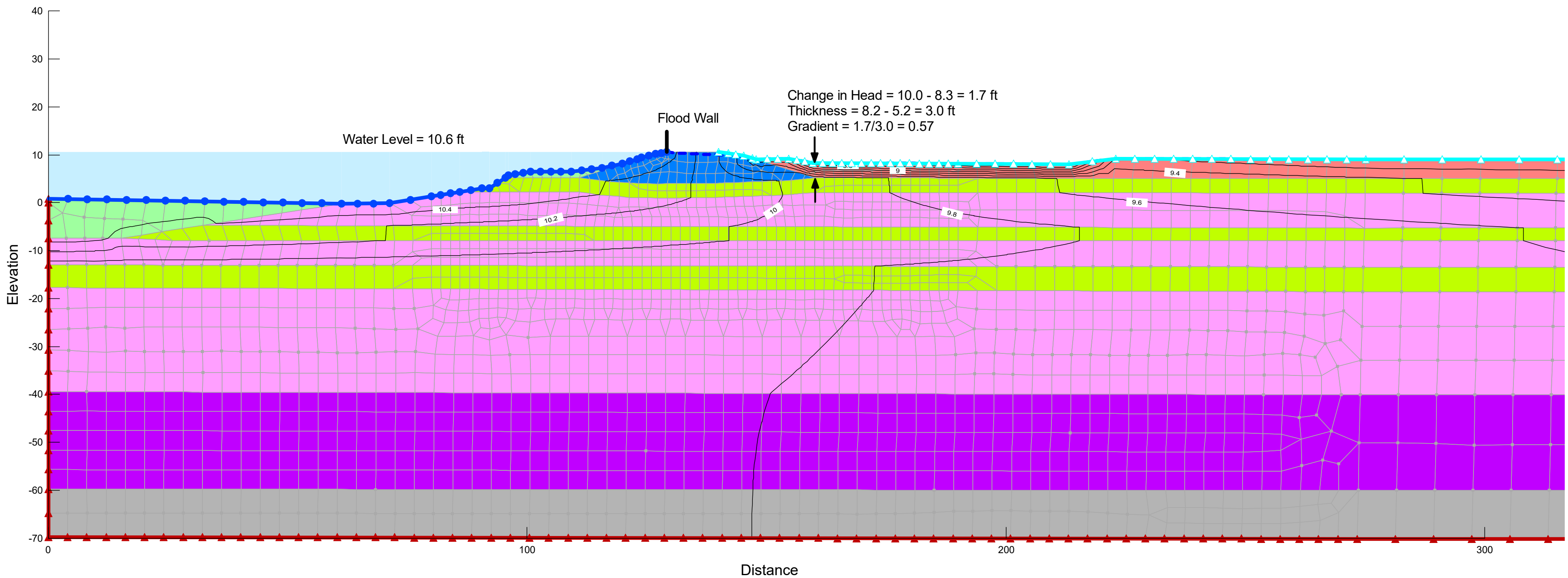
File Name: Corte Madera_Section BB'_Sensitivity_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 9.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Undocumented Fill (B-B')	Saturated Only	3.287e-08	0.67	0	63.7	0.569
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



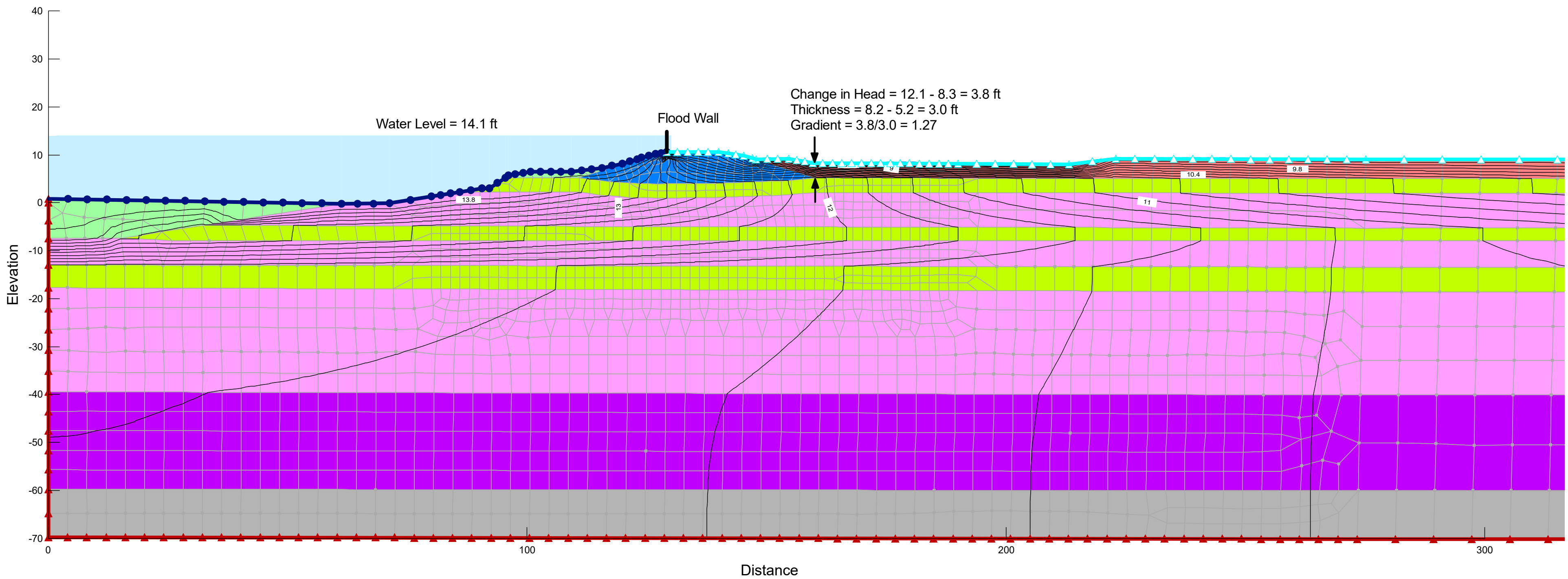
File Name: Corte Madera_Section BB'_Sensitivity_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 10.6

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Undocumented Fill (B-B')	Saturated Only	3.287e-08	0.67	0	63.7	0.569
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



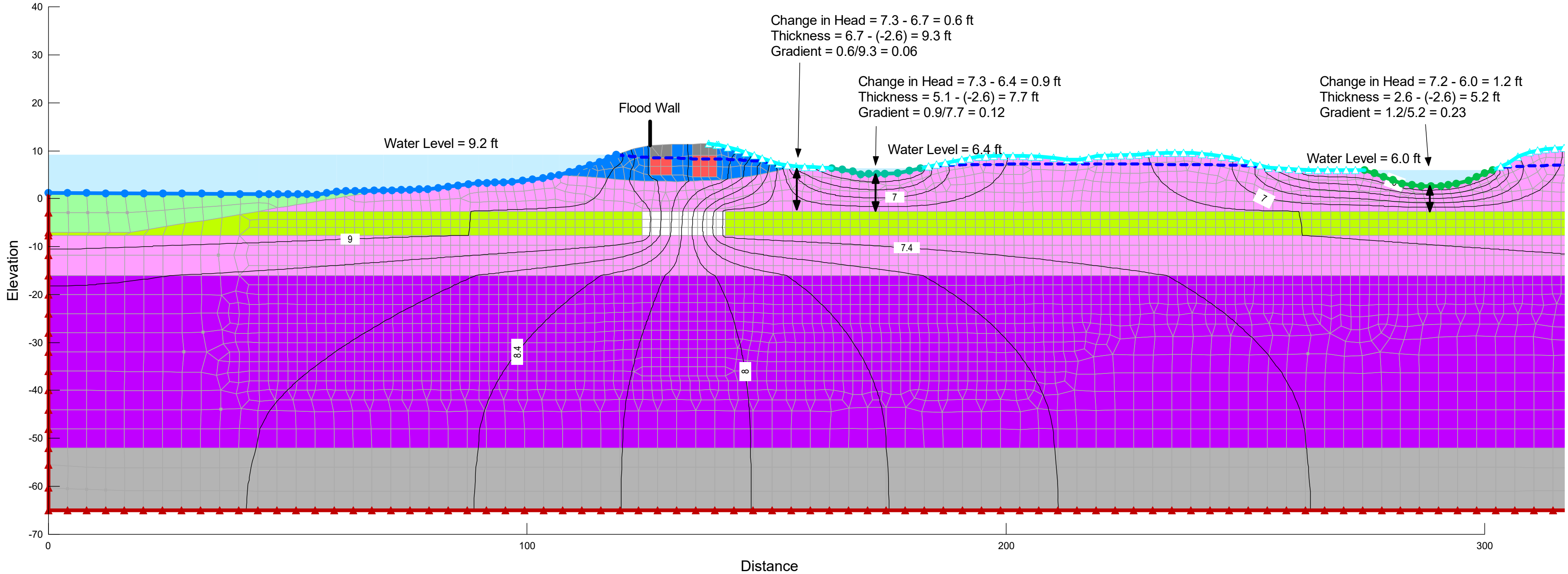
File Name: Corte Madera_Section BB'_Sensitivity_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 14.1

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Undocumented Fill (B-B')	Saturated Only	3.287e-08	0.67	0	63.7	0.569
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



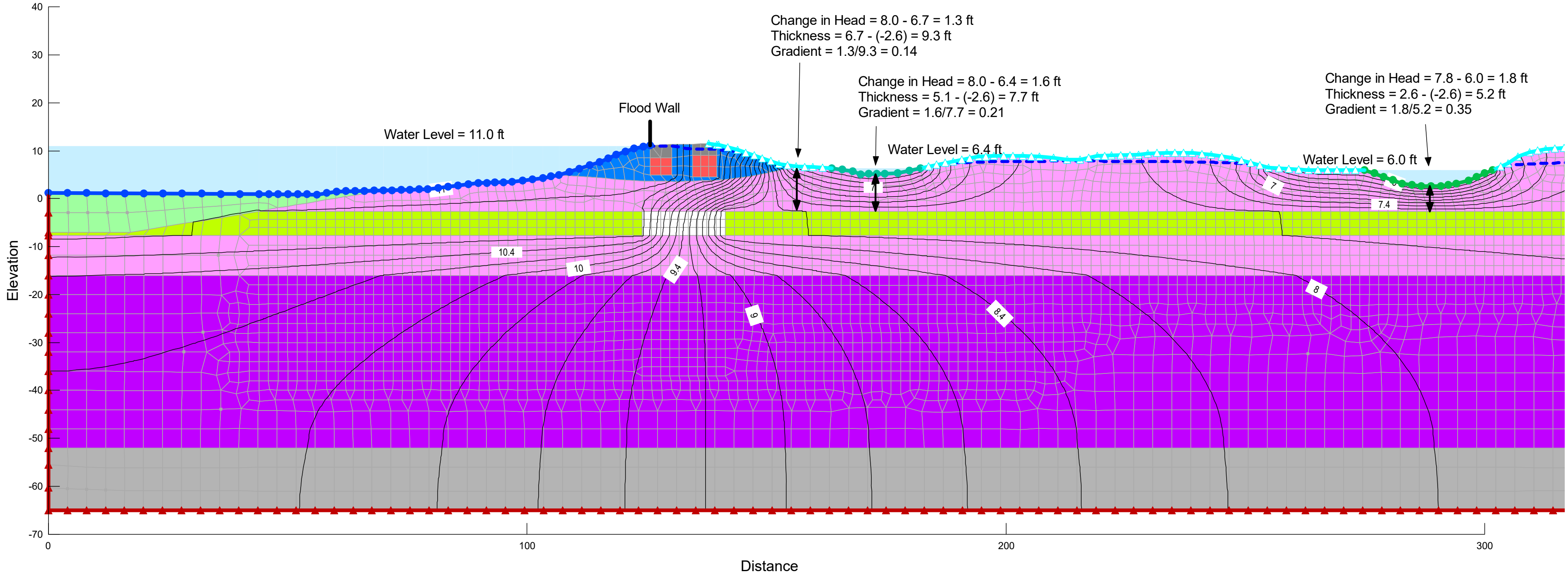
File Name: Corte Madera_Section CC'_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 9.2 with Grout, Both Channels Filled

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	3/4" Crushed Rock	Saturated Only	0.1	1	0	45.6	0
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Class 2 Aggregate Base	Saturated Only	0.01	0.5	0	40	0
	Compaction Grout Zone	Saturated Only	3.287e-07	0.25	0	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



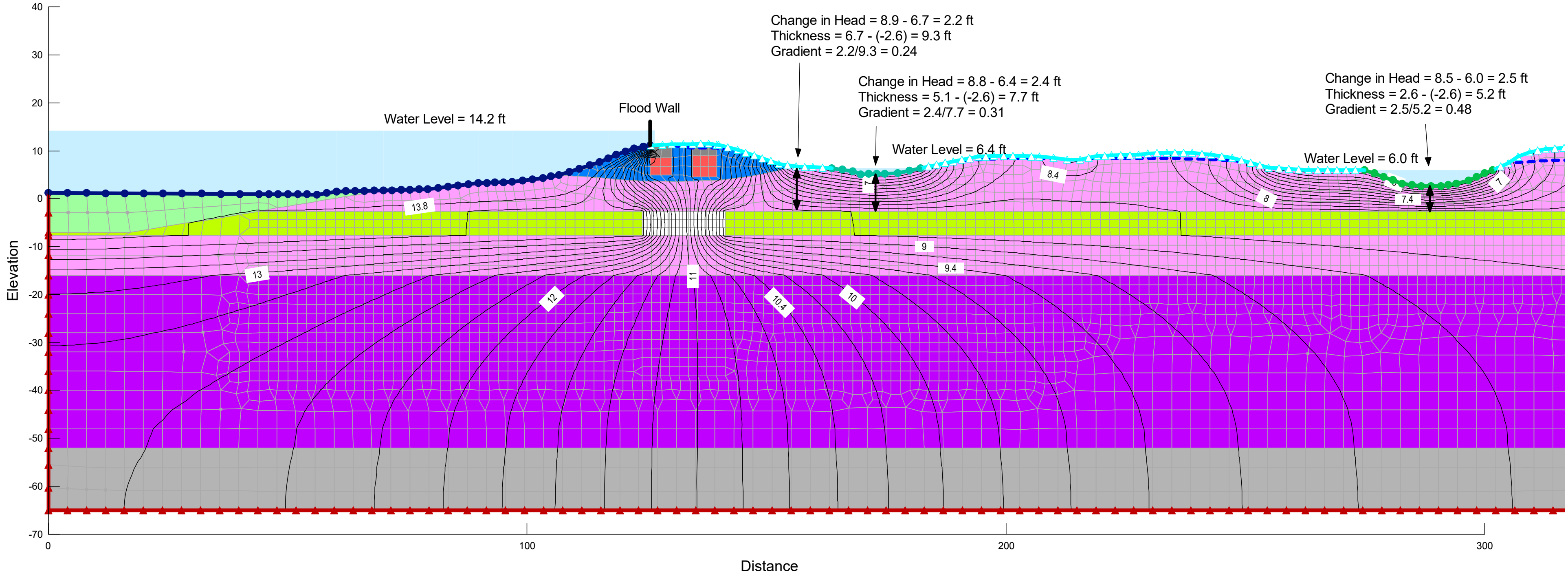
File Name: Corte Madera_Section CC'_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 11.0 with Grout, Both Channels Filled

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	3/4" Crushed Rock	Saturated Only	0.1	1	0	45.6	0
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Class 2 Aggregate Base	Saturated Only	0.01	0.5	0	40	0
	Compaction Grout Zone	Saturated Only	3.287e-07	0.25	0	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



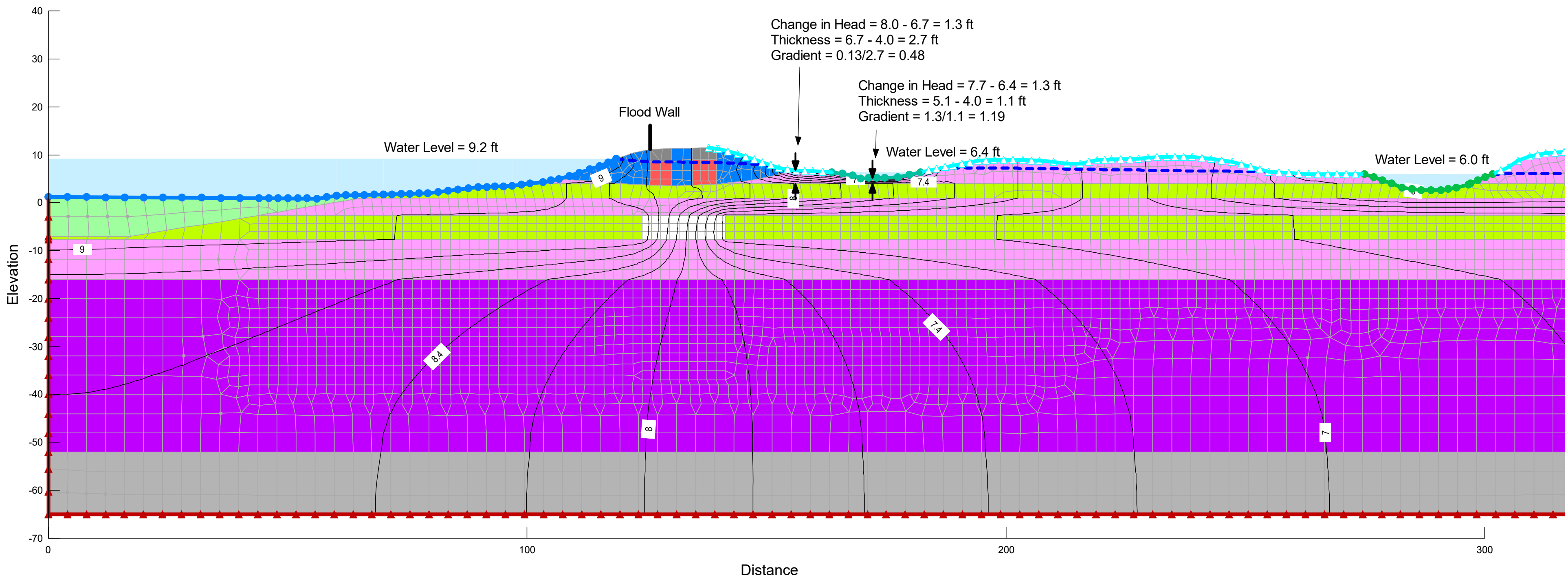
File Name: Corte Madera_Section CC'_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 14.2 with Grout, Both Channels Filled

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	3/4" Crushed Rock	Saturated Only	0.1	1	0	45.6	0
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Class 2 Aggregate Base	Saturated Only	0.01	0.5	0	40	0
	Compaction Grout Zone	Saturated Only	3.287e-07	0.25	0	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



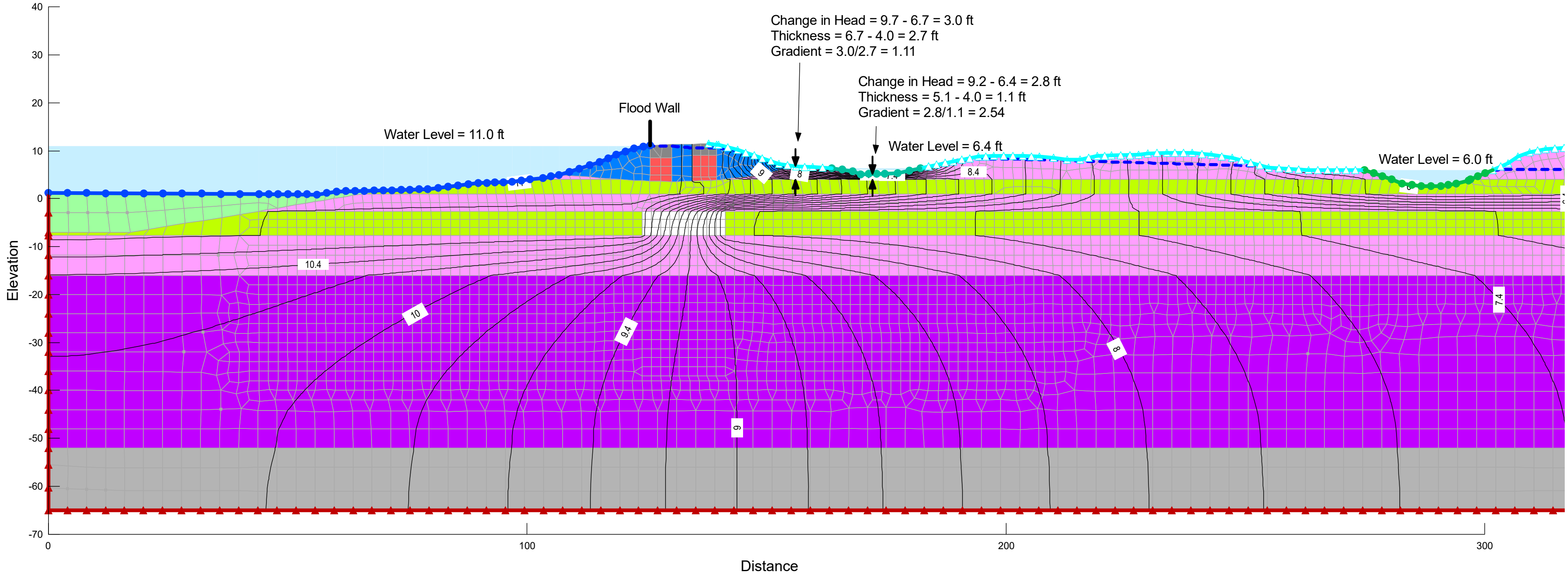
File Name: Corte Madera_Section CC'_Sensitivity_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 9.2 with Grout, Both Channels Filled

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	3/4" Crushed Rock	Saturated Only	0.1	1	0	45.6	0
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Class 2 Aggregate Base	Saturated Only	0.01	0.5	0	40	0
	Compaction Grout Zone	Saturated Only	3.287e-07	0.25	0	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



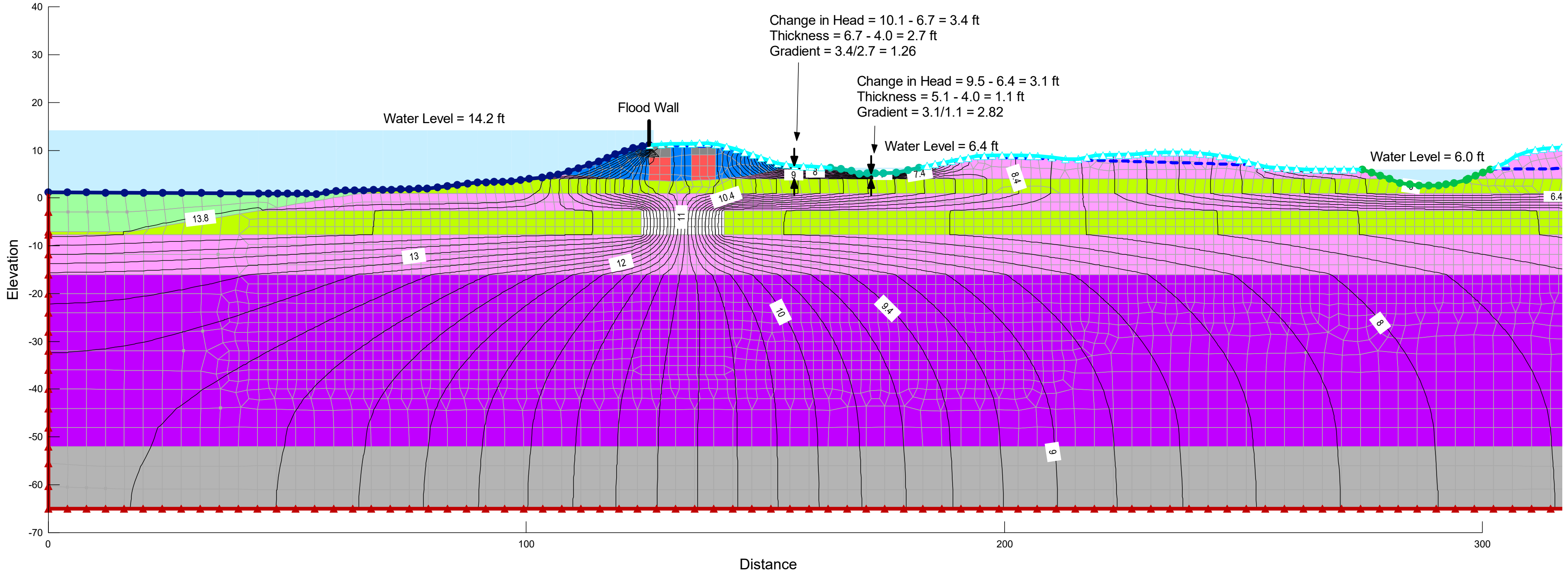
File Name: Corte Madera_Section CC'_Sensitivity_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 11.0 with Grout, Both Channels Filled

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	3/4" Crushed Rock	Saturated Only	0.1	1	0	45.6	0
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Class 2 Aggregate Base	Saturated Only	0.01	0.5	0	40	0
	Compaction Grout Zone	Saturated Only	3.287e-07	0.25	0	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569



File Name: Corte Madera_Section CC'_Sensitivity_2018.gsz
Title: Corte Madera Levee Alternatives
Name: Water Elev. 14.2 with Grout, Both Channels Filled

Color	Name	Model	Sat Kx (ft/sec)	Ky'/Kx' Ratio	Rotation (°)	Volumetric Water Content	Beta (/psf)
	3/4" Crushed Rock	Saturated Only	0.1	1	0	45.6	0
	Bedrock	Saturated Only	1e-14	1	0	10	0
	Class 2 Aggregate Base	Saturated Only	0.01	0.5	0	40	0
	Compaction Grout Zone	Saturated Only	3.287e-07	0.25	0	30.5	0
	Levee Fill	Saturated Only	3.287e-07	0.25	0	33.5	0
	Lower Marsh Deposits	Saturated Only	3.287e-07	0.25	0	39.5	0.244
	Sand and Gravel Layers	Saturated Only	3.287e-05	0.25	0	33.5	0
	Sedimentation	Saturated Only	3.287e-07	0.67	0	63.5	0.6
	Upper Marsh Deposits	Saturated Only	3.287e-08	0.67	0	63.7	0.569

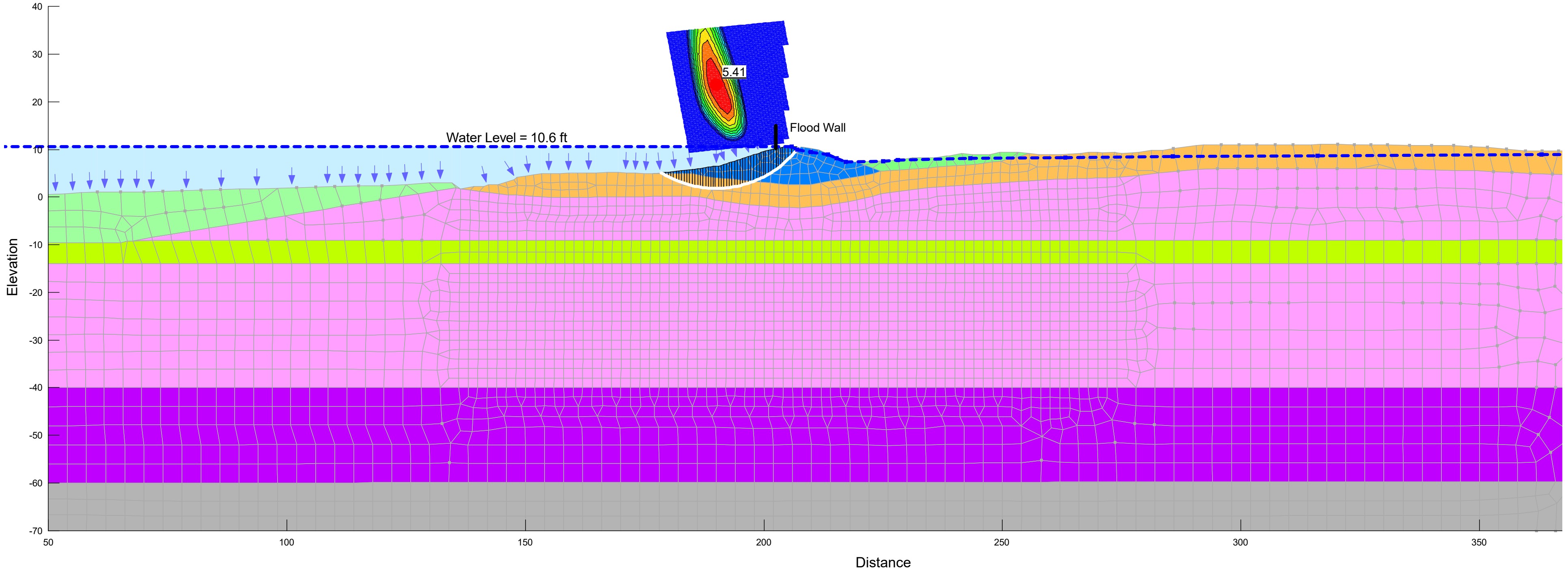


APPENDIX B

Slope Stability Analysis

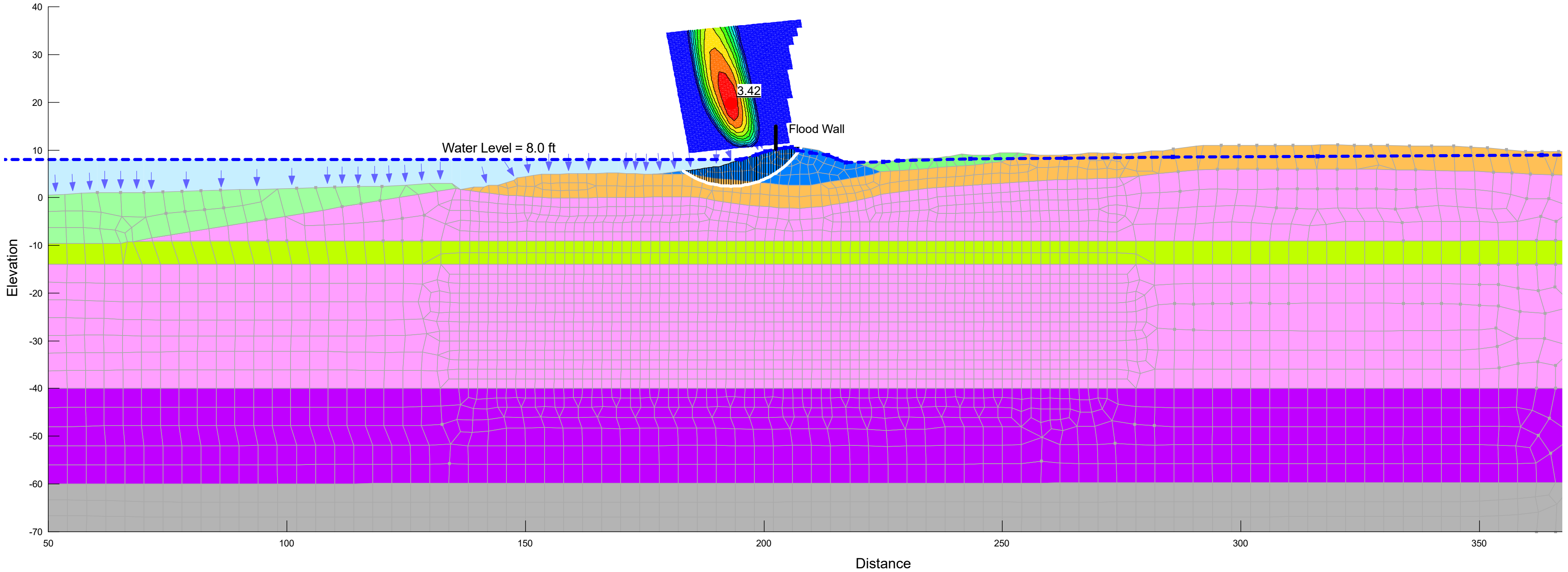
File Name: Corte Madera_Section AA'_2018 - Stability.gsz
Title: Section AA'
Name: Stability on Waterside-Before Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)					1
	General Fill	Mohr-Coulomb	130	0	36	0	1
	Levee Fill	Mohr-Coulomb	125	150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125	600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130	0	35	0	1
	Sedimentation	Mohr-Coulomb	100	50	0	0	1
	Undocumented Fill (A-A')	Mohr-Coulomb	125	0	36	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110	375	21	0	1



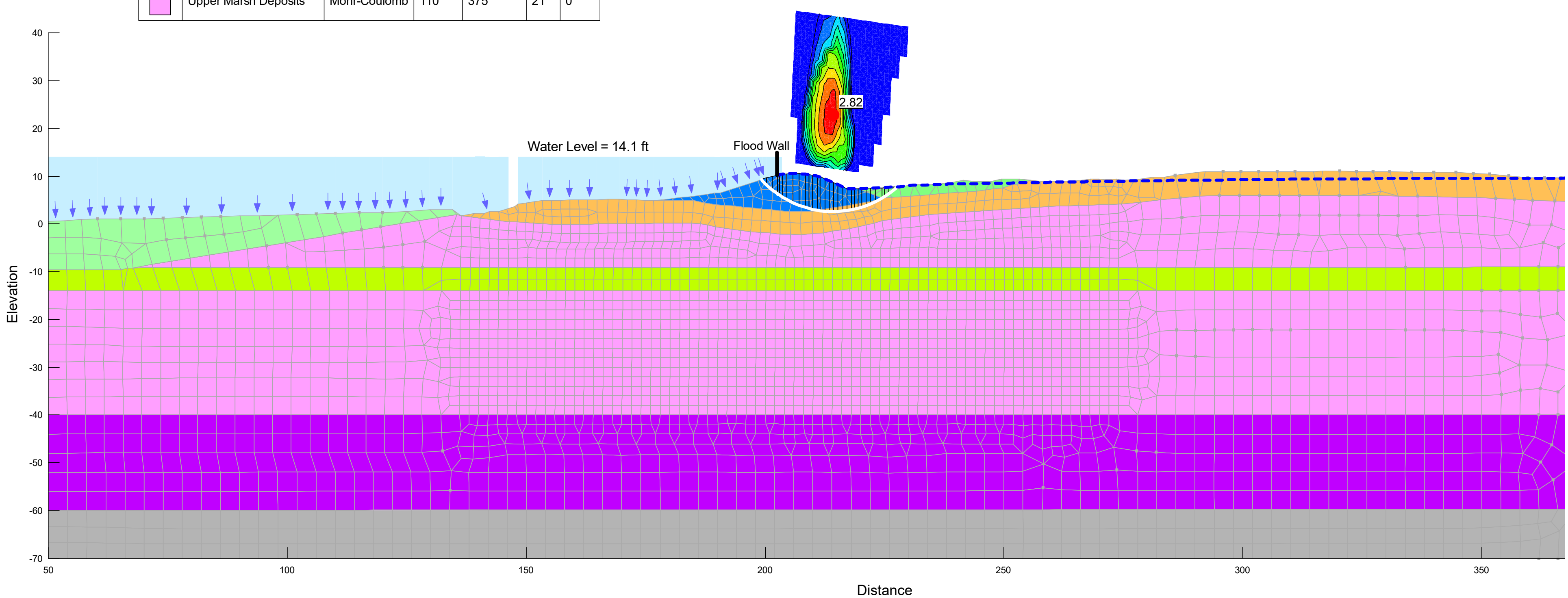
File Name: Corte Madera_Section AA'_2018 - Stability.gsz
Title: Section AA'
Name: Stability on Waterside-After Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)					1
	General Fill	Mohr-Coulomb	130	0	36	0	1
	Levee Fill	Mohr-Coulomb	125	150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125	600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130	0	35	0	1
	Sedimentation	Mohr-Coulomb	100	50	0	0	1
	Undocumented Fill (A-A')	Mohr-Coulomb	125	0	36	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110	375	21	0	1



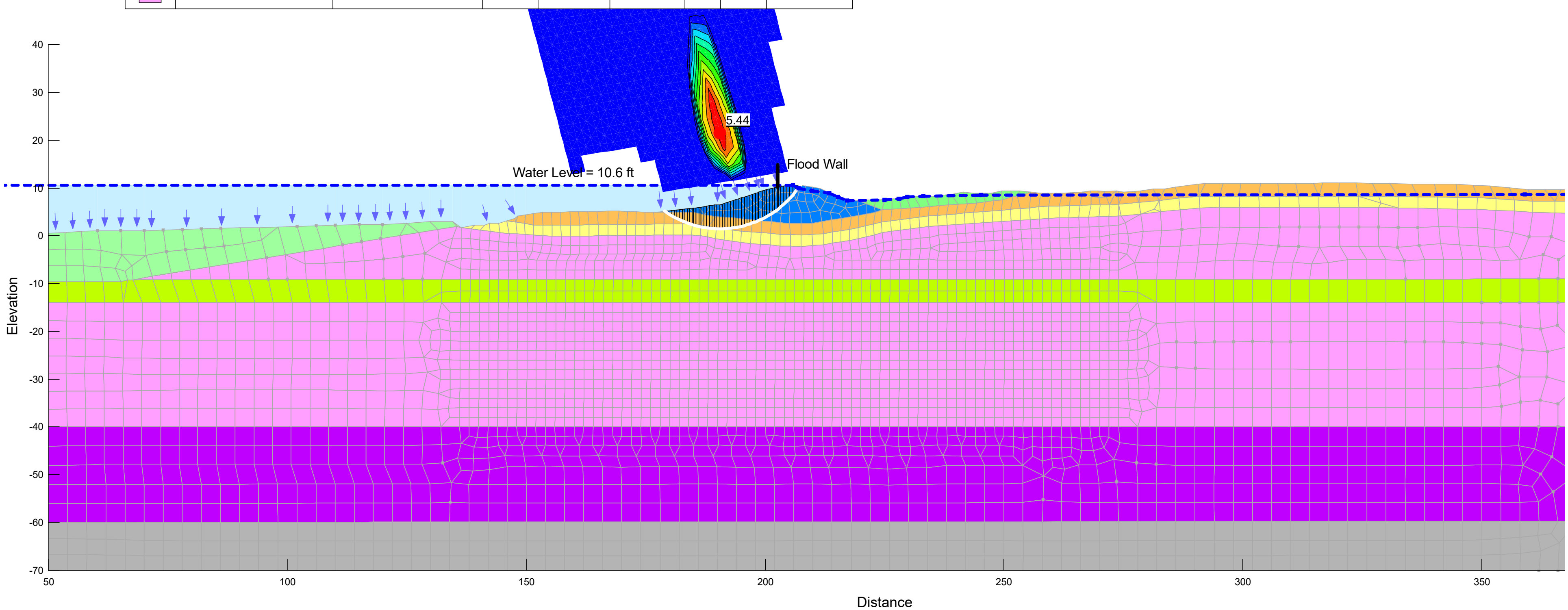
File Name: Corte Madera_Section AA'_2018 - Stability.gsz
Title: Section AA'
Name: Stability on Landside

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Bedrock (Impenetrable)				
	General Fill	Mohr-Coulomb	130	0	36	0
	Levee Fill	Mohr-Coulomb	125	150	32	0
	Lower Marsh Deposits	Mohr-Coulomb	125	600	29	0
	Sand and Gravel Layers	Mohr-Coulomb	130	0	35	0
	Sedimentation	Mohr-Coulomb	100	50	0	0
	Undocumented Fill (A-A')	Mohr-Coulomb	125	0	36	0
	Upper Marsh Deposits	Mohr-Coulomb	110	375	21	0



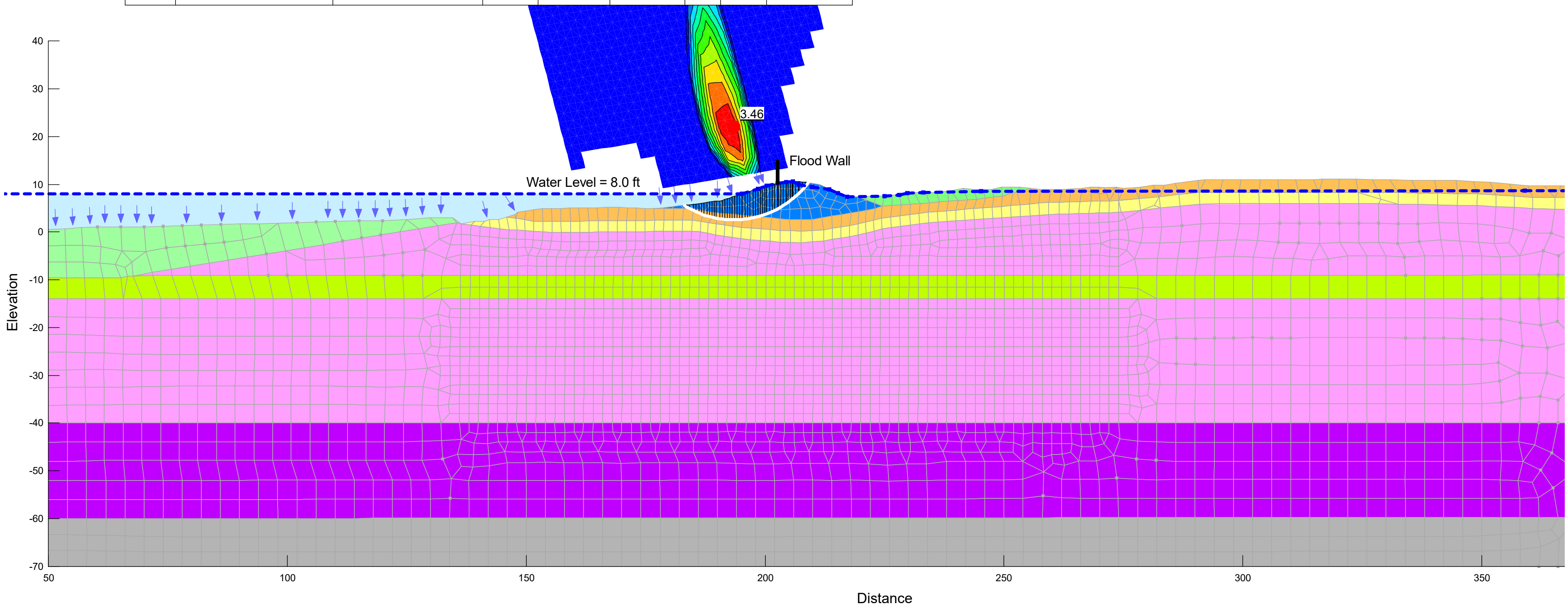
File Name: Corte Madera_Section AA'_Sensitivity_2018 - Stability.gsz
Title: Section AA'
Name: Stability on Waterside-Before Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)						1
	General Fill	Mohr-Coulomb	130		0	36	0	1
	General Fill_High K	Mohr-Coulomb	130		0	36	0	1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Undocumented Fill (A-A')	Mohr-Coulomb	125		50	30	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



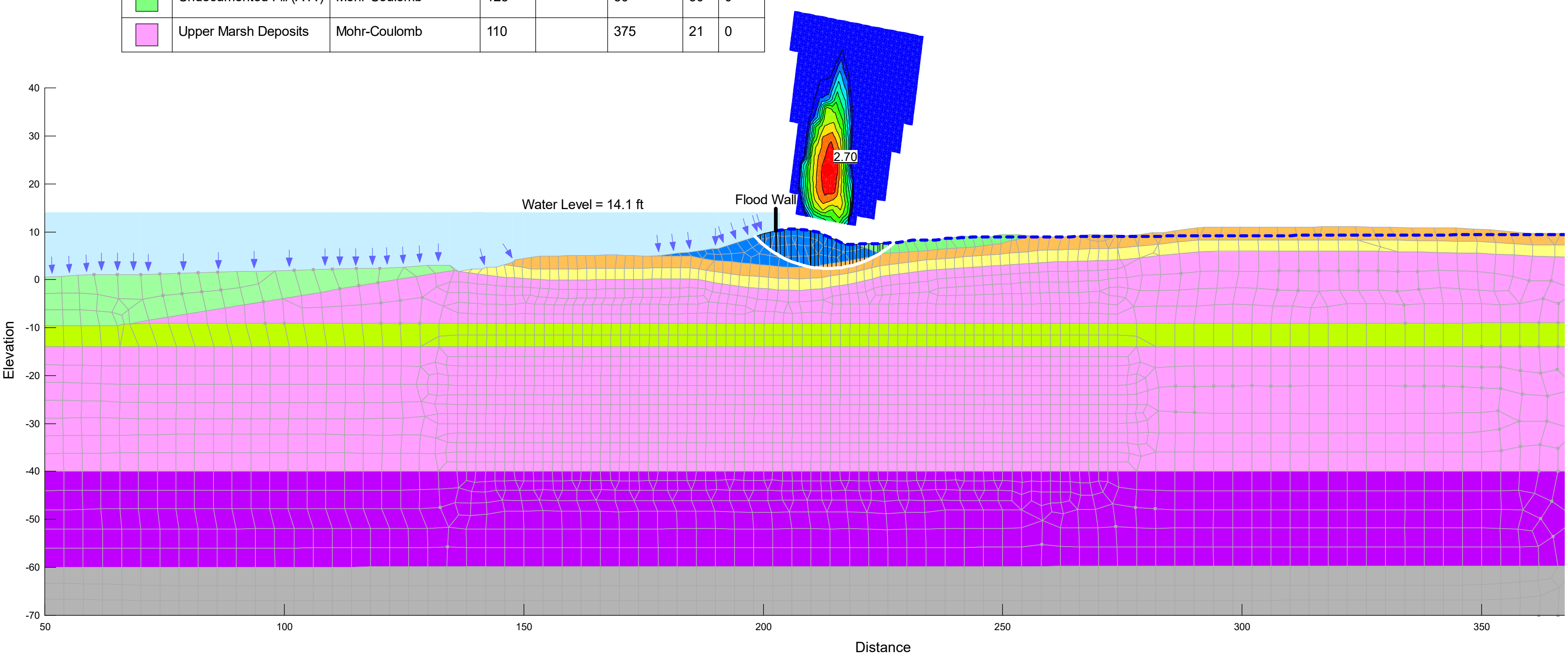
File Name: Corte Madera_Section AA'_Sensitivity_2018 - Stability.gsz
Title: Section AA'
Name: Stability on Waterside-After Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)						1
	General Fill	Mohr-Coulomb	130		0	36	0	1
	General Fill_High K	Mohr-Coulomb	130		0	36	0	1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Undocumented Fill (A-A')	Mohr-Coulomb	125		50	30	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



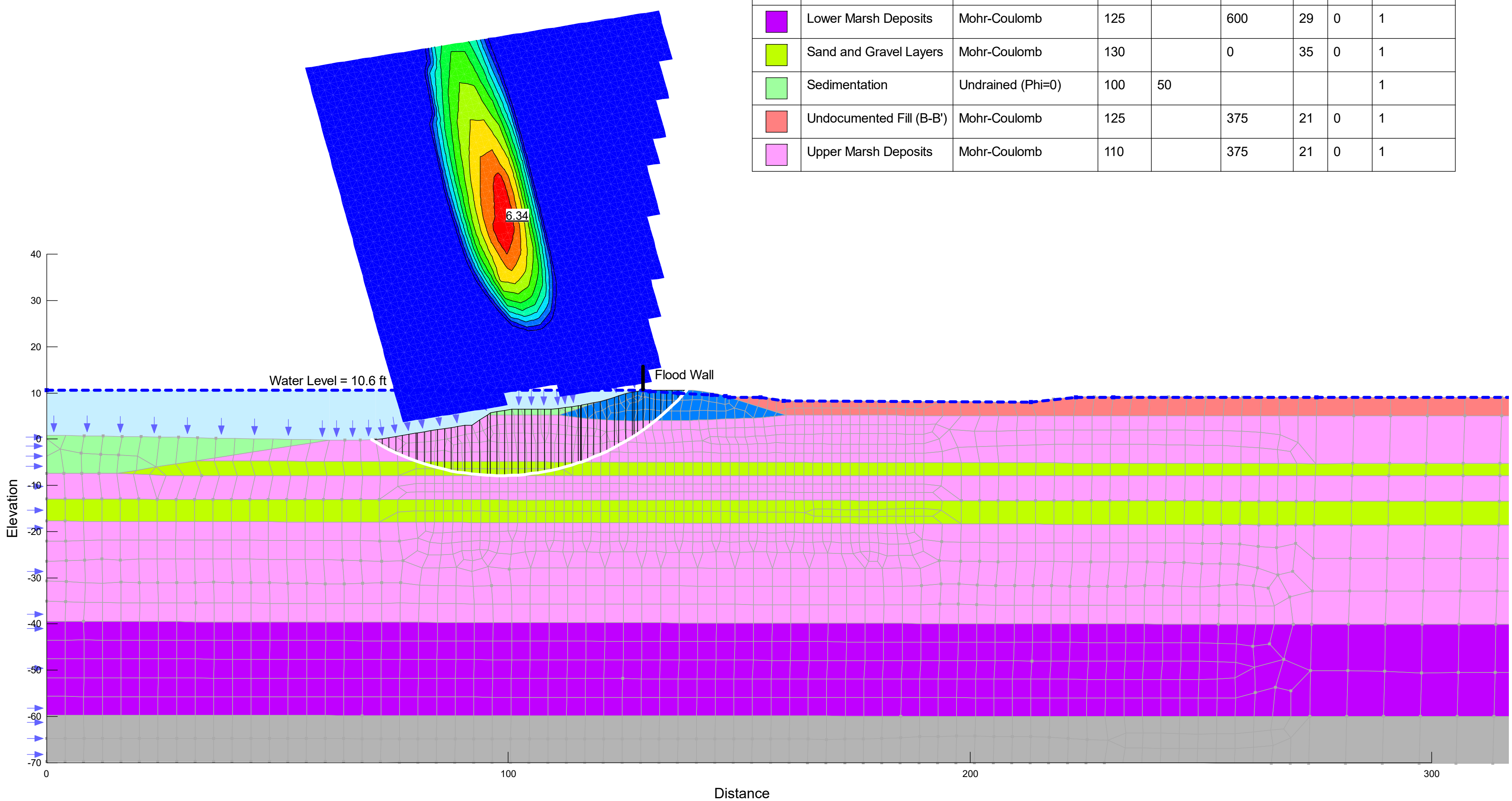
File Name: Corte Madera_Section AA'_Sensitivity_2018 - Stability.gsz
Title: Section AA'
Name: Stability on Landside

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Bedrock (Impenetrable)					
	General Fill	Mohr-Coulomb	130		0	36	0
	General Fill_High K	Mohr-Coulomb	130		0	36	0
	Levee Fill	Mohr-Coulomb	125		150	32	0
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0
	Sedimentation	Undrained (Phi=0)	100	50			
	Undocumented Fill (A-A')	Mohr-Coulomb	125		50	30	0
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0



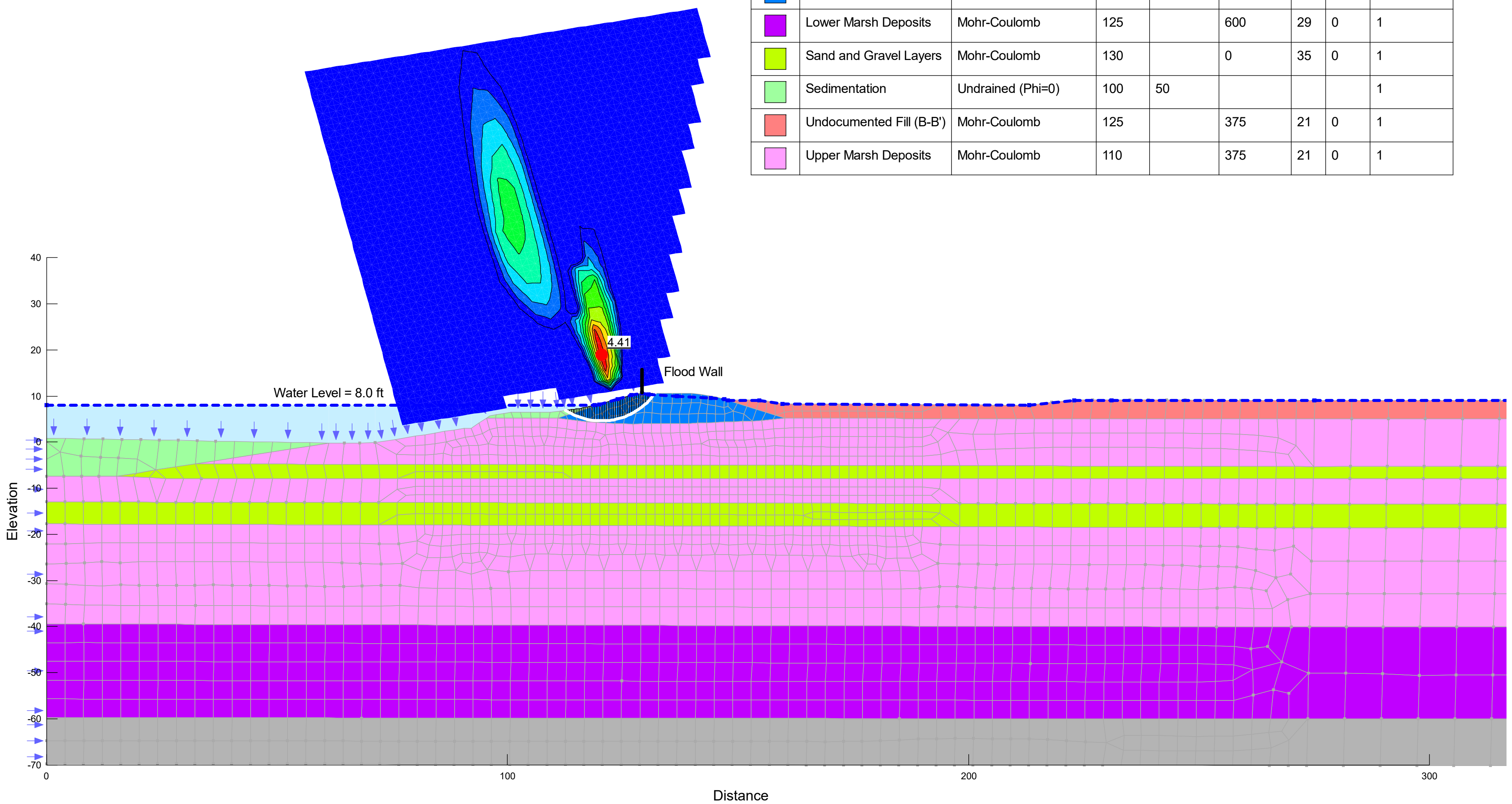
File Name: Corte Madera_Section BB'_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-Before Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)						1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Undocumented Fill (B-B')	Mohr-Coulomb	125		375	21	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



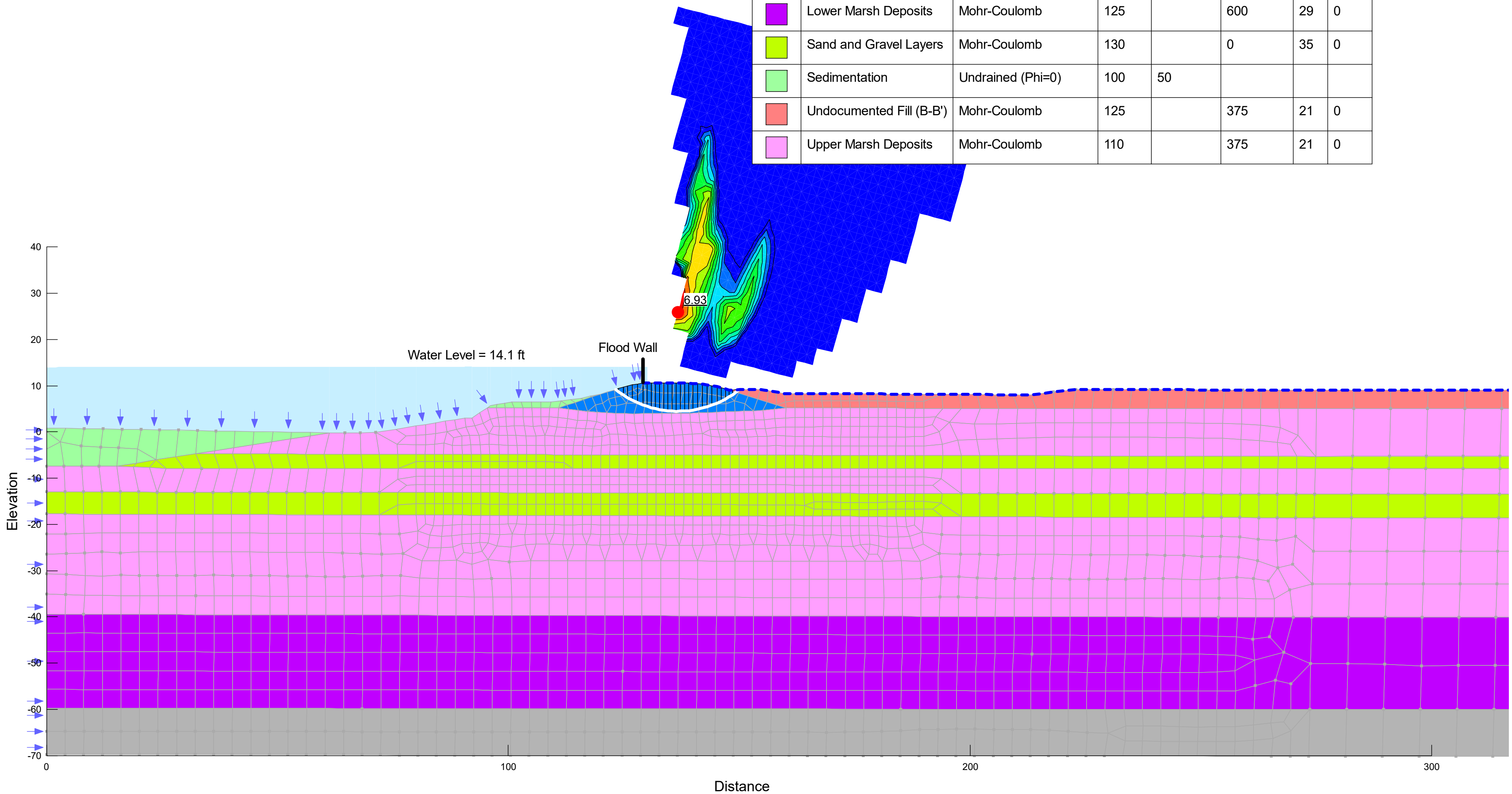
File Name: Corte Madera_Section BB'_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-After Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)						1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Undocumented Fill (B-B')	Mohr-Coulomb	125		375	21	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



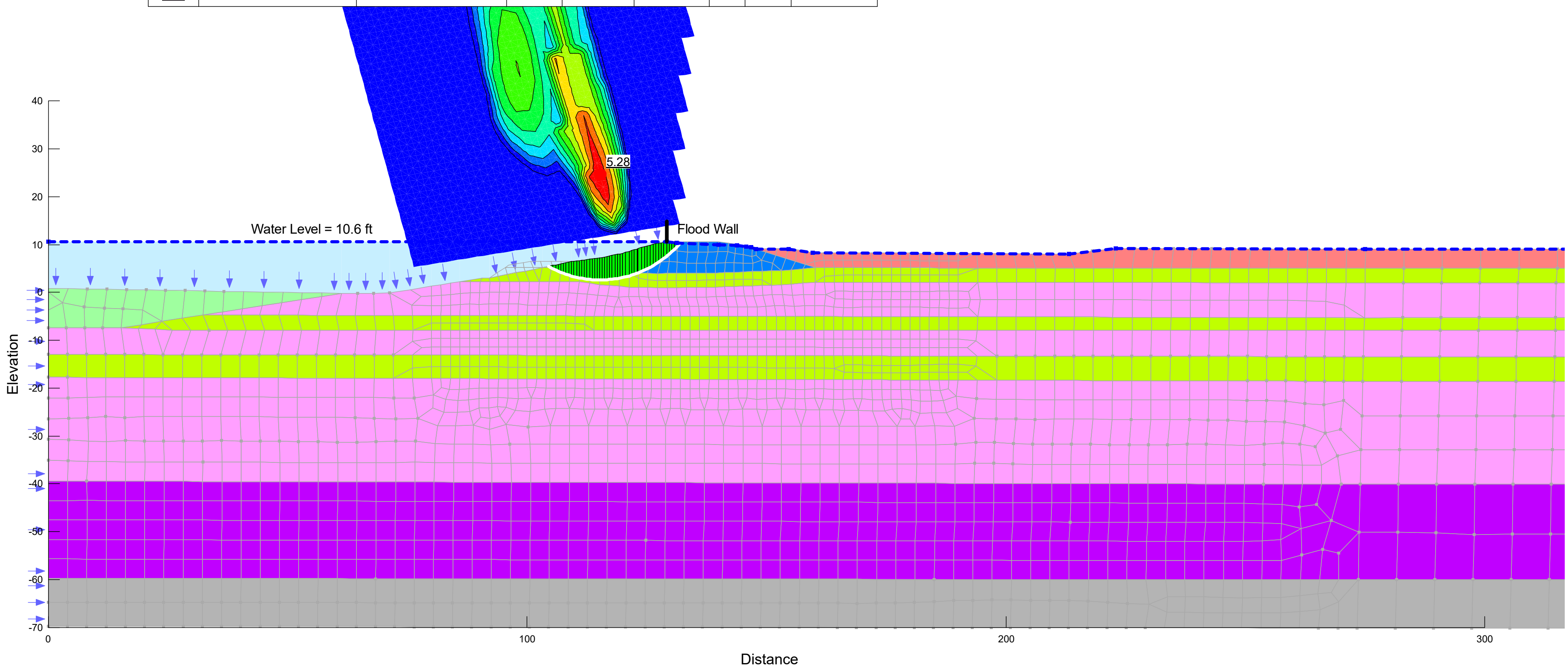
File Name: Corte Madera_Section BB'_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Landside

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Bedrock (Impenetrable)					
	Levee Fill	Mohr-Coulomb	125		150	32	0
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0
	Sedimentation	Undrained (Phi=0)	100	50			
	Undocumented Fill (B-B')	Mohr-Coulomb	125		375	21	0
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0



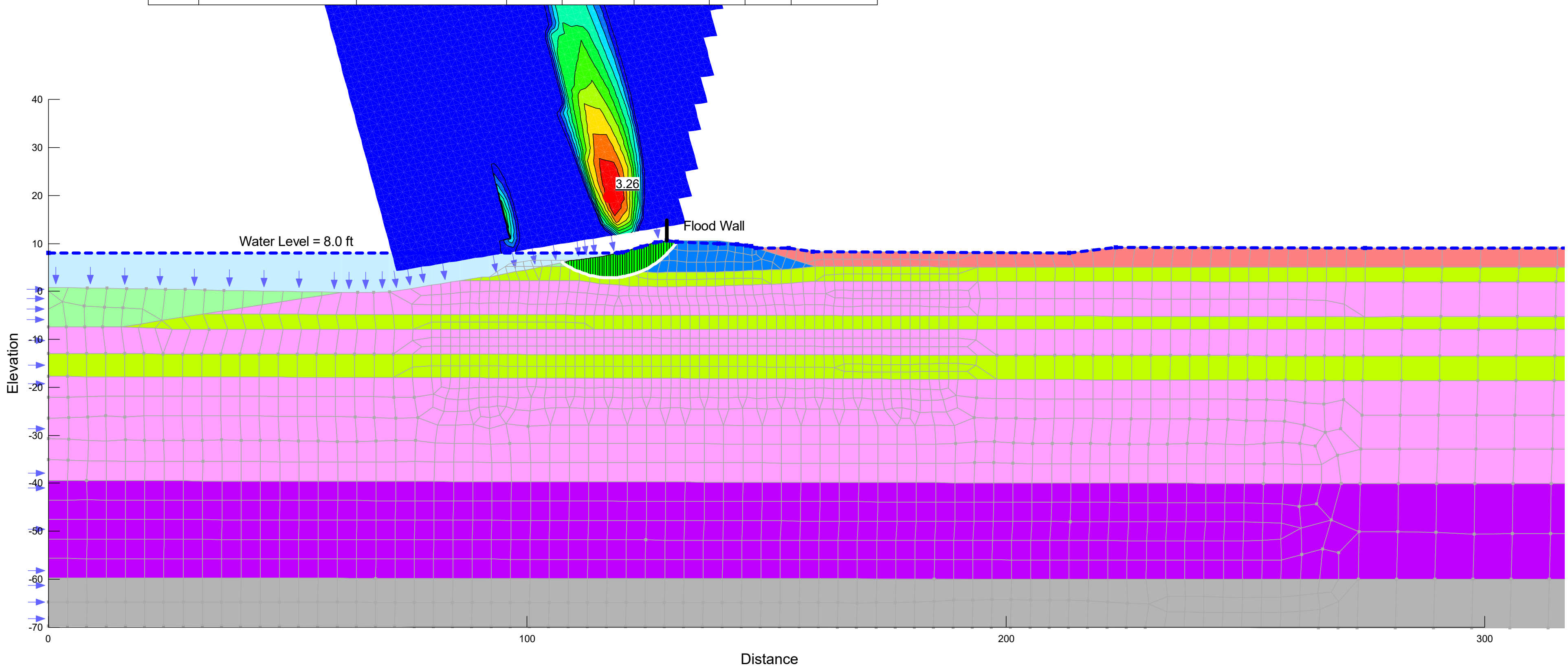
File Name: Corte Madera_Section BB'_Sensitivity_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-Before Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)						1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Undocumented Fill (B-B')	Mohr-Coulomb	125		375	21	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



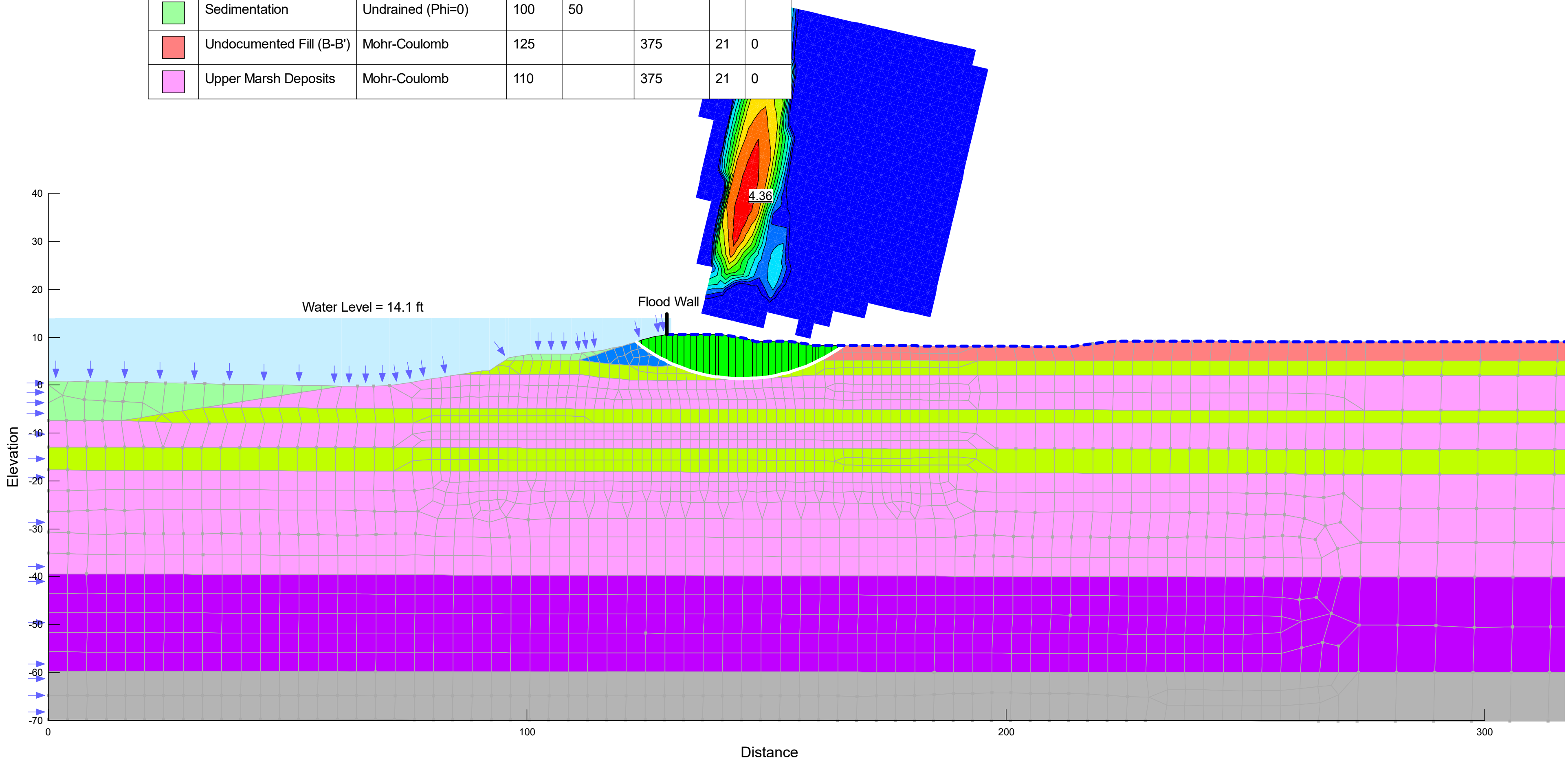
File Name: Corte Madera_Section BB'_Sensitivity_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-After Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	Bedrock	Bedrock (Impenetrable)						1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Undocumented Fill (B-B')	Mohr-Coulomb	125		375	21	0	1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



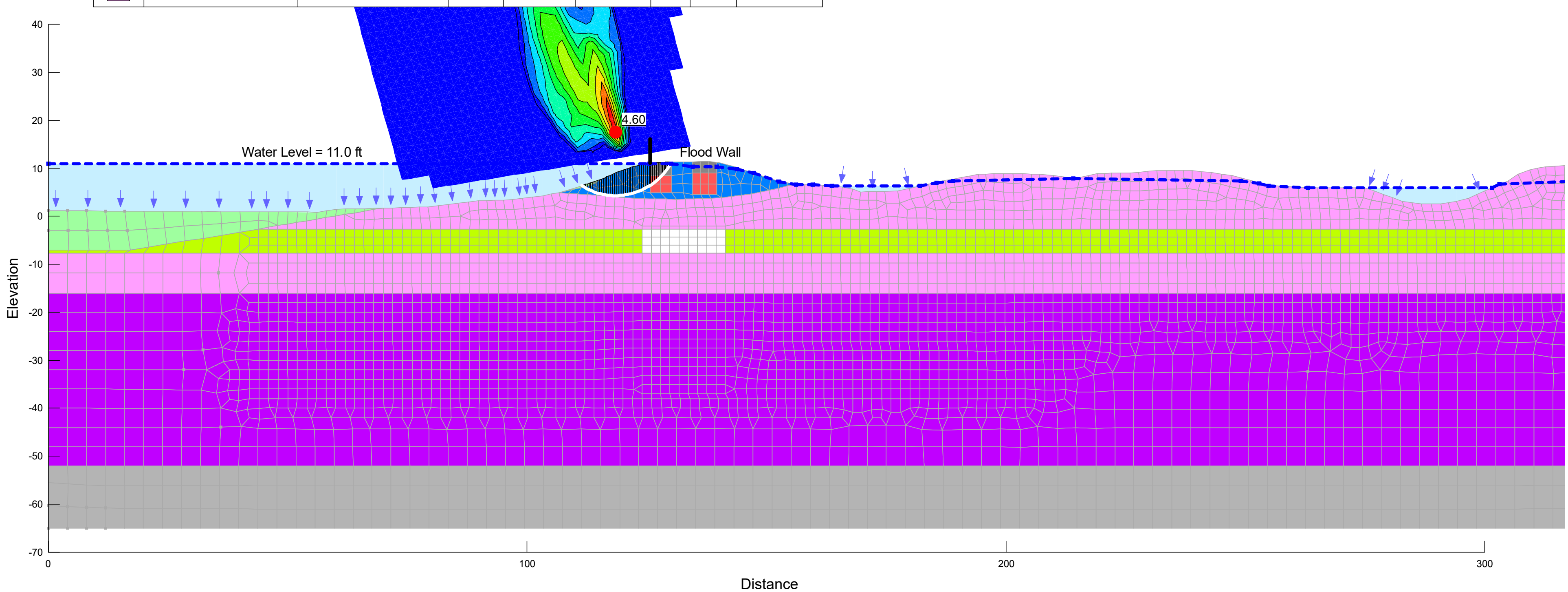
File Name: Corte Madera_Section BB'_Sensitivity_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Landside

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	Bedrock	Bedrock (Impenetrable)					
	Levee Fill	Mohr-Coulomb	125		150	32	0
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0
	Sedimentation	Undrained (Phi=0)	100	50			
	Undocumented Fill (B-B')	Mohr-Coulomb	125		375	21	0
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0



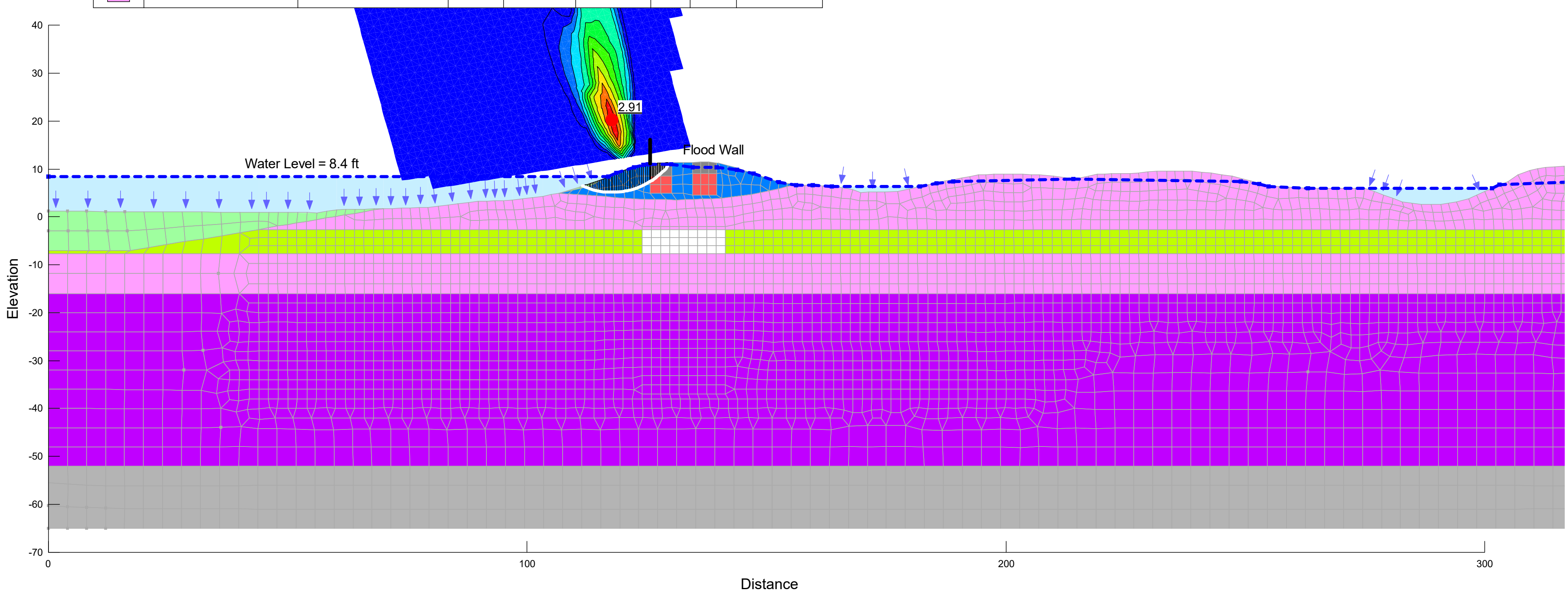
File Name: Corte Madera_Section CC'_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-Before Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	3/4" Crushed Rock	Mohr-Coulomb	120		0	32	0	1
	Bedrock	Bedrock (Impenetrable)						1
	Class 2 Aggregate Base	Mohr-Coulomb	150		0	40	0	1
	Compaction Grout Zone	Mohr-Coulomb	135		0	36.5	0	1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



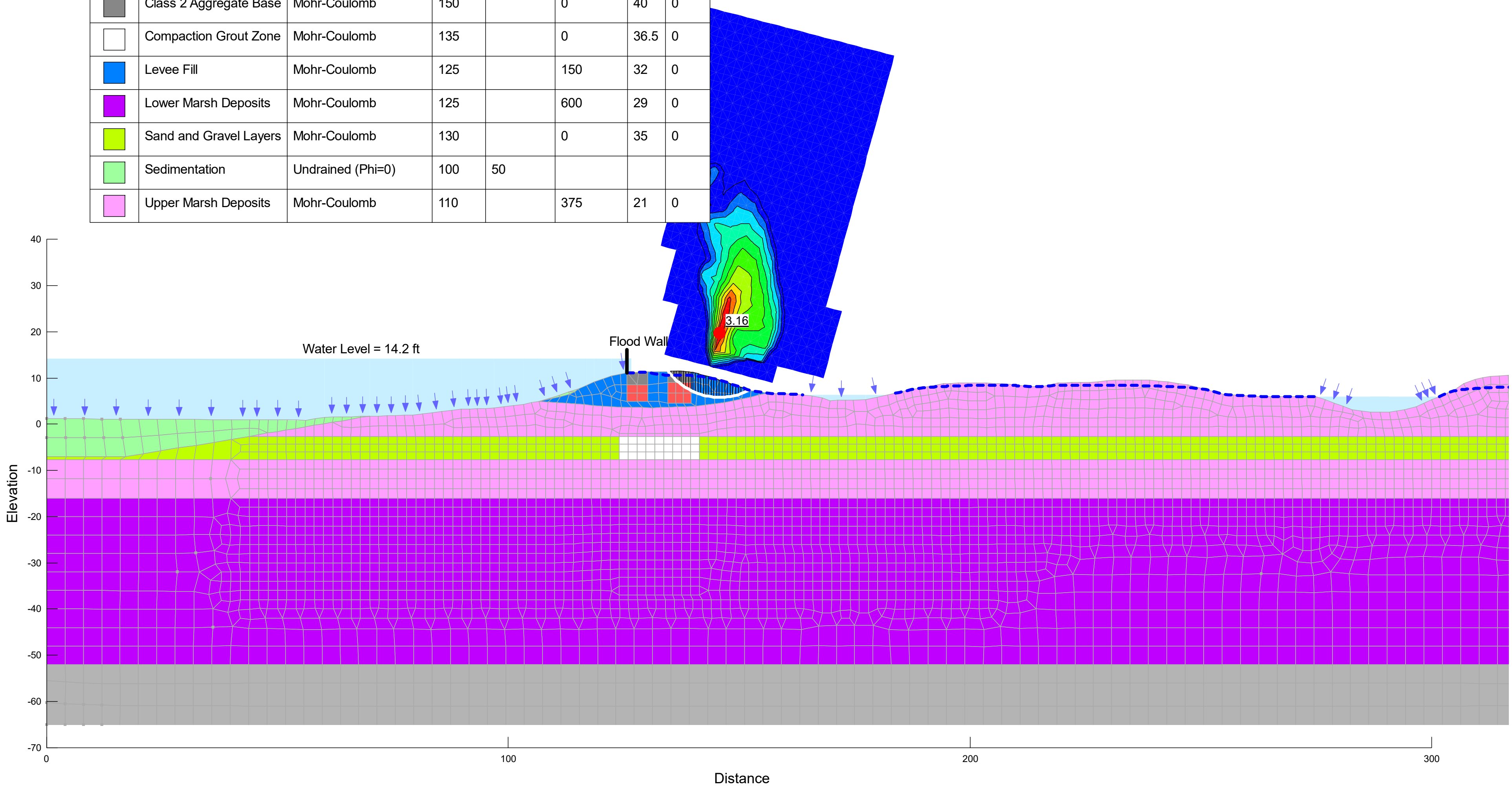
File Name: Corte Madera_Section CC'_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-After Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	3/4" Crushed Rock	Mohr-Coulomb	120		0	32	0	1
	Bedrock	Bedrock (Impenetrable)						1
	Class 2 Aggregate Base	Mohr-Coulomb	150		0	40	0	1
	Compaction Grout Zone	Mohr-Coulomb	135		0	36.5	0	1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



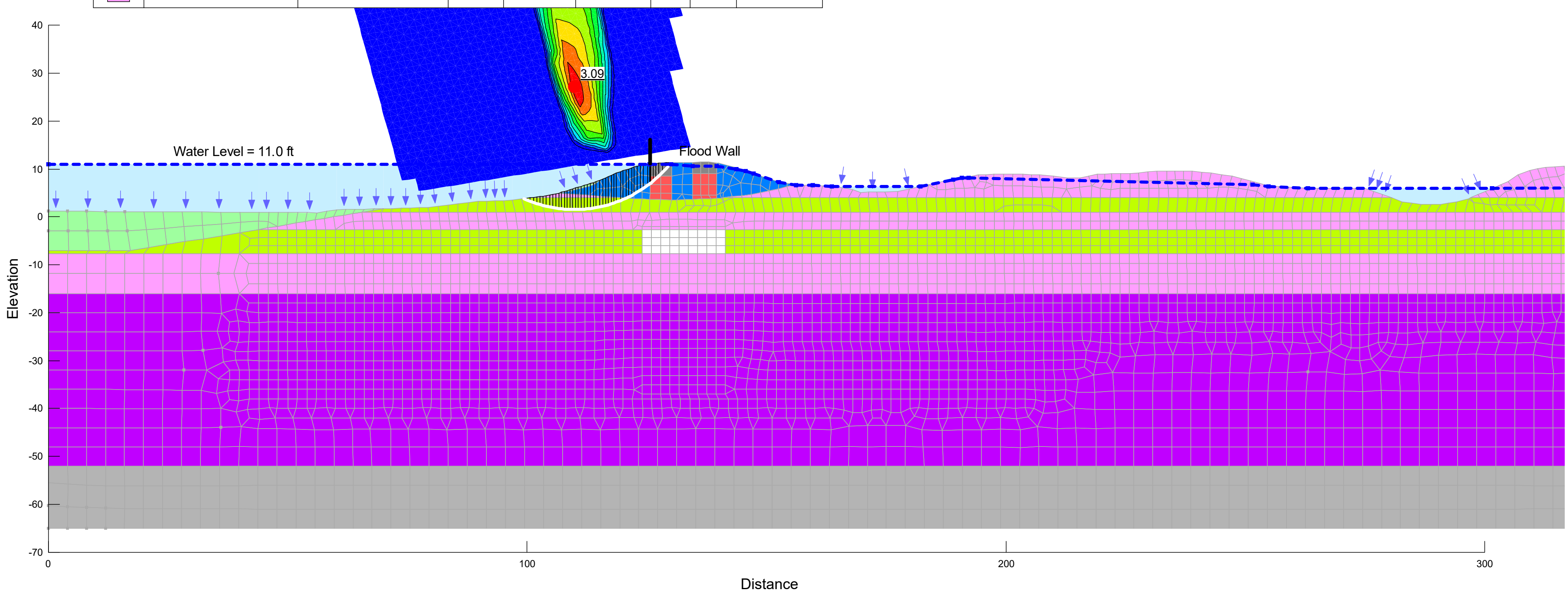
File Name: Corte Madera_Section CC'_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Landside

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	3/4" Crushed Rock	Mohr-Coulomb	120		0	32	0
	Bedrock	Bedrock (Impenetrable)					
	Class 2 Aggregate Base	Mohr-Coulomb	150		0	40	0
	Compaction Grout Zone	Mohr-Coulomb	135		0	36.5	0
	Levee Fill	Mohr-Coulomb	125		150	32	0
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0
	Sedimentation	Undrained (Phi=0)	100	50			
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0



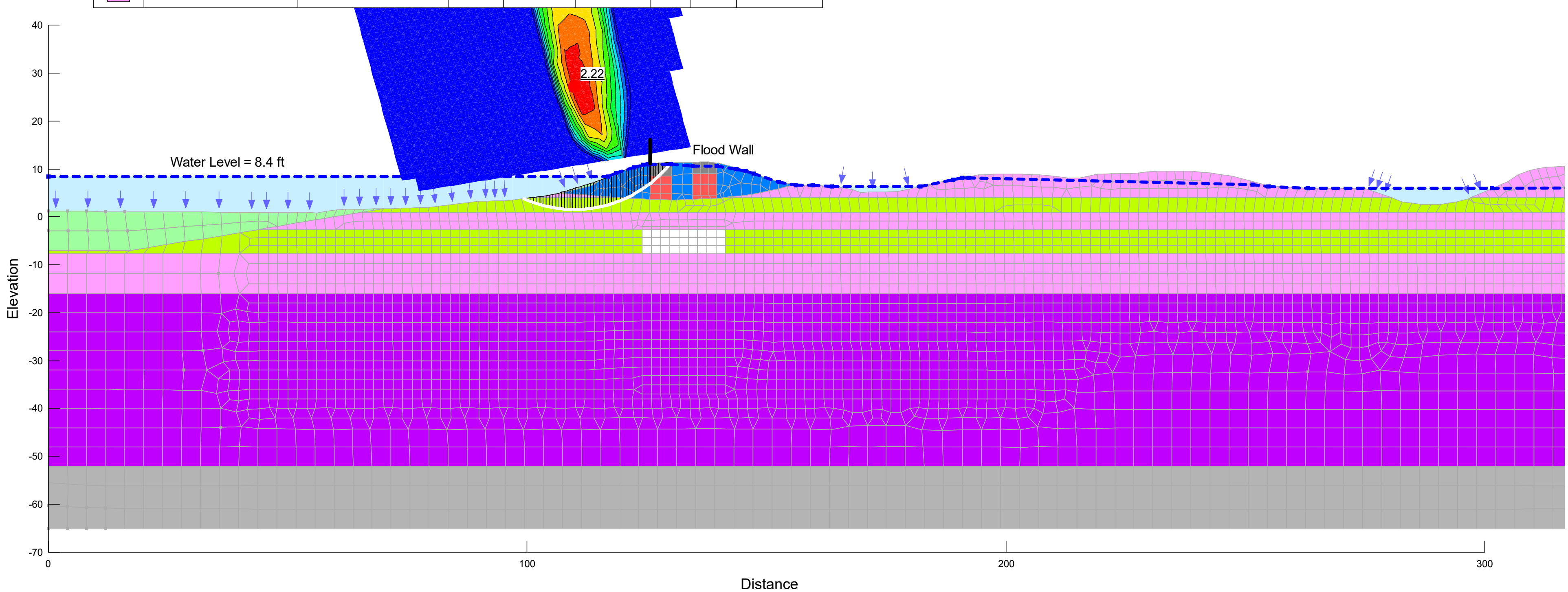
File Name: Corte Madera_Section CC'_Sensitivity_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-Before Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	3/4" Crushed Rock	Mohr-Coulomb	120		0	32	0	1
	Bedrock	Bedrock (Impenetrable)						1
	Class 2 Aggregate Base	Mohr-Coulomb	150		0	40	0	1
	Compaction Grout Zone	Mohr-Coulomb	135		0	36.5	0	1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



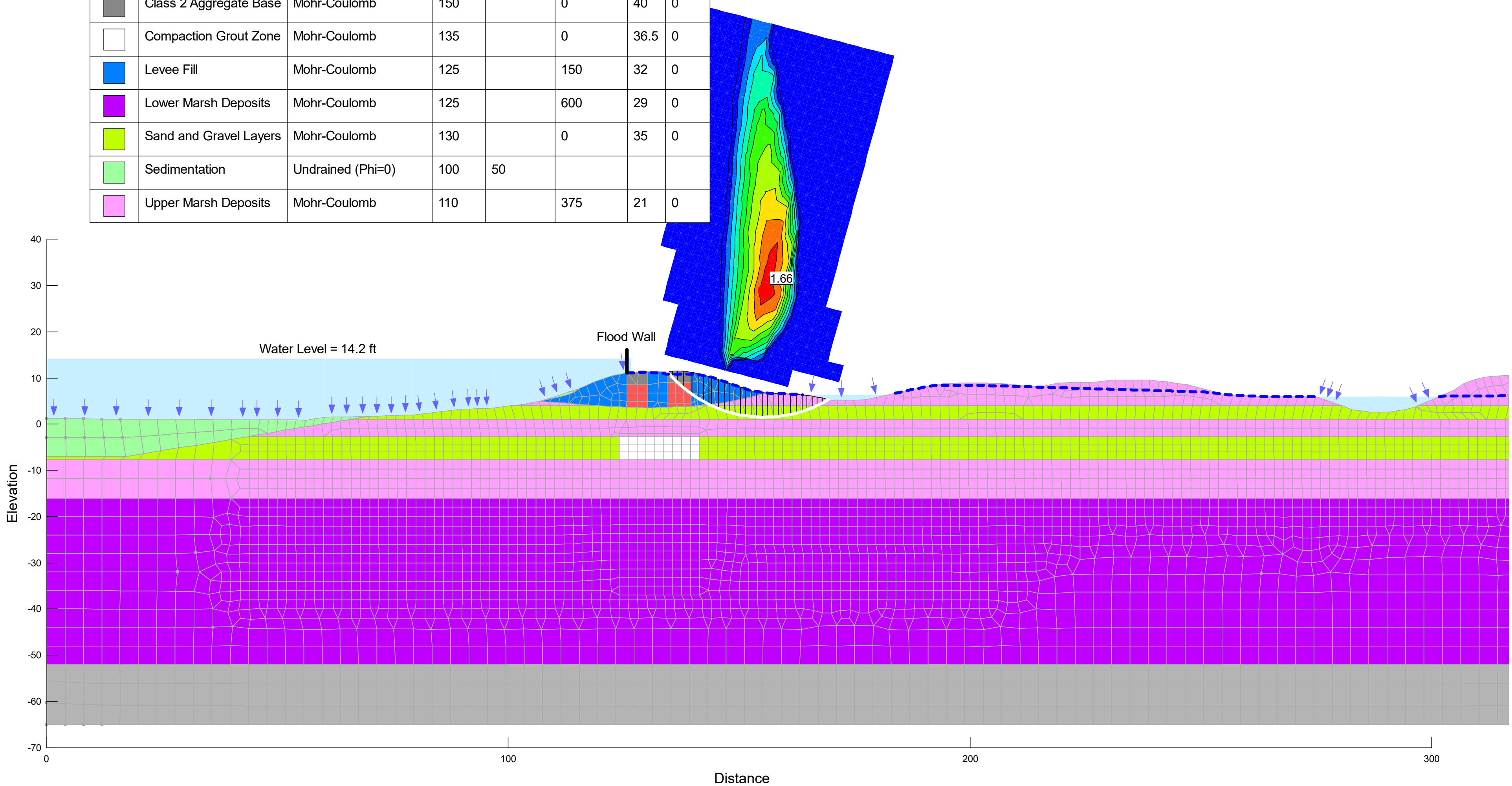
File Name: Corte Madera_Section CC'_Sensitivity_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Waterside-After Drawdown

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)	Piezometric Line
	3/4" Crushed Rock	Mohr-Coulomb	120		0	32	0	1
	Bedrock	Bedrock (Impenetrable)						1
	Class 2 Aggregate Base	Mohr-Coulomb	150		0	40	0	1
	Compaction Grout Zone	Mohr-Coulomb	135		0	36.5	0	1
	Levee Fill	Mohr-Coulomb	125		150	32	0	1
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0	1
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0	1
	Sedimentation	Undrained (Phi=0)	100	50				1
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0	1



File Name: Corte Madera_Section CC'_Sensitivity_2018 - Stability.gsz
Title: Corte Madera Levee Alternatives
Name: Stability on Landside

Color	Name	Model	Unit Weight (pcf)	Cohesion (psf)	Cohesion' (psf)	Phi' (°)	Phi-B (°)
	3/4" Crushed Rock	Mohr-Coulomb	120		0	32	0
	Bedrock	Bedrock (Impenetrable)					
	Class 2 Aggregate Base	Mohr-Coulomb	150		0	40	0
	Compaction Grout Zone	Mohr-Coulomb	135		0	36.5	0
	Levee Fill	Mohr-Coulomb	125		150	32	0
	Lower Marsh Deposits	Mohr-Coulomb	125		600	29	0
	Sand and Gravel Layers	Mohr-Coulomb	130		0	35	0
	Sedimentation	Undrained (Phi=0)	100	50			
	Upper Marsh Deposits	Mohr-Coulomb	110		375	21	0



APPENDIX C

Embankment Protection (Erosion) Analysis

Embankment Protection Analysis (100-Year Riverine Flood Event)

River Sta	Type	Parameters					Levee Fill (SC)	
		W.S. Elev	Vel Chnl	Radius	Width	Adj. Vel	Allow Velocity	Result
(ft)		(ft)	(ft/s)	(ft)	(ft)	(ft/s)	(ft/s)	
31910	Straight	8.9	9.14	10000	270	9.14	15	OK
31875	Straight	9.62	4.71	10000	270	4.71	15	OK
31850	Straight	9.79	3.25	10000	270	3.25	4.5 to 5.5	OK
31810	Straight	9.74	3.68	10000	270	3.68	4.5 to 5.5	OK
31710	Straight	9.76	3.36	10000	270	3.36	4.5 to 5.5	OK
31587	Straight	9.7	3.56	10000	270	3.56	4.5 to 5.5	OK
31393	Straight	9.73	3.11	10000	270	3.11	4.5 to 5.5	OK
31198	Straight	9.75	2.73	10000	270	2.73	4.5 to 5.5	OK
30993	Straight	9.72	2.92	10000	270	2.92	4.5 to 5.5	OK
30803	Bend	9.38	3.96	670	270	6.08	4.5 to 5.5	Exceeds
30594	Bend	9.17	4.43	670	270	6.80	4.5 to 5.5	Exceeds
30396	Bend	9.13	4.47	670	270	6.86	4.5 to 5.5	Exceeds
30204	Straight	9.06	4.62	10000	270	4.62	4.5 to 5.5	May Exceed
29994	Straight	9.05	4.41	10000	270	4.41	4.5 to 5.5	OK
29802	Straight	8.88	4.18	10000	270	4.18	4.5 to 5.5	OK
29595	Bend	8.66	4.3	665	270	6.61	4.5 to 5.5	Exceeds
29403	Bend	8.63	4.33	665	270	6.65	4.5 to 5.5	Exceeds
29188	Bend	8.63	4.14	665	270	6.36	4.5 to 5.5	Exceeds
28994	Bend	8.58	4.3	665	270	6.61	4.5 to 5.5	Exceeds
28790	Bend	8.54	4.31	665	270	6.62	4.5 to 5.5	Exceeds
28598	Straight	8.21	4.47	10000	270	4.47	4.5 to 5.5	OK
28408	Straight	7.88	4.47	10000	270	4.47	4.5 to 5.5	OK
28201	Straight	7.83	4.6	10000	270	4.60	4.5 to 5.5	May Exceed

APPENDIX D

Preliminary Liquefaction Analysis

A3GEO, Inc.
1331 Seventh Street, Unit E
Berkeley, CA 94710

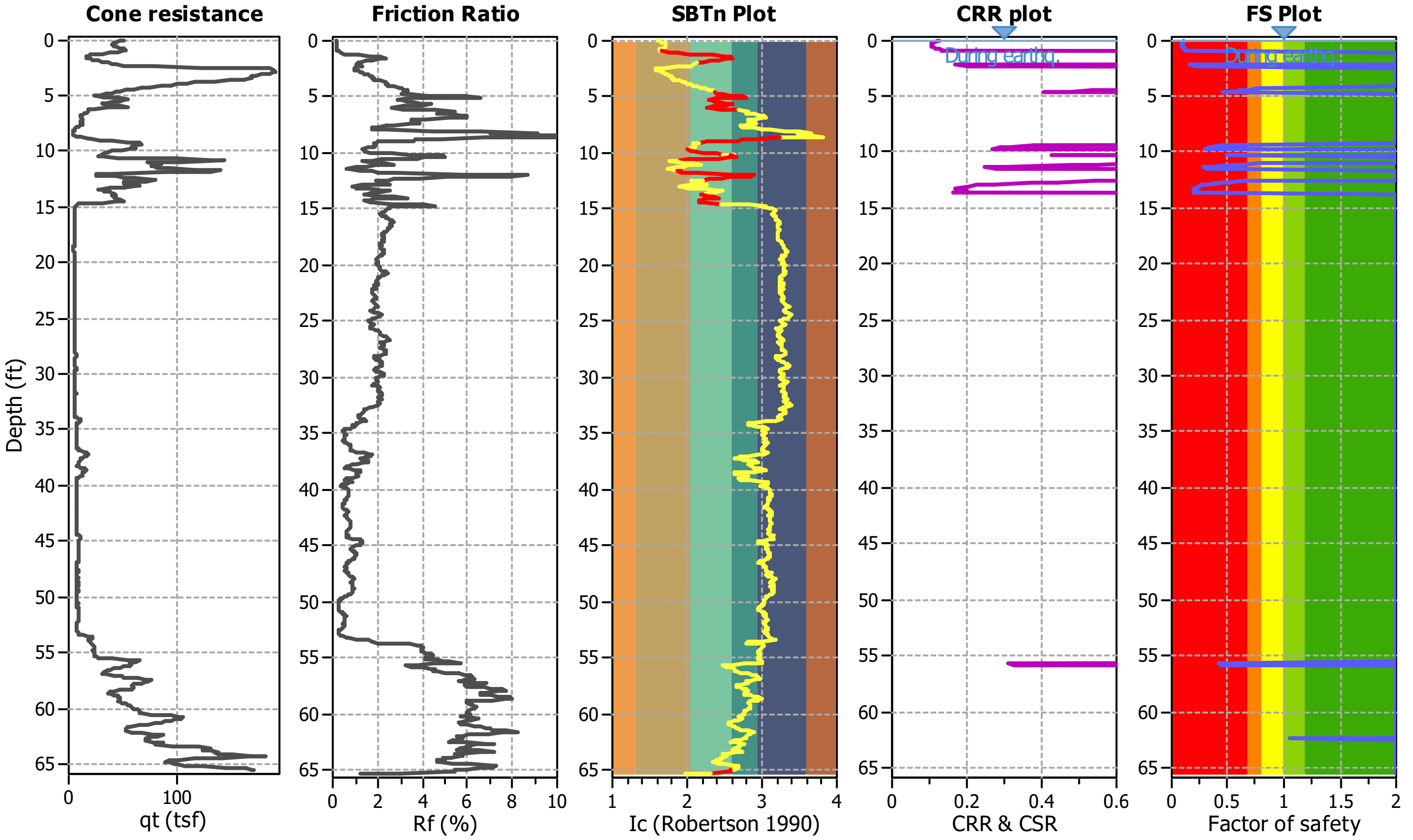
LIQUEFACTION ANALYSIS REPORT

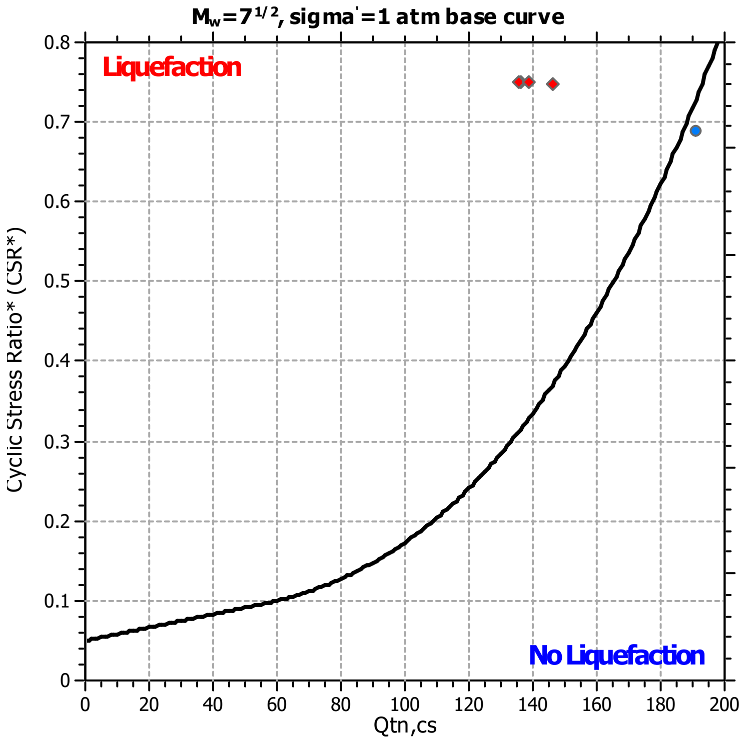
Project title : Corte Madera Levee Evaluation **Location : Marin County**

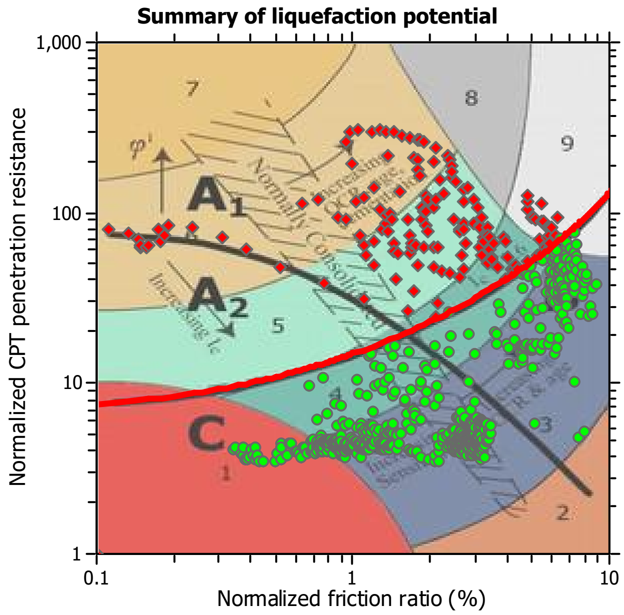
CPT file : CPT-2

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	5.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	0.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	8.05	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.53	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

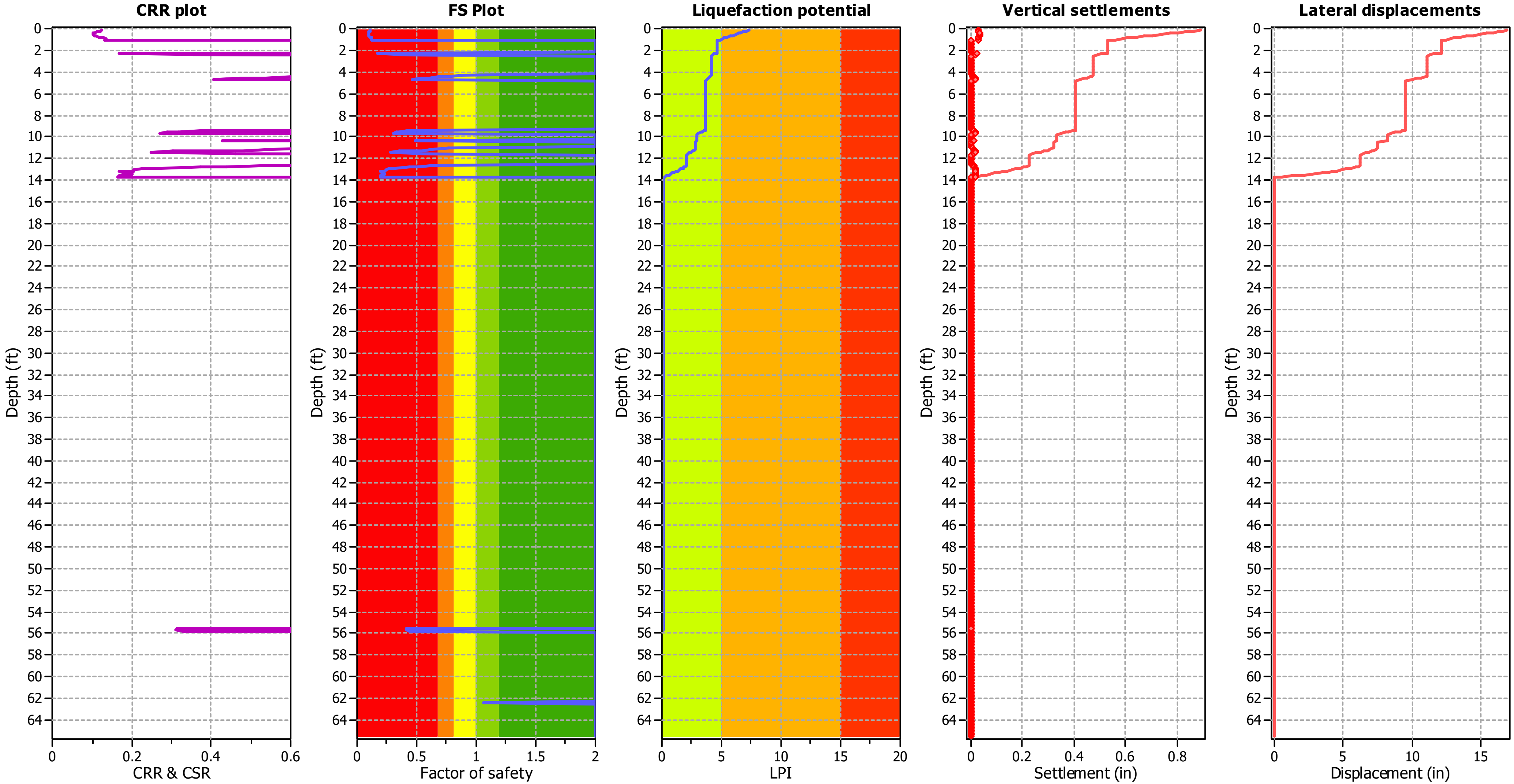






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	8.05	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.53	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	5.00 ft	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

A3GEO, Inc.
1331 Seventh Street, Unit E
Berkeley, CA 94710

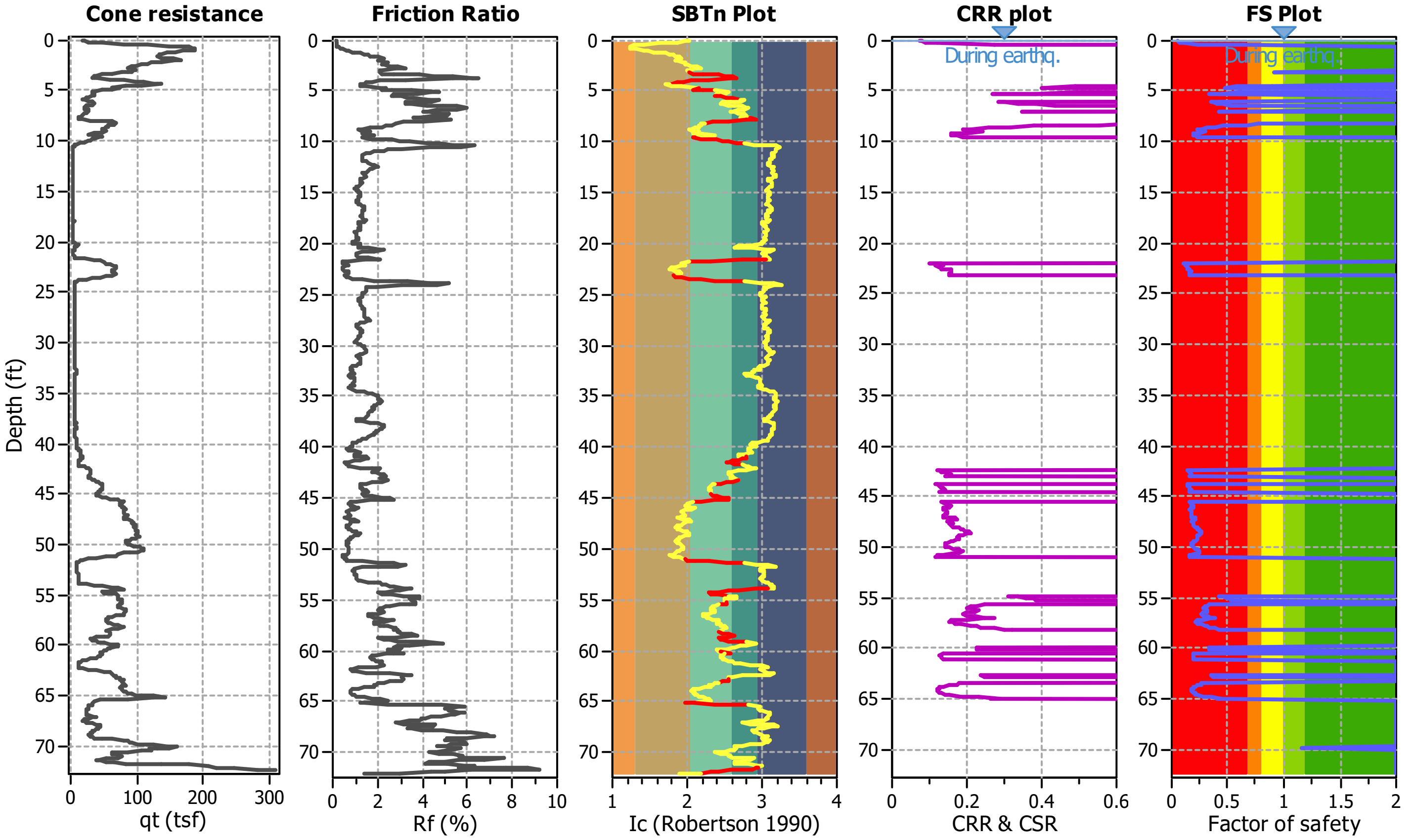
LIQUEFACTION ANALYSIS REPORT

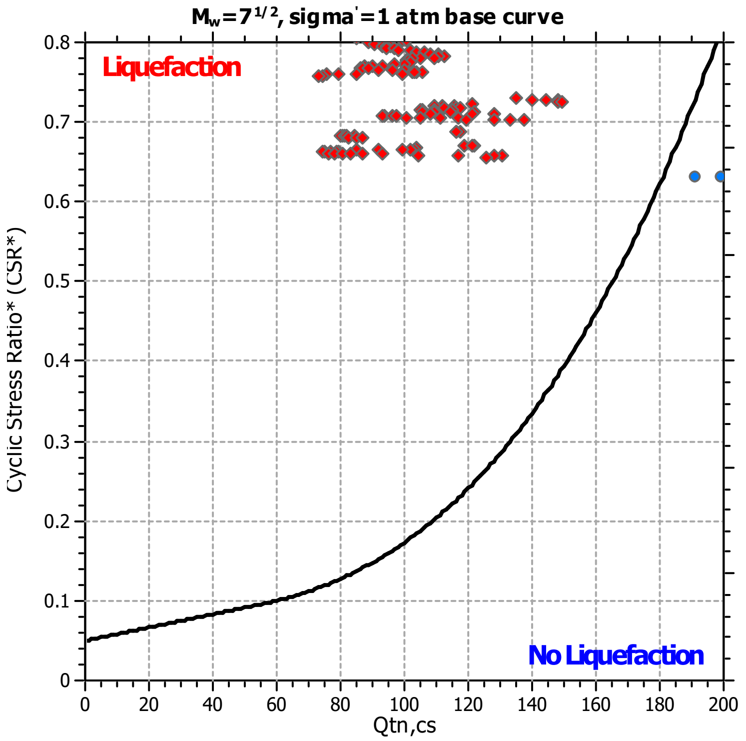
Project title : Corte Madera Levee Evaluation **Location : Marin County**

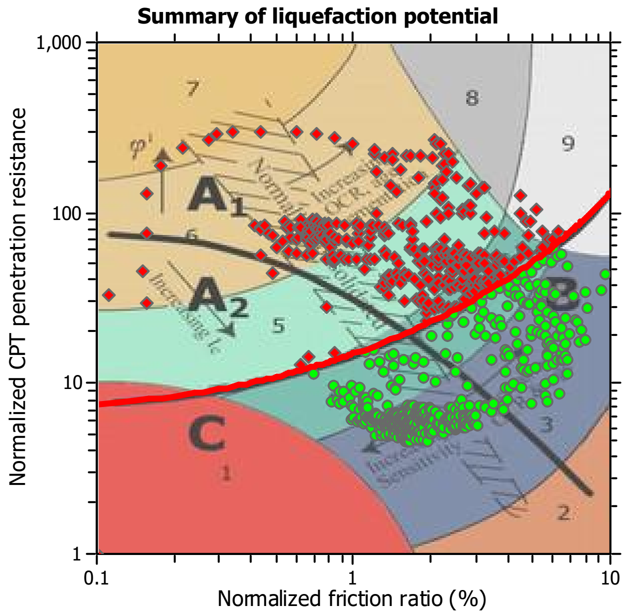
CPT file : CPT-4

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	5.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	0.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	8.05	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.53	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

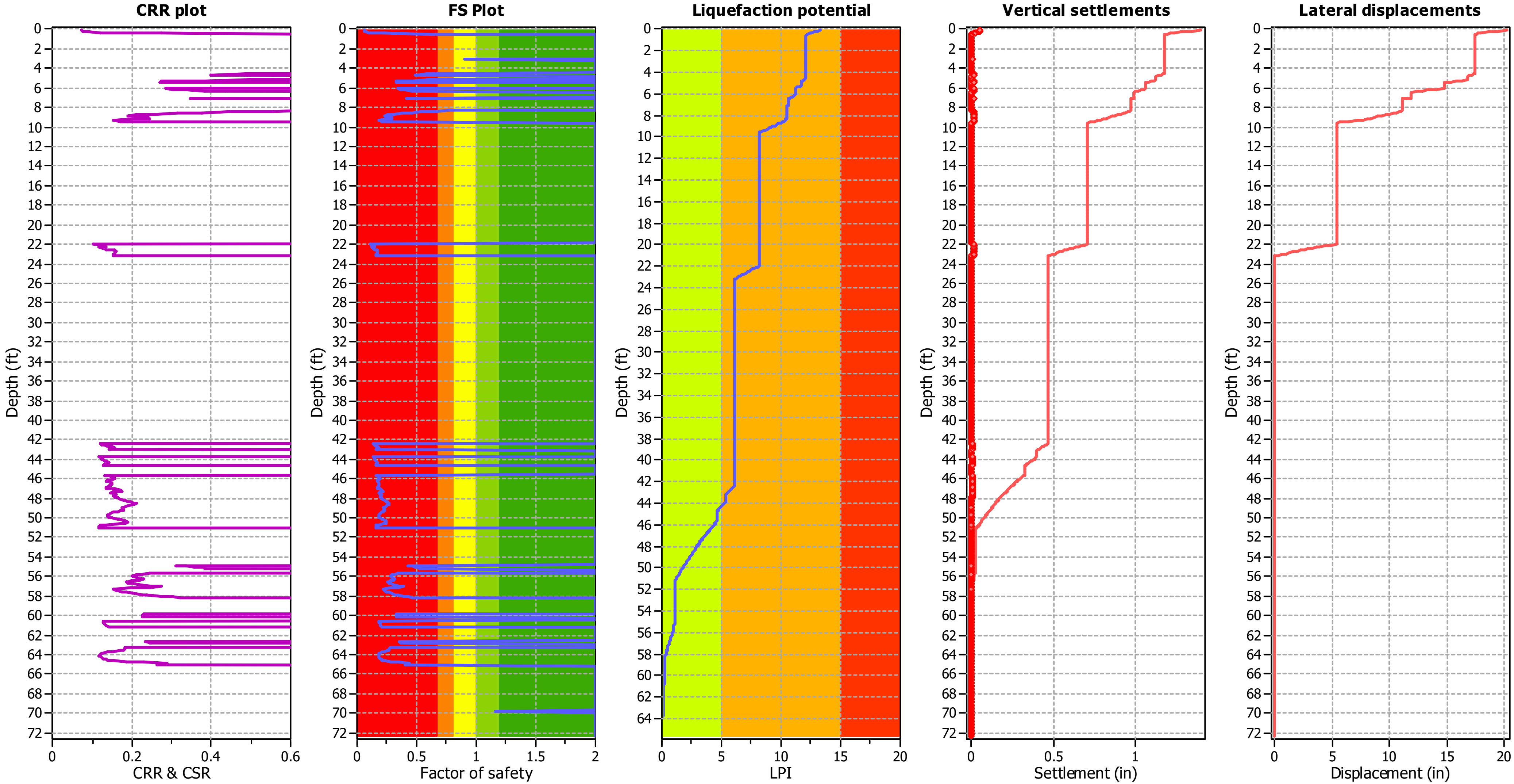






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	8.05	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.53	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	5.00 ft	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

A3GEO, Inc.
1331 Seventh Street, Unit E
Berkeley, CA 94710

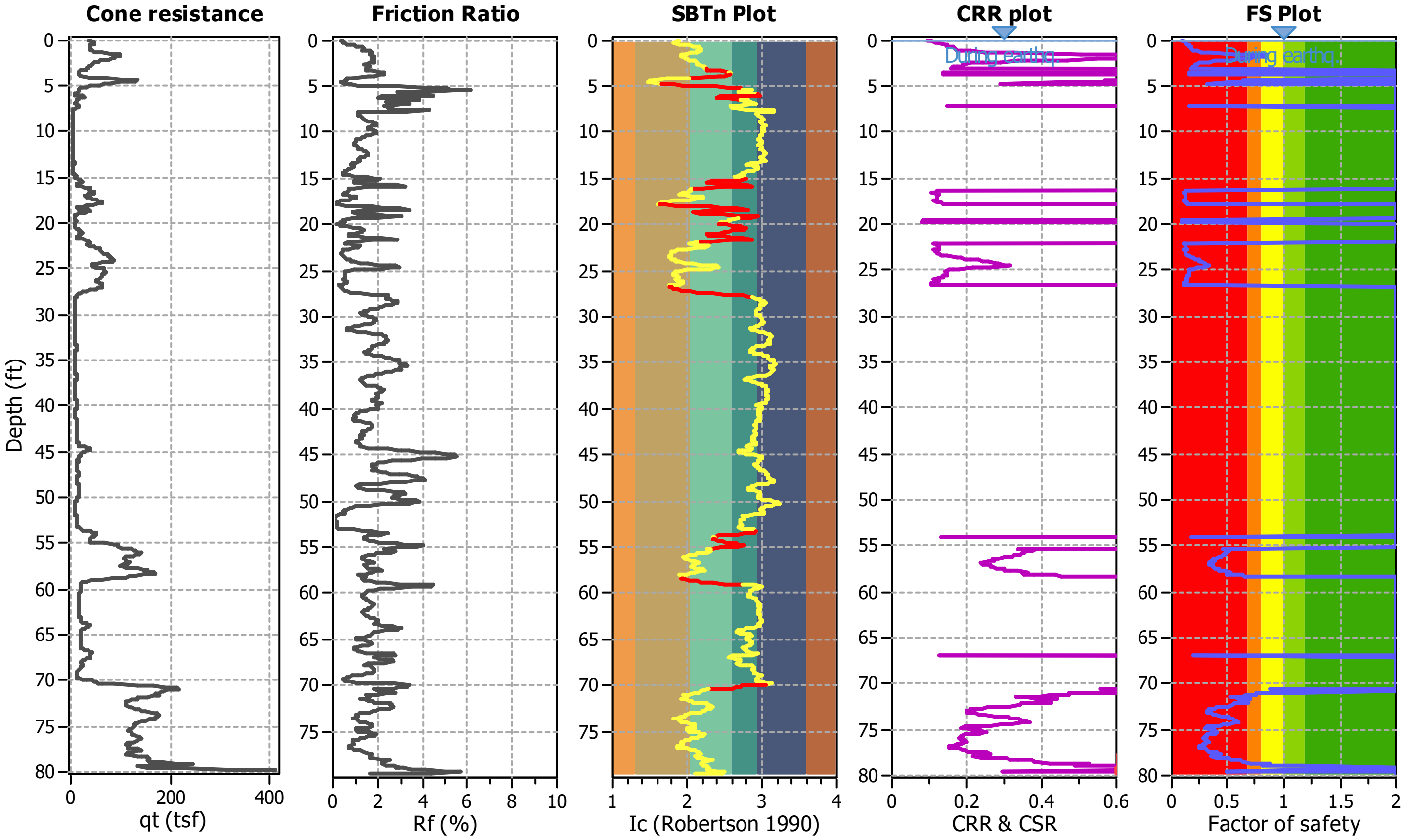
LIQUEFACTION ANALYSIS REPORT

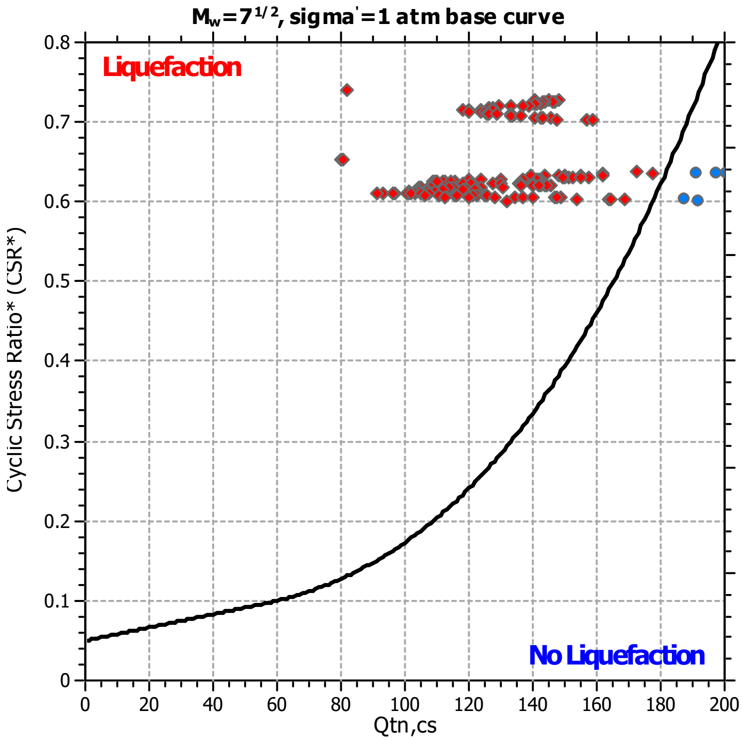
Project title : Corte Madera Levee Evaluation **Location : Marin County**

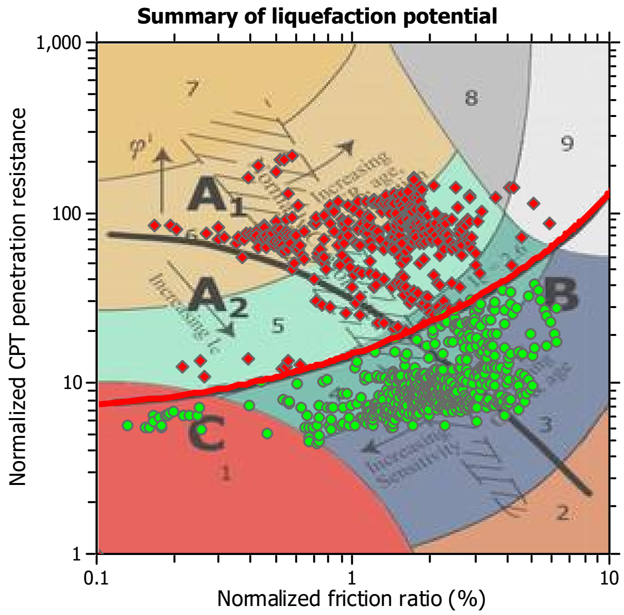
CPT file : CPT-6

Input parameters and analysis data

Analysis method:	NCEER (1998)	G.W.T. (in-situ):	5.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	0.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	8.05	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.53	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

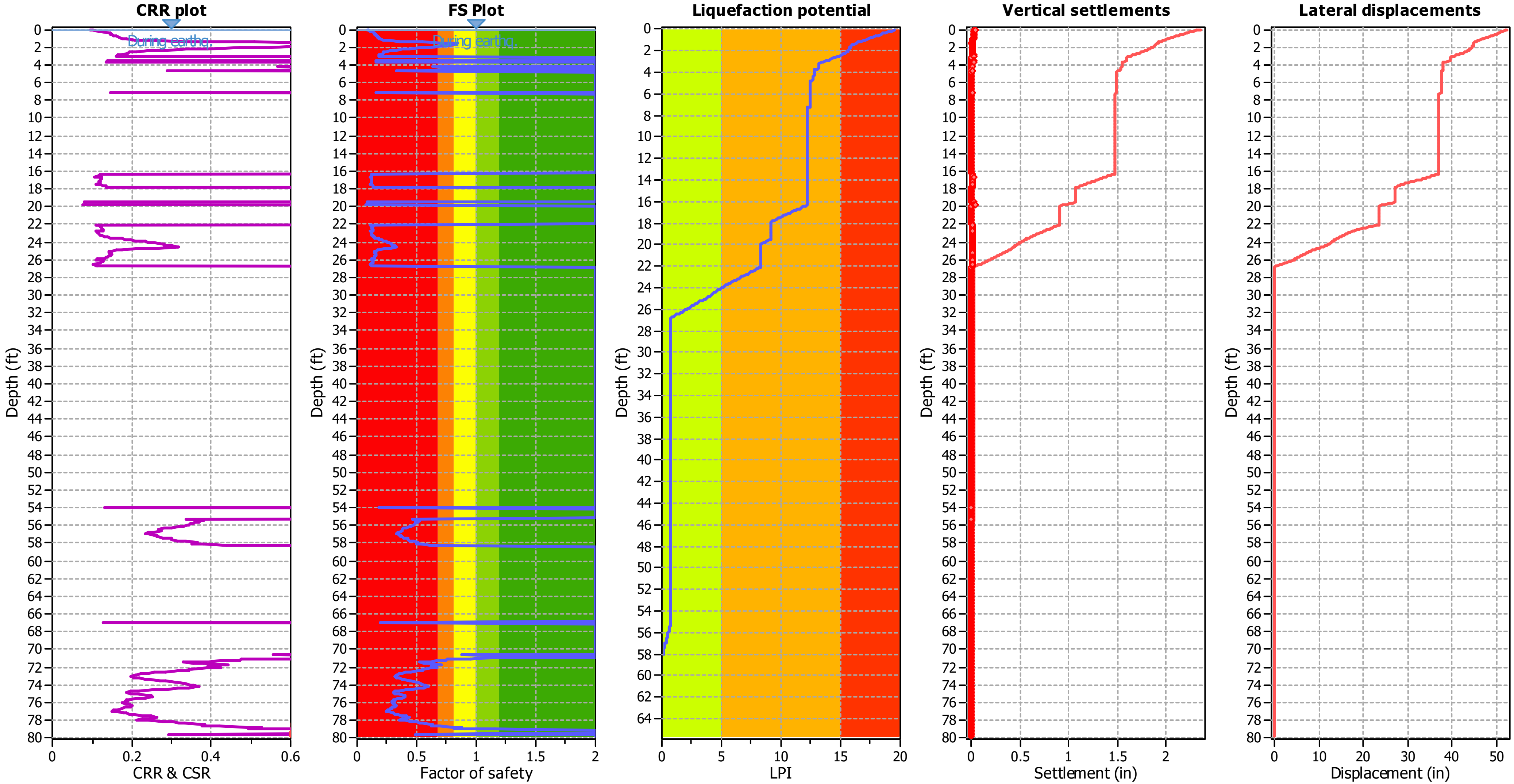






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	NCEER (1998)	Depth to water table (erthq.):	0.00 ft	Fill weight:	N/A
Fines correction method:	NCEER (1998)	Average results interval:	3	Transition detect. applied:	Yes
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	8.05	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.53	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	5.00 ft	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk