RECLAMATION

Managing Water in the West

SAN JOAQUIN RIVER RESTORATION PROGRAM

Friant WATER AUTHORITY

Feasibility Report
Appendix A – Initial Alternatives Formulation

Friant-Kern Canal Middle Reach Capacity Correction Project

November 2019



Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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- Exhibit A1a. Initial Alternatives Basis of Design Report
  - Attachment A1a1. HEC-RAS Modeling Technical Memorandum
  - Attachment A1a2. Active Turnouts Technical Memorandum
- Exhibit A1b. Selection of Future Subsidence Condition
  - Attachment A1b1. Subsidence Modeling Technical Memorandum
- Exhibit A1c. Geotechnical Interpretative Report
  - Attachment A1c1. Geotechnical Data Report

Attachment A2. Environmental Constraints Analysis Summary
Attachment A3. Initial Alternatives Evaluation and Comparison

Abbreviations and Acronyms

CEQA	California Environmental Quality Act
cfs	cubic feet per second
ESA	Endangered Species Act
FAA	Financial Assistance Agreement
FKC	Friant-Kern Canal
FWA	Friant Water Authority
HGL	hydraulic grade line
MP	Mile Post
MRSCC	Middle Reach Subsidence and Capacity Correction Project
NEPA	National Environmental Policy Act
O&M	operations and maintenance
OM&R	operations, maintenance, and replacement

Contents

PR&G	*Principles, Requirements, and Guidelines for Federal Investment in Water Resources*
Project	Middle Reach Subsidence and Capacity Correction Project
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
ROW	right-of-way
SGMA	Sustainable Groundwater Management Act
SJRRP	San Joaquin River Restoration Program
Study	FKC Middle Reach Subsidence and Capacity Correction Project Feasibility Study
WIIN Act	Water Infrastructure Improvements for the Nation Act (P.L. 114-322) of 2016

Chapter 1
Introduction

The Friant-Kern Canal (FKC) Middle Reach, located within Tulare County, extends approximately 33 miles and has experienced significant capacity loss over the past decade. The loss is a result of both regional land subsidence and an original design flaw that prevents the intended capacity to be actualized. The FKC Middle Reach Capacity Correction Project (MRSCC or Project) is being developed to provide improvements to the FKC to address reduced conveyance capacity resulting from these two issues.

The FKC Middle Reach Capacity Correction Project Feasibility Study (Study) is being developed by the Friant Water Authority (FWA) for review and approval by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation). Progress and results of the Study are being documented in a series of interim reports that will culminate in a Feasibility Report and associated National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) compliance documentation consistent with the *Principles, Requirements, and Guidelines for Federal Investment in Water Resources* (PR&G) (CEQ 2013), Reclamation directives and standards (2015), and applicable environmental laws. This Initial Alternatives Formulation is an interim planning report in the Project feasibility study process.

Purpose

The purpose of this Initial Alternatives Formulation is to describe the formulation, evaluation, and comparison of a set of Initial Alternatives that address Project planning objectives, and to define a set of alternative plans to be considered in greater detail in the Feasibility Report and NEPA/CEQA documentation.

Planning Objective

The planning objective is to restore the capacity of the FKC Middle Reach to address the original design deficiency and subsidence-induced capacity reductions. The FKC was designed to convey water at a normal capacity for the delivery of water under CVP contracts, and maximum capacity for the short-term conveyance of flood flows. The Project will provide restored conveyance capacity that satisfies both conditions.

Organization of Initial Alternatives Formulation Report

This report is organized as follows:

- **Chapter 1** provides background information about the study and related studies, projects, and programs.
- **Chapter 2** describes the measures considered that can address project objectives.
- **Chapter 3** presents the seven initial alternatives in terms of implementation requirements, costs, and other defining characteristics.
- **Chapter 4** summarizes the evaluation and comparison method used to identify the most favorable alternatives.
- **Chapter 5** represents the sequencing analysis of the top two alternatives.
- **Chapter 6** provides a list of sources consulted in preparation of this report.

Attachments, and Exhibits to the Feasibility Report include the following:

- **Attachment A.1** – Initial Alternatives Engineering Cost and Design
  - **Exhibit A.1.a** Initial Alternatives Basis of Design Report
    - **Attachment A.1.a.1** HEC-RAS Modeling Technical Memorandum
    - **Attachment A.1.a.2** Turnouts Technical Memorandum
  - **Exhibit A.1.b** Selection of Future Subsidence Condition
    - **Attachment A.1.b.1** Subsidence Modeling Technical Memorandum
  - **Exhibit A.1.c** Geotechnical Interpretive Report
    - **Attachment A.1.c.1** Geotechnical Data Report
  - **Exhibit A.1.d** Initial Alternatives Cost Estimates
- **Attachment A.2** – Environmental Constraints Analysis Summary
- **Attachment A.3** – Evaluation and Comparison of Initial Alternatives

Chapter 2
Measures

This chapter describes the project planning horizon, constraints and considerations, and the management measures considered and retained for inclusion in alternatives.

Project Planning Horizon

The Project is intended to be integrated into a long-term solution to restore capacity of the entire FKC, as part of the FKC Capacity Correction Program. The planning horizon is 50 years, consistent with the minimum Project service life.

Funding Constraints

As described in the Financial Assistance Agreement (FAA), two Federal funding sources are available for the Project, the San Joaquin River Restoration Program (SJRRP) funds and Water Infrastructure and Improvements for the Nation Act (WIIN Act) funding, for a total of $7,423,704 dollars. Of the $7,423,704, the portion covered by the WIIN Act is subject to a 50 percent cost share. However, the Project is anticipated to cost more than these two sources combined.

To cover a portion of the additional costs, funding was made available in California Proposition 3. However, Proposition 3 was defeated in November 2018, eliminating a key potential funding source for the Project. Future funding sources through state legislation, federal appropriations, or another ballot measures may fill the funding gap, but it unknown at the time of this report. The lack of funding to fully construct the Project may limit the Project scope.

Boundary Conditions

When designing either a new canal or modifications to an existing canal, the first step is to identify the boundary conditions, or the required (design) water levels at each end of the system. Boundary conditions may be difficult to define, especially since they can change significantly with relatively minor changes to the Project. Although the upstream and downstream limits for this Project are the 5th Ave. Check and the Lake Woollomes Check, hydraulics were analyzed through the canal terminus at the Kern River Check. From the analysis, it was determined that the hydraulic head varies about 25 feet between 5th Avenue Check and the Kern River. Of this, approximately 20 feet is required for the canal gradient and the remaining 5 feet is losses at canal structures, including bridges, turnouts, checks, and siphons.

The boundary conditions, along with the Project objectives, were used to establish a proposed hydraulic grade line (HGL). The proposed HGL was set as low as possible to minimize embankment raise requirements and the need to modify bridges. All management measures considered, and subsequent project alternatives, are based on maintaining the proposed HGL. The proposed HGL is shown in Figure 2-1.

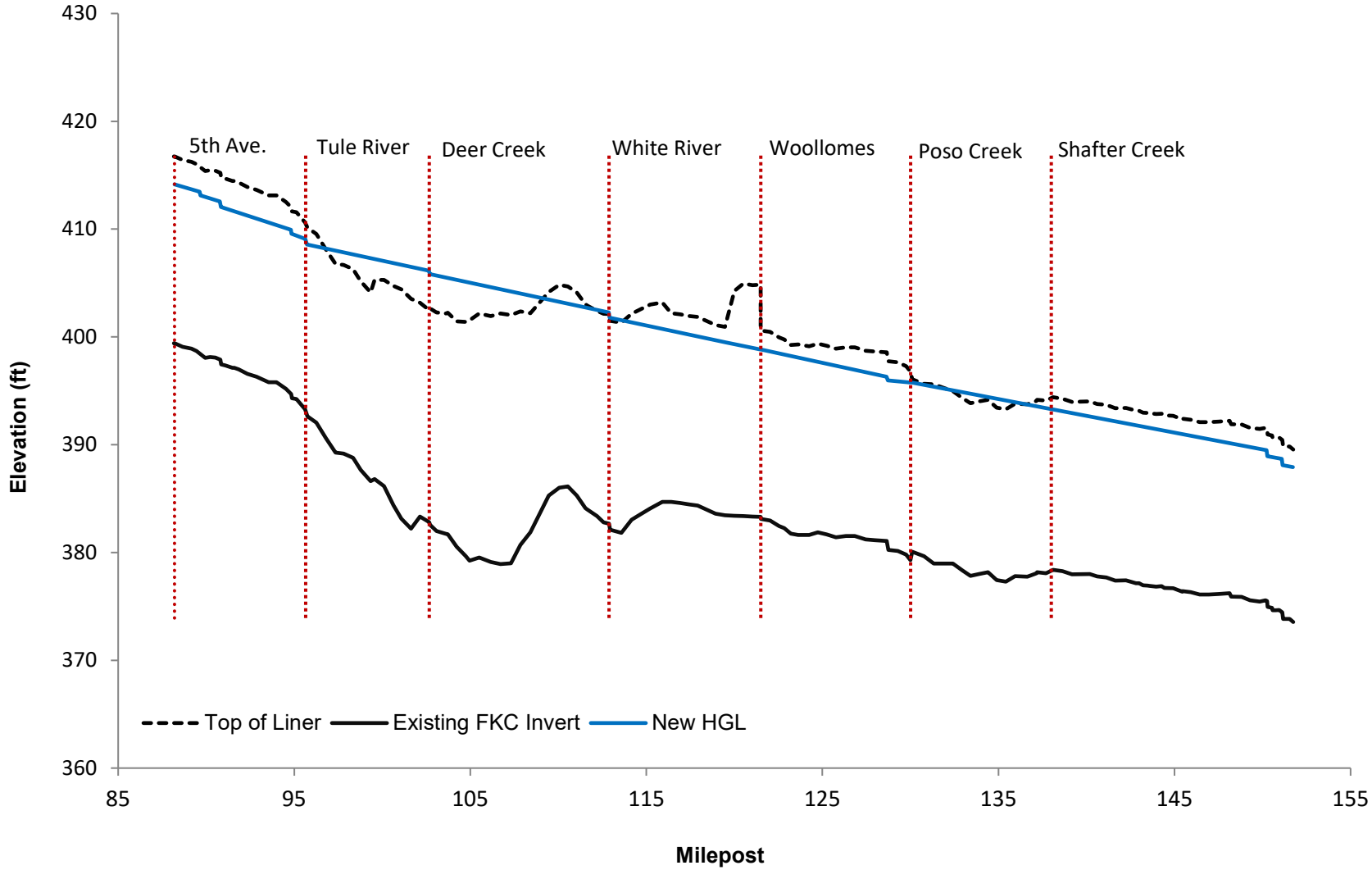


Figure 2-1. Canal Profile with Proposed Hydraulic Grade Line

Measures Considered

Once water resources problems, needs, and opportunities have been identified, and planning objectives and constraints have been developed, the next major step in the plan formulation process is identifying resource management measures. A resources management measure is any structural or nonstructural action that could address one or more planning objectives. Measures are then combined to form initial alternatives.

Several measures were identified that could contribute to the Project objective of restoring the FKC flow capacity and organized into the following categories: canal enlargement, pumping plant, new canal, bridge modification, and other. While non-structural measures would not restore the originally designed and constructed capacity, one nonstructural measure, the re-scheduling of affected water deliveries in Millerton Lake, was identified for consideration. Although this measure would not contribute to the project objective of restoring the FKC design capacity, it will be included in the No Action Alternative, and to be combined with structural measures in action alternatives to reduce water delivery impacts. This chapter provides an overview of the measures considered, and identifies measures carried into the Initial Alternatives. For detailed, technical information on the measures, refer to Appendix B Engineering Design and Cost.

Canal Enlargement

Canal enlargement can be a combination of the following actions: raise the canal embankments and extend the prism, raise and widen the entire cross section, and/or raise and widen the upper portion of the canal prism. The specific enlargement combinations will be determined during the alternative development process.

Raise Canal

Raising the canal would be accomplished by increasing the height of the existing embankments and extending the concrete liner to elevations that would provide sufficient freeboard relative to the HGL. Raising the height of the earthen embankment at the current slope of 1.25:1 increases the likelihood of seepage and threatens slope stability. Therefore, this measure entails construction of a small bench for bank stability, extension of the interior embankment at a slope of 1.5:1, and reconstruction of the entire outer embankment face at a slope of 1.5:1 to 2:1, as illustrated in Figure 2-2.

Preliminary earthwork analysis based on the existing land surface indicates that raising the FKC in this manner could be largely contained within the existing right-of-way (ROW) throughout the Middle Reach, minimizing land acquisition. The use of this measure would be limited to flow capacities less than or equal to the “Normal Design Capacity” shown on the original design drawings.

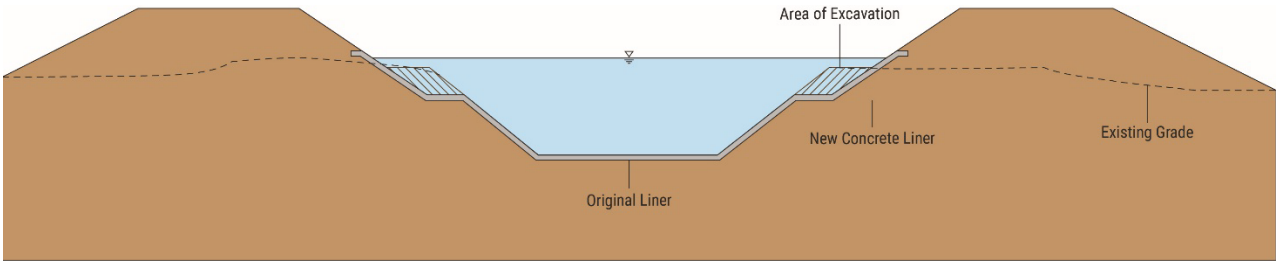


Figure 2-2. Canal Raise Cross Section

The canal raise would be accomplished by modifying the embankment and concrete liner above the existing liner. To reduce the potential for seepage, it may be desirable to remove the liner extension that was installed in the 1970s to form a more water-tight seal or reseal the cold joints to improve water-tightness. If these options are selected, the water level in the canal would need to be lowered during construction to expose the existing cold joint. If these options are not selected, effects to canal operations during construction would be minor.

Raise and Widen Canal

Since the Raise Canal measure is only capable of restoring the original Normal Design Capacity, other measures were developed to meet Project objectives. To further increase capacity, the raised canal could also be widened. Two measures were identified to raise and widen the canal, including a widening of the full cross section, and a limited widening of the upper portion of the canal.

Raise Canal and Widen Entire Cross Section Widening the entire cross section of a raised canal would entail widening both the bottom and sides of the canal as illustrated in Figure 2-3. This would require complete removal of both embankments, excavation of the below-grade portion of the widened canal, extension of the invert liner, and construction of a new embankment and liner. In order to widen the entire cross section, either the canal would need to be completely dewatered for an extended period of time or a dividing barrier would be installed down the center of the canal to allow for simultaneous construction and water delivery. While technically feasible for localized application, raising widening the entire cross section of the FKC would be costlier and more time intensive than other available measures, and would therefore have increased construction risk.

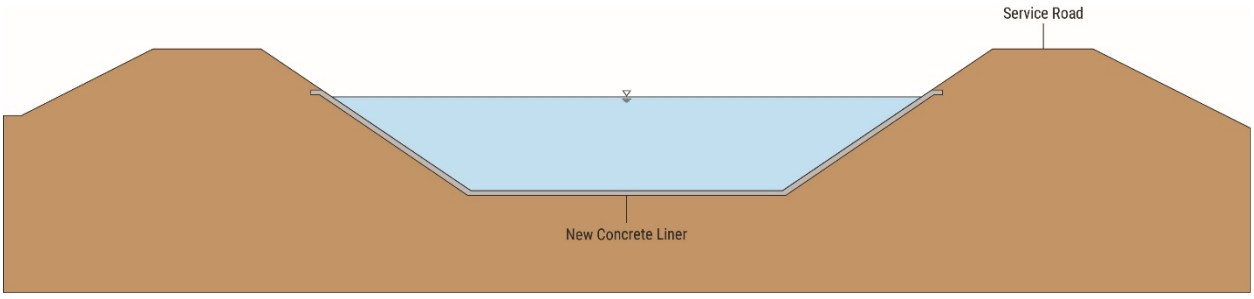


Figure 2-3. Raise Canal and Widen Entire Cross Section

Raise Canal and Widen Upper Portion of Cross Section Raising the canal and widening the upper portion of the cross section increases capacity and has fewer constructability issues than widening the entire cross section. To enlarge concrete-lined reaches, a compound trapezoidal canal section is proposed, as shown in Figure 2-4. This design uses the bottom of the existing canal and a widened top above a horizontal bench on one or both sides. Where ROW allows equal expansion on both sides of the canal, the typical bench will be 8 feet above the existing canal invert and 28 feet wide with 1.5:1 side slopes above the bench. Total height varies by location as the design flow capacity and cross-section changes.

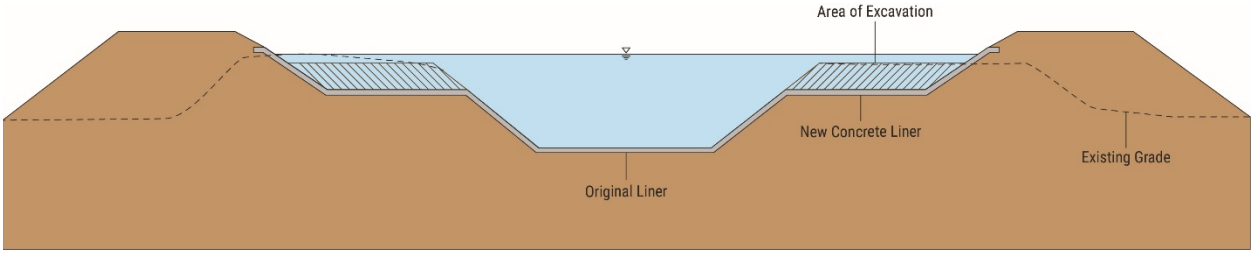


Figure 2-4. Compound Trapezoidal Typical Cross-Section

A compound trapezoidal design is recommended because it provides the optimal balance between ROW and flow; it is the best fit within the existing ROW while keeping the bench high enough to maintain some flow during construction. Once finished, the canal will be hydraulically less efficient due to the additional surface area or wetted perimeter. The augmented wetted perimeter produces slightly more friction loss which could result in sedimentation and vegetation growth, thus requiring more maintenance.

Pumping Plant

As an alternative to the current gravity conveyance method, a pump station could be installed either directly on the canal or along a bypass to establish a higher HGL in the canal reaches downstream of the pumping plant. The rationale behind changing canal operations from gravity to pumped is that it may minimize the amount of canal work required upstream of the pump station. One location for a pumping plant is in-channel at MP 109 because it is near the FKC low point and FWA owns land in the area. Another option for a pumping plant is along a bypass canal around MP 119, that would discharge into Lake Woollomes, since it would reduce the amount of canal lining required upstream. In addition to minimizing upstream modifications, pump stations provide durability against future subsidence. As the canal subsides, pumps can be upgraded to maintain the HGL.

Pump stations depend on utility power to move water, thus creating risk in the event of a power failure. Should a power outage occur, pump operations would cease, creating an upsurge (depth increase) in the canal upstream of the station and a downsurge (depth decrease) downstream. Thus, an important mitigating feature of a pump station is an emergency method such as backup generators, a spillway, or an emergency reservoir. Following a hydraulic analysis, it was determined that an emergency reservoir is the best option to mitigate a surge. Considering the

canal flow rate, outage duration, and assumed depth of the reservoir, the emergency reservoir would require about 350 to 400 acres of land. Costs for a pump station also include the cost of land for the emergency reservoir, and costs associated with pump station operations, maintenance, and replacement (OM&R).

New Canal

Rather than work within the existing canal structure, Project objectives can be met by building a new canal that bypasses the capacity-limited reaches. A new canal can either follow a different alignment or be situated immediately adjacent to the existing canal.

Bypass Canal

A bypass canal would diverge from the existing canal at a location upstream from the capacity-constrained section, traverse east with gravity flow, continue southward, and reconnect with the existing canal at a downstream location. Since the land level generally rises east of the FKC, a bypass canal would require a deeper invert than the existing FKC to maintain the proposed HGL. Construction of a bypass canal would allow portions of the existing canal to remain in service and operate as a feeder system, only conveying water to turnouts within the bypassed reach.

As illustrated in Figures 2-5 and 2-6, the bypass canal would either be in-cut or in-fill, both of which would be a conventional and optimized trapezoidal cross section. Regardless of the design and alignment, construction of a bypass canal would be independent from current canal and would have minimal impact on operations. Therefore, there would be little impact to water deliveries during construction.

A bypass canal would include new bridges, siphons, and turnouts, and would require new ROW. Based to the alignment, a bypass canal would require the installation of numerous new bridges and a few siphons, both of which can be costly and require permits. The alignment would also create an island of land between the existing canal and the new canal. If the island continues to be used for agricultural purposes, additional access both utilities and farm equipment would be required. If continued agricultural practices is not viable on these islands, a loss of land value may result.

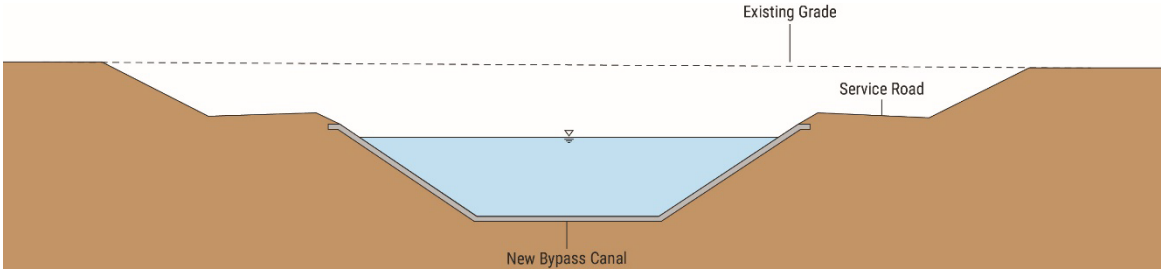


Figure 2-5. Bypass Canal Typical Cross Section In-Cut

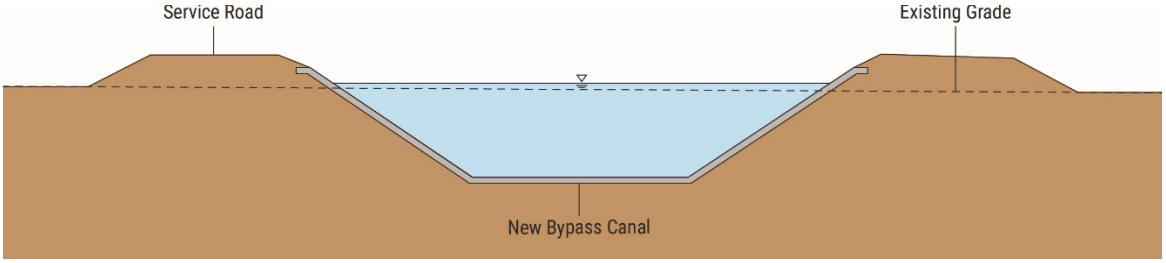


Figure 2-6. Bypass Canal Typical Cross Section In-Fill

Parallel Canal

In contrast to a bypass canal, a parallel canal would be situated immediately east and adjacent to the existing FKC, as shown in Figure 2-7. The parallel canal would have full capacity while portions of the existing canal would be used to maintain deliver water to the western turnouts. New turnouts would be built on the parallel canal to make deliveries to the east side water contractors. The parallel canal would span through the area with the most significant subsidence, a factor to be determined at the initial alternatives stage.

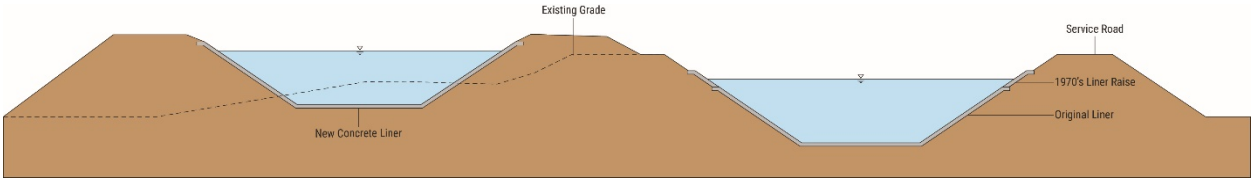


Figure 2-7. Parallel Bypass Canal Cross-Section

To construct a parallel canal, the left bank of the existing canal would be raised but would otherwise not impact FKC operations, maintenance or deliveries. The material required to raise the existing bank and add the new bank would come from the excavation of the parallel canal, reducing material requirements. Construction would require ROW acquisition, but less than a bypass canal or pump station. Since the parallel canal would be adjacent to the FKC, the parallel canal could either have new checks and siphons or tie-in at the existing check structures and siphons. New structures would meet current design standards and not require modifications, however tie-ins could reduce costs and required permitting.

Bridge Modifications

Several bridges throughout the Middle Reach restrict operations to a lower HGL. When the water surface is at the original or proposed HGL, it would encroach on the bridge's low cords, reducing velocity and threatening bridge stability. Even if the lining were raised, the water levels would remain limited by the elevation of the bridge low cords. Therefore, bridge modifications, either by raising the existing or replacing with a new bridge, are required to address Project objectives.

Bridge modifications have a limited effectiveness as a stand-alone measure. They do not restore original design capacity of the FKC other than reducing head losses. Bridge modifications are necessary, however, as an operational requirement to protect the integrity of the bridges and minimize head loss in the canal.

Raise Existing Bridge

To accommodate a higher HGL, the existing bridges could be raised. This entails installing sheet pile into the canal to divert water in the construction zone, installing jacks to lift the bridge, raising the bridge to its new height, and pouring concrete to extend the top of the existing pile caps and bridge abutments. Following the guidance from Reclamation's 1977 bridge raise, bridges would only be raised a maximum of three feet.

Replace Bridge

It is assumed that bridges would need to be completely replaced if they require more than three feet raise. A new bridge would increase the service life and meet current design standards. Trapezoidal bridges are recommended as they are more cost effective when compared to the costs of constructing more traditional pier and abutment supported bridges. Additionally, the trapezoidal deign would permit a bridge to withstand future subsidence with minimal addition cost for modifications. The bridges will be designed with more flow area than that of the canal immediately upstream and downstream from each new bridge to minimize head losses should the bridges become submerged due to future subsidence.

Pipeline

A pipeline offers an alternative means to deliver water to long-term contractors south of the subsidence section. The required HGL and existing hydraulic boundary conditions, as described above, leaves minimal head available for losses. The losses associated with a pipeline would be too great without providing additional pressure to the system via a pump station or multiple pump stations. This would require a pump station in addition to many miles of large diameter pipelines. As such, it would exceed the costs of other management measures. A pipeline is also susceptible to damage caused by subsidence and would not be any more resilient to future subsidence.

Reschedule Affected Deliveries in Millerton Lake

It is reasonable to assume that water deliveries affected by the reduced FKC capacity could be rescheduled in Millerton Lake. Class 1, Class 2, and RWA/215 water supplies could be held, to the extent possible, in Millerton Lake conservation space until adequate capacity exists in the FKC to move the water. The limitations on the ability to reschedule Millerton Lake include the required flood control space in Millerton Lake, unexpected hydrology, water rights, contract requirements, and other Reclamation policies. While this measure would not contribute to the project objective of restoring the design capacity of the FKC, it will be included in the No Action Alternative, and to be combined with structural measures in action alternatives to reduce water delivery impacts.

Measures Retained

Measures were screened based on their relative ability to contribute to Project goals and objectives, and their consistency with Project planning constraints, criteria, and other considerations. The following considerations were used to evaluate the retained resources management measures:

- Potential to directly address the planning objective without adversely impacting the ability to achieve the other objectives. To directly address a Project planning objective, measures need to have a geographic, operational, or physical relationship to problems and opportunities in the study area.
- Potential to contribute to the planning objective when part of a complete alternative plan. For example, if a measure to address a single objective could be implemented independently, and no benefit would occur in combining it with measures to address other Project objectives, it would likely be dropped from further consideration.
- Engineering (including cost), environmental, political, and institutional constraints relative to other available measures or options that are available to achieve the objective(s).

Of the nine resources management measures identified, seven were retained to use as the basis for forming alternative plans. The status of measures and rationale are listed in Table 2-1.

Table 2-1. Measures to Restore Friant-Kern Canal Capacity

Resource Management Measure	Status	Rationale
Raise Canal	Retained	Raising the canal would contribute to the Project objectives.
Raise and Widen Entire Cross Section	**Removed**	This measure is cost prohibitive and raises constructability concerns. Dropped from further consideration,
Raise and Widen Upper Portion of Cross Section	Retained	Enlarging the canal would contribute to Project objectives.
Pumping Plant	Retained	The addition of a pumping plant would help restore capacity, thus contributing to Project objectives.
Bypass Canal	Retained	A bypass canal would restore capacity, though not in the original FKC.
Parallel Canal	Retained	A parallel canal would restore capacity, though not in the original FKC.
Bridge Raise	Retained	A bridge raise does not sufficiently meet Project objectives but is an operational requirement.
Bridge Replacement	Retained	A bridge replacement does not sufficiently meet Project objectives but is an operational requirement to be included.
Pipeline	**Removed**	Initial hydraulic analysis revealed that head losses would be greater than the available head, and project would require a pump station(s) to move water. This would be more costly than other available options.
Reschedule affected deliveries in Millerton Lake	Retained	Water deliveries affected by reduced FKC capacity could be re-scheduled within available conservation space in Millerton Lake to the extent allowable by water rights, contracts, and Reclamation policy.

Chapter 3
Initial Alternatives

This chapter provides a description of the No Action Alternative and the seven initial alternatives evaluated at the Feasibility stage. The physical features of the alternatives, as well as the costs and anticipated permitting requirements, are summarized below and evaluated further in Chapter 5.

No Action Alternative

The No Action Alternative represents a projection of reasonably foreseeable future conditions that could occur if no alternatives are implemented (i.e., the future without the proposed Project). Reclamation recommends several criteria for including proposed future actions within the No Action Alternative: proposed actions should be (1) authorized; (2) approved through completion of NEPA, CEQA, and Endangered Species Act (ESA) compliance processes; (3) funded; and (4) permitted. The No Action Alternative is considered the basis for comparison with the Recommended Plan, consistent with NEPA and the PR&G (CEQ 2013) guidelines. Therefore, if no proposed action is determined feasible, the No Action Alternative is the default option.

Under the No Action Alternative, the Federal government would continue to implement reasonably foreseeable actions, as defined above, but Reclamation and FWA would not take additional actions towards restoring the capacity of the FKC. If no action is taken, the FKC would continue to be operated under capacity-restricted conditions. The capacity restrictions will evolve and likely worsen over time with additional subsidence. A quantification of the capacity restrictions will be forthcoming in the Feasibility Report.

The current capacity-restricted condition is anticipated to limit the ability of several contractors to receive water during periods of peak demand or peak flow. This could impact delivery of water under Paragraph 16(b) of the Settlement “for the purpose of reducing or avoiding impacts to water deliveries to all of the Friant Division long-term contractors caused by the Interim and Restoration Flows,” thus limiting the Secretary of the Interior’s ability to achieve the Water Management Goal of the Settlement.

In response to reduced deliveries from Friant Dam, affected Friant Division long-term contractors would likely increase groundwater pumping. However, the Sustainable Groundwater Management Act (SGMA) implementation is expected to have a significant regional effect, which may result in changes to groundwater pumping and crop patterns, as described in Chapter 2.

Capacity Restoration

As stated in Chapter 1, the objective of the Project is to restore the capacity of the FKC, consistent with Settlement Act authority. This involves restoring the original design capacity of the FKC consistent with current Reclamation design standards. The design of all initial alternatives, including canal enlargement, pump station, new bypass and new parallel canal measures are based on a canal operating capacity equal to the Design Maximum Flow Rate (Table 3-1). Canal lining depths will equate to the normal depths at the Design Maximum Flow Rates plus the established lined freeboard criteria. The design flow rates were used to develop the HGL profiles for the initial alternatives. This approach is considered conservative and is inclusive of all potential flow and freeboard design requirements.

Table 3-1. Design Flow Rates

Canal Section No.	Canal Segment (MP to MP)	Description (Check to Check)	Normal Flow Rate (cfs)	Design Maximum Flow Rate (cfs)
4	88 to 95.67	5th Avenue to Tule	3,500	4,500
5	95.67 to 112.90	Tule to White River	3,000	4,000
6.1	112.90 to 128.69	White River to HWY 99	2,500	3,500
6.2	128.69 to 130.03	HWY 99 to Poso	2,500	3,000

Key:
cfs = cubic feet per second
HWY = highway
MP = mile post

Initial Alternatives

Seven initial alternatives were developed to meet the Project objective: (1) Canal Enlargement; (2) Pump Station at MP 109; (3) Pump Station at Woollomes; (4A) Bypass Canal from Tule to White River; (4B) Bypass Canal from Tule to Woollomes; (5A) Parallel Canal from Tule to White River; and (5B) Parallel Canal from Tule to Woollomes. Although there are different approaches to meeting the Project objectives, all alternatives return the canal to its original design capacity, as described above. An overview of each alternative is provided in Tables 3-2 and 4-3. Table 3-2 describes the modifications to the FKC that would be implemented by segment for each alternative. Table 3-3 describes features the structural features that would be added to each segment for each alternative. Further details regarding the costs, material needs, environmental constraints, and other pertinent information is described below. Potential modifications to turnouts are considered on a generalized basis; in the analysis of Initial Alternatives. Detailed consideration of modifications to turnouts, or provisions to avoid affects to turnouts, is addressed in the feasibility evaluation of alternatives.

Table 3-2. Structural Modifications to Existing Canal by Initial Alternative

Alternative	Segment 1	Segment 2	Segment 3	Segment 4
	5th Ave. to Tule River (MP 88.2 – 95.6)	**Tule River to Deer Creek (MP 95.6 – 102.6)**	**Deer Creek to White River (MP 102.6 – 112.9)**	**White River to Woollomes (MP 112.9 – 121.5)**
1: Canal Enlargement	Widen and Raise Entire Segment	Widen and Raise Entire Segment	Widen and Raise Entire Segment	Widen and Raise Entire Segment
2: Pump Station at MP 109	Widen and Raise Entire Segment	Lining Raise (MP 95.9-MP 98.8)	Lining Raise (MP 102.6-MP 105.5) Widen and Raise (MP 109-112.9)	Widen and Raise Entire Segment
3: Pump to Woollomes	Widen and Raise Entire Segment	Lining Raise (MP 95.9-MP 98.8)	Lining Raise (MP 102.6-MP 105.5)	Widen and Raise (MP 119-121.5)
4A: Bypass Canal—Tule River to White River.	Widen and Raise Entire Segment	—	—	Widen and Raise Entire Segment
4B: Bypass Canal—Tule River to Woollomes	Widen and Raise Entire Segment	—	—	Widen and Raise (MP 119-121.5)
5A: Parallel Canal—Tule River to White River	Widen and Raise Entire Segment	—	—	Widen and Raise Entire Segment
5B: Parallel Canal—Tule River to Woollomes	Widen and Raise Entire Segment	—	—	Widen and Raise (MP 119-121.5)

Key:
MP = mile post

Table 3-3. Structural Additions by Initial Alternative

Alternative	Segment 1	Segment 2	Segment 3	Segment 4
	5th Ave. to Tule River (MP 88.2 – 95.6)	**Tule River to Deer Creek (MP 95.6 – 102.6)**	**Deer Creek to White River (MP 102.6 – 112.9)**	**White River to Woollomes (MP 112.9 – 121.5)**
1: Canal Enlargement	—	—	—	—
2: Pump Station at MP 109	—	—	Pump Station (MP 109), Emergency Reservoir	—
3: Pump to Woollomes	—	—	Bypass Canal (MP 105.5-112.9) Check and Siphon at White River	Pump Station (MP 119) Emergency Reservoir
4A: Bypass Canal—Tule River to White River.	—	Bypass Canal Entire Segment, Check and Siphon at Deer Creek	Bypass Canal Entire Segment, Check at White River	—
4B: Bypass Canal—Tule River to Woollomes	—	Bypass Canal Entire Segment, Check and Siphon at Deer Creek	Bypass Canal Entire Segment, Check and Siphon at White River	Bypass Canal (MP 112.9-119)
5A: Parallel Canal—Tule River to White River.	—	Parallel Canal Entire Segment	Parallel Canal Entire Segment	—
5B: Parallel Canal—Tule River. to Woollomes	—	Parallel Canal Entire Segment	Parallel Canal Entire Segment	Parallel Canal (MP 112.9-119)

Key:
MP = mile post

Alternative 1: Canal Enlargement

Alternative 1, or the baseline alternative, returns the canal to design capacity exclusively through raising or raising and widening the canal (Figure 3-1). Alternative 1 is considered the baseline alternative because all subsequent alternatives include some modifications to the FKC. For example, all Initial Alternatives include the same modifications to Segment 1 and incorporate additional measures in Segments 2 through 4.

Through Alternative 1, capacity restoration is accomplished by removing a portion of the existing liner, cutting a bench into the existing grade, and building out the embankment throughout the Middle Reach. By restoring capacity in this manner, land acquisition is minimized (170 acres total) and costs are reduced, but 67 miles of embankment will be modified. Additionally, Alternative 1 requires 1.55 million cubic yards of borrow material and modifications to 17 bridges. As currently designed, Alternative 1 has an estimated capital cost of $290 million and $300,000 annually in additional OM&R costs.

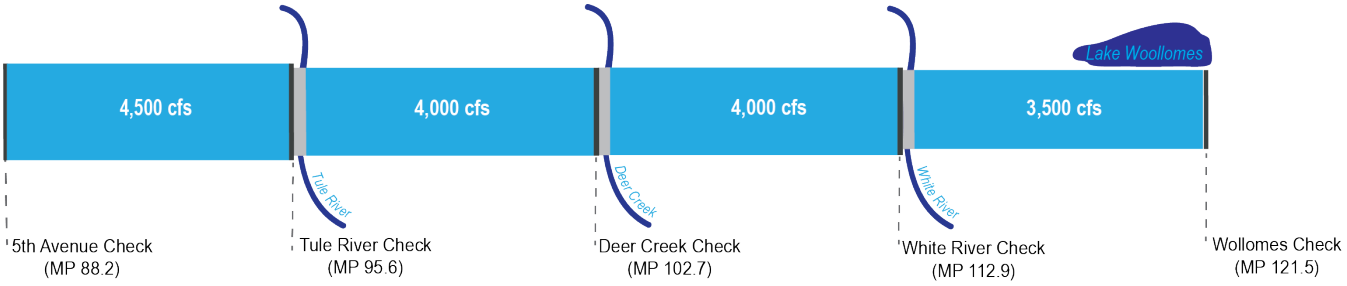


Figure 3-1. Alternative 1 Schematic – Canal Enlargement

Segment 1: 5th Avenue to Tule River

In this segment, the FKC would be modified to convey a maximum flow of 4,500 cubic feet per second (cfs). This would be achieved through a combination of raising and widening the canal. The enlargement in this segment, as well as the capacity, is the same among all alternatives.

Segment 2: Tule River to Deer Creek

In this segment, the FKC would be modified to convey a maximum flow of 4,000 cfs. This would be achieved through a combination of raising and widening the canal. All alternatives will have a capacity of 4,000 cfs in this segment

Segment 3: Deer Creek to White River

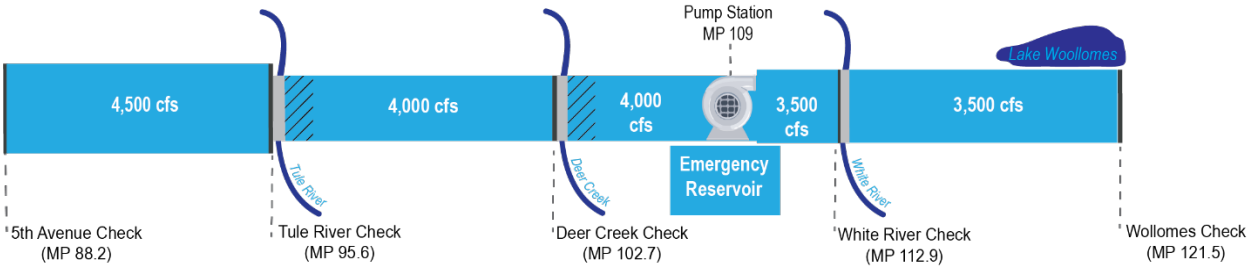
In this segment, the FKC would be modified to convey a maximum flow of 4,000 cfs. This would be achieved through a combination of raising and widening the canal. All alternatives will have a capacity of 4,000 cfs that will taper to 3,500 cfs at White River in this segment.

Segment 4: White River to Lake Woollomes

In this segment, the maximum capacity would be increased to 3,500 cfs. This would be achieved through a combination of raising and widening the canal. All alternatives will have a capacity of 3,500 cfs in this segment

Alternative 2: Pump Station at MP 109

The primary distinguishing feature between Alternatives 1 and 2 is that Alternative 2 includes a pump station at milepost (MP) 109 (see Figure 3-2). When flows are high and cannot be conveyed by gravity, water would be diverted from the original canal into a forebay then pumped back into the original canal. The initial pump station design includes eight 250-cfs pumps. In the event of a power failure, water would be directed into a 400-acre emergency reservoir to prevent a surge. Constructing the emergency reservoir, plus the canal modifications, would result in 542,000 cubic yards of surplus earthen material, 52.5 miles of modified embankment, and 14 bridge modifications. In total, these activities cost an estimated $270 million dollars to construct and $3.1 million annually in additional OM&R costs.



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Figure 3-2. Alternative 2 Schematic – Pump Station at MP 109Segment 1: 5th Ave. to Tule River

Segment 1: 5th Avenue to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The only modification along this segment of the canal is a 2-mile lining raise between Tule River (MP 95.67) and MP 98.8. The remainder of this segment would not be modified.

Segment 3: Deer Creek to White River

Alternative 2 includes several alterations along this segment: raising the canal lining; enlarging the canal; and adding a pump station. A canal lining is proposed beginning at Deer Creek (MP 102.6) and ending at MP 105.5. From MP 105.5 to the pump station (MP 109), the canal would not be modified. At MP 109, a pump station would be installed. The pump station requires an associated emergency reservoir, increasing the amount of additional ROW required by 400 acres.

Directly downstream of the pump station, the canal would be enlarged until the White River check at MP 112.9.

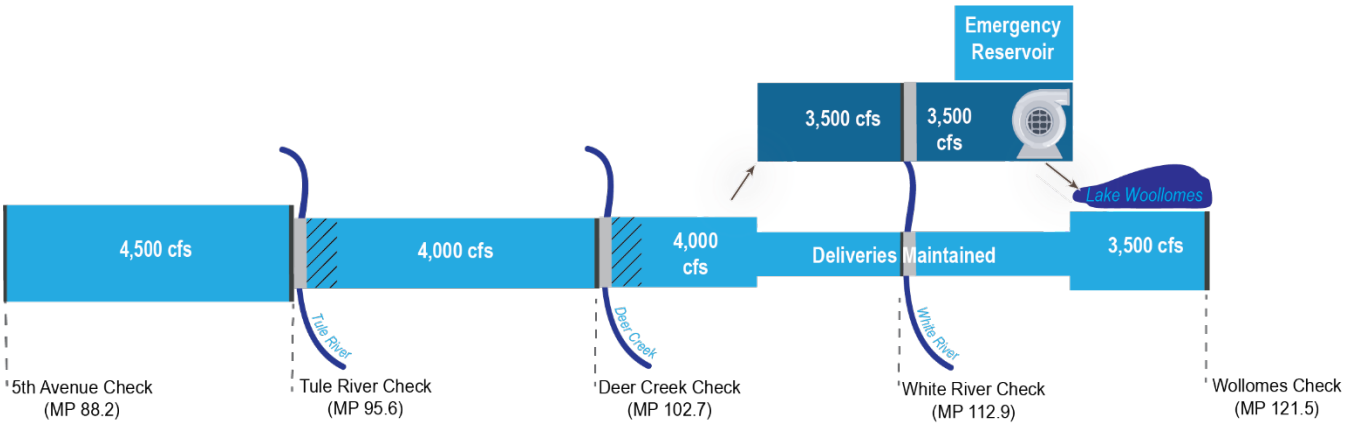
Segment 4: White River to Lake Woollomes

The canal enlargement would continue from White River down to Lake Woollomes.

Alternative 3: Pump Station at Woollomes

Similar to Alternative 2, Alternative 3 includes a pump station, but at MP 119. Capacity restoration would be achieved by moving water from the original canal into an approximately 10-mile-long bypass canal and lifting it into Lake Woollomes (see Figure 3-3). It is important to note that deliveries would be maintained in the original canal, but the majority of the water would move through the bypass canal. Due to the bypass canal, Alternative 3 requires a siphon to cross the White River, adding complexity to environmental compliance and permitting. In addition to the siphon-related compliance and permitting, Alternative 3 impacts 27 miles of embankment.

Alternative 3 also requires a 350-acre emergency reservoir to accommodate a surge in the event of a power outage. The emergency reservoir, combined with the bypass canal and embankment enlargement, would require an additional 622 acres of ROW, 23 bridge modifications, and would result in 950,000 cubic yards of surplus material. In total, these activities would cost an estimated $380 million to construct and $3.5 million annually in additional OM&R costs, making it the most expensive alternative.



Note: * Crosshatched area depicts the lining raise.

Figure 3-3. Alternative 3 Schematic – Pump Station at Woollomes

Segment 1: 5th Ave. to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The only modification along this stretch of the canal is a 2-mile lining raise between Tule River (MP 95.67) and MP 98.8. The remainder of this segment remains as is.

Segment 3: Deer Creek to White River

Alternative 3 includes many actions along this segment: raising the canal lining, constructing a bypass canal, and adding a pump station. At the beginning of the segment, Alternative 3 proposes a canal lining raise from Deer Creek (MP 102.6) to MP 105.5. The canal remains unchanged from MP 105.5 to MP 109, where the bypass canal begins. Most water would move through this bypass, past a new siphon and check structure at White River, and eventually into a pump station. The existing canal would maintain deliveries in this portion and would remain unchanged.

Segment 4: White River to Lake Woollomes

The water in the bypass canal would reach a pump station at MP 119 just before entering Lake Woollomes, thus restoring its capacity. The pump station requires an associated 400-acre emergency reservoir. The existing canal would maintain deliveries in this portion and would remain unchanged, except between MP 119 and 121.5, where the canal would be enlarged.

Alternative 4A: Bypass Canal from Tule River to White River

Alternative 4A is an offset bypass canal that would move water into a new canal at Tule River and connect back into the existing canal at White River. The existing canal would be used solely to maintain deliveries between the two checks (see Figure 3-4). While the specific alignment has not been determined, it is known Alternative 4A would require an additional 508 acres for ROW and would cross Deer Creek. The land required, and the river crossing, make Alternative 4A complex to construct and comply with environmental regulations. The bypass canal, plus modifications to the existing canal, would result in 1,750 thousand cubic yards of surplus material, 18 bridge modifications, 32 miles of modified embankment, and cost approximately $300 million to construct, and $1 million annually in additional OM&R costs.

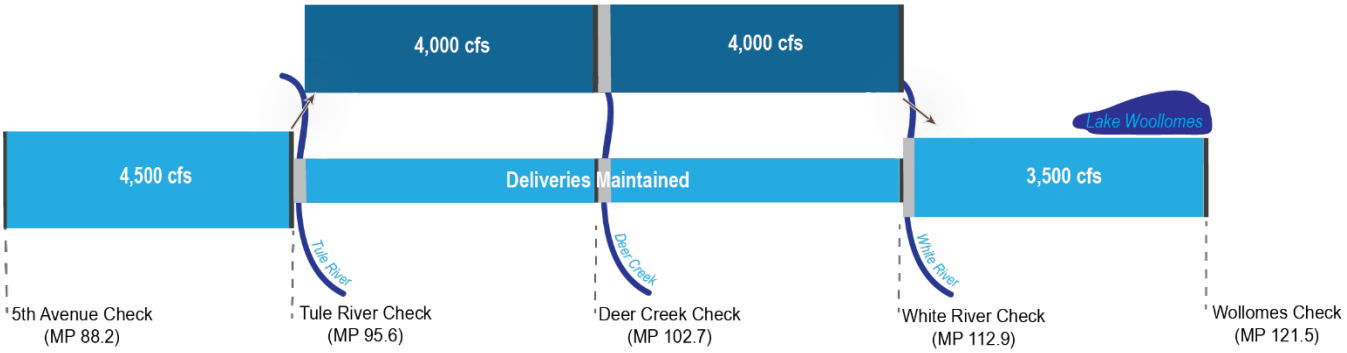


Figure 3-4. Alternative 4A Schematic – Bypass Canal from Tule River to White River

Segment 1: 5th Ave. to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The new bypass canal would begin at Tule River and extend through Deer Creek. In this segment, the bypass canal requires a new check and siphon at Deer Creek. There are no modifications to the existing canal through this segment; it would be used exclusively to maintain water deliveries.

Segment 3: Deer Creek to White River

The bypass canal continues through Deer Creek and terminates at White River, where it connects back to the existing canal. There are no modifications to the existing canal through this segment; it would be used exclusively to maintain water deliveries.

Segment 4: White River to Lake Woollomes

Actions are the same as Alternative 1.

Alternative 4B: Bypass Canal from Tule River to Woollomes

Alternative 4B is the same as Alternative 4A but extends to Woollomes (see Figure 3-5). As such, it would require more ROW (650 vs. 508 acres), result in more surplus material (2.418 million vs. 1.75 million cubic yards), but fewer miles of modified embankment (20 vs. 32 miles). Alternative 4B also crosses an additional stream at White River. Alternative 4B would cost an estimated $320 million to construct with $1.45 million annually in additional OM&R costs.

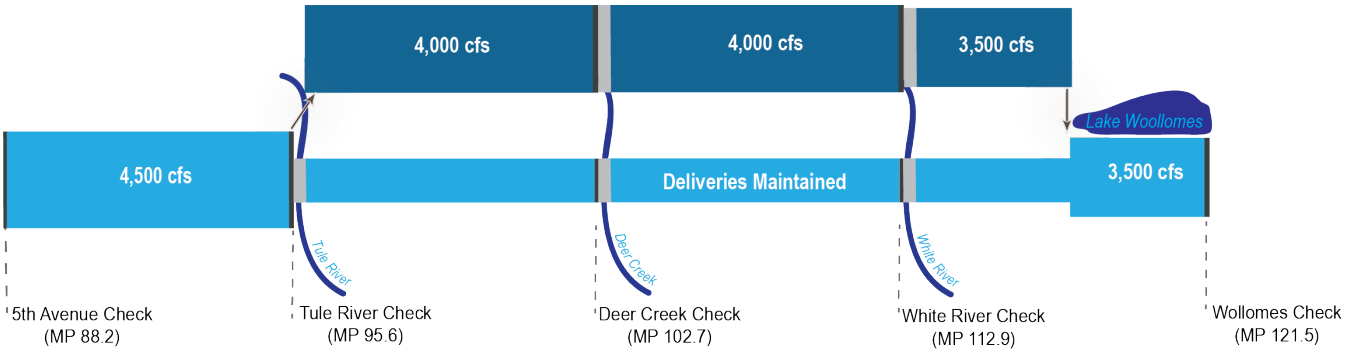


Figure 3-5. Alternative 4B Schematic – Bypass Canal from Tule River to Woollomes

Segment 1: 5th Ave. to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The new bypass canal would begin at Tule River and extend through Deer Creek. In this segment, the bypass canal requires a new check and siphon at Deer Creek. There are no modifications to the existing canal through this segment; it would be used exclusively to maintain water deliveries. These actions are the same as Alternative 4A.

Segment 3: Deer Creek to White River

Unlike Alternative 4A, the bypass canal continues through Deer Creek and extends past White River. In this segment, the bypass canal requires a new siphon at White River. There are no modifications to the existing canal through this segment; it would be used exclusively to maintain water deliveries.

Segment 4: White River to Lake Woollomes

The bypass canal continues through White River until it terminates at Lake Woollomes. In this segment, the bypass canal requires a new check structure. The existing canal would remain largely unchanged, except between MP 119 and 121.5 where the canal would be enlarged.

Alternative 5A: Parallel Canal from Tule River to White River

Alternative 5A is a combination of the canal enlargement and parallel canal measures (Figure 3-6). The parallel canal would run from Tule River to White River, the area of greatest projected subsidence. This alignment is beneficial as it pertains to ROW and earthen material. Alternative 5A has minimal additional ROW land requirements (321 acres), a material balance (i.e., excavation required is equal to construction fill needed) and modifies 49 miles of embankment. The total cost for this alternative is estimated at $300 million to construct and $950,000 annually in additional OM&R costs.

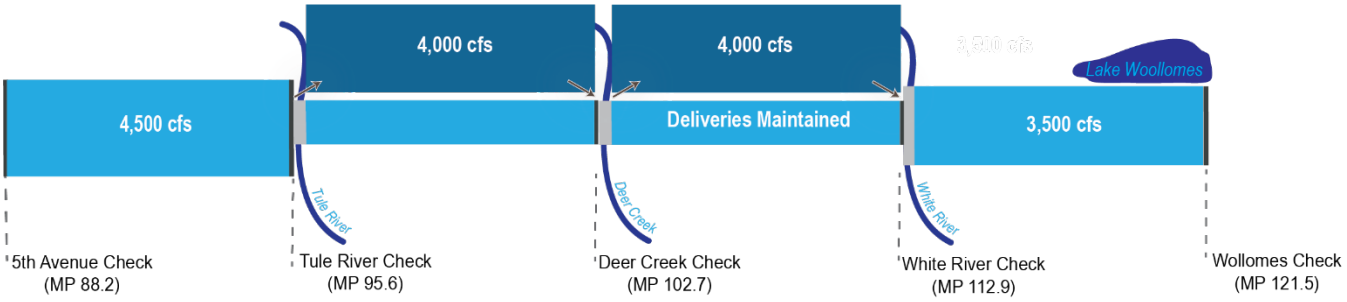


Figure 3-6. Alternative 5A Schematic – Parallel Canal from Tule River to White River

Segment 1: 5th Ave. to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The new parallel canal would begin at Tule River and extend through Deer Creek. Due to the design, no new siphons or checks are required as the parallel canal will tie into the existing infrastructure. The existing canal would only undergo slight modifications, raising the left bank to accommodate the parallel canal design.

Segment 3: Deer Creek to White River

The parallel canal would continue through Deer Creek and end at White River, tying back into the existing canal. The minor left bank canal modifications to the existing canal would be carried through this segment.

Segment 4: White River to Lake Woollomes

Actions are the same as Alternative 1.

Alternative 5B: Parallel Bypass Canal from Tule River to Woollomes

Alternative 5B is the same as Alternative 5A from Tule River to the White River but extends to Lake Woollomes (see Figure 3-7). A such, Alternative 5B has many similarities to Alternative 5A in terms of design and material balance, but differs in ROW, additional OM&R costs, and miles of modified embankment. Alternative 5B requires more ROW requirements than Alternative 5A (386 vs. 320 acres) and has greater annual additional OM&R requirements ($1.35 million vs. $950,000). Alternative 5B has the same estimated capital cost as Alternative 5A and modifies less of the existing canal (43 vs. 49 miles).

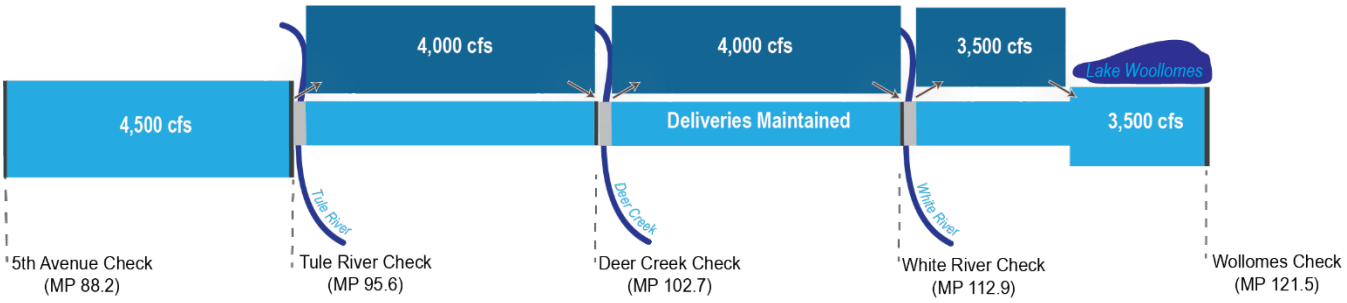


Figure 3-7. Alternative 5B Schematic – Parallel Bypass Canal from Tule River to Woollomes

Segment 1: 5th Ave. to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The new parallel canal would begin at Tule River and extend through Deer Creek. Due to the design, no new siphons or checks are required as the parallel canal would tie into the existing

infrastructure. The existing canal would only undergo slight modifications, raising the left bank to accommodate the parallel canal design. These actions are the same as Alternative 5A.

Segment 3: Deer Creek to White River

Unlike Alternative 5A, the parallel canal would continue throughout this segment. The minor left bank canal modifications to the existing canal would be carried through this segment.

Segment 4: White River to Lake Woollomes

The parallel canal would extend through White River and terminate at Lake Woollomes. The minor left bank canal modifications to the existing canal would be carried through until MP 119, where the canal would be enlarged for approximately 2 miles.

Summary

Table 3-4 highlights the defining characteristics of each alternative. The range in capital costs is attributed to the quantity and complexity of features to be modified or constructed, and the range in additional annual OM&R costs is attributed to total canal length and/or costs associated with a pump station. The pump station alternatives also require more ROW acquisition than most of the gravity-based alternatives due to the size of emergency reservoirs. The pump station alternatives and the gravity-based alternatives have similarities pertaining to bridge modification and the length of modified embankment; most alternatives require between 18 to 24 bridge modifications and impact 40 to 50 miles of embankment. A more detailed comparison of the alternatives and the ramifications of their differences is provided in the next chapter.

Table 3-4. Initial Alternative Features Summary

Alternative	Capital Cost	Present Worth Additional OM&R (M)	Material Balance[1] (1,000 yd^3)	Additional ROW Required (acres)	Bridge Modification[2]	Stream Crossing	Embankment Modification (mi)
1: Canal Enlargement	$290	$0.3	-1,550	170	17	0	66
2: Pump Station at MP 109	$270	$3.1	+542	522	14	0	52
3: Pump to Woollomes	$380	$3.5	+945	622	23	1	27
4A: Bypass Canal—Tule River to White River	$300	$1	+1,750	508	18	1	32
4B: Bypass Canal—Tule River to Woollomes	$320	$1.4	+2,418	650	24	2	20
5A: Parallel Canal—Tule River to White River	$300	$0.9	Balanced	321	18	0	49
5B: Parallel Canal—Tule River to Woollomes	$300	$1.3	Balanced	390	24	0	43

Notes:
[1] Negative values indicate borrow and positive values indicate surplus.
[2] Modifications can be a raise, replace, or new bridge. Farm bridge modifications are not included in this count.
Key:
M = million dollars
mi =miles
MP = mile post
OM&R = operations, maintenance, and replacement
yd^3 = cubic yard

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Chapter 4
Initial Alternatives Evaluation and Comparison

This chapter summarizes the process that FWA applied to evaluate and compare Initial Alternatives. The Initial Alternatives were analyzed and scored under two conditions, current land surface and land surface with future subsidence, by five evaluation criteria. The evaluation used scores ranging from one to five, with five assigned to the most favorable outcomes and one assigned to the least favorable outcomes.

For the qualitative sub-criteria, the professional judgement from engineers, planners, and environmental compliance specialists was used to assign the scores. For the quantitative sub-criteria, denoted with an asterisk in Table 4-1, the assessment values were normalized to a standard range (1 to 5). Rational scores, or those with decimals, were maintained rather than rounded to highlight the differences between each alternative. For a detailed explanation on the evaluation process, refer to Appendix A3 Evaluation and Comparison of Initial Alternatives.

Table 4-1. Evaluation Criteria and Sub-Criteria

I. Constructability	II. Operational Requirements and Flexibility	III. Cost	IV. Schedule	V. Environmental Compliance and Permitting
CON-1. Complexity to Maintain Water Deliveries during Construction	OPS-1. Additional O&M Requirements and Expertise of FWA Staff	COST-1. Construction Cost*	SCH-1. Time to Start Construction	ENV-1. Complexity of Required Environmental Compliance
CON-2. Ability to O&M during Construction	OPS-2. Operations of District Turnouts	COST-2. Non-contract Cost*	SCH-2. Construction Duration	ENV-2. Number of Stream Crossings*
CON-3. Temporary Bypasses and Tie-Ins Needed to Construct the Project*	OPS-3. Ability to Accommodate Power Outages	COST-3. Present Worth Additional OM&R Costs*	SCH-3. Time Until Benefits Realized	ENV-3. Number of Bridges*
CON-4. Extent of Dewatering			SCH-4. Potential to Phase Construction	ENV- 4. Length of Modified Existing Embankment*
CON-5. Material Balance*			SCH-5. Land Acquisition*	
			SCH-6. Schedule Risk	

Note:
*Qualitative sub-criterion
Key:
O&M = operations and maintenance
OM&R = operations, maintenance, and replacement

I. Constructability

Constructability is a broad category that refers to the ability and complexity of project construction. Constructability is characterized by five sub-criteria:

- CON-1. Complexity to Maintain Water Deliveries during Construction. *A qualitative sub-criterion that relates to the challenges associated with maintaining water deliveries during construction.*
- CON-2. Ability to operations and maintenance (O&M) Canal during Construction. *A qualitative sub-criterion that describes how construction activities may impact O&M during the construction period.*
- CON-3. Temporary Bypasses and Tie-ins needed to Construct the Project. *A quantitative sub-criterion that identifies the number of temporary canal re-routing features required during construction based on preliminary designs.*
- CON-4. Extent of Dewatering. *A qualitative sub-criterion that characterizes if there is a need for dewatering and the relative magnitude of that need.*
- CON-5. Material Balance. *A quantitative sub-criterion that identifies the extent of material borrow, surplus, or balance.*

Table 4-2 provides the summary scores for each alternative. Note only CON-5 changed scores from the current land condition to the future with subsidence land conditions.

Table 4-2. Constructability Score Summary

Initial Alternative	CON-1		CON-2		CON-3		CON-4		CON-5	
	C	F	C	F	C	F	C	F	C	F
1: Canal Enlargement	1.0	1.0	1.0	1.0	1.0	1.0	5.0	5.0	1.0	1.0
2: Pump Station at MP 109	2.0	2.0	2.0	2.0	1.2	1.2	4.0	4.0	4.3	5.0
3: Woollomes Pump Station	3.0	3.0	3.0	3.0	3.3	3.3	1.0	1.0	3.8	4.5
4A: Bypass Canal —Tule River to White River	4.0	4.0	4.0	4.0	4.5	4.5	4.0	4.0	2.7	4.7
4B: Bypass Canal —Tule River to Woollomes	5.0	5.0	5.0	5.0	5.0	5.0	3.0	3.0	1.9	4.2
5A: Parallel Canal —Tule River to White River	4.0	4.0	4.0	4.0	4.2	4.2	3.0	3.0	5.0	4.1
5B: Parallel Canal —Tule River to Woollomes	5.0	5.0	5.0	5.0	4.4	4.4	2.0	2.0	5.0	4.8

Key:
C = Current
F= Future

II. Operational Requirements and Flexibility

Operational Requirements and Flexibility pertains to the impacts on FWA's ability to operate and maintain the project, now and in the future. The criterion is made up of three sub-criteria:

- OPS-1. Additional O&M Requirements and Expertise of FWA Staff. *A qualitative sub-criterion used to distinguish how complex an alternative would affect the long-term O&M activities and required expertise of FWA O&M staff in comparison to current conditions.*
- OPS-2. Operations of Individual District Turnouts. *A qualitative sub-criterion that characterizes the relative impact of each alternative on existing FKC turnouts.*
- OPS-3. Ability to Accommodate Power Outages. *A qualitative sub-criterion that addresses how an alternative would function in the event of a power outage.*

Table 4-3 provides the summary scores for each alternative under the Operational Requirements and Flexibility criterion. Note the scores did not change between the current land condition and future with subsidence land conditions.

Table 4-3. Operational Requirements and Flexibility Score Summary

Alternative	OPS-1		OPS-2		OPS-3	
	C	F	C	F	C	F
1: Canal Enlargement	5.0	5.0	5.0	5.0	5.0	5.0
2: Pump Station at MP 109	2.0	2.0	3.0	3.0	2.0	1.0
3: Woollomes Pump Station	1.0	1.0	3.0	3.0	2.0	1.0
4A: Bypass Canal—Tule River to White River	4.0	4.0	2.0	2.0	5.0	5.0
4B: Bypass Canal—Tule River to Woollomes	3.0	3.0	1.0	1.0	5.0	5.0
5A: Parallel—Tule River to White River	4.0	4.0	4.0	4.0	5.0	5.0
5B: Parallel Canal—Tule River to Woollomes	3.0	3.0	3.0	3.0	5.0	5.0

Key:
C = Current
F = Future

III. Cost

The Cost criterion refers to the upfront and long-term costs associated with the alternatives. Cost is broken down into three sub-criteria for different cost components:

- COST-1. Construction Cost. *A quantitative sub-criterion that details the construction cost of each alternative.*
- COST-2. Non-contract Cost. *A qualitative sub-criterion that refers to the costs of work or services provided in support of implementing an alternative including environmental mitigation, planning and design, legal and administrative, and land acquisition.*
- COST-3. Present Worth Additional O&M and Replacement Costs. *The additional annual cost for FWA to operate, maintain, and replace canal features.*

Table 4-4 provides the Cost criterion summary scores for each alternative under both the current and future with subsidence land condition. For additional cost details, refer to Appendix A1 Engineering Design and Cost.

Table 4-4. Cost Score Summary

Alternative	COST-1		COST-2		COST-3	
	C	F	C	F	C	F
1: Canal Enlargement	4.1	3.2	5.0	4.8	5.0	5.0
2: Pump Station at MP 109	5.0	5.0	4.0	5.0	1.5	1.5
3: Woollomes Pump Station	1.0	1.0	1.0	1.0	1.0	1.0
4A: Bypass Canal—Tule River to White River	4.1	3.9	3.5	4.1	4.1	4.1
4B: Bypass Canal—Tule River to Woollomes	3.2	2.8	2.2	2.3	3.6	3.6
5A: Parallel—Tule River to White River	3.7	3.9	4.0	4.8	4.2	4.2
5B: Parallel Canal—Tule River to Woollomes	3.7	3.2	3.8	4.1	3.7	3.7

Key:
C = Current
F = Future

IV. Schedule

The Schedule criterion provides an indication of how long it will take to build the project and realize benefits. Schedule is made up of six sub-criteria described below. Table 4-5 provides the Schedule criterion summary scores for each alternative.

- SCH-1. Time to Start Construction. *A qualitative sub-criterion that assesses the time it will take to complete pre-construction activities and begin construction based off the expected schedule risks.*
- SCH-2. Construction Duration. *A qualitative sub-criterion that considers a generalized expected construction schedule based on the complexity of each alternative.*
- SCH-3. Time Until Benefits Realized. *A qualitative sub-criterion that addresses when increases in capacity allowing additional water delivery, either in part or in total, is expected to begin.*
- SCH-4. Potential to Phase Construction. *A qualitative sub-criterion addresses the ability to construct an alternative in phases or to expand an alternative at a later date.*
- SCH-5. Land Acquisition. *A quantitative sub-criterion that details the number of acres required to extend the permanent ROW.*
- SCH-6. Schedule Risk. *A qualitative sub-criterion that accounts for the foreseeable and unforeseeable schedule risks to a project.*

Table 4-5. Schedule Score Summary

Initial Alternative	SCH-1		SCH-2		SCH-3		SCH-4		SCH-5		SCH-6	
	C	F	C	F	C	F	C	F	C	F	C	F
1: Canal Enlargement	5.0	5.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0
2: Pump Station at MP 109	3.0	3.0	4.0	4.0	3.0	3.0	3.0	3.0	2.1	2.4	2.0	2.0
3: Woollomes Pump Station	2.0	2.0	3.0	3.0	2.0	2.0	2.0	2.0	1.2	1.2	1.0	1.0
4A: Bypass Canal —Tule River to White River	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.2	2.4	3.0	3.0
4B: Bypass Canal —Tule River to Woollomes	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0
5A: Parallel Canal —Tule River to White River	3.0	3.0	2.0	2.0	3.0	3.0	4.0	4.0	3.7	4.1	5.0	5.0
5B: Parallel Canal —Tule River to Woollomes	2.0	2.0	1.0	1.0	3.0	3.0	4.0	4.0	3.2	3.5	5.0	5.0

Key:
C = Current
F = Future

V. Environmental Compliance and Permitting

The Environmental Compliance and Permitting criterion addresses the complexity to complete NEPA/CEQA activities and documentation and obtain necessary permits. The criterion is broken down into four sub-criteria:

- ENV-1. Complexity of Required Environmental Compliance. *A qualitative sub-criterion that captures the complexity of the expected environmental compliance activities and documentation necessary to satisfy NEPA and CEQA.*

- ENV-2. Number of Stream Crossings. *A quantitative sub-criterion based on the number of new stream crossings included in an alternative.*

- ENV-3. Number of Bridges. *A quantitative sub-criterion that enumerates the county and state bridges that will need to be either constructed over a bypass canal or replaced or raised on the existing FKC.*

- ENV-4. Total Length of Modified Embankment. *A quantitative sub-criterion based on the number of miles of modified embankment or endangered San Joaquin kit fox potential habitat.*

Table 4-6 provides the Environmental Compliance and Permitting criterion summary scores. For a detailed review of the environmental considerations and constraints, refer to Appendix A2 Environmental Constraints Analysis Summary.

Table 4-6. Environmental Compliance and Permitting Score Summary

Alternative	ENV-1		ENV-2		ENV-3		ENV-4	
	C	F	C	F	C	F	C	F
1: Canal Enlargement	3.0	3.0	5.0	5.0	3.8	3.8	1.0	1.0
2: Pump Station at MP 109	1.0	1.0	5.0	5.0	5.0	5.0	2.2	2.2
3: Woollomes Pump Station	1.0	1.0	3.0	3.0	1.4	1.4	4.4	4.4
4A: Bypass Canal—Tule River to White River	1.0	1.0	3.0	3.0	3.4	3.4	4.0	4.0
4B: Bypass Canal—Tule River to Woollomes	1.0	1.0	1.0	1.0	1.0	1.0	5.0	5.0
5A: Parallel—Tule River to White River	1.0	1.0	5.0	5.0	3.4	3.4	2.5	2.5
5B: Parallel Canal—Tule River to Woollomes	1.0	1.0	5.0	5.0	1.0	1.0	3.0	3.0

Key:
C = Current
F = Future

Evaluation Uncertainties

There are several uncertainties associated with the evaluation presented above; the largest of which relate to the qualitative nature of many sub-criteria and the level of initial alternative development.

Many sub-criteria are qualitative in nature meaning that they are based on professional judgement and open to interpretation or subject to change. While the scoring was performed by experts in the field who agreed upon a single value, there may be instances where a score does not reflect the initial alternative correctly. For example, the extent of dewatering may change when the project is under construction to deal with unexpected field conditions like high groundwater levels and varied soil conditions.

Some of the unknown conditions will be determined as the project progresses. The evaluation considered the alternatives at roughly a 10 percent design. Alternative features like alignments, ROW, material required, and so on are likely to change. These features all impact the cost estimates. The costs were calculated at the appraisal level and have an associated accuracy range. Therefore, all quantities and costs should be considered preliminary and subject to change as studies and the level of design progress.

Although there are uncertainties associated with the qualitative sub-criteria and the level of development of the initial alternative plans' designs and cost estimates, it is important to note that the evaluation incorporates the best information available at this time and is useful and reasonable means to evaluate and compare the alternatives. As more information is developed, alternatives will be refined such as quantified environmental effects, avoidance measures, and construction requirements. It is anticipated that these refinements will cause some scores to change, however it is not expected that the combined effect of these refinements will substantively change the relative scoring among the Initial Alternatives as they include similar levels of uncertainty. Refinements to the Initial Alternatives would likely result in similar scoring changes, maintaining the overall ranking.

Evaluation Scoring Summary

Tables 4-7 and 4-8 provide a summary of the scoring under the current and future with subsidence conditions. The colors used in the heat map illustrate how favorable the score is with green being the most favorable (5) and red being the least favorable (1).

Table 4-7. Current Conditions Summary Scores

Alternative	I. Constructability					II. Operational Requirements and Flexibility			III. Cost			IV. Schedule						V. Environmental Compliance and Permitting			
	CON-1. Complexity to maintain water deliveries during construction	CON-2. Ability to O&M canal during construction	CON-3. Temporary bypasses and tie-ins needed to construct the work	CON-4. Extent of dewatering	CON-5. Material Balance	OPS-1. Additional O&M requirements and expertise of FWA	OPS-2. Operations of district turnouts	OPS-3. Ability to accommodate power outages	COST-1. Construction cost	COST-2. Non-contract cost	COST-3. PV of 50 Years OM&R	SCH-1. Time to start construction	SCH-2. Construction duration	SCH-3. Time until benefits realized	SCH-4. Potential to phase construction	SCH-5. Land acquisition	SCH-6. Schedule Risk	ENV-1. Complexity of required environmental compliance	ENV-2. Number of stream crossings	ENV-3. Number of bridges	ENV-4. Length of modified existing embankment
1	1.0	1.0	1.0	5.0	1.0	5.0	5.0	5.0	4.1	5.0	5.0	5.0	4.0	5.0	5.0	5.0	4.0	3.0	5.0	3.8	1.0
2	2.0	2.0	1.2	4.0	4.3	2.0	3.0	2.0	5.0	4.0	1.5	3.0	4.0	3.0	3.0	2.1	2.0	1.0	5.0	5.0	2.2
3	3.0	3.0	3.3	1.0	3.8	1.0	3.0	2.0	1.0	1.0	1.0	2.0	3.0	3.0	2.0	1.2	1.0	1.0	3.0	1.4	4.4
4A	4.0	4.0	4.5	4.0	2.7	4.0	2.0	5.0	4.1	3.5	4.1	2.0	2.0	1.0	1.0	2.2	3.0	1.0	3.0	3.4	4.0
4B	5.0	5.0	5.0	3.0	1.9	3.0	1.0	5.0	3.2	2.2	3.6	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	5.0
5A	4.0	4.0	4.2	3.0	5.0	4.0	4.0	5.0	3.7	4.0	4.2	3.0	2.0	3.0	4.0	3.7	5.0	1.0	5.0	3.4	2.5
5B	5.0	5.0	4.4	2.0	5.0	3.0	3.0	5.0	3.7	3.8	3.7	2.0	1.0	3.0	4.0	3.2	5.0	1.0	5.0	1.0	3.0

Table 4-8. Future with Subsidence Condition Summary Scores

Alternative	I. Constructability					II. Operational Requirements and Flexibility			III. Cost			IV. Schedule						V. Environmental Compliance and Permitting			
	CON-1. Complexity to maintain water deliveries during construction	CON-2. Ability to O&M canal during construction	CON-3. Temporary bypasses and tie-ins needed to construct the work	CON-4. Extent of dewatering	CON-5. Material Balance	OPS-1. Additional O&M requirements and expertise of FWA staff	OPS-2. Operations of district turnouts	OPS-3. Ability to accommodate power outages	COST-1. Construction cost	COST-2. Non-contract cost	COST-3. PV of 50 Years OM&R	SCH-1. Time to start construction	SCH-2. Construction duration	SCH-3. Time until benefits realized	SCH-4. Potential to phase construction	SCH-5. Land acquisition	SCH-6. Schedule Risk	ENV-1. Complexity of required environmental compliance	ENV-2. Number of stream crossings	ENV-3. Number of bridges	ENV-4. Length of modified existing embankment
1	1.0	1.0	1.0	5.0	1.0	5.0	5.0	5.0	3.2	4.8	5.0	5.0	4.0	5.0	5.0	5.0	4.0	3.0	5.0	3.8	1.0
2	2.0	2.0	1.2	4.0	5.0	2.0	3.0	1.0	5.0	5.0	1.5	3.0	4.0	3.0	3.0	2.4	2.0	1.0	5.0	5.0	2.2
3	3.0	3.0	3.3	1.0	4.5	1.0	3.0	1.0	1.0	1.0	1.0	2.0	3.0	2.0	2.0	1.2	1.0	1.0	3.0	1.4	4.4
4A	4.0	4.0	4.5	4.0	4.7	4.0	2.0	5.0	3.9	4.1	4.1	2.0	2.0	1.0	1.0	2.4	3.0	1.0	3.0	3.4	4.0
4B	5.0	5.0	5.0	3.0	4.2	3.0	1.0	5.0	2.8	2.3	3.6	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	5.0
5A	4.0	4.0	4.2	3.0	4.1	4.0	4.0	5.0	3.9	4.8	4.2	3.0	2.0	3.0	4.0	4.1	5.0	1.0	5.0	3.4	2.5
5B	5.0	5.0	4.4	2.0	4.8	3.0	3.0	5.0	3.2	4.1	3.7	2.0	1.0	3.0	4.0	3.5	5.0	1.0	5.0	1.0	3.0

Weighting and Ranking

The evaluation presented above is useful in understanding individual project components but does not provide a complete picture of the alternatives. A complete picture is needed for a more comprehensive comparison to support a recommendation for the alternatives that would be retained for further evaluation at the feasibility level. To obtain the complete picture of the unweighted composite score, the total scores for the five criteria were averaged. These scores were then ranked from one (best) to seven (worst). The unweighted composite scores and rank, shown in Table 4-9, readily identify which Initial Alternative plans are more favorable than others. Alternative 1 ranked the highest under both current and future with subsidence land conditions, closely followed by Alternative 5A. Alternative 3 ranked the lowest under both conditions.

Table 4-9. Alternative Unweighted Ranking

Alternative	Unweighted Composite Score		Unweighted Rank	
	Current	Future	Current	Future
1: Canal Enlargement	3.7	3.7	1	1
2: Pump Station at MP109	2.8	2.8	5	5
3: Pump to Woollomes	1.9	2.0	7	7
4A: Bypass Canal-Tule River to White River	3.2	3.1	4	4
4B: Bypass Canal-Tule River to Woollomes	2.6	2.5	6	6
5A: Parallel Canal-Tule River to White River	3.7	3.6	2	2
5B: Parallel Canal-Tule River to Woollomes	3.3	3.3	3	3

While the unweighted composite scores and associated ranking provide a comprehensive view of the alternatives, they do not reflect the relative importance of FWA's top priorities for the alternatives—schedule and cost. By weighting specific criterion to highlight a priority, it is possible to identify which alternatives best meet the priorities. Both a schedule-weighted evaluation and cost-weighted evaluation are presented in the following sections.

Schedule

Schedule is a critically important component of the Project; FWA prefers that the canal capacity be restored as quickly as possible. For the schedule-weighted ranking, the five criteria were assigned the following weight:

- Schedule: 50 percent. *This is the most important criterion*.
- Environmental Compliance and Permitting: 15 percent. *Biological and cultural consultation, as well as compliance, can impact construction timelines*.

- Constructability: 15 percent. *Factors such as materials and ability to maintain the water deliveries can impact the schedule*.

- Cost: 10 percent. *Cost and Schedule are related, but the costs have limited impact on implementation schedule. Because the cost of all Initial Alternatives is generally similar, a financing plan is not considered in their evaluation and comparison.*

- Operational Requirements and Flexibility: 10 percent. *This criterion* is *more applicable once the project is built and therefore is not a schedule driver*.

Results

As shown in Table 4-10, Alternative 1 received the best schedule-weighted score under both conditions, followed by Alternative 5A and 5B. These results are primarily a reflection of the land acquisition required for ROW. Acquiring ROW can be a lengthy process that involves environmental, cultural, and economic factors. As such, it impacts many sub-criteria, such as time to start construction, schedule risk, non-contract cost, and complexity of required environmental compliance. Alternative 1 requires the fewest acres for ROW, resulting in a more favorable score across many sub-criteria. In contrast to Alternative 1, Alternative 3 ranked the lowest with the schedule weighting since it requires the most ROW.

Table 4-10. Schedule Weighted Score and Rank

Alternative	Scheduled Weighted Composite Score		Schedule Weighted Rank	
	Current	Future	Current	Future
1: Canal Enlargement	4.0	4.1	1	1
2: Pump Station at mile post 109	2.8	2.8	4	4
3: Pump to Woollomes	2.0	1.9	6	7
4A: Bypass Canal-Tule River to White River	2.6	2.7	5	5
4B: Bypass Canal-Tule River to Woollomes	2.0	2.0	7	6
5A: Parallel Canal-Tule River to White River	3.5	3.6	2	2
5B: Parallel Canal-Tule River to Woollomes	3.2	3.2	3	3

Cost

Cost is another significant consideration in the evaluation of initial alternatives. Cost encompasses both construction costs and long-term operation, maintenance, and replacement costs. For the cost-weighted evaluation, the five criteria were assigned the following weight:

- Cost: 50 percent. *This is the most important criterion*.

- Operational Requirements and Flexibility: 15 percent. *New staff, as well as additional O&M requirements, significantly impact the cost*.

- Environmental Compliance and Permitting: 15 percent. *Monitoring and compliance can significantly impact the cost*.

- Constructability: 10 percent. *Constructability affects construction cost, however the contribution to total cost is less significant than overall cost and O&M costs*.

- Schedule: 10 percent. *Schedule delays can impact the cost, but not as directly as the other criteria*.

Results

The results from the cost weighting reveal that Alternative 1 is the most cost-effective under current conditions but is tied with Alternative 5A in the future condition (Table 4-11). Although Alternative 1 is not the most economical in terms of construction cost, it is economical in terms of non-contract costs (ROW acquisition, environmental, design, legal, and administrative) and present-value OM&R. Conversely, Alternative 3 would incur significant costs associated with construction, OM&R and staffing. Operating and maintaining a pump station would require specific expertise, and thus add cost associated with FWA staffing and/or training. Replacement is also an issue with a pump station, increasing the life cycle cost substantially.

Table 4-11. Cost Weighted Score and Rank

Alternative	Scheduled Weighted Composite Score		Schedule Weighted Rank	
	Current	Future	Current	Future
Alternative 1: Canal Enlargement	4.1	3.9	1	1
Alternative 2: Pump Station at MP 109	3.0	3.2	5	5
Alternative 3: Pump to Woollomes	1.6	1.5	7	7
Alternative 4A: Bypass Canal-Tule River to White River	3.4	3.5	4	3
Alternative 4B: Bypass Canal-Tule River to Woollomes	2.7	2.7	6	6
Alternative 5A: Parallel Canal-Tule River to White River	3.7	3.9	2	2
Alternative 5B: Parallel Canal-Tule River to Woollomes	3.4	3.4	3	4

Rank Comparison

Table 4-12 presents the alternative ranking for the unweighted, schedule weighted, and cost weighted evaluations under both the current and future conditions. Regardless of the weight or condition, Alternative 1 consistently ranked the highest and Alternative 3 consistently ranked the lowest. This result is to be expected as Alternative 1 performed well throughout the evaluation whereas Alternative 3 was scored consistently unfavorably. The other alternatives were generally consistent across ranking and land conditions as well, with some minor changes.

Table 4-12. Initial Alternative Rank Comparison

Alternative	Unweighted Rank		Schedule Weight Rank		Cost Weight Rank	
	C	F	C	F	C	F
1: Canal Enlargement	1	1	1	1	1	1
2: Pump Station at MP 109	5	5	4	4	5	5
3: Pump to Woollomes	7	7	7	7	7	7
4A: Bypass Canal-Tule River to White River	4	4	5	5	3	3
4B: Bypass Canal-Tule River to Woollomes	6	6	6	6	6	6
5A: Parallel Bypass-Tule River to White River	2	2	2	2	2	2
5B: Parallel Bypass-Tule River to Woollomes	3	3	3	3	4	4

Key:
C= Current
F= Future

Alternatives Retained for Further Evaluation

Alternatives 1 and 5A consistently outperformed the other alternatives, regardless of the land condition or weighting priorities. Given their consistently high/favorable scores and ranking, they are retained for further evaluation. However, Alternative 5B will also be included as it is a refinement to 5A that requires continued exploration and additional development. Alternatives 5A and 5B will collectively be referred to as Alternative 5 in subsequent chapters of this report.

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Chapter 5
Supplemental Analysis of Retained Alternatives

Additional refinements and evaluations were performed on Alternatives 1 and 5, which are the two alternatives retained for further evaluation. The defeat of Proposition 3 in November 2018 eliminated a key potential funding source for the Project, prompting a renewed focus on financing options for the Project. The objective of these additional evaluations was to identify potential opportunities for project sequencing,[1] sequencing refers to both the ability to phase construction by segment or further increase the capacity of constructed improvements at some time in the future.

This chapter presents an evaluation of Alternatives 1 and 5 under four design capacity objectives to identify potential challenges to phasing construction by segment or constructing a project with the intent to increase capacity at a later time. Information for this evaluation was developed at the same level of detail used to evaluate and compare Initial Alternatives. The benefits and/or consequences of the sequencing options are presented relative to one another. Through understanding the sequencing opportunities, it is possible to identify the most cost-effective and flexible means to meet Project objectives.

Capacity Options Used to Evaluate Sequencing Opportunities

The following design conditions were evaluated for Alternatives 1 and 5:

- Option 1 – Maximum Historical Flow with Flood Freeboard;[2]
- Option 2 – Design Normal Flow with Standard Freeboard;[3]
- Option 3 – Design Maximum Flow with Flood Freeboard; and
- Option 4 – Design Maximum Flow with Standard Freeboard.

[1] Note the terms sequencing and phasing are used interchangeably in this report.

[2] Flood Freeboard is reduced from the Standard Freeboard to allow for short term flood flows that enter the canal from cross drainage and can be evacuated via wasteways.

[3] Standard Freeboard includes captured flood flows (i.e., Class 2 water) that are transferred over a long period of time, with no intention of evacuating the excess flows from the canal. Both Flood and Standard Freeboard were calculated using Reclamation design standards.

These four options represent a reasonable range of design capacities to which the FKC could be restored, ranging from historical deliveries to maximum flow capacity considered in the evaluation of Initial Alternatives (see Table 5-1).

Table 5-1. Flow Capacity Options Used in Analysis of Project Sequencing

Segment of FKC Middle Reach	Feature	Option 1 Max Historical Flow / Flood Freeboard	Option 2 Design Normal Flow / Design Standard Freeboard	Option 3 Design Max Flow / Flood Freeboard	Option 4 Design Max Flow / Design Standard Freeboard
5th Ave. to Tule River	Flow (cfs)	4,008	3,500	4,500	4,500
	Freeboard (ft)	1.12	2.23	1.12	2.35
Tule River to Deer Creek	Flow (cfs)	3,497	3,000	4,000	4,000
	Freeboard (ft)	1.08	2.15	1.08	2.29
Deer Creek to White River	Flow (cfs)	2,888	3,000	4,000	4,000
	Freeboard (ft)	1.08	2.15	1.08	2.29
White River to Lake Woollomes	Flow (cfs)	2,490	2,500	3,500	3,500
	Freeboard (ft)	1.03	2.06	1.03	2.23

Key:
cfs = cubic feet per second
FKC = Friant-Kern Canal
ft = foot

Option 1 – Maximum Historical Flow with Flood Freeboard

This option would restore the capacity of the FKC Middle Reach to convey flows at a level consistent with historical deliveries. FKC daily operations data for years 2003 to 2018 were reviewed to identify the maximum historical flows associated with Friant contract deliveries in each segment of the Middle Reach. In recognition that peak deliveries in the FKC occurred during flood operations, this option applies the current Reclamation flood flow freeboard (calculated based on normal flow capacity) as the basis to determine the canal cross section required to convey historical flows.

Option 2 – Design Normal Flow with Design Standard Freeboard

This option would restore the capacity of the FKC Middle Reach to the original design normal capacity, with current Reclamation design standard freeboard requirements. The resulting maximum flow capacity would be determined based on a water surface representing the current Reclamation flood flow freeboard applied to the design based on normal flow and design standard freeboard.

Option 3 – Design Maximum Flow with Flood Freeboard

This option would restore the capacity of the FKC Middle Reach to the original design maximum capacity, with current Reclamation freeboard requirements for flood flow. The normal flow capacity would be determined by applying current Reclamation normal flow freeboard to

the design based on maximum flow and flood freeboard. Normal flow depth would be computed by subtracting normal flow freeboard from the lining height for the maximum capacity with flood freeboard condition. Then the normal flow capacity would be calculated based on this normal flow depth.

Option 4 – Design Maximum Flow with Design Standard Freeboard

This option would restore the maximum capacity for the FKC, based on the original design maximum capacity, with current Reclamation design standard freeboard requirements. This option was the basis for evaluations of the Initial Alternatives presented in Chapter 4.

Description of Approach

The four capacity options were applied to Initial Alternatives 1 and 5 to develop preliminary estimates for the following items:

- Canal cross section
- Material balance
- Bridge modification
- Canal length
- Permanent ROW
- Embankment length
- Lining required
- Construction cost

Note the analysis was conducted using the existing land surface and facilities and does not consider future subsidence. This approach identifies the various costs and required actions necessary to restore the FKC to the designated capacity for a given capacity option.

Results

The results from the sequencing analysis provides preliminary cost estimates for the above-mentioned items. From these figures, it is possible to understand the defining constraints of each capacity option and their effects on the alternatives. A summary of the analysis is provided in Table 5-2 and described in further detail below.

Table 5-2. Summary Results of Sequencing Analysis

Quantity	Alternative 1				Alternative 5			
	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4
Length of Modified Canal (miles)	17.10	24	31	31	17.08	24	31	31
Length of Modified FKC Embankment (miles)	34.20	47.20	62.00	62.00	17.08	23.60	38.40	38.43
Permanent ROW (Acres)	0	0	154	170	218	299	371	386
Excavation of Existing Canal (1,000 cubic yards)	190	577	4,015	3,709	1,533	3,014	4,871	4,875
Embankment Material Required (1,000 cubic yards)	1,883,537	2,690,072	4,359,154	5,259,535	3,110,475	3,968,826	3,552,038	4,459,080
Material Balance (Borrow / Waste) (1,000 cubic yards)	(1,694)	(2,113)	(344)	(1,551)	(1,578)	(955)	1,319	416
Borrow / Waste Disposal ROW (Acres)	210	326	469	488	195	403	396	448
Lining Required (thousand square yds)	405	488	1,612	1,686	968	1,327	1,845	1,946
Bridge Raise	2	2	3	3	0	0	1	1
Bridge Replacement/New Bridge	16	17	17	17	19	27	27	27
Parcels for Permanent ROW (acres)	8	16	131	165	70	87	189	182
Total Project Cost ($M)	$150	$191	$298	$316	$192	$270	$309	$330
Low Cost Range (-25% on Field Costs; $M)	$113	$144	$228	$240	$147	$208	$236	$252
High Cost Range (+25% on Field Costs; $M)	$185	$235	$369	$391	$236	$334	$381	$405

Key:
$M = million dollars
FKC = Friant-Kern Canal
ROW = right of way

Alternative 1

Table 5-3 presents the results from the sequencing analysis for Alternative 1. Depending on the restored capacity, the earthwork, ROW, and cost can vary significantly. The variability in these factors present decision-makers with the challenge of balancing today's costs and needs with those of the future.

Modifications in Segment 1, for example, could range from no activity to a $ 48 million raise and widening of the FKC. However, despite this wide range in modifications, Segment 1 does not present a constraint in the construction of a plan with lower initial capacity followed by future improvements to achieve greater capacity. If Option 1or Option 2 were selected for initial construction, Option 3 or Option 4 could be constructed in the future without losing an initial investment in Segment 1. A similar relationship finding would apply to Segment 4 with initial construction of Option 1 followed by future expansion to Option 2.

In Segments 2 and 3, the sequencing analysis reveals constraints if Alternative 1 were to be constructed to an initial lower capacity and increase capacity at a future time; Options 1 and 2 involve raising the existing canal whereas Options 3 and 4 include a raise and widen. The difference between the two activities have implications on cost and future actions. Although exclusively raising the canal is less costly in the short term, this approach would likely cost more in the long term. If modifications are made to increase capacity in the future, the canal would need to be widened to achieve the increased capacity at the proposed HGL and to provide bank stability. A future widening would effectively result in a lost investment—some of the improvements made to raise the canal would need to be removed and replaced with a widened canal. In addition, additional ROW would be required to accommodate the widen and raise. Constructing Options 1 and 2 would therefore limit flexibility for phasing future capacity expansion. Costs would be significantly higher to make modifications if additional capacity is needed in the future.

In addition to future phasing, the sequencing analysis considered the opportunity to construct a project in segments, such as making improvements to Segments 2 and 3 initially, followed by improvements to Segments 1 and 4 at a later time. The most significant criterion to consider for this analysis is material balance. The Initial Alternatives evaluated in Chapter 4 assumed that all segments would be constructed under the same construction phase, and that material balance could be achieved to the greatest extent possible by using surplus material from one segment to provide borrow for other segments. If the most subsided segments (Segments 2 and 3) were constructed without concurrent construction in Segments 1 and 4, all borrow would need to be obtained from other sources. Greater ROW would be required to provide the borrow, and sites would need to be in the proximity of the construction activities.

Alternative 5

As shown in Table 5-4, the Alternative 5 actions and quantities for Segment 1 are the same as those for Alternative 1. The two alternatives diverge at Segment 2 where a parallel canal would begin and continue through Segment 4. The requirements to construct a parallel canal through

Segment 2 are largely the same across all options, with a few exceptions. Therefore, results in Segments 1 and 2 do not provide sufficient justification for recommending one option over the other.

However, in Segments 3 and 4, there is a difference in the cost and other metrics that could make one option more attractive than another. Option 1 is the least costly and requires the least ROW; however, Option 1 does not provide an alignment and ROW necessary for future expansion. Should Option 1 be selected, it would either be capped at the historical maximum capacity or would need to be designed for possible future expansion. This would increase the material requirements for the base of the shared embankment and increase ROW requirements. Future construction would then be limited to adding embankment and lining to the embankments that create the parallel canal. The additional ROW requirements and material would increase Option 1 and Option 2 costs closer to those of Options 3 and 4.

If Alternative 5 were to be constructed in the most subsided segments first, borrow material would be required from sources other than excess material from Segments 1 and 4, as assumed in the evaluation of Initial Alternatives in Chapter 4.

Table 5-3. Alternative 1 Quantities by Option

Segment	Feature	Option 1	Option 2	Option 3	Option 4
1 5th Ave. to Tule River	Canal Cross Section	N/A	N/A	Widen and Raise	Widen and Raise
	Modified Embankment (miles)	N/A	N/A	14.80	14.80
	Permanent Right of Way (Acres)	N/A	N/A	36	40
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	N/A	N/A	(+) 717	(+) 523
	Borrow / Waste Disposal Right of Way (Acres)	N/A	N/A	89	65
	Lining Required (1,000 square yards)	N/A	N/A	384	397
	Bridge Replacement/New Bridge	N/A	N/A	1	1
	Total Project Cost ($ million)	N/A	N/A	$47	$48
2 Tule River to Deer Creek	Canal Cross Section	Raise	Raise	Widen and Raise	Widen and Raise
	Modified Embankment (miles)	13.80	13.80	13.80	13.80
	Permanent Right of Way (Acres)	0	0	36	40
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	(-) 544	(-) 796	(-) 599	(-) 864
	Borrow / Waste Disposal Right of Way (Acres)	67	99	74	107
	Lining Required (1,000 square yards)	164	184	361	379
	Bridge Replacement/New Bridge	7	7	7	7
	Total Project Cost ($ million)	$60	$67	$79	$86
3 Deer Creek to White River	Canal Cross Section	Raise	Raise	Widen and Raise	Widen and Raise
	Modified Embankment (miles)	20.40	20.40	20.40	20.40
	Permanent Right of Way (Acres)	0	0	55	60
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	(-) 1,150	(-) 1,547	(-) 1,464	(-) 1,867
	Borrow / Waste Disposal Right of Way (Acres)	143	195	181	233
	Lining Required (1,000 square yards)	241	269	530	556
	Bridge Replacement/New Bridge	11	11	11	11
	Total Project Cost ($ million)	$90	$101	$123	$132
4 White River to Lake Woollomes	Canal Cross Section	N/A	Raise	Widen and Raise	Widen and Raise
	Modified Embankment (miles)	N/A	13.00	13.00	13.00
	Permanent Right of Way (Acres)	N/A	0	27	30
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	N/A	(+) 257	(+) 1,001	(+) 666
	Borrow / Waste Disposal Right of Way (Acres)	N/A	32	125	83
	Lining Required (1,000 square yards)	N/A	35	336	354
	Bridge Replacement/New Bridge	N/A	1	1	1
	Total Project Cost ($ million)	N/A	$23	$49	$50

Table 5-4. Alternative 5 Quantities by Option

Segment	Feature	Option 1	Option 2	Option 3	Option 4
1 5th Ave. to Tule River	Canal Cross Section	N/A	N/A	Widen and Raise	Widen and Raise
	Modified Embankment (miles)	N/A	N/A	14.80	14.80
	Permanent Right of Way (Acres)	N/A	N/A	36	40
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	N/A	N/A	(+) 717	(+) 523
	Borrow / Waste Disposal Right of Way (Acres)	N/A	N/A	89	65
	Lining Required (1,000 square yards)	N/A	N/A	384	397
	Bridge Replacement/New Bridge	N/A	N/A	1	1
	Total Project Cost ($ millions)	N/A	N/A	$47	$48
2 Tule River to Deer Creek	Canal Cross Section	Parallel Canal	Parallel Canal	Parallel Canal	Parallel Canal
	Modified Embankment (miles)	6.92	6.92	6.92	6.92
	Permanent Right of Way (Acres)	92	87	99	102
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	(-) 415	(-) 685	(-) 210	(-) 487
	Borrow / Waste Disposal Right of Way (Acres)	51	85	26	58
	Lining Required (1,000 square yards)	408	397	437	463
	Bridge Replacement/New Bridge	8	8	8	8
	Total Project Cost ($ millions)	$77	$81	$76	$83
3 Deer Creek to White River	Canal Cross Section	Parallel Canal	Parallel Canal	Parallel Canal	Parallel Canal
	Modified Embankment (miles)	10.16	10.16	10.16	10.16
	Permanent Right of Way (Acres)	126	127	144	149
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	(-) 1,162	(-) 1,147	(-) 724	(-) 1,131
	Borrow / Waste Disposal Right of Way (Acres)	144	176	90	140
	Lining Required (1,000 square yards)	560	583	641	680
	Bridge Replacement/New Bridge	11	11	11	11
	Total Project Cost ($ millions)	$115	$121	$113	$124
4 White River to Lake Woollomes	Canal Cross Section	N/A	Parallel Canal	Parallel Canal	Parallel Canal
	Modified Embankment (miles)	N/A	6.52	6.52	6.55
	Permanent Right of Way (Acres)	N/A	85	92	95
	Material Balance (1,000 cubic yards; ± Surplus/Borrow)	N/A	(+) 1,147	(+) 1,537	(+) 1,492
	Borrow / Waste Disposal Right of Way (Acres)	N/A	142	191	185
	Lining Required (1,000 square yards)	N/A	347	383	406
	Bridge Replacement/New Bridge	N/A	8	8	8
	Total Project Cost ($ millions)	N/A	$68	$73	$75

Chapter 6
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RECLAMATION

Managing Water in the West

SAN JOAQUIN RIVER RESTORATION PROGRAM

Friant WATER AUTHORITY

Feasibility Report
Attachment A1 – Initial Alternatives Engineering Design and Cost

Friant-Kern Canal Middle Reach Capacity Correction Project

October 2019



Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Attachments

- **Exhibit A1a.** Initial Alternatives Basis of Design Report
  - **Attachment A1a1.** HEC-RAS Modeling Technical Memo
  - **Attachment A1a2.** Active Turnouts Technical Memo
- **Exhibit A1b.** Selection of Future Subsidence Condition
  - **Attachment A1b1.** Subsidence Modeling Technical Memo
- **Exhibit A1c.** Geotechnical Interpretive Report
  - **Attachment A1c1.** Geotechnical Data Report
- **Exhibit A1d.** Initial Alternatives Cost Estimates

Abbreviations and Acronyms

AACEI	Association for the Advancement of Cost Engineering International
BODR	Initial Alternatives Basis of Design Report

CEQA	California Environmental Quality Act
cfs	cubic feet per second
CGPS	continuously-operating GPS reference stations
CP	critical path
CPI	Caltrans Price Index
CPT	Cone Penetration Test
D&S	Directive & Standards
FHWA	Federal Highway Administration
FKC	Friant-Kern Canal
FR	Feasibility Report
FWA	Friant Water Authority
GDR	Geotechnical Data Report
GIR	Geotechnical Investigation Report
GIS	geographic information system
GPS	global positioning system
HGL	Hydraulic Grade Line
HSA	hollow-stem auger
IDC	Interest During Construction
LiDAR	Light Detection and Ranging
MC	Modified California sampling
MP	milepost
NAD	North American Datum
NAVD	North Atlantic Vertical Datum
NEPA	National Environmental Policy Act
NTP	notice to proceed
O&M	operations and maintenance
OM&R	operations, maintenance, and replacement
OPPC	Opinions of Probable Project Cost
PFR	Plan Formulation Report
PR&G	*Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies*
Project	FKC Middle Reach Subsidence and Capacity Correction Project
Reclamation	U.S. Department of the Interior, Bureau of Reclamation
SPT	Standard Penetration Testing
ST	Shelby tube sampling
Study	FKC Middle Reach Subsidence and Capacity Correction Project Feasibility Study
TM	technical memorandum
WBS	work breakdown structure

Chapter 1
Introduction

This technical attachment to the Feasibility Report for the Friant-Kern Canal Middle Reach Subsidence and Capacity Correction Project (Project) documents the engineering setting and cost estimate analyses to support federal project feasibility evaluation. The Project is a feasibility study evaluating alternatives to increase water supply reliability and improve deliveries to Friant Division long-term contractors in the Southern San Joaquin Valley of California.

Scope and Purpose of this Appendix

The Middle Reach of the Friant-Kern Canal (FKC), located within Tulare County, extends approximately 33 miles and has experienced significant subsidence over the past decade. This reach also was originally designed with outdated standards that prevent the intended capacity to be actualized. Due to these two issues, the capacity in portions of the Middle Reach is estimated to be less than half the original design capacity. The Project is being developed to provide improvements to the FKC to address reduced conveyance capacity resulting from regional land subsidence, as well as from a design deficiency.

The FKC Middle Reach Subsidence and Capacity Correction Project Feasibility Study (Study) is being developed by the Friant Water Authority (FWA) for review and approval by the U.S. Department of the Interior, Bureau of Reclamation (Reclamation). Progress and results of the Study are being documented in a series of interim reports that will culminate in a Feasibility Report and associated National Environmental Policy Act (NEPA) and California Environmental Quality Act (CEQA) compliance documentation consistent with the *Principles, Requirements, and Guidelines for Federal Investment in Water Resources* (PR&G) (CEQ 2013), Reclamation directives and standards, and applicable environmental laws. The Feasibility Report (FR) is an interim planning report in the Project feasibility study process.

In the Plan Formulation stage, FWA, in collaboration with the Friant Division long-term contractors and Reclamation, developed, evaluated, and ranked seven Project alternatives. Of these, two projects were recommended for further development. The objective of this Appendix B – Engineering Design and Cost (Engineering Appendix) is to provide detail regarding these two Project alternatives, including an assessment of the existing features affected, the new features added, the engineering design considerations, and cost estimation methodology and results.

Organization of This Appendix

This appendix is organized as follows:

Chapter 1, **Introduction**, provides the scope, purpose, and organization of this appendix.

Chapter 2, Engineering Setting, summarizes the existing conditions of the FKC and related facilities, along the geologic setting and geotechnical analyses.

Chapter 3, Overview of Alternatives, provides a high-level summary of the seven initial alternatives and the measures proposed, by canal segment.

Chapter 4, Cost Estimates and Cost Estimate Basis, discusses the Reclamation cost estimate levels and the appraisal-level cost estimate approach,

Chapter 5, Construction Costs, the appraisal-level cost estimates for each of the project alternatives, both with and without consideration of future subsidence.

References, lists the sources used in preparing this technical appendix.

There are four Exhibits associated with this Initial Alternatives Engineering Design and Cost Attachment, as follows:

- **Exhibit A1a.** Initial Alternatives Basis of Design Report
  - **Attachment A1a1.** HEC-RAS Modeling Technical Memo
  - **Attachment A1a2.** Active Turnouts Technical Memo
- **Exhibit A1b.** Selection of Future Subsidence Condition
  - **Attachment A1b1.** Subsidence Modeling Technical Memo
- **Exhibit A1c.** Geotechnical Interpretive Report
  - **Attachment A1c1.** Geotechnical Data Report
- **Exhibit A1d.** Initial Alternatives Cost Estimates

Chapter 2
Engineering Setting

This chapter describes major existing facilities, surveying information, and available geotechnical data for the Project. The Initial Alternatives Basis of Design Report provides the engineering parameters necessary for the appraisal-level engineering design and cost estimate work presented in this appendix.

Existing Facilities

Elements of the built environment in the study area are described in this section, including water resources facilities and related infrastructure. Constructed facilities include the FKC, in-canal structures, turnouts, bridges, and utilities along the FKC.

Friant-Kern Canal

The FKC flows 151.8 miles from Friant Dam to the Kern River at an average slope of approximately 6 inches per mile. The FKC was constructed by Reclamation in 1945, prior to the development of Reclamation's current Design Standards No. 3, Release No. DS-3-5, dated 1967, and revised in 1994. Approximately 85 percent of the FKC is concrete-lined, with 15 percent earth-lined. The canal initially had a maximum capacity of 5,000 cubic feet per second (cfs), gradually decreasing to 2,500 cfs to accommodate conveyance to downstream demand. In the late 1970s, Reclamation raised the FKC's concrete lining from the headworks to the Kings River Siphon, increasing the maximum capacity in this reach to 5,300 cfs. The FKC conveys Central Valley Project water to 28 Friant Division long-term contractors and delivers water to these contractors via gravity or pump turnouts primarily in Fresno, Tulare and Kern Counties.

It is important to understand the original design parameters in order to reestablish the original canal design intent and to establish new boundary conditions for rehabilitation of the subsided canal. The original design of the FKC consisted of 9 different canal (geometric) cross sections for its entire 152-mile length – 7 seven concrete-lined sections and 2 earth-lined sections. This Project is focused on evaluating the original design for the 33.6-mile reach of canal from the 5th Avenue Check (milepost (MP) 88.2) to the Kern River Check (MP 151.8). This segment was designed and constructed with concrete-lined canal Section Nos. 4 through 7 and earthen canal Section No. 2.

The 1992 *Information Report on the Friant-Kern Canal* (Friant Water Users Authority, 1992) included schematics for typical canal cross sections, for both the concrete-lined segments (Figure 2-1) and the compacted earth-lined segments (Figure 2-2).

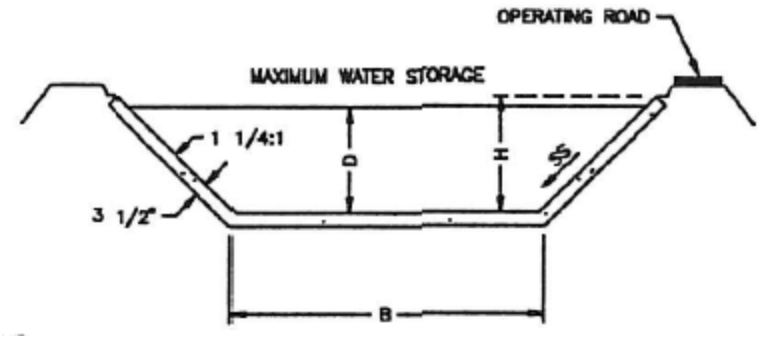


Figure 2-1. Typical Section, Concrete-lined Canal Segments.

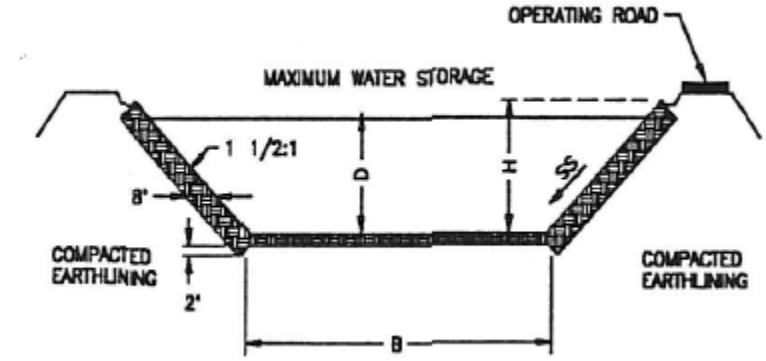


Figure 2-2. Typical Section, Compacted Earth-lined Canal Segments.

Additionally, the original Reclamation "Profiles and Sections" design drawings for the FKC (1948-1949) included schematics for typical canal cross sections, shown here for the concrete-lined Section 6 for thorough cut sections, one bank sections, and two bank sections (Figures 2-3 through 2-5, respectively).

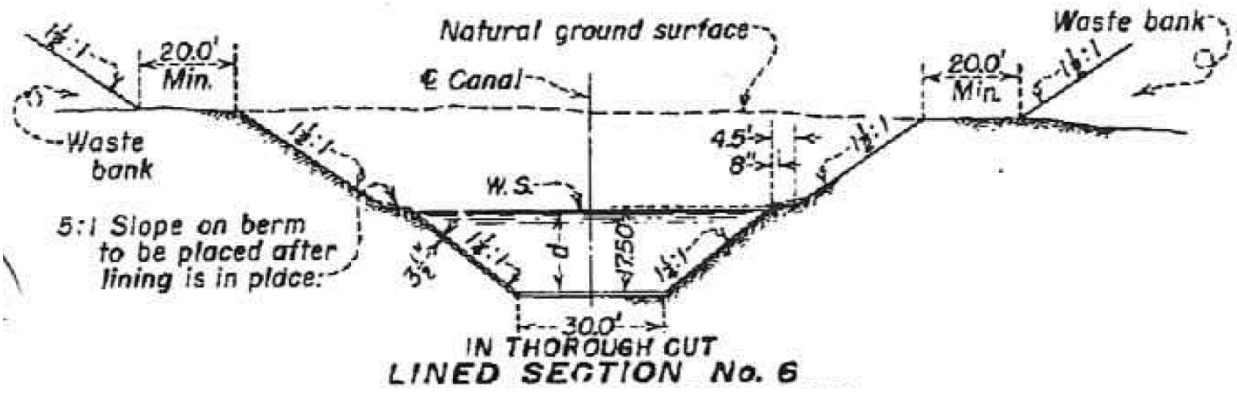


Figure 2-3. Typical Section, in Lined Thorough Cut Section

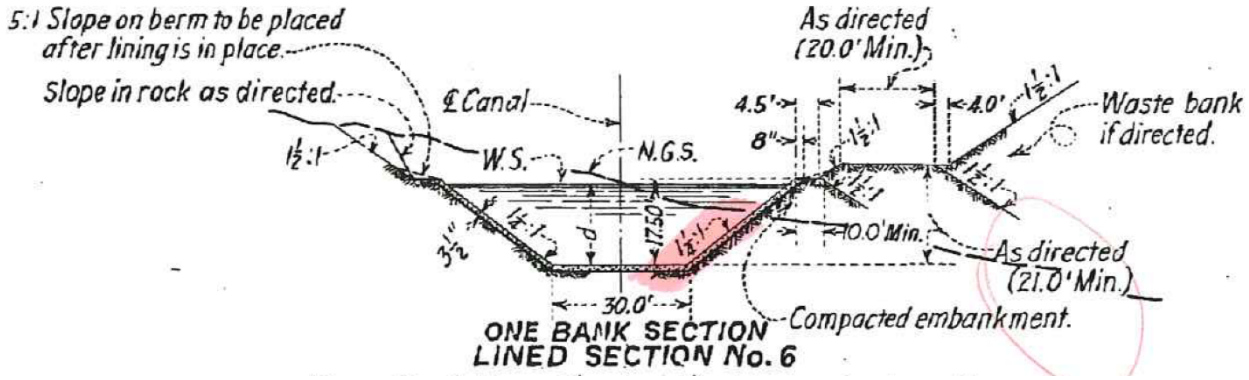


Figure 2-4. Typical Section, in Lined One Bank Section

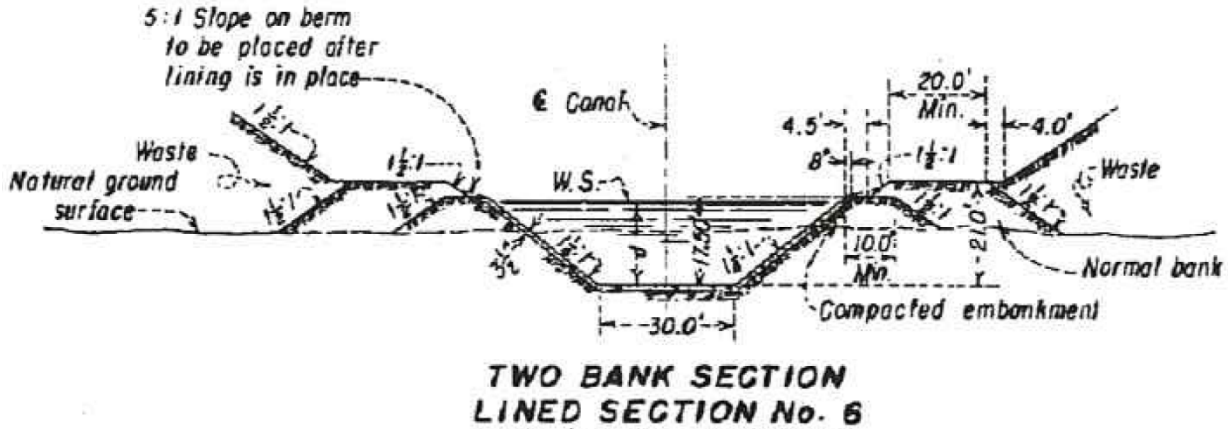


Figure 2-5. Typical Section, in Lined Two Bank Section

Table 2-1 and Table 2-2 provide geometric data for these canal sections for two design flow scenarios: (1) Normal Design Flow and (2) Max Design Flow. The Normal Design Flow represents the largest planned operational flows. The Max. Design Flow was provided to accommodate two primary functions: (1) transport short-terms flood flows released into the canal from the San Joaquin River for delivery to member districts as Class 2 water and/or released into various major cross drainage systems intercepted by the canal; and (2) accept cross drainage flows into the canal at specific locations rather than pass them over or under the canal.

Table 2-1. Original Design Canal Section Data for “Normal Design Flow”

Canal Data	Design Q (cfs)	Design V (ft/s)	Manning’s n	Bottom slope	B (ft)	d (ft)	Side slope (h:v)	D (ft)	Fb (ft)	MP	Lining
Section 2	2503	2.64	0.020	0.000055	40	14.50	2.00:1	15.2	2.3	119.5 – 121.5	Earth
Section 4	3500	4.32	0.014	0.000082	36	14.66	1.25:1	17.3	2.64	88.21 – 98.88	Concrete
Section 5	2998	4.04	0.014	0.000060	36	14.73	1.25:1	17.5	2.77	98.88 – 112.90	Concrete
Section 6	2502	3.61	0.014	0.000060	30	14.43	1.25:1	17.5	3.07	112.90-119.50	Concrete

Key:
cfs – cubic feet per second
D – depth of canal lining
Fb – freeboard
ft – feet
ft/s – feet per second
h:v – horizontal:vertical

Table 2-1. Original Design Canal Section Data for “Max Design Flow”

Canal Data	Design Q (cfs)	Design V (ft/s)	Manning’s n	Bottom slope	B (ft)	d (ft)	Side slope (h:v)	D (ft)	Fb (ft)	MP	Lining
Section 2	3502	2.90	0.020	0.000055	40	17.22	2.00:1	15.2	2.3	119.5 – 121.5	Earth
Section 4	4500	4.61	0.014	0.000082	36	17.04	1.25:1	17.3	0.26	88.21 – 98.88	Concrete
Section 5	3999	4.04	0.014	0.000060	36	17.21	1.25:1	17.5	0.29	98.88 – 112.90	Concrete
Section 6	3502	3.94	0.014	0.000060	30	17.24	1.25:1	17.5	0.26	112.90-119.50	Concrete

Key:
cfs – cubic feet per second
D – depth of canal lining
Fb – freeboard
ft – feet
ft/s – feet per second
h:v – horizontal:vertical

When the FKC was originally designed, Reclamation used the Manning's equation with an "n" roughness value ranging from 0.014 to 0.0143 for the concrete-lined sections. In the 1960s, Reclamation conducted field tests as part of an extensive study of hydraulic losses in about a dozen large concrete-lined canals including the FKC. That study concluded that flow resistance in the five largest canals in the study (including the FKC) was larger than anticipated. Values of Manning's n computed from the field tests ranged from 0.015 to 0.019 and were about 10 to 25 percent higher than design values.

A Manning's n value of 0.016 has been adopted for design of the FKC rehabilitation projects. This selection is described further in the Initial Alternatives Basis of Design Report (BODR) attachment. Applying this n value (instead of 0.014) to the original canal geometry results in approximately one foot of increased normal flow depth for the Normal Design Flow condition.

The 1992 report included the following canal dimensions and hydraulic properties:

- Length: 152 miles
- Typical maximum section (concrete-lined):
  - Lining Thickness: 3-1/2 inches
- Length of concrete-lined section: approx. 127 miles
- Typical maximum section (compacted earth lining):
  - Lining Thickness: 2 feet on bottom, 8 feet minimum horizontal thickness on sides
- Length of compacted earth-lined section: approx. 25 miles

In-Canal Structures

The Project reach includes numerous in-canal structures, including check structures, siphons, wasteways, checks, overchutes, and the Lake Woollomes equalizing reservoir. Checks are associated with Fifth Avenue, the Tule River, Deer Creek, and the White River. The 30 percent design will include further enumeration and discussion of the in-canal structures.

The 1992 report contained the following canal structures summary (note that these totals encompass the entire canal, not just the Project area):

- Major canal siphons: 34
- Wasteways: 8
- Checks: 14
- Overchutes: 11
- Equalizing reservoir: 1

- State highway bridges: 14
- Canal operating road bridges: 11
- Farm bridges: 82
- County highway bridges: 104
- Railroad bridge: 1
- Culvert: 68
- Turnouts: 109
- Inlet drains: 344
- Sump pumps: 21

Turnouts

The Project reach includes numerous turnouts, on both the east and west sides of the canal. Further discussion of the existing turnouts can be found in the *Turnout Inventory Technical Memorandum*, by Provost and Pritchard Consulting Group (September 2018) exhibit to the BODR attachment. Additionally, the 30 percent design will include further enumeration and discussion of the in-canal structures.

Bridges

The Project reach includes 48 bridges in total, including five farm bridges and 43 state or county bridges. Most of the county bridges consist of two equal simply supported spans made up of five cast-in-place reinforced "T" beams. The "T" beam depths vary from 2'-8" to 2'-10" and includes the 6" concrete deck thickness. The beams are supported on a reinforced concrete pier wall and reinforced concrete seat type abutments with monolithic wingwalls. All supports are founded on reinforced concrete spread footings. The bridge lengths vary from 84'-4" to 102'-2" end to end, and span lengths vary from 41'-3" to 50'-0" centerline bearing to centerline bearing. Bridge skews vary from 0 to 35 degrees. The bridges have an outside width of 28'-4" and a curb to curb roadway width of 26'-0". The bridges carry two lanes of traffic, one in each direction. State Highway 65 is a notable exception at 40 feet in width. The farm bridges are typically 16 feet wide, single-lane, and made of timber. The farm bridges are typically designed to H-10 or H-20 loading, and the county bridges are typically designed to H-15 or H-20 loading.

Utilities

The Project reach includes over 100 utility crossings. Some utilities are attached to the upstream or downstream side of roadway bridges. Others cross over or under the canal, away from roadways. The utilities include power, natural gas, telephone, irrigation, and TV cable. The 30-percent design will include further enumeration and discussion of the utility crossings.

Study Area

The FKC Middle Reach extends from MP 88.2 (Fifth Avenue check) to MP 121.5 (Lake Woollomes check), encompassing the Immediate Repairs section (MP 103.6 to MP 107.3). The Middle Reach includes the service areas of six Friant Division long-term contractors that can experience water supply reductions as a result of capacity restrictions in this reach, and the areas that would be directly affected by construction-related activities.

Physical Environment

Elements of the physical environment in the FKC vicinity are described in this section, including regional topography, geology, and soils. For further detailed discussion of these topics, please refer to the BODR, the Preliminary Geotechnical Interpretive Report (GIR), and the Geotechnical Data Report exhibits.

Topography

Land surface subsidence as a result of groundwater extraction has been well documented in California's Central Valley. Documentation of historical land subsidence in the 1950s and 1960s includes the portion of the Tule Sub-basin where the FKC is located. Land subsidence in this area was essentially arrested in the late 1970s and 1980s as the introduction of imported water into the area allowed for reduced groundwater pumping and groundwater levels recovered. The land subsidence was likely reactivated again in the 1990s with the return of groundwater overdraft conditions, and subsidence rates appear to have accelerated after 2007 due to increased pumping and drought conditions. The regional setting generally consists of rural agricultural farming communities. In general, the canal traverses open farmland and has few associated structures. An assortment of county bridges cross over the FKC.

Geology and Soils

Site Geologic Conditions

The project site is located in the southern portion of the Great Valley Geomorphic Province in Central California. This region is characterized as a 50-mile-wide and 400-mile-long sediment filled trough in which the sediments have been deposited, almost continuously, since the Jurassic period. The geology of the Great Valley generally consists of marine and continental deposits resting on a basement complex of metamorphic and igneous rocks.

Locally, the project site resides within the San Joaquin Valley. Geology within the San Joaquin Valley and the project area mainly consists of Jurassic to recent, marine, alluvial, and lake deposits that are several thousand feet thick. The regional surficial geology along the canal is mapped as Quaternary Alluvium and Older Alluvium (California Division of Mines and Geology, 1964 and 1965). For more information, a geologic map of the project area is presented as Figure 2 in the GIR exhibit. The site is located in a moderately active seismic area. The southern end of the project area is closer to known active faults than the northern project area. The estimated distance from the southern end of the project area (MP 110.3) to selected nearby mapped active faults is presented in Table 2-3.

Table 2-3. Active Faults in Site Vicinity

Fault	Distance (miles)[1]	Maximum Moment Magnitude[1]
Great Valley 14 (Kettleman Hills)	43.9	7.2
White Wolf	48.3	7.2
South San Andreas	51.7	8.2
Pleito	55.6	7.1
Great Valley 13 (Coalinga)	57.5	7.1

Note:
[1] Measured from National Seismic Hazard Maps (USGS, 2008).

As noted above, the closest known active fault is the Great Valley 14 Fault, located approximately 44 miles northwest of MP 110.3. For more information, a Regional Fault and Seismicity Map is presented as Figure 3 in the GIR exhibit.

Site Geotechnical Conditions

The Phase 1 geotechnical field investigation for the FKC Subsidence Correction Project was performed between September 11 and September 25, 2018, and consisted of the following:

- Nine hollow-stem auger (HSA) borings with Standard Penetration Testing (SPT), Modified California Sampling (MC), and Shelby tube (ST) sampling
- Seven Cone Penetration Tests (CPT).

Details of the subsurface conditions are presented in the Geotechnical Data Report – Phase 1 (GDR) exhibit. The information in the GDR was based on the Phase 1 geotechnical investigation performed by Stantec in September of 2018.

Based on the geometry of the embankment as described in the original as-built construction drawings from 1945 and the as-built construction drawings of the embankment raise in the 1970s, we developed a subsurface model comprising three units. The three soil units include uncompacted fill, compacted fill, and alluvium. The Phase 1 investigations only intersected the uncompacted fill and the alluvium. The compacted fill zone is located too close to the canal side of the embankment to be intersected by the Phase 1 explorations.

The GIR exhibit provides a summary of the material properties and interpreted design parameters for the encountered subsurface soil.

Groundwater

Groundwater was not observed in the borings or CPTs performed for the Phase 1 geotechnical investigation. Possible perched groundwater was observed in boring B-1 at a depth of approximately 25 feet as the sampler and sample were wet. However, the hole was dry upon completion of soil augering. The moisture content of a sample from boring B-8 at a depth of

approximately 30 feet is close to saturation, which may also indicate perched groundwater at this location.

We understand the regional groundwater level is at least 100 feet below the ground surface. The seepage from the canal into the embankment likely travels vertically and horizontally in an unsaturated condition. Some of the seepage may also be lost through evapotranspiration.

Concrete is permeable and there is likely leakage into the embankment from the canal through both the intact concrete and the joints and cracks within the concrete lining. However, the leakage appears to be sufficiently small such that extensive saturated soil layers do not develop within the embankment.

Seepage

Seepage analyses were performed on a cross-section with the conditions/configuration observed at the Boring B-2/CPT-2 (MP 104.1) location in the Immediate Repair Area (MP 103.5 to 107.3). The purpose of the seepage analyses was to assist in developing mitigation options for ongoing toe seepage issues which have occurred at several locations within the Immediate Repair Area. However, implementation of mitigation for seepage control is no longer being considered as it is costly and does not provide a capacity increase. A secondary purpose for performing seepage analyses was to better understand flows during toe seepage events for a temporary raised canal level.

An HDPE liner will be constructed above the existing concrete liner to implement the temporary canal level raise. The information from the seepage analyses has been used in the slope stability analyses.

Relatively significant seepage has occurred at multiple locations at the land side toe of the embankment within the Immediate Repair Area; FWA has observed toe seepage at MP 99.5, 104.9, and 105.63. Seepage model calibration indicated that there may be relatively significant voids or piping channels (created by internal soil erosion) in the embankment soils at these locations that are resulting in large seepage volumes that would be unlikely for a homogenous embankment with the observed clayey material types. The implications of the presence of these potential voids and piping channels are discussed in the slope stability section of the GIR exhibit. Further discussion of the seepage analysis, including the resulting seepage volume and permeabilities used in the analyses, are presented in the GIR.

*S*lope Stability

Slope stability analyses were performed at the Immediate Repair Area to evaluate stability of the current embankment with higher canal water levels, and at other areas of the existing canal alignment to evaluate stability of an enlarged canal geometry that is currently being considered as a mitigation option. Two cross-sections (MP 104.1 and 106.1) have been evaluated in the Immediate Repair Area for the existing geometry and seven cross-sections (MP 97.5, 104.1, 106.1, 107.1, 108.9, 110.3, and 115.6) have been evaluated for the enlarged canal geometry.

Slope stability factor of safety and seismic loading criteria were provided by Reclamation; see GIR Tables 6 and 7 for more detail.

Static and seismic slope stability analyses were conducted to evaluate the stability of the existing embankment in the Immediate Repair Area, and the proposed embankments for the enlarged canal.

The analyses were completed to assess the factor of safety against instability using a limit equilibrium slope stability method (Spencer method of slices) incorporated into the software program Slope/W (Geo-Slope, 2018). The findings of the analysis are presented briefly here, and more detail can be found in the GIR exhibit.

All of the static loading conditions for the enlarged canal were found to meet or exceed the Reclamation criteria. The Downstream Seismic loading at MP 97.5, 104.1, and 107.1 do not meet criteria from Reclamation. However, at MP 97.5 and 104.1, the factors of safety do meet criteria when the slip surfaces are forced to extend laterally to at least the canal side of the embankment crest.

Seismic Deformation Analysis

Seismic deformation was evaluated for the MP 107.1 cross section using the simplified seismic deformation model developed by Bray and Travasarou (2007), which is a commonly used method in California.

The Bray and Travasarou procedure estimates seismically induced deformations based on the earthquake demand including magnitude and spectral acceleration, site geometry and dynamic properties including slope height and shear wave velocity, and dynamic slope capacity characterized by the yield acceleration. The earthquake characteristics were obtained from the 2014 US Geological Survey deaggregation using a 2,475-year return period with a Seismic Site Class D soil.

The calculated median and plus one standard deviation seismic deformation using the parameters above is 4 inches and 8 inches, respectively. At the time of this report, Reclamation has not provided criteria for seismic deformation, and instead US Army Corps of Engineers regulations (ER 1110-2-1806 “Earthquake design and evaluation for civil works projects”) were used. Using the regulations, the calculated values are considered indicators that seismic deformations will be relatively small, and that the embankment is likely to perform adequately if subjected to the design seismic event. Similarly, the other cross sections at MP 97.5 and 104.1 will have lower estimated seismic deformations than those calculated above. Accordingly, these cross-sections are also likely to perform adequately if subjected to the design seismic event.

Slope Stability Conclusions

The slope stability analyses performed for the proposed enlarged canal indicate that the modified canal embankments will meet factor of safety criteria provided by Reclamation. Some of the assumptions and qualifications associated with this conclusion and with the evaluations performed are provided below.

- The evaluations in this report are based on geotechnical information obtained from The Phase 1 geotechnical investigation performed on the operations and maintenance (O&M) road. The Phase 1 geotechnical investigation will be supplemented by a Phase 2 investigation that will focus on explorations at the toe of the existing embankments and at

other locations where canal modifications are proposed. Accordingly, the results and recommendations provided in this report should be considered preliminary and subject to revision based on the findings from the Phase 2 investigation.

- The scope of the current investigation and evaluations is based on a 30 percent design level deliverable. Additional investigations and evaluations beyond the Phase 1 and Phase 2 efforts will need to be performed to support the project final design.

- The evaluations assume that all of the uncompacted fill in the existing embankment will be removed and replaced as compacted fill. Additional earthwork recommendations will be provided in subsequent reports. These will include recommendations relating to excavation, benching, compaction and moisture, material types, testing and observation, and other related earthwork recommendations.

- The shear strength of the compacted fill used in the slope stability analyses was based on limited laboratory testing. Relatively large volumes of imported fill will be needed to construct the enlarged canal. Shear strength testing of the imported fill will need to be performed to ensure minimum shear strengths equal to or greater than those used in the analyses are obtained. As discussed previously, the seepage analyses performed in the area where toe seepage was observed by FWA indicates there may be voids and piping channels in the embankment at these locations. While there has not been any reported slope instability at these toe seepage areas, piping channels and voids in the embankment can potentially cause slope instability. Some options to mitigate the potential instability include construction of a seepage barrier such as a slurry wall, or by removing the uncompacted material and increasing the width of the embankment such as what is proposed for the enlarged canal.

- The slope stability analyses performed indicate that the proposed enlarged canal will be grossly stable in both static and seismic conditions.

- The static factors of safety calculated for the existing canal in the Immediate Repair Area generally meet Reclamation criteria. The dry canal condition may potentially be considered a temporary condition. The calculated factor of safety for this dry canal is lower than Reclamation criteria (1.2 calculated versus 1.3 Reclamation criteria). These analyses indicate that the existing canal in the Immediate Repair Area is considered grossly stable for static conditions.

Subsidence

Stantec retained Thomas Harder & Company to conduct a hydrogeological analysis of potential future subsidence specifically focused along the FKC using a calibrated numerical groundwater flow model of the Tule Subbasin and surrounding area. The results of the analysis are presented in Exhibit A1b, Selection of Future Subsidence Condition, and its Attachment A1b1, Subsidence Modeling Technical Memorandum (TM).

In order to provide adequate flow capacity into the future, the performance of alternative designs must be evaluated relative to potential future conditions after additional subsidence has occurred. Subsidence projection studies were developed using the Tule Subbasin Groundwater Model under four potential groundwater pumping and hydrologic scenarios. Results for each scenario are provided by decade (2030 – 2070), providing a total of 20 potential subsidence profiles in the project area.

Possible future subsidence along the canal alignment was represented using four potential ground profiles of estimated subsidence, combined with four possible scenarios of the timing and magnitude of future groundwater pumping and various hydrologic conditions. Attachment B.2 notes that "Neither future groundwater pumping nor future hydrology can be predicted with certainty. Therefore, it is impossible to quantify exactly how and when subsidence will occur;" thus, "It is more informative to frame and analyze subsidence possibilities without tying these possibilities to exact conditions that cause them or to dates when they will occur." Group 3, a severe mid-term profile that represents a blend of moderate scenario results from 2030 through 2070 ("Scenario 2 in the years 2040 to 2070 and Scenario 3B in the year 2030"), is the recommended subsidence projections, and it results in an 8-ft maximum subsidence point in the most affected area of the canal profile. Note that 8 feet is the maximum subsidence under the Group 3 profile, but it is not the maximum subsidence across all projections. Further discussion of the subsidence modeling performed and the range of subsidence projections can be found in the Thomas Harder & Company Subsidence Modeling TM, and exhibit to the Selection of Future Subsidence Conditions TM.

Survey and Mapping

General

The aerial surveying and mapping for the Project was performed by Towill, Inc. Additional supplemental surveying for Friant Division contractor turnouts was performed by Provost and Pritchard Consulting Group. Aerial and topographic mapping was conducted along the length of the project in August 2018. This data is currently being processed to create topographic base mapping to cover the extents of the project area. The completed survey data files are anticipated to be completed by the end of September 2018.

Additional flight lines were conducted approximately 3,000 to the east to pick up airborne Light Detection and Ranging (LiDAR) data of the FKC and an approximate area for a bypass canal alternative. The LiDAR was collected by an aircraft suitable to map the terrain within the mapping corridor. The LiDAR data was prepared at a nominal density of nine points per square meter. No imagery, planimetrics, or "bare-earth" classification of LiDAR data was processed initially; however, it may be post-processed at a later date, if needed.

Primary Control Points

A survey control network was established at approximately one-mile intervals. Survey datums are referenced to the North American Datum (NAD)83 (CSRS Epoch 2011.00) horizontal datum and Geoid 2012B North Atlantic Vertical Datum (NAVD)88 vertical datum, based on continuously-operating GPS reference stations (CGPS) reference stations that are remotely situated and are not affected by local ground subsidence. Global positioning system (GPS)

surveying technology was used to accomplish the control survey. The basis for the coordinate projection is California Zone 4 with distances measured in feet.

Mapping

Upon completion of the ground control survey and acquisition of aerial photography, analytical aerotriangulation was performed to extend control throughout the project photography to achieve a network of points. A digital topographic map will be compiled at a scale of 1" = 100' for the mapping area. Planimetric features – such as buildings, roads, fences, bridges, and the like will be digitized at elevations that provide the best horizontal accuracy. The final topographic mapping will have a contour interval of 1 foot.

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Chapter 3
Overview of Alternatives

Capacity Restoration

The objective of the Project is to restore the capacity of the FKC, consistent with Settlement Act authority. The Settlement Act is the San Joaquin River Restoration Settlement (Title X, Subtitle A) provisions of Public Law 111-11, the Omnibus Public Land Management Act of 2009. This involves restoring the original design capacity of the FKC consistent with current Reclamation design standards. Therefore, the design of all canal enlargement, pump stations, new bypass and new parallel canal measures have a canal operating capacity equal to the Design Maximum Flow Rate (Table 3-1).

A new hydraulic grade line (HGL) was established as a first step in the design of the canal restoration. This HGL is constrained by the operating depths of the existing FKC at the 5th Avenue Check, at the Tule River Check, at the Lake Woollomes Check, and the Kern River Check which is the FKC terminus. Since the elevations at the beginning of the project and the terminus of the FKC are fixed the gradient for the hydraulic grade line in various canal reaches has to be no steeper than the original design slope which is 0.000060 feet per foot.

Constrained by the above-described HGL, new canal sections were determined (sized) to convey the design capacities for each reach of the canal assuming normal depth under uniform flow conditions. The full canal lining depths will equate to the normal depths at the Design Maximum Flow Rates plus the established lined freeboard criteria.

Note that, for the new parallel canal system, “normal” depth design concepts apply since the canal bottom gradient is uniform.

For the existing FKC, portions of canal have a constant canal bottom gradient and lining depth. However, in the area where the large differential subsidence has occurred, the canal bottom gradient varies. From upstream to downstream, it becomes steeper, then flattens, then reverses slope until out of the differential subsided area. In this section of the FKC the flow depths vary and the flow regime changes from uniform flow to gradually varied flow. Since the canal restoration is tied to the HGL (not the existing bottom of the canal) the same canal section was carried through the subsided area of the FKC. In other words, the design assumes a constant normal depth measured from the HGL, not from the actual canal bottom. This may seem over conservative however, there is no assurance the canal will not accumulate sediment between the three year scheduled dewatering in which sediment is removed. If this occurs, the full section will be required since the flow regime will revert back to uniform flow.

The design flow rates that are presented in Table 3-1 are significant to establish the backwater curve results.

Table 3-1. Design Flow Rates

Canal Section No.	Canal Segment (MP to MP)	Description (Check to Check)	Normal Flow Rate (cfs)	Design Maximum Flow Rate (cfs)
4	88 to 95.67	5th Avenue to Tule	3,500	4,500
5	95.67 to 112.90	Tule to White River	3,000	4,000
6.1	112.90 to 128.69	White River to HWY 99	2,500	3,500

Key:
cfs = cubic feet per second
HWY = highway
MP = milepost

Hydraulic Grade Line

A water surface control elevation of 399.13 feet was established on the upstream side of the Woollomes check structure. This elevation is the key balance point for the system. This elevation can be held without significant modifications to the existing Lake Woollomes Check or the Lake Woollomes Regulating Reservoir.

As a result of analysis, this level was chosen for the following reasons:

- This HGL elevation of 399.13 feet is 1.14 feet lower than the original design water surface elevation at Woollomes. There has been 2.54 feet of subsidence at that location, so the control elevation of 399.13 is 1.4 feet higher than the original level relative to canal invert. Thus, the normal depth at the Lake Woollomes check will also be 1.4 feet higher than the normal depth shown for the original design.

- The additional 1.4 feet of relative HGL provides valuable head to supply flow downstream to Kern River in the future.

- This HGL also significantly reduces cost in the canal upstream from Woollomes by maintaining water levels throughout the Middle Reach that reduced canal cost (e.g., new canal size, enlarged canal size, and/or pump head).

- This HGL permits full use of regulatory storage in Woollomes Reservoir, which is a major benefit to canal operations.

Freeboard

Lining Freeboard

The minimum operating freeboard provided for the concrete lining, from maximum water depth at the design flow to the top of the concrete lining, is shown for each reach of the canal sections in Table 3-2.

Table 3-2. Design Freeboard Requirements

CANAL REACH			FREEBOARD AT RECLAMATION FLOOD FLOW AND MAX FLOW				
Canal Section No.	Canal Reach (Milepost to Milepost)	Description	Design Flow (cfs)	Flood Flow Lining Freeboard (ft)	Required Canal Lining Height at Flood Flow[1] (ft)	Max Flow Lining Freeboard (ft)	Required Canal Lining Height at Max Flow[1] (ft)
4	88 to 95.67	5th Ave. to Tule	4,500	1.18	19.30	2.35	20.47
5	95.67 to 112.90	Tule to White River	4,000	1.15	19.63	2.29	20.77
6	112.90 to 128.69	White River to Poso	3,500	1.11	19.62	2.23	20.74

Notes:
[1] Freeboard calculated per Reclamation canal design standards.
Key:
cfs – cubic feet per second
ft – feet

The flood flow lining freeboard and resulting canal lining height at flood flow shown in Table 3-2 represents the minimum standard that Reclamation would require the canal prism to be designed to. This is the freeboard requirement that Reclamation has designed previous phases of FKC rehabilitation projects to. Reclamation allows for the reduction in max flow lined freeboard by one-half for short term flood flows that enter the canal from cross drainage and can be evacuated from canal by wasteways. However, the FKC max design flow freeboard includes captured flood flows (i.e., Class 2 water) that are transferred over a long period of time, with no intention of evacuating the excess flows from the canal. Based on this, the design assumption is that minimum lined freeboard for the FKC alternatives will be as shown in the "Max Flow" conditions in Table- 3-2.

Earth Freeboard

In all cases the minimum earthen freeboard, from the top of the concrete lining to the top of the earthen embankment will be 2.5 feet per Reclamation standards.

Initial Alternatives

Seven initial alternatives were developed to meet Project objectives: (1) Canal Enlargement, (2) Pump Station at MP 109, (3) Pump Station at Woollomes, (4A) Bypass Canal from Tule to White River, (4B) Bypass Canal from Tule to Woollomes, (5A) Parallel Canal from Tule to White River, and (5B) Parallel Canal from Tule to Woollomes. Although there are different approaches to meeting the Project objectives, all alternatives return the canal to its original design capacity.

Alternative 1: Canal Enlargement

Alternative 1, or the baseline alternative, would return the canal to full capacity exclusively through raising and or widening the canal (Figure 3-1). Capacity restoration is accomplished by

removing a portion of the existing liner, cutting a bench into the existing grade, and building out the embankment throughout the Middle Reach.

Segment 1: 5th Ave. to Tule River

Enlarging the canal from 5th Ave. to Tule River would increase the capacity from 3,500 cfs to 4,500 cfs. The enlargement in this segment, as well as the restored capacity, is the same among all alternatives.

Segment 2: Tule River to Deer Creek

Enlarging the canal from Tule River to Deer Creek would increase the capacity from 3,000 cfs to 4,000 cfs. All alternatives will restore the canal to 4,000 cfs in this segment.

Segment 3: Deer Creek to White River

Enlarging the canal from Deer Creek to White River would increase the capacity from 3,000 cfs to 4,000 cfs. All alternatives will restore the canal to 4,000 cfs at the beginning of this segment and taper down to 3,500 cfs by the end..

Segment 4: White River to Lake Woollomes

Enlarging the canal from White River to Lake Woollomes would increase the capacity from 2,500 cfs to 3,500 cfs. All alternatives will restore the canal to 3,500 cfs in this segment

Alternative 2: Pump Station at MP 109

The distinguishing feature between Alternatives 1 and 2 is that Alternative 2 involves a pump station at MP 109 (Figure 3-2). When flows are high and cannot be conveyed by gravity, water would be diverted from the original canal into a forebay and then pumped back into the original canal. The initial pump station design includes eight 250-cfs pumps. In the event of a power failure, water would be directed into a 400-acre emergency reservoir to prevent a surge.

Segment 1: 5th Ave. to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The only modification along this stretch of the canal is a 2-mile lining raise between Tule River (MP 95.67) and MP 98.8. The remainder of this segment remains as is.

Segment 3: Deer Creek to White River

Alternative 2 includes several alterations along this segment: raising the canal lining, enlarging the canal, and adding a pump station. A canal lining is proposed beginning at Deer Creek (MP 102.6) and ending at MP 105.5. From MP 105.5 to the pump station (MP 109), the canal would not be modified. At MP 109, a pump station would be installed. The pump station requires an associated emergency reservoir, raising the total amount of right of way by 400 acres. Directly downstream of the pump station, the canal would be enlarged until the White River check at MP 112.9.

Segment 4: White River to Lake Woollomes

The canal expansion would continue from White River down to Lake Woollomes.

Alternative 3: Pump Station at Woollomes

Similar to Alternative 2, Alternative 3 involves a pump station. Capacity restoration would be achieved by moving water from the original canal into an approximately 10-mile-long bypass canal and lifting it into Lake Woollomes (see Figure 3-3). It is important to note that deliveries would be maintained in the original canal, but the majority of the water would move through the bypass canal. Alternative 3 also requires a 350-acre emergency reservoir to accommodate a surge in the event of a power outage.

Segment 1: 5th Ave. to Tule River

Actions are the same as Alternative 1.

Segment 2: Tule River to Deer Creek

The only modification along this stretch of the canal is a 2-mile lining raise between Tule River (MP 95.67) and MP 98.8. The remainder of this segment remains as is.

Segment 3: Deer Creek to White River

Alternative 3 includes many actions along this segment: raising the canal lining, constructing a bypass canal, and adding a pump station. At the beginning of the segment, Alternative 3 proposes a canal lining raise from Deer Creek (MP 102.6) to MP 105.5. The canal remains unchanged from MP 105.5 to MP 109, where the bypass canal begins. Most water would move through this bypass, past a new siphon and check structure at White River, and eventually into a pump station. The existing canal would maintain deliveries in this portion and would remain unchanged.

Segment 4: White River to Lake Woollomes

The water in the bypass canal would move to a pump station at MP 119 just before entering Lake Woollomes, thus restoring its capacity. The pump station requires an associated 400-acre emergency reservoir. The existing canal would maintain deliveries in this portion and would remain unchanged, except between MP 119 and 121.5, where the canal would be enlarged.

Alternative 4A: Bypass Canal from Tule River to White River

Alternative 4A is an offset bypass canal that would move water into a new canal at Tule River and connect back into the existing canal at White River (Figure 3-4). The existing canal would be used solely to maintain deliveries between the two checks. The specific alignment has not been determined.

Segment 1: 5th Ave. to Tule River

Enlarging the canal from 5th Ave. to Tule River. This action is the same among all alternatives.

Segment 2: Tule River to Deer Creek

The new bypass canal would begin at Tule River and extend through Deer Creek. There are no modifications to the existing canal through this segment.

Segment 3: Deer Creek to White River

The bypass canal continues through Deer Creek and terminates at White River, where it connects back to the existing canal. There are no modifications to the existing canal through this segment.

Segment 4: White River to Lake Woollomes
Enlarging the canal from White River to Lake Woollomes.

Alternative 4B: Bypass Canal from Tule River to Woollomes
Alternative 4B is the same as Alternative 4A but extends to Woollomes (Figure 3-5).

Segment 1: 5th Ave. to Tule River
Enlarging the canal from 5th Ave. to Tule River. This action is the same among all alternatives.

Segment 2: Tule River to Deer Creek
The new bypass canal would begin at Tule River and extend through Deer Creek. Note that there are no modifications to the existing canal through this segment. These actions are the same as Alternative 4A.

Segment 3: Deer Creek to White River
Unlike Alternative 4A, the bypass canal continues through Deer Creek and extends past White River. There are no modifications to the existing canal through this segment

Segment 4: White River to Lake Woollomes
The bypass canal continues through White River until it terminates at Lake Woollomes. The existing canal would remain largely unchanged, except between MP 119 and 121.5 where the canal would be enlarged.

Alternative 5A: Parallel Canal from Tule River to White River
Alternative 5A is a combination of the canal enlargement and parallel canal measures (Figure 3-6). The parallel canal would run from Tule River to White River, the area of greatest projected subsidence.

Segment 1: 5th Ave. to Tule River
Enlarging the canal from 5th Ave. to Tule River. This action is the same among all alternatives.

Segment 2: Tule River to Deer Creek
The new parallel canal would begin at Tule River and extend through Deer Creek. The existing canal would only undergo slight modifications: raising the left bank to accommodate the parallel canal design.

Segment 3: Deer Creek to White River
The parallel canal would continue through Deer Creek and end at White River, tying back into the existing canal. The minor left bank canal modifications to the existing canal would be carried through this segment.

Segment 4: White River to Lake Woollomes
Enlarging the canal from White River to Lake Woollomes.

Alternative 5B: Parallel Bypass Canal from Tule River to Woollomes
Alternative 5B is the same as Alternative 5A but extends to Woollomes (Figure 3-7). A such, Alternative 5B has many similarities to Alternative 5A.

Segment 1: 5th Ave. to Tule River
Enlarging the canal from 5th Ave. to Tule River. This action is the same among all alternatives.

Segment 2: Tule River to Deer Creek
The new parallel canal would begin at Tule River and extend through Deer Creek. The existing canal would only undergo slight modifications: raising the left bank to accommodate the parallel canal design. These actions are the same as Alternative 5A.

Segment 3: Deer Creek to White River
Unlike Alternative 5A, the parallel canal would continue throughout this segment without end. The minor left bank canal modifications to the existing canal would be carried through this segment.

Segment 4: White River to Lake Woollomes
The parallel canal would extend through White River and terminate at Lake Woollomes. The minor left bank canal modifications to the existing canal would be carried through until MP 119 where the canal would be enlarged for approximately 2 miles.

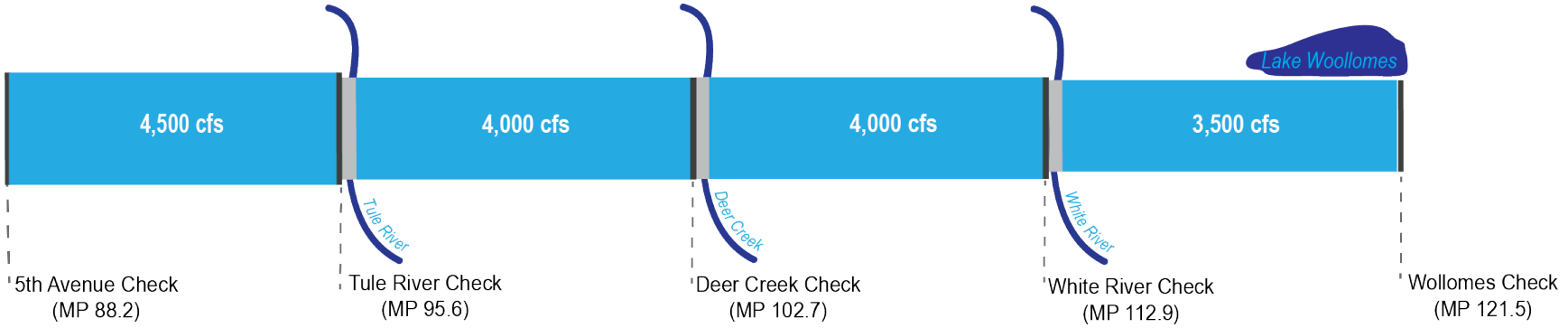
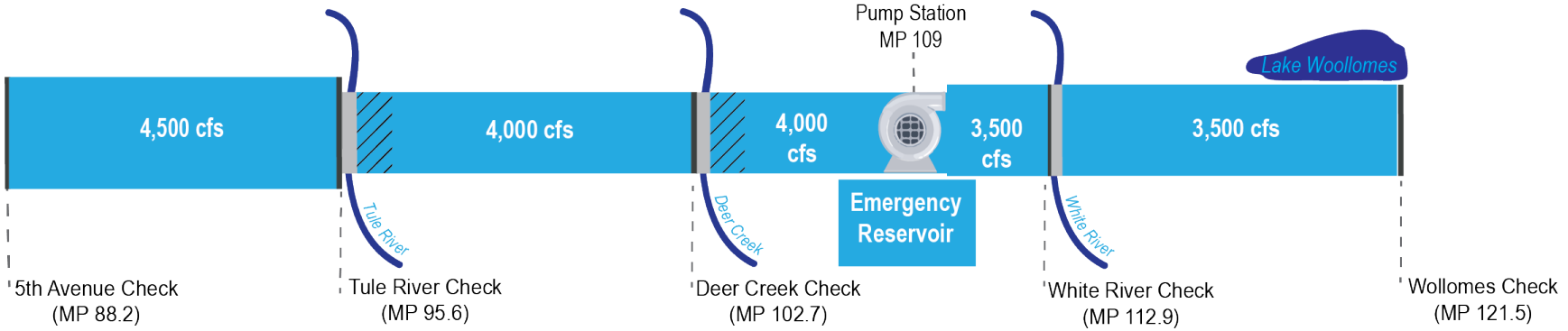
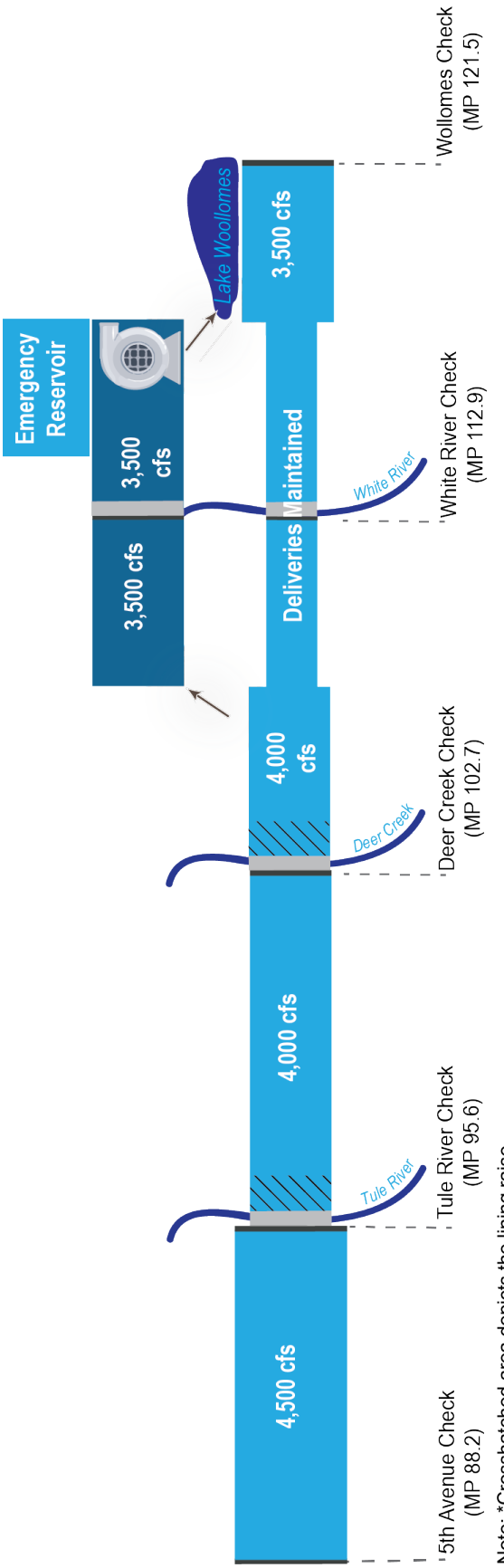


Figure 3-1. Alternative 1 Schematic



Note: *Crosshatched area depicts the lining raise.

Figure 3-2. Alternative 2 Schematic



Note: *Crosshatched area depicts the lining raise.

Figure 3-3. Alternative 3 Schematic

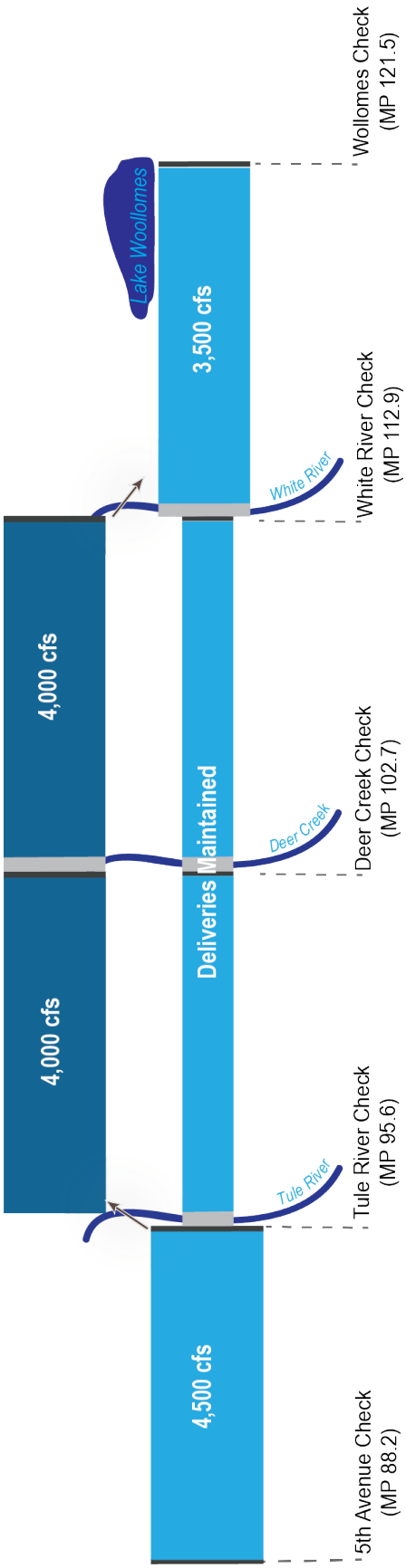


Figure 3-4. Alternative 4A Schematic

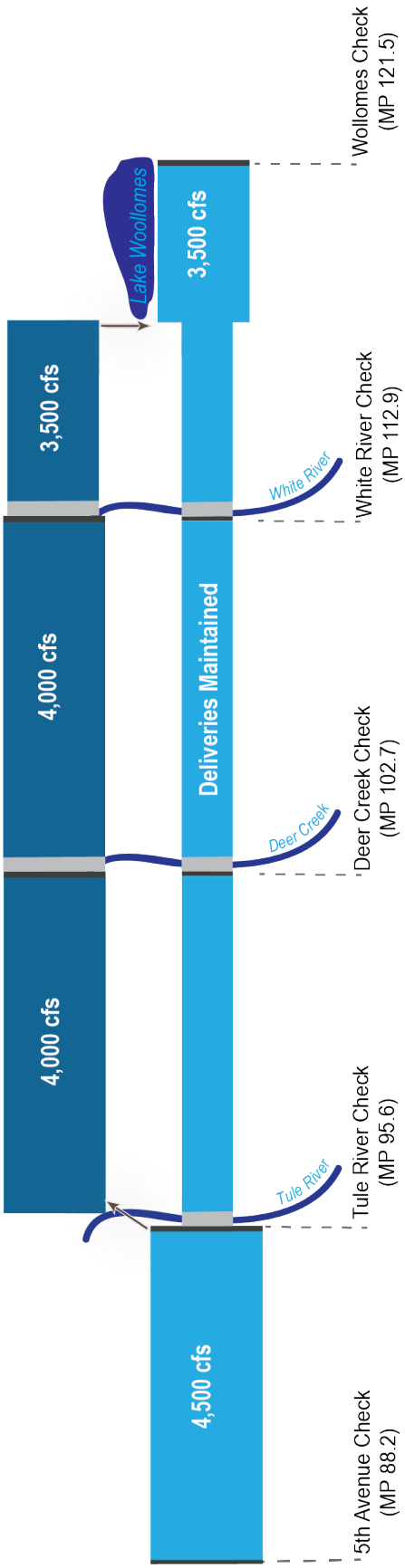


Figure 3-5. Alternative 4B Schematic

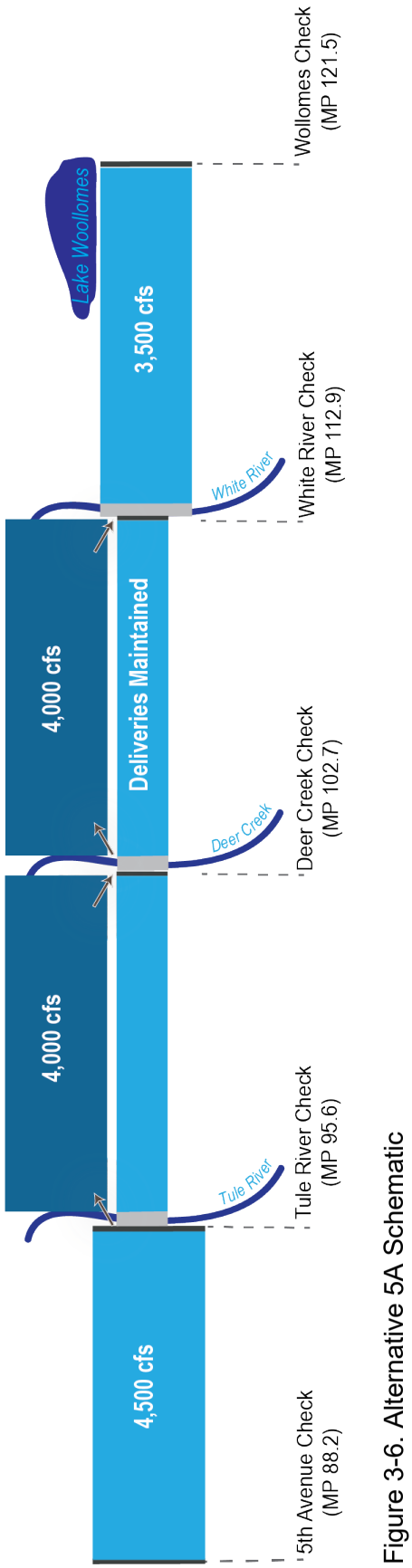


Figure 3-6. Alternative 5A Schematic

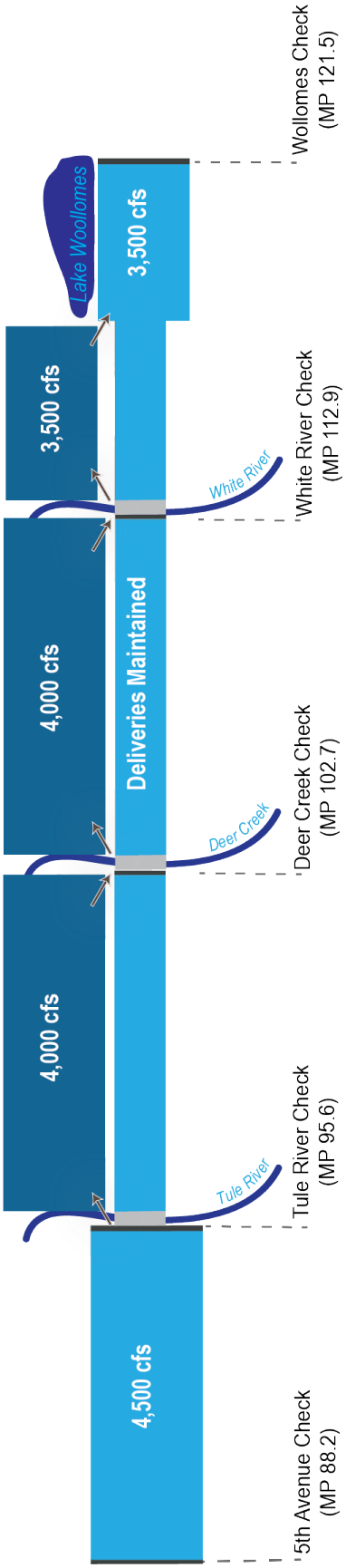


Figure 3-7. Alternative 5B Schematic

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Chapter 4
Cost Estimates and Cost Estimate Basis

Information presented in this Engineering Appendix was developed from prior studies, field reconnaissance, appraisal-level designs and estimated costs, professional experience with similar studies, and subsequent analysis. This chapter describes the methods and general approach used in developing designs and cost estimates for project features.

Reclamation Cost Estimate Levels

As described in Reclamation's Directive & Standards (D&S) FAC 09-01 (2016), different levels of cost estimates are required to plan and fund projects. As a project moves through its development, each subsequent estimate level reflects increasing detail and refinement of the project features. Reclamation recognizes six different levels of construction cost estimates, as follows:

- Preliminary
- Appraisal
- Feasibility
- Percent Final Design (Updated Feasibility)
- Pre-validation of Funds
- Independent Government (Award and Contract Modifications)

Cost estimates are typically developed in the chronological order shown, and each supersedes the previous estimate. They differ in degree of detail, maturity, refinement, use, and confidence, depending on the amount of certainty regarding the engineering and geological data that are available at the time the cost estimates are prepared. The cost estimating output presented here employs Reclamation's appraisal level general methodology as described in FAC 09-01 as the basis for alternative comparison and total project cost budget communication.

Appraisal Cost Estimates

Per D&S FAC 09-01:

> *Appraisal cost estimates are used in appraisal reports to determine whether more detailed investigations of a potential project are justified. These estimates may be prepared from cost graphs, simple sketches, or rough general designs that use the available site-specific design data. These estimates are intended to be used as an aid in selecting the most economical*

plan by comparing alternative features such as dam types, dam sites, canal or transmission line routes, and powerplant or pumping plant capacities. Appraisal cost estimates are not suitable for requesting project authorization or construction fund appropriations from the Congress due to the early stage of project development.

AACEI Cost Estimate Maturity

Cost estimating personnel associated with this assignment are certified via the Association for the Advancement of Cost Engineering International (AACEI). As such, reference and documentation of AACEI standards as related to the aforementioned Reclamation estimating guidance are presented to highlight compatibility and define overlapping nomenclatures.

Per Reclamation practice, appraisal level cost estimates are considered compatible with AACEI Class 4 criteria as defined in their Recommended Practice 18R-97. The Recommended Practice outlines a prescriptive cost estimating classification system that relates cost estimate maturity to four criteria: level of project definition, end usage, methodology and level-of-effort. Specifically, the AACEI defines a Class 4 cost estimate as:

Class 3 Estimates *are generally prepared based on limited information and subsequently have fairly wide accuracy ranges. They are typically used for project screening, determination of feasibility, concept evaluation, and preliminary budget approval. Typically, engineering is from 1% to 15% complete, and would comprise at a minimum the following: plant capacity, block schematics, indicated layout, process flow diagrams (PFDs) for main process systems, and preliminary engineered process and utility equipment lists.*

Level of Project Definition*: 1% to 15%*

End Usage*: prepared for a number of purposes, such as but not limited to, detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic and/or technical feasibility, and preliminary budget approval or approval to proceed to next stage.*

Estimating methodology*: generally use stochastic estimating methods such as equipment factors, Lang factors, Hand factors, Chilton factors, Peters-Timmerhaus factors, Guthrie factors, the Miller method, gross unit costs/ratios, and other parametric and modeling techniques.*

Level-of-Effort*: Typically, as little as 20 hours or less to perhaps more than 300 hours, depending on the project and the estimating methodology used.*

Expected Accuracy Range*: -15% to -30% on the low side, and +20% to +50% on the high side, depending on the technological complexity of the project, appropriate reference information, and other risks (after inclusion of an appropriate contingency determination). Ranges could exceed those shown if there are unusual risks.*

Note that the expected accuracy range is used to communicate the relative uncertainty inherent in the cost opinion based on the above noted criteria. While the indicated point-value of the cost estimate is considered the expected value, the low and high values express best-case and worst-case conditions respectively. Monte Carlo analysis can be used, if desired, to model the relative probability of all three conditions based on three-point estimating techniques. While high and low range values communicate the underlying range uncertainty to decision makers they are not utilized in any substantive manner in the course of this study.

Only current estimated construction costs have been provided (i.e., no escalation is included in the estimates). The estimates of construction costs shown, and any resulting conclusions on the project's financial requirements, economic feasibility, or funding requirements, have been prepared from the best information available at the time the estimate was prepared. Final project costs and resulting feasibility would depend on actual labor and material costs, competitive market conditions, and other variable factors, and should include escalation to the midpoint of construction in future feasibility-level estimates. Accordingly, the final project cost will vary from the estimate. Therefore, project feasibility, benefit/cost analysis, risk, and funding would need to be carefully reviewed prior to making specific funding decisions and/or establishing the project budget.

Appraisal-Level Cost Estimate Methodology

Cost estimates or Opinions of Probable Project Cost (OPPC) presented in this Appendix are developed at an appraisal level of detail. Most designs and cost estimates presented here were developed at an appraisal level of detail. Only standard structure types, consistent with current engineering principles and practices, were considered. All other design layouts, sections, and dimensions are based on standard practice and experience with similar facilities. The structures presented here are considered to be technically viable, based on available information. At the current level of design, limited efforts were made to optimize the design or minimize cost. The following sub-sections will highlight the specific appraisal-level methodology for determining costs for the project alternatives under consideration.

Appraisal-Level Data and Analyses

Detailed design data have not been gathered at this phase of the Investigation. This section summarizes some of the data and analyses used in developing appraisal-level designs and cost estimates. Information on topography, geology, and soils, and existing facilities in the project area is included in Chapter 2.

Major Cost Estimate Assumptions

The assumptions listed for direct cost line items, and specifically factors used to determine indirect costs, are critically important to the overall accuracy of the estimate and should be reviewed and understood by all parties. The employed pricing methodology will be consistent with a detailed unit price. Only current estimated construction costs have been provided with escalation from notice to proceed to mid-point of construction (i.e., no escalation from published price level to notice to proceed is included in the estimates). The estimates of construction costs shown, and any resulting conclusions on the project's financial requirements, economic feasibility, or funding requirements, have been prepared from the best information available at

the time the estimate was prepared. Final project costs and resulting feasibility would depend on actual labor and material costs, competitive market conditions, and other variable factors. Accordingly, the final project cost will vary from the estimate. Therefore, project feasibility, benefit/cost analysis, risk, and funding would need to be carefully reviewed before making specific funding decisions and/or establishing the project budget.

Competitive Market Conditions at the Time of Bid Tender

Estimates assume that Builder's Risk Insurance would be available to the contractor. If Builder's Risk Insurance is not available to the contractor because of the scope, security implications, or magnitude of the project, increased bid margins can be expected since the contractor would need to assume and include costs against those additional risks.

Cost Estimate Contingency Factors

Contingency is a percentage that is applied to the estimated direct cost details to account for unforeseen market conditions, scope unknowns. Contingency allocations are generally higher with lower level cost estimates and typically decrease over time with increasing design definition. The feasibility-level cost estimates under this analysis consider two contingency components relative to reclamation policy: design and construction.

The first contingency component is a standard ***design*** construction contingency used to offset scope variations and unknown site conditions. For the feasibility-level cost estimates, the design contingency was applied at 0 percent of direct costs to account for planning phase design and scope changes.

A second contingency component covers ***construction*** related issues or changed field conditions. For the canal subsidence feasibility-level cost estimates, the construction contingency was set at 20 percent of direct costs.

Scope Quantification

As a major earthworks project, excavation and embankment volumes were calculated using Revit Civil 3D software. Developed earthwork quantities were then plotted relative to project stationing to determine average haul distances per mass-haul diagram techniques. Earthwork embankment quantities were adjusted (increased) by 20 percent to account for compaction shrinkage. When designs were not progressed for certain structures or facilities consistent with feasibility-level definition, relevant go-by designs (i.e., as-builts, etc.) were utilized to quantify the components on a detailed basis.

Direct Cost Development

Direct costs representing the project's fixed physical scope are estimated against a work breakdown structure (WBS) to organize the cost estimate details. Software or spreadsheet functionality allows the direct cost detail to be decomposed to multiple sub-levels, which are referred to as item activities or sub tasks. Direct costs are those directly associated with construction activities, and generally consist of the cost of labor, construction equipment and materials required to construct a feature. Management, engineering, contractor's overheads and other such costs are excluded from the direct cost.

Indirect Cost Development

Indirect costs representing the contractor's time related variable field management expenses or general conditions costs are typically factored in Class 4 OPPCs in a top-down approach as a function of the running direct cost total. For the OPPCs, indirect costs were "factored" in or considered by adding an allowance expressed as a percentage of the direct cost. The factor selected is based on Stantec's experience in building up indirect costs for other similar type projects.

Estimate Adders

Estimate add-ons representing the contractor's allowances for home office overhead expenses, sales taxes, insurance costs, risk provision and fee are added to the cost estimate as a function of running direct costs and are spread back (i.e., prorated) to the established main pay items via factoring. Non-Pay Items are typically organized in a separate account to ensure costs for important support and setup activities are captured and ultimately included as a component of the main item bid prices.

Labor Rate Development

Labor rates are used in the detailed crew analysis direct cost build-up methodology. All-inclusive craft labor rates are built-up from local Davis-Bacon wage determinations to include all applicable fringes (i.e., health and welfare, vacation, training and union dues,) and tax burdens (i.e., workers compensation, payroll taxes). Shift differentials are applied in accordance with expected contractor means and methods and known schedule constraints. Finally, allowances for per-diems are included to account for remote project conditions and the need to attract skilled labor resources.

Equipment Rate Development

Equipment rates are used in the detailed crew analysis direct cost build-up methodology. All-inclusive rolling equipment rates are built-up using depreciation schedules and calculated hourly operating costs. Developed equipment rates are calibrated against published rental rate schedules such as Equipment Rate Blue Book and are adjusted for 80 percent of the ownership cost. Software functionality allows the default fuel rate to be adjusted to account for fluctuating fuel costs or and overall adjustment of the equipment rate per suspected market conditions.

Cost Escalation

The FWA alternative OPPCs include an allowance for cost escalation for the period of construction. As such, the estimated construction duration is divided by two to provide theoretical mid-point of construction expressed terms of years and then multiplied by a 4 percent (see next subsection's discussion) yearly escalation rate to calculate the allowance.

In keeping with Reclamation practice, escalation from the indicated pricing level (Q1 2019) to the Notice to Proceed (NTP) is not included as the duration is currently unknown and not determinable. Reclamation typically requests legislative language be included with Congressional authorization to ensure adequate funding is provided for the planning period leading up to NTP.

California Cost Escalation

The appraisal-level cost estimates include, as mentioned above, cost escalation exclusive to the period of construction. For economic analysis and future project budgeting, a preliminary escalation rate of 4 percent per year is used to calculate the escalation allowance to the estimated midpoint of construction. For these appraisal-level estimates, a 2.5-year project duration was assumed. Stantec relied on local cost escalation data as opposed to relying on Reclamation's cost trends index to determine the yearly escalation rate. The rational for reliance on localized data vs. standardized data is based on the robust nature of the local data and the variance for which that data supports a higher yearly escalation recommendation.

The preliminary escalation value of 4 percent annual rate of inflation is based primarily on reliance on cost escalation data from the Caltrans Price Index (CPI), California Department of Transportation). The Caltrans Price Index demonstrates that California is experiencing price inflation in highway and heavy civil construction infrastructure work above nominal CPI.

Under linear regression techniques, both the Federal Highway Administration (FHWA) California and Caltrans Price indices confirm a fundamental positive shift away from long-term escalation trend lines, beginning in 1999. Figure 4-1 shows FHWA National and California price trends from 1972 to present. Figure 4-1 also shows Caltrans highway construction price trends from 1986 through the present. From these data, expected long-term price trends have been projected through 2027.

While future inflation trends are difficult to predict, new market forces (e.g., higher material commodity pricing, energy costs, lack of competition) will likely continue to have considerable impacts on heavy civil infrastructure construction costs for the foreseeable future. Future studies and coordination should be undertaken to determine the appropriate escalation factor to be used for budgetary approval.

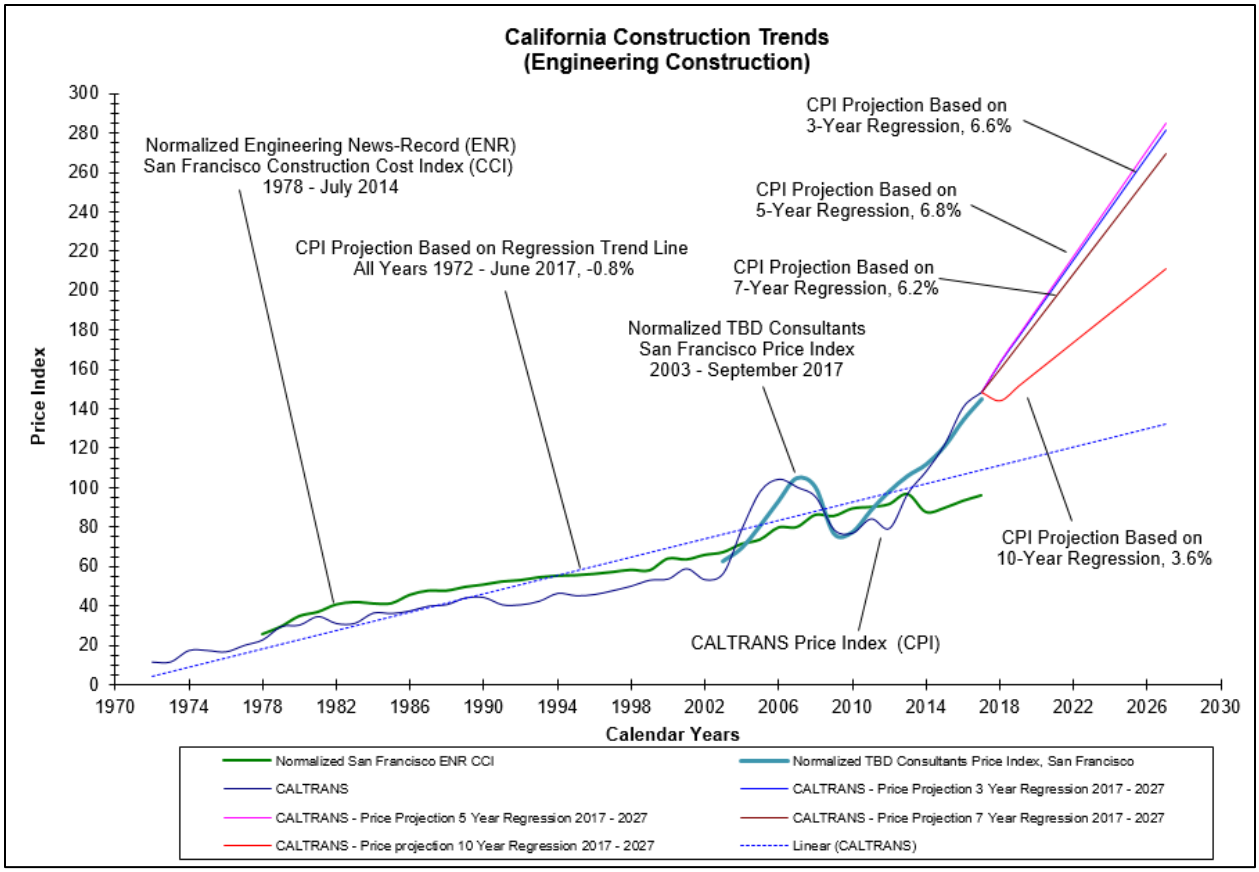


Figure 4-1. California Construction Price Trends (Engineering Construction)

General Estimating Assumptions

The developed OPPCs consider the following general standard estimating assumptions:

- Unlimited construction resources (i.e., agency and contractors)
- Contractor and agency resources are trained and competent
- Competitive market conditions will prevail
- Cash flow will accommodate the contracting strategy
- Stable market conditions will prevail
- Standard industry commercial terms will attach to all procurements
- Normal weather conditions will prevail
- Major natural disasters will not impact the project's critical path (CP)

- New regulatory legislation or Environmental Impact Statement/Record of Decision directives will not impact the CP
- Unknown claim issues or procurement protests will not impact the CP
- Unknown legal challenges will not impact the CP
- Contractors will be mobilized once per contract
- Contractor interference issues or traffic impacts will be mitigated
- Staging space will be optimized to maximize concurrent operations
- The chosen contracting strategy will realize competitive conditions

Specific Estimating Assumptions

The developed OPPCs consider the following specific estimating assumptions:

- A 2-2.5-year execution duration pending detailed scheduling
- Contractors will be mobilized once per contract
- Davis-Bacon wage rate determination CA20170032
- FWA reserves the right to award the project to other than the low bidder
- FWA will acquire pre-construction necessary borrow and spoils pits/areas
- Costs associated with the loss of water due to construction requirement affecting customer deliveries
- Single shift field execution basis (8-10 hours /day)
- Required permitting and land acquisition activities will not delay the CP
- Contractor will take lead for project quality control responsibilities, FWA will support
- Viable water sources will support construction per required needs
- Annualized capital costs are estimated over 50 years at the current 2.875 percent Federal discount rate (Fiscal Year 2019)

Specific Estimating Exclusions

The developed OPPCs exclude the following:

- Interest During Construction (IDC)
- Contractor responsibility for dewatering or shunting down existing facilities

- Undefined historical, cultural or environmental mitigations
- Costs escalation from the pricing level to NTP
- Unknown required agency fees and/or inspections

Non-Contract Costs

Non-contract costs include work or services provided by agency personnel, or acquisitions to facilitate project development, such as land acquisition, environmental mitigation, and distributive costs for planning, engineering, design, and construction management.

Engineering, Permitting, and Construction Management

The allowance for planning, engineering, design, and construction management is estimated to be about 10 percent of the field cost.

Environmental Mitigation

NEPA and CEQA require an assessment of environmental impacts of major projects. The environmental impact analyses determine the significance of the impact based on the degree of resource impact in relationship and context of the local and regional resource setting. An impact assessment has not yet been performed; rather the preliminary analysis included as an Appendix to the Plan Formulation Report presents generalized impacts for each alternative. Moreover, potential impacts of other project elements not yet defined could result in additional impacts. These elements include borrow pits, construction staging areas, and installation of construction access roads.

Compensation for habitat losses may include an array of measures including replacement habitat (i.e., preservation of off-site habitat) to compensate for lost ecosystem functions and values. The mitigation value of replacement habitat may be augmented by habitat enhancements, restoration, and creation. Baseline mitigation to offset these losses would likely require habitat replacement at a minimum ratio of 2:1 but may include a ratio as high as 4:1 to fully mitigate project impacts and comply with NEPA and CEQA. The actual ratio employed for any given project is a result of interagency negotiations. Ratios are generally higher for wetland and riparian habitats and habitat for special-status species than it is for general wildlife habitat.

Conceptually, compensation for the loss of upland habitats that have been shown to not support special-status species is likely to be in the range of 2:1 to 3:1. Compensation for wetlands and riparian habitat is more typically in the 3:1 to 4:1 range. The California Department of Fish and Game considers the functional capacity replacement for wetlands and riparian habitats to be 4:1. Habitat for special-status species generally carries at least a 3:1 ratio but is species dependent.

For these appraisal-level cost estimates, an allowance for environmental mitigation (and which includes cultural resources mitigation) is estimated to be about 5 percent of the field cost.

Legal and Administrative

The allowance for legal and administrative costs is estimated to be about 2 percent of the field cost.

Project Area Lands

To create a value estimate for private lands potentially affected by the FKC alternatives, a geographic information system (GIS) search was used to identify properties potentially affected by each alternative. Parcel information for the affected parcels and comparable sales in nearby counties was obtained.

The project area lands include lands to be acquired in fee for Right of Way including the embankment areas and overflow reservoirs (where applicable), as well as for construction phase activities, including staging areas, borrow pits, and stockpile/dump sites. Values for private lands within or near the project area were estimated at September 2018 price level and estimated to be on average $25,000 per acre.

Cost Summary Terminology

- Contract Cost = Expected bid tender amount including the design contingency
- Field Cost = Contract cost plus the construction contingency
- Non-contract Costs = Project support costs
- Total Project Cost = Field Cost plus Non-contract costs

Total Annual Costs

The total estimated capital cost was annualized, and estimated annual costs were also included for operations, maintenance, and replacement (OM&R) to obtain the estimated annual cost for each alternative configuration.

Annualized Capital Costs

The total estimated capital costs of each alternative were annualized to facilitate comparison to annual benefits. Total annual costs for each alternative were estimated by interest and amortization of the capital cost over 50 years and at the current Federal discount rate of 2.875 percent (Fiscal Year 2019).

Present Worth Additional OM&R Cost

Estimates for both canal and pump station-related OM&R costs were developed for the initial alternatives. The OM&R costs for the canal represent additional costs resulting from the new structures to be built, on top of FWA's existing annual OM&R budget. For the pump station OM&R annual costs, the estimate includes power consumption, labor costs, and major equipment rehabilitation and replacement over 50 years. The pump station rehabilitation and replacement costs include mobilization, contingency, and non-contract costs. All costs were estimated at the September 2018 price level and were estimated by interest and amortization of the total OM&R cost over 50 years at the current Federal discount rate of 2.875 percent (Fiscal Year 2019).

OPPC Disclaimer

The estimates of construction costs shown, and any resulting conclusions on the project's financial requirements, economic feasibility, or funding requirements, have been prepared from the best information available at the time the estimate was prepared. Final project costs and resulting feasibility would depend on actual labor and material costs, competitive market

conditions, and other variable factors, and should include escalation to the midpoint of construction in future feasibility-level estimates. Accordingly, the final project cost will vary from the cost estimate. Therefore, project feasibility, benefit/cost analysis, risk, and funding would need to be carefully reviewed prior to making specific funding decisions and/or establishing the project budget.

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Chapter 5
Construction Costs

Tables 5-1 through 5-7 summarize the components of the OPPC including field cost, non-contract costs, total capital cost, annualized capital costs assuming a 50-year project lifespan, and annual costs for operations, maintenance, repair, replacement, and power consumption for each of the seven FKC initial alternatives, both with and without consideration of future subsidence. Table 5-8 is a compiled summary of the appraisal-level/Class 4 OPPCs for each alternative, with and without future subsidence. All costs shown are September 2018 price levels. The costs summarized in these tables are based on the worksheets presented in Attachment B.4. Note that the costs have been rounded according to Reclamation guidelines, so the numbers within a table may not directly add up to the total depicted on that table.

Table 5-1. Appraisal-level Cost Estimates for Alternative 1, with and Without Future Subsidence

Item	Reference	Cost	Additional Cost with Future Subsidence	Total Cost with Future Subsidence	Notes/ Inclusions
Canal Widening	from estimate	$135,383,722	$26,765,279	$162,149,001	Embankments and concrete liner
Ancillary Facilities	from estimate	$56,482,764	$3,055,921	$59,538,685	Bridges and in-canal structures
Construction Allowances	from estimate	$2,188,735	$0	$2,188,735	Contractor quality control
Subtotal		*$194,055,220*	*$29,821,200*	*$223,876,421*	
Mobilization	from estimate	$4,311,063	$0	$4,311,063	
Startup, Commission, and Owner Training	from estimate	$148,365	$0	$148,365	
Subtotal		*$198,514,648*	*$29,821,200*	*$228,335,849*	
Contract Cost Allowance – Design Contingency	0%	$0	$0	$0	
Contract Cost		**$200,000,000**	**$30,000,000**	**$230,000,000**	Rounded
Construction Contingencies	20%	$40,000,000	$6,000,000	$46,000,000	
FIELD COST		**$240,000,000**	**$36,000,000**	**$280,000,000**	Rounded
Land Purchase – Right of Way		$4,250,000	$1,275,000	$5,525,000	170 acres without subsidence; 51 additional acres with future subsidence
Land Purchase – Construction Phase		$1,000,000	$1,000,000	$2,000,000	40 acres without; 40 additional acres with
Interest During Construction	0%	$0	$0	$0	Assume no interest during construction
Environmental Mitigation	5%	$12,000,000	$1,800,000	$14,000,000	Calculated as % of Field Cost
Engineering, Permitting, and Construction Management	10%	$24,000,000	$3,600,000	$28,000,000	Calculated as % of Field Cost
Legal and Administrative	2%	$4,800,000	$720,000	$5,600,000	Calculated as % of Field Cost
Non-Contract Costs		**$46,000,000**	**$8,400,000**	**$55,000,000**	Rounded
TOTAL CAPITAL COST		**$290,000,000**	**$44,000,000**	**$340,000,000**	Rounded
Annualized Capital Cost		$11,004,945	-	$12,902,349	2.875% (Fiscal Year 19) over 50 years
Present Worth Additional operations, maintenance, and replacement Cost - Canal		$284,611	$0	$284,611	Excludes current operations and maintenance costs; 2.875% (Fiscal Year 19) over 50 years
Present Worth operations, maintenance, and replacement Cost - Pump Station		$0	$0	$0	2.875% (Fiscal Year 19) over 50 years
TOTAL ANNUAL COST		**$11,500,000**		**$13,000,000**	Rounded

Table 5-2. Appraisal-level Cost Estimates for Alternative 2, with and Without Future Subsidence

Item	Reference	Cost	Additional Cost with Future Subsidence	Total Cost with Future Subsidence	Notes/ Inclusions
Canal Widening	from estimate	$82,004,080	$4,934,042	$86,938,122	Embankments and concrete liner
Ancillary Facilities	from estimate	$50,488,440	$2,651,222	$53,139,662	Bridges and in-canal structures
Pump Station at MP 109.0	from estimate	$16,812,000	$4,483,200	$21,295,200	Complete-in-Place
Pump Station Overflow Reservoir at MP 109.0	from estimate	$23,235,652	$0	$23,235,652	Excavation
Construction Allowances	from estimate	$1,967,076	$0	$1,967,076	Contractor quality control
Subtotal		*$174,507,249*	*$12,068,464*	*$186,575,713*	
Mobilization	from estimate	$4,735,380	$0	$4,735,380	
Startup, Commission, and Owner Training	from estimate	$147,105	$0	$147,105	
Subtotal		*$179,389,734*	*$12,068,464*	*$191,458,198*	
Contract Cost Allowance - Design Contingency	0%	$0	$0	$0	
Contract Cost		**$180,000,000**	**$12,000,000**	**$190,000,000**	Rounded
Construction Contingencies	20%	$36,000,000	$2,400,000	$38,000,000	
FIELD COST		**$220,000,000**	**$14,500,000**	**$230,000,000**	Rounded
Land Purchase – Right of Way		$13,050,000	$300,000	$13,350,000	522 acres without subsidence; 12 additional acres with future subsidence
Land Purchase - Construction Phase		$1,575,000	$0	$1,575,000	63 acres without; 0 additional acres with
Interest During Construction	0%	$0	$0	$0	Assume no interest during construction
Environmental Mitigation	5%	$11,000,000	$725,000	$11,500,000	Calculated as % of Field Cost
Engineering, Permitting, and Construction Management	10%	$22,000,000	$1,450,000	$23,000,000	Calculated as % of Field Cost
Legal and Administrative	2%	$4,400,000	$290,000	$4,600,000	Calculated as % of Field Cost
Non-Contract Costs		**$52,000,000**	**$2,800,000**	**$54,000,000**	Rounded
TOTAL CAPITAL COST		**$270,000,000**	**$17,500,000**	**$280,000,000**	Rounded
Annualized Capital Cost		$10,245,983	-	$10,625,464	2.875% (Fiscal Year 19) over 50 years
Present Worth Additional operations, maintenance, and replacement Cost - Canal		$202,390	$0	$202,390	Excludes current operations and maintenance costs; 2.875% (Fiscal Year 19) over 50 years
Present Worth operations, maintenance, and replacement Cost - Pump Station		$2,919,348	$0	$2,919,348	2.875% (Fiscal Year 19) over 50 years
TOTAL ANNUAL COST		**$13,500,000**		**$13,500,000**	Rounded

Table 5-3. Appraisal-level Cost Estimates for Alternative 3, with and Without Future Subsidence

Item	Reference	Cost	Additional Cost with Future Subsidence	Total Cost with Future Subsidence	Notes/ Inclusions
Canal Widening	from estimate	$68,426,853	$17,917,947	$86,344,800	Embankments and concrete liner
New Canal Bypass	from estimate	$57,005,617	$0	$57,005,617	Embankments and concrete liner
Ancillary Facilities	from estimate	$63,155,529	$4,364,906	$67,520,436	Bridges and in-canal structures
Pump Station at MP 109.0	from estimate	$19,656,000	$4,492,800	$24,148,800	Complete-in-Place
Pump Station Overflow Reservoir at MP 109.0	from estimate	$43,499,265	$0	$43,499,265	Excavation
Construction Allowances	from estimate	$2,805,297	$0	$2,805,297	Contractor quality control
Subtotal		*$254,548,561*	*$26,775,654*	*$281,324,215*	
Mobilization	from estimate	$5,082,480	$0	$5,082,480	
Startup, Commission, and Owner Training	from estimate	$147,420	$0	$147,420	
Subtotal		*$259,778,461*	*$26,775,654*	*$286,554,115*	
Contract Cost Allowance - Design Contingency	0%	$0	$0	$0	
Contract Cost		**$260,000,000**	**$27,000,000**	**$285,000,000**	Rounded
Construction Contingencies	20%	$52,000,000	$5,400,000	$57,000,000	
FIELD COST		**$310,000,000**	**$32,000,000**	**$340,000,000**	Rounded
Land Purchase – Right of Way		$15,575,000	$1,200,000	$16,775,000	623 acres without subsidence; 48 additional acres with future subsidence
Land Purchase - Construction Phase		$1,387,500	$0	$1,387,500	55.5 acres without; 0 additional acres with
Interest During Construction	0%	$0	$0	$0	Assume no interest during construction
Environmental Mitigation	5%	$15,500,000	$1,600,000	$17,000,000	Calculated as % of Field Cost
Engineering, Permitting, and Construction Management	10%	$31,000,000	$3,200,000	$34,000,000	Calculated as % of Field Cost
Legal and Administrative	2%	$6,200,000	$640,000	$6,800,000	Calculated as % of Field Cost
Non-Contract Costs		**$70,000,000**	**$6,600,000**	**$76,000,000**	Rounded
TOTAL CAPITAL COST		**$380,000,000**	**$38,500,000**	**$420,000,000**	Rounded
Annualized Capital Cost		$14,420,273	-	$15,938,196	2.875% (Fiscal Year 19) over 50 years
Present Worth Additional operations, maintenance, and replacement Cost - Canal		$600,845	$0	$600,845	Excludes current operations and maintenance costs; 2.875% (Fiscal Year 19) over 50 years
Present Worth operations, maintenance, and replacement Cost - Pump Station		$2,919,348	$0	$2,919,348	2.875% (Fiscal Year 19) over 50 years
TOTAL ANNUAL COST		**$18,000,000**		**$19,500,000**	Rounded

Table 5-4. Appraisal-level Cost Estimates for Alternative 4A, with and Without Future Subsidence

Item	Reference	Cost	Additional Cost with Future Subsidence	Total Cost with Future Subsidence	Notes/ Inclusions
Canal Widening	from estimate	$60,876,232	$15,509,768	$76,386,000	Embankments and concrete liner
New Canal Bypass	from estimate	$77,027,803	$0	$77,027,803	Embankments and concrete liner
Ancillary Facilities - Both	from estimate	$54,649,901	$3,450,077	$58,099,977	Bridges and in-canal structures
Construction Allowances	from estimate	$2,203,791	$0	$2,203,791	Contractor quality control
Subtotal		*$194,757,727*	*$18,959,845*	*$213,717,572*	
Mobilization	from estimate	$5,672,000	$0	$5,672,000	
Startup, Commission, and Owner Training	from estimate	$148,890	$0	$148,890	
Subtotal		*$200,578,617*	*$18,959,845*	*$219,538,462*	
Contract Cost Allowance - Design Contingency	0%	$0	$0	$0	
Contract Cost		**$200,000,000**	**$19,000,000**	**$220,000,000**	Rounded
Construction Contingencies	20%	$40,000,000	$3,800,000	$44,000,000	
FIELD COST		**$240,000,000**	**$23,000,000**	**$260,000,000**	Rounded
Land Purchase – Right of Way		$12,650,000	$900,000	$13,550,000	506 acres without subsidence; 36 additional acres with future subsidence
Land Purchase - Construction Phase		$1,294,989	$0	$1,294,989	506 acres without; 36 additional acres with
Interest During Construction	0%	$0	$0	$0	Assume no interest during construction
Environmental Mitigation	5%	$12,000,000	$1,150,000	$13,000,000	Calculated as % of Field Cost
Engineering, Permitting, and Construction Management	10%	$24,000,000	$2,300,000	$26,000,000	Calculated as % of Field Cost
Legal and Administrative	2%	$4,800,000	$460,000	$5,200,000	Calculated as % of Field Cost
Non-Contract Costs		**$55,000,000**	**$4,800,000**	**$59,000,000**	Rounded
TOTAL CAPITAL COST		**$300,000,000**	**$28,000,000**	**$320,000,000**	Rounded
Annualized Capital Cost		$11,384,426	-	$12,143,388	2.875% (Fiscal Year 19) over 50 years
Present Worth Additional operations, maintenance, and replacement Cost - Canal		$999,300	$0	$999,300	Excludes current operations and maintenance costs; 2.875% (Fiscal Year 19) over 50 years
Present Worth operations, maintenance, and replacement Cost - Pump Station		$0	$0	$0	2.875% (Fiscal Year 19) over 50 years
TOTAL ANNUAL COST		**$12,500,000**		**$13,000,000**	Rounded

Table 5-5. Appraisal-level Cost Estimates for Alternative 4B, with and Without Future Subsidence

Item	Reference	Cost	Additional Cost with Future Subsidence	Total Cost with Future Subsidence	Notes/ Inclusions
Canal Widening	from estimate	$35,934,132	$15,492,200	$51,426,331	Embankments and concrete liner
New Canal Bypass	from estimate	$117,341,369	$0	$117,341,369	Embankments and concrete liner
Ancillary Facilities - Both	from estimate	$62,539,929	$4,587,126	$67,127,054	Bridges and in-canal structures
Construction Allowances	from estimate	$2,444,263	$0	$2,444,263	Contractor quality control
Subtotal		*$218,259,693*	*$20,079,325*	*$238,339,018*	
Mobilization	from estimate	$5,656,000	$0	$5,656,000	
Startup, Commission, and Owner Training	from estimate	$148,470	$0	$148,470	
Subtotal		*$224,064,163*	*$20,079,325*	*$244,143,488*	
Contract Cost Allowance - Design Contingency	0%	$0	$0	$0	
Contract Cost		**$220,000,000**	**$20,000,000**	**$245,000,000**	Rounded
Construction Contingencies	20%	$44,000,000	$4,000,000	$49,000,000	
FIELD COST		**$260,000,000**	**$24,000,000**	**$290,000,000**	Rounded
Land Purchase – Right of Way		$16,250,000	$937,500	$17,187,500	650 acres without subsidence; 37.5 additional acres with future subsidence
Land Purchase - Construction Phase		$2,107,500	$0	$2,107,500	84.3 acres without; 0 additional acres with
Interest During Construction	0%	$0	$0	$0	Assume no interest during construction
Environmental Mitigation	5%	$13,000,000	$1,200,000	$14,500,000	Calculated as % of Field Cost
Engineering, Permitting, and Construction Management	10%	$26,000,000	$2,400,000	$29,000,000	Calculated as % of Field Cost
Legal and Administrative	2%	$5,200,000	$480,000	$5,800,000	Calculated as % of Field Cost
Non-Contract Costs		**$63,000,000**	**$5,000,000**	**$69,000,000**	Rounded
TOTAL CAPITAL COST		**$320,000,000**	**$29,000,000**	**$360,000,000**	Rounded
Annualized Capital Cost		$12,143,388	-	$13,661,311	2.875% (Fiscal Year 19) over 50 years
Present Worth Additional operations, maintenance, and replacement Cost - Canal		$1,429,378	$0	$1,429,378	Excludes current O&M costs; 2.875% (Fiscal Year 19) over 50 years
Present Worth operations, maintenance, and replacement Cost - Pump Station		$0	$0	$0	2.875% (Fiscal Year 19) over 50 years
TOTAL ANNUAL COST		**$13,500,000**		**$15,000,000**	Rounded

Table 5-6. Appraisal-level Cost Estimates for Alternative 5A, with and Without Future Subsidence

Item	Reference	Cost	Additional Cost with Future Subsidence	Total Cost with Future Subsidence	Notes/ Inclusions
Canal Widening	from estimate	$59,947,317	$15,043,133	$74,990,450	Embankments and concrete liner
New Canal Bypass	from estimate	$89,401,447	$0	$89,401,447	Embankments and concrete liner
Ancillary Facilities - Both	from estimate	$49,540,573	$3,435,478	$52,976,052	Bridges and in-canal structures
Construction Allowances	from estimate	$2,261,558	$0	$2,261,558	Contractor quality control
Subtotal		*$201,150,895*	*$18,478,611*	*$219,629,506*	
Mobilization	from estimate	$4,843,160	$0	$4,843,160	
Startup, Commission, and Owner Training	from estimate	$148,260	$0	$148,260	
Subtotal		*$206,142,315*	*$18,478,611*	*$224,620,926*	
Contract Cost Allowance - Design Contingency	0%	$0	$0	$0	
Contract Cost		**$210,000,000**	**$18,500,000**	**$220,000,000**	Rounded
Construction Contingencies	20%	$42,000,000	$3,700,000	$44,000,000	
FIELD COST		**$250,000,000**	**$22,000,000**	**$260,000,000**	Rounded
Land Purchase – Right of Way		$8,000,000	$375,000	$8,375,000	320 acres without subsidence; 15 additional acres with future subsidence
Land Purchase - Construction Phase		$1,912,500	$500,000	$2,412,500	76.5 acres without; 20 additional acres with
Interest During Construction	0%	$0	$0	$0	Assume no interest during construction
Environmental Mitigation	5%	$12,500,000	$1,100,000	$13,000,000	Calculated as % of Field Cost
Engineering, Permitting, and Construction Management	10%	$25,000,000	$2,200,000	$26,000,000	Calculated as % of Field Cost
Legal and Administrative	2%	$5,000,000	$440,000	$5,200,000	Calculated as % of Field Cost
Non-Contract Costs		**$52,000,000**	**$4,600,000**	**$55,000,000**	Rounded
TOTAL CAPITAL COST		**$300,000,000**	**$27,000,000**	**$320,000,000**	Rounded
Annualized Capital Cost		$11,384,426	-	$12,143,388	2.875% (Fiscal Year 19) over 50 years
Present Worth Additional operations, maintenance, and replacement Cost - Canal		$967,676	$0	$967,676	Excludes current operations and maintenance costs; 2.875% (Fiscal Year 19) over 50 years
Present Worth operations, maintenance, and replacement Cost - Pump Station		$0	$0	$0	2.875% (Fiscal Year 19) over 50 years
TOTAL ANNUAL COST		**$12,500,000**		**$13,000,000**	Rounded

Table 5-7. Appraisal-level Cost Estimates for Alternative 5B, with and Without Future Subsidence

Item	Reference	Cost	Additional Cost with Future Subsidence	Total Cost with Future Subsidence	Notes/ Inclusions
Canal Widening	from estimate	$31,704,132	$15,101,928	$46,806,059	Embankments and concrete liner
New Canal Bypass	from estimate	$111,256,771	$0	$111,256,771	Embankments and concrete liner
Ancillary Facilities - Both	from estimate	$57,016,996	$4,405,322	$61,422,319	Bridges and in-canal structures
Construction Allowances	from estimate	$2,281,135	$0	$2,281,135	Contractor quality control
Subtotal		*$202,259,035*	*$19,507,250*	*$221,766,285*	
Mobilization	from estimate	$5,668,000	$0	$5,668,000	
Startup, Commission, and Owner Training	from estimate	$148,785	$0	$148,785	
Subtotal		*$208,075,820*	*$19,507,250*	*$227,583,070*	
Contract Cost Allowance - Design Contingency	0%	$0	$0	$0	
Contract Cost		**$210,000,000**	**$19,500,000**	**$230,000,000**	Rounded
Construction Contingencies	20%	$42,000,000	$3,900,000	$46,000,000	
FIELD COST		**$250,000,000**	**$23,000,000**	**$280,000,000**	Rounded
Land Purchase – Right of Way		$9,650,000	$412,500	$10,062,500	386 acres without subsidence; 16.5 additional acres with future subsidence
Land Purchase - Construction Phase		$792,500	$500,000	$1,292,500	31.7 acres without; 20 additional acres with
Interest During Construction	0%	$0	$0	$0	Assume no interest during construction
Environmental Mitigation	5%	$12,500,000	$1,150,000	$14,000,000	Calculated as % of Field Cost
Engineering, Permitting, and Construction Management	10%	$25,000,000	$2,300,000	$28,000,000	Calculated as % of Field Cost
Legal and Administrative	2%	$5,000,000	$460,000	$5,600,000	Calculated as % of Field Cost
Non-Contract Costs		**$53,000,000**	**$4,800,000**	**$59,000,000**	Rounded
TOTAL CAPITAL COST		**$300,000,000**	**$28,000,000**	**$340,000,000**	Rounded
Annualized Capital Cost		$11,384,426	-	$12,902,349	2.875% (Fiscal Year 19) over 50 years
Present Worth Additional operations, maintenance, and replacement Cost - Canal		$1,366,131	$0	$1,366,131	Excludes current operations and maintenance costs; 2.875% (Fiscal Year 19) over 50 years
Present Worth operations, maintenance, and replacement Cost - Pump Station		$0	$0	$0	2.875% (Fiscal Year 19) over 50 years
TOTAL ANNUAL COST		**$13,000,000**		**$14,500,000**	Rounded

Table 5-8. Appraisal-level Cost Estimate Summary for Each Alternative, with and Without Future Subsidence

		Without Future Subsidence			With Future Subsidence		
Alt #	**Description**	**Field Cost**	**Total Capital Cost**	**Total Annual Cost**	**Field Cost**	**Total Capital Cost**	**Total Annual Cost**
1	Canal Enlargement	$240,000,000	$290,000,000	$11,500,000	$280,000,000	$340,000,000	$13,000,000
2	MP 109 Pump Station	$220,000,000	$270,000,000	$13,500,000	$230,000,000	$280,000,000	$13,500,000
3	Woollomes Pump Station	$310,000,000	$380,000,000	$18,000,000	$340,000,000	$420,000,000	$19,500,000
4A	Bypass Canal Tule to White River	$240,000,000	$320,000,000	$13,000,000	$260,000,000	$320,000,000	$13,000,000
4B	Bypass Canal Tule to Woollomes	$260,000,000	$320,000,000	$13,500,000	$290,000,000	$360,000,000	$15,000,000
5A	Parallel Canal Tule to White River	$250,000,000	$300,000,000	$12,500,000	$260,000,000	$320,000,000	$13,000,000
5B	Parallel Canal Tule to Woollomes	$250,000,000	$300,000,000	$13,000,000	$280,000,000	$340,000,000	$14,500,000

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Chapter 6
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Feasibility Report
Exhibit A1a
Initial Alternative Formulation Basis of Design Report
Friant Kern Canal Middle Reach Capacity Correction Project

Technical Memorandum

Submitted to: Friant Water Authority



October 2019

Stantec

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Project Friant-Kern Canal Subsidence Correction Project

Subject Plan Formulation Basis of Design Report

Date: March 15, 2019

File: FKC_SubsidenceCorrection_PlanFormulationBODR_DRAFT_v03_20181214.docx

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Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ac-ft	Acre Feet
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASTM	American Society of Testing and Materials
AWG	American Wire Gauge
AWS	American Welding Society
Caltrans	California Department of Transportation
CCR	California Code of Regulations, Title 24
CCTV	Closed Circuit Television
CEC	California Electrical Code
CEQA	National Environmental Quality Act
cfs	Cubic Feet Per Second
CPT	Cone Penetration Test
FKC	Friant-Kern Canal
FWA	Friant Water Authority
ft	Feet
ft/s	Feet Per Second
HGL	Hydraulic Grade Line
HI	Hydraulic Institute
hp	Horsepower

Abbreviations and Acronyms

HSS	Hollow Structural Shapes
h:v	horizontal:vertical
IBC	International Building Code
IEEE	Institute of Electrical and Electronics Engineers
ISA	Instrument Society of America
ksi	Kips Per Square Inch
lbs	Pounds
LiDAR	Light Detection and Ranging
mA	Milliamp
LRFD	Load and Resistance Factor Design
MP	Milepost
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NEPA	National Environmental Policy Act
NETA	National Electrical Testing Association
NFPA	National Fire Protection Association
OSHA	Occupational Safety and Health Act
pcf	Pounds Per Cubic Foot
PLC	Programmable Logic Controller (PLC) and
plf	Pounds Per Linear Foot
POE	Power Over Ethernet
Project	Friant-Kern Canal Subsidence Correction Project
psf	Pounds Per Square Foot

Abbreviations and Acronyms

psi	Pounds Per Square Inch
PVC	Polyvinyl chloride
RCPP	Reinforced Concrete Pressure Pipe
Reclamation	United States Department of the Interior, Bureau of Reclamation
ROW	Right-of-Way
SCADA	Supervisory Control and Data Acquisition
SCE	Southern California Edison
SSRV	Solid-State Reduced Voltage
TEFC	Totally Enclosed, Fan-Cooled
TOL	Top of Liner
UL	Underwriters' Laboratories, Inc
VAC	Volts of Alternating Current
VFD	Variable Frequency Drive

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1. INTRODUCTION

1.1 Purpose

The intent of this Plan Formulation Basis of Design Report is to:

- Document work performed to study and evaluate the original Friant-Kern Canal (FKC) design;
- Investigate and evaluate the current subsided condition;
- Develop hydraulic concepts that will guide the preliminary design;
- Present the design criteria that was used as the basis for project alternative development and evaluation, hydraulic analysis, preliminary design, and development of cost estimates for the Friant-Kern Canal Subsidence Correction Project (Project).

The compressed project schedule for completing alternative analysis drove the need to efficiently develop the concepts and criteria presented herein. It is anticipated that this work will be carried forward for preparation of a Basis of Design Report prepared during the 30-percent final design phase for the selected project alternative. Given the manner in which this project design has progressed, a primary objective for this report is to ensure that all interested stakeholders fully understand and agree with the assumptions made to develop the controlling project criteria used for alternative development. In addition, this report will provide a design reference as the design progresses.

As the project evolves, it is expected that changes to the design criteria will be required. Another primary objective of this report is to present the current design criteria already established and list the critical criteria still required to begin design of the facilities. Where criteria have been established through coordination with Friant Water Authority (FWA), their criteria are presented. Where specific criteria have yet to be established, a list of criteria to be determined is provided based on experience with similar Reclamation projects, best practices and current codes. The final agreed-to design criteria will be further defined and included in the final design phase Basis of Design Report for the Project.

1.2 Background

The designed conveyance capacity of the FKC has been compromised by various factors since it began operation in 1951. Limitation in the original design, increased roughness in the canal, vegetation, land subsidence, and other issues have all lead to a reduction in capacity. Subsidence, which is the surface expression of compacted land surface, has negatively affected the FKC's ability to convey water because the canal was designed as a gravity conveyance feature. The

FKC was designed with a constant fall of approximately 6 inches per mile for its 152-mile journey. The rapid and severe land subsidence in the Corcoran/Tulare Basin area, which underlies a portion of the FKC has caused an estimated 60% reduction in capacity. There is currently no way to operate the canal to prevent negative impacts to water users who depend on its water supplies.

In coordination with United States Department of the Interior, Bureau of Reclamation (Reclamation), FWA is developing solutions to address reduced capacity in the FKC, and identified the general objectives of FKC modifications based on the canal reaches (see **Figure 1-1**) identified below:

Upper Reach – Milepost (MP) 29 (Downstream of Kings River Siphon) to MP 88 (5th Avenue Check): The primary objective is to address capacity reductions resulting from changes in design standards.

Middle Reach – MP 88 (5th Avenue Check) to MP 121 (Lake Woollomes Check): The primary objective is to address capacity reductions that result from subsidence and changes in design standards. This portion of the FKC has an estimated conveyance capacity of 1,900 cubic feet per second (cfs) in a reach that was originally designed for 3,500 cfs.

Lower Reach – MP 121 (Lake Woollomes Check) to MP 152 (Kern River Check): The primary objective is to provide pump back capability to convey water from the Cross-Valley Canal through the lower reaches of the FKC and address capacity reductions resulting from changes in design standards as may be appropriate.

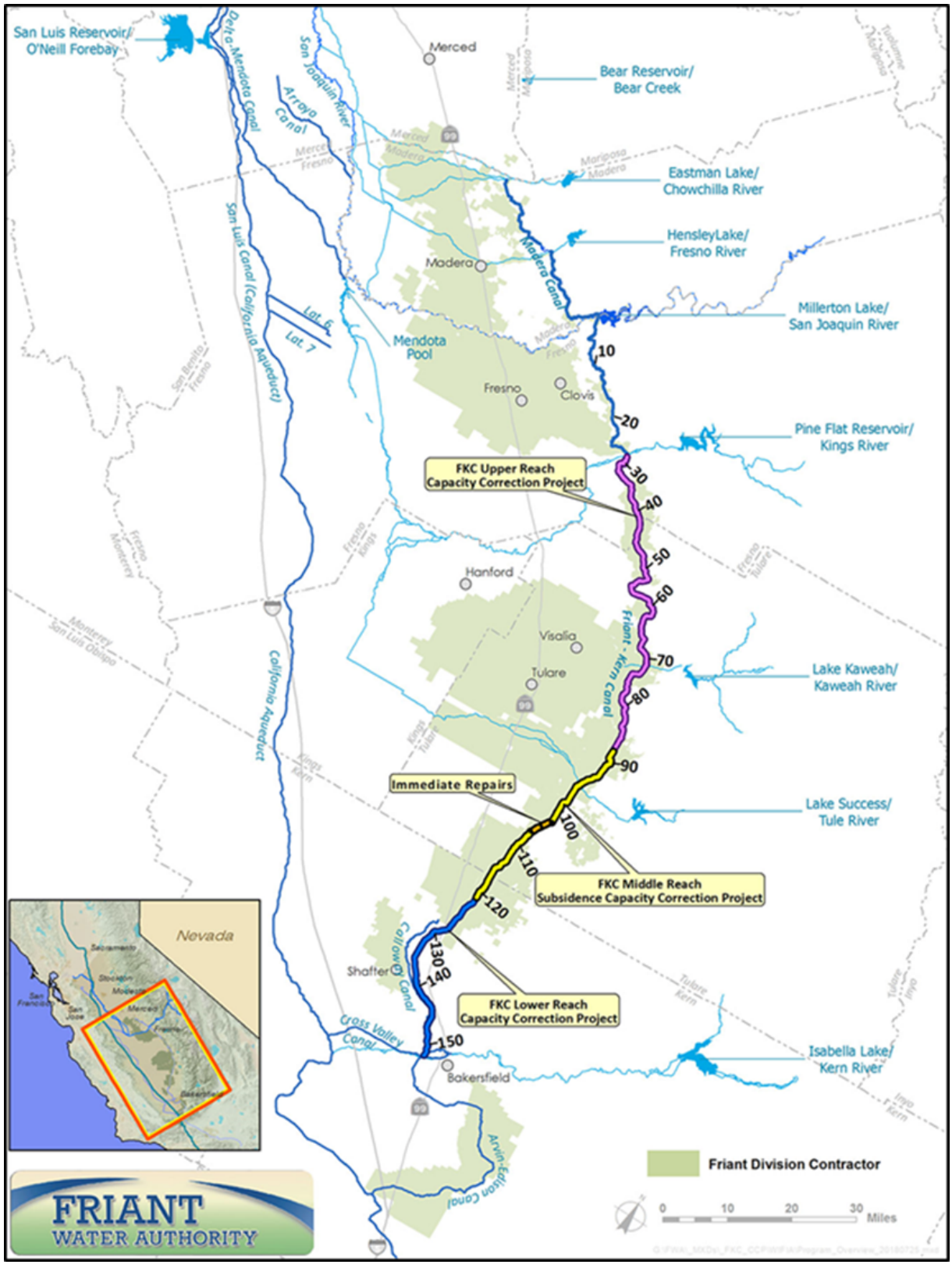


Figure 1-1 - Friant-Kern Canal Capacity Correction Program Map

Work to restore FKC capacity has been divided into four projects that will accomplish the goals and objectives of the Friant-Kern Canal Capacity Correction Program. These projects are separated by location and by the nature of corrective work to be accomplished. All corrective work will increase canal capacity compared with the current condition. Some work (Immediate Repair) has a goal to meet immediate needs with a short-term fix that is not intended as a long-term solution, and other work (Subsidence Correction) has a goal to fix issues directly caused by subsidence. The four projects currently identified to complete the FKC Capacity Correction Program are:

- FKC Upper Reach (MP29 to MP88) – Capacity Correction Project
- FKC Middle Reach (MP103 to MP107) – Immediate Repair Work Project
- FKC Middle Reach (MP88 to MP121) – Subsidence and Capacity Correction Project
- FKC Lower Reach (MP121 to MP152) – Capacity Correction Project

This document addresses only the Subsidence and Capacity Correction Project in the FKC Middle Reach.

2. PROJECT MEASURES AND ALTERNATIVE DEVELOPMENT

2.1 Measures and Alternative Development Purpose and Process

For this project, alternatives will consist of a singular measure or combinations of measures. Measures that have been evaluated include:

- Pump station
- New bypass canal around the east side of the subsided canal
- New parallel canal adjacent to the existing canal
- Enlargement of the existing canal prism including canal lining and bank raises and canal widening

The results presented herein, especially those related to hydraulic boundary conditions and constraints, guided the development of measures and ultimately the project alternatives that included a set of measures.

The planning, design, and construction of economical solutions for these types of canal modifications can be complex. A significant number of design criteria requirements must be met along with challenging constraints such as schedule and available funding. Multiple elements of the design must be resolved simultaneously. During development, evaluation, and selection of alternatives, proposed designs needed to meet multiple criteria:

- Standard design criteria for canals and related structures
- Future water operation requirements
- Safety and risk
- Future subsidence
- Schedule – time required to implement the fix
- Cost

Additionally, design possibilities were limited by numerous constraints:

- Boundary conditions – hydraulic grade line (HGL) requirements above and below middle reach
- Existing bridges – location and elevation

- Existing subsidence – assumed area and amount
- Minimal interruption to water operations during construction
- Existing right-of-way (ROW) – approximately 260-feet (ft) width
- Seepage issues
- Geotechnical stability
- Environmental requirements
- Budget

The hydraulic design process involved analyzing potential design measures that could then be evaluated for structural design, earthwork, construction, and cost considerations. Key elements have included:

- Establish canal HGL
- Establish and apply design criteria
- Scope different methods to convey water through or around the subsided zone
- Evaluate pumping requirements
- Determine and evaluate possible canal alignments
- Evaluate alternative canal cross sections (size, shape)

Gravity flow in man-made canals is one of the most economical means for conveying large volumes of water, especially over long distances. Large flow volumes can be safely conveyed with relatively slow velocities and gentle channel gradients (less than 0.5 ft/mile). Irrigation canals like FKC are generally designed for economy with the canal prism sized to convey the specified design flow at normal depth in the "unchecked" condition (i.e. check gates open). Check structures are constructed at regular intervals along the canal for operational control, including maintaining high enough water levels at low canal flows to serve all turnouts.

Alternative designs were developed in order to meet the following goals:

- Restore maximum flow capacity
- Maintain delivery head
- Meet deliveries during minimum canal flow rate
- Maintain beneficial use of Woollomes Reservoir
- Minimize additional ROW needs
- Efficient earthwork and constructability
- Provide reliable and manageable operations

- Allow cost-effective future modifications to accommodate continued subsidence
- Economy of earthwork and canal lining
- Minimize check structure modifications
- Minimize long-term Operation and Maintenance (O&M) costs

2.2 Friant-Kern Canal Original Design Parameters

It is important to understand the original design parameters in order to reestablish the original canal function and to establish new boundary conditions for rehabilitation of the subsided canal. The original design of the FKC consisted of seven different canal (geometric) cross sections for its entire 152-mile length. This Subsidence Correction Project is focused on evaluating the original design for the segment of canal from the 5th Avenue Check (MP 88.2) to the Kern River Check (MP 151.8). This segment was designed and constructed with concrete-lined canal Section Nos. 4 through 7 and earthen canal Section No. 2. **Table 2-1** and **Table 2-2** provide geometric data for these canal sections for two design flow scenarios: (1) Normal Design Flow and (2) Max Design Flow. The Normal Design Flow represents the largest planned operational flows. The Max Design Flow represents the largest allowed short-term flow for transfer and release of flood flows captured at cross drainage inlets.

Table 2-1 - Original Design Canal Section Data for "Normal Design Flow"

Canal Data	Design Q (cfs)	Design V (ft/s)	Manning's n	Bottom slope	B (ft)	d (ft)	Side slope (h:v)	D (ft)	Fb (ft)
Section 2*	2503	2.64	0.020	0.000055	40	14.50	2.00:1		
Section 4	3500	4.32	0.014	0.000082	36	14.66	1.25:1	17.3	2.64
Section 5	2998	4.04	0.014	0.000060	36	14.73	1.25:1	17.5	2.77
Section 6	2502	3.61	0.014	0.000060	30	14.43	1.25:1	17.5	3.07
Section 7	2001	3.44	0.014	0.000060	24	14.01	1.25:1	16.0	1.99

Key:
cfs – cubic feet per second
ft – feet
ft/s – feet per second
h:v – horizontal:vertical

Table 2-2 - Original Design Canal Section Data for "Max Design Flow"

Canal Data	Design Q (cfs)	Design V (ft/s)	Manning's n	Bottom slope	B (ft)	d (ft)	Side slope (h:v)	D (ft)	Fb (ft)
Section 2	3502	2.90	0.020	0.000055	40	17.22	2.00:1		
Section 4	4500	4.61	0.014	0.000082	36	17.04	1.25:1	17.3	0.26
Section 5	3999	4.04	0.014	0.000060	36	17.21	1.25:1	17.5	0.29
Section 6	3502	3.94	0.014	0.000060	30	17.24	1.25:1	17.5	0.26
Section 7	2500	3.64	0.014	0.000060	24	15.73	1.25:1	16.0	0.27

Key:
cfs – cubic feet per second
ft – feet
ft/s – feet per second
h:v – horizontal:vertical

When the FKC was originally designed, Reclamation used the Manning's equation with an "n" value ranging from 0.014 to 0.0143 for the concrete-lined sections. In the 1960's, Reclamation conducted field tests as part of an extensive study of hydraulic losses in about a dozen large concrete-lined canals including FKC. That study concluded that flow resistance in the five largest canals in the study (including FKC) was larger than anticipated. Values of Manning's n computed from the field tests ranged from 0.015 to 0.019 and were about 10% to 25% higher than design values.

A Manning's n-value of 0.016 has been adopted for design of the FKC rehabilitation projects. Applying this n-value (instead of 0.014) to the original canal geometry results in approximately one foot of increased normal flow depth for the Normal Design Flow condition.

2.3 Existing Canal Condition and Immediate Repairs

Present conditions were established based on new survey data, field testing by FWA, and observations and knowledge from operations personnel. These data were used to update and calibrate the previous version of a HEC-RAS model of the FKC, and to identify areas for immediate repairs. The following existing conditions were quantified:

- Current (subsided) canal invert and top-of-lining (TOL) elevations
- Canal HGL elevation profile for design conditions
- Flow restrictions or limitations
    - Bottlenecks that restrict capacity
    - Maximum existing capacities

- Existing freeboards
- Delivery restrictions

The FKC was originally designed with canal gradients of 0.000082 ft/ft from 5th Avenue Check to Tule River Check and 0.00006 ft/ft from Tule River Check to the canal terminus at the Kern River. Due to subsidence, the elevation profile of the existing canal is now different and lower than the original profile. **Figure 2-1** shows a profile comparison of the existing canal to the original design for the FKC from 5th Avenue to the Kern River. The red lines are the existing data for invert and top-of-lining from the 2018 Towill survey.

From inspection of **Figure 2-1**, it is apparent that a significant portion of the subsided FKC can be rehabilitated to operate as originally designed at a hydraulic grade line that is approximately 1.5 to 2 ft lower and parallel to the original design hydraulic grade lines (i.e. slopes of 0.000082 and 0.00006 for reaches of the canal upstream of Tule River and downstream of Tule River, respectively).

Since the FKC essentially functions as a gravity delivery canal in that its primary deliveries are westerly and downhill into the valley and the valley has generally more subsidence than the FKC, it is anticipated to perform as designed when rehabilitated to operate at full capacity at this slightly lower elevation. Some larger turnouts have a Parshall Flume for flow measurement. Measurement with this type of structure requires availability of significant head. Should any of the turnouts need to be modified, it may be possible to replace them with a more efficient flow measurement structure (e.g. long-throated flume).

Figure 2-2 shows this concept of a lower canal section invert and TOL projected onto the existing condition. Note the line on the graph labeled “Trial Invert” is not an actual canal invert except in lengths along the canal where it is coincident with the current existing invert. It is described later in the report as a “Theoretical Bottom” when used as part of the geometry for the alternative to enlarge the existing canal.

Current operations of the canal at the check structure locations along the canal are listed and briefly described below.

- **Tule River Check** – although this check structure has subsided nearly 2 ft, initial data suggests that it is capable of maintaining a checked water surface sufficient to make all upstream turnout deliveries at full normal design capacity under all flow conditions. This will require confirmation during the final design phase of the selected alternative.
- **Deer Creek Check** – this facility is normally operated with the radial gates in a “full checked” state in order to maintain upstream deliveries.
- **White River Check** – Due to subsidence, the White River Check is operated with its radial gates fully opened and raised out of the water. The structure is not currently used for flow control.

- **Lake Woollomes Check** – The Lake Woollomes Check forms the boundary where the flow control method changes. The FKC automated water level control above this check structure is "upstream controlled" while FKC flow control below this check structure is "downstream controlled". This facility must be operated to hold a minimum water depth of 14 ft to maintain upstream deliveries.
- **Poso Creek Check** – this check structure is normally operated with the radial gates out of the water. The configuration of this check and siphon as originally designed and constructed appears to include an error in the HGL. As a result, the structure introduces up to one foot or more upstream water level necessary to overcome losses through the structure. In that regard, it includes an element of "self-checking" even with the gates out of the water.
- **Kern River Check** – a depth of 14 ft is normally maintained at this canal terminus check structure.

2.3.1 Subsidence Low Point

The subsidence-related "low point" exists in an approximate two-mile length of the canal starting at approximately MP 104. This length of canal restricts flow and creates levels that are detrimental to the Friant Division contractors downstream of the Tule River Check Structure down to the Kern River Check Structure. This is an area that will be addressed in the immediate repairs project.

2.3.2 Existing Bridges that Require Correction – Located in Middle Reach

Approximately nineteen bridges located between MP 96 and MP 114 must be raised or replaced.

2.3.3 Subsidence near Kimberlina Road

Although beyond the current project area, the length of the FKC between the Poso Creek Check and the Shafter Check (MP 130 to MP 138) has subsided greater than 2 ft. This area will require additional subsidence correction at some point in the future when capacity correction is undertaken for the lower section of the FKC. This will also require raising or replacing four or five bridges.

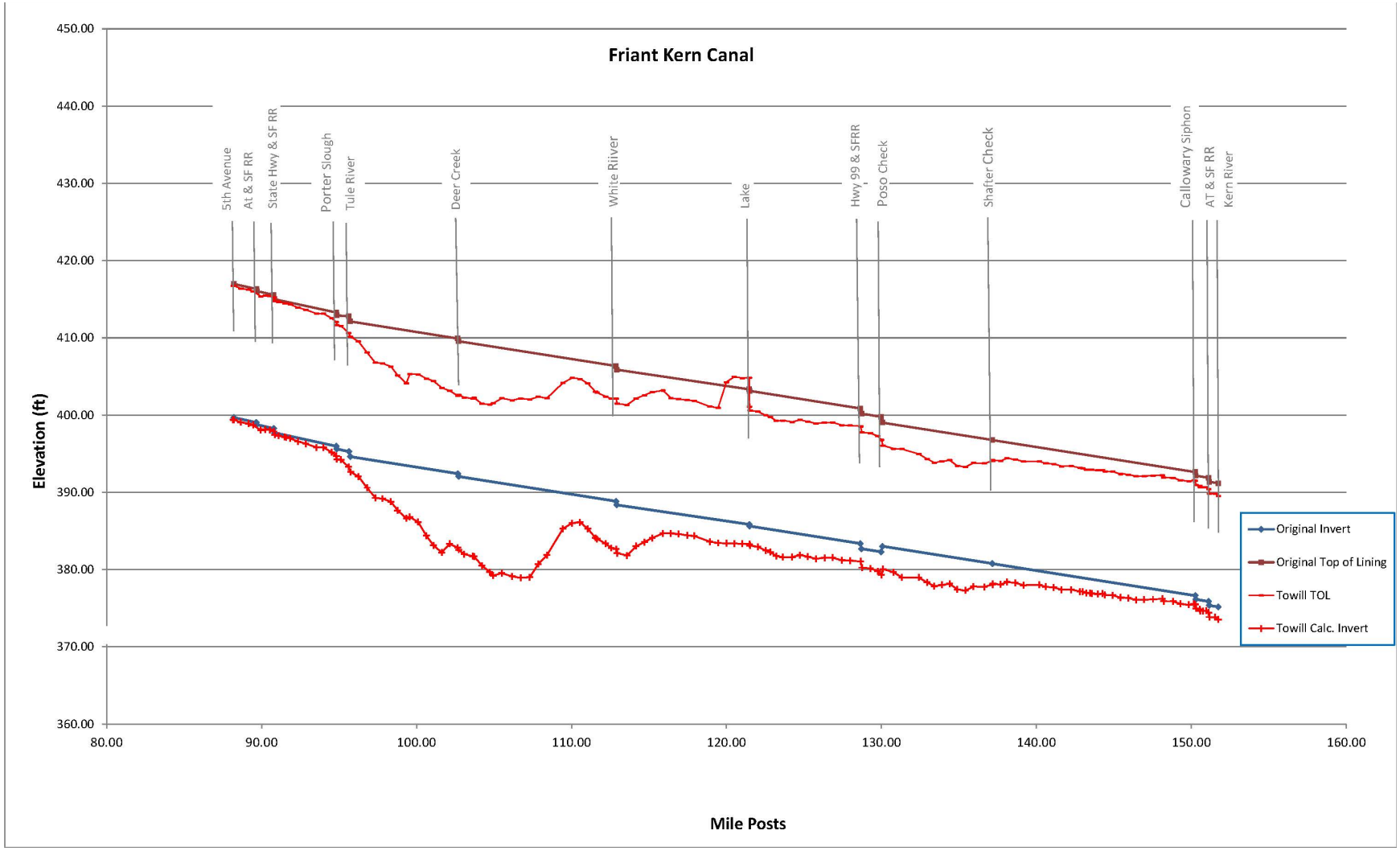


Figure 2-1 - Profile of Existing Canal vs. Original Canal

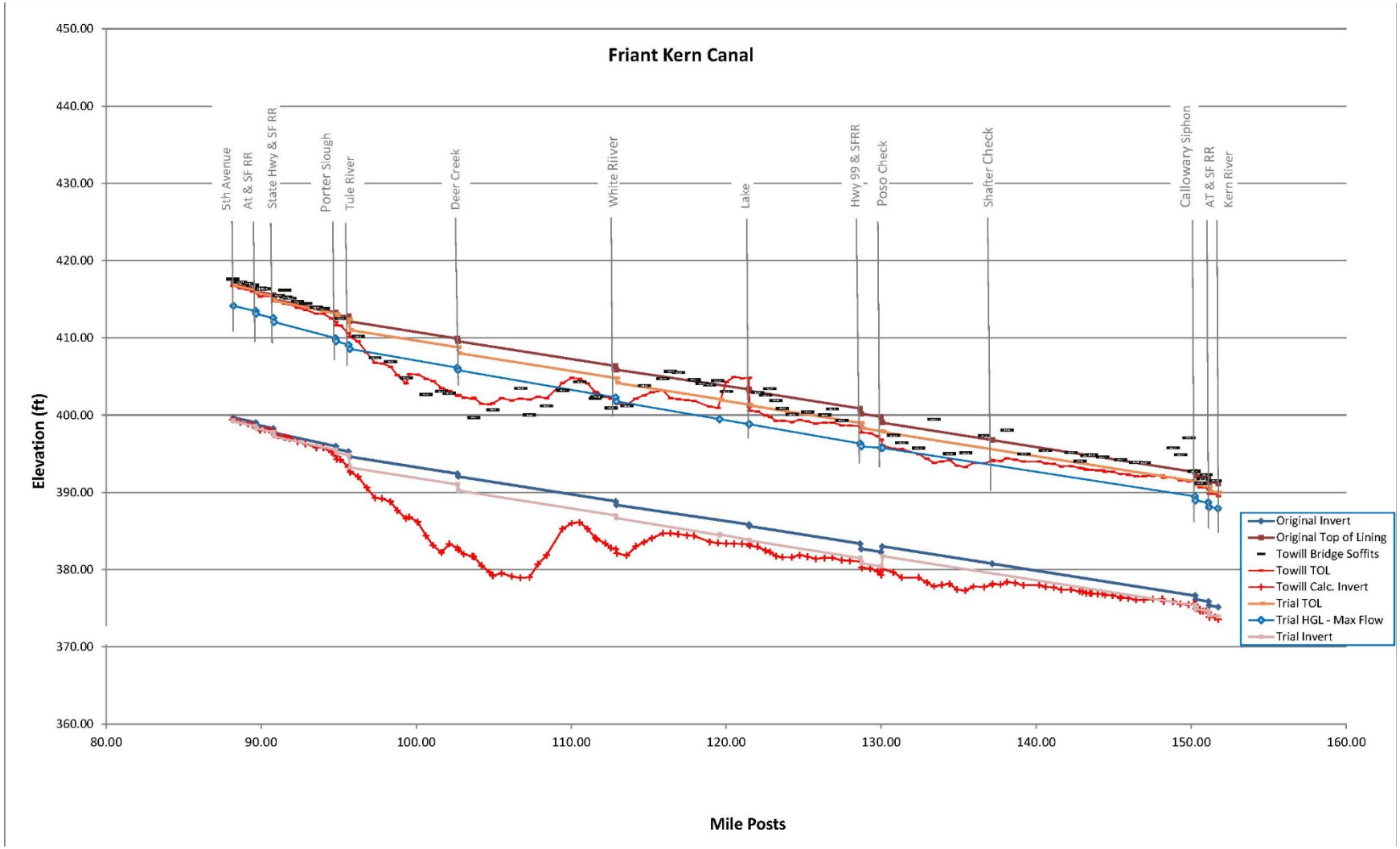


Figure 2-2 - Profile of Existing Canal, Original Canal, and Proposed Rehabilitation

2.4 Boundary Conditions and Other Design Constraints

When designing either a new canal or modifications to an existing canal, the first step is to clearly identify the boundary conditions. Boundary conditions are not always apparent and can change significantly with relatively minor changes to the facility or operations. Therefore, evaluation of boundary conditions during the FKC Subsidence Correction design should consider both the currently existing condition and potential changes that could occur after implementation of the project (e.g. subsidence). Key boundary conditions, elevations, and depths are shown in **Table 2-3**.

Table 2-3 - Boundary Conditions, Elevations, and Depths

Location					Design	Target
	Design Invert	Current Invert	Present Subsidence	Design Water	Water Surface	Water Surface
	Elevation	Elevation	Amount	Depth	Elevation	Elevation
	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
5th Ave Check Outlet Transition	399.67	399.38	0.29	14.66	414.33	414.43
Tule River Inlet Transition	395.28	393.27	2.01	14.66	409.94	410.05
Tule River Outlet Transition	394.62	392.63	1.99	14.73	409.35	408.71
Woollomes Check Inlet Transition	385.84	383.3	2.54	14.43	400.27	399.13
Kern River Check Inlet Transition	375.17	373.55	1.62	14.01	389.18	387.92
Key: ft – feet						

2.4.1 Available Head

Quantifying the available head is an important first step in evaluating trial canal designs. From **Table 2-3** above, the original design consisted of **25.15 ft** of water surface change from the 5th Avenue Check to the Kern River Check. Note that the design gradient for normal flow in the canal pools consumes most of this available head differential as follows:

- 38,492 ft of canal pools at 0.000082 ft/ft = 3.15 ft
- 293,596 ft of canal pools at 0.00006 ft/ft = 17.62 ft
- Total for canal pools 20.77 ft

This leaves **4.38 ft** for all other losses. Using the values shown in **Table 2-3** for the current enlargement design, the remaining (after subtracting the same 20.77 ft for pool gradients) is **5.74 ft**. However, the current design must account for new losses resulting from canal constrictions at

existing bridges, the large turnouts, and potentially new bridge/culverts. Thus, the head available for use in structure losses must be carefully managed.

2.4.2 HGL Required at Lake Woollomes Check – Key "Balance Point"

A water surface control elevation of **399.13 ft** was established on the upstream side of the Woollomes check structure. This elevation is the key balance point for the system. This elevation can be held without significant modifications to the existing Lake Woollomes Check or the Lake Woollomes Regulating Reservoir.

As a result of analysis, this level was chosen for the following reasons:

- This HGL elevation of 399.13 ft is 1.14 ft lower than the original design water surface elevation at Woollomes. There has been 2.54 ft of subsidence at that location, so the control elevation of 399.13 is 1.4 ft higher than the original level relative to canal invert. Thus, the normal depth at the Lake Woollomes check will also be 1.4 ft higher than the normal depth shown for the original design.
- The additional 1.4 ft of relative HGL provides valuable head to supply flow downstream to Kern River in the future.
- This HGL also significantly reduces cost in the canal upstream from Woollomes by maintaining water levels throughout the Middle Reach that reduced canal cost (e.g. new canal size, enlarged canal size, and/or pump head).
- This HGL permits full use of regulatory storage in Woollomes Reservoir, which is a major benefit to canal operations.

2.4.3 Conditions and Requirements in the Upper Reach

The following conditions were required upstream from the Tule River Check Structure:

- Correction alternatives for the Middle Reach must not create negative effects in the Upper Reach.
- For all flow conditions studied, the resulting HGL upstream from Tule River needed to meet design criteria for conveyance capacity, delivery criteria, freeboard, and flow velocity.
- A water surface control elevation of 410.05 ft was established on the upstream side of the Tule River check structure.
- Because the large subsidence between Tule River and White River created an enlarged canal section (see **Section 5** below), the HGL at Tule River remained low enough to meet requirements in the Upper Reach.
- Some excess head was available at Tule River for most of the design alternatives, allowing the Tule River check gates to be less than wide open while creating a checked water surface at elevation 410.05 ft. Further design optimization may be able to lower cost by reducing the excess head at Tule River.

- The target elevation for the 5th Avenue Check is 414.43 ft which will match and not impact upstream reaches. It is noted that Reclamation has evaluated capacity improvements for the FKC from MP 28 to MP 88. Holding this target elevation may provide opportunities to reevaluate Reclamation's preliminary design to reduce costs for upstream improvements.

2.4.4 Conditions and Requirements in the Lower Reach

The following conditions were required downstream from the Lake Woollomes Check Structure:

- Subsidence in the Lower Reach from Woollomes to Kern River has been relatively uniform, so a future enlargement solution should have a uniform change in the HGL elevation profile.
- A water surface control elevation of 387.92 ft was established on the upstream side of the Kern River check structure.
- This control water surface is 1.26 ft lower than the original design water surface elevation and there has been 1.62 ft of subsidence in the area. Therefore, relative to the canal invert, the control elevation of 387.92 ft is 0.36 ft higher than the original level. Thus, the normal depth at the Kern River check will also be 0.36 ft higher than the normal depth shown for the original design.
- The new control elevation provides additional head for increased flow capacity through the turnouts located near the Kern River.
- This boundary condition improves the feasibility to increase capacity to Kern River, but details of an enlarged design from Woollomes to Kern River are left for future work.

2.4.5 Bridges and Related Hydraulic Losses

Total project cost will be significantly impacted by work to modify, raise, and replace bridge structures. Evaluation of alternative designs included the following issues related to bridges:

- Minimize bridge replacement and raises
- Develop efficient designs for replacement bridges:
    - trapezoidal culvert bridge
    - build new bridges wide enough for future maximum flow and subsidence conditions
- Establish criteria for freeboard clearance between water surface and bridge girders
- Establish criteria for bridge tie-ins, widening, transitions, and hydraulic losses
- Determine which bridges should be replaced for each flow condition and design alternative

Trapezoidal bridge structures show promise to be a cost-effective replacement choice. This design is a trapezoid-shaped culvert structure designed for bridge loading. The structure can flow full with top seal inlet submergence, with headwalls to contain upstream canal water levels above the roadway elevation. This design would permit a bridge to withstand future subsidence with minimal cost for

modifications. The bridges will be designed with more flow area than that of the canal immediately upstream and downstream from each new bridge to minimize head losses should the bridges become submerged due to future subsidence.

Criteria may yet need to be clarified for the minimum allowable clearance between existing bridge substructures and the maximum water surface level. Logically, these criteria should vary for different bridge designs and different types of road crossing. For the purpose of this design alternative analysis, it was assumed that minimum bridge level for **existing** bridges would equal top-of-lining level.

2.4.6 Siphons and Related Hydraulic Losses

Hydraulic losses through siphons were evaluated and updated to improve accuracy compared with original design values. The original design of the Poso Creek Siphon did not correctly balance head loss across the siphon with the change in water surface elevation from the upstream canal to the downstream canal. For the normal flow condition with 2,000 cfs through the siphon, head loss through the siphon should be about 0.6 ft. Existing downstream canal invert is 0.73 ft higher than the upstream canal invert, so upstream canal depth needs to be 1.33 ft greater than downstream canal depth. Original design depths were 14.43 ft in the upstream canal and 14.01 ft in the downstream canal, so there is an error of 0.9 ft in the original design. Depth in the upstream canal needs to be 0.9 ft higher than the original design value to get 2000 cfs through the siphon.

With the present “new normal” condition, flow through Poso Creek Siphon will be 2,500 cfs. This will create a head loss of 0.9 ft across the siphon, so depth in the upstream canal must be 1.63 ft greater than downstream canal depth. Hydraulic analysis explored the effect of replacing Poso Creek Siphon with an open flume to eliminate siphon loss. Cost associated with a replacement structure would be offset by savings in the canal upstream, such as from fewer bridge modifications and reduced canal enlargement, so the possibility of replacing Poso Creek Siphon should be explored as the design progresses.

At most of the other siphons in the middle reach, head loss estimated in the original design appears to be appropriate or even a little on the conservative side for the original normal flow condition. However, increasing the flow rate to the “new normal” flow through siphons will increase head losses and require that head be conserved elsewhere.

2.4.7 Hydraulic Losses at Transitions

A significant portion of the total head loss through the project area occurs in open channel transition structures at bridges, siphons, and check structures. Generally, these structures are a type classified as *straight warp transitions*. However, the length-to-width ratio for convergence and divergence varies from structure to structure. Based on historical data and Reclamation design criteria references, transition head loss coefficients are estimated as follows:

Converging (inlet) transitions: C = 0.15 to 0.25

Diverging (outlet) transitions: C = 0.2 to 0.35

Where: Head Loss = C * $(V1-V2)^2$

(V1 and V2 are flow velocities upstream and downstream from transition)

For preliminary analysis and design, a reasonable conclusion is to use ***C=0.2 for converging transitions*** and ***C=0.3 for diverging transitions***. As the level of design progresses, individual transitions can be analyzed and specific transition lengths can be used to develop more precise coefficient values.

2.4.8 Common HGL

All project alternatives were modeled with a common hydraulic grade line. Maintaining the common HGL that has been established is important in order to meet the required boundary conditions but, it also allows considerable flexibility to interchange measures within alternatives for economic and/or sequencing benefits.

2.5 Summary of Measures

2.5.1 Enlargement of Existing Canal

Enlargement of the existing canal by widening and raising the banks and canal lining was evaluated for constructability and hydraulic feasibility for the entire length of canal from 5th Avenue Check to the Kern River Check (canal terminus). Enlargement of the existing canal prism in order to maintain the desired HGL and/or increase canal capacity, was found to be generally feasible and is the only measure evaluated that could be used for the entire length of the canal rehabilitation project.

Enlargement options needed to balance multiple priorities and restrictions, including:

- Maintain a workable HGL elevation
- ROW limitations
- Earthwork cost
- Geotechnical considerations
- Bridge raises and replacements
- Constructability
- Maintaining water deliveries during construction
- Hydraulic efficiency

As the best way to satisfy the above priorities and restrictions, a Compound Trapezoidal Section is proposed for enlargement of concrete-lined reaches. **Figure 2-3** shows an example of a compound trapezoidal section. This canal section will maintain the HGL elevation, keep the canal in limited service during construction, and stay within existing ROW. This Compound Trapezoidal Section uses the bottom portion of the existing canal and a widened top portion above a horizontal bench on

one or both sides. This design is hydraulically less efficient than an optimal trapezoidal section, because there is relatively more wetted perimeter for a given flow area which produces slightly more friction loss.

Hydraulics were analyzed to produce an optimal balance between bench height and bench width that would best fit in the existing ROW while keeping the bench high enough to maintain minimal flow capacity in the remaining portion of the existing canal during construction. Steady state hydraulic analysis yielded normal depth for given flow rates, allowing iteration of various cross section dimensions and shapes. Where ROW allows equal expansion on both sides of the canal, the typical bench will be 8 ft above the existing canal invert and 28-ft wide with 1.5:1 side slopes above the bench. Total height and other details can vary depending on design flow capacity and specific location. **Table 2-4** provides the section data for key geometric elements. **Table 2-4** should be used with **Figure 2-3**. The compound trapezoidal section was designed to maintain the same depth or slight greater than as the original design sections for Normal Design Flow, which varied by reach. For newly constructed canal segments or where subsidence has been relatively uniform, the original design bottom slope of 0.00006 can be maintained and the canal will remain nearly prismatic with the optimal shape. **Figure 2-3** shows an example compound trapezoid section where the theoretical and existing inverts are coincident.

However, in subsided areas and especially in the highly subsided areas between Tule River and White River, the existing invert is much lower than the theoretical constant-slope level of the prismatic canal design section. Building the enlarged portion onto the existing canal below the bench results in a much larger depth below the bench, so the section become much larger than the optimized section. In these deeper sections, the existing 1¼:1 side slopes were carried up to the level of the new bench. The benches remained 28-ft wide and at a constant level below the canal top, so these deep sections were also wider. **Figure 2-4** shows an example compound trapezoid section in the subsided condition.

Additional enlargement of the canal section where the existing invert is highly subsided provided an important benefit to save head and lower the upstream HGL. It was anticipated that this conservation of head would be used to absorb new head losses that are introduced at the canal constrictions at the existing bridges and turnouts. The conserved head loss might be needed for future submergence of new trapezoidal bridges but still further refinement is possible. Reducing the bench width on these deeper sections would reduce ROW needs, and the benches could be wider in the shallower sections to compensate and produce a similar HGL result at Tule River. This type of optimization should be pursued as the design progresses.

Table 2-4 - Trapezoidal Canal Section Data for "New Design Flow"

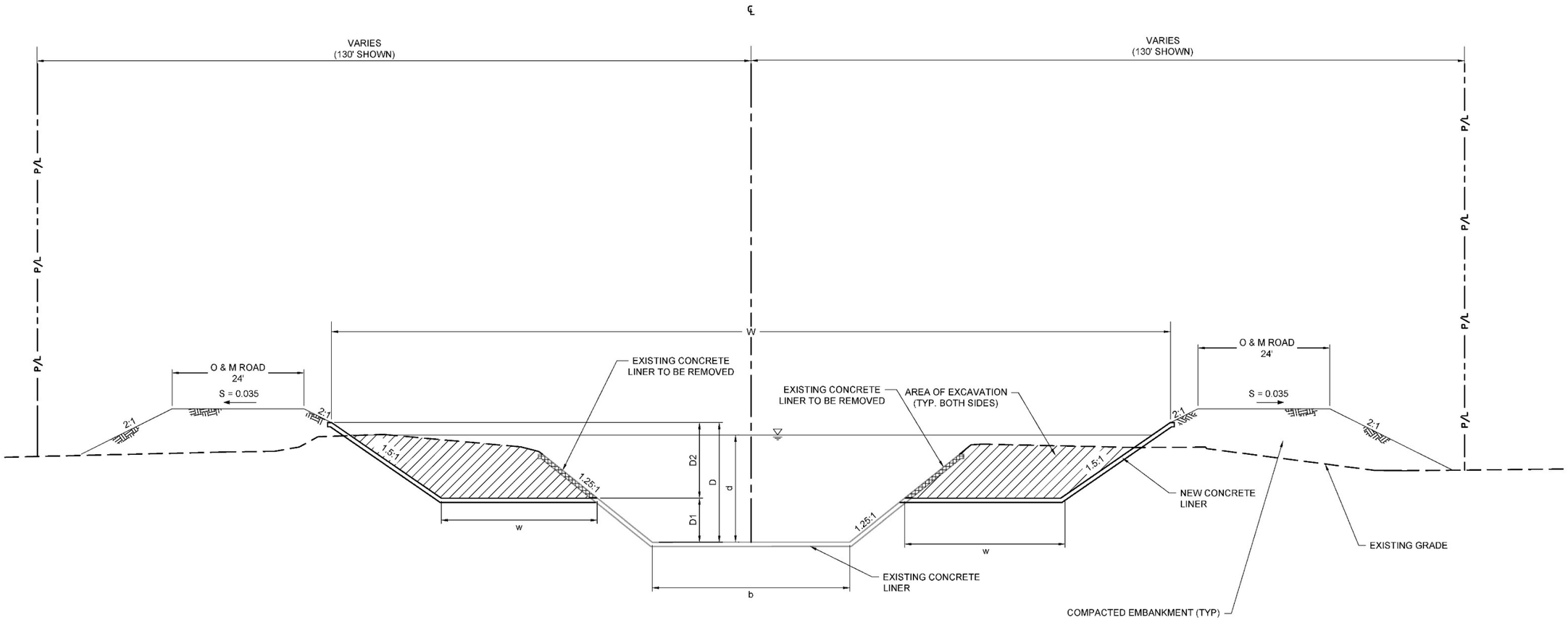
Canal Data	Section 2	Section 4	Section 5	Section 6	Section 7
Design Q (cfs)	3500	4500	4000	3500	2500
Design V (ft/s)	2.55	3.58	3.10	2.99	2.70

Canal Data	Section 2	Section 4	Section 5	Section 6	Section 7
A (ft^2)	1373.45	1258.63	1291.74	1169.46	925.63
n	0.022	0.016	0.016	0.016	0.016
Slope	0.00006	0.000082	0.00006	0.00006	0.00006
Theoretical b (ft)	60	36	36	30	24
Bench width (ft)	N/A	28.00	28.00	28.00	28.00
d (ft)	15.27	15.25	15.50	15.27	14.00
D_1 (ft)	N/A	8.00	8.00	8.00	8.00
D_2 (ft)	N/A	9.60	9.79	9.50	8.06
D (ft)	N/A	17.60	17.79	17.50	16.06
W (ft)	N/A	140.80	141.37	134.50	124.18
s:s	2:1	Varies	Varies	Varies	Varies
FB (ft)		2.35	2.29	2.23	2.06
Data Reproduced from Original Normal Design (Table 2-1) for Comparison Purposes					
Design Q (cfs)	2503	3500	2998	2502	2001
Design V (ft/s)	2.90	4.61	4.04	3.94	3.64
D (ft)	14.5	14.66	14.73	14.43	14.01
FB (ft)		2.64	2.77	3.07	1.99

Key:
cfs – cubic feet per second
ft – feet
ft/s – feet per second
h:v – horizontal:vertical

Table 2-5 is included below for reference. It provides the data used to advance the previously updated HEC-RAS model (for current existing condition) to represent an enlarged concrete canal section that would be used for a canal enlargement design alternative. Refer to **Section 2.6.1** for a description of each project alternative analyzed.

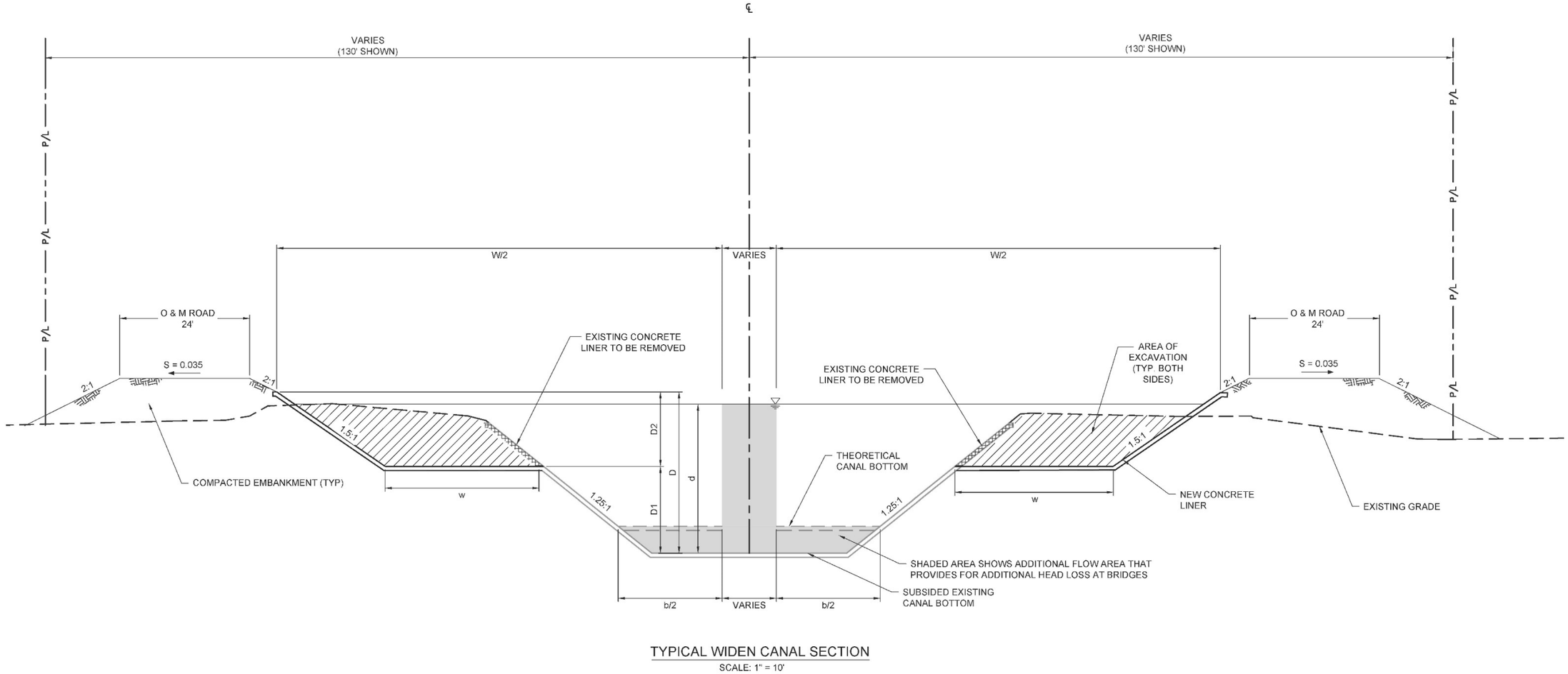
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TYPICAL WIDEN CANAL SECTION
SCALE: 1" = 10'

Figure 2-3 - Compound Trapezoid Canal Section Where Invert is Coincident with Existing FKC Invert

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TYPICAL WIDEN CANAL SECTION
SCALE: 1" = 10'

Figure 2-4 - Compound Trapezoid Canal Section Where Invert is Above Existing FKC Invert

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Table 2-5 - Canal Enlargement Design Data – Used for HEC-RAS Model for Alternative 1

Widened Section	Canal Station	New TOL	Length	Slope	Bench Elev.	cl	FB	New Canal Depth/ Invert	To will Invert	n-value	Design Water Surface	Design Q	Original Max Q	Original Normal Q
	Pool 0					15.25	2.35	17.60		0.016		4500	4500	3500
Inlet	4773+00	416.88			407.38			399.28	399.38		414.53			
	5th Ave Chk		121.00	0.1								4500	4500	3500
Outlet	4774+21	416.78			407.28			399.18	399.38		414.43			
Section 4	Pool 1		7574.00	0.000082		15.25	2.35	17.60		0.016		4500	4500	3500
Inlet	4849+95	416.16			406.66			398.56	398.64		413.81			
	Railroad		169.00	0.29								4500	4500	3500
Outlet	4851+64	415.87			406.37			398.27	398.35		413.52			
Section 4	Pool 2		5866.00	0.000082		15.25	2.35	17.60		0.016		4500	4500	3500
Inlet	4910+30	415.39			405.89			397.79	397.89		413.04			
	Hwy		288.00	0.57								4500	4500	3500
Outlet	4913+18	414.82			405.32			397.22	397.44		412.47			
Section 4	Pool 3		20995.00	0.000082		15.25	2.35	17.60		0.016		4500	4500	3500
Inlet	5123+13	413.10			403.60			395.50	394.71		410.75			
	Porter Creek		173.00	0.36								4500	4500	3500
Outlet	5124+86	412.74			403.24			395.14	394.30		410.39			
Section 4	Pool 4		4144.00	0.000082		15.25	2.35	17.60		0.016		4500	4500	3500
Inlet	5166+30	412.40			402.90			394.80	393.27		410.05			
	Tule		500.00	0.66								4000	4000	3000
Outlet	5171+30	411.00			401.50			393.21	392.63		408.71			
Section 5	Pool 5		36591.00	0.00006		15.50	2.29	17.79		0.016		4000	4000	3000
Inlet	5537+21	408.80			399.30			391.01	392.83		406.51			
	Deer Creek		279.00	0.36								4000	4000	3000
Outlet	5540+00	408.02			398.52			390.23	392.55		405.73			
Section 5	Pool 6		53635.00	0.00006		15.50	2.29	17.79		0.016		4000	4000	3000
Inlet	6076+35	404.80			395.30			387.01	392.67		402.51			
	White River		281.00	0.48								3500	3500	2500
Outlet	6079+16	404.17			394.67			386.67	392.12		401.94			
Section 6	Pool 7		35101.00	0.00006		15.27	2.23	17.50		0.016		3500	3500	2500
	6430+17	402.06			392.56			384.56			399.83			
	Transition			0.1								3500	3500	2500
	6430+18	401.96			392.46			384.46			399.73			
Section 2	Pool 8		10039.00	0.00006		15.27	2.23	17.50		0.022		3500	3500	2500
Inlet	6530+57	401.36			391.86			383.86	383.30		399.13			
	Woollomes Ck		125.00	0.1								3500	3500	2500
Outlet	6531+82	401.26			391.76			383.76	383.10		399.03			
Section 6	Pool 9		37754.00	0.00006		15.27	2.23	17.50		0.016		3500	3500	2500
Inlet	6909+36	398.99			389.49			381.49	381.03		396.76			
	Hwy 99		440.00	0.68								2500	3500	2500
Outlet	6913+76	398.31			388.81			380.81	380.25		396.08			
Section 6M	Pool 10		6656.00	0.00006		15.27	2.23	17.50		0.016		2500	2500	2500
Inlet	6980+32	397.91			388.41			380.41	379.30		395.80			
	Poso Creek		471.00	0.1								2500	2500	2000
Outlet	6985+03	397.81			388.31			381.75	380.06		395.75			
Section 7	Pool 11		106445.00	0.00006		14.00	2.06	16.06		0.016		2500	2500	2000
Inlet	8049+48	391.43			381.93			375.37	375.49		390.64			
	Calloway		200.00	0.48								2500	2500	2000
Outlet	8051+48	390.95			381.45			374.89	374.96		388.89			
Section 7	Pool 12		4380.00	0.00006		14.00	2.06	16.06		0.016		2500	2500	2000
Inlet	8095+28	390.68			381.18			374.62	374.44		388.62			
	RR		235.00	0.52								2500	2500	2000
Outlet	8097+63	390.16			380.66			374.10	373.85		388.10			
Section 7	Pool 13		3066.00	0.00006		14.00	2.06	16.06		0.016		2500	2500	2000
Inlet	8128+29	389.98			380.48			373.92	373.55		387.92			

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2.5.2 Pump Stations

As stated above, canal enlargement is the only measure evaluated that could be used for the entire project length. A pump station measure could be substituted for portions of canal enlargement. When downstream water demands are high and cannot be conveyed by gravity, water would be diverted from the canal into the pump station forebay where the low head high flow pumps would lift the water to the required downstream HGL necessary to provide higher flows downstream. A gate structure would be constructed within the existing canal. During lower demand periods when gravity conveyance is possible this gate structure would remain open, bypassing the pump station. During higher demand periods the gates would close diverting all flow to the pump station.

An In-line pump station measure was evaluated at two potential locations on the FKC. Refer to **Section 2.6** for a summary of project alternatives including those with pump station measures. Compared to gravity-flow alternatives, adding a pump station can introduce significant additional complications and risk. Additional cost for O&M complexities can be estimated, but O&M for a pump station is still undesirable for project personnel. For reasonable comparison between alternatives, additional risk from pumping must be minimized so as not to differ significantly from gravity-flow alternatives. This means that surge from pump operations must be addressed so as not to create either additional risk or additional canal lining height.

Alternatives with pump station measures were analyzed for surge caused by pump power failure that shuts down pumps, which is an inevitable event that must be addressed. The maximum design condition is full flow rejection at the pump station that creates upsurge (depth increase) in the canal upstream from the pump station and downsurge (depth decrease) in the downstream canal. These surges will take the form of an immediate change in water level in the pump station forebay and afterbay, followed by translatory waves that migrate upstream and downstream through the canal at a relatively high velocity.

A sudden pump shutdown during maximum flow will create translatory waves with a height of approximately 2 ft that will travel with a wave speed (celerity) of approximately 20 ft/s. Subsequent leveling in the canal water surface would create about an additional 1 ft increase of depth on the upstream side of the pump station, so the total depth increase would be about 3 ft. This depth increase could translate a long distance upstream, requiring additional canal lining and bank height.

As an alternative to raising the canal lining and bank, methods to reduce the amount of surge were analyzed. These included:

- Backup generators to quickly restart pumps
- Rapid management of flows throughout the canal both upstream and downstream from the pump station
- One of more wasteways to spill excess water from the canal

- Spill into drainage channels
- Spill into one or more reservoirs

After evaluating feasibility, reliability, staffing, maintenance, and operating considerations, the emergency wasteway to a storage reservoir was chosen as the preferred alternative. A spillway weir would need to pass 3,500 cfs with canal water level below the lining freeboard level. Assuming a worst case--with spill flow continuing for 10 hours before the canal can be completely shut down--yields a total spill volume of 3,000 acre-ft. Therefore, an emergency storage reservoir needs to have 3,000 acre-ft of available storage space. The cost of these features must be added to any pump station alternative. Refer to **Section 3.4** for further pump station design criteria assumptions.

Figures 2-5 and **2-6** depict preliminary pump station plan and section views, respectively.

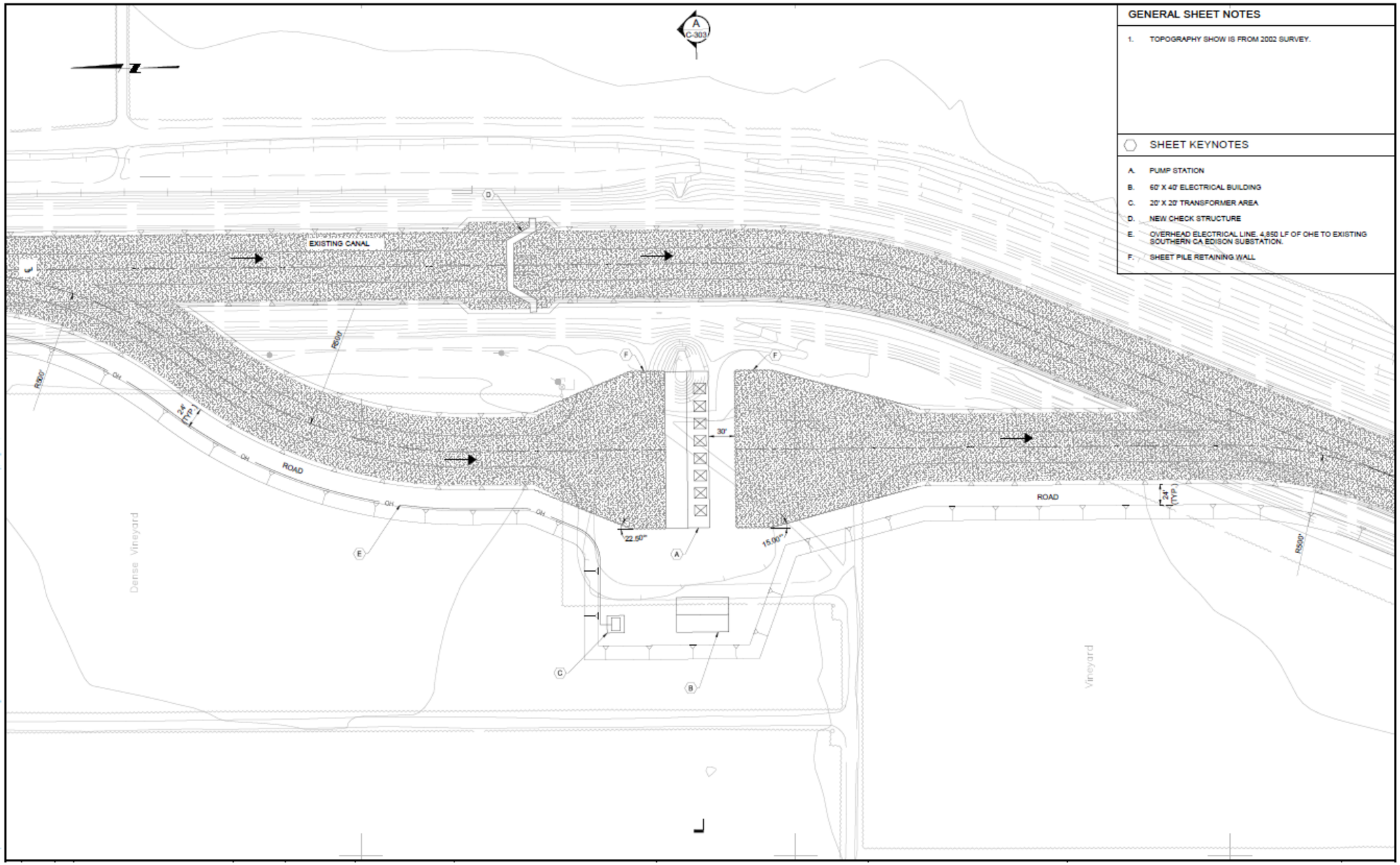


Figure 2-5 - Pump Station Plan

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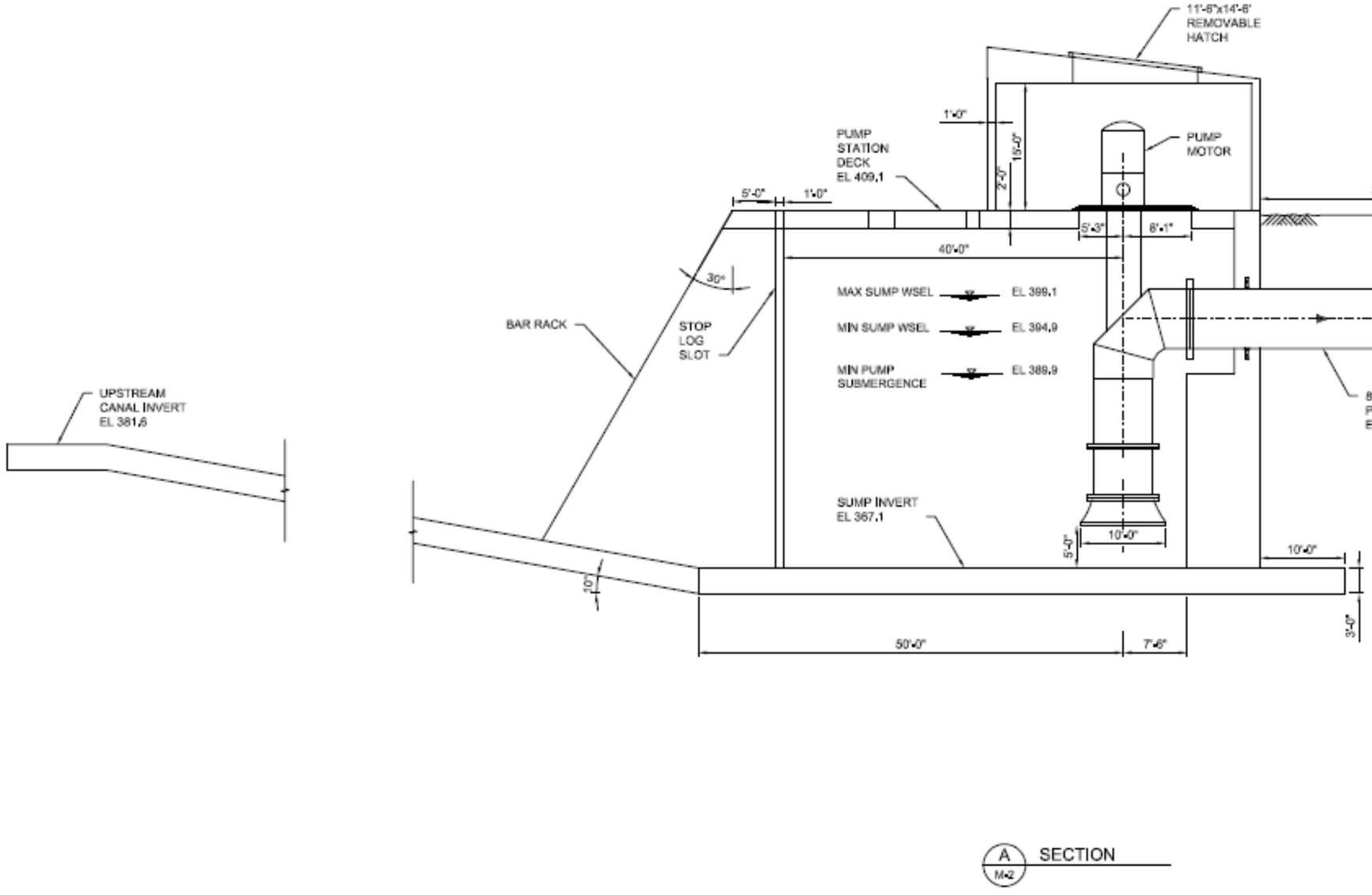


Figure 2-6 - Pump Station Section

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2.5.3 Bypass Canal

The bypass canal measure consists of a new canal to bypass a portion of the existing canal prism. An upslope bypass canal diverges from the existing canal and follows a new alignment upslope and east from the existing canal, with gravity flow bypassing the zone of most subsidence before reconnecting with the existing canal further downstream. The canal sections were selected to maintain the upstream and downstream HGL established for the canal enlargement alternative. **Figure 2-7** shows a bypass canal typical cross section.

Two such upslope bypass routes were evaluated:

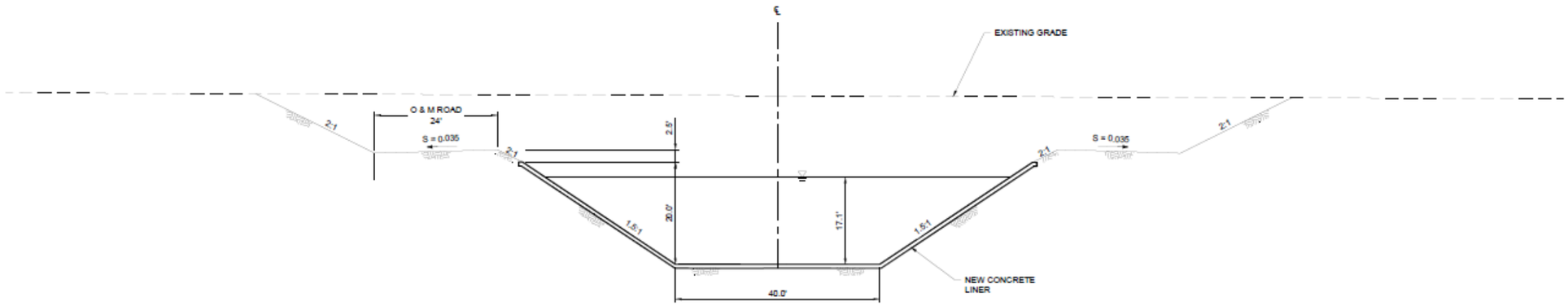
1. A bypass from Tule River to White River
   - Full capacity
   - Splits from existing canal just downstream from existing Tule River Siphon
   - New check structure and siphon at Deer Creek
   - Rejoins existing canal just upstream from White River Check
   - Existing canal from Tule River to White River remains in service to supply existing turnouts
   - Existing canal dead ends upstream from where new bypass canal rejoins; HGL in existing canal is lower than in bypass canal
   - Possibility for one or more turnouts from the bypass canal to deliver water to the lower existing canal, to help supply deliveries
2. A bypass from Tule River to Lake Woollomes
   - Full capacity
   - Splits from existing canal just downstream from existing Tule River Siphon
   - New check structures and siphons at Deer Creek and at White River
   - Flow directly into Lake Woollomes, and possibly also into existing earth canal section parallel to Lake Woollomes
   - Existing canal from Tule River to near Lake Woollomes remains in service to supply existing turnouts
   - Existing canal dead ends upstream from Lake Woollomes; HGL in existing canal is lower than in bypass canal
   - Possibility for one or more turnouts from the bypass canal to deliver water to the lower existing canal, to help supply deliveries

These upslope bypass alternatives have the following characteristics:

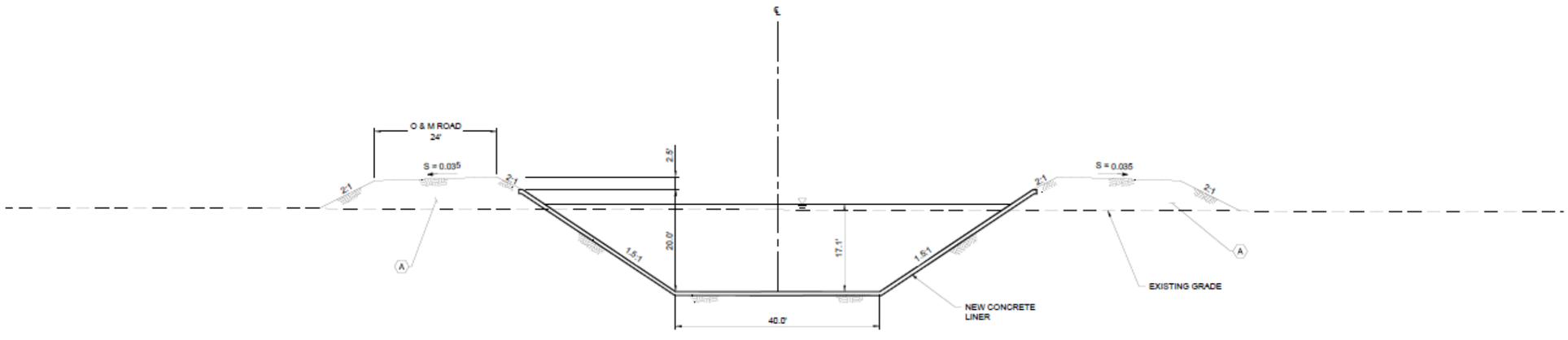
- Construction is mostly independent from canal operation
- Alignment avoids the area with largest amount of subsidence
- Significant additional ROW acquisition required
- Construction will include sections with a relatively large cut
- Conventional and optimized trapezoidal cross section
- Relatively low additional cost required for future enlargement

SHEET KEYNOTES

A. COMPACTED EMBANKMENT



TYPICAL OFFSET BYPASS CANAL SECTION IN CUT
SCALE: 1" = 10'



TYPICAL OFFSET BYPASS CANAL SECTION IN FILL
SCALE: 1" = 10'

Figure 2-7 - Bypass Canal Typical Sections

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2.5.4 Parallel Canal

A second form of bypass canal measure is a new *Parallel Canal*, which is constructed immediately east and adjacent to the existing canal. **Figure 2-8** shows a parallel canal typical cross section.

This Parallel Canal would bypass the existing canal from Tule River to Lake Woollomes, and would be constructed as follows:

- The canal sections were selected to maintain the upstream and downstream HGL established for the canal enlargement alternative.
- The existing canal left embankment would be used as the new canal's right bank

– Full capacity

– Splits from existing canal just downstream from existing Tule River Siphon

– Existing check structures and siphons at Deer Creek and at White River would still be used; new parallel canal would tie in upstream from each check and split off downstream from each siphon

– Parallel canal would flow directly into Lake Woollomes, and possibly also into existing earth canal section parallel to Lake Woollomes

– Segments of the existing canal from Tule River to near Lake Woollomes would remain in service to supply existing turnouts

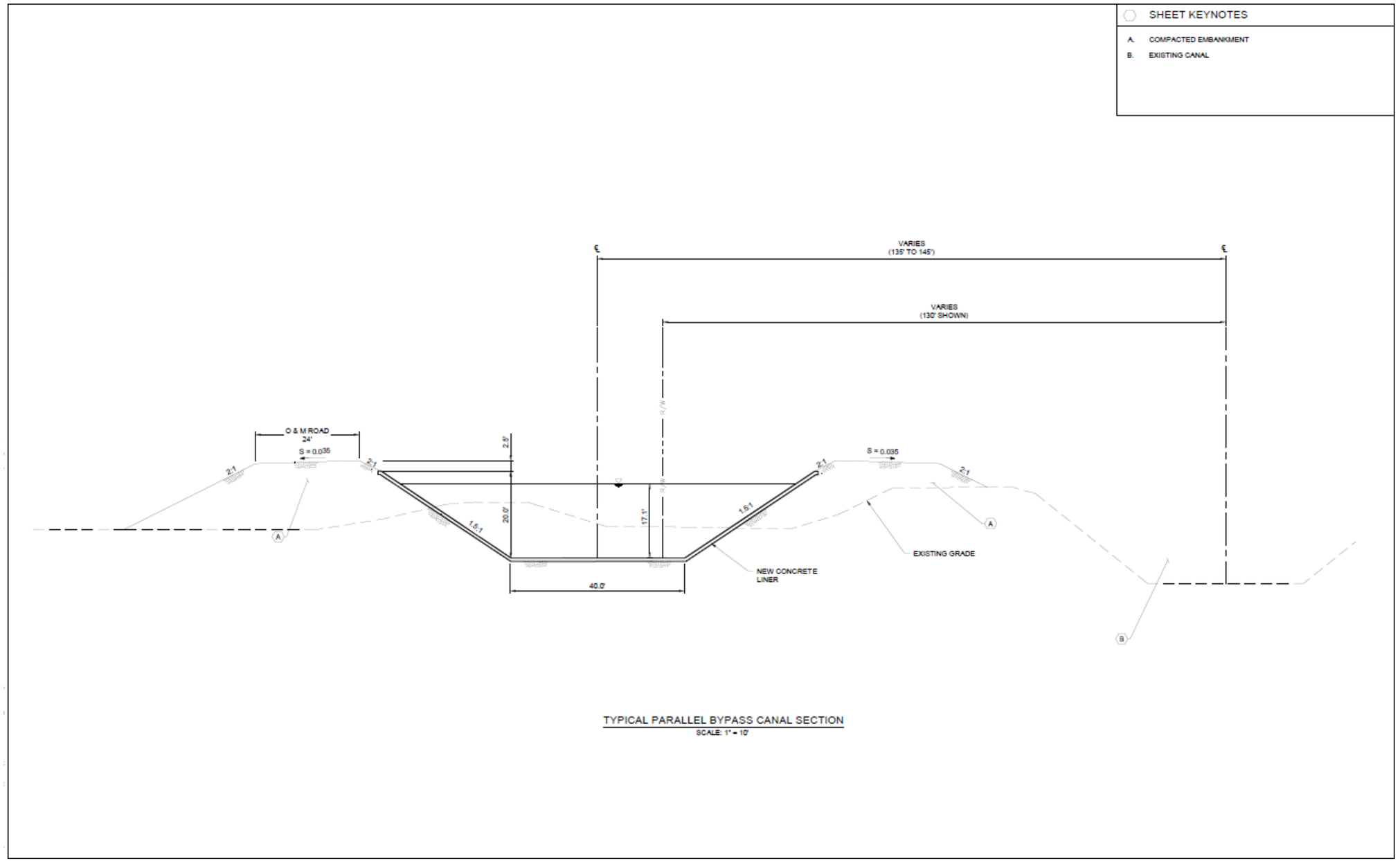
– Existing canal dead ends upstream from Lake Woollomes; HGL in existing canal is lower than in parallel canal

– Possibility for one or more turnouts from the parallel canal to deliver water to the lower existing canal, to help supply deliveries

The *Parallel Canal* alternative would have the following characteristics:

- Construction will raise the existing canal left bank
- Most construction would not impact canal operation
- Alignment would remain in the area with significant subsidence
- Some additional ROW acquisition required
- Construction will include a relatively large amount of borrow and fill
- Conventional and optimized trapezoidal cross section
- Relatively low additional cost required for possible future enlargement

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TYPICAL PARALLEL BYPASS CANAL SECTION
SCALE: 1" = 10'

Figure 2-8 - Parallel Bypass Canal Typical Section

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2.6 Summary of Project Alternatives

Seven alternatives to mitigate the problem have been identified. Each project alternative includes a single measure or combination of measures including enlarging (raising and/or widening) the existing canal, a new bypass canal in an upslope alignment corridor, a new parallel canal immediately adjacent to the existing canal, and adding a pumping plant. These alternatives include modifications to existing facilities, and new facilities such as bridges and associated approach roadways, check structures, wasteways, and water supply delivery turnouts to Friant Division contractors. The seven project alternatives considered during this analysis are summarized below and diagrammatically presented in **Figure 2-9**.

2.6.1 Alternative 1 – Canal Enlargement

Alternative 1, or the baseline alternative, returns the canal to full capacity exclusively through raising and or widening the canal. As shown in **Figures 2-3** and **2-4**, capacity restoration is accomplished by removing some of the original liner, cutting a bench into the existing grade, and building out the embankment throughout all 33.3 miles of the middle reach. Enlarging the canal from the 5th Ave check structure to Lake Woollomes involves replacing and/or raising approximately 17 county/state bridges. Additionally, the Deer Creek and White River check structures would need significant modification if not complete replacement.

2.6.2 Alternative 2 – Pump Station at MP 109

The main distinguishing feature between Alternatives 1 and 2 is that Alternative 2 involves a 3,500 cfs maximum capacity pump station at MP 109. When flows are high and cannot be conveyed by gravity, water would be diverted from the original canal into the pump station forebay and pumped back into the original canal. In the event of a power failure, the water would move into a 400-acre emergency reservoir to prevent a surge. Canal enlargement, similar to Alternative 1, would still be necessary for approximately 5.2 miles of existing canal as part of Alternative 2. Enlarging the canal under this alternative involves replacing and/or raising approximately 10 county/state bridges.

2.6.3 Alternative 3 – Pump Station at Woollomes

Similar to Alternative 2, Alternative 3 involves a 3,500 cfs maximum capacity pump station. Capacity restoration would be achieved by moving water from the original canal into an approximately 10-mile-long bypass canal and lifting it into Lake Woollomes. It is important to note that deliveries would be maintained in the original canal, but the majority of the water would move through the bypass canal. By creating a new bypass canal, Alternative 3 requires a siphon to cross the White River, adding complexity to environmental compliance and permitting. Alternative 3 also requires a 350-acre emergency reservoir to accommodate a surge in the event of a power outage. Canal enlargement and new bypass canal construction will be necessary

throughout all 33.3 miles of the middle reach as part of Alternative 3. This alternative requires a combination of approximately 29 county/state bridge replacements, raises, or new construction.

2.6.4 Alternative 4A – Bypass Canal from Tule River to White River

Alternative 4A is a combination of the canal enlargement and bypass canal measures that would move water into a new bypass canal at Tule River and connect back into the existing canal at White River. The existing canal would be used solely to maintain deliveries between the two checks. The land required to build a new bypass canal, and the new canal crossing at Deer Creek make Alternative 4A complex to construct and comply with environmental regulations. Alternative 4A would require approximately 16 miles of canal enlargement and 17 miles of new bypass canal construction. This alternative requires a combination of approximately 17 county/state bridge replacements, raises, or new construction as well as a new siphon crossing at Deer Creek.

2.6.5 Alternative 4B – Bypass Canal from Tule River to Woollomes

Alternative 4B is the same as Alternative 4A but extends to Lake Woollomes. Because this Alternative 4B has more bypass canal than 4A, more ROW acquisition would be necessary. Alternative 4B would require approximately 8 miles of canal enlargement and 25 miles of new bypass canal construction. This alternative requires a combination of approximately 24 county/state bridge replacements, raises, or new construction as well as two new siphon crossings at Deer Creek and White River.

2.6.6 Alternative 5A – Parallel Canal from Tule River to White River

Alternative 5A is a combination of the canal enlargement and parallel canal measures. The parallel canal would run from Tule River to White River, the area of greatest subsidence. The parallel canal would tie into the existing canal near the Tule River, Deer Creek, and White River check structures eliminating the need for new check structures and siphons. The existing canal would continue to be used to maintain deliveries between the Tule River and White River checks. The land required to build a parallel canal is anticipated to be considerably less than a bypass canal such as those in Alternatives 4A and 4B. Alternative 5A would require approximately 16 miles of canal enlargement and 17 miles of new parallel canal construction. This alternative requires a combination of approximately 18 county/state bridge replacements, raises, or new construction.

2.6.7 Alternative 5B – Parallel Canal from Tule River to Woollomes

Alternative 5B is the same as Alternative 5A but extends the new parallel canal to Lake Woollomes. Alternative 5B would require approximately 8 miles of canal enlargement and 25 miles of new parallel canal construction. This alternative requires a combination of approximately 24 county/state bridge replacements, raises, or new construction.

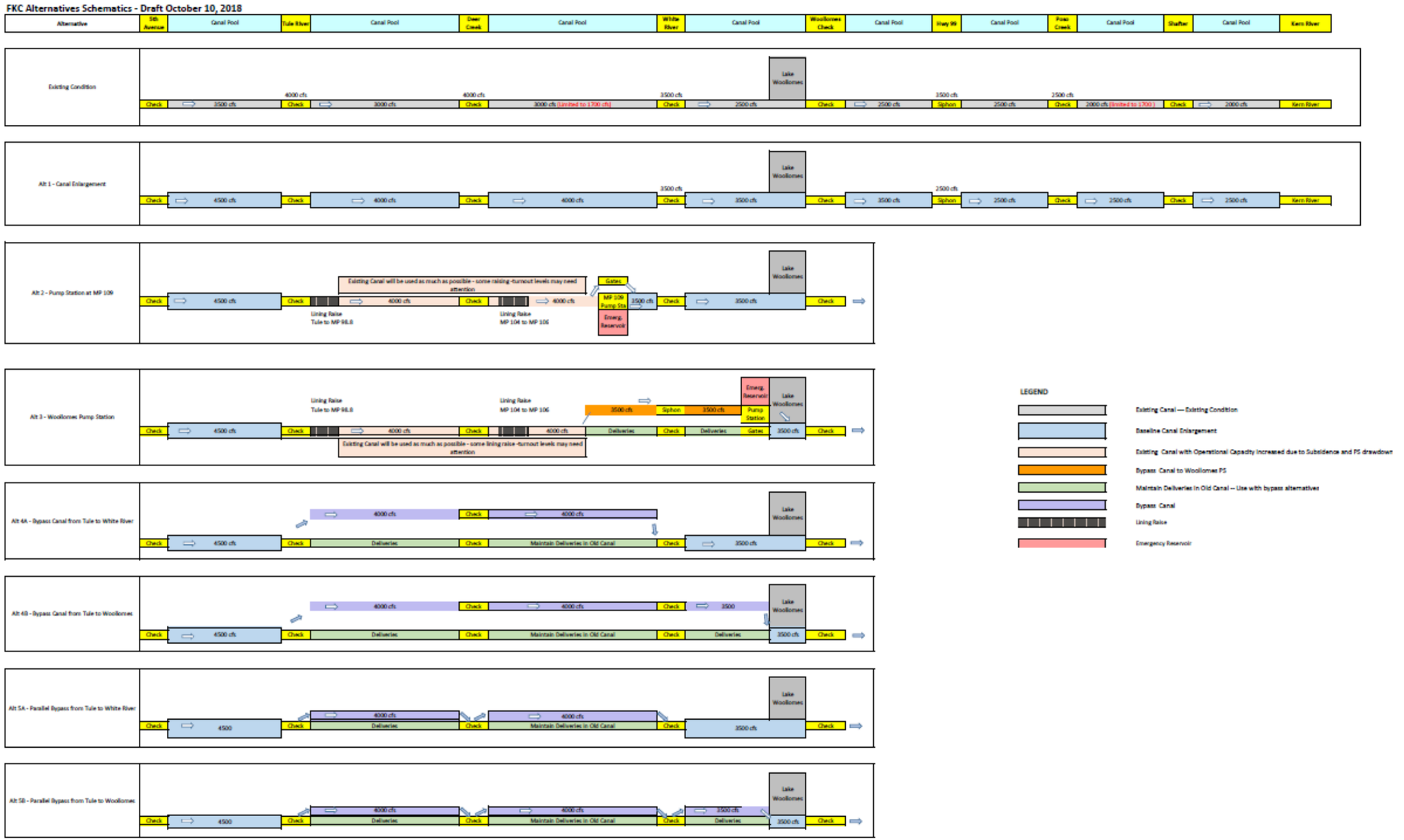


Figure 2-9 - Project Alternatives Considered

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3. PRELIMINARY DESIGN CRITERIA

3.1 SURVEY AND MAPPING

3.1.1 General

The aerial surveying and mapping for this Project was performed by Towill, Inc. Additional supplemental surveying for Friant Division contractor turnouts was performed by Provost and Pritchard Consulting Group. Aerial and topographic mapping was conducted along the length of the project in August of 2018. This data is currently being processed to create topographic base mapping to cover the extents of the project. The completed survey data files are anticipated to be completed by the end of September 2018.

Additional flight lines were conducted approximately 3,000 ft to the east to pick up airborne Light Detection and Ranging (LiDAR) data of the FKC and an approximate area for a bypass canal alternative. The LiDAR was collected by an aircraft suitable to map the terrain within the mapping corridor. The LiDAR data was prepared at a nominal density of nine points per square meter. No imagery, planimetrics, or "bare-earth" classification of LiDAR data was processed initially; however, it may be post-processed, at a later date if needed.

3.1.2 Primary Control Points

A survey control network was established at approximately one-mile intervals. Survey datums are referenced to the NAD83 (CSRS Epoch 2011.00) horizontal datum and Geoid 2012B NAVD88 vertical datum, based on CGPS reference stations that are remotely situated and are not affected by local ground subsidence. GPS surveying technology was used to accomplish the control survey. The basis for the coordinate projection is California Zone 4 with distances measured in ft. A Control Survey Report is provided in a separate document.

3.1.3 Mapping

Upon completion of the ground control survey and acquisition of aerial photography, analytical aerotriangulation was performed to extend control throughout the project photography to achieve a network of points. A digital topographic map will be compiled at a scale of 1" = 100ft for the mapping area. Planimetric features – such as buildings, roads, fences, bridges, and the like will be digitized at elevations that provide the best horizontal accuracy. The final topographic mapping will have a contour interval of 1ft.

3.2 GEOTECHNICAL INVESTIGATION

Phase 1 geotechnical field investigations (top of embankment) were performed by Stantec in September 2018.

The geotechnical investigations consisted of drilling multiple borings with an 8-inch diameter hollow stem auger drill rig and advancing Cone Penetration Tests (CPTs) with a 25 Ton CPT truck at locations along the project alignment. The borings and CPT's were located on top of the O&M road and at the land-side toe of the canal's western O&M Road. All explorations were located within the Reclamation ROW. The borings and CPTs extended to depths of 20 ft to 50 ft below ground surface.

Stantec has performed preliminary slope stability analyses using the results of the Phase 1 investigation and laboratory testing to evaluate factors of safety for the proposed canal alternatives with different slope inclination and geometry. The results of these analyses and the interpretive analysis can be found in the *Draft Geotechnical Data Report-Phase 1 FKC Subsidence Correction Project Tulare County, CA, by Stantec, 14- November-18* and *Draft Preliminary Geotechnical Interpretive Report - Phase 1, FKC Subsidence Correction Project, Tulare County, CA, by Stantec, 17- December-18.*

3.3 CANAL DESIGN CRITERIA

3.3.1 Design References

Bureau of Reclamation design references include the following:

- FKC Technical Record of Design and Construction, May 1958
- Design Standards No. 3, Water Conveyance Systems, DS-3-2 – 1994, Chapters 11 and 12
- Design Standards No. 3, Canals and Related Structures, DS-3-5 – December 8, 1967
- Technical Memorandum 661, Analysis and Descriptions of Capacity Tests in Large Concrete-Lined Canals, April 1964
- Concrete Manual, Eighth Edition, Revised 1981, Reprinted 1998
- Linings for Irrigation Canals, First Edition 1963, Second Printing 1976
- Earth Manual, Part 1, Third Edition, 1998
- Safety and Health Standards, 1993, Reprinted 2001
- Design of Small Canal Structures, 1978
- Water Measurement Manual, Third Edition, 1997
- Construction Activities, Reclamation Manual FAC 03-02

Other design references include the following:

- FKC Structures List, Friant Water Authority, November 2007
- Drawings for the Construction of FKC, Record Drawings, September 1947
- Drawings for the Construction of FKC Rehabilitation, Record Drawings, June 1976

3.3.2 Canal Design Capacity

The design normal flow rate and design maximum flow rate are shown in **Table 3-1**.

Table 3-1 - Design Flow Rate

Canal Section No.	Canal Reach (Milepost to Milepost)	Description (Check to Check)	Normal Flow Rate (cfs)	Design Maximum Flow Rate (cfs)
4	88 to 95.67	5th Ave. to Tule	3,500	4,500
5	95.67 to 112.90	Tule to White River	3,000	4,000
6.1	112.90 to 128.69	White River to HWY 99	2,500	3,500
6.2	128.69 to 130.03	HWY 99 to Poso	2,500	3,000
7	130.03 to 151.60	Poso to Kern River	2,000	2,500
Key: cfs – cubic feet per second				

FWA has directed Stantec to design all canal enlargement, new bypass and new parallel canal alternatives for a canal operating capacity equal to the Design Maximum Flow Rate. Canal lining depths will equate to the normal depths at the Design Maximum Flow Rates plus the established lined freeboard criteria.

3.3.3 Locations for Design Capacity Reductions

As was typical for Reclamation canal designs, the original design carried a constant design flow rate through the end of each canal reach. This strategy is appropriate when maximum flows (e.g. from uncontrolled flood inflows to the canal) must be carried to the end of a reach where excess flow is spilled through a wasteway. However, a specified flow rate representing a water delivery condition will taper more gradually as water is diverted through turnouts. Therefore, the maximum canal capacity can also taper through the length of some reaches instead of suddenly reducing by 500 cfs or 1,000 cfs from one reach to the next. Applying this strategy to normal design capacity will better predict the actual operating conditions, saving head and realistically reducing the design HGL elevation upstream.

The above logic was applied to study a more realistic maximum flow between Highway 99 Siphon and Poso Creek. Although the original design used 3,500 cfs for the maximum flow condition all the way to Poso Creek (to pass flood flow to the wasteway there), design maximum

flow rate was reduced to 3,000 cfs at Highway 99 for these studies. This flow reduction seems more realistic and saves head through this canal segment and through the Highway 99 siphon, which reduces the size of the canal in this segment and further upstream.

Table 3-1 shows design flow rates used to develop HGL profiles for design alternatives.

3.3.4 Canal Stationing

The original design canal stationing has several station equations. For the preliminary analyses, Stantec has established a revised stationing with no equations to facilitate computer generated earthwork quantities. The project stationing starts at the beginning of the inlet transition to 5th Avenue Check Structure at Station 4773+00 and continues sequentially with no equations. During final design it will need to be decided whether this same stationing methodology will be used.

3.3.5 Canal Curve Radius

The minimum radius of curvature for new canal centerlines will be 250 ft except where there is a specific need to have a reduced radius. However, no radius will be less than 1.5 x TW, where TW is the width of the water surface at design flow.

3.3.6 Canal b/d Ratio

The minimum canal b/d ratio for new canal prisms will be 1.3, where “b” is the canal bottom width and “d” is the normal depth at the design normal depth flow rate.

3.3.7 Canal Prism

The typical canal section for enlargement of the existing canal section will be via a compound trapezoidal section that will consist of a lined bench widened section. From the lined benches the concrete-lined side slopes will be 1.5 horizontal to 1 vertical (1.5:1). The compound trapezoid section may have excess flow area along lengths of the existing FKC where the deeper subsidence conditions exist. Once all current and future bridge losses are accounted for, the bench portion of the trapezoidal section might be reduced. This would reduce cost and the amount of new ROW that may be required. Refer to **Section 2** for a description of the compound trapezoidal section.

The typical canal section for new bypass and parallel canals will have a more traditional trapezoidal shape with concrete-lined side slopes of 1.5 horizontal to 1 vertical (1.5:1).

The earthen freeboard portion of all canal sections whether enlargement of existing canal prisms or new canals will be sloped at 2:1.

The typical canal cross sections for enlarging the existing canal and new parallel and bypass canals are shown in **Figures 2-3** and **2-6** in **Section 2**.

3.3.8 Canal Banks and O&M Roads

O&M roads may be provided on both sides of the canal if desired by the Owner. Canal bank roads will have a minimum road width of 24 ft. For the cost estimating purposes, it was assumed that an all-weather road with a 4" aggregate base finish course would be provided along one side of the canal and the other canal bank would not have an all-weather finish.

The inside radius of the travel way shall be a minimum of 20 ft at all intersections with public and private roads as well as all access ramps to the O&M road.

The outside slopes of the O&M road banks will be determined after a slope stability analysis is performed by the geotechnical engineer and factors of safety are determined for a range of potential slopes. Stantec will perform preliminary slope stability analyses using the results of the Phase 1 investigation and laboratory testing to evaluate factors of safety for the proposed canal alternatives with different slope inclination and geometry. A decision can then be made on bank slope design considering slope stability, acceptable factors of safety, and impacts on land acquisition. The bank slopes considered will likely range from 1.5:1 to 2:1. 2:1 slopes were assumed during this phase of alternative analysis.

3.3.9 Concrete Thickness

Reclamation standards for the minimum lining thicknesses for unreinforced concrete lining in canals with flow rates between 1,500 cfs and 3,500 cfs is 3.5 inches and between 3,500 cfs and 7,000 cfs will be 4.0 inches.

There will be significant cost implications when comparing lining costs associated with a 3.5 inch and 4.0 inch concrete lining. For this project, the minimum thickness for all machine-placed canal lining will be 3.5 inches, however further analysis will be performed during design comparing the cost impacts of 3.5 inch and 4.0 inch linings for canal sections greater than 3,500 cfs. The cost impacts may lead FWA to propose a 3.5 inch thick concrete lining for all canal sections.

3.3.10 Canal Lining Joints

Transverse and longitudinal contraction joints will be spaced a maximum of 15 ft apart on centers. All joints will be standard PVC water stop, sealed type joints. For concrete canal lining it is the accepted practice to plan for anticipated shrinkage cracking and install contraction joints to induce and control crack location. By inducing cracking at the contraction joints, random cracking is controlled and the leakage from the lining is kept to a relatively small amount.

The design team advises against the use of expansion joints on concrete canal linings except at structures that intersect the lining. Expansion joints are not recommended for the following reasons:

- Compressive stresses from the effects of water and temperature expansion of the concrete is normally not a concern as the stresses are normally within allowable stresses of good concrete.
- It is difficult to construct an effective expansion joint in the canal lining.
- The additional joint (expansion) interrupts the construction lining process.
- The typical expansion joints used in the past handle only about 10% of the anticipated expansion and therefore are not effective in eliminating problems from expansion in the canal lining.
- The lining is most susceptible to expansion problems when the canal is dry. An occasional buckle may occur in the canal lining which will require repair.

3.3.11 Lining Freeboard

The minimum operating freeboard provided for the concrete lining, from maximum water depth at the design flow to the top of the concrete lining is shown for each reach of the canal sections in **Table 3-2**.

Table 3-2 - Design Freeboard Requirements

CANAL REACH			FREEBOARD AT RECLAMATION FLOOD FLOW AND MAX FLOW				
Canal Section No.	**Canal Reach (Milepost to Milepost)**	**Description**	**Design Flow (cfs)**	**Flood Flow Lining Freeboard (ft)**	**Required Canal Lining Height at Flood Flow[(1)] (ft)**	**Max Flow Lining Freeboard (ft)**	**Required Canal Lining Height at Max Flow[(1)] (ft)**
4	88 to 95.67	5th Ave. to Tule	4,500	1.18	19.30	2.35	20.47
5	95.67 to 112.90	Tule to White River	4,000	1.15	19.63	2.29	20.77
6	112.90 to 128.69	White River to Poso	3,500	1.11	19.62	2.23	20.74
7	128.69 to 151.60	Poso to Kern River	2,500	1.03	17.91	2.06	18.94

Key:
cfs – cubic feet per second
ft – feet

(1) *Freeboard calculated per Reclamation canal design standards.*

The flood flow lining freeboard and resulting canal lining height at flood flow shown in Table 3-2 represents the minimum standard that Reclamation would require the canal prism to be designed to. This is the freeboard requirement that Reclamation has designed previous phases of FKC rehabilitation projects to. Reclamation allows for the reduction in max flow lined freeboard by one-half for short term flood flows that enter the canal from cross drainage and can be

evacuated from canal by wasteways. However, the FKC max design flow freeboard includes captured flood flows (i.e. Class 2 water) that are transferred over a long period of time, with no intention of evacuating the excess flows from the canal. Based on this, the design assumption is that minimum lined freeboard for the FKC alternatives will be as shown in the "Max Flow" conditions in **Table- 3-2**.

3.3.12 Earth Freeboard

In all cases the minimum earthen freeboard, from the top of the concrete lining to the top of the earthen embankment will be 2.5 ft per Reclamation standards.

3.3.13 Compacted Embankment

Depending on whether the existing canal modifications or new canal is in cut or fill, the sides of the canal will be formed from firm original earth or compacted embankment, respectively. For compacted embankments (in fill areas), earth materials will be placed and spread evenly in uniformly compacted horizontal layers. Each horizontal layer will not exceed 6 inches in compacted thickness. The compacted embankments will be homogeneous, free from lenses, pockets, streaks, laminations, or other imperfections. Prior to and during compaction operations, the earth materials will have a moisture content no greater than two percent wet or less than two percent dry of the optimum moisture content.

3.3.14 Hydraulic Losses

The Manning's n-value for the project shall be n= 0.016. The basis for this criteria is described below.

Several different empirical formulations have been commonly used to estimate hydraulic losses from frictional resistance in canals. When the FKC was originally designed, Reclamation used the Manning's equation with an "n" value ranging from 0.014 to 0.0143 for the concrete-lined sections. In the 1960's, Reclamation conducted field tests as part of an extensive study of hydraulic losses in about a dozen large concrete-lined canals including FKC. That study yielded the following conclusions:

A. Flow resistance in the five largest canals in the study (including FKC) was larger than anticipated. Values of Manning's n computed from the field tests ranged from 0.015 to 0.019 and were about 10% to 25% higher than design values.

- Head losses through siphons were generally less than design assumptions, creating some overcapacity and a "safety cushion" effect.
- Seasonal aquatic growths (weeds, algae, etc.) caused considerable increase in flow resistance, and likely caused much of the increase in computed friction factors.
- Algal growth has been well controlled using copper sulfate, creating consistently lower "n" values in FKC. Testing showed that after regular copper sulfate treatments in 1962,

"the first 28 miles of FKC conveyed 4500 cfs with 0.2 ft of freeboard at 'tight spots', from which n values of .0145 to .0166 were computed."

B. Based on the results of Reclamation's study and on experience of FKC operations staff, the following recommendations are made regarding design criteria for hydraulic losses:

- Design should assume continued maintenance to retard weed growth. Manning's n value used for design should not be increased to account for seasonal aquatic weeds.
- Conditions on the bottom of the canal are unknown. Significant accumulation of silt and/or clams may exist but this condition can be improved with maintenance. Manning's n value should not be increased artificially to account for sedimentation or other accumulation on the canal invert. If the effective cross-sectional area is different than the original design—whether from accumulation of material or from subsidence—the best approximation of the actual canal section should be used in hydraulic analysis.
- Actual roughness of the existing concrete lining may have increased over time. The roughness coefficient used for new design should account for actual condition of old concrete that will remain in place.
- Siphon losses are generally less than original design assumptions. However, there appears to be an anomaly in the original design for the Poso Creek Siphon, which does not allow for any loss for the design condition.
- Accounting for all of the above factors, a Manning's n value of 0.016 is considered appropriate for hydraulic analysis and design criteria.

3.3.15 Operating Velocity Range

The maximum velocity allowed for unreinforced concrete-lined canals per Reclamation standards is 6.0 ft/sec. The new canal operating velocity range will ideally be between 3.0 ft/sec and 5.9 ft/sec.

Differential subsidence has increased channel slope in portions of the existing canal. In alternatives where these steep segments will remain in use, high velocity must be addressed in the design. Where velocities would exceed the allowable velocity of 6 ft/s, steep sections of the existing canal would need to be modified.

3.3.16 Sediment Transport

No specific sediment transport analysis for the canal system was scoped to be undertaken and none is anticipated. However, operating velocities in canal reaches should be designed to range between 3.0 ft/sec and 5.9 ft/sec. At these velocities, the canal sections will tend to reach various levels of equilibrium under varying flow conditions. Once in equilibrium, all new sediment entering the system will be passed through during low flows. During higher flows, the deposits will scour out.

3.3.17 Water Level Drawdown

The rate of water level drawdown is critical to ensure the longevity of canal lining. If the water within the canal prism drops more rapidly than groundwater in the soil behind the lining, hydrostatic backpressure can break and displace the lining. Therefore, drawdown rate is a function of drainage in the soil foundation material. Standard, conservative drawdown criteria should be used unless designers can be sure of good drainage behind the canal lining, either from naturally well-drained soil or from an engineered under-drainage system.

It is not yet clear where rapid drawdown will and will not be acceptable. More information on groundwater and soil drainage properties is needed before maximum drawdown rate can be finalized. The allowable drawdown rates may not be constant through the length of the selected project alternative, because soil properties may vary significantly.

Where the acceptability of more rapid drawdown cannot be ensured, design should be based on a maximum drawdown rate of 6 inches in one hour or 12 inches in 24 hours. Although this rate will be assumed during the design process, a higher rate of drawdown may prove to be acceptable during future operations of the canal.

3.3.18 Escape Ladders

Both existing canal modifications and new canals will require escape ladders. For new canal construction escape ladders will be installed at 375-foot intervals on alternating sides of the canal with 750 ft between ladders on a given side. The escape ladders will be the expansion-anchored type, in accordance with current Reclamation standards and epoxy coated. For existing canal modifications the ladder spacing and design will match existing ladders. For cost estimating purposes the 750 ft between ladders on a given side criteria was assumed for all alternatives.

3.3.19 Safety Buoys

Where not already provided, safety buoys will be installed at the entrances to siphons and check structures. There are essentially two options for buoys, spherical and elongated cylindrical. The spherical buoys provide better clearance for passing floating debris.

3.3.20 Check Structure Modifications

Depending on the project alternative, existing check structures may have to be modified or replaced and new check structures may have to be added. Check structures will be designed to maintain water levels required to supply turnouts. Check structures will be designed to meet the most current governing codes and standards for structural design.

Future capacity improvements investigated by FWA downstream of the Lake Woollomes Check should include an evaluation of an option to eliminate the Poso Creek Siphon by constructing the canal across Poso Creek (possibly a flume) and constructing culverts to take Poso Creek flows under the canal.

3.3.21 Turnouts

The condition of turnouts related to current capability vs. original design capability will be investigated in more detail. Some the largest turnouts have Parshall flumes for flow measurement. Parshall flumes require significant head drop across the structure. If improvements are required at any of these types of turnouts, one option might consist of replacing the structure with a more efficient means of flow measurement. Refer to **Exhibit B** for the *Turnout Inventory Technical Memorandum, by Provost and Pritchard, 25-September-18.*

Impacts on existing turnouts will be further assessed with the selected project alternatives. In general, the turnout design procedure will adhere to the following steps:

A. Determine the existing minimum canal water surface elevation at all delivery locations and delivery capacity required at each turnout.

B. Determine the elevation of the minimum required canal water surface under the new hydraulic conditions resulting from the project alternative.

- If water surface elevations are calculated to have minimal change from existing conditions minor modifications to existing turnouts may be required.
- If changes in water surface elevations reduce turnout delivery capacity or increase head beyond the existing turnout design capacity, significant turnout modifications or replacement may be necessary.

3.4 PUMP STATION DESIGN CRITERIA

3.4.1 Pump Station Criteria

A pump station measure could be substituted for portions of canal enlargement and modification. An In-line pump station measure was evaluated as part of two project alternatives. Refer to **Section 2** for an operational description of the pump station measure as well as a summary of the two project alternatives including pump stations. The following criteria summarizes the design assumptions used in developing the pump station alternatives.

3.4.2 Flows

A pump station on the FKC will be designed to meet the maximum design flow of the downstream canal reaches. Depending on the pump station location along the canal, this flow design could range from 4,000 cfs to 2,500 cfs. Based on the current project alternatives including a pump station, the maximum design flow is anticipated to be 3,500 cfs. The design minimum pump station flow is anticipated to be 1,800 cfs.

3.4.3 Operational Levels

Based on the reported project hydraulic modeling results, preliminary operational water surface elevations (WSEL) have been established for the Pump Station located a MP 109. The results are summarized in **Table 3-3** below. The required static lift varies from 5 to 7 ft.

Table 3-3 - Pump Station Operational Levels

Description	Operational WSEL (ft)	Pump Station Design Flow Assumptions (Min/Max)
Design Minimum Upstream WSEL	394.9	1,800 cfs Canal Flow Rate (Design Min.)
Design Maximum Upstream WSEL	399.1	3,500 cfs Canal Flow Rate (Design Max.)
Design Minimum Downstream WSEL	399.9	1,800 cfs Canal Flow Rate (Design Min.)
Design Maximum Downstream WSEL	406.1	3,500 cfs Canal Flow Rate (Design Max.)
Key: ft – feet min – minimum max – maximum WSEL – water surface elevations		

3.4.4 Pump Station Surge

Any alternative with a pump station in the canal must be analyzed for surge caused by a power failure that shuts down pumps. Although the frequency of a pump shutdown event is hard to predict, it is an inevitable event that must be addressed in the design. The maximum design condition is full flow rejection at the pump station that creates upsurge (depth increase) in the canal upstream from the pump station and downsurge (depth decrease) in the downstream canal. These surges will take the form of an immediate change in water level in the pump station forebay and afterbay, followed by translatory waves that migrate upstream and downstream through the canal at a relatively high velocity. Translatory waves are the moving interface between the stopped flow and the canal flow continuing to approach from upstream and to pull away downstream. These waves will continue to translate through the canal until they reach a hydraulic boundary condition—such as a structure or reservoir—that reduces and/or reflects the wave. After the initial sudden depth change caused by the wave, the canal will continue to fill or drain until corrective action is taken to reduce flow upstream and downstream from the pump station. The canal water surface will also level out into a zero-flow profile.

A sudden pump shutdown that stops all flow (Qmax = 3500 cfs) will create a translatory wave with a height of approximately 2 ft. This wave will travel with a wave speed (celerity) of approximately 20 ft/s. On the upstream side of the pump station, a 2-foot depth increase will occur immediately and proceed upstream for 30-40 minutes until reaching the next upstream

check/siphon structure (either White River or Deer Creek, depending on pump station location). If check gates are closed within this 30-40 minute time period, the canal pool between the upstream check and the downstream pump station will level out without additional water volume increase. This leveling will further increase depth on the upstream side of the pump station by an additional 1 foot, so the final depth increase will be about 3 ft.

If the upstream check gates do not close within the first 30-40 minutes, water will continue to fill the canal pool upstream from the pump station. Whether the gates close or not, the surge will proceed upstream from the check structure into successive canal pools. Surge magnitude may diminish but the problem will persist until inflow is stopped or outflow through the pump station is restored.

3.4.5 Surge Control Methods

To prevent damage from surge, the canal can be constructed with additional freeboard to contain an increased depth and/or the amount of depth change can be limited. Additional measures may be required to prevent damage in the downstream canal from sudden water level drawdown. Methods to reduce the amount of water level change following a pump power failure include:

A. Restart the pumps quickly using backup generators or engine-driven pumps. Potential disadvantages to this method are cost, maintenance, and reliability. Even with increased staffing and instrumentation for 24-hour response, it's difficult to ensure 100% restart reliability at any time and during all conditions.

B. Spill excess water from the canal upstream from the pump station using a wasteway. The most reliable method to prevent excess depth in the canal is to have an overflow spillway, which will never fail to spill excess water from the canal by gravity. Without a suitable wasteway channel that can safely pass the canal's full flow capacity, a reservoir must be built to store the large volume spilled during a pump shutdown event.

C. Adjust canal flow upstream and downstream from the pump station. Quickly reducing the canal flow from upstream can limit the amount depth increase in the canal upstream from the pump station, and reducing canal flow downstream can limit drawdown on the downstream side of the pump station. Effectiveness depends on how quickly the flow can be adjusted and the distance to check structures. This method will not prevent level changes during the initial surge, but can reduce subsequent depth change from continued volume change (filling/draining) and from water surface leveling effects.

3.4.6 Surge Control Requirements and Design Criteria

An emergency wasteway to a storage reservoir (Method 2) is recommended as the most reliable choice because it can never fail to operate and it doesn't require the increased staffing, maintenance, and operating complexities of the other methods.

An emergency wasteway will need capacity to spill the full 3,500 cfs pump station capacity over a spillway weir designed to pass 3,500 cfs with canal water level below the lining freeboard

level. The current design criteria assumes a worst case with spill flow continuing for 10 hours before the canal can be completely shut down and yields a total spill volume of approximately 3,000 acre-ft. Therefore, an emergency storage reservoir should have 3,000 acre-ft of available storage space. The required reservoir sizes for a range of 3,500 cfs spill flow durations and reservoir depths are shown in **Table 3-4.**

Table 3-4 - Surge Control Reservoir Sizes

Spill Flow Duration	Surge Reservoir Surface Area (Acres)					Storage Volume (ac-ft)
	Reservoir Capacity Depth (ft)					
	4-ft	6-ft	8-ft	10-ft	12-ft	
4-hours	289	193	145	116	96	1,157
8-hours	579	386	289	231	193	2,314
10-hours	723	482	362	289	241	2,893
12-hours	868	579	434	347	289	3,471
16-hours	1,157	771	579	463	386	4,628
24-hours	1,736	1,157	868	694	579	6,942
Key: Ac-ft – acre feet ft – feet						

3.4.7 Governing Standards and Guidelines

Pump station design will meet the following standards as summarized below.

- American National Standards Institute (ANSI)/Hydraulic Institute (HI) Pump Intake Design Standard 9.8
- ANSI/HI Rotodynamic Pump for Pump Piping Standard 9.6.6
- EM 110-2-3105 Mechanical and Electrical Design of Pumping Stations by U.S. Army Corps of Engineers (USACE)
- Pumping Station Design by Garr M. Jones
- AWWA M-11 Steel Pipe – A Guide for Design and Installation
- AWWA C512 – Air Release, Air/Vacuum, and Combination Air Valves for Water and Wastewater Service
- ANSI/HI 2.1-2.2 – Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Nomenclature and Definitions

- ANSI/HI 2.3 – Rotodynamic Vertical Pumps of Radial, Mixed, and Axial Flow Types for Design and Application
- ANSI/HI 9.1-95 – Pumps – General Guidelines
- ANSI/HI 9.6.1 – Rotodynamic Pumps Guideline for NPSH Margin
- ANSI/HI 9.6.2 – Rotodynamic Pumps for Assessment of Applied Nozzle Loads
- ANSI/HI 9.6.3 – Rotodynamic (Centrifugal and Vertical) Pumps – Guideline for Allowable Operating Region
- ANSI/HI 9.6.5 – Rotodynamic Pumps Guideline for Condition Monitoring
- ANSI/HI 9.6.8 – Rotodynamic Pumps – Guideline for Dynamics of Pumping Machinery

3.4.8 Pump Selection and Configuration

Pump type, number of units, and drive type will be critical decisions and serve as the basis of the pump station design. Based on preliminary analysis, current assumptions for some criteria are listed. As the pump station concept progresses some of these criteria will evolve.

- Pump Type - High Flow/Low Head Vertical Axial Flow Pumps
- Number of Units – 8 Duty, 0 Standby
- Design Flow Per Pump – 437.5 cfs
- Design total design head (TDH) at Design Flow – 10.5 ft
- Min Flow Per Pump (assume 2 pumps provided with VFDs) – 250 cfs
- Pump Minimum Efficiency at Best Efficiency Point – 80 percent
- Motor – 6 each constant speed, 2 each variable frequency drive (VFD) rated
- Pump Rated Horsepower (HP) – 700 HP
- Motor Voltage – 4160 Volts (V)
- Location – Indoors. Pump deck enclosed by pump house structure.

The following additional critical pump criteria will have to be established if the pump station concept is selected for further analysis and the design progresses.

- Drive type and combination – solid state reduced voltage (SSRV) and VFD starters and number of each.
- Standby pumps and standby power requirements.
- Pump Removal – Crane removal through roof hatch (assumed) or permanent bridge crane in structure.

- Pump bay and discharge isolation requirements – Valves, gates, stop logs, etc.
- Pump Station control strategies.
- Site access and security.

3.5 BRIDGE DESIGN CRITERIA

Depending on the project alternative, bridge impact assessment will fall into one of the following scenarios:

A. No Impacts: Existing canal bridges with soffit elevations above the maximum canal operational water levels plus lined freeboard will require no modification.

B. Above Max Water Levels: Existing bridges with soffit elevations within the canal lined freeboard zone but above the maximum canal operational water levels may require some modification.

C. Inundated by Max Water Levels: Existing bridges with soffit elevations that will be inundated by the maximum canal operational water levels and can be raised.

D. New Bridge Design: Existing bridges with soffit elevations that will be inundated by the maximum canal operational water levels or within a canal reach that is to be raised significantly. New bridges that are required on a new bypass canal. Structural design for the project will adhere to the following governing codes and standards and be constructed from the following materials.

3.5.1 Governing Codes and Standards

The following documents will form the basis for design and construction of the bridge where they are applicable, as referenced in this document.

- AASHTO LRFD Bridge Design Specifications, 8th Edition, 2017 for all elements except the cables
- AASHTO Standard Specifications for Highway Bridges, 17th Edition, 2002 for the cables.
- AASHTO LRFD Guide Specifications for the Design of Pedestrian Bridges, 2nd Edition 2009 with 2015 Interim Revisions
- AASHTO Guide Design Specifications for Bridge Temporary Works, 2nd Edition, 2017
- California Amendments (to the AASHTO LRFD Bridge Design Specifications – 6th Ed.), March 2014
- Caltrans, Seismic Design Criteria Version 1.7, April 2013 (CA SDC)
- Caltrans, Seismic Design Specifications for Steel Bridges, 2nd Ed. 2016 (CA GSSDSB)

- Caltrans, Bridge Memo to Designers (Seismic Design Methodology per MTD 20-1)
- Caltrans, Bridge Design Aids, August 2016
- Caltrans, Bridge Design Practice, 4th Ed., 2015 (CA BDP)
- Caltrans Standard Specifications, 2015
- ACI 318-14 Building Code Requirements for Structural Concrete and Commentary, 2014
- AASHTO Guide Specifications for LRFD Seismic Bridge Design, 2nd Ed., 2011 (AASHTO Guide Specs)
- AASHTO Guide Specifications for Seismic Isolation Design, 4th Ed., 2014
- AISC Steel Construction Manual, 14th Ed., 2011 (AISC)
- ANSI / AASHTO / AWS D1.5, Bridge Welding Code (Bridge Welding Code)
- ANSI / AASHTO / AWS D1.1, Structural Welding Code (Structural Welding Code)
- ANSI / AASHTO / AWS D1.4, Rebar Welding Code (Rebar Welding Code)
- ANSI / ASCE 7-16, Minimum Design Loads for Buildings and Other Structures, 2016
- Tulare and Kern County Standards for Structural Materials

3.5.2 Structural Materials

Structural materials are anticipated to meet the following requirements. However, as preliminary design progresses material requirements may be revised.

3.5.3 Concrete

- Structural Applications (with exception of bridge decks) – 4,000 lbs per square inch (psi)
- Bridge Decks – 4,500 psi
- Prestressed Concrete – 5,500 psi
- Prestressed concrete shall meet load factor design requirements and be limited to the following allowable stresses:
    - Temporary stresses during construction and before losses:
    - f'ci = 3500 psi min. at time of prestressing operations
    - fci = 0.60 f'ci compression for pretension members
    - fci = 0.55 f'ci compression for post-tensioned members
    - fci = $3\sqrt{f'ci}$ tension

Bridge Design Criteria

The documents as presented in **Section 3.5.1** will form the basis for design and construction of the bridges, including coordination and design reviews with Tulare and Kern County, and Caltrans where applicable.

In general, the Load and Resistance Factor Design (LRFD) method as required by AASHTO will be used for the design of all bridges. Live load deflection, steel fatigue limits and concrete crack control shall be checked to ensure serviceability of the bridge. Independent design checks in accordance with Caltrans policy shall be performed to ensure design accuracy, as well as drawing and specification quality. Bridge design loads shall be based on unit weights of materials and the computed volumes of the structural elements as follows:

A. Dead Loads

- Concrete, Reinforced or Prestressed: Normal Weight Concrete = 150 pcf
- Fabricated Plate Steel = 490 pcf
- Rolled Shapes = 490 pcf
- Wire or strand = 490 pcf

B. Added Dead Load

- Steel Components = 490 pcf
- Concrete Curb/Barriers = 150 pcf
- 3 inch asphalt wearing surface (if applicable) = 36 psf
- Maintenance facilities and utilities = Actual Weight
- Provision for future utilities = 25 plf

C. Live Loads

- The bridge will be designed for HL-93 standard truck and lane loads and other applicable permit live load as per the AASHTO LRFD Bridge Design Criteria. All design live loads shall be positioned both transversely and longitudinally so as to produce the maximum influence on the structure.

D. Pedestrian Live Loads

- Pedestrian loads of 90 psf shall be included in the design.

E. Impact/Dynamic Load Allowance

- Dynamic load allowance will be applied in accordance with the Section 3.6.2 of AASHTO LRFD Bridge Design Specifications.

F. Seismic Demands on Structural Components: Seismic demand is represented using an elastic 5% damped response spectrum. In general, the Design Spectrum is defined as the greater of:

- A probabilistic spectrum based on a 5% in 50 years probability of exceedance (or 975-year return period.
- A deterministic spectrum based on the largest of median response resulting from the maximum rupture (corresponding to Mmax) of any fault in the vicinity of the bridge site
- A statewide minimum spectrum defined as the median spectrum generated by a magnitude 6.5 earthquake on a strike-slip fault located 12 kilometers from the bridge site.

Development of the design spectrum requires special knowledge related to the determination of fault location and interpretation of the site profile and geologic setter for incorporation of site effects. These aspects of the design spectrum will be coordinated with the geotechnical engineer for the project.

Two seismic design methodologies are available:

- Force Based Design Method: AASHTO LRFD Bridge Design Specifications
- Displacement Based Design Method: AASHTO Guide Specifications for LRFD Seismic Bridge Design & Caltrans Seismic Design Criteria

The seismic design requirements presented by Caltrans Seismic Design Criteria Version 1.7, April 2013 (CA SDC) will form the basis for seismic demands on all structural components, capacity of structure components, analysis, foundation performance, design and detailing of the bridges.

4. ANALYSIS

4.1 Gradually-Varied Flow Analysis

Design alternatives have been analyzed using HEC-RAS and other numerical analysis tools. HEC-RAS modeling has been applied to the existing canal condition and to the various alternative designs as they have been developed, yielding water surface profiles for different flow rates. These studies have provided extensive information to evaluate technical and economic feasibility. **Attachment A1a1** contains the *Draft Friant-Kern Canal Subsidence Correction Project HEC-RAS Modeling Technical Memorandum, by Stantec., 15-March-19.* As described in **Section 2.5.1** above, enlarged canal cross sections in highly subsided areas combined the lower portion of the existing canal with a new raised and widened section above a horizontal bench. HEC-RAS models were based on the modified compound trapezoidal sections as per the descriptions in Section 5 above. For all capacity correction alternative designs, HEC-RAS modeling used design flow rates shown in **Table 3-1**.

In addition to HEC-RAS, simpler analysis methods were used to establish and evaluate designs. Analysis tools were developed to quickly study multiple canal sections, hydraulic properties, and flow rates. These hydraulic computations yielded normal depths and velocities in prismatic reaches of canal, head losses through structures, sensitivity to different friction factors, effects of sedimentation, and effects of possible design modifications.

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5. CONSTRUCTABILITY

A contractor with extensive large canal lining experience briefly reviewed Alternative 1 - Enlargement of the existing canal by widening and raising and Alternative 5 - New parallel Canal for constructability. The contractor found both alternatives to be constructible utilizing existing and proven construction methods. Specific comments made for each alternative are listed below.

5.1 Alternative 1 – Raise/Widen

The existing canal can be enlarged and raised as outlined herein utilizing existing construction methods. However, the ROW limitations and the requirement to maintain acceptable water deliveries will impact the constructability requiring phasing of the work, an extended overall construction time frame.

- Much of the earthwork and structure work could be undertaken within a normal work schedule.
- Based upon a very preliminary estimate, once the preparatory work is complete, a contractor could complete at least 7 miles of canal and the affected portions of structures in any given 2-month window.
- Multiple shifts would be required during the reduced delivery periods to accomplish the work required that is below the normal flow surface. The longer the reduced flow window is available, the more efficient the work would be which would have a direct impact on construction cost.

Zero-clearance trimming and paving against the existing canal slope has been done for literally hundreds of miles during the raising of the California Aqueduct in the 1980’s.



Figure 5-1 - Zero Clearance Trimming and Paving Against Existing Canal Slope on the California Aqueduct

5.2 Alternative 5 – Parallel Canal

A new parallel canal can be constructed utilizing existing construction methods as shown in **Figure 5-2**. Significantly more ROW would be needed for the construction of a parallel canal, however there would be substantial constructability benefits as outlined herein.

- Given adequate ROW, building a new parallel canal would be much less difficult to construct than Alternative 1.
- Existing canal construction methods can be directly and efficiently applied as the canal would be constructed totally unrestricted by operations and water delivery requirements.
- The work would be completed in a substantially shorter construction window and likely not cost much more while yielding a state-of-the-art finished product.
- The only phasing required would be the tie-ins at the beginning and the end of the project.
- The re-alignment and lining of the All American Canal in 2007-08 is a perfect example of the end result.



Figure 5-2 - The Re-alignment and Lining of the All American Canal in 2007-08 is a Perfect Example of the End Result

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6. ISSUES FOR FUTHER CONSIDERATION

This section provides a "parking lot" for issues that shouldn't be lost or forgotten as the design progresses.

6.1 High Velocity in Existing Canal

Differential subsidence has increased channel slope in portions of the existing canal. In alternatives where these steep segments will remain in use, high velocity must be addressed in the design. Where velocities would exceed the allowable velocity of 6 ft/s, steep sections of the existing canal would need to be modified.

6.2 Earthwork

Earthwork volumes were computed for all canal sections, which vary between the different design alternatives. For enlargement modifications to the existing canal, the new HGL elevation and resulting top-of-bank elevation was combined with the existing canal invert. Through subsided areas, this existing invert is lower than the theoretical level of the prismatic canal design section that has a constant bottom slope. This lower invert creates a deeper and wider canal section for which earthwork volumes were computed.

6.3 Locations for Design Capacity Reductions

As was typical for Reclamation canal designs, the original design carried a constant design flow rate through the end of each canal reach. This strategy is appropriate when maximum flows (e.g. from uncontrolled flood inflows to the canal) must be carried to the end of a reach where excess flow is spilled through a wasteway. However, a specified flow rate representing a water delivery condition will taper more gradually as water is diverted through turnouts. Therefore, the maximum canal capacity can also taper through the length of some reaches instead of suddenly reducing by 500 cfs or 1,000 cfs from one reach to the next. Applying this strategy to normal design capacity will better predict the actual operating conditions, saving head and realistically reducing the design HGL elevation upstream.

The above logic was applied to study a more realistic maximum flow between Highway 99 Siphon and Poso Creek. Although the original design used 3,500 cfs for the maximum flow condition all the way to Poso Creek (to pass flood flow to the wasteway there), design maximum flow rate was reduced to 3,000 cfs at Highway 99 for these studies. This flow reduction seems more realistic and saves head through this canal segment and through the Highway 99 siphon, which reduces the size of the canal in this segment and further upstream.

Table 3-1 in **Section 3** shows design flow rates used to develop HGL profiles for design alternatives.

6.4 Modifications to Poso Creek Check and Siphon

Future capacity improvements downstream of the Lake Woollomes Check should include an evaluation of an option to eliminate the Poso Creek Siphon by constructing the canal across Poso Creek (possibly a flume) and constructing culverts to take Poso Creek flows under the canal.

6.5 Compound Trapezoid Refinement

The compound trapezoid section may have excess flow area along lengths of the existing FKC where the deeper subsidence conditions exist. Once all current and future bridge losses are accounted for, the bench portion of the trapezoidal section might be reduced. This would reduce cost and the amount of new ROW that may be required.

6.6 Common HGL

Maintaining the common HGL that has been established is important in order to meet the required boundary conditions but, it also allows considerable flexibility to interchange alternatives and elements of alternatives for economic and/or sequencing benefits.

6.7 Differential Subsidence in the Area of Kimberlina Road

Future capacity improvements downstream of the Lake Woollomes Check will need to address the differential subsidence (greater than 2 ft) that has occurred in the area of Kimberlina Road in Kern County.

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2018c Draft Friant-Kern Canal Subsidence Correction Project HEC-RAS Modeling Technical Memorandum. Stantec. 25-October-18.

Provost and Pritchard

2018a Friant-Kern Canal Active Turnouts Inventory. Provost and Pritchard. September-18.

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Attachment A1 Exhibit A.1

HEC-RAS Modeling TM

Friant-Kern Canal

Middle Reach Capacity Correction Project

Technical Memorandum

Submitted to: Friant Water Authority



March 15, 2019

Stantec

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Project: Friant-Kern Canal Capacity Correction Project

Subject HEC-RAS Modeling Technical Memorandum

Date: March 15, 2019

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Abbreviations and Acronyms

cfs	Cubic Feet per Second
d/s	downstream
EPDM	Ethylene Propylene Diene Monomer
FKC	Friant-Kern Canal
fps	Feet Per Second
ft	Foot/Feet
FWA	Friant Water Authority
HDPE	High-density polyethylene
HEC-RAS	Hydrologic Engineering Center River Analysis System
HGL	Hydraulic Grade Line
MP	Milepost
NAVD 88	North American Vertical Datum of 1988
PVC	Polyvinyl Chloride
Reclamation	United States Department of the Interior, Bureau of Reclamation
RM	River Mile
sq ft	Square Foot

Abbreviations and Acronyms

STA	Station
TM	Technical Memorandum
TO	Turnout
u/s	upstream
WSEL	Water Surface Elevation

1. INTRODUCTION

This Technical Memorandum (TM) presents the hydraulic design parameters and methods that were applied to the various hydraulic models in support of alternative evaluation and preliminary design for subsidence correction to the middle reach of the Friant-Kern Canal (FKC). The FKC is an irrigation delivery system located in Central California. This canal delivers water from Friant Dam of Millerton Lake, north of Fresno, south along the eastern edge of the San Joaquin Valley to the Kern River near Bakersfield.

Stantec was retained to investigate the causes of capacity reduction within the FKC middle reach and provide capacity improvement recommendations. The entire 152-miles of FKC is divided into four reaches as shown on **Figure 1.1** and described below:

1) Immediate Repair, approximately 4 miles, milepost (MP) 102 to MP 106,
2) Upper Reach, approximately 88 miles, MP 0 to MP 88.22,
3) Middle Reach, 34 miles from MP 88.22 to MP 121.51, and
4) Lower Reach, 30 miles from MP 121.51 to MP 152.

The intent of this TM is to present the current HEC-RAS model input parameters already established in the 2017 base subsidence model and document current (2018) updates to the existing condition and proposed alternative subsidence correction modeling efforts.

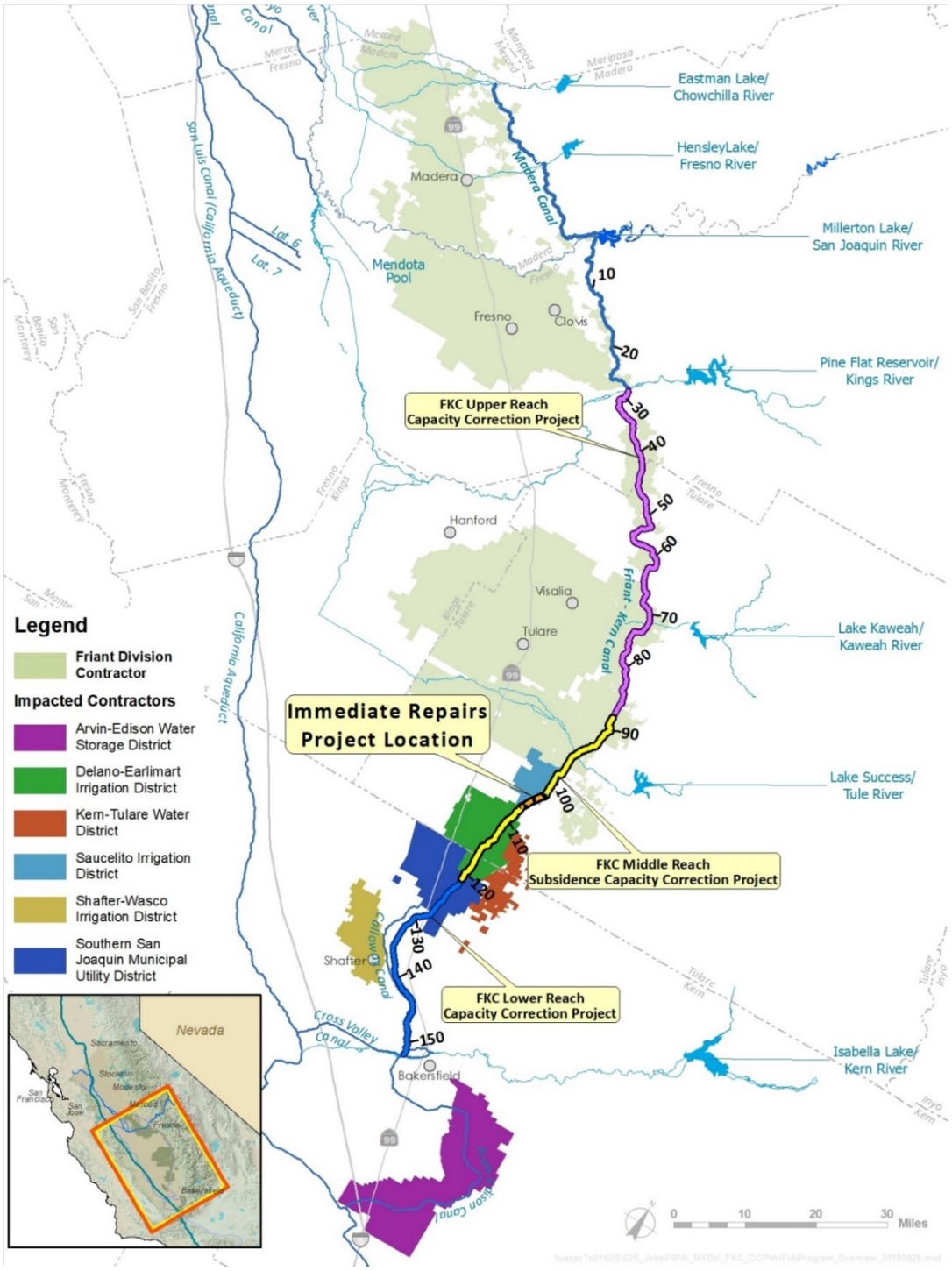


Figure 1-1 - Location Map

1.1 Data Collection

Friant Water Authority (FWA) provided several data sets as well as some observations of operational constraints for the FKC middle reach.

1.1.1 Operational Constraints

Operational constraints reported by Friant Water Authority are provided below in ***Section 2.2***.

1.1.2 Data Collected from FWA

The following data was collected from FWA:

- Existing condition 2017 HEC-RAS base model for the entire 152 miles of FKC
- Listing of existing turnouts located within the middle reach of FKC
- Listing of drainage inlets and overchutes located within the middle reach of FKC
- Listing of abandoned turnouts located within the middle reach of FKC

The 2018 updates are listed below in ***Section 2*** and are based on current observed physical conditions of the system, experience with similar Reclamation projects, best practices and current codes.

1.1.3 Data Collected from Other Sources

The following data was collected from the sources listed below in support of HEC-RAS modeling:

- 2018 survey data, performed by Towill Inc. and consisting of:
    - Top of concrete lining shots at every structure and every ½ mile
    - Bridge deck and low chord elevations
- Check Structure record drawings
    - This data was previously input into HEC-RAS. Final design may provide scope to survey the existing check structures and confirm / verify correct coding in HEC-RAS, depending on the recommended alternative.

- Siphon Structure record drawings
    - This data was previously input into HEC-RAS. Final design will provide scope to survey the existing check structures and confirm / verify correct coding in HEC-RAS.
- Turnout Structure information
    - Locations of turnouts, delivery obligations, including required FKC WSEL data was not previously input into HEC-RAS. Final design will provide scope to survey the existing turnout structures and confirm / verify correct coding in HEC-RAS.
- Structure locations were confirmed / verified using Google Earth overlay on the Construction Station control. Further verification and adjustments will be made during final design.

2. EXISTING CONDITION MODEL

FWA provided Stantec with a copy of the existing condition HEC-RAS model for the entire 152-mile reach. The prior model is known as the 2017 base subsidence model.

2.1 2018 Updates for Entire 152-Mile Reach

The existing condition Friant-Kern 2017 base subsidence model was updated to reflect several current existing conditions that were not previously modeled. The 2018 overall model updates include:

- Elevation adjustments to North American Vertical Datum of 1988 (NAVD 88)
- Design rates of flow

A general review of the 2017 base model was performed with respect to modeling approach of existing structures and parameters. The existing HEC-RAS model was trimmed to only include the lower and middle subsidence correction reaches. The lower reach (Kern River to Woollomes) influences upstream capacity due to backwater above the Poso and Highway 99 siphon structures. Stantec understands downstream restrictions can be eliminated in the future, but felt providing some insight to these issues would be helpful.

2.2 2018 Updates to the 64-Mile Middle and Lower Reaches

Improvements to FKC upstream of Fifth Avenue Check (MP 88.22) are not included in the Middle Reach updates. As such, the model improvements modeled were truncated to exclude anything above the Fifth Avenue Check. Due to potential backwater above Poso and Highway 99 siphon structures, the existing condition Friant-Kern 2017 base subsidence modeling efforts included the lower and middle reaches from Fifth Avenue Check at MP 88.22 all the way downstream to Kern River at MP 151.81. This 64-mile reach, consisting of the middle / subsidence and lower reaches, was then updated to reflect the following 2018 existing condition model updates:

- Longitudinal distances between modeled structure locations were adjusted
- Four existing public bridge crossings were added
- Physical elevations were updated to account for current subsidence conditions by:
    - adjusting top of canal lining to match the 2018 Towill survey at every structure and ½ mile
    - adjusting existing structure elevations to match 2018 Towill survey
    - adjusting existing bridge low chord elevations to match 2018 Towill survey

Miscellaneous 2018 model updates to the middle and lower 64-mile reach included:

- Cross section names revised to match historic river mile designations
- Existing turnout locations hard coded into the existing geometry data
- Required hydraulic delivery elevation markers added at each turnout location
- Update summary comments added to RAS input description cells

The 2018 model updates were limited to our study reach or as described below. Specific detail of 2018 updates are described below.

2.2.1 RATE OF FLOW

The models are updated to run the magnitudes of flow shown in **Table 2-1.**

Table 2-1 - Design Flow Rate

Canal Section No.	Canal Reach (Milepost to Milepost)	Description (Check to Check)	Normal Flow Rate (cfs)	Design Max Flow Rate (cfs)	Minimum Flow Rate (cfs)
4	88.22 to 95.67	Fifth Ave. CK to Tule	3,500	4,500	500
5	95.67 to 112.90	Tule to White River	3,000	4,000	500
6.1	112.90 to 128.69	White River to HWY 99	2,500	3,500	500
6.2	128.69 to 130.03	HWY 99 to Poso	2,500	3,000	500
7	130.03 to 151.81	Poso to Kern River	(Exist = 1,200) 2,000	1,200 (existing) 2,000 (improved)	500
Key: cfs – cubic feet per second					

FWA directed Stantec to consider the design maximum flow rate, which includes design delivery flow (normal flow rate) plus Class 2 flow for any alternative intended to increase the FKC delivery capacity. Class 2 water is defined as "*The supply of water which can be made available for delivery from Millerton Lake and the Friant-Kern and Madera Canals in addition to the supply of Class 1 Water. Because of its uncertainty as to availability and time of occurrence, such water will be undependable in character and will be furnished only if, as, and when it can be made available as determined by the Contracting Officer"* per the United States Department of the Interior, Bureau of Reclamation (Reclamation) Water Management Planner (2017). Canal lining depths established in the HEC-RAS modeling equate to the normal flow depth at the design maximum flow plus the established lining freeboard criteria.

It should be noted that the middle reach alternative improvements modeled and discussed in later sections of this report are influenced by the capacity of the lower reach. It is estimated that an un-improved lower reach (MP 121.51 to MP 151.81) can pass about 1,200 cfs before backwater overcomes the operational WSEL of 399.1, or 16-feet deep, at Woollomes Check (MP 121.51).

Our design team took this opportunity to investigate enlarged channel improvements downstream of the Woollomes Check (MP 121.51 to MP 151.81). Existing capacity limitations

shown in this report for MP 121.51 to MP 151.81 were arrived at by assuming similar enlarged canal geometry as shown in **Figure 4.1** get applied while keeping the existing siphon structures at Highway 99 and Tule. The large head losses at these existing structures shown on **Figure 4.2** suggest increasing capacity of these structures could increase the downstream capacity limitations suggested in this memo. Final design of the downstream reach improvements for MP 121.51 to MP 151.81 will ultimately determine this capacity limitation.

2.2.2 2018 GEOMETRY UPDATES

The 2017 base model was truncated to the lower 64 miles (FKC Middle and Lower reaches). The following geometry revisions are included in the 2018 updates.

2.2.2.1 Manning's roughness coefficients

HEC-RAS utilizes Manning's equation to compute water surface elevations and frictional losses of open channel systems. The following Manning's n-values were applied to the 2018 update:

- Plastic liner: n = 0.010 (bare plastic, HDPE, PVC, EPDM or other)
- Concrete lined channel: n = 0.016 (accounts for sediment, weed growth and clams)
- Earthen channel: n = 0.025 – 0.035 (depending on dune / anti-dune height)
- Earthen overbank: n = 0.035

2.2.2.2 Contraction and expansion coefficients

Contraction or expansion coefficients are used to estimate hydraulic losses caused by non-uniform channel geometry within a reach. For a lined canal of uniform geometry, contraction and expansion coeffects are negligible and were set to zero within HEC-RAS. Slight geometry changes such as gradual transitions were modeled with the RAS default of 0.1/0.3 for coefficient of contraction / expansion, respectively. **Table 2-2** illustrates the contraction and expansion coefficients types applied to the 2018 model update. **Table 2-3** specifies the contraction and expansion coefficients assigned to each reach within the 2018 model update.

Table 2-2 - Contraction / Expansion Coefficients

Transition Type	Longitudinal Transition Rate (length : contraction)	Contraction Coefficient	Expansion Coefficient
Uniform Canal Geometry	Uniform channel geometry	0	0
Gradual Transition	3:1 contraction 4:1 expansion	0.1	0.3
More than gradual	2:1 contraction 3:1 expansion	0.2	0.4
Typical Bridge Transitions, for riverine systems	1:1 contraction 2:1 expansion	0.3	0.5

Table 2-3 - Contraction Expansion Coefficients Assigned to Existing HEC-RAS Model

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	STRUCTURE
88.208	88.231	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Fifth Ave Check
88.231	89.680	0	0	Uniform Section	
89.680	89.686	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	A.T.&S.F. R.R. Siphon Inlet
89.686	89.706	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	A.T.&S.F. R.R. Siphon
89.706	89.713	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	A.T.&S.F. R.R. Siphon Outlet
89.713	90.820	0	0	Uniform Section	
90.820	90.826	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	S.P.R.R. Siphon Inlet
90.826	90.865	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	S.P.R.R. Siphon
90.865	90.872	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	S.P.R.R. Siphon Outlet
90.872	94.850	0	0	Uniform Section	
94.850	94.856	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
94.856	94.877	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
94.877	94.883	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
94.883	95.662	0	0	Uniform Section	
95.662	95.669	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
95.669	95.749	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
95.749	95.758	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
95.758	102.682	0	0	Uniform Section	
102.682	102.696	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
102.696	102.727	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	STRUCTURE
102.727	102.735	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
102.735	112.873	0	0	Uniform Section	
112.873	112.892	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon Inlet
112.892	112.899	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
112.899	112.932	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon Inlet
112.932	112.943	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
112.943	121.497	0	0	Uniform Section	
121.497	121.521	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Woollomes Check
Key: MP – Milepost STA – Station					

2.2.2.3 Elevation adjustments to cross sections

After adjusting HEC-RAS elevations to NAVD 88, all cross section data for the lower 64-mile long reach were updated for current subsidence as measured by the 2018 Towill survey. Surface elevations at all siphon headwalls, check structures and bridge decks along with low chord of bridges were surveyed. The top of canal lining was surveyed at every structure and at ½ mile increments. The 2018 updates include elevation adjustments as reported by the 2018 Towill survey. The modeled cross section inverts were estimated using the record drawing lining heights and applying the magnitude of surface subsidence found resulting from the Towill survey.

2.2.2.4 Adjustments to cross section locations and identification

The HEC-RAS cross sections were renamed to correspond to the existing river mile stationing. The distances between structures were reviewed and revised to match current longitudinal distances. It should be noted that the cumulative distances do not exactly reproduce the historic river mile (RM) designations. The 2018 model updates do include current longitudinal distances between cross sections along with cross section identifiers set to match historic RM markers.

2.2.2.5 Existing turnout locations added

Existing turnout locations and gate sizes documented in the 2018 P&P document entitled "*Friant-Kern Canal Active Turnouts*" are repeated in **Table 2-4**. These turnout locations were then hard coded into the HEC-RAS geometry and labeled as T/O for turnout.

Table 2-4 - Existing Turnouts

Turnout (T/O) Location			Number of Gates and Sizes	Required Delivery	
Mile Post	Const. STA	T/O Direction		Max Q (cfs)	HGL (ft)
89.35	4832+85	West	1 - 20"	3	408.2
91.12	4926+17	East	4'x4'	22	408.2
91.12	4926+17	West	2 - 4.5'x4.5'	72	408.2
92.13	4979+67	West	2 - 7'x7'	557	408.2
93.86	5070+41	West	2 - 4.5'x4.5'	25	408.2
94.92	5126+75	West	2 - 5'x5'	52	408.2
95.50	5157+99	East	1 - 4.5'x4.5'	32	408.2
95.63	5166+77	West	Weir	764	408.2
95.64	5166+77	West	4 - 11'x10.75'		408.2
95.78	5172+34	West	3-4'x4'	270	403.3
96.39	5204+25	East	1-36"	24	398.5
96.87	5229+51	West	2-4.5'x4.5'	203	403.0
97.35	5255+02	West	2 - 4.5'x4.5'	40	398.9
97.86	5281+91	East	1-36"	8	391.9
98.62	5322+16	West	3 - 4.5'x4.5'	237	399.0
99.37	5360+89	East	1 - 3'x3'	38	397.5
100.64	5428+88	West	2 - 4'x4'	82	391.6
102.65	5534+69	East	1 - 3'x3'	52	389.6
102.65	5534+69	West	2 - 4.5'x4.5'	102	390.8
103.64	5587+33	East	Pumping plant	111	390.2
104.96	5656+99	West	2 - 4'x4'	77	387.3
107.35	5782+98	East	2 - 3.5'x3.5'	13	386.6
109.46	5894+58	East	1 - 4.5'x4.5'	29	394.3
109.46	5894+60	West	2 - 4.5'x4.5'	110	394.3
111.56	6005+41	East	1 - 4'x4'	22	391.9
111.56	6005+43	West	2 - 4.5'x4.5'	86	392.5
111.96	6031+98	East	1 - 4'x4'	22	398.9
112.36	6058+95	West	2 - 4.5'x4.5'	42	391.0
112.90	6076+77	East	10' x 11' Tantor	29	397.0
112.90	6076+77	West	2-10'x11' Tantor		N/A
113.60	6112+60	East	1 - 4.5'x4.5'	52	403.1
113.62	6114+09	East	1 - 4.5'x4.5'	39	391.5
113.62	6114+09	West	2 - 4.5'x4.5'	113	390.6
115.95	6236+79	West	2 - 4'x4'	110	392.7
116.93	6288+03	West	3 - 4.5'x4.5'	23	395.9
117.44	6315+39	West	2 - 4.5'x4.5'	39	400.7
117.96	6342+98	East	1 - Unknown	59	392.1

Turnout (T/O) Location			Number of Gates and Sizes	Required Delivery	
Mile Post	Const. STA	T/O Direction		Max Q (cfs)	HGL (ft)
118.45	6369+07	West	1 - 3'x3'	30	390.8
119.55	6425+52	East	4 - 2.5'		398.0
120.06	6453+98	West	2 - 4.5'x4.5'	82	390.6
121.49	6530+32	East	2 - 3'x3'		395.0
122.06	6559+60	East	2 - 3.5'x3.5'	92	389.2
122.06	6559+60	West	2 - 4.5'x4.5'	115	390.1
124.28	6676+83	West	2 - 4.5'x4.5'	96	390.1
124.28	6676+83	East	2 - 4.5'x4.5'	92	390.2
125.29	6729+88	East	2 - 4'x4'		389.4
125.87	6760+81	West	2 - 3'x3'	31	388.5
126.38	6787+77	East	1 - 36"		392.7
127.43	6843+05	West	1 - 3.5'x3.5'	36	388.7
127.97	6871+66	East	1 - 4.5'x4.5'	59	389.6
130.03	6980+18	West	2 -10'x13' Tantor	297	394.2
134.42	7211+99	West	3 - 4'x4'	163	386.0
137.17	7357+18	West	3 - 4'x4'	189	386.0
144.91	7764+70	West	3 - 8' (need to confirm)	571	389.2
150.38	8076+72	West	1 - 3'x3'		381.8
151.80	8126+70	West	2 - 5'x5'	1,031	380.7
Key: cfs – cubic feet per second ft – feet STA – Station TO – turnout					

The maximum delivery rate of flow listed above was provided by FWA resulting from the historical maximum daily delivery recorded between January 2003 and August 2017. Turnout locations upstream of Tule (MP 89.35 to 95.64) were not included in the P&P turnout data (2018) and need to be surveyed during final design. The unknown data will be determined during final design.

2.2.2.6 Required hydraulic delivery elevations added

It was desired to report required hydraulic delivery elevations, also known as required hydraulic grade line (HGL), for each turnout location. The required delivery elevations were estimated by applying the following:

- Comparing the 2018 P&P top of lining survey elevation to the 2018 Towill top of lining survey and adjusting the P&P turnout structure floor elevation to match 2018 Towill survey.
- Assuming turnout gate invert is located 1.5 ft above turnout floor
- Setting the required turnout HGL at 2-ft above top of turnout gate

This information will be confirmed during final design.

2.2.2.7 Canal Lining Freeboard

The FKC is currently, and will be, operated to meet variable flow demands. For future design improvements, the proposed lining height needs to provide the minimum lining freeboard shown in **Table 2-5**. These values are based on the maximum design rate of flow, which includes rainfall runoff flow that is intended on remaining in the system. For existing condition flow profiles, the minimum lining freeboard values reported in **Table 2-5** were used to evaluate potential lining height increases.

Table 2-5 - Required Freeboard

Canal Section No.	Canal Reach (Milepost to Milepost)	Description (Check to Check)	Design Maximum Flow Rate (cfs)	Required Lining FB (ft)	Required Earthen FB (ft)
4	88 to 95.67	Fifth Ave. CK to Tule	4,500	2.35	1.60
5	95.67 to 112.90	Tule to White River	4,000	2.29	1.50
6	112.90 to 128.69	White River to Poso	3,500	2.23	1.45
7	128.69 to 151.60	Poso to Kern River	2,000	1.95	1.23
Key: cfs – cubic feet per second ft – feet					

2.2.2.8 Structures

The structures included in the 2017 base HEC-RAS model were carried forward into the 2018 update. Check structures and siphon structures were not updated, other than elevation change due to subsidence survey and longitudinal location as reported above. Entrance and exit (contraction/expansion) transitional losses to structures were revised to match the transitional losses reported above in the 2018 updated models. The majority of the structure revisions and/or updates relate to bridges.

Several bridges and/or siphon structures were modeled with a cross section lid. This approach of modeling bridges and/or closed pressure flow conduits is confirmed to be appropriate for modeling pressure flow once the cross section lid becomes submerged in HEC-RAS.

Further description of structure parameters adjusted in the 2018 update are detailed below.

2.2.2.8.1 Bridge Structures

The 2018 model updates for bridge structures include two categories: (1) bridge locations already modeled and (2) bridge locations added to model.

2.2.2.8.1.1 Bridge locations already modeled

The 2018 HEC-RAS model updates to bridge locations already modeled include:

- Moving the longitudinal location of bridge to correctly match the geophysical location of each bridge and in relation to adjacent upstream and downstream structures
- Adjusting the elevation of the bridge deck and low chord to match 2018 Towill survey
- Updating cross section geometry to account for existing bridge piers
- Updating cross section geometry to correctly model upstream and downstream transitions

2.2.2.8.1.2 Bridge locations added to model

The 2018 HEC-RAS model updates include the addition/modification of the following bridge locations:

- Olive Drive: Added a new bridge at STA 7939+42 that was not previously modeled
- Jet Way: Added a new bridge deck at STA 8075+89 that was not previously modeled
- Rosedale HWY 48: Added a new bridge deck at STA 8065+73 that was not previously modeled
- Coffee Rd: Added a new bridge deck at STA 8045+67 that was not previously modeled
- Hageman Rd: Added a new bridge deck at STA 7999+62 that was not previously modeled
- Snow Rd: Widened existing bridge deck at STA 7875+64 to match current bridge width
- Seventh Standard Rd: Widened existing deck to model parallel bridge not previously included
- Farm Bridge: Existing RAS modeled bridge at STA 6760+00 was removed
- State HWY 65 Bridge: Widened existing deck to model the parallel bridge not previously included

2.2.2.8.1.3 Modeling of bridge piers

Bridges were modeled two different ways in the 2017 HEC-RAS base model. Sometimes they were coded as in-line structures using the RAS bridge editor, which is the method recommended in the HEC-RAS User Manual. Some of the existing bridge locations were coded using the cross-section lid option rather than coding as an in-line bridge structure within HEC-RAS. Modeling a bridge with a cross section lid is an acceptable time savings approach. However, when coding a bridge with a cross section lid, bridge piers should be modeled using the obstructed flow option rather than editing the cross section data to hard code the bridge pier as a wall into the cross section. HEC-RAS models hydraulic losses differently for cross section walls and bridge piers or obstructions. Additionally, a cross section needs to be added at each face of the bridge deck (lid).

The 2018 HEC-RAS model updates include the geometry refinements listed above at bridge locations coded with the lid option.

2.2.2.8.1.4 Modeling of bridge decks

The 2018 HEC-RAS model updates include revisions to all bridge decks for the following parameters:

- Bridge deck elevations adjusted to 2018 Towill survey (NAVD 88)
- Bridge low chord elevations adjusted to 2018 Towill survey (NAVD 88)
- Bridge longitudinal locations confirmed using 2018 Google Earth and construction stationing
- Bridge deck widths confirmed using 2018 Google Earth

2.2.2.8.2 Check Structures

The 2018 model updates for check structure include:

- Vertical adjustments to correct surface elevations to 2018 Towill survey (NAVD 88)
- Longitudinal adjustments to correct for physical location in relation to adjacent upstream/downstream structures

Future updates for low flow runs can be input using rating curves, rather than modeling physical check structure geometry changes or estimating a gate positions and frictional coefficients.

2.2.2.8.3 Siphon Structures

The 2018 model updates for siphon structures include:

- Vertical adjustments to update surface elevations to 2018 Towill survey (NAVD 88)
- Longitudinal adjustments to correct for physical location in relation to adjacent upstream/downstream structures

2.2.2.8.4 Drainage Inlet Structures and Overshoots

No HEC-RAS model updates were made to represent drainage inlet structures and drainage overshoots crossing the canal. FWA provided the following list of drainage structures, but these structure locations were not included in the 2018 Towill survey. Drainage structures that may affect flow capacity of the FKC:

- Drainage Inlet near MP 102.23 (STA 5510+00) – need to determine if this inlet is properly plugged
- Drainage overshot or utility bridge near MP 133.70 (7187+00) – need to determine potential flow constraint at this location
- Drainage Inlet near MP 134.20 (STA 7215+00) – need to determine if this inlet is properly plugged

- Drainage overshot or utility bridge near MP 134.52 (7230+00) – need to determine potential flow constraint at this location
- Reported drainage structure near MP 138.12 (STA 7420+00) – need to confirm this location

It is recommended that final design survey and incorporate vertical elements of these locations into HEC-RAS modeling.

2.2.2.8.5 Siphon structures crossing under FKC

No HEC-RAS model updates were made to represent drainage or perpendicular siphon structure(s) crossing beneath the FKC. These structure locations are similar to other utility crossings beneath the FKC and they do not affect HEC-RAS hydraulic modeling efforts. The horizontal locations can be observed by inspection of Google Earth and are not being provided in the HEC-RAS model. The vertical constraints and clearances will be confirmed during final design.

2.2.2.9 Utility Crossings

Various utilities cross and/or parallel the FKC. No HEC-RAS model updates were made to represent utilities and/or crossings in the vicinity of this canal. Documenting locations of utilities and or crossings is not required for HEC-RAS modeling unless they are found to cause a flow restriction. Horizontal and vertical locations of utilities will be identified during final design.

2.2.3 MODELING RESULTS FOR THE 2018 EXISTING CONDITION UPDATES

Key water surface profile elevations and corresponding hydraulic parameters for the Existing Condition (2018 Towill survey) FKC are summarized in **Table 2-6**.

Table 2-6 - Summary of HEC-RAS Hydraulic Results for 2018 Existing Conditions

Mile Post	Location	Q (cfs)	WSEL (ft)	Vel (fps)	Area (sq ft)	Froude No	Lining EL (ft)	Lining FB (ft)	Req FB (ft)
88.208	Fifth Ave Check (u/s)	3,500	413.92	4.44	787.6	0.24	416.71	2.79	2.23
88.231	Fifth Ave Check (d/s)	3,500	413.74	4.53	772.6	0.24	416.71	2.97	2.23
89.680	RR Siphon (u/s)	3,500	412.82	4.60	761.1	0.25	415.97	3.15	2.23
89.713	RR Siphon (d/s)	3,500	412.72	3.17	1,105.1	0.16	415.68	2.96	2.23
90.820	RR Siphon (u/s)	3,500	411.97	4.65	752.3	0.25	415.22	3.25	2.23
90.872	RR SIPHON (d/s)	3,500	411.61	4.59	762.4	0.25	414.77	3.16	2.23
94.850	Porter Creek Siphon (u/s)	3,500	408.74	4.67	748.9	0.25	412.04	3.30	2.23
94.883	Porter Creek Siphon (d/s)	3,500	408.49	4.59	761.8	0.25	411.63	3.14	2.23
95.662	Tule River CK/Siphon (u/s)	1,900	408.37	2.29	828.1	0.12	410.60	2.23	1.92

95.758	Tule River CK/Siphon (d/s)	1,900	402.84	3.82	497.7	0.24	410.13	7.29	1.92
102.682	Deer Creek CK/Siphon (u/s)	1,900	401.50	1.70	1,118.6	0.08	402.50	1.00	1.92
102.735	Deer Creek CK/Siphon (d/s)	1,900	400.74	1.78	1,068.9	0.09	402.64	1.90	1.92
104.249	Subsidence Reach "Pinch Point"	1,900	400.58	1.51	1,258.5	0.07	401.45	0.87	1.92
104.757	Subsidence Reach "Pinch Point"	1,900	400.56	1.45	1,312.1	0.07	401.40	0.84	1.92
112.873	White River CK/Siphon (u/s)	1,900	399.70	1.94	979.4	0.10	402.12	2.42	1.92
112.946	White River CK/Siphon (d/s)	1,900	399.42	2.13	893.5	0.11	401.50	2.08	1.92
121.497	Woollomes CK (u/s)	1,900	396.14	2.28	835.1	0.13	404.34	8.20	1.25
121.521	Woollomes CK (d/s)	1,900	396.67	2.98	637.3	0.17	400.60	3.93	1.92

Key:
cfs – cubic feet per second
ft – feet
fps – feet per second
sq ft – square feet
u/s - upstream
d/s - downstream

The above values are summarized at check structure and siphon structure locations for the maximum capacity passing through the pinch point without over-topping lining.

2.2.4 EVALUATION OF EXISTING BRIDGES

Several existing bridge structures limit conveyance capacity through the existing FKC. Low chord bridge elevations can result in pressure flow conditions when the canal water surface elevation rise above this low chord, adding additional head loss and reducing flow capacity. For the existing conditions, the bridge deck elevations were modeled in HEC-RAS per the 2018 Towill survey. **Table 2-7** provides a listing of bridge locations affected by the existing flow profile.

Table 2-7 - Summary of Bridges and WSEL for Existing Canal

Bridge	MP	Design Q (cfs)	WSEL (ft)	Lining FB (ft)	Bridge Low Chord EL (ft)	Bridge FB (ft)	Elevation Adjustment
HESSE Ave (Ave 120)	100.650	1,900	401.63	3.10	402.67	1.04	RD EL Below O&M EL
Ave 112	101.660	1,900	401.57	1.96	403.06	1.49	RD EL Below O&M EL
TIMBER FARM BRIDGE	102.160	1,900	401.53	1.63	402.85	1.32	RD EL Below O&M EL
Ave 96	103.660	1,900	400.69	1.47	399.89	-0.80	EL ADJ REQUIRED
COUNTY ROAD 208	103.740	1,900	400.64	1.60	399.67	-0.97	EL ADJ REQUIRED
Ave 88	104.980	1,900	400.55	0.98	400.68	0.13	EL ADJ

Bridge	MP	Design Q (cfs)	WSEL (ft)	Lining FB (ft)	Bridge Low Chord EL (ft)	Bridge FB (ft)	Elevation Adjustment
							RECOMMENDED
Ave 80	106.190	1,900	400.50	1.43	400.75	0.25	EL ADJ RECOMMENDED
COUNTY ROAD 192	107.340	1,900	400.45	1.58	400.02	-0.43	EL ADJ REQUIRED
Ave 64	108.440	1,900	400.35	1.86	401.17	0.82	EL ADJ RECOMMENDED
AVE 56/DUCOR HWY	109.470	1,900	400.20	3.97	403.20	3.00	RD EL Below O&M EL
Ave 48	110.570	1,900	399.97	4.72	404.30	4.33	RD EL Below O&M EL
Ave 40	111.570	1,900	399.83	3.20	402.15	2.32	RD EL Below O&M EL
Ave 32	112.590	1,900	399.73	2.41	400.92	1.19	RD EL Below O&M EL
ABANDONED S.P.R.R.	116.450	1,900	398.74	3.45	399.09	0.35	EL ADJ RECOMMENDED
Key: cfs – cubic feet per second ft – feet							

As shown above, three (3) bridge locations may require an elevation adjustment because the existing bridge low chord becomes submerged when the existing canal operates at the limiting flow. There are four (4) bridge locations that may require elevation adjustment because they do not provide more than 1-ft of separation between existing bridge low chord and existing WSEL, and another seven (7) existing bridge deck elevations that are lower than the proposed canal embankment.

2.3 Summary and Conclusions for 2018 Existing Condition Updates

The following operational restrictions have been reported by FWA:

- At Woollomes check structure, the WSEL needs to be maintained at 399.13 to make upstream deliveries, regardless of flow magnitude in the FKC
- FKC operators have recorded a flow limitation of 1,600 cfs passing Woollomes check when the upstream backwater is 2-ft below existing top of lining near MP 109
- FKC operators can only pass about 1,900 cfs through the Woollomes check without exceeding the upstream top of lining near MP 109

The 2018 existing condition modeling results appear to generally fall in line with observed capacity restrictions at Woollomes check structure (MP 121.51) and near MP 109. As such, we feel the existing condition model is a useful tool to evaluate future improvements to increase delivery capacity within the FKC middle reach.

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3. ALTERNATIVE SUMMARY

Multiple alternatives to increase FKC capacity were evaluated but not all of them require HEC-RAS modeling. Refer to the document entitled *"Plan Formulation Basis of Design Report" (Jan 2018)* for a full listing of initial alternatives considered to increase delivery capacity for the FKC Middle Reach.

3.1 Initial Alternatives Considered – Some Modeling Performed

There were several initial alternatives supported by HEC-RAS modeling, but deemed not favorable for further consideration. These less feasible alternatives were only modeled to a sufficient level to eliminate them from further consideration. They were not fully modeled and/or evaluated to the same level of detail as the preferred alternatives that moved forward for further design consideration. The following less feasible alternatives were evaluated and/or supported using HEC-RAS:

- Alt A1: In-line pumping plant at MP 109
- Alt A2: In-line pumping plant at Shafter
- Alt D1: Canal enlargement assuming lining raise
- Alt D2: Canal enlargement assuming widening and minimal increase in lining elevation
- Alt E1: Bypass from Tule to White River
- Alt E2: Parallel bypass from Tule to White River
- Alt F1: Bypass from Tule to Woollomes
- Alt F2: Parallel bypass from Tule to Woollomes

3.2 Initial Alternatives Considered – Eliminated from Design Consideration

Of the eight initial alternatives listed above, two pumping alternatives required additional HEC-RAS modeling to better define preliminary lifecycle costs presented at the October 10, 2018 workshop. HEC-RAS modeling modifications for the two pump station alternatives are documented below in ***Section 5***. The following alternatives were deemed too costly from a lifecycle cost analysis or deemed less favorable at the October 10, 2018 workshop. As such, the alternatives listed below were dropped from further consideration for final design:

- Alternative 2: Pump Station at MP 109 (formerly known as Alt A1), refer to ***Section 5***

- Alternative 3: Pump Station at Woollomes (formerly known as Alt B and Alt C), refer to ***Section 5***
- Alternative 4A: Bypass from Tule to White River (formerly known as Alt E1)
- Alternative 4B: Bypass from Tule to Woollomes (formerly known as Alt F1)
- Alternative 5A: Parallel bypass from Tule to White River (formerly known as Alt E2)

3.3 Alternatives Moving Forward to Preliminary Design

The following alternatives made the short list of alternatives for preliminary design consideration:

- Alternative 1: Canal Enlargement (formerly known as Alt D), refer to ***Section 4***
- Alternative 5B: Parallel bypass from Tule to Woollomes (formerly known as Alt F2), refer to ***Section 4***

The existing condition 2018 HEC-RAS model updates document FKC middle reach limiting capacity for the bypass alternatives (Alt 4A, 4B, 5A and 5B). HEC-RAS modeling was not required for these initial alternatives because hydraulic evaluation could be based on normal depth calculations. Gradually-varied flow analysis confirmed bypass canal capacity. The technical memorandum entitled *"Plan Formulation Basis of Design Report"* (Jan 2019) provides adequate documentation of these conclusions for these initial alternatives.

The Alternative 1 canal enlargement required extensive HEC-RAS modeling revisions to represent the enlarged geometry. Alternative 1 HEC-RAS revisions are documented below in ***Section 4.*** The HEC-RAS effort used to further define the pumping lifecycle costs for Alternative 2 and Alternative 3 are described below in ***Section 5***.

4. ALTERNATIVE 1: CANAL ENLARGEMENT

The enlarged canal alternative utilizes a dual bench, one on each side, to widen the canal along with elevating the top of lining and earthen embankment above what it currently is today. There are reaches of improvements that do not require embankment elevation adjustment, but the embankments will move outward to provide the widened section, while accommodating the existing operations and maintenance road. The improved cross section illustrating the benches and proposed lining height increase is illustrated on **Figure 4-1**. The improved canal profile illustrating change in lining heights, embankment elevations, and water surface elevations is provided on **Figure 4-2**.

4.1 HEC-RAS Revisions for Alternative 1

The existing condition 2018 base HEC-RAS model was revised to include the following:

- Elevations updated to the 2018 Towill survey (NAVD 88 datum)
- Flow profiles set to match **Table 2-1**
- Manning's n-values set to match ***Section 2.2.2.1***
- Contraction / Expansion coefficients set to match **Table 2-2**
- Geometry data updated to match cross section shown on **Figure 4-1** with top of lining (TOL) set to provide required freeboard per Table 2-5, which matches the TOL profile shown on **Figure 4-2**
- Geometry data updated to include longitudinal transitions upstream and downstream of existing structures at 3:1 contraction and 4:1 expansion
- Geometry data revised to elevate any bridge low chords from becoming submerged
- Geometry data revised to provide turnout locations and estimated delivery elevation requirements
- Rating curves can be added at check structures to model low flow profiles once low flow is identified by FWA

Table 2-2 illustrates the contraction expansion coefficients types applied to the 2018 model update. **Table 4-1** specifies the contraction expansion coefficients assigned to each reach within the Alternative 1 (enlarged canal).

Table 4-1 - Contraction Expansion Coefficients Assigned to Alt 1 (Enlarged Canal) HEC-RAS Model

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
88.208	88.252	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Fifth Ave Check

ALTERNATIVE 1: CANAL ENLARGEMENT

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
88.252	88.662	0	0	Uniform Section	
88.662	88.678	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
88.678	88.683	0	0	Uniform Section	Bridge
88.683	88.704	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
88.704	89.171	0	0	Uniform Section	
89.171	89.187	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
89.187	89.193	0	0	Uniform Section	Bridge
89.193	89.214	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
89.214	89.462	0	0	Uniform Section	
89.462	89.478	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
89.478	89.483	0	0	Uniform Section	Bridge
89.483	89.504	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
89.504	89.664	0	0	Uniform Section	
89.664	89.680	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Siphon
89.680	89.686	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
89.686	89.706	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
89.706	89.713	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
89.713	89.734	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Siphon
89.734	89.951	0	0	Uniform Section	
89.951	89.967	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
89.967	89.973	0	0	Uniform Section	Bridge
89.973	89.994	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
89.994	90.221	0	0	Uniform Section	
90.221	90.237	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
90.237	90.244	0	0	Uniform Section	Bridge
90.244	90.265	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
90.265	90.521	0	0	Uniform Section	
90.521	90.537	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
90.537	90.544	0	0	Uniform Section	Bridge

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
90.544	90.565	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
90.565	90.804	0	0	Uniform Section	
90.804	90.820	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Siphon
90.820	90.826	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
90.826	90.865	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
90.865	90.872	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
90.872	90.893	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Siphon
90.893	91.091	0	0	Uniform Section	
91.091	91.107	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
91.107	91.113	0	0	Uniform Section	Bridge
91.113	91.134	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
91.134	91.518	0	0	Uniform Section	
91.518	91.534	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
91.534	91.572	0	0	Uniform Section	Bridge
91.572	91.593	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
91.593	91.602	0	0	Uniform Section	
91.602	91.618	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
91.618	91.625	0	0	Uniform Section	Bridge
91.623	91.644	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
91.644	91.852	0	0	Uniform Section	
91.852	91.868	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
91.868	91.872	0	0	Uniform Section	Bridge
91.872	91.893	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
91.893	92.352	0	0	Uniform Section	
92.352	92.368	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
92.368	92.372	0	0	Uniform Section	Bridge
92.372	92.393	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
92.393	92.851	0	0	Uniform Section	
92.851	92.867	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge

ALTERNATIVE 1: CANAL ENLARGEMENT

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
92.867	92.872	0	0	Uniform Section	Bridge
92.872	92.893	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
92.893	93.551	0	0	Uniform Section	
93.551	93.567	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
93.567	93.574	0	0	Uniform Section	Bridge
93.574	93.595	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
93.595	94.010	0	0	Uniform Section	
94.010	94.026	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
94.026	94.034	0	0	Uniform Section	Bridge
94.034	94.055	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
94.055	94.834	0	0	Uniform Section	
94.834	94.850	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Siphon
94.850	94.856	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
94.856	94.877	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
94.877	94.883	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
94.883	94.904	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Siphon
94.904	95.130	0	0	Uniform Section	
95.130	95.146	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
95.146	95.153	0	0	Uniform Section	Bridge
95.153	95.174	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
95.174	95.646	0	0	Uniform Section	
95.646	95.662	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Siphon
95.662	95.669	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
95.669	95.749	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
95.749	95.758	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
95.758	95.783	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Siphon
95.783	96.260	0	0	Uniform Section	

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
96.260	96.276	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
96.276	96.284	0	0	Uniform Section	Bridge
96.284	96.305	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
96.305	96.368	0	0	Uniform Section	
96.368	96.384	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout
96.384	96.387	0	0	Uniform Section	Turnout
96.387	96.408	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
96.408	96.846	0	0	Uniform Section	
96.846	96.861	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout
96.861	96.865	0	0	Uniform Section	Turnout
96.865	96.886	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
96.886	97.330	0	0	Uniform Section	
97.330	97.366	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout/Bridge
97.366	97.374	0	0	Uniform Section	Bridge
97.374	97.395	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
97.395	97.841	0	0	Uniform Section	
97.841	97.857	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout
97.857	97.859	0	0	Uniform Section	Turnout
97.859	97.881	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
97.881	98.351	0	0	Uniform Section	
98.351	98.367	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
98.367	98.373	0	0	Uniform Section	Bridge
98.373	98.394	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
98.394	98.606	0	0	Uniform Section	
98.606	98.622	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout
98.622	98.626	0	0	Uniform Section	Turnout
98.626	98.647	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
98.647	99.340	0	0	Uniform Section	
99.340	99.367	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
99.367	99.373	0	0	Uniform Section	Bridge
99.373	99.394	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
99.394	100.618	0	0	Uniform Section	

ALTERNATIVE 1: CANAL ENLARGEMENT

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
100.618	100.648	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
100.648	100.653	0	0	Uniform Section	Bridge
100.653	100.674	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
100.674	101.641	0	0	Uniform Section	
101.641	101.657	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
101.657	101.662	0	0	Uniform Section	Bridge
101.662	101.683	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
101.683	102.142	0	0	Uniform Section	
102.142	102.158	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
102.158	102.162	0	0	Uniform Section	Bridge
102.162	102.183	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
102.183	102.617	0	0	Uniform Section	
102.617	102.682	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Siphon
102.682	102.696	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
102.696	102.727	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
102.727	102.735	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
102.735	102.756	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Siphon
102.756	103.629	0	0	Uniform Section	
103.629	103.657	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
103.657	103.663	0	0	Uniform Section	Bridge
103.663	103.684	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
103.684	103.720	0	0	Uniform Section	
103.720	103.736	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
103.736	103.743	0	0	Uniform Section	Bridge
103.743	103.764	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
103.764	104.952	0	0	Uniform Section	
104.952	104.977	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
104.977	104.983	0	0	Uniform Section	Bridge
104.983	105.004	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
105.004	106.170	0	0	Uniform Section	
106.170	106.186	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
106.186	106.193	0	0	Uniform Section	Bridge
106.193	106.212	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
106.212	106.722	0	0	Uniform Section	
106.722	106.738	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
106.738	106.742	0	0	Uniform Section	Bridge
106.742	106.763	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
106.763	107.320	0	0	Uniform Section	
107.320	107.336	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
107.336	107.343	0	0	Uniform Section	Bridge
107.343	107.373	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge/Turnout
107.373	108.423	0	0	Uniform Section	
108.423	108.439	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
108.439	108.442	0	0	Uniform Section	Bridge
108.442	108.463	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge/Turnout
108.463	109.437	0	0	Uniform Section	
109.437	109.453	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
109.453	109.473	0	0	Uniform Section	Bridge
109.473	109.494	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
109.494	110.551	0	0	Uniform Section	
110.551	110.567	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
110.567	110.573	0	0	Uniform Section	Bridge
110.573	110.594	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
110.594	111.544	0	0	Uniform Section	
111.544	111.560	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
111.560	111.573	0	0	Uniform Section	Bridge/Turnout
111.573	111.594	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
111.594	111.660	0	0	Uniform Section	
111.660	111.676	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
111.676	111.685	0	0	Uniform Section	Bridge
111.685	111.706	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge

ALTERNATIVE 1: CANAL ENLARGEMENT

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
111.706	112.048	0	0	Uniform Section	
112.048	112.064	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout
112.064	112.068	0	0	Uniform Section	Turnout
112.068	112.089	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
112.089	112.560	0	0	Uniform Section	
112.560	112.587	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
112.587	112.593	0	0	Uniform Section	Bridge
112.593	112.614	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
112.614	112.857	0	0	Uniform Section	
112.857	112.884	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Siphon/Turnout
112.884	112.906	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Inlet
112.906	112.932	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Siphon
112.932	112.943	0.2	0.4	Headwall and/or drop transition including steep-slope drop, splitting flow into multiple barrels, etc.	Siphon Outlet
112.943	112.967	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Siphon
112.967	113.578	0	0	Uniform Section	
113.578	113.607	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
113.607	113.624	0	0	Uniform Section	Bridge/Turnout
113.624	113.646	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge/Turnout
113.646	114.711	0	0	Uniform Section	
114.711	114.727	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
114.727	114.733	0	0	Uniform Section	Bridge
114.733	114.754	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
114.754	115.921	0	0	Uniform Section	
115.921	115.937	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
115.937	115.943	0	0	Uniform Section	Bridge
115.943	115.971	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge/Turnout
115.971	116.422	0	0	Uniform Section	
116.422	116.438	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridges
116.438	116.451	0	0	Uniform Section	Bridges (2)

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
116.451	116.472	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridges
116.472	116.901	0	0	Uniform Section	
116.901	116.936	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
116.936	116.943	0	0	Uniform Section	Bridge
116.943	116.964	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
116.964	117.423	0	0	Uniform Section	
117.423	117.439	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout
117.439	117.441	0	0	Uniform Section	Turnout
117.441	117.462	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
117.462	117.930	0	0	Uniform Section	
117.930	117.946	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
117.946	117.954	0	0	Uniform Section	Bridge
117.954	117.987	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
117.987	118.432	0	0	Uniform Section	
118.432	118.457	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge/Turnout
118.457	118.463	0	0	Uniform Section	Bridge
118.463	118.484	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge/Turnout
118.484	118.941	0	0	Uniform Section	
118.941	118.957	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
118.957	118.963	0	0	Uniform Section	Bridge
118.963	118.984	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
118.984	119.463	0	0	Uniform Section	
119.463	119.479	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
119.479	119.482	0	0	Uniform Section	Bridge
119.482	119.519	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Earth Section/Turnout
119.519	119.521	0	0	Uniform Section	Turnout
119.521	119.528	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
119.528	120.041	0	0	Uniform Section	
120.041	120.047	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Bridge
120.047	120.053	0	0	Uniform Section	Bridge
120.053	120.061	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Bridge
120.061	120.063	0	0	Uniform Section	

From STA (MP)	To STA (MP)	Contraction Coefficient	Expansion Coefficient	Comment	Structure
120.063	120.070	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Turnout
120.070	121.484	0	0	Uniform Section	
121.484	121.490	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Turnout
121.490	121.491	0	0	Uniform Section	
121.491	121.505	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition to Woollomes Check
121.505	121.506	0	0	Uniform Section	
121.506	121.542	0.1	0.3	Gradual transition of side walls to/from uniform section to/from headwall and/or drop transition	Transition from Woollomes Check
Key: MP – Milepost					

4.1.1 FLOW

The enlarged canal geometry documented within the Alternative 1 HEC-RAS will convey the design rates of flow documented in while providing the Reclamation required freeboard documented above in **Table 2-5**. The maximum design **Table 2-1** rates of flow and corresponding HEC-RAS computed water surface elevations are illustrated on **Figure 4-2**.

A minimum flow profile was generated using 500 cfs to confirm turnout delivery elevations can be maintained during low flow conditions in the improved canal. Known operational water surface elevations were input upstream of each check structure location to model check gates partially closed during low flow operations. The low flow operational profile is included on **Figure 4-2**.

4.1.2 GEOMETRY

The existing condition 2018 geometry updates described above are included in the Alternative 1 HEC-RAS model. In addition, the cross section geometry was updated to include the dual benched widened and raised lining illustrated on **Figure 4-1**. The short reach of earthen canal parallel to Lake Woollomes was enlarged by widening only, no benching. Top of lining elevations were coded to match the profile shown on **Figure 4-2** and will provide the required freeboard documented above in **Table 2-4**.

4.1.3 STRUCTURES

The majority of existing condition 2018 updates to HEC-RAS structures are carried forward into the Alternative 1 model. The 2018 structure updates carried forward include:

- Structure elevations adjusted to match 2018 Towill survey (NAVD 88)

- Structure longitudinal locations adjusted to match adjacent upstream and downstream distance
- Correcting cross section geometry for existing bridge pers
- Adding bridge locations not previously modeled in HEC-RAS

The following structure features modeled in HEC-RAS were updated for Alternative 1:

- Upstream and downstream longitudinal transitions to match 2:1 contraction and 3:1 expansion
- Bridge low chords elevated above the maximum WSEL, as explained below
- Rating curves can be added at check structures to model low flow conditions

4.1.3.1 Bridge Structures

The Alternative 1 enlarged canal improvements provide additional capacity while reducing the amount of net water surface elevation rise. Several bridge structures may require improvements to elevate the existing bridge low chord elevation above the improved water surface elevation. Rather than try to estimate each bridge elevation adjustment, the following assumptions apply:

- Capacity improvements require bridge elevation adjustments
- Pressure flow operations will result in reduced capacity
- Bridge elevations were raised out of the water for all Alternative 1 improvement runs
- Existing bridge elevations were reported relative to improved WSEL to indicate elevation adjustment requirements

ALTERNATIVE 1: CANAL ENLARGEMENT

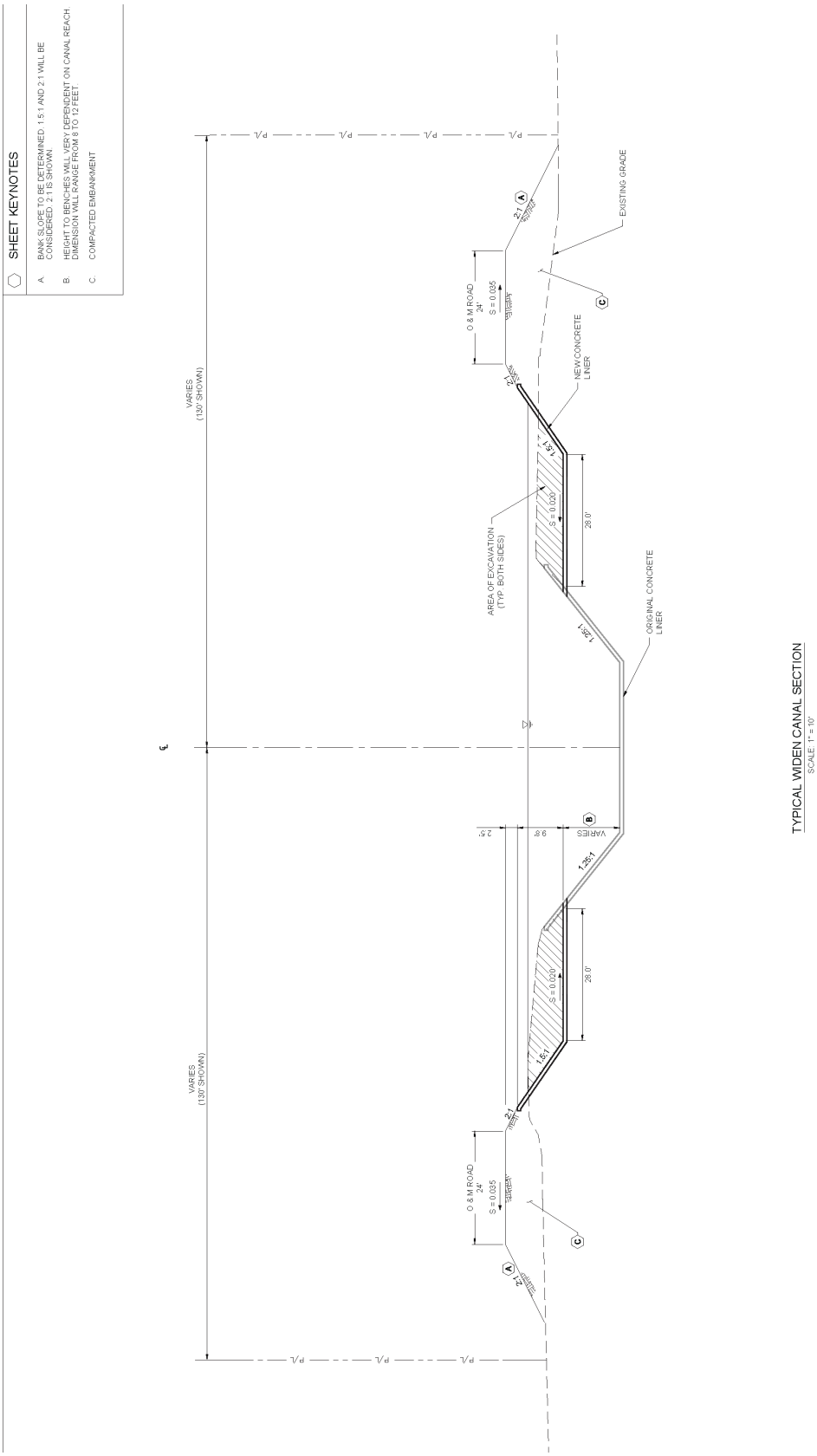


Figure 4-1 - Alternative 1 - Enlarged Canal Typical Section

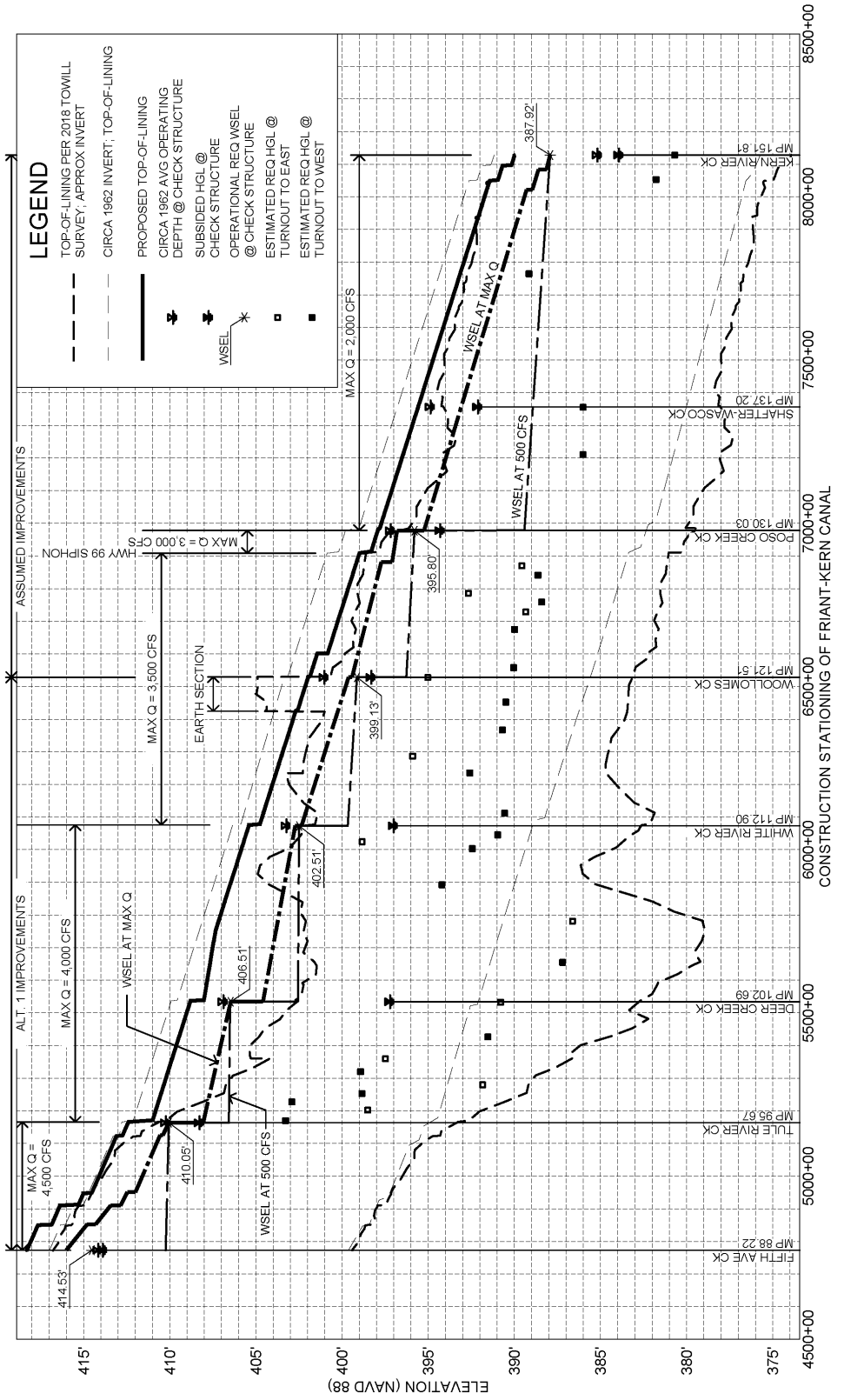


Figure 4-2 - Alternative 1 - Enlarged Canal Profile

Table 4-2 provides a listing of bridge locations affected by Alt 1 improvements.

Table 4-2 - Summary of Bridges and WSEL for Alt 1

Bridge	MP	Design Q (cfs)	WSEL (ft)	Lining FB (ft)	Bridge Low Chord EL (ft)	Bridge FB (ft)	Elevation Adjustment
6TH Ave	88.680	4,500	415.62	2.47	417.21	1.59	RD EL Below O&M EL
7TH Ave	89.190	4,500	415.36	2.51	417.04	1.68	RD EL Below O&M EL
County RD 232	89.480	4,500	415.18	2.57	416.81	1.63	RD EL Below O&M EL
Frazier HWY	89.970	4,500	414.46	2.29	416.25	1.79	RD EL Below O&M EL
Ave 8	90.240	4,500	414.25	2.38	416.35	2.10	RD EL Below O&M EL
Olive Ave (Ave 152)	96.280	4,000	407.73	3.11	410.08	2.38	RD EL Below O&M EL
ST HWY 190 (Ave 144)	97.370	4,000	407.41	3.08	407.43	0.02	EL ADJ RECOMMENDED
Ave 136	98.370	4,000	407.12	3.05	406.90	-0.22	EL ADJ REQUIRED
Ave 128	99.370	4,000	406.93	2.93	404.82	-2.11	EL ADJ REQUIRED
Hesse Ave (Ave 120)	100.650	4,000	406.75	2.70	402.67	-4.08	EL ADJ REQUIRED
Ave 112	101.660	4,000	406.65	2.48	403.06	-3.59	EL ADJ REQUIRED
Timber Farm Bridge	102.160	4,000	406.58	2.39	402.85	-3.73	EL ADJ REQUIRED
Ave 96	103.660	4,000	404.47	3.40	399.89	-4.58	EL ADJ REQUIRED
County RD 208	103.740	4,000	404.44	3.41	399.67	-4.77	EL ADJ REQUIRED
Ave 88	104.980	4,000	404.33	3.32	400.68	-3.65	EL ADJ REQUIRED
Ave 80	106.190	4,000	404.21	3.23	400.75	-3.46	EL ADJ REQUIRED
Ave 74	106.740	4,000	404.15	3.20	403.48	-0.67	EL ADJ REQUIRED
County RD 192	107.340	4,000	404.09	3.07	400.02	-4.07	EL ADJ REQUIRED
Ave 64	108.440	4,000	403.92	2.89	401.17	-2.75	EL ADJ REQUIRED
Ave 56/Ducor HWY	109.470	4,000	403.63	2.86	403.20	-0.43	EL ADJ REQUIRED
Ave 48	110.570	4,000	403.27	2.87	404.30	1.03	RD EL Below O&M EL
Ave 40	111.570	4,000	403.04	2.78	402.15	-0.89	EL ADJ REQUIRED
County RD 184	111.680	4,000	402.99	2.80	402.38	-0.61	EL ADJ REQUIRED
Ave 32	112.590	4,000	402.80	2.70	400.92	-1.88	EL ADJ REQUIRED
Ave 24	113.610	3,500	402.14	2.43	401.18	-0.96	EL ADJ REQUIRED
Ave 16	114.730	3,500	401.85	2.36	403.83	1.98	RD EL Below O&M EL
Abandoned SPRR	116.450	3,500	401.28	2.38	405.65	-2.19	EL ADJ REQUIRED

Key:
cfs – cubic feet per second
ft – feet
MP – Milepost

As shown above, eighteen (18) bridge locations require an elevation adjustment because the existing bridge low chord becomes submerged when the improved canal operates at the max design flow. There is one (1) bridge location that may require elevation adjustment because it does not provide more than one foot of separation between existing bridge low chord elevation and improved WSEL, and another eight (8) existing bridge deck elevations that are lower than the improved canal embankment.

4.1.3.2 Check Structures

The 2018 existing condition updates as described above in ***Section 2.2.2.8*** for check structures were carried forward into Alternative 1. No additional modifications were made to the existing check structures.

Future updates for low flow runs can be input using rating curves, rather than modeling physical check structure geometry changes.

4.1.3.3 Siphon Structures

Modifications to the 2018 existing condition update for siphon structures as described above in ***Section 2.2.2.8*** were carried forward into Alternative 1. No additional modifications were made to the existing siphon structures.

4.1.3.4 Turnouts

The 2018 existing condition updates as described above in ***Section 2.2.2.5*** for turnouts were carried forward into Alternative 1. No additional modifications were made to for existing turnouts.

4.1.3.5 Drainage Inlets and Overshoots

The 2018 existing condition updates as described above in ***Section 2.2.2.8*** for drainage structures (including drainage inlets and overshoots) were carried forward into Alternative 1. No additional modifications were made.

4.1.3.6 Miscellaneous Structures and Utilities

Various utilities cross and/or parallel the FKC. No HEC-RAS model updates were made to represent utilities and/or crossings in the vicinity of this canal. Locations of utilities and or crossings will be documented during final design.

4.2 Modeling Results for Alternative 1

4.2.1 WATER SURFACE PROFILES

Key water surface profile elevations and corresponding hydraulic parameters for Alternative 1 are summarized below in **Table 4-3**.

Table 4-3 - Summary of HEC-RAS Hydraulic Results for Alt 1

Mile Post	Location	Q (cfs)	WSEL (ft)	Vel (fps)	Area (sf)	Froude #	Lining EL (ft)	Lining FB (ft)	Req FB (ft)
88.208	Fifth Ave CK (u/s)	4,500	416.04	4.75	946.84	0.24	418.38	2.34	2.35
88.231	Fifth Ave CK (d/s)	4,500	415.85	4.83	931.98	0.24	418.28	2.43	2.35
89.680	AT&SF RR Siphon (u/s)	4,500	415.02	4.87	924.84	0.25	417.66	2.64	2.35
89.713	AT&SF RR Siphon (d/s)	4,500	414.62	4.91	916.77	0.25	416.86	2.24	2.35
90.820	SPRR Siphon (u/s)	4,500	413.84	5.06	889.89	0.26	416.38	2.54	2.35
90.872	SPRR Siphon (d/s)	4,500	413.25	5.10	881.92	0.26	415.30	2.05	2.35
94.850	Porter Creek Siphon (u/s)	4,500	410.80	4.99	902.52	0.26	413.10	2.30	2.35
94.883	Porter Creek Siphon (d/s)	4,500	410.39	4.98	902.78	0.26	412.77	2.38	2.35
95.662	Tule River CK/Siphon (u/s)	4,000	410.05	4.18	956.04	0.21	412.40	2.35	2.29
95.758	Tule River CK/Siphon (d/s)	4,000	407.97	4.73	846.14	0.25	411.00	3.03	2.29
102.682	Deer Creek CK/Siphon (u/s)	4,000	406.51	2.57	1,553.41	0.11	408.80	2.29	2.29
102.735	Deer Creek CK/Siphon (d/s)	4,000	404.59	2.86	1,400.89	0.13	408.03	3.44	2.29
104.217	Subsidence Reach "Pinch Point"	4,000	404.42	2.08	1,919.19	0.10	407.77	3.35	2.29
104.725	Subsidence Reach "Pinch Point"	4,000	404.38	2.00	1,999.42	0.10	407.68	3.30	2.29
112.873	White River CK/Siphon (u/s)	3,500	402.76	2.85	1,227.85	0.13	405.41	2.65	2.23
112.946	White River CK/Siphon (d/s)	3,500	402.26	3.15	1,111.27	0.15	404.77	2.51	2.23
121.497	Woollomes CK (u/s)	3,500	399.61	2.96	1,184.07	0.16	401.96	2.35	1.46
121.521	Woollomes CK (d/s)	3,500	399.33	4.29	816.08	0.22	401.86	2.53	2.23

Key:
cfs – cubic feet per second
ft – feet
MP – Milepost

The above values are summarized at check structure and siphon structure locations for the maximum design flow.

4.2.2 BRIDGE CROSSINGS AFFECTED

4.2.2.1 Replacement / Major Improvements

As indicated in **Table 4-3**, the following eighteen (18) bridge structures are recommended for replacement and/or major improvements to elevate the low chord elevation above the improved delivery water surface elevation:

- Ave 136 bridge near MP 98.37
- Ave 128 bridge near MP 99.37
- Ave 120 (Hesse Ave) bridge near MP 100.65
- Ave 112 bridge near MP 101.66
- Timber farm bridge near MP 102.16
- Ave 96 bridge near MP 103.660
- County Rd 208 bridge near MP 103.74
- Ave 88 bridge near MP 104.98
- Ave 80 bridge near MP 106.19
- Ave 74 bridge near MP 106.74+
- County Rd 192 bridge near MP 107.34
- Ave 64 bridge near MP 108.44
- Ave 56 (Ducor HWY) bridge near 109.47
- Ave 40 bridge near MP 111.57
- County Rd 184 bridge near MP 111.68
- Ave 32 bridge near MP 112.59
- Ave 24 bridge near MP 113.61
- Abandoned SPRR bridge near MP 116.45

4.2.2.2 Further Evaluation / Elevation Considerations – FKC Embankment Encroachment

The following eight (8) bridge structures are recommended for evaluation of elevation adjustments and special grading at interface of bridge and FKC embankment because the improved canal embankment is elevated above the existing bridge deck:

- 6th Ave bridge near MP 88.68
- 7th Ave bridge near MP 89.19
- County Rd 232 bridge near MP 89.48
- Fraizer HWY bridge near MP 89.97
- Ave 8 bridge near MP 90.24
- Olive Ave (Ave 152) bridge near MP 96.28

- Ave 48 bridge near MP 110.57
- Ave 16 Bridge near MP 114.73

4.2.2.3 Further Evaluation / Possible Replacement – Low Chord Encroachment

The following two bridge structures are recommended for evaluation of elevation adjustments or possible replacement because they do not provide more than 1-ft of separation between bridge low chord and improved delivery water surface elevation:

- St HWY 190 (Ave 144) bridge near MP 97.37
- Ave 48 bridge near MP 110.57

4.3 Summary and Conclusions for Alternative 1

The enlarged canal improvements documented within will allow FKC to deliver the maximum design flow through the middle reach of this system. There are a few assumptions and operating conditions that must be met for this to occur. Those conditions are:

- The downstream reach, Woollomes to Kern River, (MP 121.51 to MP 151.81) requires improvements to convey more than 1,200 cfs downstream of Woollomes.
- If we assume the enlarged channel improvements are applied to the downstream reach, Woollomes to Kern River, (MP 121.51 to MP 151.81) we find about 2,000 cfs before the Woollomes check becomes submerged with an increased backwater propagation upstream.
- It is recommended that the Poso Creek and HWY 99 Siphon structures be evaluated for capacity improvements to gain the full 2,000 – 2,500 capacity from Woollomes to Kern River
- The FKC reach upstream of the Fifth Ave Check (upstream of MP 88.22) was not evaluated to determine if 4,500 cfs can be safely delivered to Fifth Avenue
- Coordination with the upstream improvements to establish WSEL tie at the Fifth Ave Check needs to occur – this may trigger enlarged canal geometry revisions in the FKC upper reach from Tule to Fifth Ave Check
- Eighteen (18) existing bridges need to be elevated and/or replaced to eliminate additional upstream backwater that is not modeled (Alt 1 HEC-RAS models bridges out of the water)
- Eight (8) additional existing bridges may need to be elevated for elevation transitions at bridges due to canal embankment being elevated above bridge deck
- Two (2) existing bridges may require elevation adjustments or possible replacement because they do not provide more than 1-ft of separation between bridge low chord and improved delivery water surface elevation

4.4 Next Steps for Alternative 1 – Enlarged Canal

- Continue updating HEC-RAS with design refinements for the enlarged canal
- Design refinements to include optimization of lining height for the enlarged canal
- Confirm turnout delivery obligations (both elevation and rate of flow)
- Confirm turnout structure, gate size and delivery info at MP 112.9 East
- Confirm turnout structure, gate invert and delivery info at MP 117.44 West
- Confirm turnout structure, gate size and delivery info at MP 117.96 East
- Confirm turnout structure, gate size and delivery info at MP 125.28 East
- Confirm turnout structure, gate size and delivery info at MP 126.38
- Confirm turnout structure, gate size and delivery info at MP 144.91
- Provide survey of turnout gates upstream of Tule (MP 89.35 to MO 95.64)
- Coordinate upstream boundary conditions with Reclamation at Fifth Avenue Check (MP 88.22)
- + Verify 4,500 cfs plus upstream delivery obligations can be safely delivered to Fifth Ave Check
- + Ensure middle reach improved WSEL at Fifth Ave Check does not submerge the upstream existing and/or improved WSEL
- Coordinate downstream boundary conditions with FWA and Reclamation (Woollomes to Kern River)
- + Verify existing 1,200 cfs bottleneck with operations and/or confirm lower reach improvements
- + Confirm capacity of lower reach improvements
- Implement design level mapping and adjust HEC-RAS modeled lengths accordingly
- Field review of mapping to confirm existing structures already modeled in HEC-RAS, including checks, waste ways, siphons, turnouts, bridges, and culverts.
- Field review and survey of any structures not included in the HEC-RAS model, including drainage inlets, drainage overshoots or utilities that could restrict flow.
- Field review of FKC and design mapping to confirm all structures.

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5. ALTERNATIVES 2 AND 3: PUMPING ALTERNATIVES

The following describes HEC-RAS modeling efforts in support of:

- Alternative 2 for a new pump station located near MP 109. Alternative 2 (formerly known as Alt A1) was dropped from further design consideration due to undesirable capital and lifecycle operational cost projections.
- Alternative 3 for a new pump station located upstream of Woollomes Reservoir near MP 119.64. Alternative 3 (formerly known as Alt B and Alt C) was dropped from further design consideration due to undesirable capital and lifecycle operational cost projections.

5.1 HEC-RAS Revisions for Pumping Alternatives

The existing condition 2018 base HEC-RAS model was revised to include the following:

- Elevations updated to the 2018 Towill survey (NAVD 88 datum)
- Flow profiles set to match **Table 2-1**
- Manning's n-values set to match ***Section 2.2.2.1***
- Contraction / Expansion coefficients set to match **Table 2-2**
- Geometry data updated to match cross section shown on **Figure 4-1** with top of lining (TOL) set to provide required freeboard per **Table 2-5**, which matches the TOL profile shown on **Figure 4-2**
- Geometry data updated to include longitudinal transitions upstream and downstream of existing structures at 3:1 contraction and 4:1 expansion
- Geometry data revised to elevate any bridge low chords from becoming submerged
- Geometry data revised to provide turnout locations and estimated delivery elevation requirements
- ALT 2 Pump station modeled by setting known WSEL values at MP 109
- ALT 3 Pump station modeled by setting known WSEL values at Woollomes (MP 119.64)
- Rating curves can be added at check structures to model low flow profiles once low flow is identified by FWA

Detail of 2018 HEC-RAS model updates for Alternative 2 (pump station at MP 109) and Alternative 3 (pump station at Woollomes (MP 119.64) are described below.

5.1.1 FLOW

The rates of flow documented in **Table 2-1** were applied to the pump station alternatives. The drawdown created by pumping the design flow at each pumping plant location allows for some of the existing FKC to remain in-place. To safely convey the increased flow, the majority of the FKC middle reach requires canal enlargement to meet Reclamation required freeboard documented above in **Table 2-5**. Special care should be taken when setting the draw down as to not increase upstream velocities. Both of these alternatives provide unstable flow profiles and undesirable flow velocity results upstream of the pumping plant.

5.1.2 GEOMETRY

The existing condition 2018 geometry updates described above were included in the HEC-RAS models for pumping alternatives.

5.1.2.1 Geometry for Pump Station at MP 109

Existing cross section geometry from MP 109 upstream to about MP 121.18 can remain as-is due to pumping draw down upstream of MP 109. The remainder of the middle reach canal geometry was updated to include the dual bench widened and raised lining illustrated on **Figure 4-1**. The short reach of earthen canal parallel to Lake Woollomes was enlarged by widening only, no benching. It should be noted that unsteady flow will likely occur upstream of the pumping plan with undesirable velocities.

5.1.2.2 Geometry for Pump Station at Woollomes (MP 119.64)

Existing cross section geometry from MP 119.64 upstream to about MP 122.82 can remain as-is due to pumping draw down upstream of MP 119.64. The remainder of the middle reach canal geometry was updated to include the dual bench widened and raised lining illustrated on **Figure 4-1**. The short reach of earthen canal parallel to Lake Woollomes was enlarged by widening only, no benching. It should be noted that unsteady flow will likely occur upstream of the pumping plan with undesirable velocities.

5.1.3 STRUCTURES

The majority of existing condition 2018 updates to HEC-RAS structures were carried forward into the pumping alternative models. The 2018 structure updates carried forward include:

- Structure elevations adjusted to match 2018 Towill survey (NAVD 88 vertical datum)
- Structure longitudinal locations adjusted to match adjacent upstream and downstream distance
- Correcting cross section geometry for existing bridge pers
- Adding bridge locations not previously modeled in HEC-RAS

The following structure features modeled in HEC-RAS were updated for pumping alternatives:

- Upstream and downstream longitudinal transitions to match 2:1 contraction and 3:1 expansion
- Bridge low chords elevated above the maximum WSEL
- Rating curves can be added at check structures to model low flow conditions

The proposed pump station alternatives require a new check structure at the pumping plant. HEC-RAS does not require this check structure to be modeled because setting a known WSEL to represent the pump station drawdown provides the hydraulic profile results necessary.

5.1.3.1 Proposed Pump Station MP 109

The proposed pump station at MP 109 was modeled by setting a known WSEL to represent the pumping draw down. Assuming downstream improvements, pumping drawdown at MP 109 will be:

- Assume pump drawdown equals the upstream normal depth projected to MP 109. This scenario results in the following:
  - Pump lift of 5.5-ft at 3,500 cfs
  - Existing lining to remain upstream: about 18,400-ft upstream of MP 109, but subject to potential unsteady flow and undesirable velocities

Alt 2 pump station at MP 109 requires several new structures. These new structures do not require HEC-RAS modeling and consist of:

- New check structure at MP 109
- Parallel intake split from FKC to pump station forebay
- New pump station and parallel discharge connection back to FKC
- New spillway and storage area to capture excess volume in case of pumping power outage.

5.1.3.2 Proposed Pump Station at Woollomes (MP 119.64)

The proposed pump station near MP 119.64 was modeled by setting a known WSEL to represent the pumping draw down. Assuming downstream improvements, pumping drawdown at Woollomes (MP 119.64) consists of:

- Assume maximum drawdown without exceeding 6-fps upstream. This scenario results in the following:
  - Pump lift of 3.05-ft at 3,500 cfs

  - Existing lining to remain upstream: about 16,800-ft upstream of MP 119.64 and another 18,600-ft can remain above MP 96, but subject to potential unsteady flow and undesirable velocity

Alternative 3 pump station at Woollomes requires several new structures near MP 119.64. These new structures are not required to be modeled in HEC-RAS and consist of:

- New check structure near MP 119.64
- Parallel intake split from FKC to pump station forebay
- New pump station and parallel discharge connection back to FKC
- New spillway and storage area to capture excess volume in case of pumping power outage.
-

5.2 Modeling Results for Alt 2 and ALT 3

The pumping alternatives were deemed too costly to continue forward based on estimated capital cost and project annualized O&M costs. As such, further detailed HEC-RAS modeling regarding these alternatives is not warranted.

5.3 Summary and Conclusions for Pumping Alternatives

Two pump station locations were considered. One near MP 109 combined with enlarged canal improvements. The second pumping location considered was near Woollomes (MP 119.64) combined with enlarged canal improvements. Both of these alternatives (Alternative 2 and Alternative 3) were dropped from further consideration due to:

- Capital cost combined with annualized lifecycle operations and maintenance costs are too high
- Undesirable velocities and unstable flow concerns upstream of pumping plant
- Anticipated spill volume due to electrical or pump outages cause crop damage
- The downstream reach (Woollomes to Kern River) requires improvements to convey more than 1,200 cfs downstream of Woollomes. Pushing more flow downstream will result in submergence of the existing Woollomes check structure, with increased backwater propagation upstream into the lining freeboard for the FKC middle reach
- Assume the enlarged channel improvements are applied to the downstream reach (Woollomes to Kern River). This assumption increases the bottleneck capacity to about 2,000 cfs before the Woollomes check becomes submerged with an increased backwater propagation upstream

- It is recommended that the Poso Creek and HWY 99 Siphon structures be evaluated for capacity improvements to gain the full 2,000 – 2,500 capacity from Woollomes to Kern River
- The FKC reach upstream of the Fifth Ave Check was not evaluated to determine if 4,500 cfs can be safely delivered to Fifth Avenue.
- Coordination with the upstream improvements to establish WSEL tie at the Fifth Ave Check needs to occur – this may trigger enlarged canal geometry revisions in our upper reach from Tule to Fifth Ave Check
- Number of bridges to be elevated and/or replaced to eliminate additional upstream backwater does not change from Alternative 1
- Number of existing bridges to be elevated and/or replaced due to canal embankment elevated above bridge deck does not change from Alternative 1

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6. ALTERNATIVE 5B: PARALLEL BYPASS FROM TULE TO WOOLLOMES

The parallel bypass option from Tule to Woollomes does not require HEC-RAS to model estimated backwater for Alternative 5B. The hydraulic properties of the bypass reach were estimated using normal depth computations. Head losses at structures were estimated utilizing spreadsheet applications. Hydraulic computations to support Alternative 5B (formerly known as Alt F2) are provided within the technical memorandum entitled *"Plan Formulation Basis of Design Report"* (January 2019).

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7. REFERENCES

Bureau of Reclamation design references include the following:

- Design Standards No. 3, Water Conveyance Systems, DS-3-2 – 1994, Chapters 11 and 12
- Design Standards No. 3, Canals and Related Structures, DS-3-5 – 12/8/67
- Concrete Manual, Eighth Edition, Revised 1981, Reprinted 1998
- Linings for Irrigation Canals, First Edition 1963, Second Printing 1976
- Earth Manual, Part 1, Third Edition, 1998
- Safety and Health Standards, 1993, Reprinted 2001
- Design of Small Canal Structures, 1978
- Water Measurement Manual, Third Edition, 1997
- Construction Activities, Reclamation Manual FAC 03-02

Other design references include the following:

- Brader, King, *Handbook of Hydraulics 7th ED,* McGraw Hill, NY, 1996.
- Chow, *Open Channel Hydraulics,* McGraw Hill, NY, 1959.
- Drawings for the Construction of Friant-Kern Canal, Record Drawings, September 1947
- Drawings for the Construction of Friant-Kern Canal Rehabilitation, Record Drawings, June 1976
- Friant-Kern Canal Structures List, Friant Water Authority, November 2007
- Provost and Pritchard Consulting Group (P&P), *Friant-Kern Canal Active Turnouts*, 2018.
- Stantec Consulting Services, DRAFT – *Feasibility Report for FKC Capacity Correction Program – Immediate Repairs Project*, October 2018
- Stantec Consulting Services, DRAFT – *Plan Formulation Basis of Design Report*, January 2019
- U.S. Army Corps of Engineers, *HEC-RAS (River Analysis System) version 5.04,* Hydrologic Engineering Center, Davis California, April 2018.
- U.S. Army Corps of Engineers, *HEC-RAS Users Manual v5.0,* Hydrologic Engineering Center, Davis California, February 2016.

- U.S. Army Corps of Engineers, *HEC-RAS Hydraulic Reference Manual v5.0,* Hydrologic Engineering Center, Davis California, February 2016.
- U.S. Bureau of Reclamation, *Water Management Planner, Developed to Meet the 2017 Standard Criteria for Agricultural and Urban Water Management Plans*, Reclamation Mid-Pacific Region, January 2017.

Feasibility Report Attachment A.1.a.2

Active Turnouts TM

Friant-Kern Canal Middle Reach Capacity Correction Project

Technical Memorandum

Submitted to: Friant Water Authority



March 15, 2019

Friant Water Authority
854 N Harvard Ave
Lindsay, CA 93247

To: Doug DeFlitch and Alan Stroppini
Friant Water Authority

From: Provost & Pritchard Consulting Group

Author: Provost & Pritchard Consulting Group

Project: Friant-Kern Canal Capacity Correction Project

Subject FKC Active Turnouts

Date: March 15, 2019

Friant-Kern Canal Active Turnouts

Overview Map



Notes:

1. All elevations are from a P&P survey conducted in July/August 2018.
2. All elevations are in NAVD 88.
3. Latitude, Longitude and milepost are approximate locations.
4. Number of gates, sizes, and receiving contractor are based on the 1992 Friant-Kern Canal Information Report, as well as visual inspection.
5. This list only contains the active turnouts between the Tule Check and the Kern River. A separate list of drains and abandoned turnouts will be provided.

IMG_0189.JPG

Title: Turnout #1



Attributes	
Mile Post	95.78
HEC-RAS Station	5169+18.60
Side of Canal	West
Latitude	N 36° 04' 20.27"
Longitude	W 119° 05' 20.64"
Top of Bank	414.63
Top of Liner	410.31
Number of Gates & Sizes	3 - 4'x4'
Receiving Contractor	Lower Tule River ID, Wood Central Ditch
Invert	397.00

IMG_0191.JPG

Title: Turnout #2



Attributes	
Mile Post	96.39
HEC-RAS Station	5201+02.00
Side of Canal	East
Latitude	N 36° 03' 51.98"
Longitude	W 119° 05' 36.59"
Top of Bank	413.25
Top of Liner	409.53
Number of Gates & Sizes	1 - 3'
Receiving Contractor	Lower Tule ID, Porterville ID
Invert	393.29

IMG_0238.JPG

Title: Turnout #3



Attributes	
Mile Post	96.87
HEC-RAS Station	5226+37.20
Side of Canal	West
Latitude	N 36° 04' 10.41"
Longitude	W 119° 04' 52.02"
Top of Bank	411.82
Top of Liner	408.12
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	Lower Tule River, Porterville ID, Tipton Ditch
Invert	396.08

IMG_0192.JPG

Title: Turnout #4



Attributes	
Mile Post	97.35
HEC-RAS Station	5251-90.00
Side of Canal	West
Latitude	N 36° 03' 05.26"
Longitude	W 119° 05' 48.98"
Top of Bank	410.81
Top of Liner	407.02
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	Lower Tule River, Porterville ID, Popular Ditch
Invert	392.09

IMG_0194.JPG

Title: Turnout #5



Attributes	
Mile Post	97.86
HEC-RAS Station	5278+95.00
Side of Canal	East
Latitude	N 36° 02' 39.00"
Longitude	W 119° 05' 50.85"
Top of Bank	410.25
Top of Liner	406.57
Number of Gates & Sizes	1 - 3'
Receiving Contractor	Porterville ID
Invert	386.61

IMG_0237.JPG

Title: Turnout #6



Attributes	
Mile Post	98.62
HEC-RAS Station	5319+30.57
Side of Canal	West
Latitude	N 36° 01' 58.95"
Longitude	W 119° 05' 50.63"
Top of Bank	409.7
Top of Liner	405.76
Number of Gates & Sizes	3 - 4.5'x4.5'
Receiving Contractor	Lower Tule River ID, Casa Blanca Ditch
Invert	392.53

IMG_0199.JPG

Title: Turnout #7



Attributes	
Mile Post	99.37
HEC-RAS Station	5358+62.69
Side of Canal	East
Latitude	N 36° 01' 20.76"
Longitude	W 119° 05' 52.52"
Top of Bank	408.28
Top of Liner	404.18
Number of Gates & Sizes	1 - 3'x3'
Receiving Contractor	Tea Pot Dome ID
Invert	392.06

IMG_0200.JPG

Title: Turnout #8



Attributes	
Mile Post	100.64
HEC-RAS Station	5426+00.00
Side of Canal	West
Latitude	N 36° 00' 28.65"
Longitude	W 119° 06' 24.44"
Top of Bank	407.25
Top of Liner	404.74
Number of Gates & Sizes	2 - 4'x4'
Receiving Contractor	Saucelito ID
Invert	385.12

IMG_0204.JPG

Title: Turnout #9



Attributes	
Mile Post	102.65
HEC-RAS Station	5532+10.40
Side of Canal	East
Latitude	N 35° 58' 44.04"
Longitude	W 119° 06' 24.80"
Top of Bank	405.1
Top of Liner	402.41
Number of Gates & Sizes	1 - 3'x3'
Receiving Contractor	Terra Bella ID
Invert	383.94

NO IMAGE AVAILABLE

Title: Turnout #10

Attributes	
Mile Post	102.65
HEC-RAS Station	5532+10.40
Side of Canal	West
Latitude	N 35° 97' 89.26"
Longitude	W 119° 10' 67.87"
Top of Bank	405.19
Top of Liner	402.70
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	Saucelito ID
Invert	383.99

IMG_0206.JPG

Title: Turnout #11



Attributes	
Mile Post	103.64
HEC-RAS Station	5584+50.00
Side of Canal	East
Latitude	N 35° 57' 52.45"
Longitude	W 119° 06' 24.66"
Top of Bank	403.71
Top of Liner	402.1
Number of Gates & Sizes	Pumping Plant
Receiving Contractor	Terra Bella
Invert	383.09

IMG_0210.JPG

Title: Turnout #12



Attributes	
Mile Post	104.96
HEC-RAS Station	5658+25.00
Side of Canal	West
Latitude	N 35° 56' 59.59"
Longitude	W 119° 07' 16.73"
Top of Bank	404.28
Top of Liner	401.73
Number of Gates & Sizes	2 - 4'x4'
Receiving Contractor	Saucelito ID
Invert	380.98

IMG_0217.JPG

Title: Turnout #13



Attributes	
Mile Post	107.35
HEC-RAS Station	5784+25.00
Side of Canal	East
Latitude	N 35° 55' 15.85"
Longitude	W 119° 08' 37.90"
Top of Bank	404.59
Top of Liner	402.18
Number of Gates & Sizes	2 - 3.5'x3.5'
Receiving Contractor	Saucelito ID
Invert	380.40

IMG_0221.JPG

Title: Turnout #14



Attributes	
Mile Post	109.46
HEC-RAS Station	5893+75.00
Side of Canal	East
Latitude	N 35° 53' 31.15"
Longitude	W 119° 09' 07.09"
Top of Bank	406.78
Top of Liner	403.95
Number of Gates & Sizes	1 - 4.5'x4.5'
Receiving Contractor	Delano-Earlimart ID
Invert	386.45

IMG_0222.JPG

Title: Turnout #15



Attributes	
Mile Post	109.46
HEC-RAS Station	5893+75.00
Side of Canal	West
Latitude	N 35° 53' 30.99"
Longitude	W 119° 09' 06.24"
Top of Bank	406.64
Top of Liner	404.02
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	Delano-Earlimart ID
Invert	386.47

IMG_0228.JPG

Title: Turnout #16



Attributes	
Mile Post	111.56
HEC-RAS Station	6005+98.55
Side of Canal	East
Latitude	N 35° 51' 47.62"
Longitude	W 119° 09' 39.34"
Top of Bank	405.49
Top of Liner	403.00
Number of Gates & Sizes	1 - 4'x4'
Receiving Contractor	Delano-Earlimart ID
Invert	385.40

IMG_0229.JPG

Title: Turnout #17



Attributes	
Mile Post	111.56
HEC-RAS Station	5005+50.00
Side of Canal	West
Latitude	N 35° 51' 47.50"
Longitude	W 119° 09' 38.76"
Top of Bank	405.16
Top of Liner	403.09
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	Delano-Earlimart ID
Invert	385.58

IMG_0231.JPG

Title: Turnout #18



Attributes	
Mile Post	111.96
HEC-RAS Station	6026+38.00
Side of Canal	East
Latitude	N 35° 51' 22.65"
Longitude	W 119° 09' 42.99"
Top of Bank	405.33
Top of Liner	402.71
Number of Gates & Sizes	1 - 4'x4'
Receiving Contractor	Delano-Earlimart ID
Invert	392.64

IMG_0232.JPG

Title: Turnout #19



Attributes	
Mile Post	112.36
HEC-RAS Station	6047+11.00
Side of Canal	West
Latitude	N 35° 50' 55.74"
Longitude	W 119° 09' 41.59"
Top of Bank	404.27
Top of Liner	402.15
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	Kern Tulare
Invert	384.06

IMG_0233.JPG

Title: Turnout #20



Attributes	
Mile Post	112.90
HEC-RAS Station	6067+41.39
Side of Canal	East
Latitude	N 35° 50' 38.75"
Longitude	W 119° 09' 42.58"
Top of Bank	404.23
Top of Liner	402.06
Number of Gates & Sizes	Weir
Receiving Contractor	White River Wasteway Parshall
Invert	396.88

IMG_0239.JPG

Title: Turnout #21



Attributes	
Mile Post	113.60
HEC-RAS Station	6113+08.00
Side of Canal	East
Latitude	N 35° 50' 03.68"
Longitude	W 119° 09' 46.31"
Top of Bank	403.9
Top of Liner	401.7
Number of Gates & Sizes	1 - Unknown
Receiving Contractor	Kern Tulare WD
Invert	385.68

IMG_0240.JPG

Title: Turnout #22



Attributes	
Mile Post	113.62
HEC-RAS Station	6114+17.00
Side of Canal	East
Latitude	N 35° 50' 02.70"
Longitude	W 119° 09' 46.37"
Top of Bank	405.46
Top of Liner	401.65
Number of Gates & Sizes	1 - 4.5’ x 4.5’
Receiving Contractor	Delano-Earlimart ID
Invert	383.93

IMG_0241.JPG

Title: Turnout #23



Attributes	
Mile Post	113.62
HEC-RAS Station	6114+17.00
Side of Canal	West
Latitude	N 35° 50' 02.65"
Longitude	W 119° 09' 45.19"
Top of Bank	405.48
Top of Liner	401.69
Number of Gates & Sizes	2 4.5’ x 4.5’
Receiving Contractor	Delano-Earlimart ID
Invert	383.10

IMG_0244.JPG

Title: Turnout #24



Attributes	
Mile Post	115.95
HEC-RAS Station	6235+16.00
Side of Canal	West
Latitude	N 35° 48' 18.26"
Longitude	W 119° 10' 41.52"
Top of Bank	407.44
Top of Liner	401.89
Number of Gates & Sizes	2 - 4'x4'
Receiving Contractor	Delano-Earlimart ID
Invert	385.82

IMG_0247.JPG

Title: Turnout #25



Attributes	
Mile Post	116.93
HEC-RAS Station	6285+39.00
Side of Canal	West
Latitude	N 35° 47' 27.37"
Longitude	W 119° 10' 42.45"
Top of Bank	405.53
Top of Liner	401.96
Number of Gates & Sizes	3 - 4.5'x4.5'
Receiving Contractor	Delano-Earlimart ID
Invert	388.76

IMG_0318.JPG

Title: Turnout #26



Attributes	
Mile Post	117.44
HEC-RAS Station	6313+78.46
Side of Canal	wEST
Latitude	N 35° 47' 00.14"
Longitude	W 119° 10' 40.81"
Top of Bank	410.78
Top of Liner	402.07
Number of Gates & Sizes	2 - 4.5'X4.5'
Receiving Contractor	SSJMUD
Invert	402.84

IMG_0250.JPG

Title: Tunrout #27



Attributes	
Mile Post	117.96
HEC-RAS Station	6341+74.00
Side of Canal	East
Latitude	N 35° 46' 32.85"
Longitude	W 119° 10' 41.85"
Top of Bank	407.14
Top of Liner	401.63
Number of Gates & Sizes	1 - Unknown
Receiving Contractor	Kern Tulare WD
Invert	385.74

IMG_0252.JPG

Title: Turnout #28



Attributes	
Mile Post	118.45
HEC-RAS Station	6389+24.00
Side of Canal	East
Latitude	N 35° 46' 07.50"
Longitude	W 119° 10' 36.69"
Top of Bank	406.78
Top of Liner	401.32
Number of Gates & Sizes	1 - 3'x3'
Receiving Contractor	Delano-Earlimart ID
Invert	385.09

IMG_0254.JPG

Title: Turnout #29



Attributes	
Mile Post	119.55
HEC-RAS Station	6444+54.00
Side of Canal	East
Latitude	N 35° 45' 13.32"
Longitude	W 119° 10' 41.82"
Top of Bank	405.39
Top of Liner	Unlined Section
Number of Gates & Sizes	4 - 2.5'
Receiving Contractor	Lake Woollomes Equalizing Reservoir
Invert	398.03

IMG_0255.JPG

Title: Turnout #30



Attributes	
Mile Post	120.06
HEC-RAS Station	6471+71.21
Side of Canal	West
Latitude	N 35° 44' 48.85"
Longitude	W 119° 10' 56.27"
Top of Bank	405.32
Top of Liner	Unlined Section
Number of Gates & Sizes	2 – 4.5'x4.5'
Receiving Contractor	SSJMUD Airport and Hiett
Invert	383.91

IMG_0256.JPG

Title: Turnout #31



Attributes	
Mile Post	121.49
HEC-RAS Station	6547+25.00
Side of Canal	East
Latitude	N 35° 43' 33.03"
Longitude	W 119° 10' 57.09"
Top of Bank	404.91
Top of Liner	Unlined Section
Number of Gates & Sizes	2 - 3'x3'
Receiving Contractor	Lake Woollomes Equalizing Reservoir
Invert	389.63

IMG_0258.JPG

Title: Turnout #32



Attributes	
Mile Post	122.06
HEC-RAS Station	6576+02.44
Side of Canal	East
Latitude	N 35° 43' 03.74"
Longitude	W 119° 10' 56.87"
Top of Bank	406.27
Top of Liner	400.44
Number of Gates & Sizes	2 - 3.5'x3.5'
Receiving Contractor	SSJMUD
Invert	384.46

IMG_0259.JPG

Title: Turnout #33



Attributes	
Mile Post	122.06
HEC-RAS Station	6575+94.94
Side of Canal	West
Latitude	N 35° 43' 04.29"
Longitude	W 119° 10' 55.88"
Top of Bank	405.72
Top of Liner	400.45
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	SSJMUD
Invert	384.42

IMG_0264.JPG

Title: Turnout #34



Attributes	
Mile Post	124.28
HEC-RAS Station	6691+10.60
Side of Canal	West
Latitude	N 35° 41' 20.70"
Longitude	W 119° 11' 43.59"
Top of Bank	403.17
Top of Liner	399.32
Number of Gates & Sizes	2 - 4.5'x4.5'
Receiving Contractor	SSJMUD
Invert	383.23

IMG_0263.JPG

Title: Turnout #35



Attributes	
Mile Post	125.28
HEC-RAS Station	6691+11.60
Side of Canal	East
Latitude	N 35° 41' 27.10"
Longitude	W 119° 11' 44.86"
Top of Bank	403.09
Top of Liner	399.30
Number of Gates & Sizes	1 - Unknown
Receiving Contractor	SSJMUD
Invert	383.35

IMG_0267.JPG

Title: Turnout #36



Attributes	
Mile Post	125.29
HEC-RAS Station	6744+15.00
Side of Canal	East
Latitude	N 35° 40' 27.90"
Longitude	W 119° 11' 44.69"
Top of Bank	403.47
Top of Liner	399.39
Number of Gates & Sizes	2 - 4'x4'
Receiving Contractor	SSJMUD
Invert	383.32

IMG_0313.JPG

Title: Turnout #37



Attributes	
Mile Post	125.87
HEC-RAS Station	6775+08.20
Side of Canal	West
Latitude	N 35° 40' 01.42"
Longitude	W 119° 12' 00.70"
Top of Bank	402.92
Top of Liner	399.16
Number of Gates & Sizes	2 - 3'x3'
Receiving Contractor	SSJMUD
Invert	383.09

IMG_0269.JPG

Title: Turnout #38



Attributes	
Mile Post	126.38
HEC-RAS Station	6801+16.73
Side of Canal	East
Latitude	N 35° 39' 38.33"
Longitude	W 119° 12' 06.88"
Top of Bank	402.73
Top of Liner	399.37
Number of Gates & Sizes	1 - 3'
Receiving Contractor	Unknown
Invert	394.31

IMG_0312.JPG

Title: Turnout #39



Attributes	
Mile Post	127.43
HEC-RAS Station	6856+83.15
Side of Canal	West
Latitude	N 35° 38' 42.72"
Longitude	W 119° 12' 14.44"
Top of Bank	403.64
Top of Liner	398.95
Number of Gates & Sizes	1 - 3.5'x3.5'
Receiving Contractor	SSJMUD
Invert	382.91

IMG_0272.JPG

Title: Turnout #40



Attributes	
Mile Post	127.97
HEC-RAS Station	6885+42.67
Side of Canal	East
Latitude	N 35° 63’ 77.25”
Longitude	W 119° 20’ 55.02”
Top of Bank	403.53
Top of Liner	398.91
Number of Gates & Sizes	1 - 4.5'x4.5'
Receiving Contractor	SSJMUD
Invert	382.82

IMG_0273.JPG

Title: Turnout #41



Attributes	
Mile Post	130.03
HEC-RAS Station	6989+94.60
Side of Canal	West
Latitude	N 35° 37' 11.89"
Longitude	W 119° 14' 01.99"
Top of Bank	400.48
Top of Liner	397.18
Number of Gates & Sizes	Poso Creek Waste Way
Receiving Contractor	Shafter Wasco ID and Others
Invert	384.68

IMG_0280.JPG

Title: Turnout #42



Attributes	
Mile Post	134.42
HEC-RAS Station	7225+04.00
Side of Canal	West
Latitude	N 35° 33' 30.22"
Longitude	W 119° 14' 45.36"
Top of Bank	399.36
Top of Liner	394.26
Number of Gates & Sizes	3 - 4'x4'
Receiving Contractor	Shafter-Wasco ID
Invert	379.62

IMG_0310.JPG

Title: Turnout #43



Attributes	
Mile Post	137.17
HEC-RAS Station	7370+43.00
Side of Canal	West
Latitude	N 35° 31' 25.09"
Longitude	W 119° 13' 38.78"
Top of Bank	397.77
Top of Liner	394.00
Number of Gates & Sizes	3 - 4'x4'
Receiving Contractor	Shafter-Wasco ID
Invert	379.43

IMG_0309.JPG

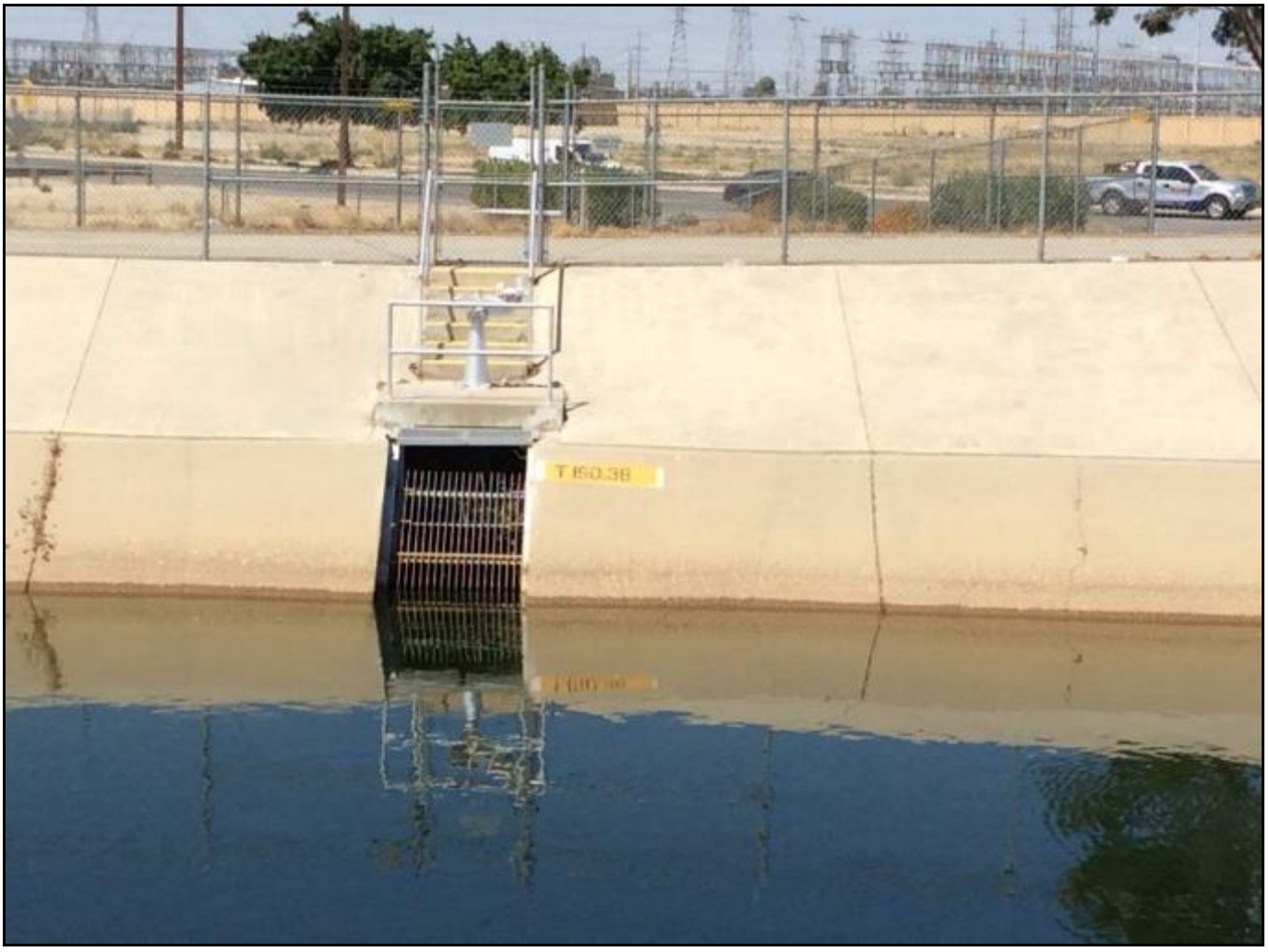
Title: Turnout #44



Attributes	
Mile Post	144.91
HEC-RAS Station	7798+92.00
Side of Canal	West
Latitude	N 35° 27' 22.73"
Longitude	W 119° 07' 34.78"
Top of Bank	397.84
Top of Liner	392.82
Number of Gates & Sizes	3 - 8'
Receiving Contractor	North Kern
Invert	378.78

IMG_0308.JPG

Title: Turnout #45



Attributes	
Mile Post	150.38
HEC-RAS Station	8136+22.00
Side of Canal	West
Latitude	N 35° 22' 49.93"
Longitude	W 119° 05' 28.24"
Top of Bank	395.01
Top of Liner	390.86
Number of Gates & Sizes	1 - 3'x3'
Receiving Contractor	PG&E Steam Plant
Invert	376.42

IMG_0306.JPG

Title: Turnout #46



Attributes	
Mile Post	151.80
HEC-RAS Station	8183+67.70
Side of Canal	West
Latitude	N 35° 22' 04.59"
Longitude	W 119° 05' 14.24"
Top of Bank	394.01
Top of Liner	389.66
Number of Gates & Sizes	2 – 5’ x 5’
Receiving Contractor	Arvin-Edison WSD
Invert	372.93

Feasibility Report
Attachment A1b
Selection of Future Subsidence Conditions
Friant-Kern Canal Middle Reach Capacity Correction Project

Technical Memorandum

Submitted to: Friant Water Authority



March 2019

Friant Water Authority
854 N Harvard Ave
Lindsay, CA 93247

Stantec Consulting Services Inc
3301 C Street, Suite 1900
Sacramento, CA 95816

Tel: 916-924-8844
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To: Doug DeFlitch

From: Janet Atkinson

Authors: William Swanson, David Rogers

Project: Friant-Kern Canal Subsidence Correction Project

Subject Selection of Future Subsidence Conditions Technical Memorandum

Date: March 15, 2019

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Abbreviations and Acronyms

AASHTO	American Association of State Highway and Transportation Officials
ac-ft	acre feet
EPDM	Ethylene Propylene Diene Monomer
FKC	Friant-Kern Canal
FWA	Friant Water Authority
Harder	Thomas Harder & Company
HEC-RAS	Hydrologic Engineering Center River Analysis System
MP	Mile Post
NAVD 88	North American Vertical Datum of 1988
PVC	Polyvinyl Chloride
RM	River Mile
TM	Technical Memorandum
TO	Turnout
WSEL	Water Surface Elevation

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1. DESIGNING FOR FUTURE SUBSIDENCE

Stantec retained Thomas Harder & Company (Harder) to conduct a hydrogeological analysis of potential future subsidence specifically focused along the FKC using a calibrated numerical groundwater flow model of the Tule Subbasin and surrounding area. The results of the analysis are presented in a report titled *Analysis of Potential Subsidence Along the Friant-Kern Canal Using a Groundwater Flow Model* by Thomas Harder, 25-Sep-2018. This report is attached as **Appendix A**.

The following sections present a description of this technical issue as it relates to selecting potential future subsidence conditions for use as design criteria, conclusions reached, and supported reasons and considerations in reaching the conclusions.

2. DESCRIPTION OF TECHNICAL ISSUE

This technical memorandum (TM) addresses the selection of potential future subsidence conditions to be used in the evaluation and design of project alternatives. In order to provide adequate flow capacity into the future, the performance of alternative designs must be evaluated relative to potential future conditions after additional subsidence has occurred. Subsidence projection studies were developed using the Tule Subbasin Groundwater Model under four potential groundwater pumping and hydrologic scenarios. Results for each scenario are provided by decade (2030 – 2070), providing a total of 20 potential subsidence profiles in the project area. Because it is not feasible to evaluate each design alternative over such a large number of subsidence projections, it is necessary to define a small number of potential future subsidence conditions that represent a reasonable range of future outcomes. To achieve this, results of subsidence scenarios have been reviewed and grouped into a small number of potential future subsidence conditions that will be used in design development and evaluation.

2.1 RECOMMENDATIONS

Possible future subsidence along the canal alignment can be represented using four potential ground profiles, which show estimated subsidence resulting from the follow conditions:

- Condition 1 – Minimal near-term subsidence
- Condition 2 – Moderate mid-term subsidence
- Condition 3 – Severe mid-term subsidence
- Condition 4 – Severe long-term subsidence.

Recommendations for the use of these future conditions to evaluate design alternatives are as follows:

- Condition 1 (minimal near-term) represents the minimum subsidence condition. Because it does not differ enough from present conditions, Condition 1 should not be used for an additional specific analysis and comparison of alternatives; evaluation of the present conditions is sufficient to represent near-term conditions.
- Condition 4 (severe long-term) should be used as a worst-case condition to analyze and evaluate design alternatives.
- Conditions 2 and 3 (mid-term possibilities) could be used separately or could be combined to create a single mid-term average condition. In either case, mid-term conditions would allow further evaluation and comparison of design alternatives. Whether and how to use these projections of mid-term subsidence may depend on project funding or other variables that are not yet defined.

- Stantec recommends proceeding with alternative analysis using a severe mid-term subsidence condition that is a combination of Conditions 2 and 3. As described below, this subsidence projection is called *Group 3* and results in an 8-ft maximum subsidence point in the most affected area of the canal profile.

SUPPORTING REASONS

Potential future subsidence along Friant-Kern Canal has been predicted using model analysis. (Reference **Appendix A**: Technical Memorandum on *Analysis of Potential Subsidence Along the Friant-Kern Canal Using a Groundwater Flow Model, by Thomas Harder, 25-September-18*). Analysis considered four possible scenarios that include timing and magnitude of future groundwater pumping and various hydrologic conditions, as follows:

- **Scenario 1** - assumes that current rates of groundwater pumping in the Tule Subbasin will be reduced to sustainable levels (as determined from the sustainable yield of the subbasin) by the year 2025 (5-yr ramp down). This scenario incorporates an average hydrology, based on the historical period from 1986 to 2017, for the entire 50-yr future simulation.

- **Scenario 2** - assumes that current rates of groundwater pumping in the Tule Subbasin will be reduced to sustainable levels by 2040 on a gradual basis (20-yr ramp down). This scenario incorporates an average hydrology, based on the historical period from 1986 to 2017, for the entire 50-yr future simulation.

- **Scenario 3** - assumes that current rates of groundwater pumping in the Tule Subbasin will continue until 2030 before being reduced to sustainable levels by 2040 (10-yr ramp downs starting in 2030). This scenario assumes the following hydrology:

    - The hydrology for first 18 years of the planning horizon (2020 to 2038) is the average of the historical period from 1998/99 to 2015/16, which represents below average precipitation conditions

    - The hydrology for years 2038 to 2050 of the planning horizon is the average of the historical period from 1986/87 to 1997/98, which represents above-average precipitation conditions;

    - The hydrology for years 2050 to 2070 of the planning horizon is the average of the historical period from 1986/87 to 2016/17, which represents the long-term average.

- **Scenario 4** - assumes that current rates of groundwater pumping in the Tule Subbasin will be reduced to sustainable levels by 2030 (10-yr ramp down). This scenario applies the same hydrology described under Scenario 3.

The Harder study yielded different patterns and magnitudes of subsidence over the time period from 2030 to 2070. Fifteen different future land surface elevation maps were produced, resulting in 15 potential future canal invert profiles. Sometimes several of these profiles were quite similar, even though each was caused by a different combination of hydrology and groundwater

pumping. A group of these similar profiles could then be averaged to produce a single profile assumption that is representative of several possible future conditions.

In order to compare alternative designs using a manageable number of design conditions, it makes sense to use just a few representative subsided canal profiles. Results from multiple subsidence scenarios that all produce a similar future ground profile can yield a single design condition.

Results of modeled scenarios have been grouped as shown in **Figure 1** and the subsequent subsidence profiles for each group are shown in **Figure 2**.

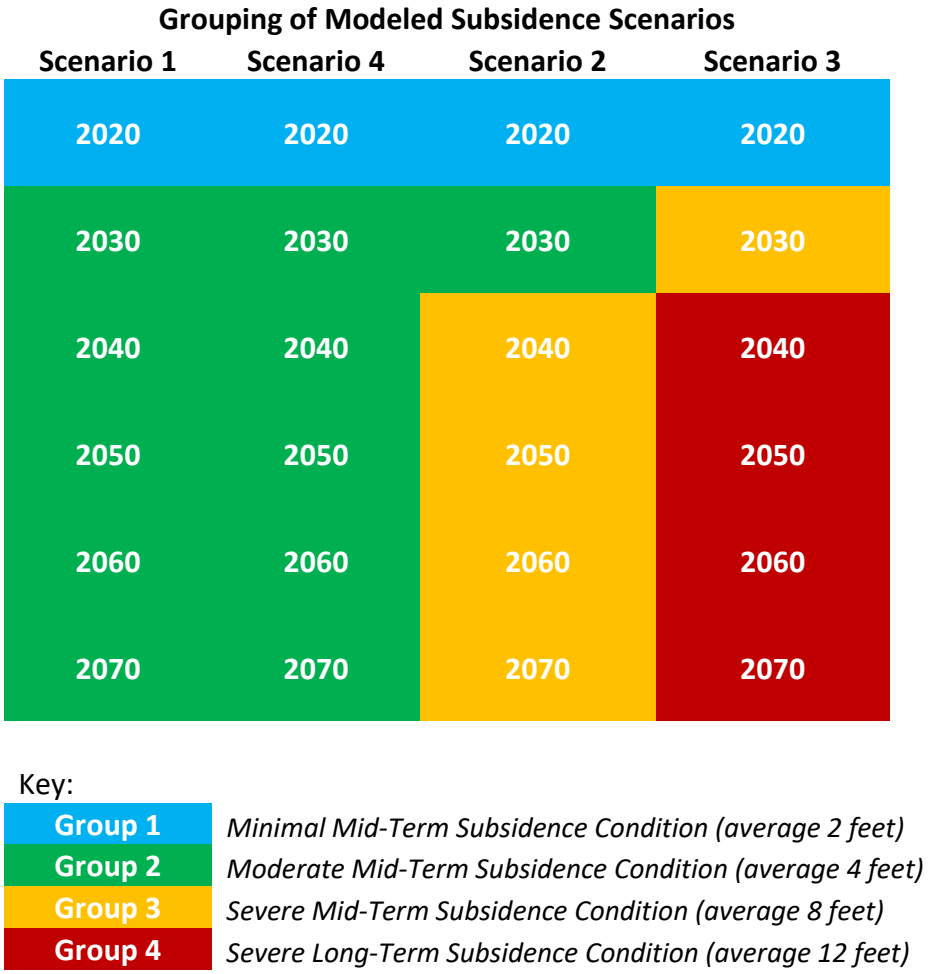


Figure 1. Future Groundwater Subsidence Conditions used for Project Design

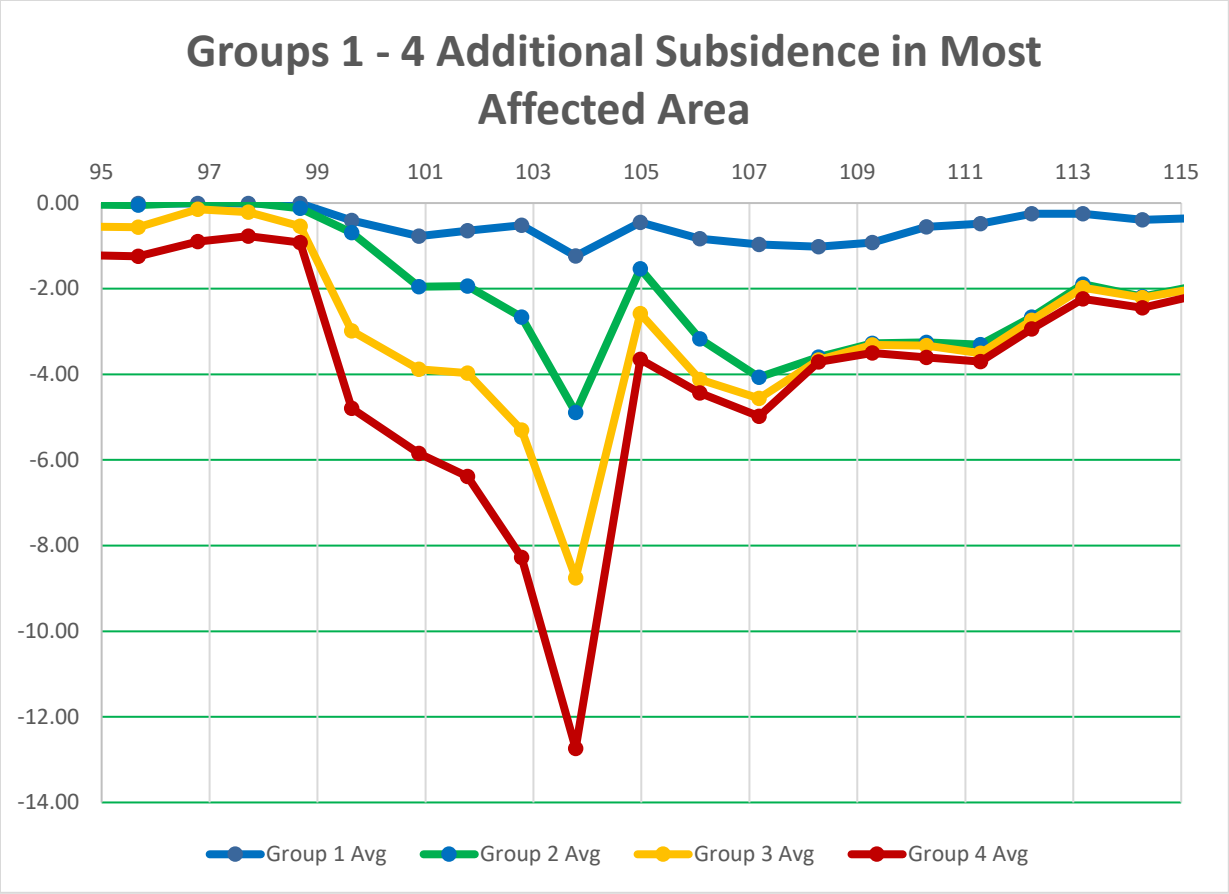


Figure 2. Future Subsidence Profiles

ADDITIONAL CONSIDERATIONS AND CONCLUSIONS

- Neither future groundwater pumping nor future hydrology can be predicted with certainty. Therefore, it is impossible to quantify exactly how and when subsidence will occur.
- It is more informative to frame and analyze subsidence possibilities without tying these possibilities to exact conditions that cause them or to dates when they will occur.
- Scenario 1 represents a minimal subsidence conditions. It is considered to be an overly optimistic prediction of reductions to groundwater pumping.
- For the purpose of evaluating design alternatives, four representative subsidence conditions can be framed:
    - Minimal Mid-term Subsidence Condition
    - Moderate Mid-term Subsidence Condition
    - Severe Mid-term subsidence Condition

- Severe Long-term Subsidence Condition

- A minimal mid-term subsidence condition may occur in the next few years, and therefore may exist by the time the current correction project is constructed; a design based on this condition would not provide adequate protection against future subsidence.

- A moderate mid-term subsidence condition can result from either a slower rate of groundwater pumping over a longer period of time or a greater rate of groundwater pumping over a shorter time, resulting from dry hydrologic conditions. This condition would produce a mid-term design solution with a probable life-span of about ***10-20 years*** (2030-2040).

- A severe mid-term subsidence condition can result from a greater rate of groundwater pumping over a longer period of time under dry hydrologic conditions. This condition would produce a mid-term design solution, with a probable life-span of between ***20 and 40 years*** (2040-2060).

- A severe long-term subsidence condition would result from greater groundwater pumping, which could occur either at a fast rate for an intermediate time period or a moderate rate over a long time. This severe condition would produce a long-term design solution, with a probable life-span of between ***30 and 50 years*** (2050-2070).

- Scenario 1 provides a bookend to show the minimum subsidence condition. Eliminating the results from Scenario 1 assumptions allows results from Scenarios 2, 3 and 4 to be combined into three representative future subsidence conditions:

  - Group 2 – A Moderate Mid-term profile that represents Scenario 4 in the years 2030-2070 and Scenario 2 in the year 2030.

  - Group 3 – A Severe Mid-term profile that represents Scenario 2 in the years 2040-2070 and Scenario 3B in the year 2030.

  - Group 4 – A Severe Long-term profile that represents Scenario 3 in the years 2040-2070.

- Stantec recommends proceeding with alternative analysis using Group 3 subsidence projections that result in an 8-ft maximum subsidence point in the most affected area of the canal profile.

- This study of potential future subsidence conditions does not include evaluation of cost impacts, and recommendations are not based on cost comparisons.

- Conclusions and recommendations in this memorandum are intended to provide information to be used in subsequent analysis and comparison of design alternatives. Design criteria used in the development of these alternatives include embankment and lining heights based on subsidence projections. These details, along with technical and economic evaluation of design alternatives, are documented in the Plan Formulation Basis of Design Report.

- After producing the September 2018 report with subsidence predictions (see **Appendix A**), Thomas Harder has continued to calibrate and refine his model of subsidence in the Tule Basin. Recent simulations with a recalibrated model have produced results that support similar qualitative findings and groupings as presented in this Stantec TM. Due to ongoing refinements in calibration, future studies are likely to produce minor variations to subsidence predictions.

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Feasibility Report Attachment A1b1
Subsidence Modeling TM
Friant-Kern Canal Middle Reach
Capacity Correction Project

Technical Memorandum

Submitted to: Friant Water Authority



March 15, 2019

Friant Water Authority
854 N Harvard Ave
Lindsay, CA 93247

To: Doug DeFlitch and Alan Stroppini
Friant Water Authority

From: Thomas Harder & Co.

Author: Thomas Harder & Co.

Project: Friant-Kern Canal Capacity Correction Project

Subject Potential Subsidence Along the Friant-Kern Canal

Date: March 15, 2019

Technical Memorandum

To: Ms. Janet Atkinson
Stantec

From: Thomas Harder, P.G., CH.G.
Thomas Harder & Co.

Date: 25-Sep-18

Re: Analysis of Potential Subsidence Along the Friant-Kern Canal Using a Groundwater Flow Model

1 INTRODUCTION

This technical memorandum (TM) summarizes an analysis of potential future subsidence along a section of the Friant-Kern Canal in the eastern portion of the Tule Subbasin in Tulare County California (see Figure 1). The analysis was conducted using a calibrated numerical groundwater flow model that includes a land subsidence package. The model is calibrated to historical groundwater levels and land surface elevation. In order to assess potential future land subsidence in the vicinity of the Friant-Kern Canal, four model analysis scenarios were used to predict, to the extent possible, the range of potential groundwater conditions that could be realized in the future. The key inputs for the future scenarios included the timing and magnitude of future groundwater pumping and estimates of future hydrological conditions. This work is being conducted to inform engineering design alternatives under evaluation by Stantec to mitigate current and potential future flow restrictions within the Friant-Kern Canal caused by land subsidence.

1.1 PURPOSE AND SCOPE

The purpose of the analysis presented herein is to estimate potential future land subsidence along a section of the Friant-Kern Canal, located within the Tule Subbasin in Tulare County, based on assumptions with respect to potential future groundwater pumping and recharge in the vicinity of the canal. The methodology to conduct the analysis incorporates the use of a calibrated numerical groundwater flow model of the Tule Subbasin and surrounding area.

The scope of work to address the objective includes:

1. Developing future groundwater production and recharge scenarios for analysis with the groundwater flow model.

2. Developing the model input files for each scenario that accounts for a range of potential future pumping and hydrological conditions.
3. Using the groundwater flow model to analyze the scenarios.
4. Preparing this TM describing the methodologies and results of the subsidence analysis.

1.2 LAND SUBSIDENCE FROM GROUNDWATER WITHDRAWAL

Land surface subsidence from groundwater withdrawal occurs in areas where the subsurface aquifer system includes relatively thick aquitards and the groundwater level is lowered over long periods of time (typically decades). Aquitards are low permeability layers with relatively high silt and clay content. As the aquitards are compressible, the release of pore pressure caused by the lowering of groundwater levels results in compression of the low permeability layers. Within a limited range of groundwater level fluctuation, the compressed aquitards can accept water back into their structure when groundwater levels rise resulting in elastic rebound. However, if groundwater levels are maintained at these lower levels for long enough periods of time as a result of groundwater pumping, the compression of aquitards becomes permanent. This permanent compression of subsurface layers results in land surface subsidence.

When aquitards are compressed, they release water into the adjoining aquifers. This release of water results in a one-time transfer of water to aquifer storage. Preliminary estimates indicate that between water years 1986/87 and 2016/17, approximately 2,400,000 acre-ft of water was expelled from aquitards in the Tule Subbasin. The most compressible sediments in the subsurface beneath the Tule Subbasin are the Corcoran Clay, which occurs at depths of 350 feet to 400 feet below land surface, and Pliocene marine deposits which occur at depths ranging from 400 feet to greater than 2,000 feet below land surface. For the groundwater flow model used to evaluate land subsidence, these sediments are correlative with model layers 2 and 4 (see Section 2 of this TM). However, the subsurface beneath the Tule Subbasin consists of multiple interbedded clay layers, apart from the definable Corcoran Clay and Pliocene marine deposits. All of these interbedded clay layers can potentially compress and result in land subsidence.

In the Tule Subbasin, land surface subsidence as a result of groundwater production has been well documented.[1] Documentation of historical land subsidence in the 1950s and 1960s includes the portion of the Tule Subbasin where the Friant-Kern Canal is located.[2] Land subsidence in this area was essentially arrested in the late 1970s and 1980s as the introduction of imported water into the area allowed for reduced groundwater pumping and groundwater levels recovered.

[1] Ireland, R.L., Poland, J.F., and Riley, F.S., 1984. Land Subsidence in the San Joaquin Valley, California, as of 1980. USGS Professional Paper 437-I.
Faunt, C.C., 2009. Groundwater Availability of the Central Valley Aquifer, California. USGS Professional Paper 1766.
Luhdorff and Scalmanini, 2014. Land Subsidence from Groundwater Use in California. Prepared in Cooperation with the California Water Foundation.
[2] Lofgren, B.E. and Klausing, R.L., 1969. Land Subsidence Due to Ground-Water Withdrawal, Tulare-Wasco Area, California. USGS Professional Paper 437-B.

The land subsidence was likely reactivated again in the 1990s with the return of groundwater overdraft conditions and subsidence rates appear to have accelerated after 2007 due to increased pumping and drought conditions.

1.3 HYDROGEOLOGICAL CONDITIONS THAT CAUSE LAND SUBSIDENCE NEAR THE FRIANT-KERN CANAL IN THE TULE SUBBASIN

The subsurface sediments in the vicinity of the Friant-Kern Canal consist of interbedded layers of sand, silt and clay. The percentage of clay layers (which are compressible) relative to sand layers (which are not compressible) that makes up the cross-sectional subsurface area varies from place to place. As shown on Figure 2, the area of the Friant-Kern Canal where historical land subsidence has been greatest is also an area where the percentage of subsurface coarse-grained sediments is relatively low and fine-grained sediments (which includes clay) is relatively high (dark brown areas). As such, these areas of substantial thickness of subsurface clay are conducive to subsidence. While there is not a significant amount of groundwater level data in the areas of highest subsidence along the canal, it is well documented that the Tule Subbasin is in a state of overdraft and groundwater levels in most areas of the subbasin have been generally dropping over time, a trend that has accelerated since 2007 with the advent of prolonged below normal precipitation conditions in the area.[3]

[3] TH&Co, 2017. *Hydrogeological Conceptual Model and Water Budget of the Tule Subbasin*. Prepared for the Tule Subbasin MOU Group. Dated August 1, 2017.

2 LAND SUBSIDENCE ANALYSIS METHODOLOGY - GROUNDWATER FLOW MODEL

Potential future land subsidence near the portion of the Friant-Kern Canal that is within the Tule Subbasin was conducted using a calibrated numerical groundwater flow model programmed to analyze land subsidence. The model utilized for this work was developed for the Tule Subbasin MOU Group in support of their compliance with the Sustainable Groundwater Management Act (SGMA). The model domain (i.e. active model area) is focused on the Tule Subbasin but extends approximately 4 to 6 miles outside the subbasin on each side (see Figure 1). The work to prepare the model was initiated in July 2017 and the draft calibrated model was presented to the Tule MOU Group on August 15, 2018.

2.1 MODEL CODE

The Tule Subbasin model was developed using MODFLOW. MODFLOW is a block centered, finite difference groundwater flow modeling code developed by the United States Geological Survey (USGS) for simulating groundwater flow.[4] MODFLOW is one of the most widely used and critically accepted model codes available.[5] The version of MODFLOW utilized for this work is the USGS One Water Hydrologic Flow Model,[6] which integrates both surface water and groundwater processes. The model includes a subsidence and aquifer system compaction package,[7] which was utilized for the analysis of subsidence in this study.

2.2 MODEL DOMAIN AND BOUNDARY CONDITIONS

The Tule Subbasin model domain is as shown on Figure 1. This domain encompasses the Tule Subbasin alluvial groundwater system covering an area of approximately 1,500 square miles (i.e., approximately 1 million acres). The model is subdivided into uniform 1,000-foot by 1,000-foot cells. Vertically, the model is subdivided into five hydrostratigraphic layers, which represent groupings of geologic sediments with generally similar properties. The vertical layers are described as follows (from shallow to deep):

- Layer 1 is the upper unconfined aquifer and ranges in thickness from approximately 100 feet in the northeast part of the subbasin to approximately 400 feet in the northwestern part of the subbasin;

[4] McDonald, M.G., and Harbaugh, A.W., 1988. *A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model:* in Techniques of Water-Resources Investigations of the United States Geological Survey; Book 6 Modeling Techniques.

[5] Anderson, M.A., and Woessner, W.W., 2002. *Applied Groundwater Modeling, Simulation of Flow and Advective Transport*. Academic Press.

[6] Hanson, R.T., Boyce, S., Schmid, W., Hughes, J.D., Mehl, S.M., Leake, S.A., Maddock, T., and Niswonger, R.G., 2014. *One-Water Hydrologic Flow Model (MODFLOW-OHWM)*. USGS Techniques and Methods, 6-A51.

[7] Hoffman, J., Leake, S.A., Galloway, D.L., and Wilson, A.M., 2003. *MODFLOW-2000 Ground Water Model, Users Guide to the Subsidence and Aquifer System Compaction (SUB) Package.* USGS Open-File Report 03-233.

- Layer 2 is an underlying comparatively low permeability unit separating the upper and lower aquifers and generally coincides with the Corcoran Clay west of Highway 99. This layer ranges in thickness from approximately 300 feet in the western part of the subbasin to zero in the eastern part of the subbasin;
- Layer 3 is the lower alluvial aquifer, which is semi-confined in the east and confined below the Corcoran Clay in the west. This layer ranges in thickness from approximately 200 feet on the east side of the subbasin to greater than 1,600 feet on the west side;
- Layer 4 is a low permeability layer separating the lower alluvial aquifer from the underlying Santa Margarita Formation aquifer. This layer ranges in thickness from approximately 200 feet on the east side of the subbasin to more than 800 feet in the central part of the subbasin; and
- Layer 5 is the Santa Margarita Formation aquifer, which is located at depth only on the eastern side of the subbasin. This layer ranges in thickness from approximately 200 feet on the east side of the subbasin to more than 600 feet in the central part of the subbasin.

Groundwater flow into and out of the model area is controlled by boundary conditions. On the north, south and west boundaries of the Tule Subbasin model, historical groundwater flow is conditioned to measured groundwater levels (i.e. hydrographs) from wells located along the boundaries. On the east side of the model, groundwater flow from the bedrock of the Sierra Nevada Mountains is difficult to simulate due to the fractured nature of the granitic rock and lack of data. This issue has been addressed by assigning the area of the Sierra Nevada Mountains as "no flow" or inactive and assigning recharge from the mountains as a boundary condition along the bedrock/alluvium interface. The granitic bedrock also forms the base of the model (assumed to be impermeable) in the subsurface beneath model Layer 5. This boundary is not vertical but slopes towards the west consistent with our understanding of how the Sierra Nevada basement extends beneath the subbasin.

2.3 MODEL TRANSIENT SETUP AND CALIBRATION

The Tule Subbasin model has been calibrated from 1986 through 2017 with monthly stress periods. Thus, historical groundwater pumping and recharge data is input into the model on a monthly basis. The model calibration was achieved for the 1986 to 2017 time period by adjusting aquifer parameters until the best possible match between measured and model-generated groundwater levels was obtained. The model calibration process included both manual and automated methods. Calibration hydrographs of selected wells in the model domain are provided as Attachment A. Based on the comparison of model-generated and measured groundwater levels, it is our opinion that the historical model is adequately calibrated to measured data for this analysis.

In addition to calibrating groundwater levels, TH&Co also calibrated model-generated land subsidence with measured land subsidence in the Tule Subbasin. Measured historical changes in

land surface elevation were obtained from Global Positioning System (GPS) stations in the subbasin and satellite data (Interferometric Synthetic Aperture Radar or InSAR). GPS measures land surface elevation at any given time based on position relative to multiple satellites. TH&Co received GPS data from the Friant Water Authority for multiple stations with records from 2005 to 2018. InSAR enables estimates of changes in land surface elevation over time based on radar images from multiple satellite passes over the same area. Changes in land surface elevation were obtained from the Jet Propulsion Laboratory (JPL) for the following time periods:

- InSAR Dataset 1: 2007 - 2011
- InSAR Dataset 2: 2014 – 2015
- InSAR Dataset 3: 2015 – 2017

Results of the land subsidence calibration is provided as Attachment B. Based on comparison of model generated and measured rates of land surface subsidence in the Tule Subbasin, the calibration of land elevation changes over time was considered acceptable for analyzing future projections of land subsidence under varying pumping conditions in the subbasin.

It is noted that the Tule Subbasin model used to analyze potential future land subsidence is based on the best available data at the time it was calibrated in August 2018. Additional data was presented at the 15-Aug-2018 Tule Subbasin MOU Group meeting and the Group has requested that TH&Co update the model to incorporate these data. The data include additional groundwater levels, soil lithology, groundwater pumping data, and aquifer property data that had not previously been made available. Further, CDWR submitted land use data for 2014 in August 2018. The Tule MOU Group requested that TH&Co update the model to incorporate these data.

As part of the model update, it will need to be recalibrated. As additional data become available, the model will periodically be refined to account for new information. Ongoing model refinements may result in changes to model outcomes. However, it is our opinion that the Tule Subbasin model used in this analysis is the best tool currently available for predicting potential future groundwater levels and land subsidence under any given basin management scenario.

Future model calibrations will also include a sensitivity and uncertainty analysis, to provide an assessment of the model parameters that have the greatest impact on model results, and provide an indication of potential variability of model results.

3 DESCRIPTION OF FUTURE SCENARIOS

It is generally recognized that future groundwater pumping for agricultural irrigation in the Tule Subbasin will need to be reduced in order to comply with SGMA. The timing of this reduction in pumping, however, has not been determined. Many Groundwater Sustainability Agencies (GSAs) in the area of the affected Friant-Kern Canal have discussed a transitional decline in pumping. Four future scenarios were analyzed to account for a range of potential future pumping "ramp down" conditions. The scenarios also incorporate a range or variation of hydrological conditions, which could also impact groundwater levels and, thus, subsidence. Each scenario was run for 50 years into the future (i.e. 50-yr planning horizon).

The starting year for each scenario was assumed to be 2020 as this is the year when each GSA's Groundwater Sustainability Plan (GSP) is due to the California Department of Water Resources (CDWR). For scenarios 1, 2, and 4, the pumping ramp down begins in 2020, in recognition of the urgency of addressing declining groundwater levels and mitigating land subsidence. Scenario 3 was considered a "worst case" production ramp down as it relates to land subsidence as pumping reduction was not started until 2030.

For each scenario, groundwater pumping in the Tule Subbasin was reduced over a prescribed period of time to a target pumping level that was considered "sustainable." Sustainability in this case was assumed to be the level of pumping which results in no net negative change in groundwater storage after the year 2040. In the interest of time, the pumping target was initially assigned based on the sustainable yield estimate for the subbasin previously reported in TH&Co (2017). However, analysis of the scenarios shows that there is still some net negative change in groundwater storage in the Tule Subbasin after 2040 at the assumed pumping ramp down target and that the sustainable yield is lower than originally estimated. The implication for the subsidence analyses presented herein is that the subsidence estimates, particularly after 2040, may be slightly higher than would be expected in reality under the same pumping ramp down schedule but lower pumping target. Nonetheless, given the scenarios analyzed and based on the available data, we consider the subsidence estimates from this analysis acceptable as they are likely conservative with respect to canal design considerations. Future model updates and refinements will enable more representative predictions of subsidence as additional data become available.

The following subsections describe the model scenarios analyzed for this study.

3.1 SCENARIO 1

Scenario 1 assumes that current rates of groundwater pumping in the Tule Subbasin will be reduced to sustainable levels (as determined from the sustainable yield of the subbasin) by 2025 (5-yr ramp down). This scenario incorporates an average hydrology, based on the historical period from 1986 to 2017, for the entire 50-yr future simulation (see Figure 3 and Table 1).

3.2 SCENARIO 2

Scenario 2 assumes that current rates of groundwater pumping in the Tule Subbasin will be reduced to sustainable levels by 2040 (20-yr ramp down). This scenario incorporates an average hydrology, based on the historical period from 1986 to 2017, for the entire 50-yr future simulation.

3.3 SCENARIO 3

Scenario 3 assumes that current rates of groundwater pumping in the Tule Subbasin will continue until 2030 before being reduced to sustainable levels by 2040 (10-yr ramp down starting in 2030). This scenario assumes the following hydrology:

- The hydrology for first 18 years of the planning horizon (2020 to 2038) will be the average of the historical period from 1998/99 to 2015/16, which represents below-average precipitation conditions (see Table 1);
- The hydrology for years 2038 to 2050 of the planning horizon will be the average of the historical period from 1986/87 to 1997/98, which represents above-average precipitation conditions;
- The hydrology for years 2050 to 2070 of the planning horizon will be the average of the historical period from 1986/87 to 2016/17, which represents the long-term average.

3.4 SCENARIO 4

Scenario 4 assumes that current rates of groundwater pumping in the Tule Subbasin will be reduced to sustainable levels by 2030 (10-yr ramp down). This scenario assumes the same hydrology as Scenario 3.

4 MODEL-PREDICTED SUBSIDENCE ALONG THE FRIANT-KERN CANAL

Model-predicted changes in ground surface elevation along the length of the Friant-Kern Canal within the Tule Subbasin are shown in profile view in Attachment C. Change in land surface elevation, relative to the 2017 canal elevation, is provided for the years 2030, 2040, 2050, 2060, and 2070. As shown, all four scenarios result in additional subsidence along the canal relative to 2017 with Scenarios 1, 2 and 3 resulting in progressively greater amounts of subsidence. Land subsidence associated with Scenario 4 (10-year groundwater production ramp down) was slightly more than predicted for Scenario 1. The largest amounts of subsidence occur at Mile Posts 102.69 and 103.78, which are near the canal intersection with Deer Creek (see Table 2). At these locations, the maximum relative change in land elevation is predicted to range from approximately 4.8 feet (Scenarios 1 and 4) to 13.6 feet (Scenario 3) by 2070.

Model-predicted annual changes in ground surface elevation from 2017 through 2070 are shown in Attachment D for selected mile posts along the canal. At almost all points, the rate of subsidence reduces to near 0 ft/yr by the end of the 50-yr planning horizon (2070), which occurs as a result of groundwater levels stabilizing from reduced pumping.

Maps showing areal distribution of cumulative land subsidence near the Friant-Kern Canal at years 2030, 2040, 2050, 2060, and 2070 are provided in Attachment E. Along the Friant-Kern Canal, the area of greatest subsidence occurs east of the canal/Deer Creek intersection and is approximately correlative with the area of high subsurface clay content shown on Figure 2. Increasing cumulative land subsidence with time is also predicted in the model area west and northwest of the canal.

5 SUMMARY OF FINDINGS

The following summarizes our findings with respect to the analysis of model scenarios presented herein:

- The portion of the Friant-Kern Canal where the greatest land subsidence has been historically observed (near the intersection between the canal and Deer Creek) correlates to an area where there is a high percentage of clay in the subsurface that is susceptible to aquitard compaction (see Figure 2).
- Review of all future projection scenarios analyzed suggests that land subsidence beneath the Friant-Kern Canal is projected to continue into the future.
- Future model projection scenarios that simulate the most rapid decline in groundwater pumping over the 50-yr planning horizon (Scenarios 1 and 4) result in the lowest simulated land subsidence rate and lowest cumulative subsidence in the vicinity of the Friant-Kern Canal.
- The maximum cumulative subsidence at the Friant-Kern Canal predicted for Scenarios 1 and 4 (5- and 10-yr production ramp down, respectively) is on the order of 4.5 to 5 feet and is located at mile post 103.78 (near Deer Creek).
- Land subsidence rates are predicted to be higher east of the Friant-Kern Canal south of Deer Creek and along State Highway 65. As such, relocating the canal to the east of the current location would not avoid additional subsidence without reducing groundwater pumping.
- The rate and magnitude of simulated land subsidence is sensitive to the magnitude and timing of groundwater production. Of the four scenarios, Scenario 3, which simulates groundwater production at current rates through 2030 and ramping down to the sustainable target by 2040, is anticipated to result in the highest initial rate of simulated land subsidence and greatest cumulative subsidence in the vicinity of the Friant-Kern Canal over the 50-yr planning horizon. Under this scenario, the maximum cumulative land subsidence at the Friant-Kern Canal is predicted to be on the order of 14 feet at mile post 103.78 (near Deer Creek).

Tables

Table 1

Available Surface Water in the Tule Subbasin

Water Year	Stream Inflow	Imported Water	Total	Long-Term Average	Period Average
1986 - 1987	242,928	291,601	534,529	492,949	537,918
1987 - 1988	77,544	250,927	328,471		
1988 - 1989	49,579	257,528	307,107		
1989 - 1990	55,151	180,417	235,569		
1990 - 1991	59,884	244,525	304,409		
1991 - 1992	39,144	222,082	261,226		
1992 - 1993	134,685	659,775	794,460		
1993 - 1994	69,369	254,998	324,367		
1994 - 1995	261,129	508,921	770,049		
1995 - 1996	203,525	577,298	780,823		
1996 - 1997	425,669	488,537	914,206		
1997 - 1998	564,249	335,554	899,803		
1998 - 1999	134,345	444,331	578,676		434,888
1999 - 2000	122,462	453,632	576,095		
2000 - 2001	66,960	297,393	364,352		
2001 - 2002	89,752	303,240	392,992		
2002 - 2003	146,557	376,902	523,459		
2003 - 2004	60,970	296,815	357,785		
2004 - 2005	201,818	544,370	746,188		
2005 - 2006	227,123	557,865	784,988		
2006 - 2007	47,303	192,436	239,739		
2007 - 2008	84,796	272,596	357,392		
2008 - 2009	63,108	338,882	401,990		
2009 - 2010	166,328	446,184	612,512		
2010 - 2011	326,342	505,876	832,218		
2011 - 2012	102,178	260,081	362,259		
2012 - 2013	36,205	196,128	232,332		
2013 - 2014	16,663	70,161	86,824		
2014 - 2015	11,067	40,153	51,220		
2015 - 2016	93,437	233,532	326,968		
2016 - 2017	421,349	577,072	998,421		

Note: All values in acre-ft.

Maximum Additional Subsidence along the Friant-Kern Canal Relative to 2017

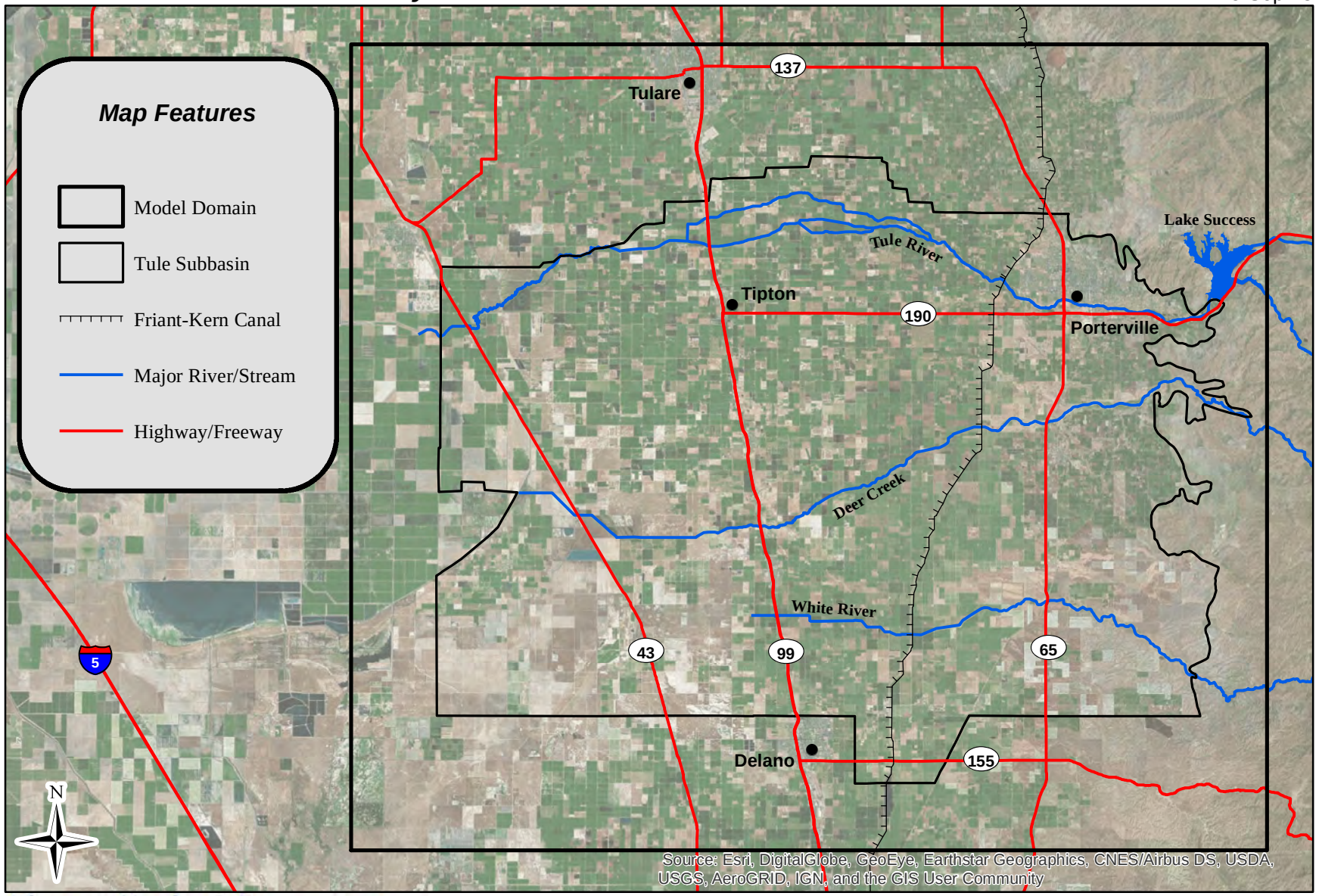
	2020	2030	2040	2050	2060	2070
Scenario 1	1.2	4.1	4.8	4.8	4.8	4.8
Scenario 2	1.3	5.7	8.5	9.5	9.5	9.5
Scenario 3	1.3	6.7	10.8	12.9	13.6	13.6
Scenario 4	1.2	4.6	5.1	5.1	5.1	5.1

Notes:

Maximum additional subsidence predicted to occur at Mile Post 103.78.
Values in feet.

Figures

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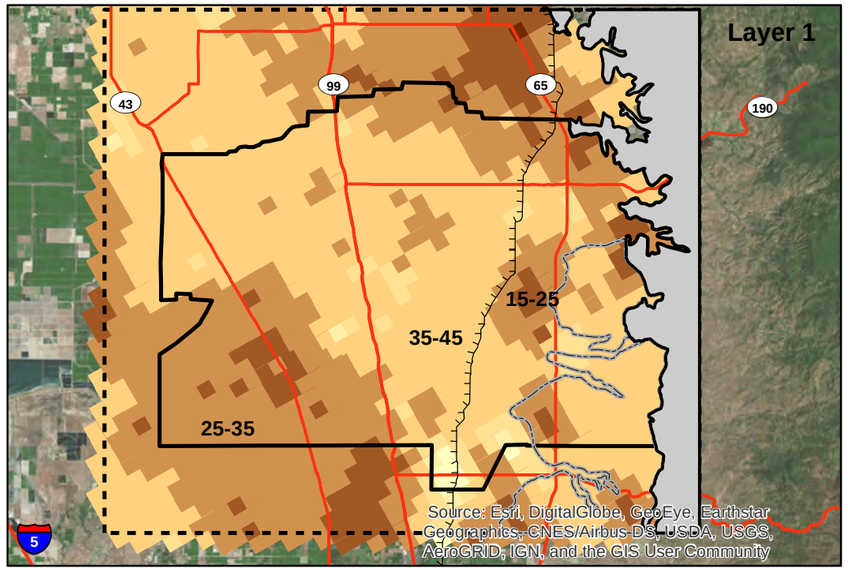
Area Map

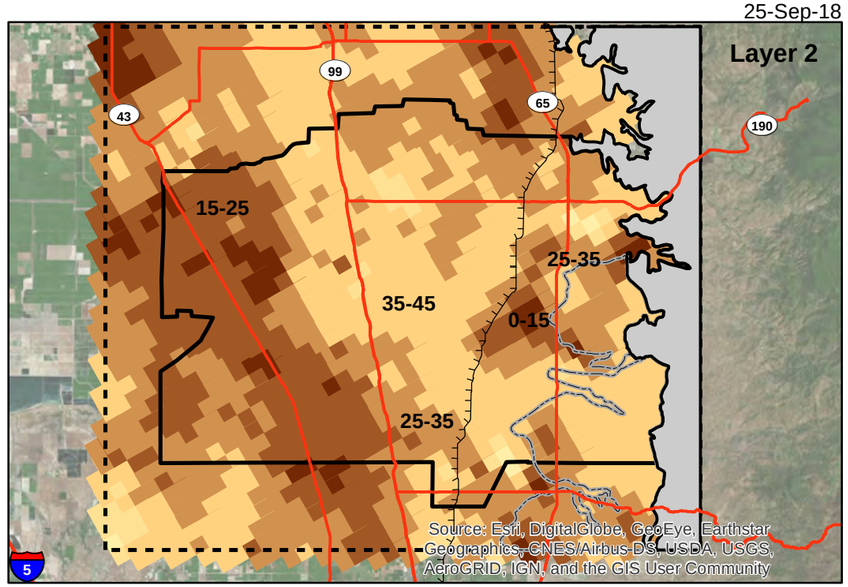
Figure 1

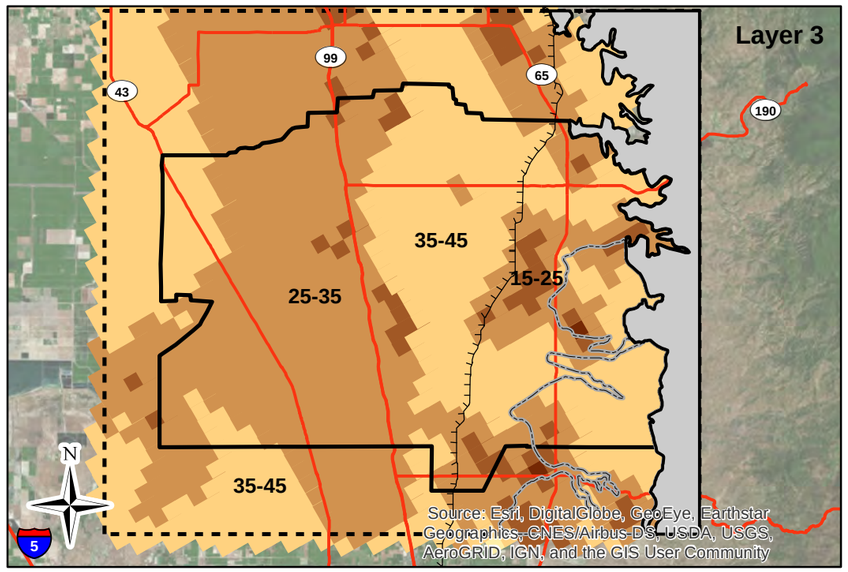
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25-Sep-18

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal







0 5 10 20 Miles

NAD 83 State Plane Zone 4

Map Features

Percent Coarse-Grained Sediments

- < 15
- 15 - 25
- 25 - 35
- 35 - 45
- 45 - 55
- 55 - 65
- 65 - 75
- Friant-Kern Canal
- Dissected Uplands
- Model Domain
- Model No Flow Zone
- Tule Groundwater Subbasin
- Major Highway

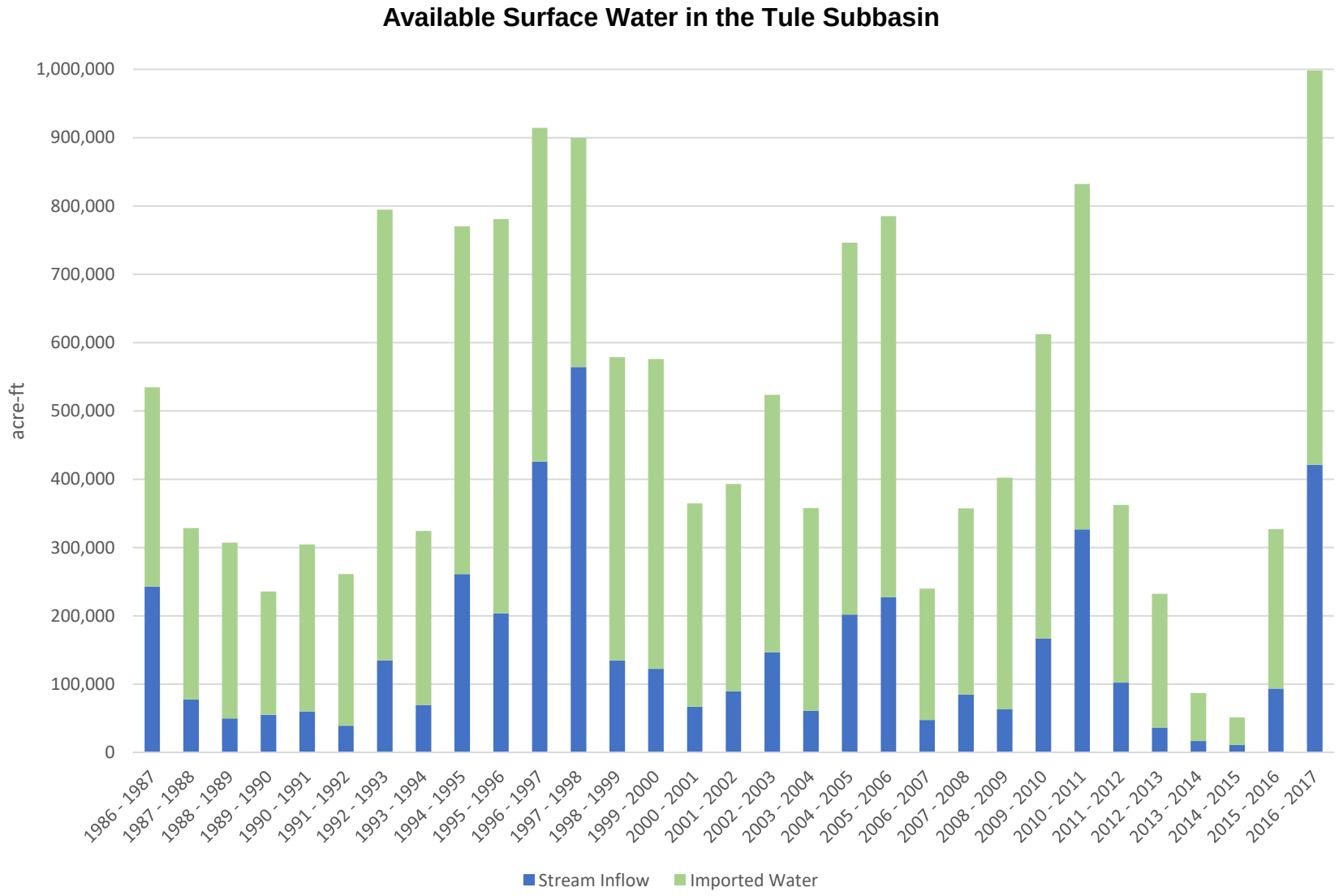
Note: Percent coarse data modified from USGS Professional Paper 1766

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Textural Analysis Percent Coarse-Grained Sediments by Model Layer

Figure 2

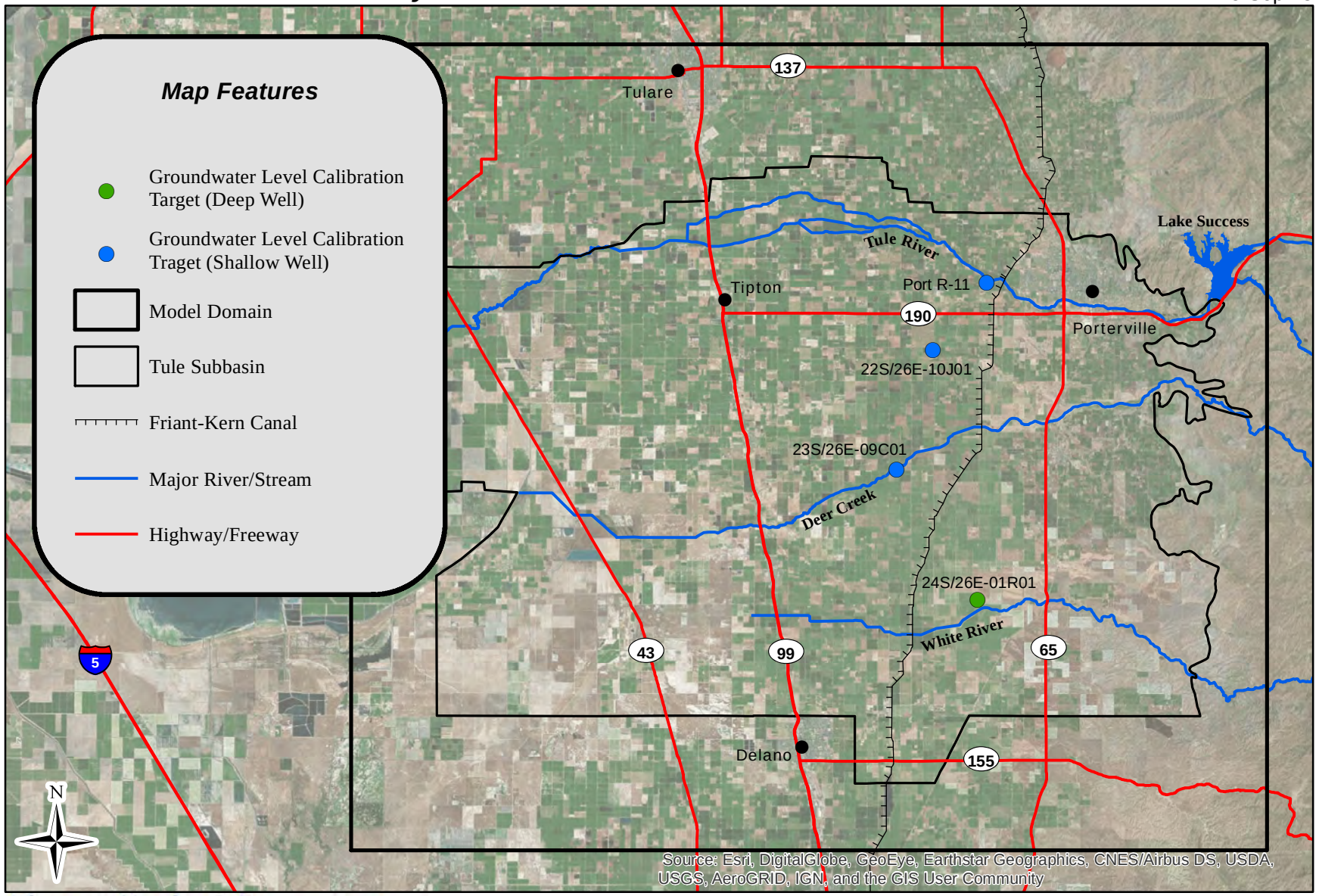
Figure 3


Available Surface Water in the Tule Subbasin
acre-ft
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
1986 - 1987
1987 - 1988
1988 - 1989
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2016 - 2017
Stream Inflow
Imported Water

Attachment A

Groundwater Level Calibration Charts

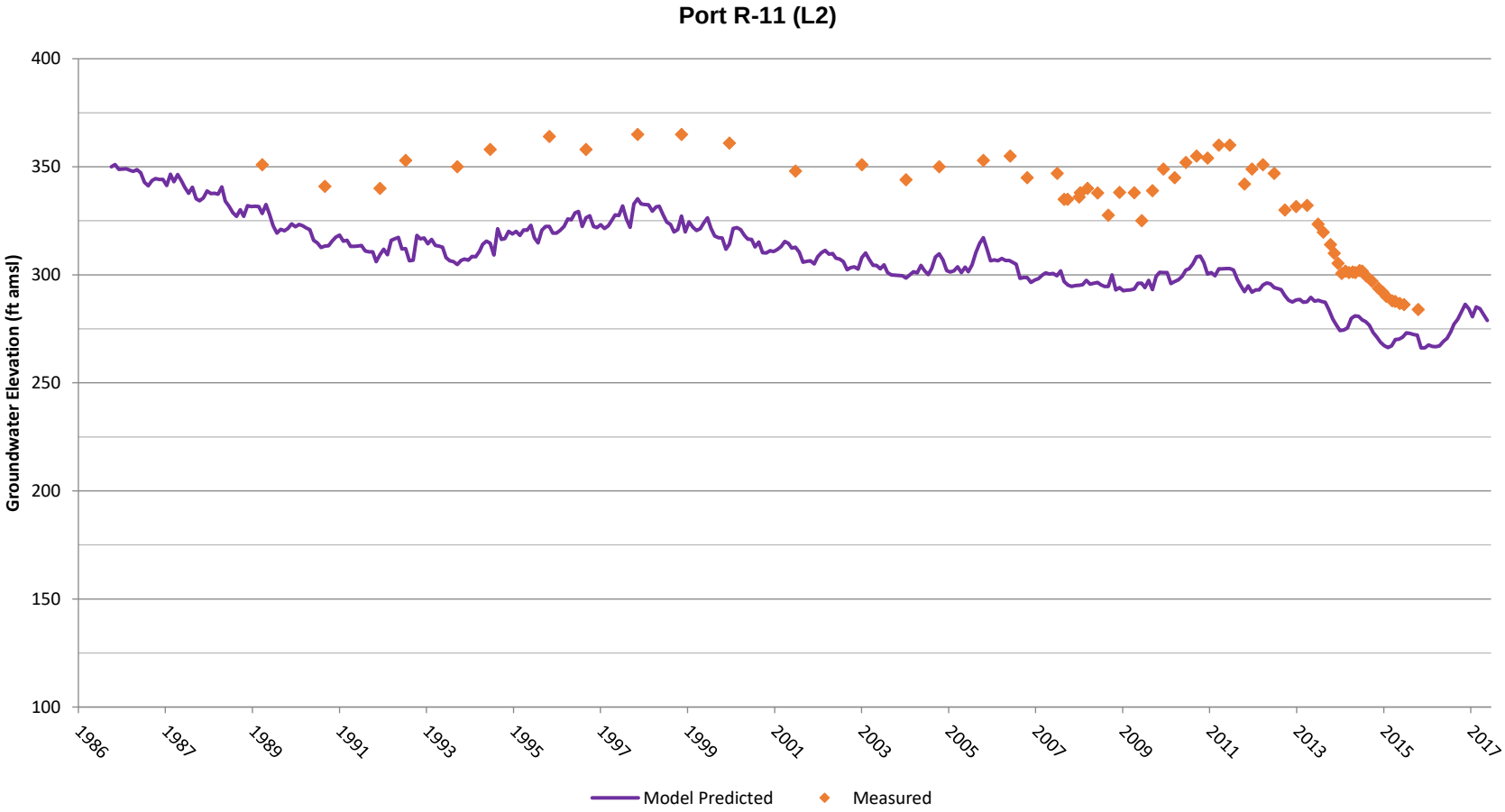
Stantec / Friant Water Authority



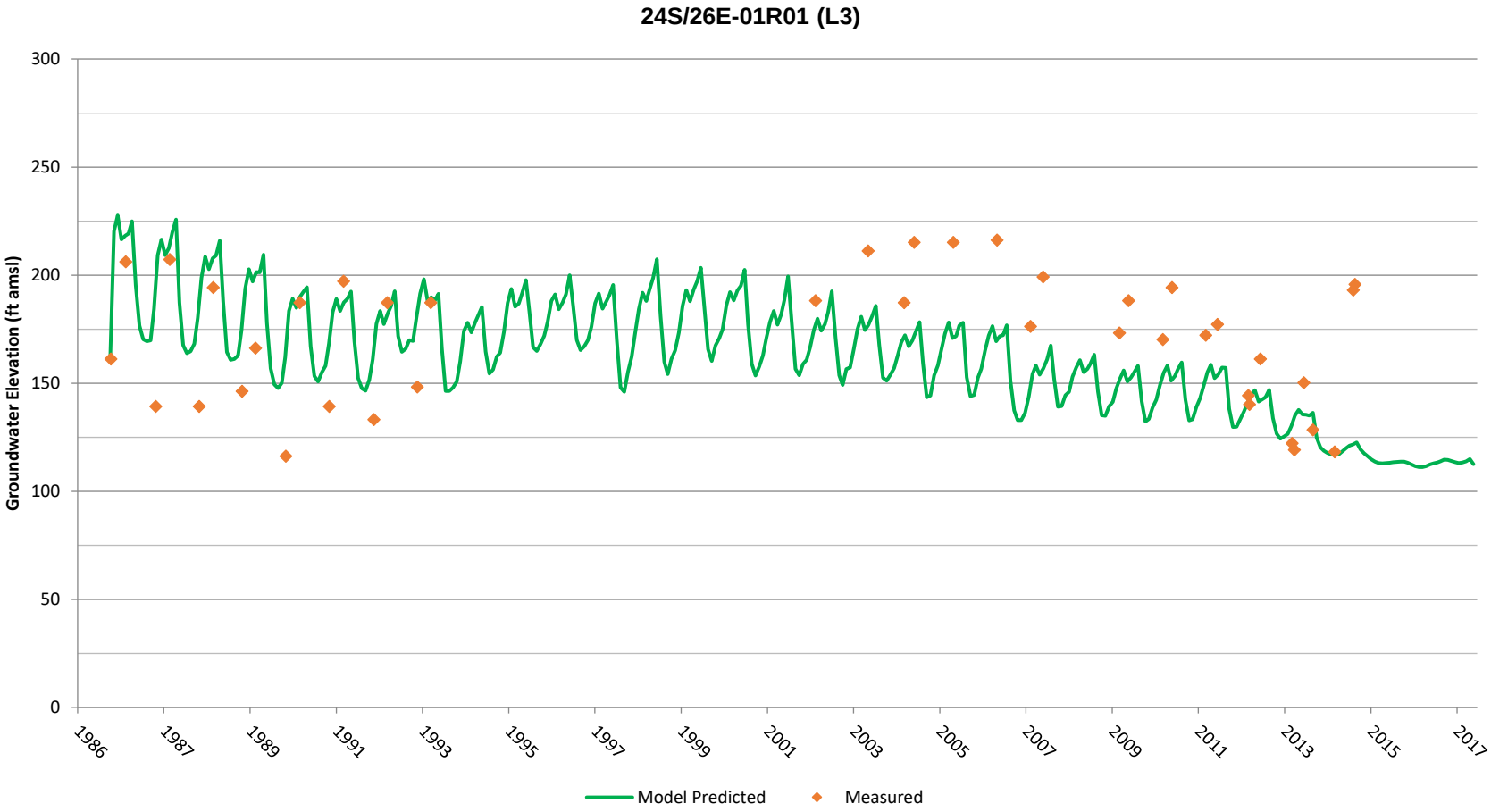
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Attachment A Figure A-1

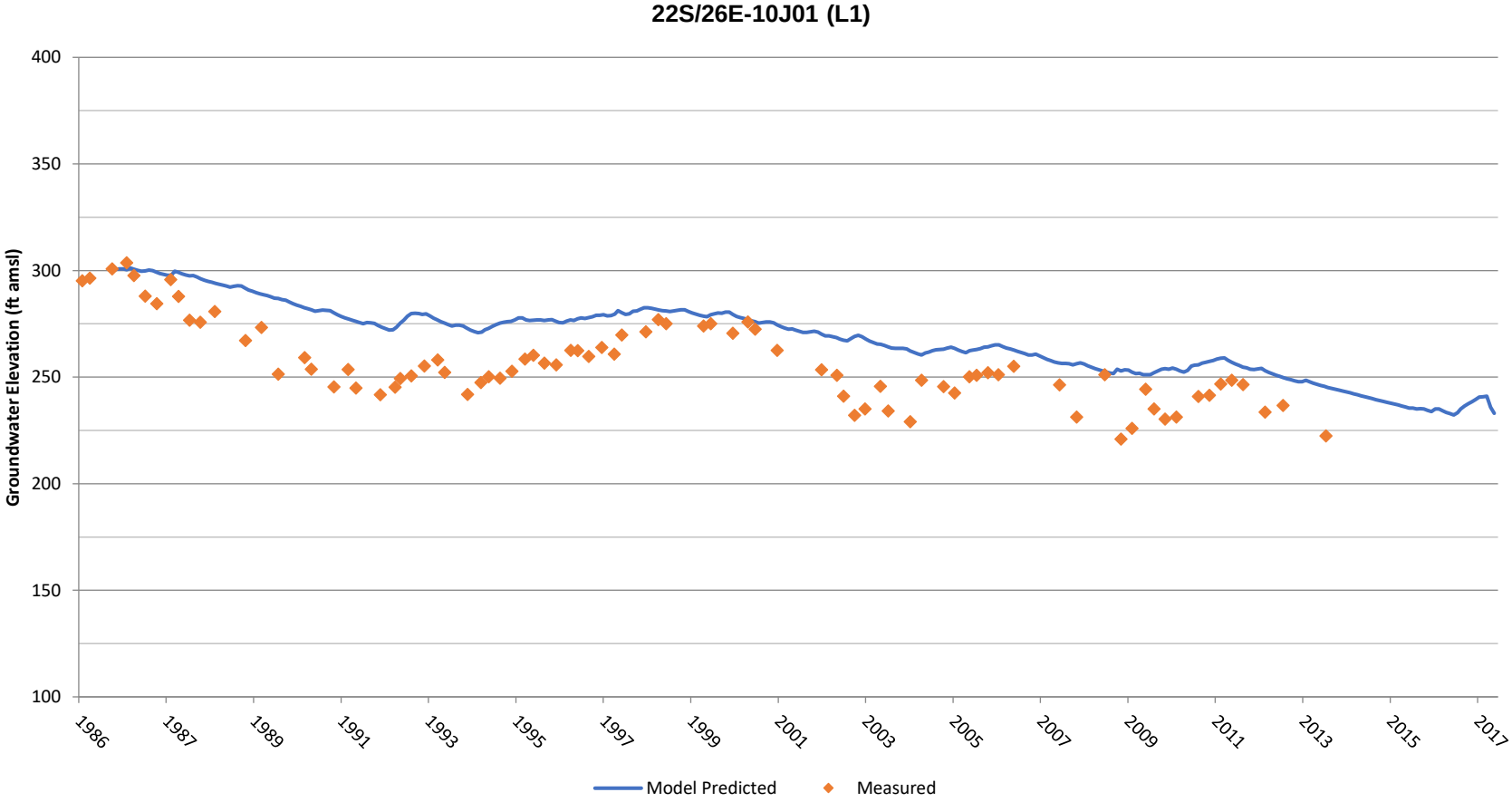
Groundwater Level Calibration Charts



Groundwater Level Calibration Charts

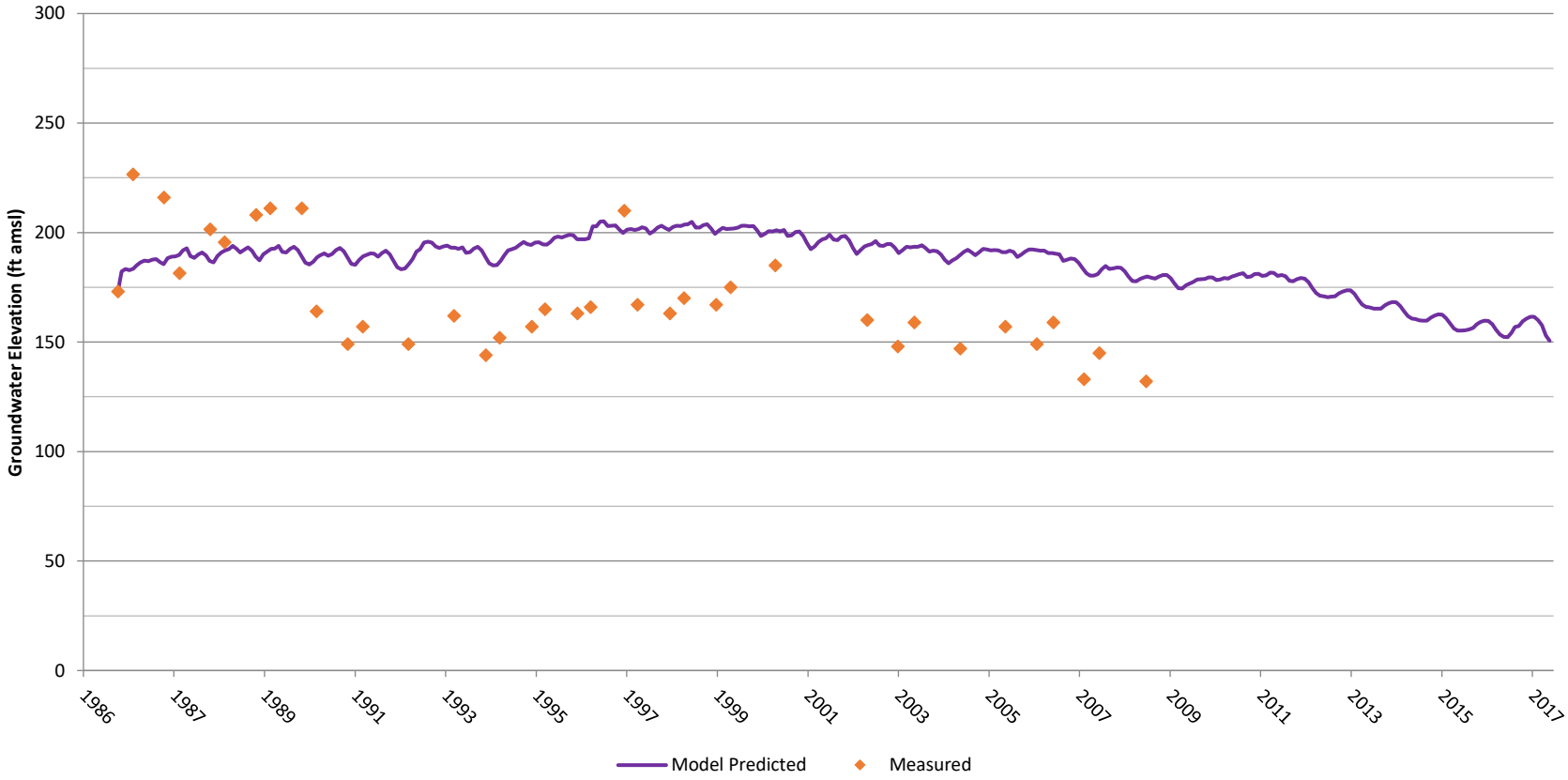


Groundwater Level Calibration Charts



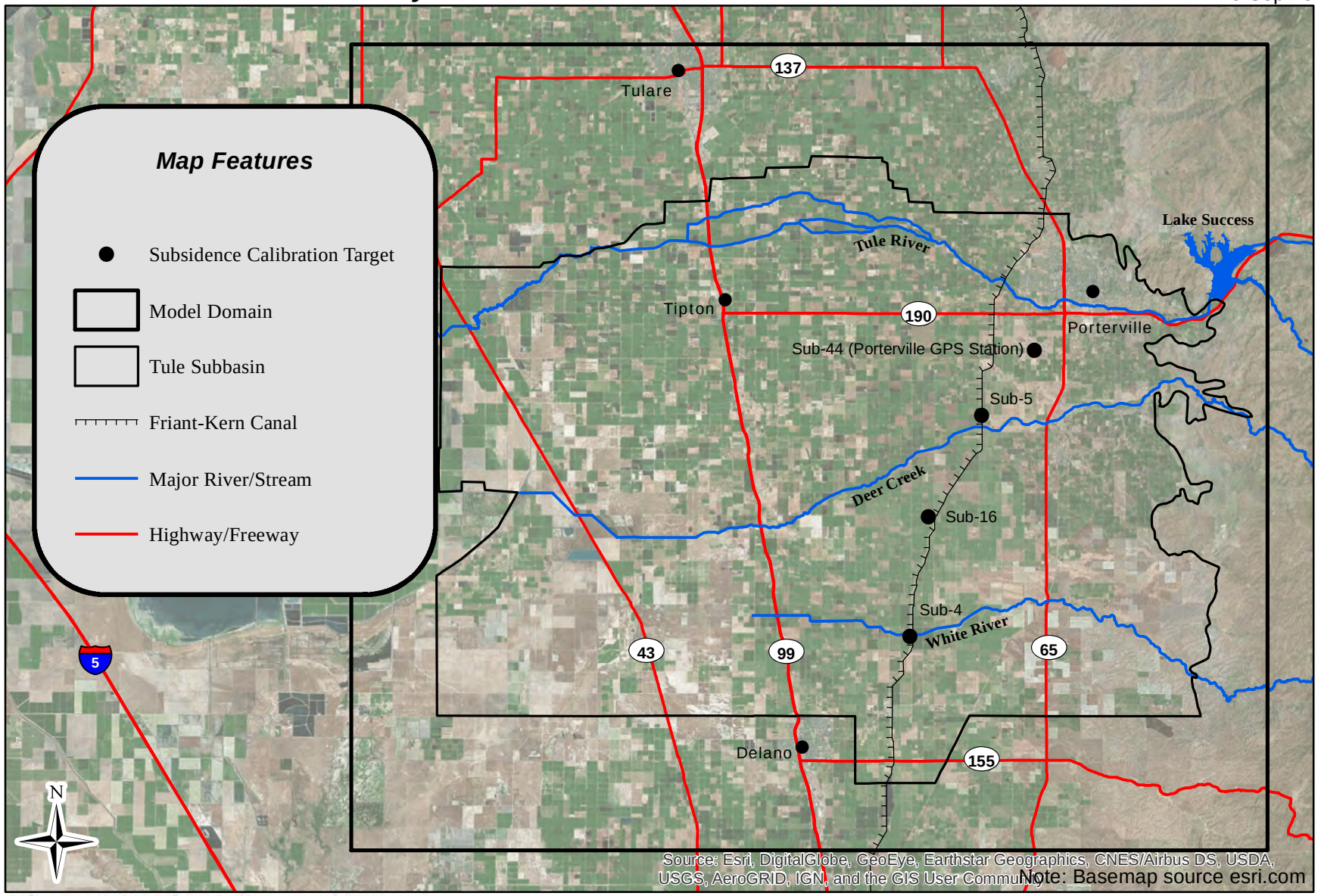
Groundwater Level Calibration Charts

23S/26E-09C01 (L2)



Attachment B
Subsidence Calibration Charts

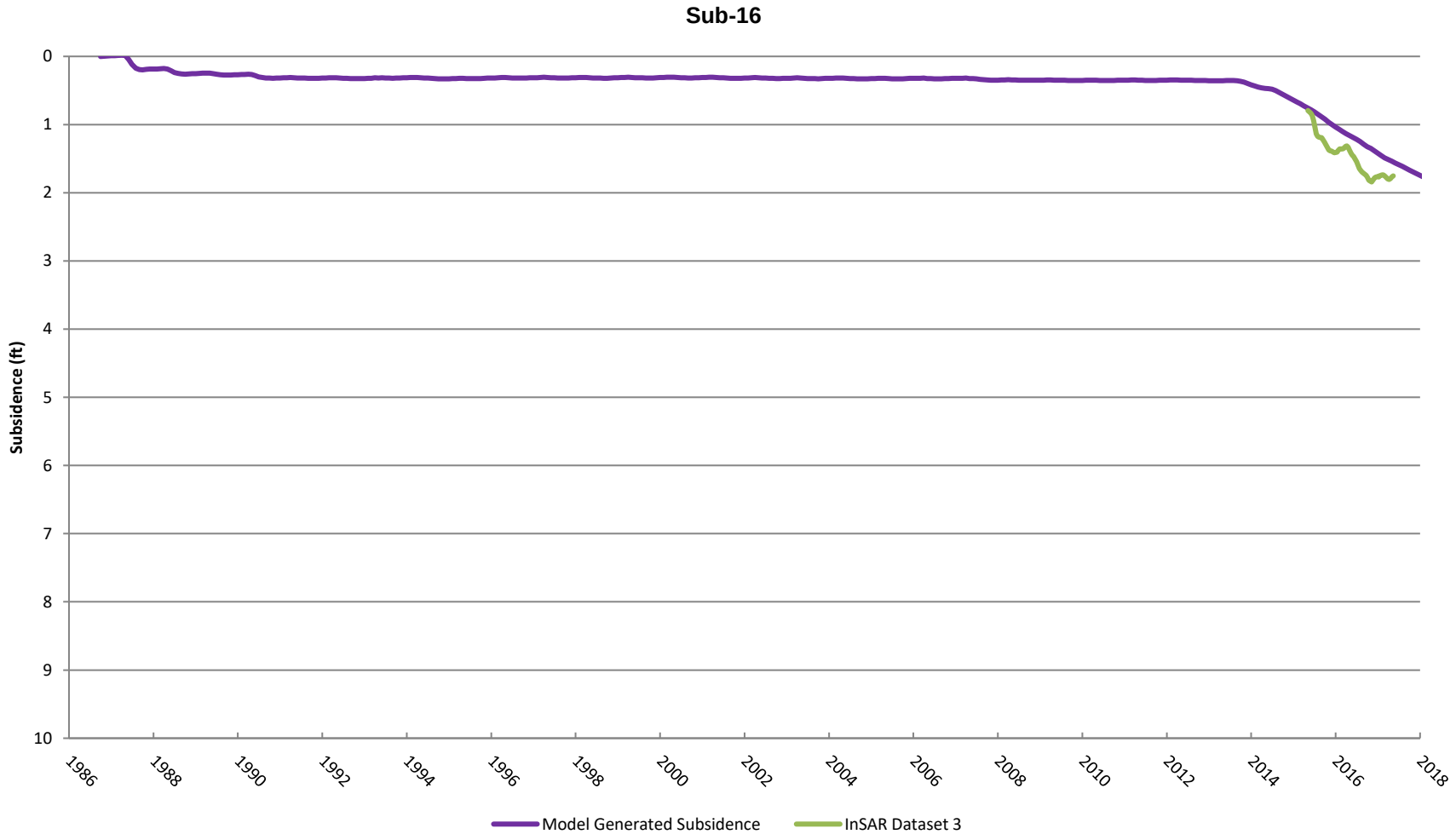
Stantec / Friant Water Authority



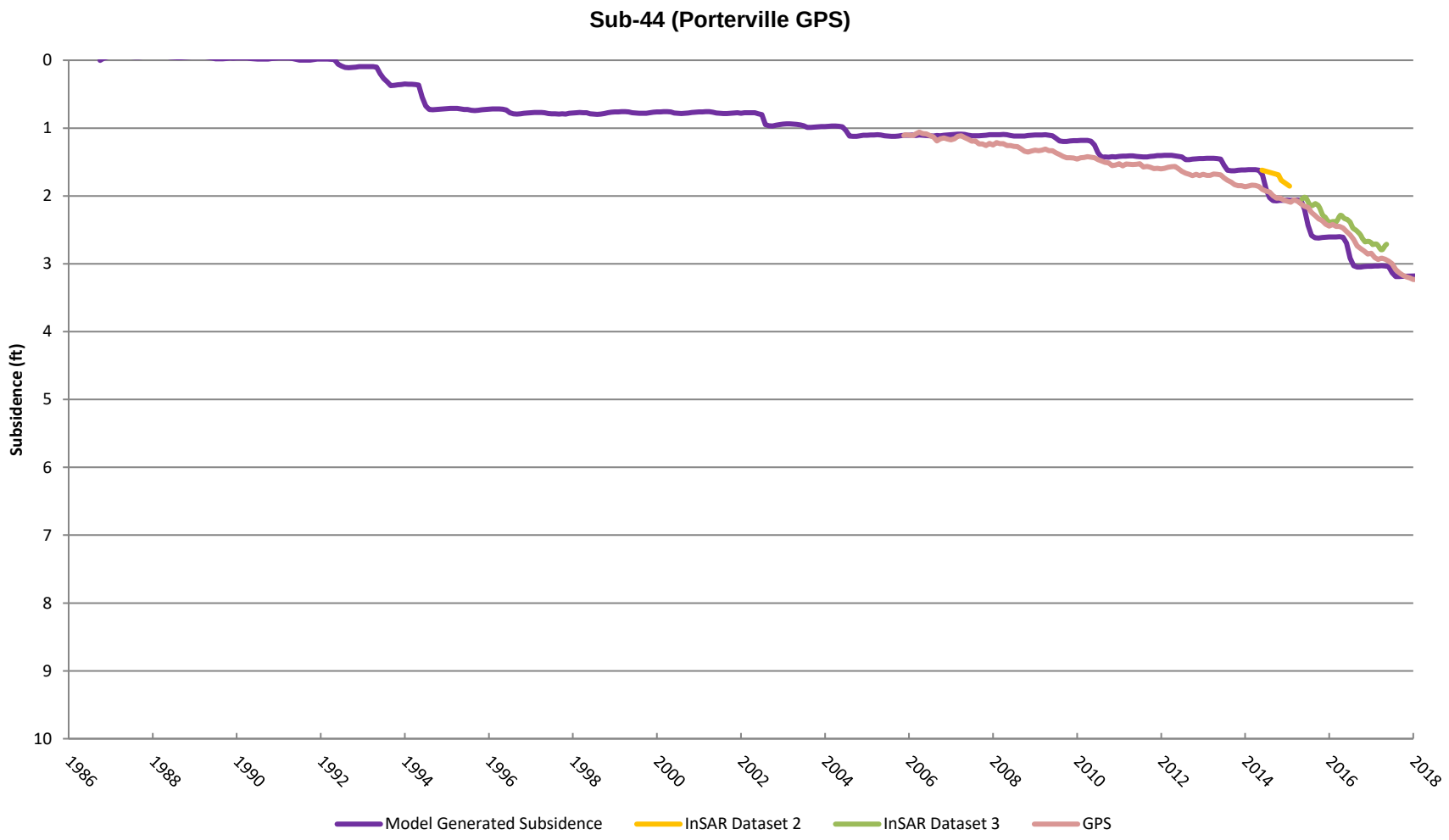
Thomas Harder & Co.
Groundwater Consulting

Attachment B Figure B-1

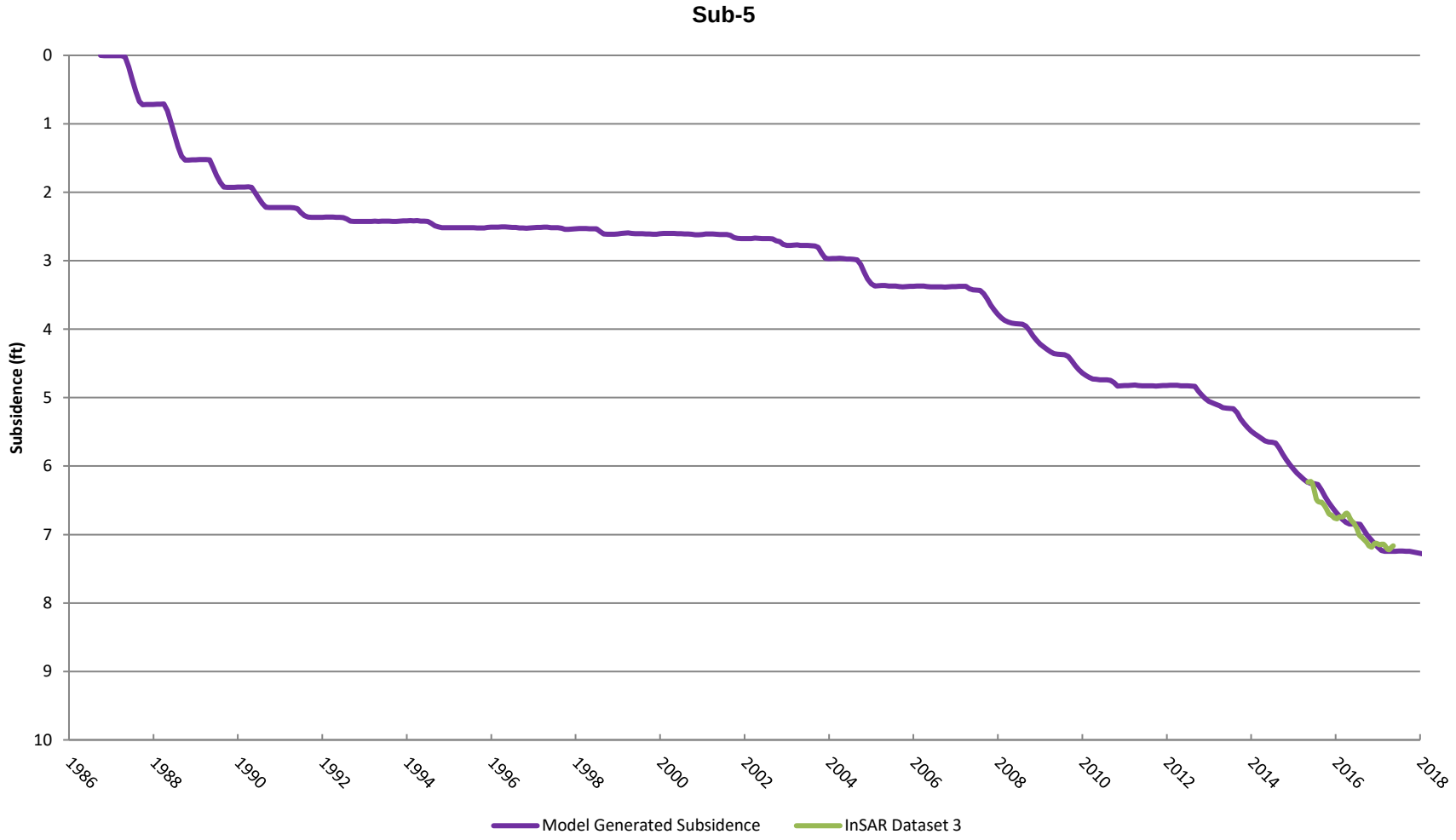
Subsidence Calibration Charts



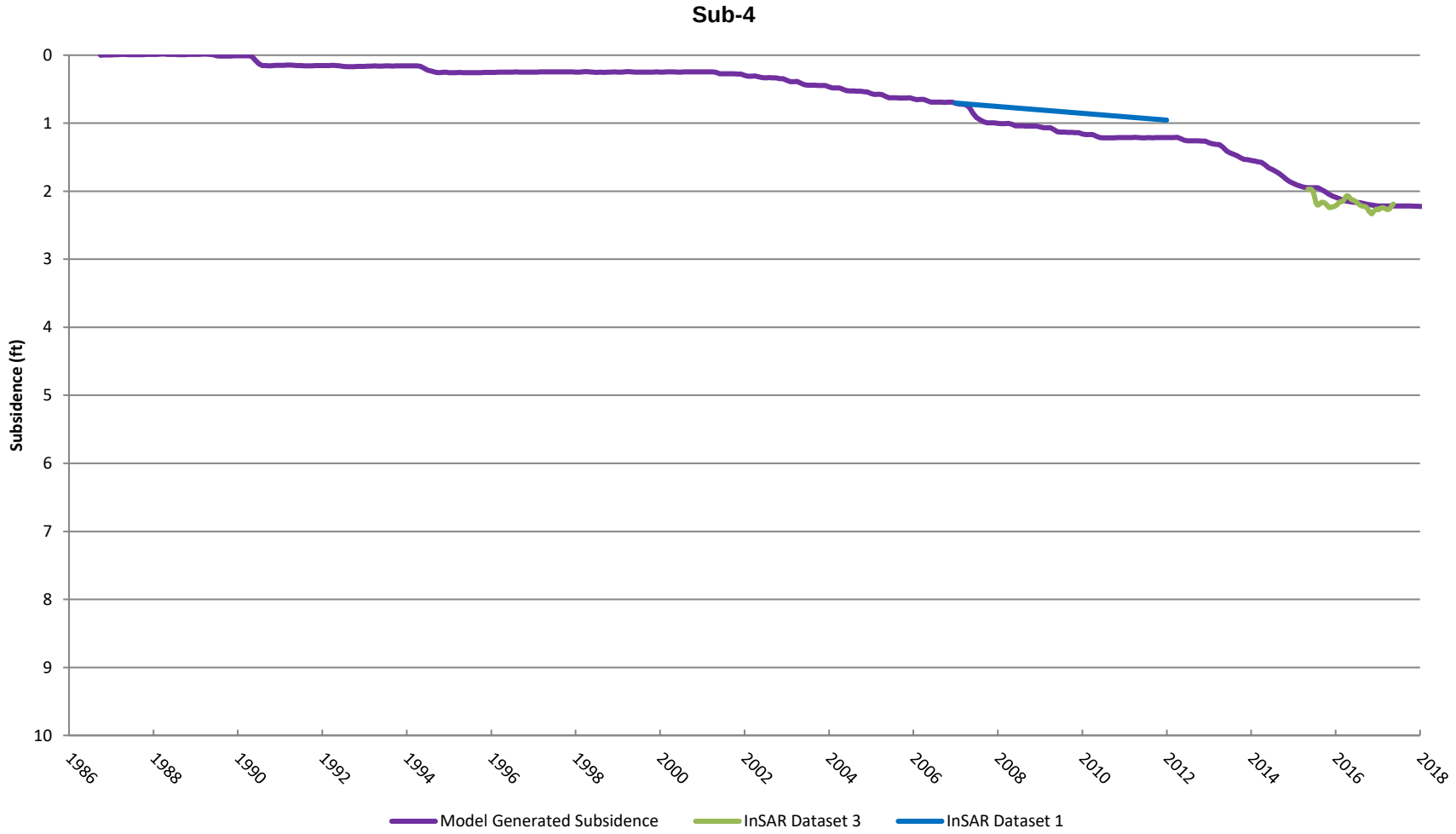
Subsidence Calibration Charts



Subsidence Calibration Charts



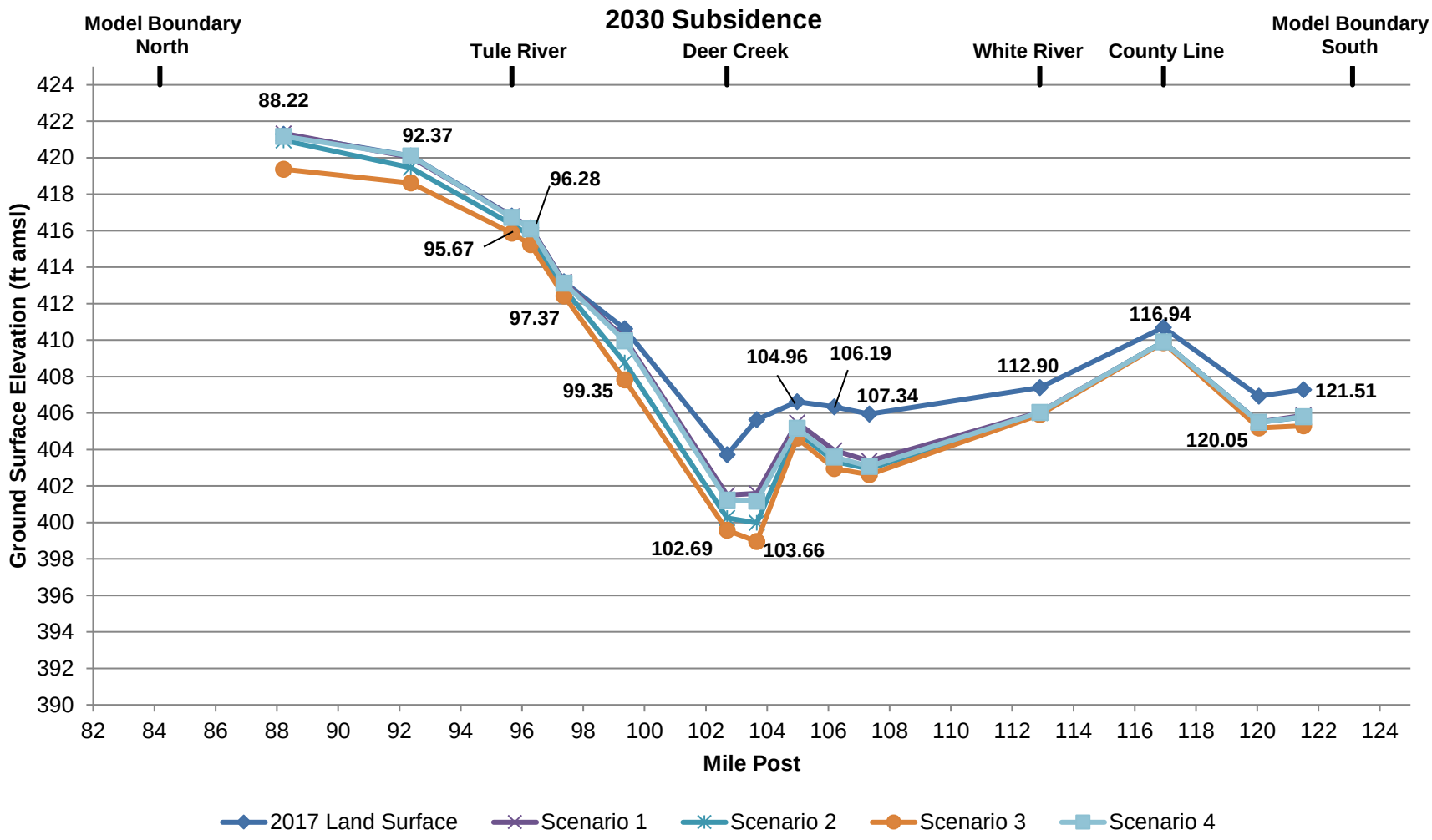
Subsidence Calibration Charts



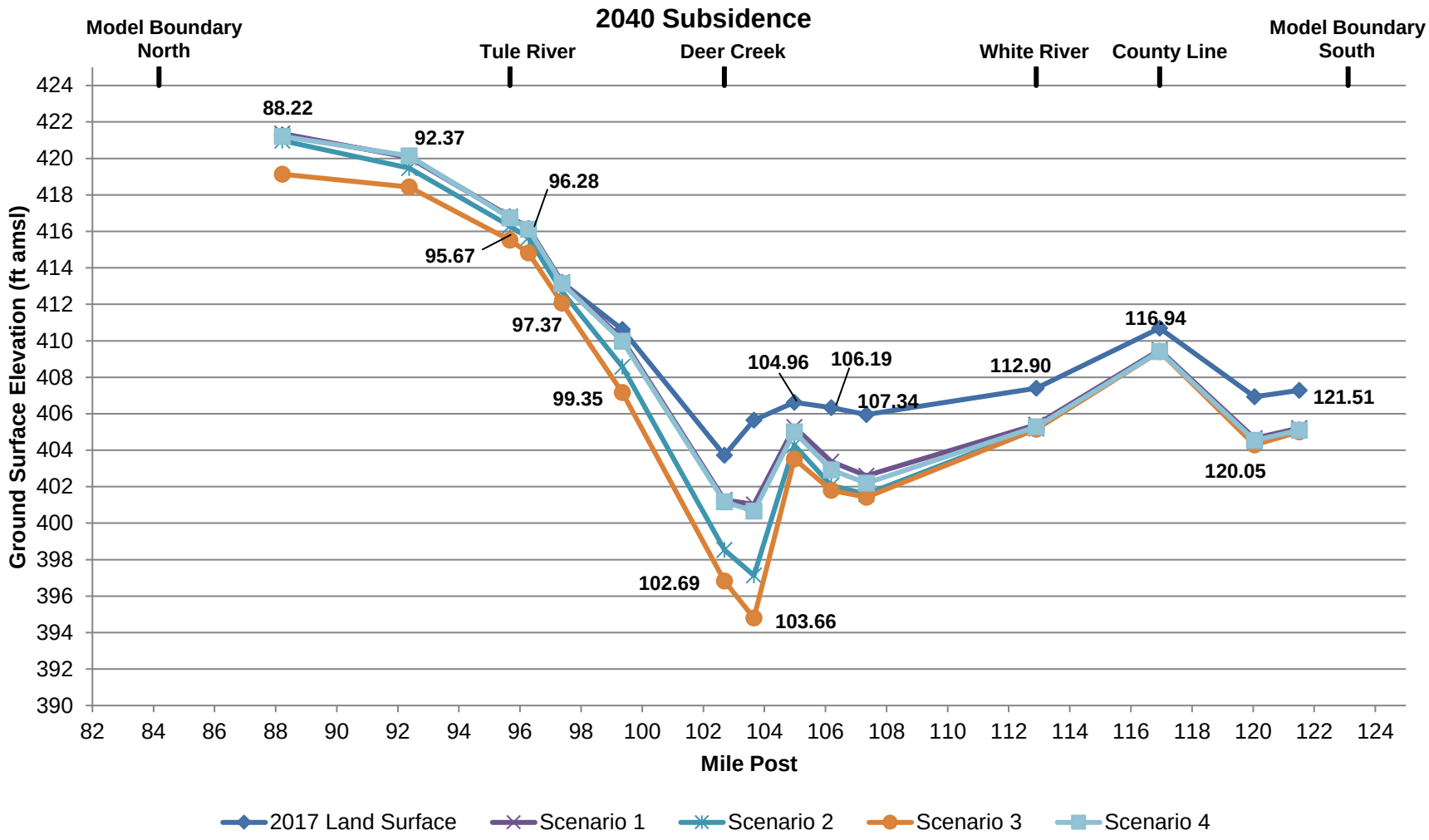
Attachment C

Model-Predicted Subsidence Along the Friant-Kern Canal

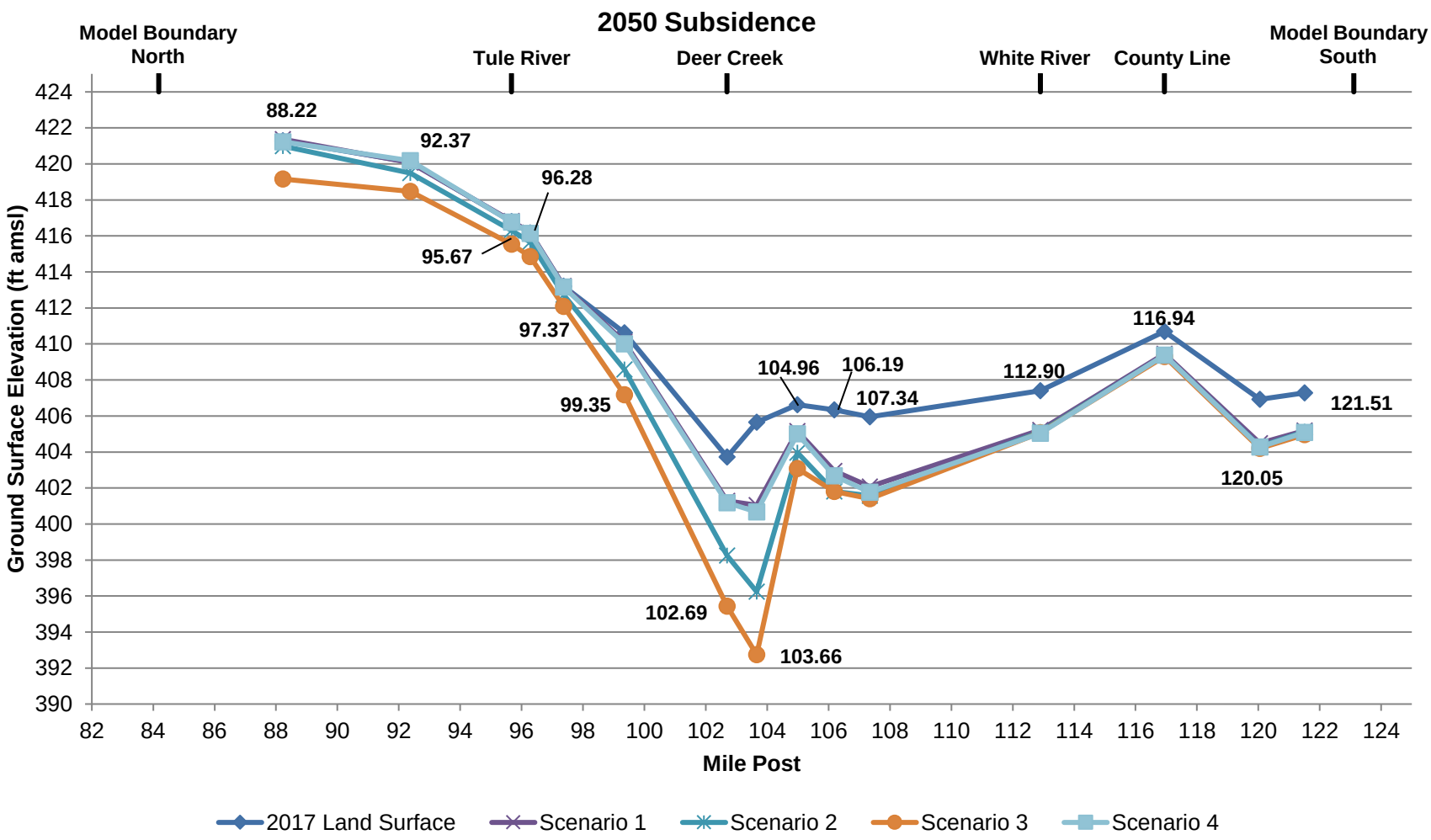
Model-Projected Subsidence Along the Friant-Kern Canal



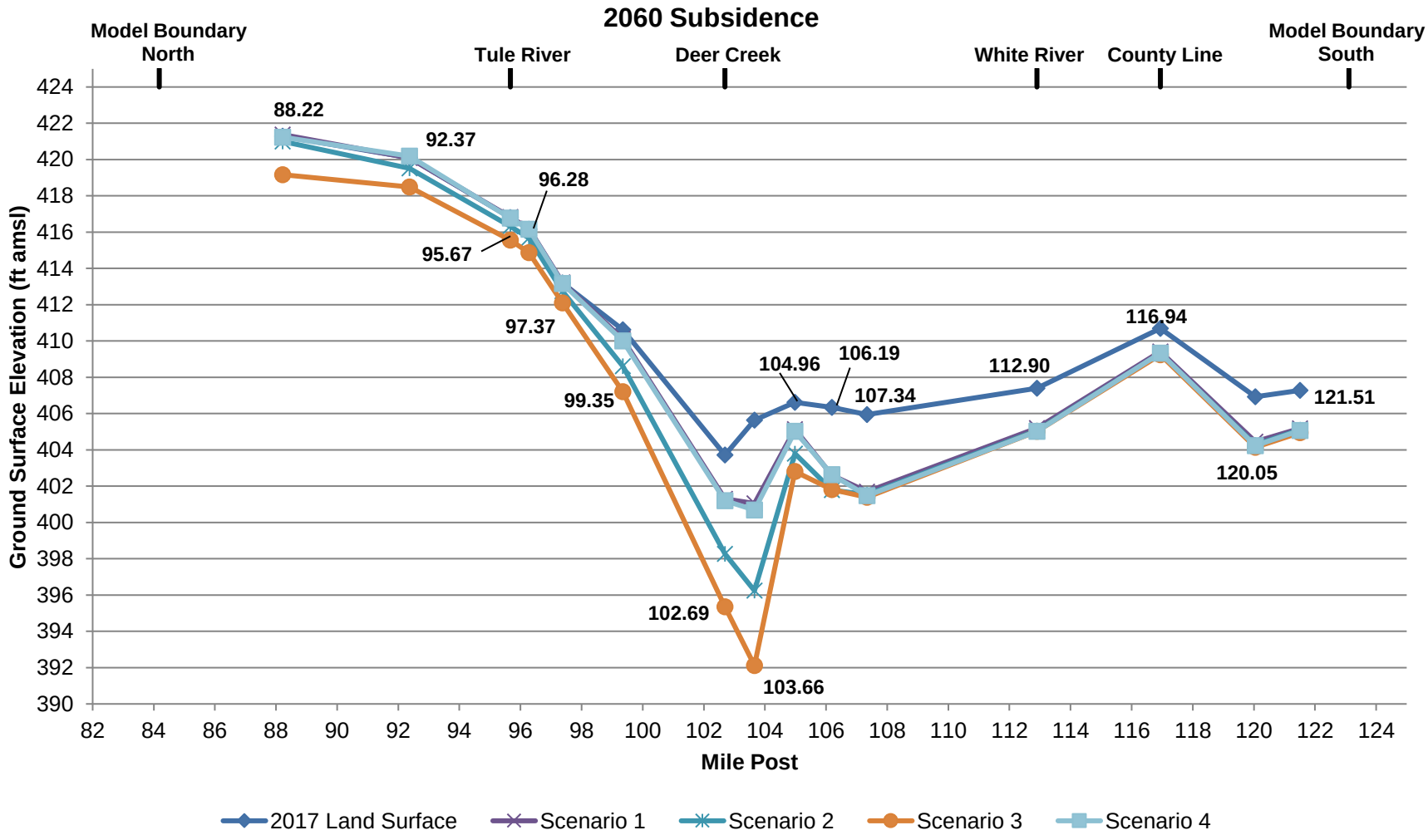
Model-Projected Subsidence Along the Friant-Kern Canal



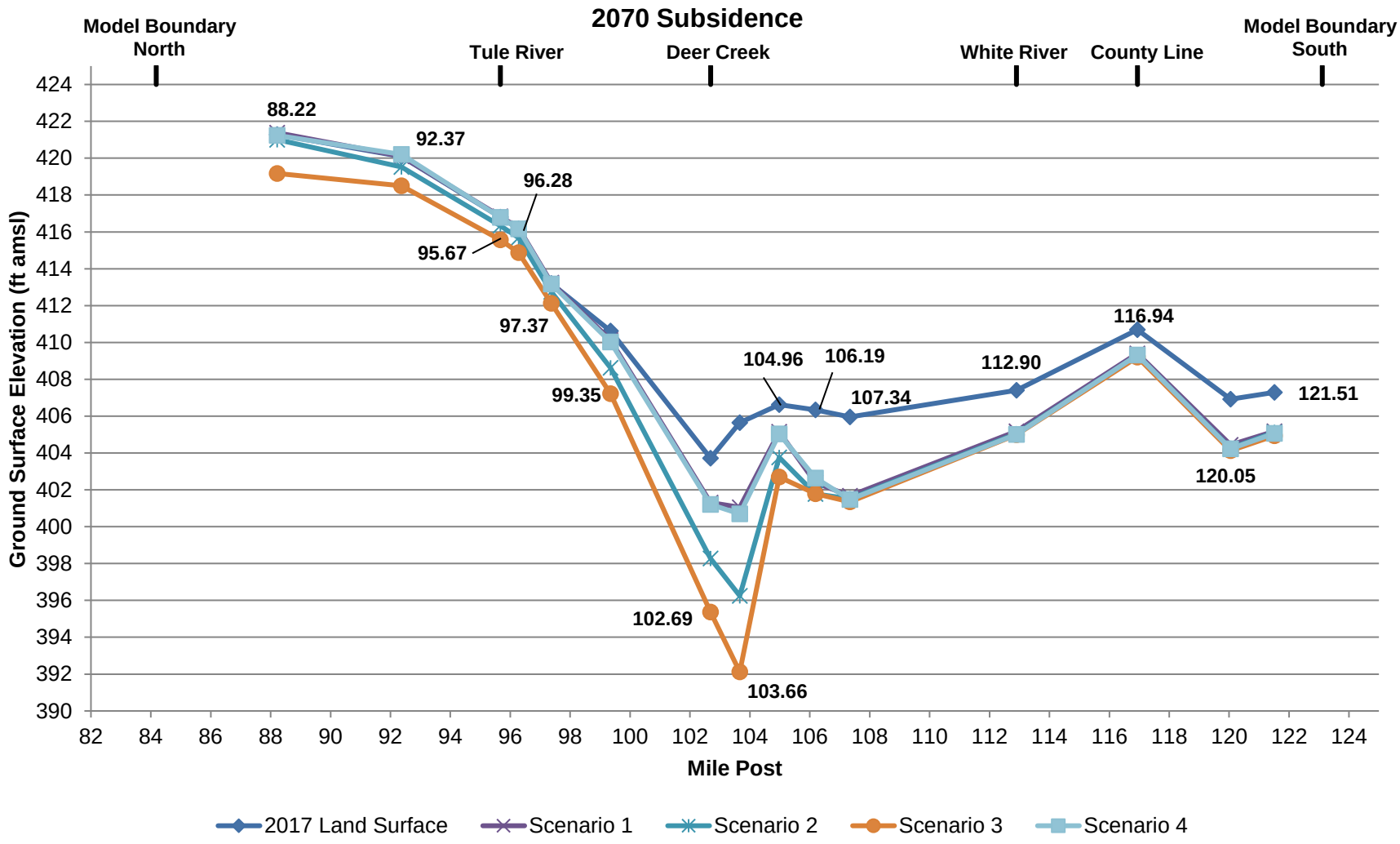
Model-Projected Subsidence Along the Friant-Kern Canal



Model-Projected Subsidence Along the Friant-Kern Canal



Model-Projected Subsidence Along the Friant-Kern Canal

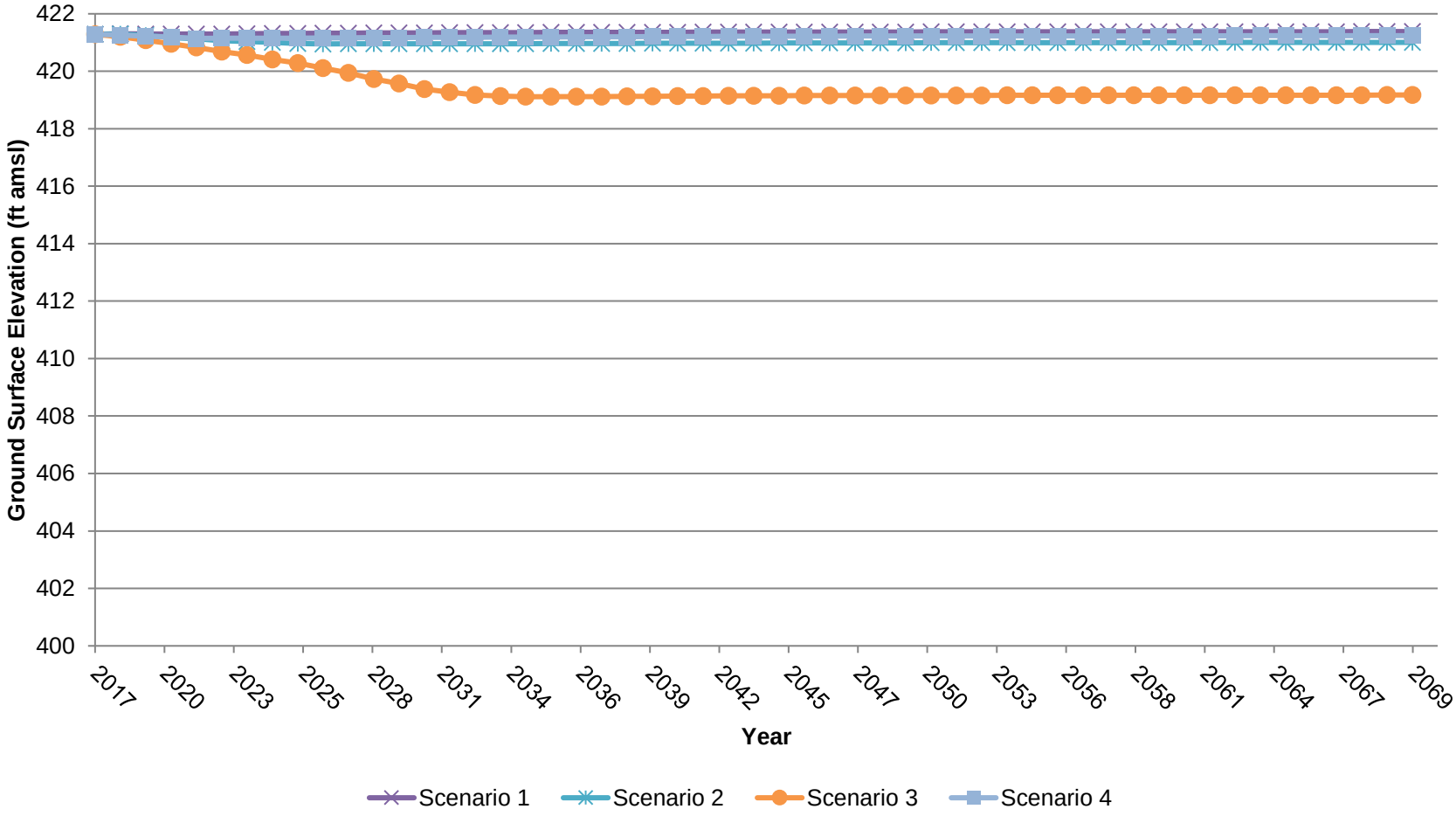


Attachment D

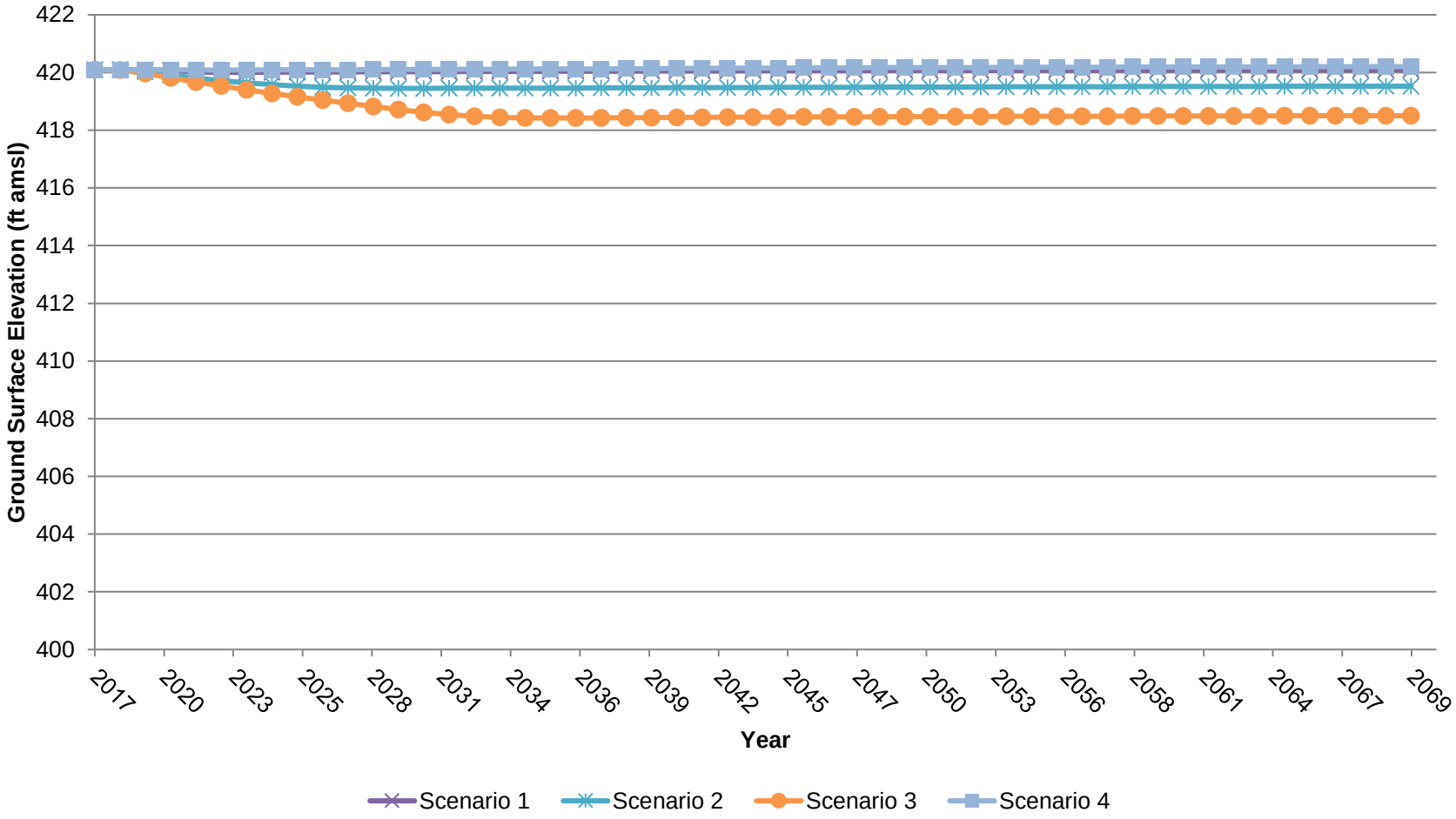
Model-Projected Land Subsidence at Selected Mile Posts

Model-Projected Land Subsidence at

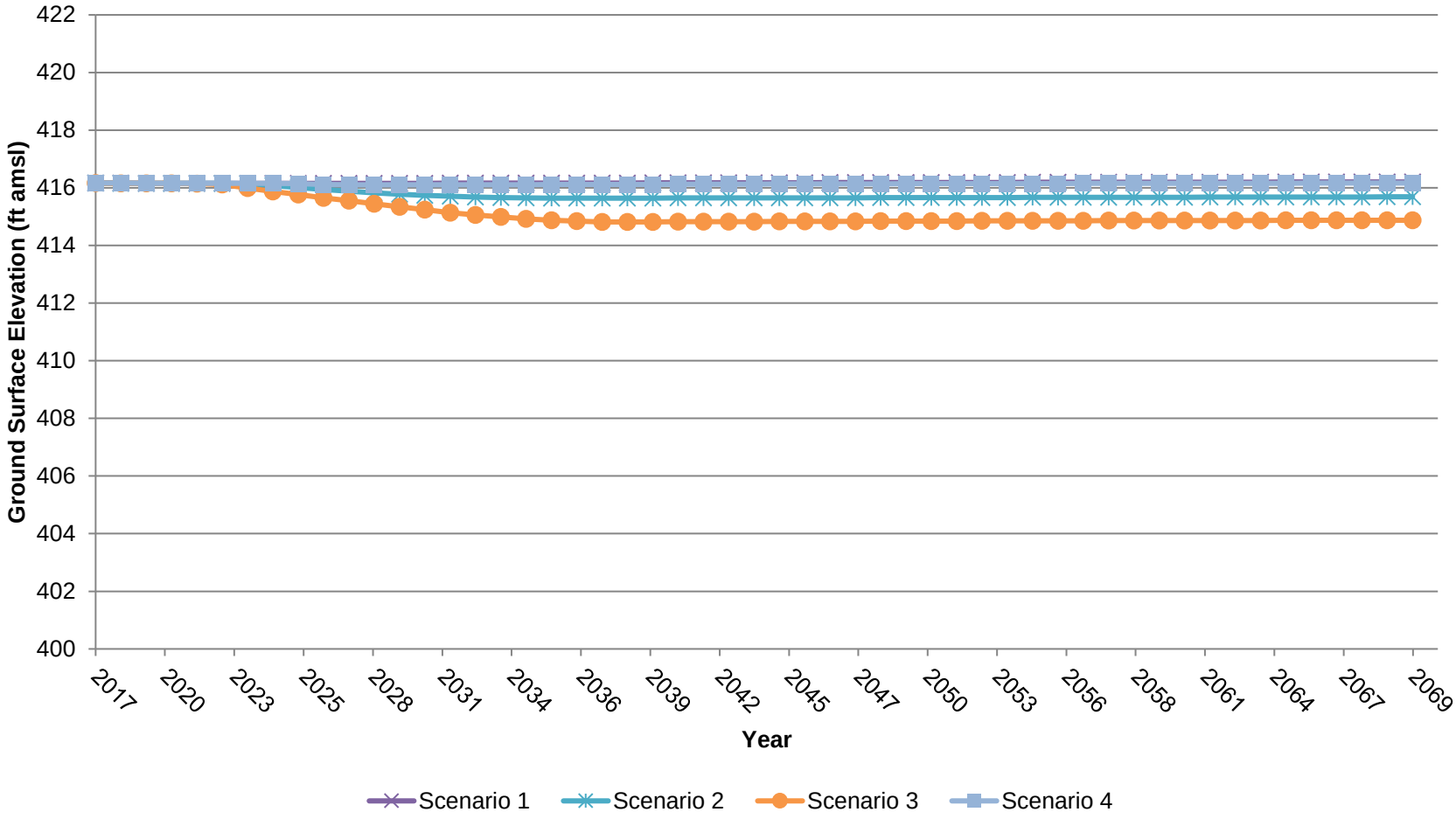
Mile Post 88.22



Model-Projected Land Subsidence at Mile Post 92.37

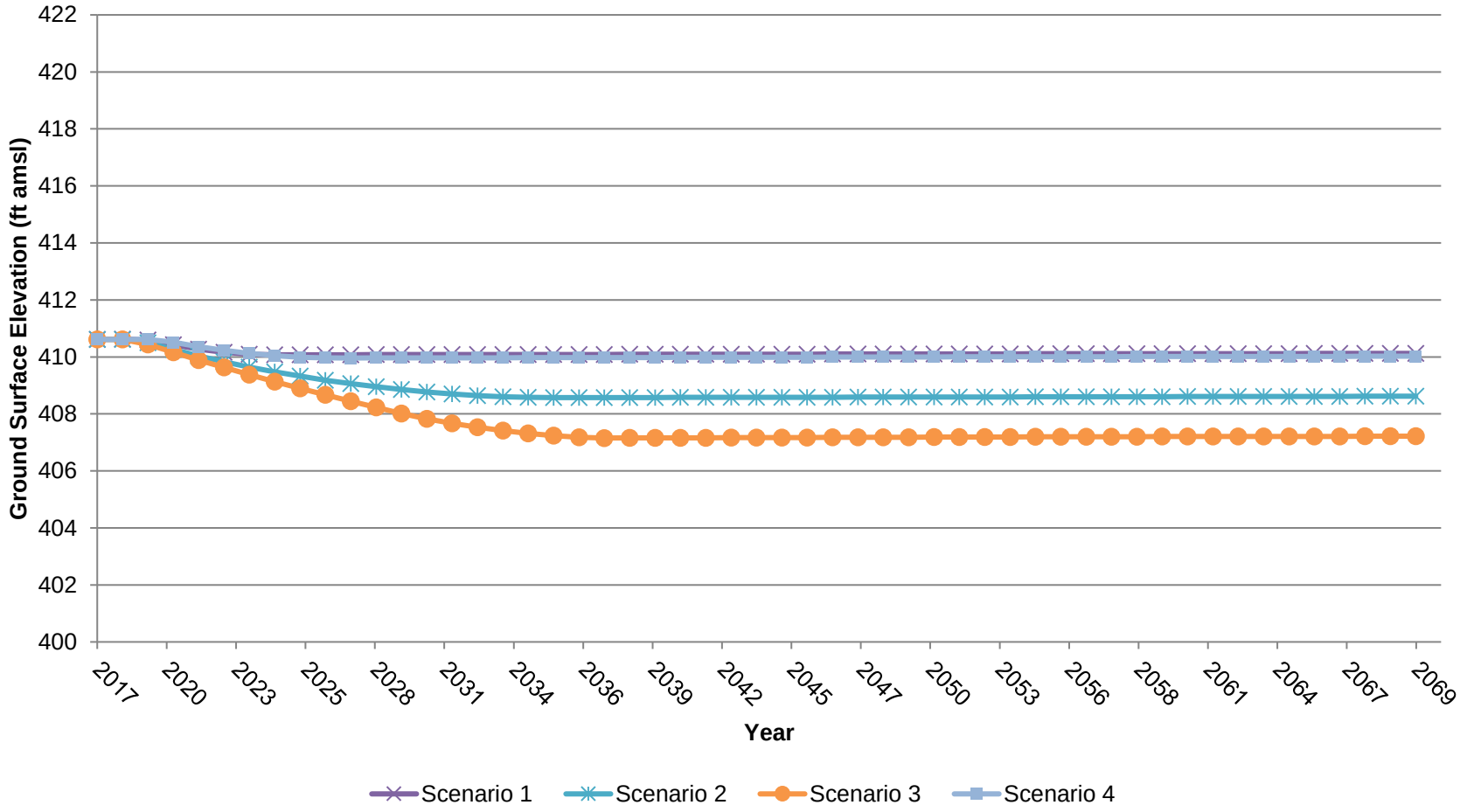


Model-Projected Land Subsidence at Mile Post 96.28

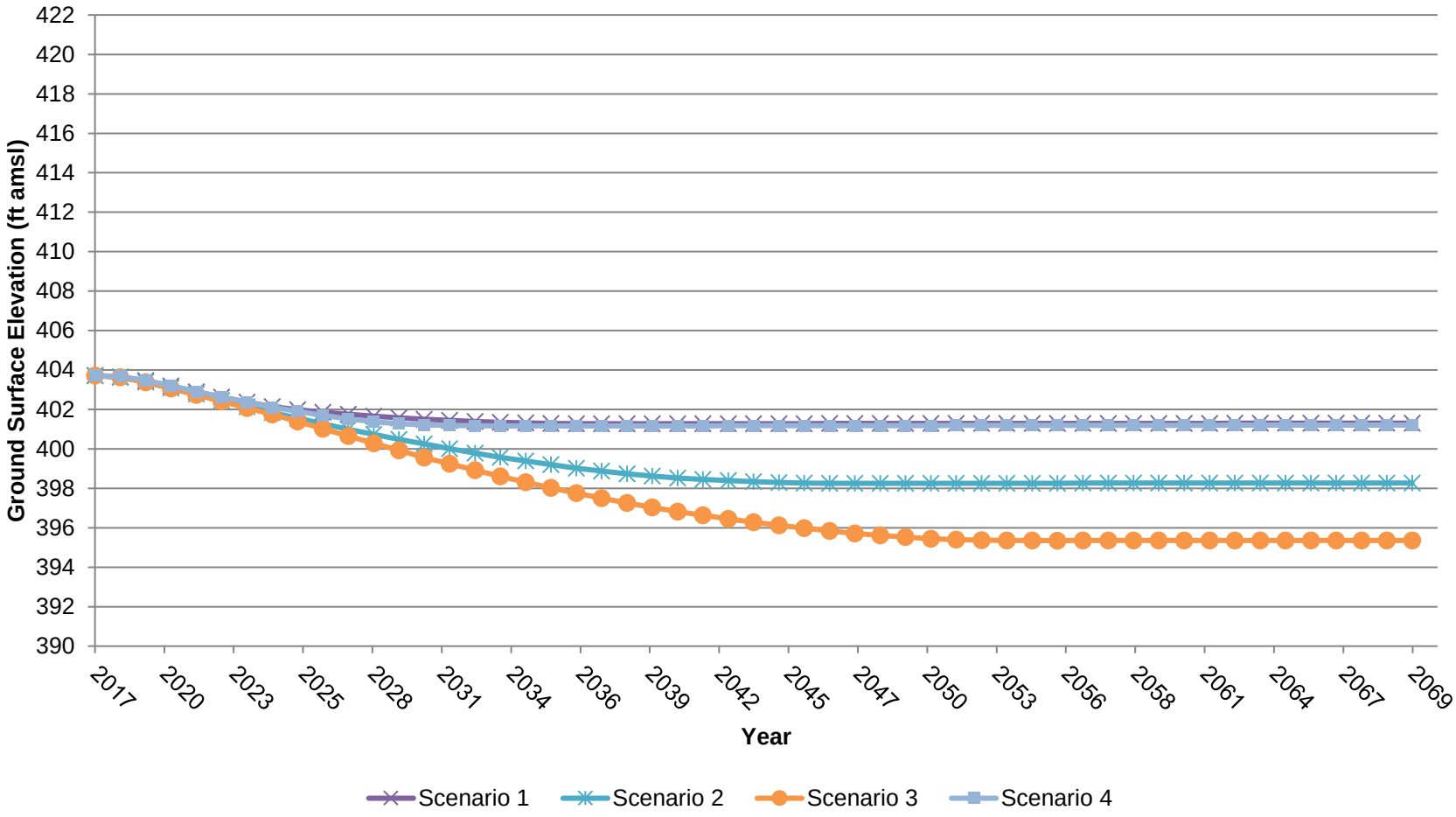


Model-Projected Land Subsidence at

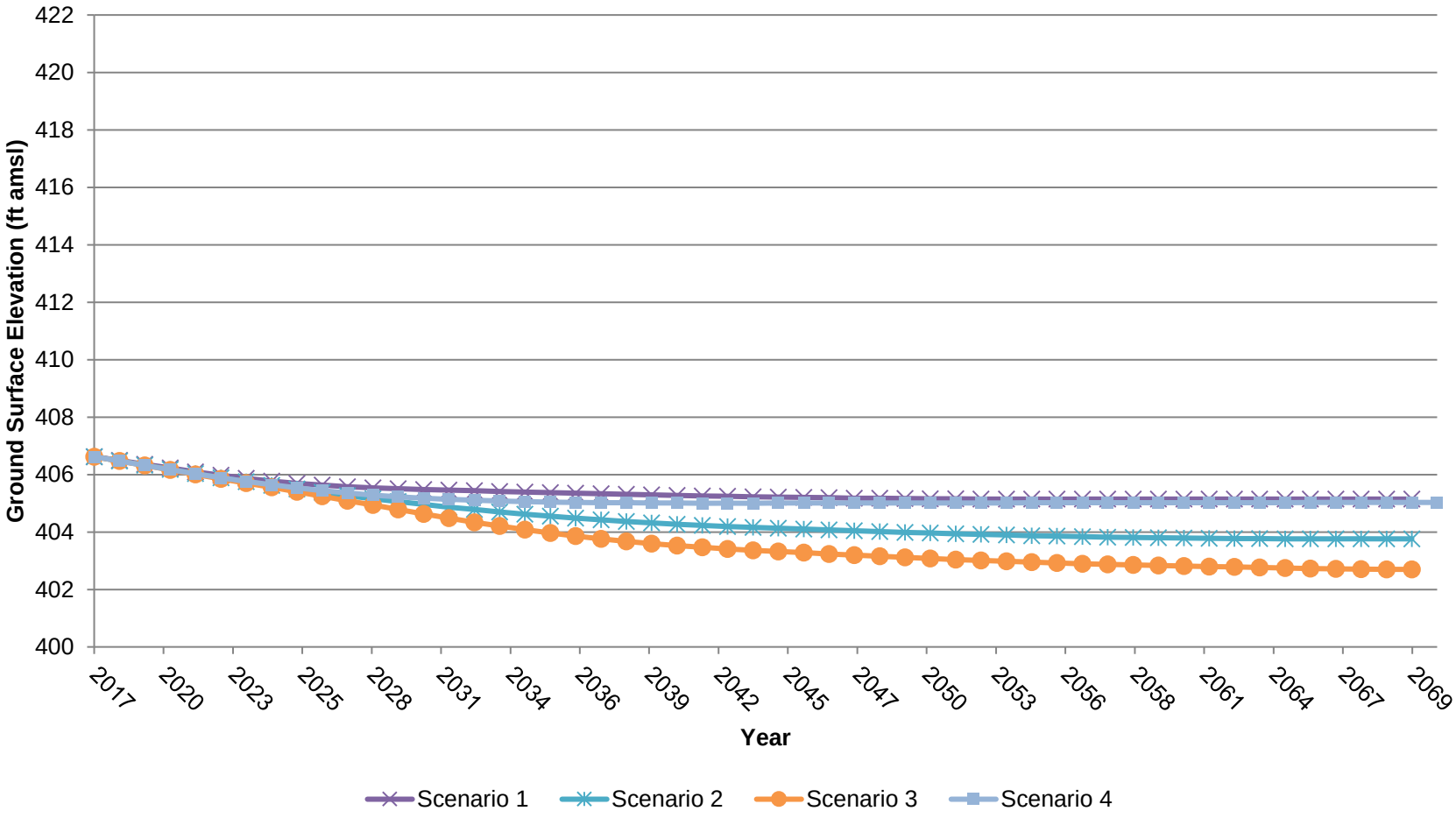
Mile Post 99.35



Model-Projected Land Subsidence at Mile Post 102.69

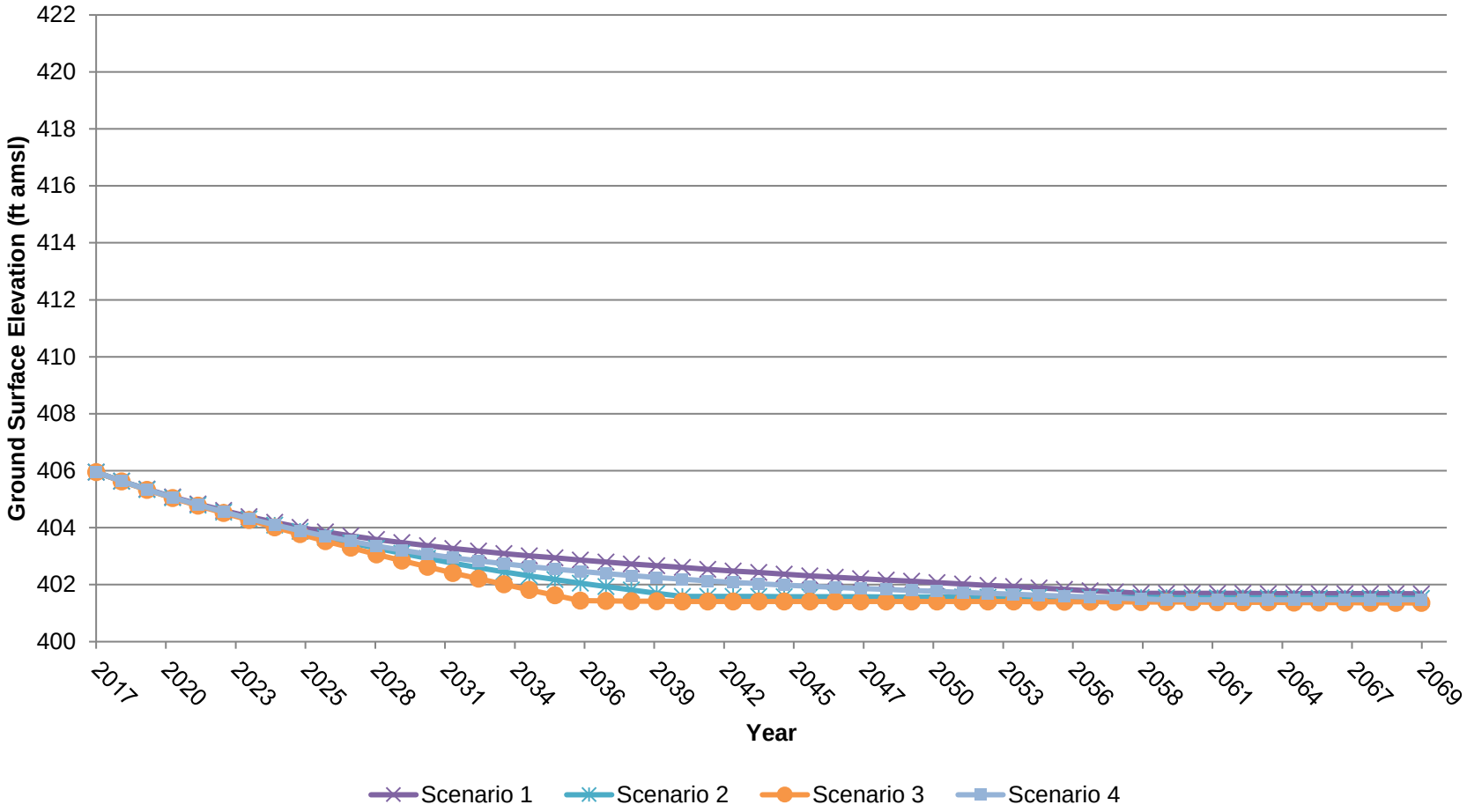


Model-Projected Land Subsidence at Mile Post 104.98



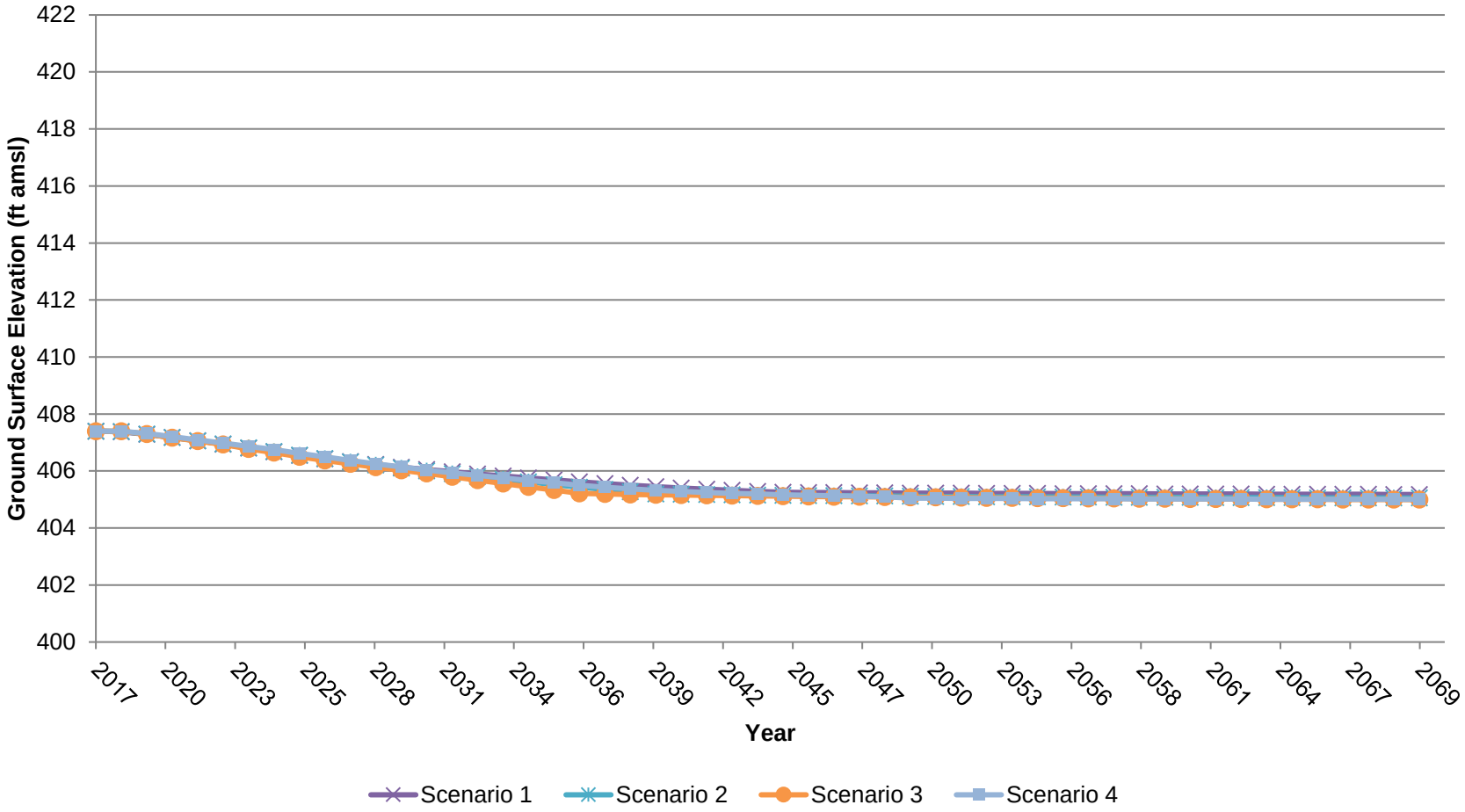
Model-Projected Land Subsidence at

Mile Post 107.34

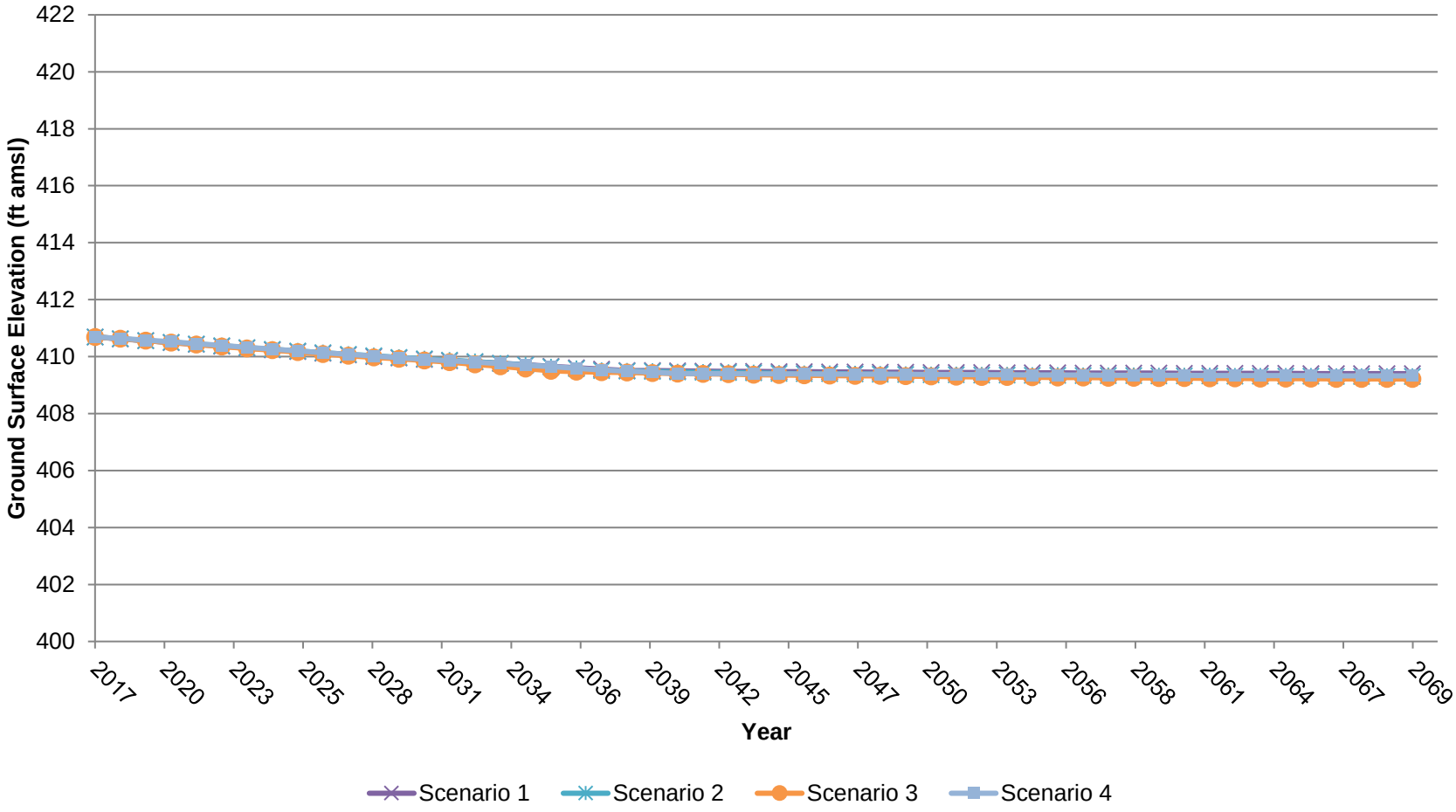


Model-Projected Land Subsidence at

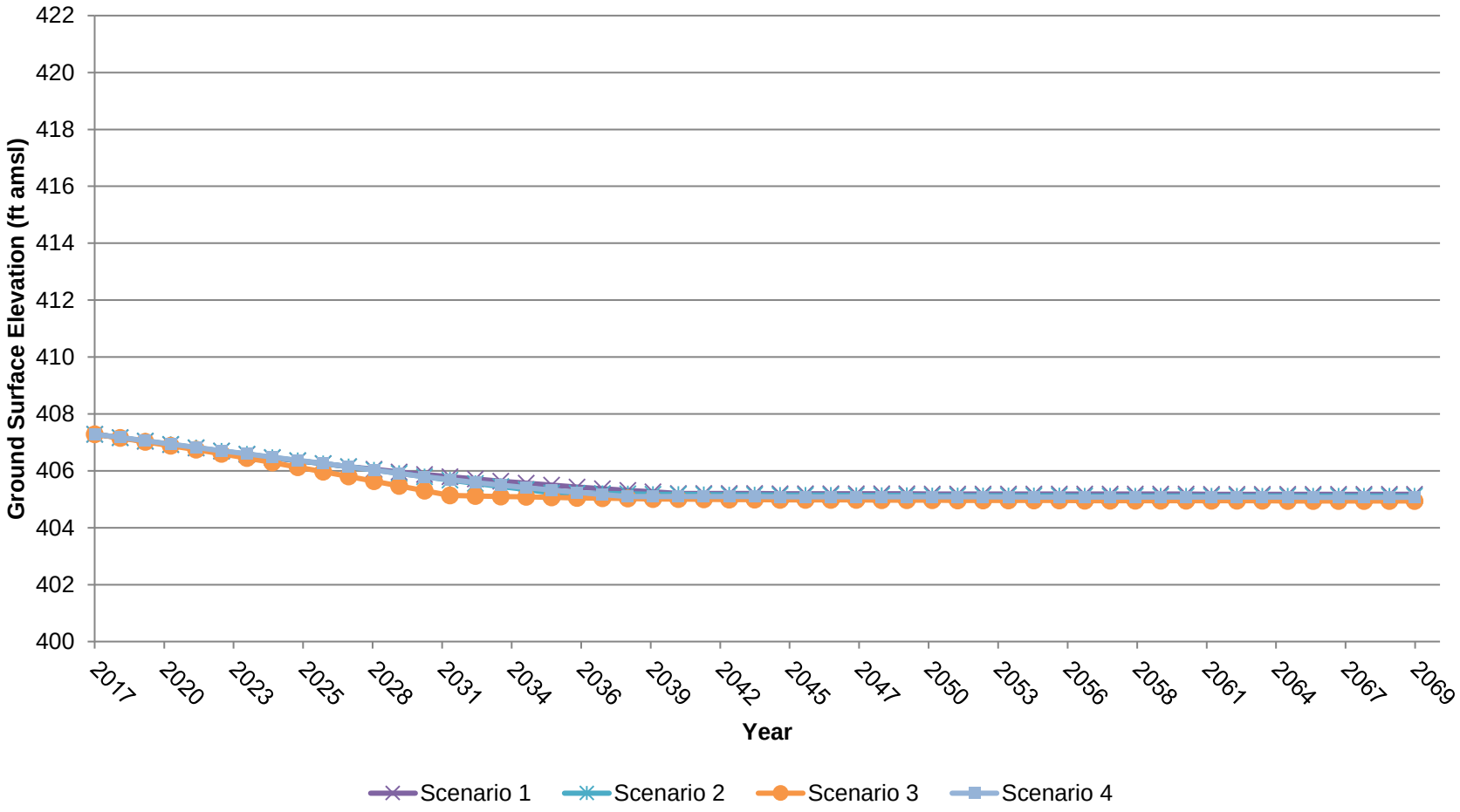
Mile Post 112.9



Model-Projected Land Subsidence at Mile Post 116.94



Model-Projected Land Subsidence at Mile Post 121.51



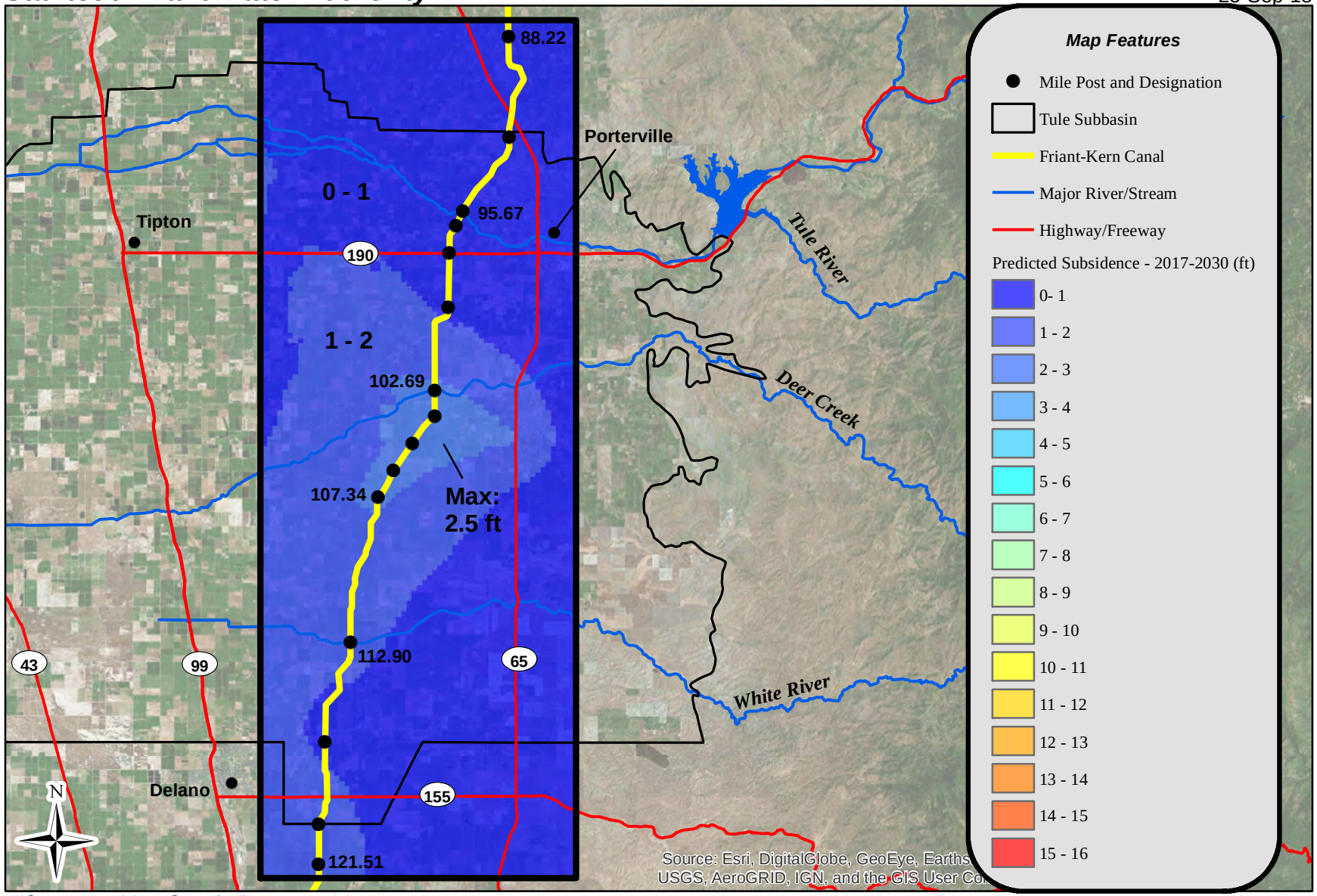
Attachment E

Model-Predicted Subsidence along the Friant-Kern Canal - Maps

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

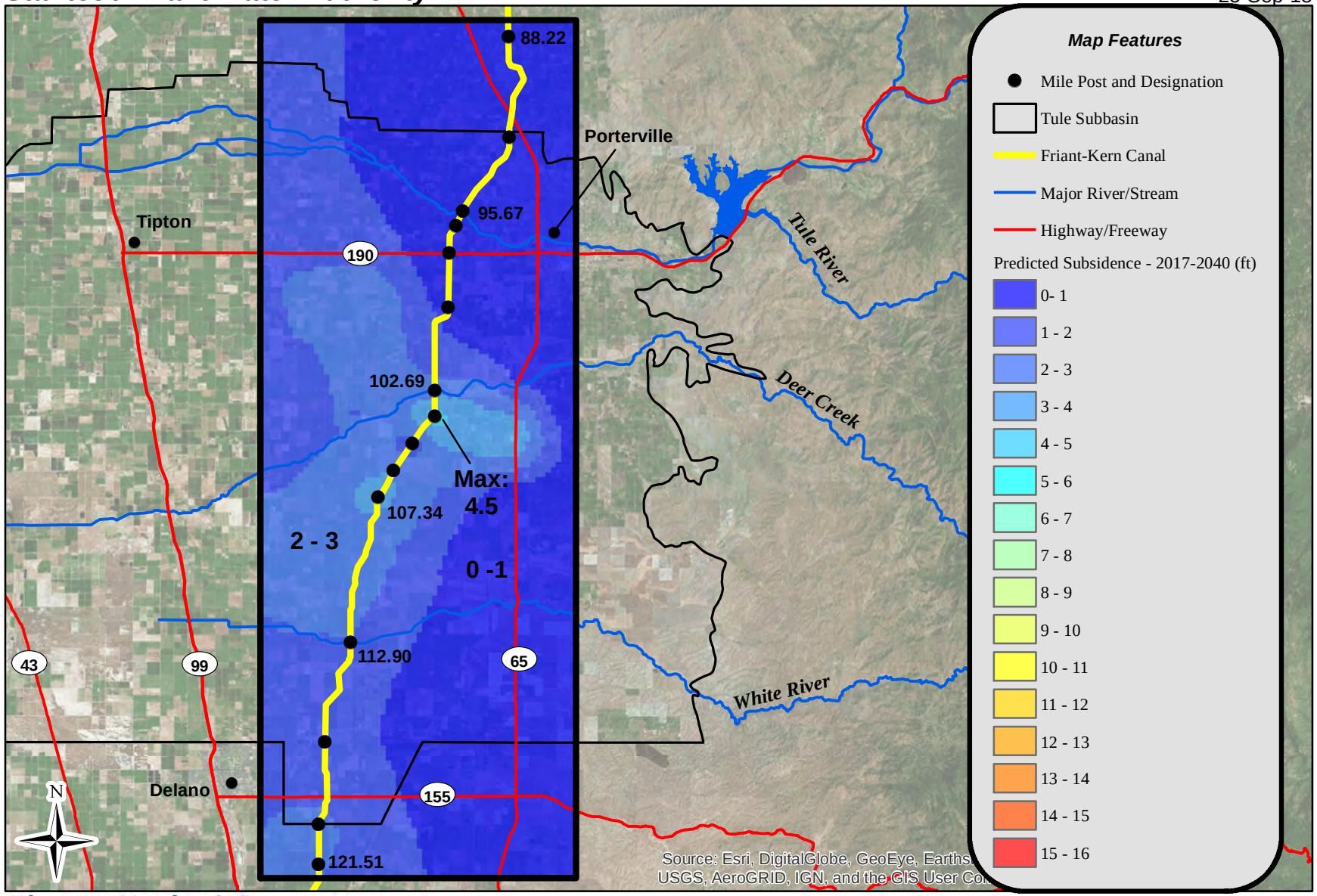
Friant-Kern Canal Subsidence
2017 to 2030
Scenario 1

Attachment E Figure E-1

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



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Groundwater Consulting

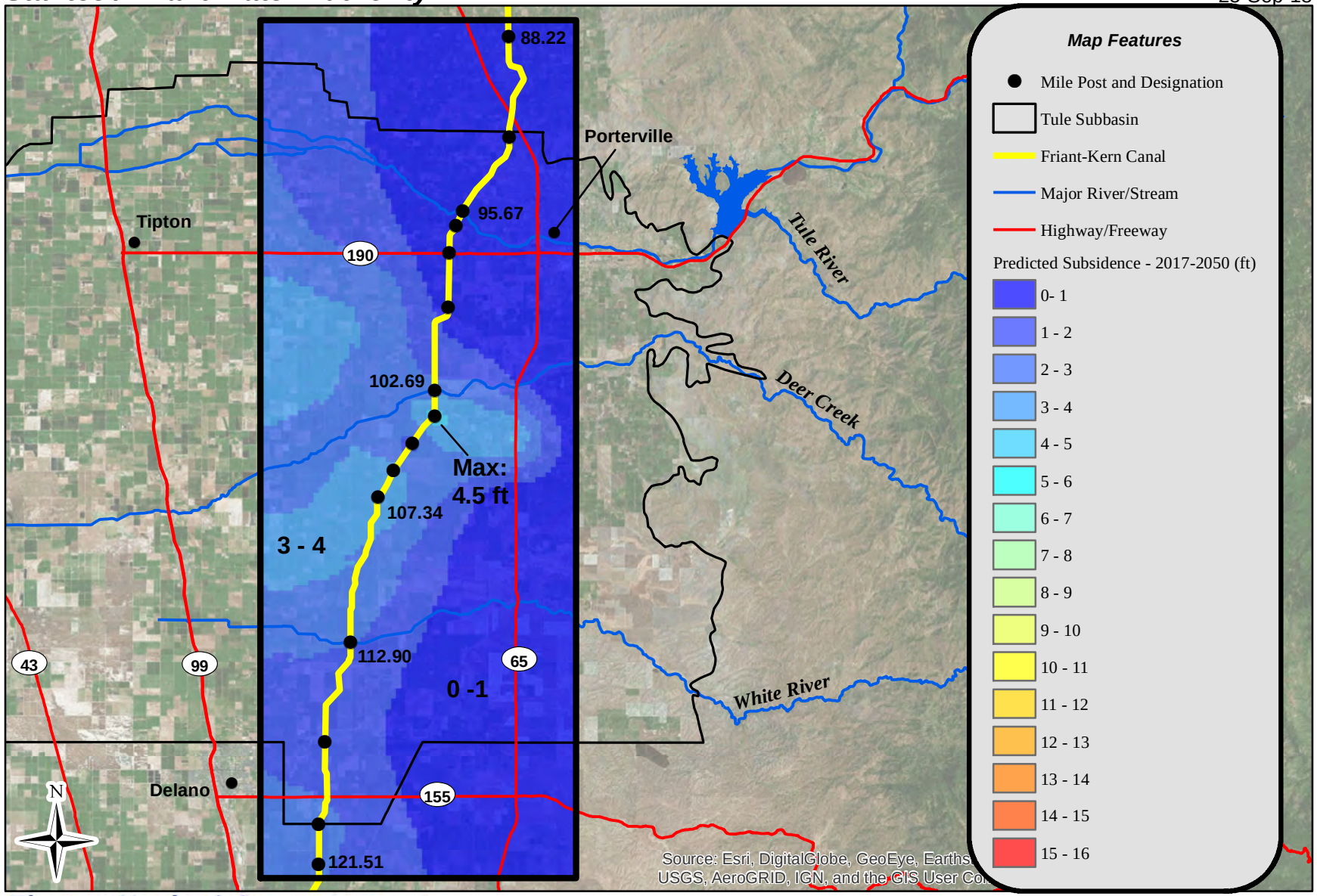
Friant-Kern Canal Subsidence 2017 to 2040 Scenario 1

Attachment E Figure E-2

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

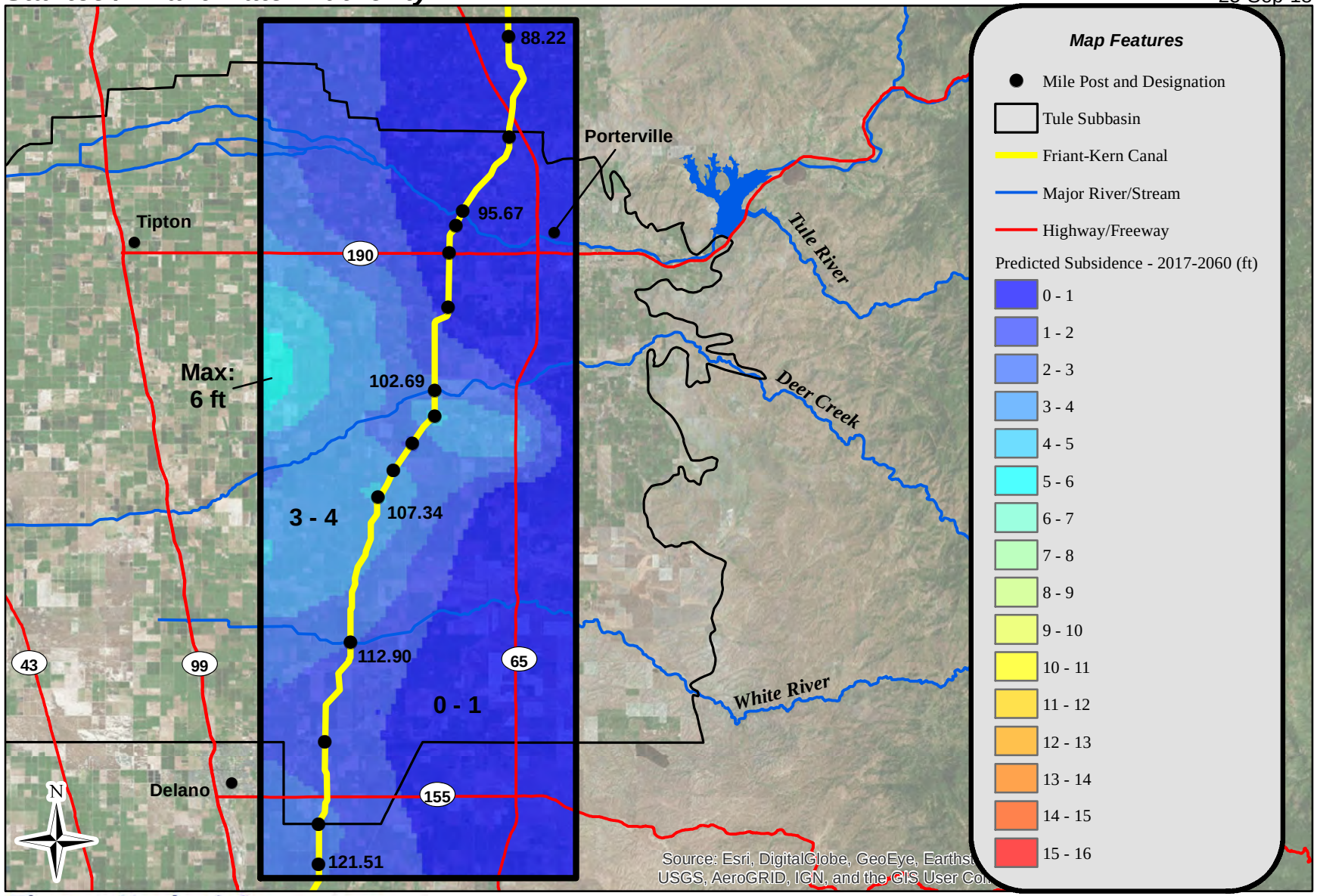
Friant-Kern Canal Subsidence 2017 to 2050 Scenario 1

Attachment E Figure E-3

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

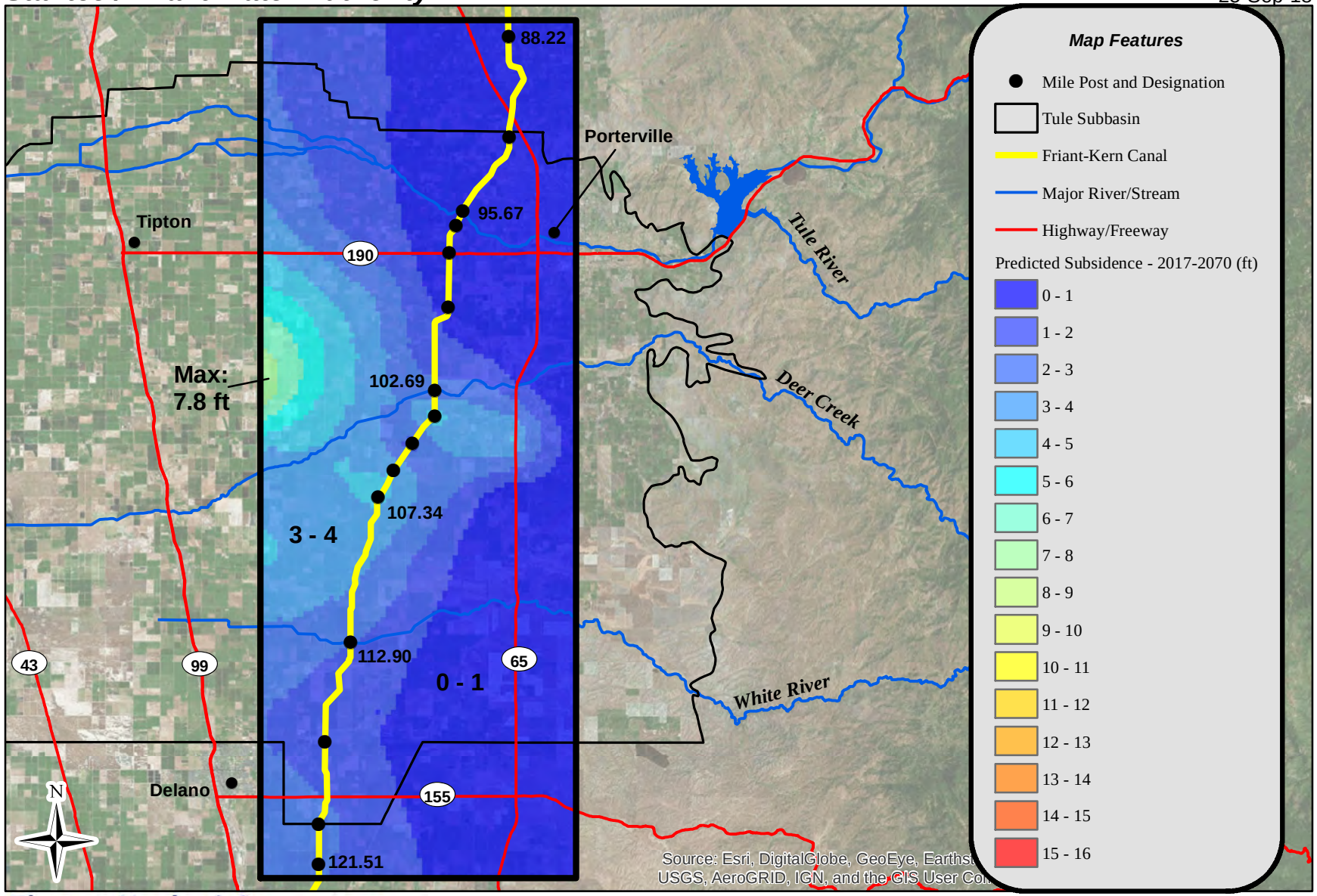
Friant-Kern Canal Subsidence 2017 to 2060 Scenario 1

Attachment E Figure E-4

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

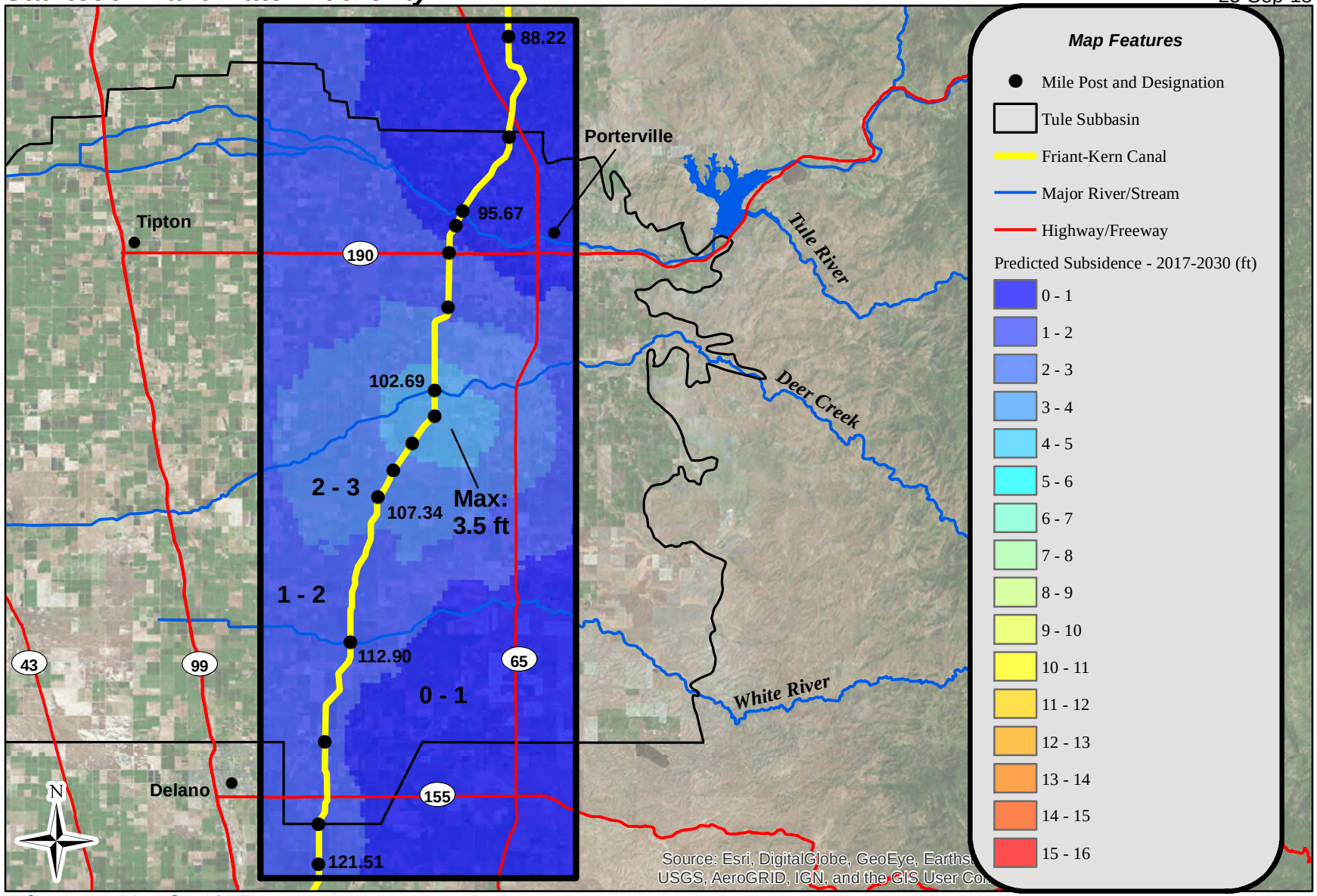
Friant-Kern Canal Subsidence
2017 to 2070
Scenario 1

Attachment E Figure E-5

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

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Groundwater Consulting

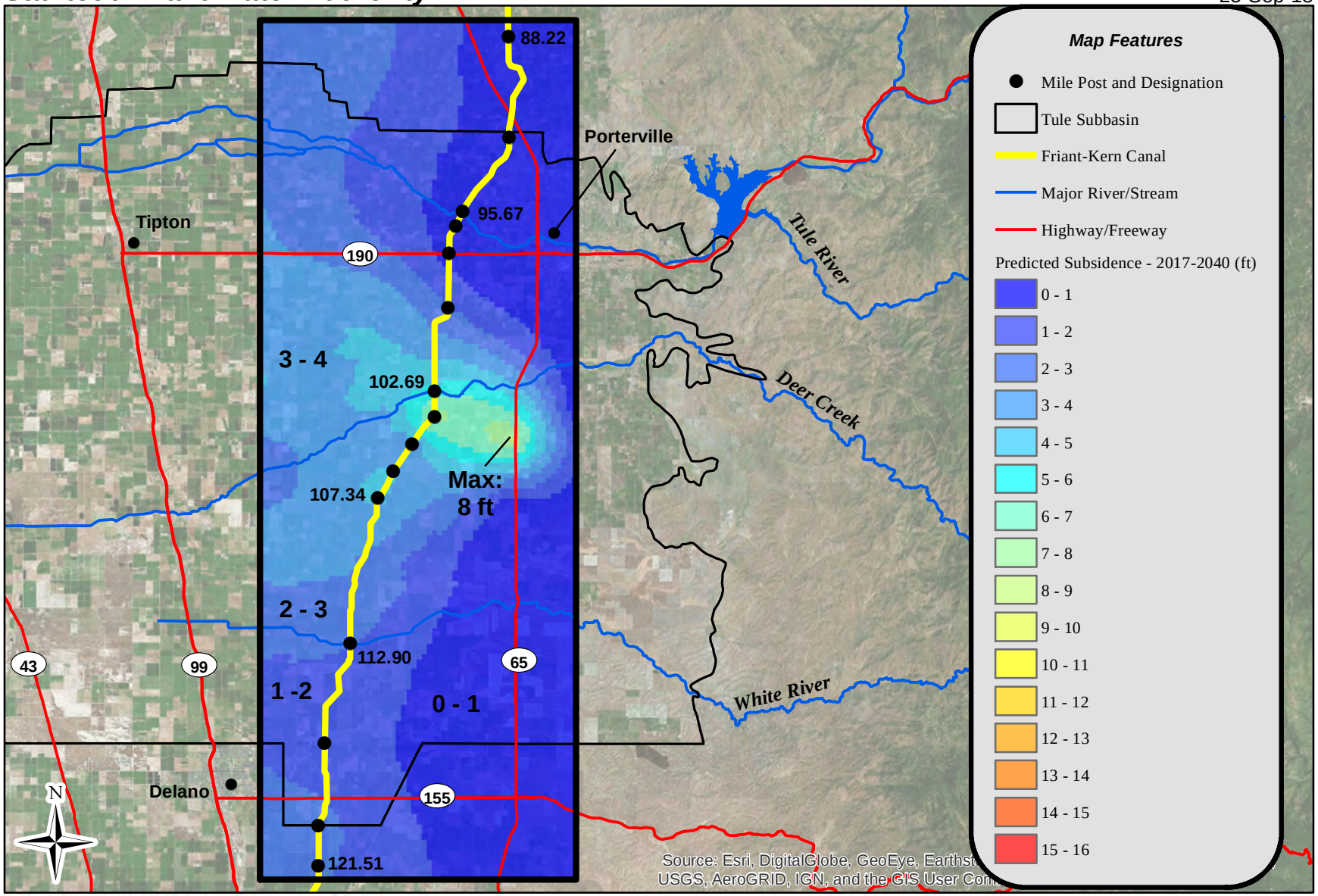
Friant-Kern Canal Subsidence 2017 to 2030 Scenario 2

Attachment E Figure E-6

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



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Groundwater Consulting

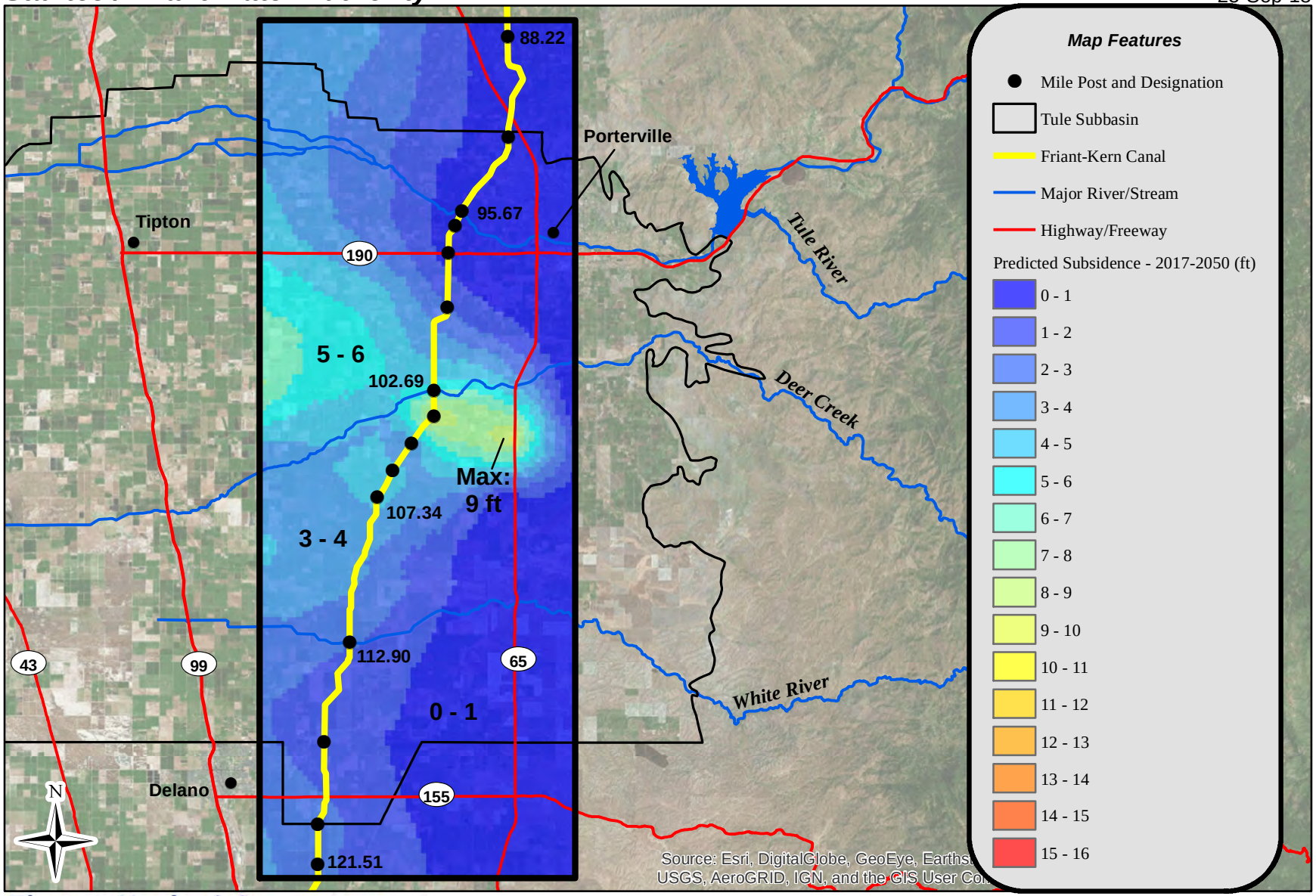
Friant-Kern Canal Subsidence 2017 to 2040 Scenario 2

Attachment E Figure E-7

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

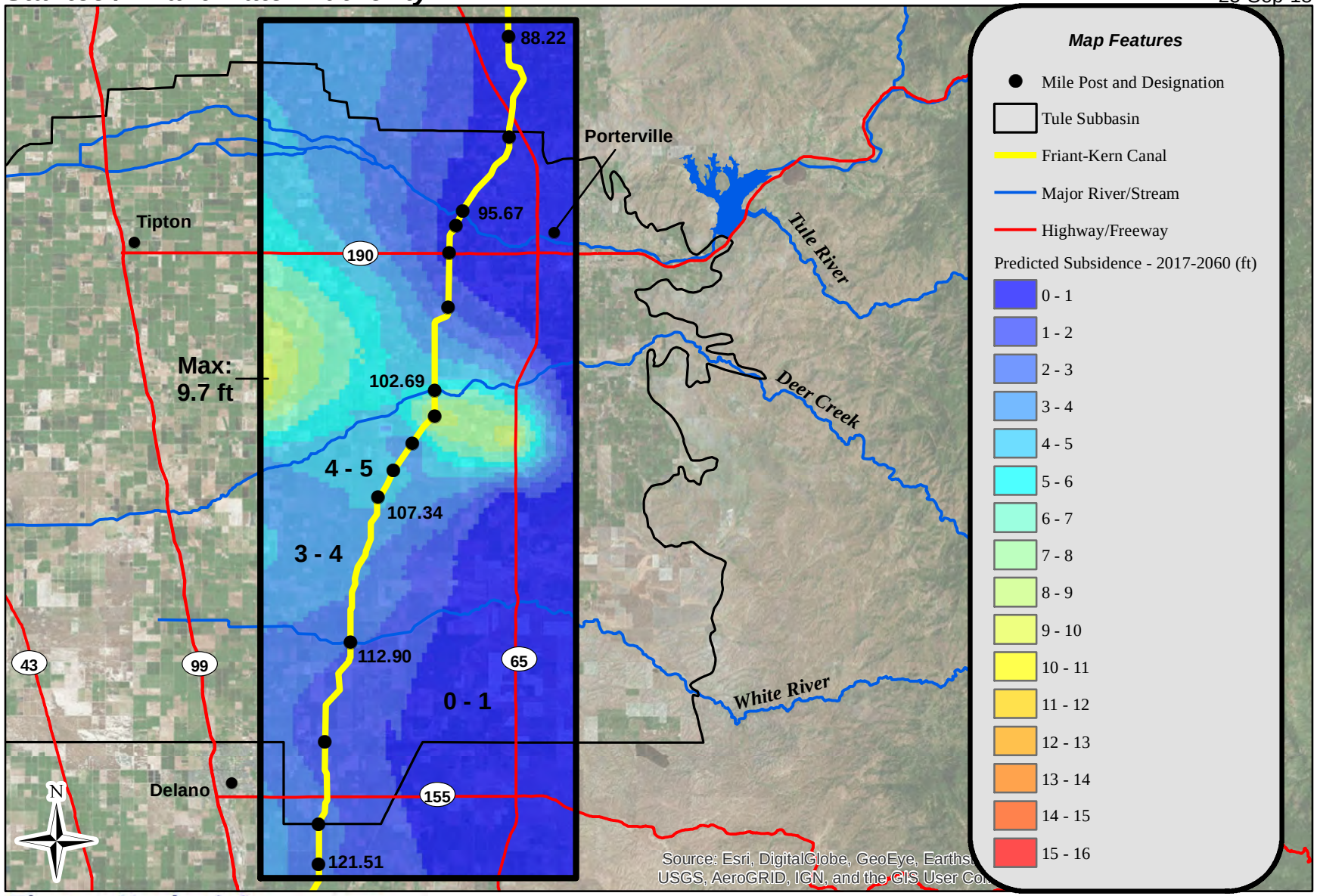
Friant-Kern Canal Subsidence 2017 to 2050 Scenario 2

Attachment E Figure E-8

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

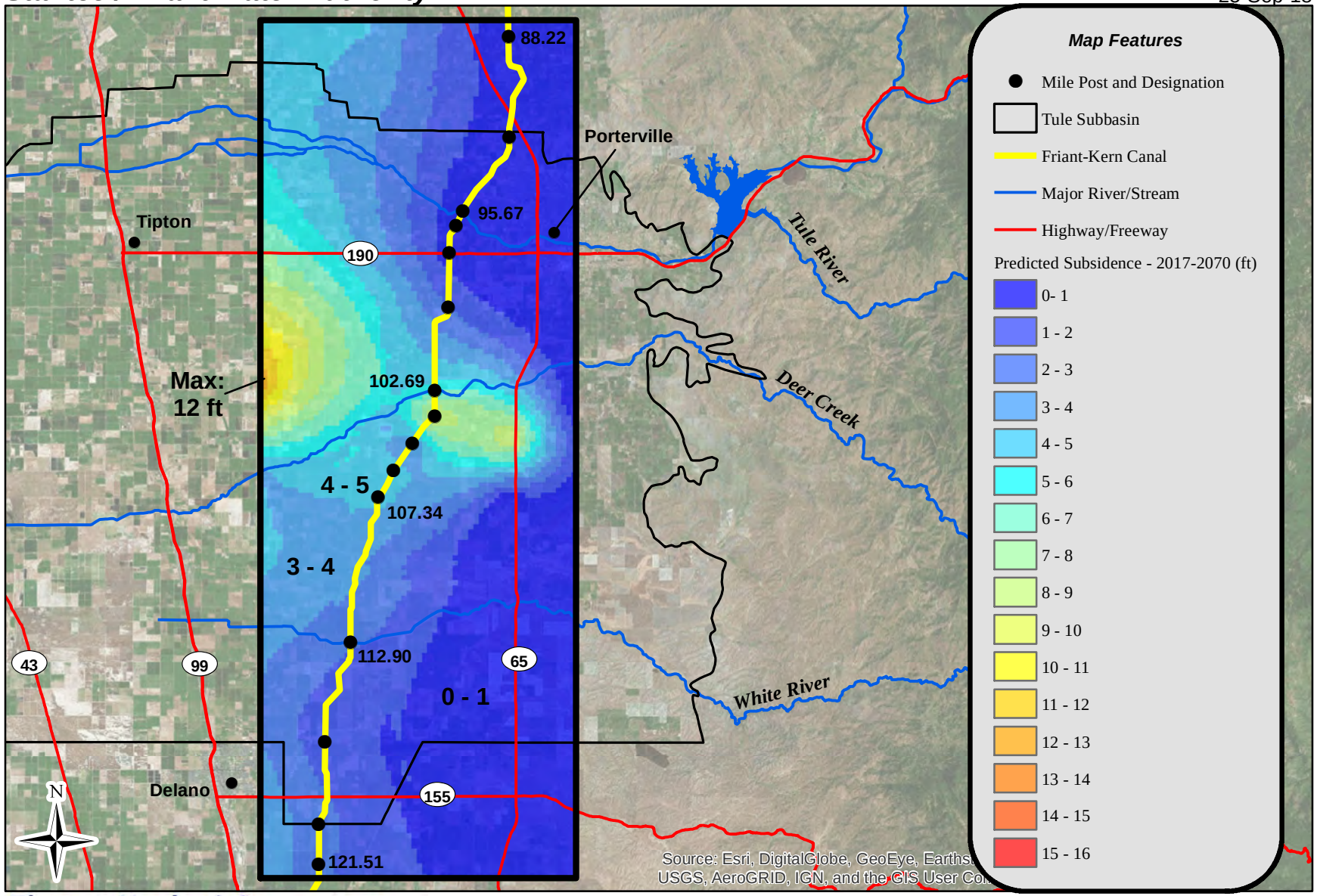
Friant-Kern Canal Subsidence 2017 to 2060 Scenario 2

Attachment E Figure E-9

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

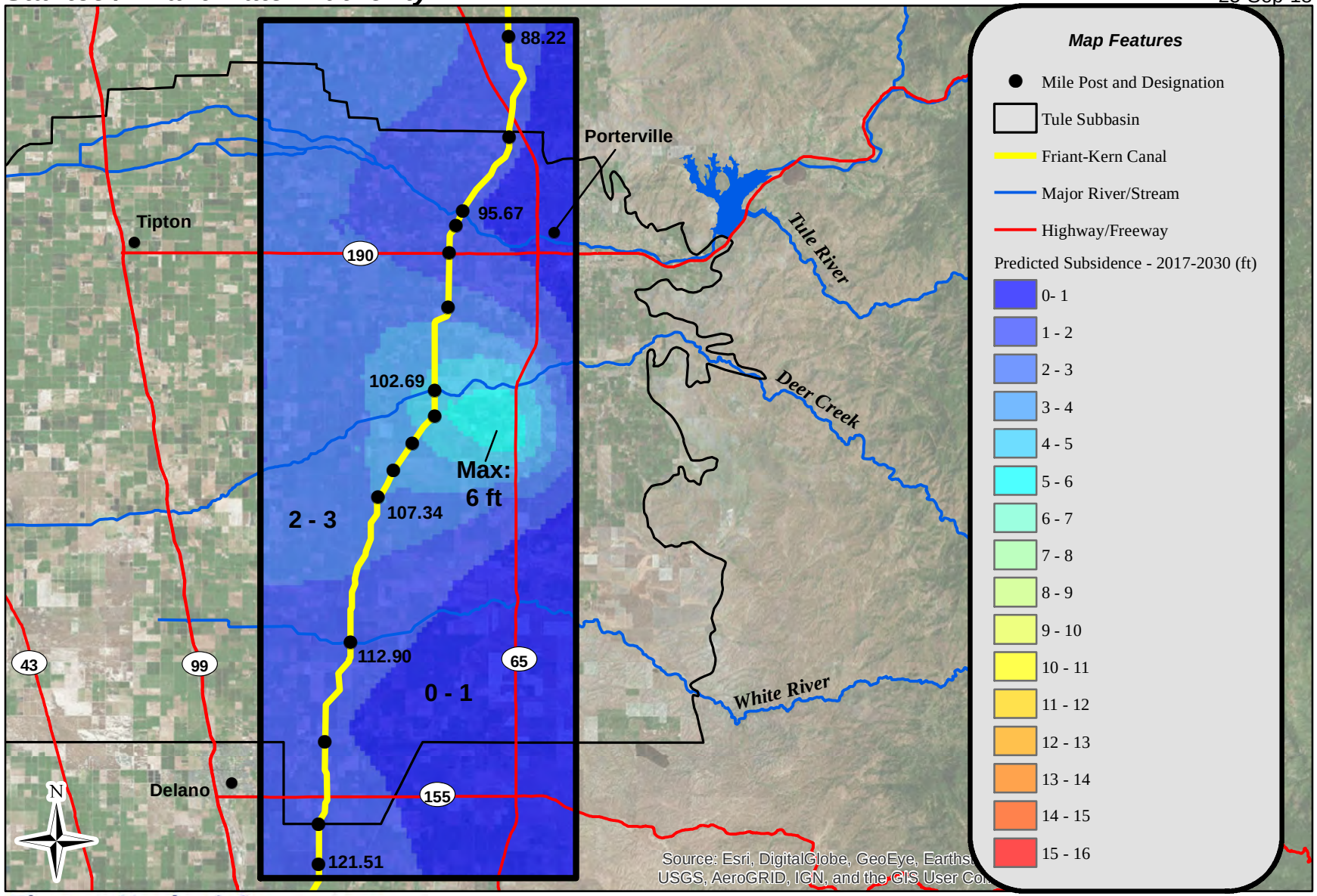
Friant-Kern Canal Subsidence 2017 to 2070 Scenario 2

Attachment E Figure E-10

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

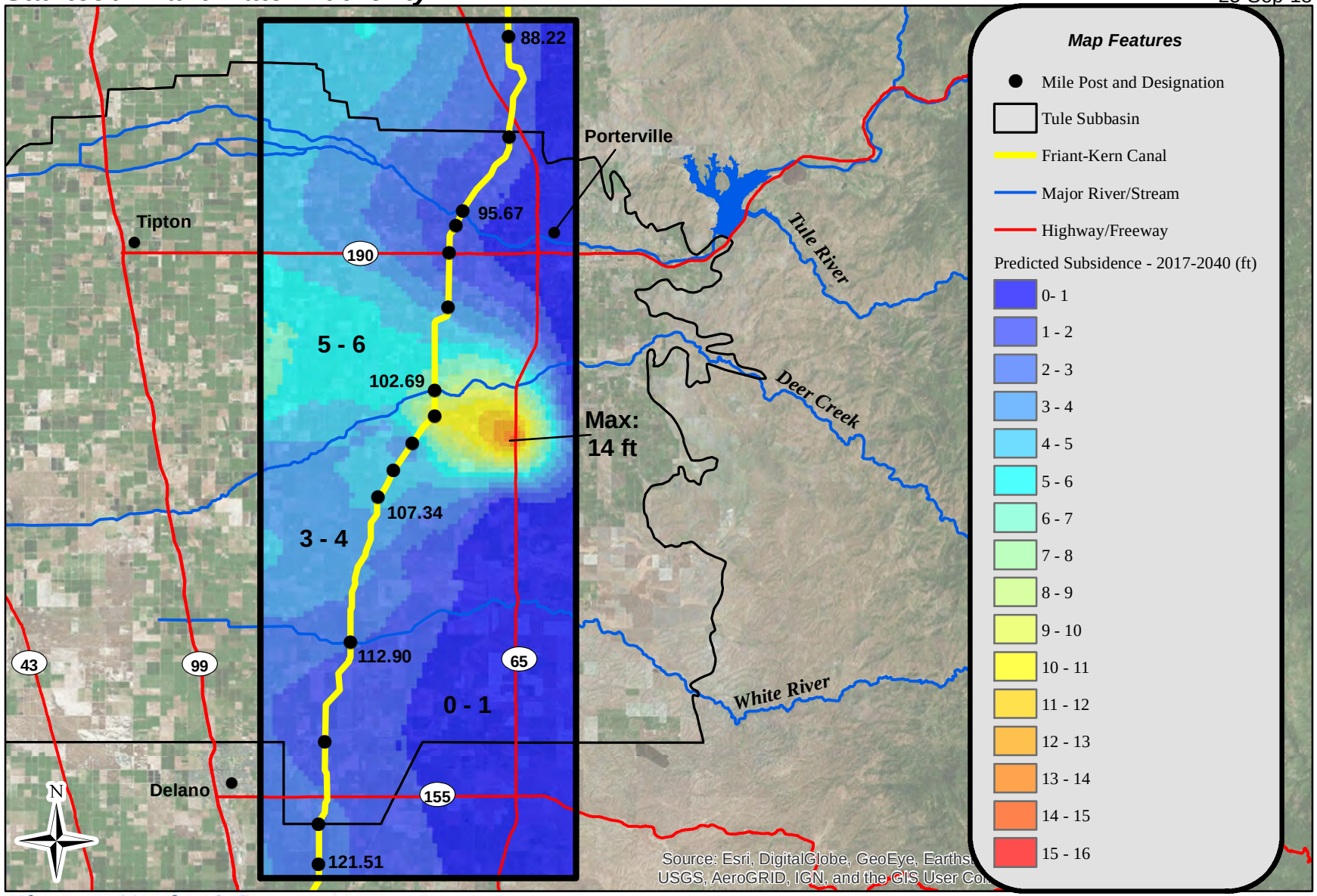
Friant-Kern Canal Subsidence 2017 to 2030 Scenario 3

Attachment E Figure E-11

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

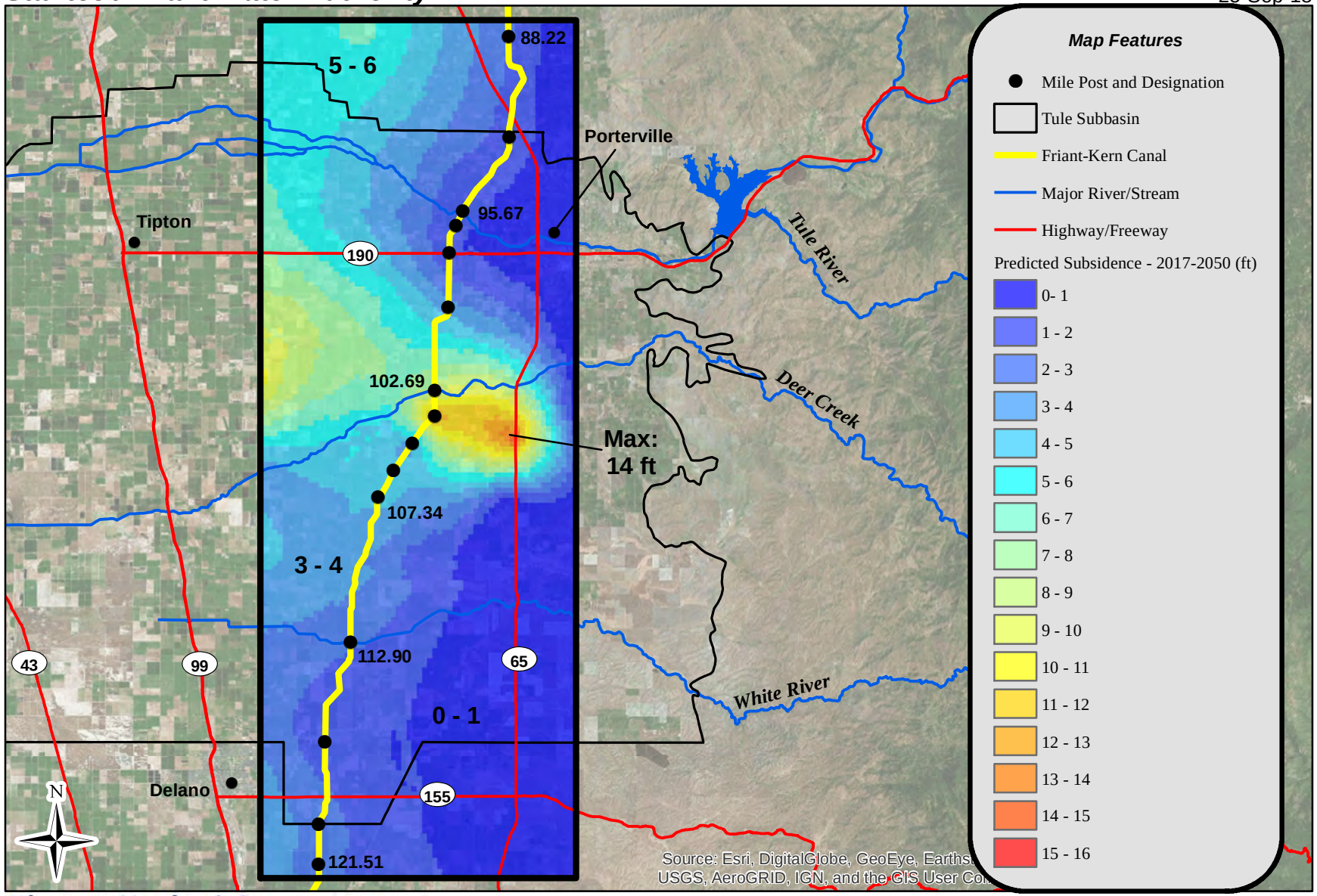
Friant-Kern Canal Subsidence 2017 to 2040 Scenario 3

Attachment E Figure E-12

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



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Groundwater Consulting

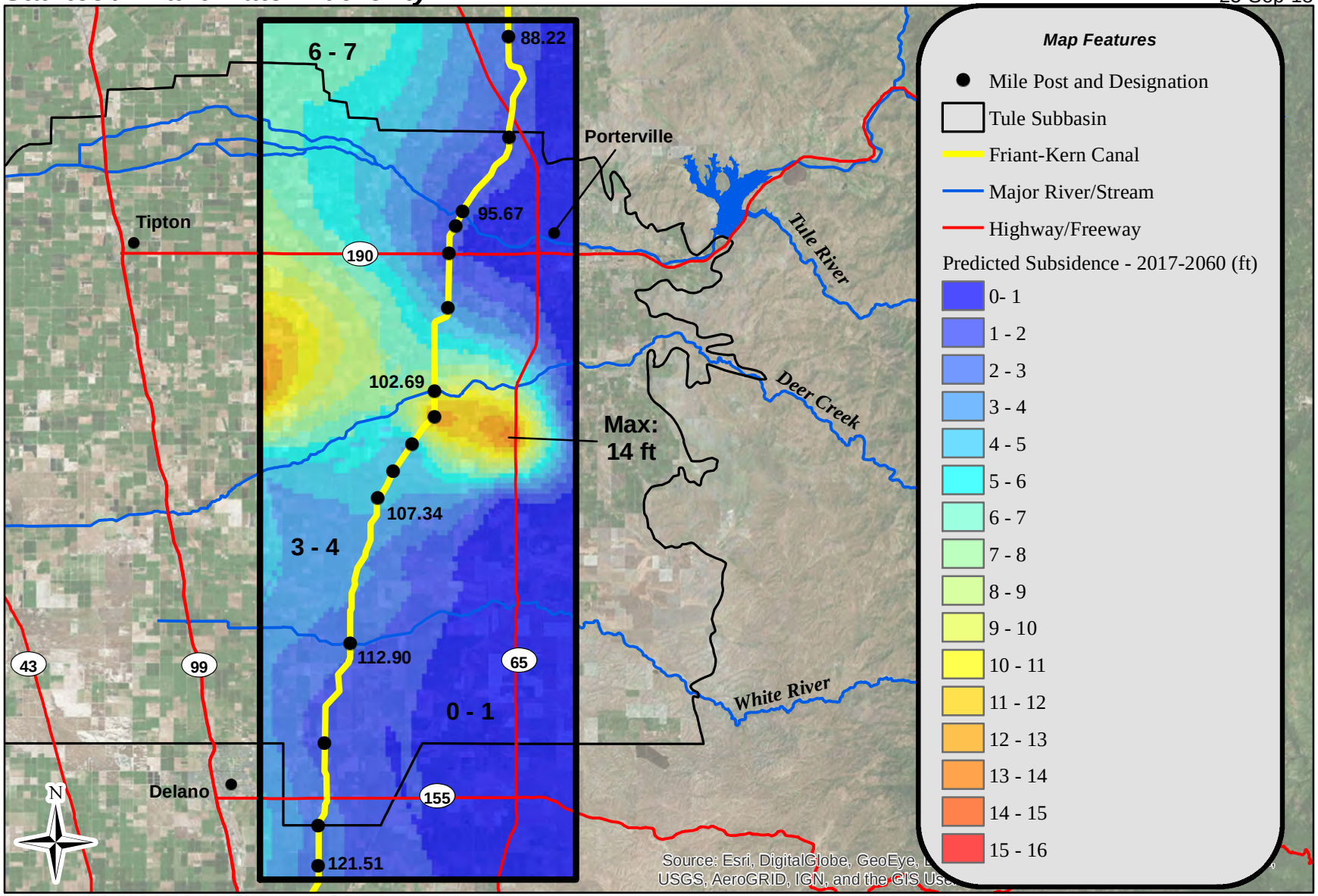
Friant-Kern Canal Subsidence
2017 to 2050
Scenario 3

Attachment E Figure E-13

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

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Groundwater Consulting

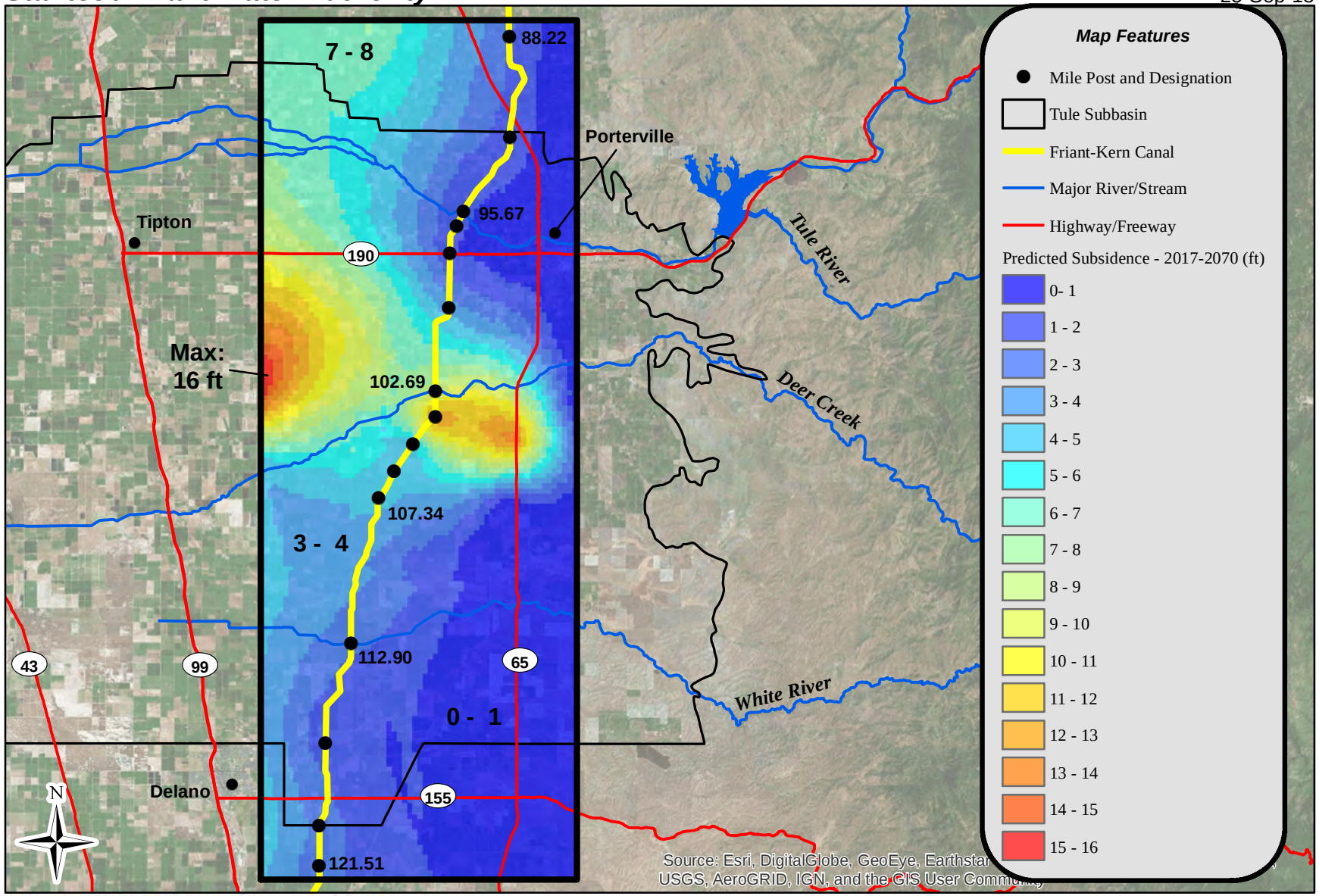
Friant-Kern Canal Subsidence
2017 to 2060
Scenario 3

Attachment E Figure E-14

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



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Groundwater Consulting

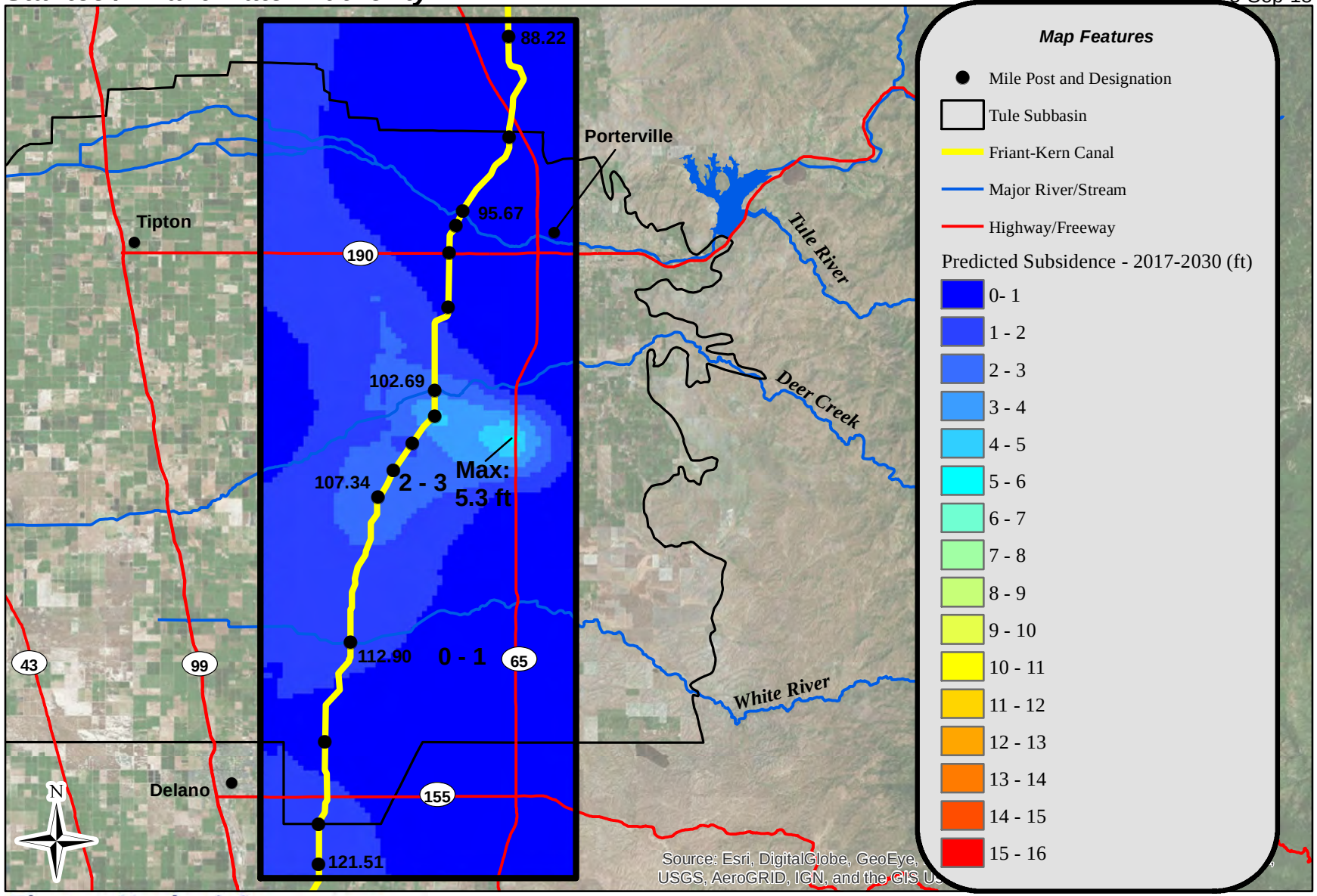
Friant-Kern Canal Subsidence
2017 to 2070
Scenario 3

Attachment E Figure E-15

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

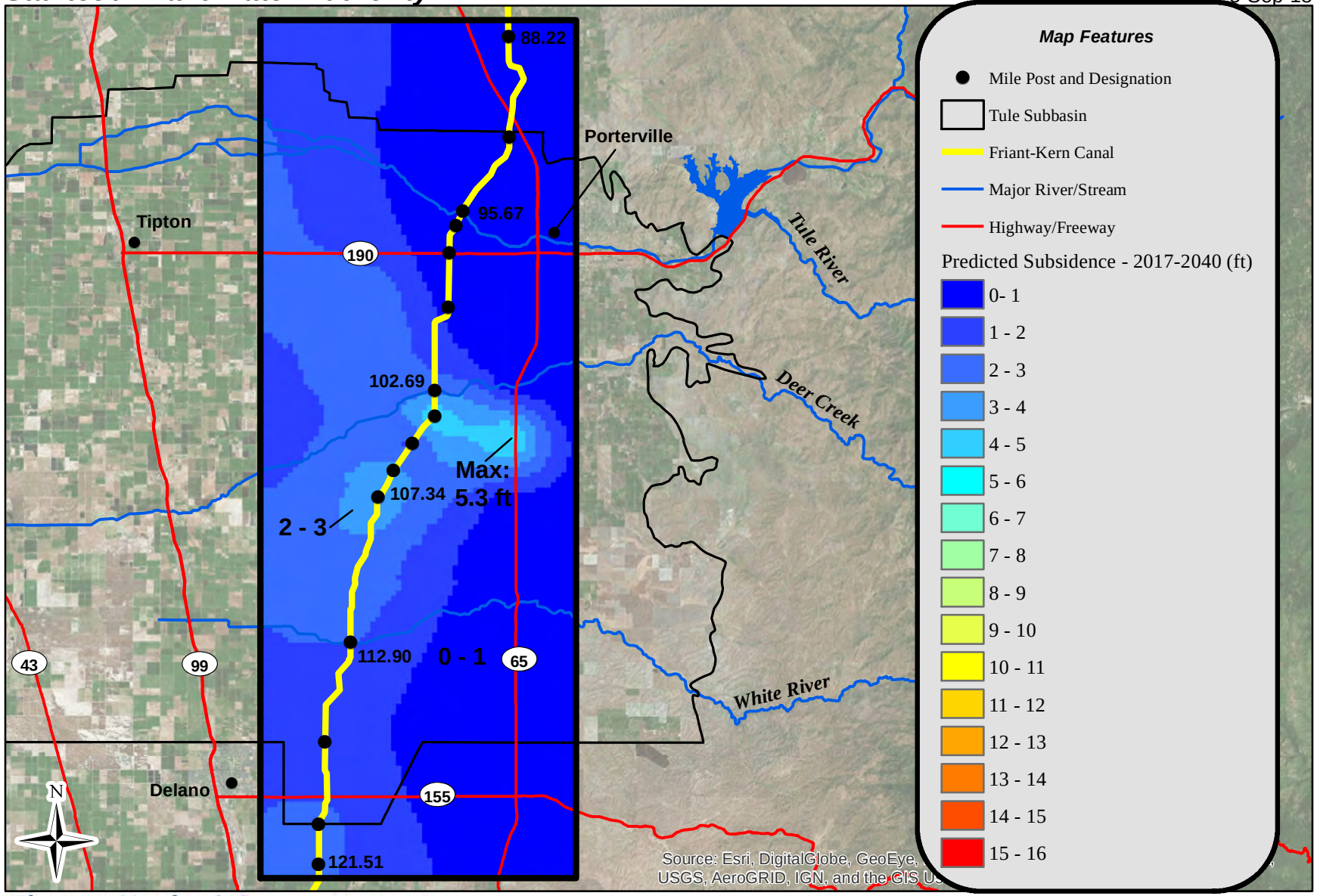
Friant-Kern Canal Subsidence
2017 to 2030
Scenario 4

Attachment E Figure E-16

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

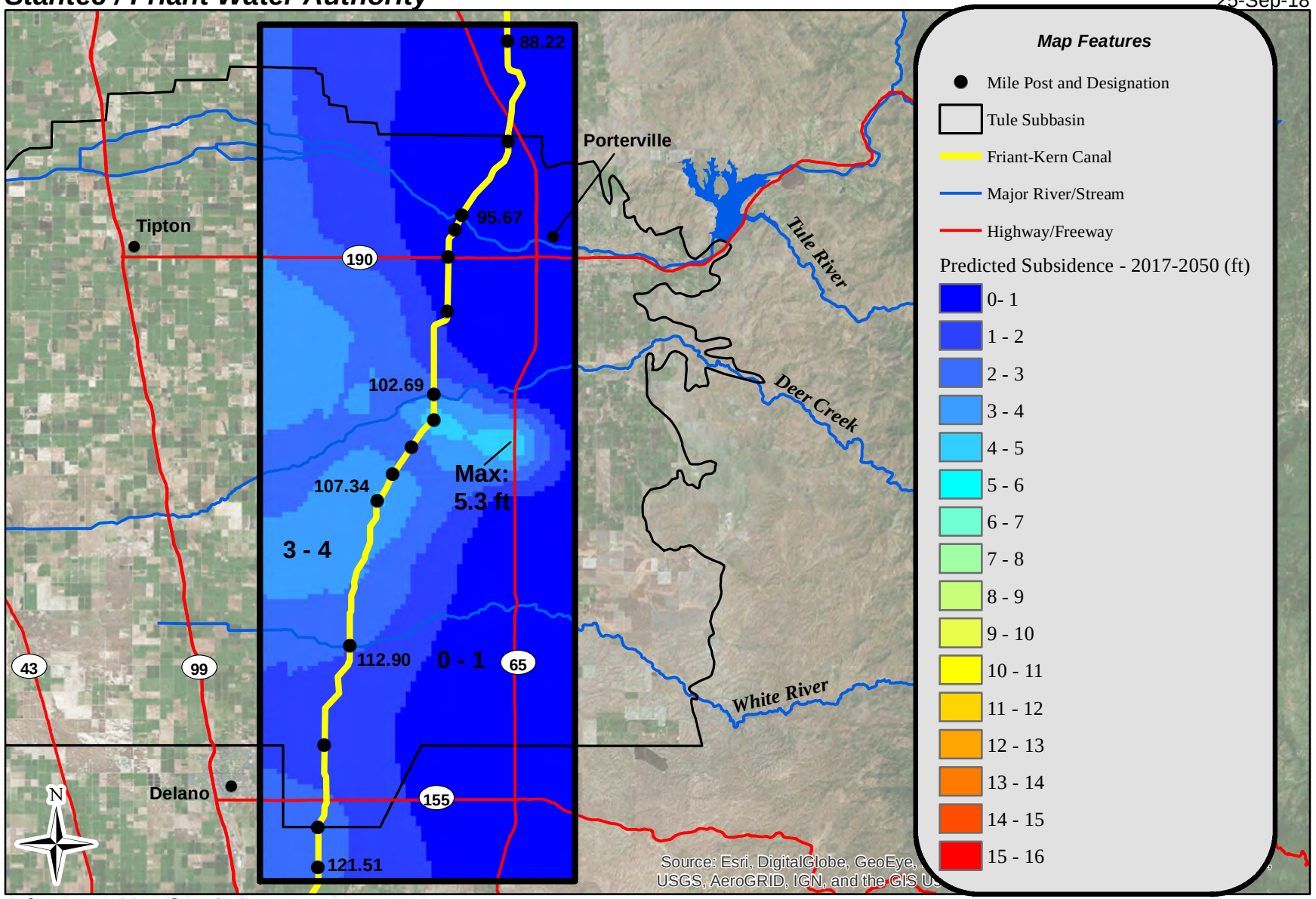
Friant-Kern Canal Subsidence 2017 to 2040 Scenario 4

Attachment E Figure E-17

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

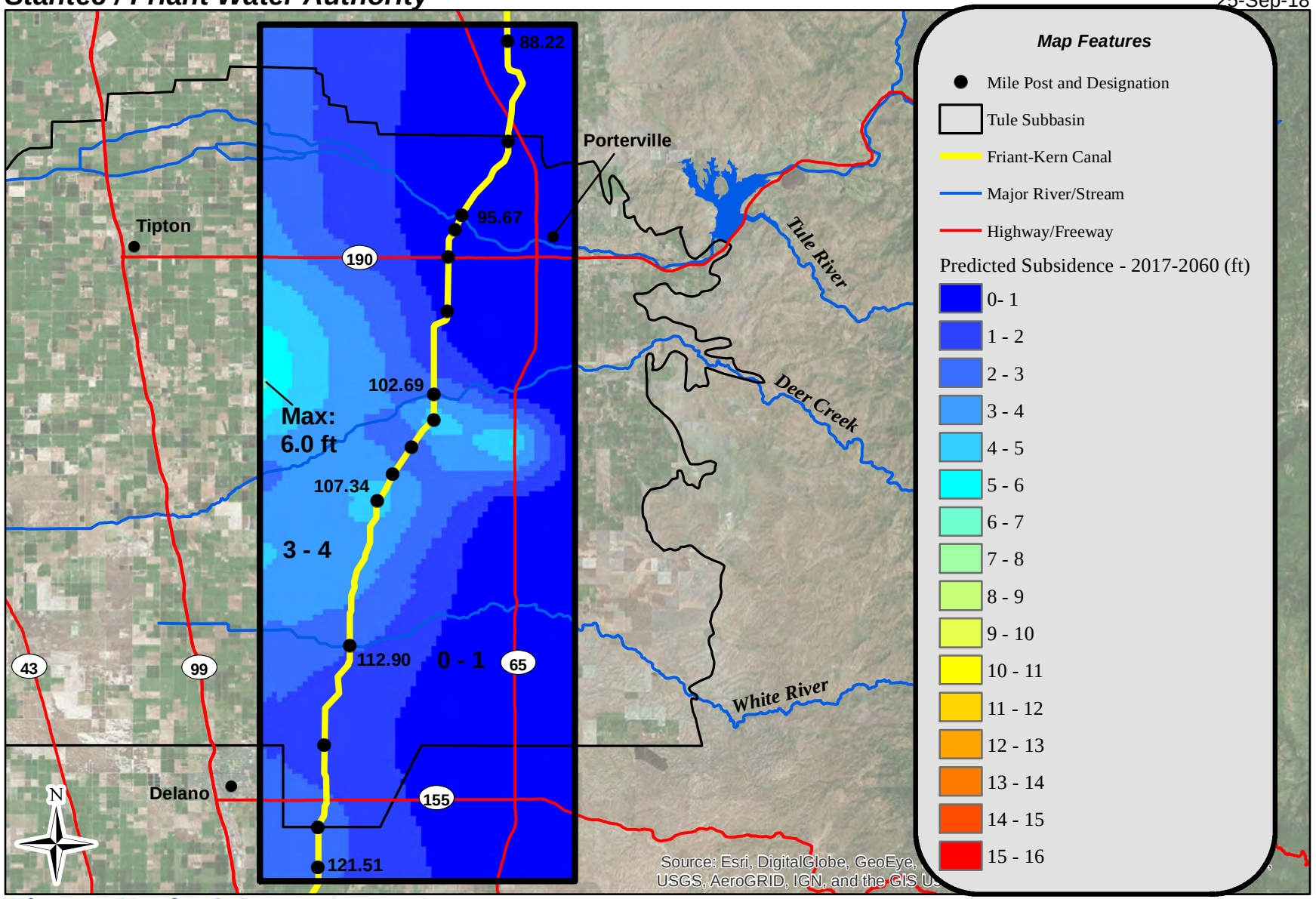
Friant-Kern Canal Subsidence
2017 to 2050
Scenario 4

Attachment E Figure E-18

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

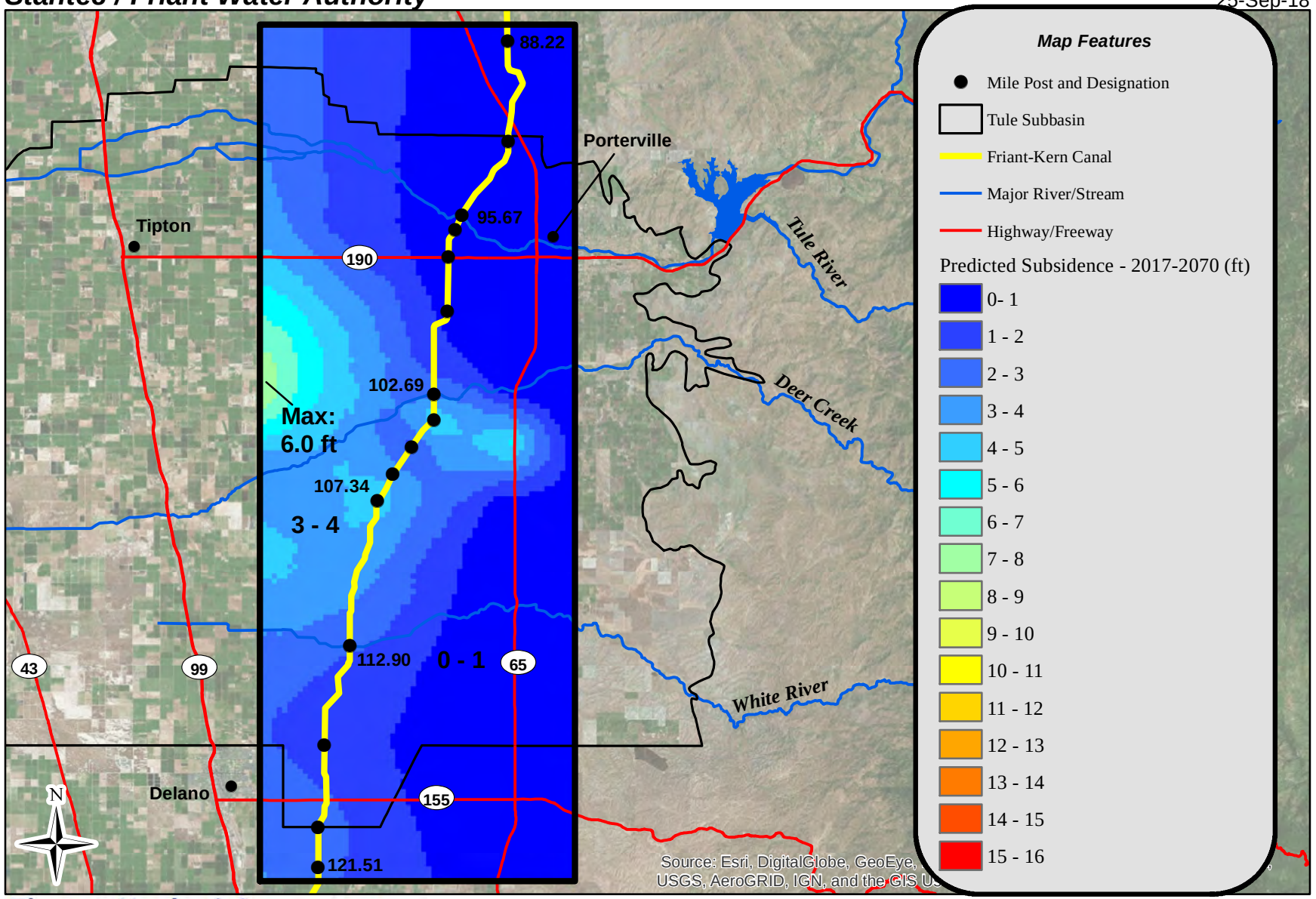
Friant-Kern Canal Subsidence
2017 to 2060
Scenario 4

Attachment E Figure E-19

Groundwater Flow Model Scenarios for Evaluating Potential Subsidence Along the Friant-Kern Canal

Stantec / Friant Water Authority

25-Sep-18



Thomas Harder & Co.
Groundwater Consulting

Friant-Kern Canal Subsidence
2017 to 2070
Scenario 4

Attachment E Figure E-20

PRELIMINARY GEOTECHNICAL INTERPRETIVE REPORT - Phase 1, Friant-Kern Canal Capacity Correction Project, Tulare County, CA

March 2019

Prepared for:

Friant Water Authority
854 N. Harvard Avenue
Lindsay, CA 93247

Prepared by:

Stantec Consulting Services Inc.
3301 C Street, Suite 1900
Sacramento, CA 95816

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Stantec
3301 C St #1900
Sacramento, CA 95816

March 2019

Attention: Mr. Doug DeFlitch
Friant Water Authority
854 N. Harvard Avenue
Lindsay, CA 93247

Dear Mr. DeFlitch,

Reference: Geotechnical Data Report - Phase 1
Friant-Kern Capacity Correction Project
Tulare County, California

Stantec Consulting Services Inc. (Stantec) is pleased to provide the following Preliminary Geotechnical Interpretive Report (GIR) for the ongoing geotechnical investigation for the above referenced project. This report presents an interpretation of the data and other factual information obtained from the Phase 1 geotechnical investigation, and our analyses and preliminary recommendations for the currently proposed canal modifications.

Stantec appreciates the opportunity to provide these engineering services for Friant Water Authority. If you have any questions or require additional information, please contact our office.

Regards,

Stantec Consulting Services Inc.

Maurice Amendolagine, PE, GE
Senior Geotechnical Engineer

Phone: (858) 633-4296
Maurice.Amendolagine@Stantec.com

Dan Back, PE, GE
Senior Geotechnical Engineer, Principal

Phone: (859) 422-3034
Dan.Back@Stantec.com

cc. Janet Atkinson

Sign-off Sheet

This document entitled PRELIMINARY GEOTECHNICAL INTERPRETIVE REPORT – Phase 1 Friant-Kern Canal Subsidence Correction Project was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Friant Water Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in this report and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

(signature)

Maurice Amendolagine, PE, GE

Reviewed by _____

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Abbreviations (Use Style Contents/ES)

ASTM	American Society for Testing and Materials
CDMG	California Division of Mines and Geology
cfs	Cubic Feet Per Second
CGS	California Geological Survey
CME	Central Mine Equipment Company
CPT	Cone Penetration Testing
CSDS RTN	California Surveying and Drafting Supply Real-Time Network
CTM	California Test Method
DGPS	Differential Global Positioning System
FKC	Friant-Kern Canal
FWA	Friant Water Authority
GIR	Geotechnical Interpretive Report
GDR	Geotechnical Data Report
GPM	Gallons Per Minute
GS	Grab Sample
HDPE	High Density Polyethylene
HSA	Hollow Stem Auger
Kx	Horizontal Permeability
Ky	Yield Coefficient
LL	Liquid Limit
MC	Modified California Sampler
MP	Milepost
Mw	Moment Magnitude
NP	Non-Plastic
O&M Road	Operations and Maintenance Road
PGA	Peak Ground Acceleration
PI	Plasticity Index
PL	Plastic Limit



pcf	Pounds Per Cubic Feet
psf	Pounds Per Square Foot
Reclamation	United States Bureau of Reclamation
RTK	Real Time Kinematic
Sa	Spectral Acceleration
SPT	Standard Penetration Test
ST	Shelby Tube
Stantec	tantec Consulting Services Inc.
Su	Undrained Shear Strength
Ts	Initial Fundamental Period
USACE	United States Army Corps of Engineers
USA North	Northern California Underground Service Alert
USGS	United States Geological Survey

1.0 INTRODUCTION

Stantec Consulting Inc. (Stantec) has prepared this Preliminary Geotechnical Interpretive Report (GIR) as part of the deliverables for the geotechnical services outlined in the contract between the Friant Water Authority (FWA) and Stantec (Professional Services Agreement for Friant Kern Canal Subsidence Correction – Task Order No. 1 dated June 6, 2018). This report presents an interpretation of the data and other factual information obtained from the Phase 1 geotechnical investigation and presents our analyses and recommendations for the currently proposed canal modifications relative to a 30 percent design level deliverable. This report will be revised in the near future to incorporate the information obtained from the forthcoming Phase 2 geotechnical investigation. A Boring and CPT Location Map for the Phase 1 geotechnical investigation is presented in Figure 1.

The factual information from the Phase 1 investigation including descriptions of sampling procedures, description of field tests and test results, laboratory test results, groundwater conditions, Cone Penetration Testing (CPT) soundings and boring logs are provided in the Geotechnical Data Report – Phase 1 (Stantec, 2018).

The Phase 1 geotechnical investigation will be supplemented by a Phase 2 investigation that will focus on explorations at the toe of the existing embankments and at other locations where canal modifications are proposed. Accordingly, the results and recommendations provided in this report should be considered preliminary and subject to revision based on the findings from the Phase 2 investigation. Scheduling of the Phase 2 investigation is currently awaiting environmental approval.

1.1 PROJECT DESCRIPTION

The primary goal of the Friant-Kern Canal (FKC) Subsidence Correction Project (Project) is to improve the FKC capacity through the subsidence area, approximately 33 miles of canal (Milepost 88 to 121). Mitigation alternatives are currently being developed for a 30 percent design level deliverable.

The Phase 1 geotechnical investigation was performed to provide an initial characterization of the geotechnical conditions along the approximate 33-mile stretch of the FKC for the 30 percent design level deliverable. Results of analyses and recommendations are presented in this report for the Phase 1 geotechnical investigation. Additional Phase 2 investigations and analyses will be needed to provide 30 percent design level recommendations. Additional investigations and analyses beyond Phase 2 will need to be performed for final design level recommendations for the selected corrective action.

1.2 CANAL HISTORY AND DESCRIPTION

The FKC is a 152-mile canal owned by the United States Bureau of Reclamation (Reclamation) and operated by FWA to convey water to augment irrigation capacity in Fresno, Tulare, and Kern counties. The FKC was constructed between 1945 to 1951 with a canal lining raise in some areas in the 1970s.

Land surface subsidence as a result of groundwater extraction has been well documented in California's Central Valley. Documentation of historical land subsidence in the 1950s and 1960s includes the portion of the Tule Sub-basin where the FKC is located. Land subsidence in this area was essentially arrested in the late 1970s and 1980s as the introduction of imported water into the area allowed for reduced groundwater pumping and groundwater levels

recovered. The land subsidence was likely reactivated again in the 1990s with the return of groundwater overdraft conditions and subsidence rates appear to have accelerated after 2007 due to increased pumping and drought conditions.

The regional setting generally consists of rural agricultural farming communities. In general, the canal traverses open farmland and has few associated structures. An assortment of County bridges cross over the FKC.

The typical canal section varies throughout its length (depending on whether in cut or fill areas, or combination). The canal is a concrete lined (3.5 inches thick) trapezoidal channel with longitudinal and transverse joints. The canal includes numerous check structures for flow control and checking the water surface for deliveries to the various irrigation districts, cities, and farms. The check structures are generally multi-bay concrete structures with radial gates.

The inner concrete lining of the canal has a slope of approximately 1.25 horizontal to 1 vertical (1.25H:1V) and the canal has a base width of approximately 36 feet. The canal within the subsidence area consists of embankment heights that range from approximately 5 feet to 16 feet above the original ground with the western side of the canal generally being taller than the eastern side. The outer slopes within the subsidence area generally range from approximately 1.75H:1V to 2H:1V with some isolated areas that are as steep as 1.5H:1V.

Based on a review of documents from the original canal construction and the 1970's canal raise, the canal embankment consists partially of compacted (i.e. engineered) fill and partially uncompacted (i.e. common) fill. A typical section showing approximate zones of the compacted and uncompacted fill in relation to a typical Phase 1 exploration location and depth is presented below. As shown, the explorations in the Phase 1 investigation intersected the uncompacted fill and alluvium, but not the compacted fill zones. The typical section on the following page is located in a 1970's canal raise area.

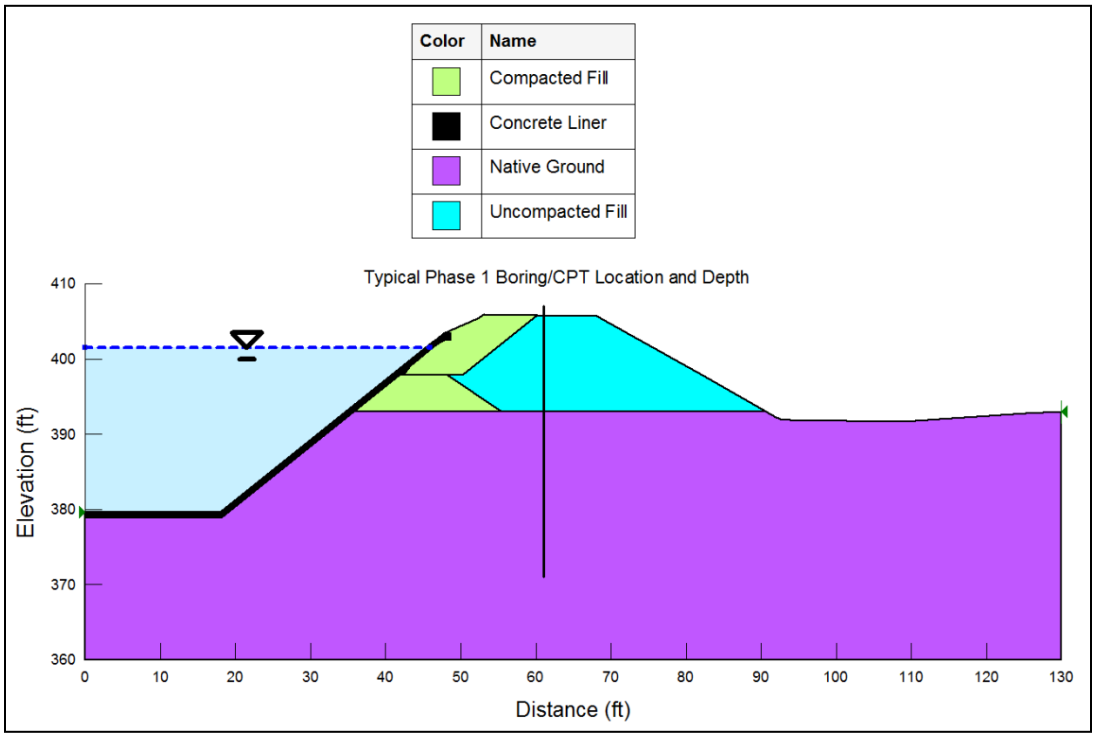


Figure 1. Canal Embankment Section Showing a Typical Phase 1 Boring or CPT

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2.0 GEOLOGIC SETTING

The project site is located in the southern portion of the Great Valley Geomorphic Province in Central California. This region is characterized as a 50-mile-wide and 400-mile-long sediment- filled trough in which the sediments have been deposited, almost continuously, since the Jurassic period. The geology of the Great Valley generally consists of marine and continental deposits resting on a basement complex of metamorphic and igneous rocks.

Locally, the project site resides within the San Joaquin Valley. Geology within the San Joaquin Valley and the project area mainly consists of Jurassic to recent, marine, alluvial, and lake deposits that are several thousand feet thick.

The regional surficial geology along the canal is mapped as Quaternary Alluvium and Older Alluvium (California Geological Survey, 2017 and California Division of Mines and Geology, 1964). A geologic map of the project area is presented in Figure 2.

The site is located in a moderately active seismic area. The southern end of the project area is closer to known active faults than the northern project area. The estimated distance from the southern end of the project area (Milepost 110.3) to selected nearby mapped active faults is presented in the table below.

Table 1. Active Faults in Site Vicinity

Fault	Distance (miles) [1]	Maximum Moment Magnitude [1]
Great Valley 14 (Kettleman Hills)	43.9	7.2
White Wolf	48.3	7.2
South San Andreas	51.7	8.2
Pleito	55.6	7.1
Great Valley 13 (Coalinga)	57.5	7.1

[1] Measured from 2008 National Seismic Hazard Maps - USGS (USGS, 2008).

As noted above, the closest known active fault is the Great Valley 14 Fault, located approximately 44 miles northwest of Milepost 110.3. A Regional Fault and Seismicity Map is presented in Figure 3.

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3.0 SUBSURFACE INVESTIGATION

The Phase 1 geotechnical field investigation for the FKC Subsidence Correction Project was performed between September 11 and September 25, 2018, and consisted of the following:

Nine hollow-stem auger (HSA) borings with Standard Penetration Testing (SPT), Modified California Sampling (MC), and Shelby tube (ST) sampling

Seven Cone Penetration Tests (CPT)

A summary of the exploration locations relative to the mileposts is provided in the tables below.

Table 2. Summary of Borings

Boring ID	Approximate Canal Milepost	Ground Elevation[1] (feet)	Depth (feet)
B-1	97.5	409.8	36.5
B-2	104.1	404.4	36.5
B-3	106.1	404.7	36.5
B-4	107.1	404.9	41.5
B-5	108.9	405.8	36.5
B-6	108.9	405.5	36.5
B-7	110.3	407.7	11.5
B-7A[2]	110.3	407.6	36.5
B-8	115.6	397.9	36.5
B-9	115.6	397.9	21.5

Notes:
1. Elevations were collected by the Stantec field engineer with the use of a survey grade RTK DGPS referencing the CSDS RTN.

Table 3. Summary of CPTs

CPT ID	Approximate Canal Milepost	Ground Elevation[1] (ft)	Depth (ft)
CPT-1	97.5	409.7	38.1
CPT-2	104.1	404.4	38.1
CPT-3	106.1	404.8	37.9
CPT-4	107.1	404.9	47.2
CPT-5	110.3	407.6	37.7
CPT-6	115.6	407.4	37.9
CPT-7	115.6	397.9	21.5

Notes:
1. Elevations were collected by the Stantec field engineer with the use of a survey grade RTK DGPS referencing the CSDS RTN.

Photographs of the canal during the Phase 1 investigation are provided in Appendix F. With the exceptions of Boring B-9 and CPT-7, the borings and CPTs were located in the middle of the Operations and Maintenance Road (O&M Road). The Programmatic Agreement between Reclamation and the California State Historic Preservation Office area of potential effect is limited to the area from the eastern outside toe to the western outside toe of the respective canal embankments. Selection of boring and CPT locations outside this area for the Phase 1 field investigations was not

possible because obtaining approvals would have taken longer than the time available to conduct the field investigations within the project schedule.

A summary of the type of in-situ testing, sampling method and number of samples obtained from the borings are shown in the table below.

Table 4. In-Situ Testing and Sampling Quantities

Test	Number of Tests/Samples
Cone Penetration Test (CPT)	7 soundings
Shelby Tube (ST)	3 samples
Standard Penetration Test (SPT)	61 tests
Modified California Sampling (MC)	26 tests
Grab Sample (GS)	8 samples

The laboratory testing results in the GDR also refer to the MC samples as “Cal” samples with a J, R, or S suffix referring to a jar, ring, or sleeve as the type of container used for the MC sample. Grab samples are also referred to as “Bulk” samples in the laboratory testing results in the GDR. Shelby tube samples are identified in the GDR as “ST” as noted in Table 1 of this report.

4.0 SUBSURFACE CONDITIONS

4.1 GENERAL

Details of the subsurface conditions are presented in the Geotechnical Data Report – Phase 1 (GDR), (Stantec, 2018). The information in the GDR was based on the Phase 1 geotechnical investigation carried out by Stantec in September of 2018. Figure 1 shows the locations of the Stantec Phase 1 exploratory borings and CPT soundings.

Based on the geometry of the embankment as described in the original as-built construction drawings from 1945 and the as-built construction drawings of the embankment raise in the 1970s, we developed a subsurface model comprising three units. The three soil units include uncompacted fill, compacted fill, and alluvium. As shown in the sketch in Section 1.2, the Phase 1 investigations only intersected the uncompacted fill and the alluvium. The compacted fill zone is located too close to the canal side of the embankment to be intersected by the Phase 1 explorations.

The following sections provide a summary of the material properties and interpreted design parameters for the encountered subsurface soil.

4.2 SOIL CONDITIONS

4.2.1 Uncompacted Fill

The uncompacted fill encountered in the explorations consisted of sandy lean clay (Unified Soil Classification System Symbol: CL), fat clay (CH), clayey sand (SC), and well graded sand (SW). The uncompacted fill was typically more clayey in the northern section of the alignment (Milepost 97.5 to 107.1), and sandier in the southern section of the alignment (Milepost 108.9 through 115.6). The uncompacted fill thickness varied at the boring locations from approximately 9 feet to 16 feet.

The consistency of the sandy lean clay and fat clay generally varied from firm to hard and the relative density of the clayey sand and well graded sand varied from loose to dense. One relatively thin soft clay layer was encountered at the uncompacted fill/alluvium contact in Boring B-4 at a depth of approximately 13 feet to 16 feet, and in CPT-4 at a depth of approximately 15 feet to 18 feet. Soft soil was also observed at the uncompacted fill/alluvium contact at other exploration locations.

Selected index properties of the uncompacted fill are summarized below.

The fines content (materials finer than the No. 200 sieve) of the clayey fill varied between approximately 32 percent and 60 percent.

The Plasticity Index (PI) of the clayey fill varied between approximately 9 and 21.

The in-place moisture content of the clayey fill varied between approximately 4 percent and 16 percent. A plot of the moisture content versus depth within the uncompacted fill is presented in Appendix B.

The percent saturation of the clayey fill varied between approximately 53 percent and 86 percent. A plot of the percent saturation versus depth within the uncompacted fill is presented in Appendix B.

The SPT N60 blow counts within the uncompacted fill varied between 3 and 53. A plot of the SPT N60 blow counts versus depth within the uncompacted fill is presented in Appendix B.

4.2.1.1 Uncompacted Fill Shear Strength

The shear strength of the uncompacted fill was evaluated from in-situ testing such as SPT blow counts from the borings, correlations from CPT data, and from laboratory direct shear testing of samples from the borings.

Since the uncompacted fill was predominantly clayey, the blow counts from the borings were not considered to be a reliable method for evaluating shear strength. The undrained shear strength (S_U) of the uncompacted fill based on CPT data correlations varies between approximately 1,000 pounds per square foot (psf) to greater than 4,000 psf. The three-foot thick soft clay layer encountered in Boring B-4 and CPT-4 had an undrained shear strength of approximately 400 psf based on the CPT data. Effective stress peak friction angles of the sandy materials based on CPT data correlations varies between approximately 32° and 50° for the uncompacted fill. Parameter interpretations from the CPT's including undrained shear strength and effective stress peak friction angles are provided in Appendix C.

Ultimate or post-peak effective stress friction angles from the laboratory direct shear tests vary from 29° to 31°, with cohesion varying between 150 psf to 450 psf. A summary of the laboratory direct shear tests is provided in Appendix B.

From our evaluation of the shear strength data above, we selected an effective stress shear strength with a friction angle of 29° and cohesion of 50 psf for use in the slope stability analyses described later. The selected shear strength envelope is essentially the lower bound from the four direct shear tests performed on the uncompacted fill. We believe this is a reasonably conservative shear strength for use in the slope stability evaluations based on the current geotechnical information.

4.2.2 Alluvium

The alluvium encountered in the explorations consisted of sandy lean clay and lean clay with sand (CL), fat clay (CH), clayey sand (SC), well graded sand with gravel (SW), well graded sand with silt (SW-SM), and silty sand (SM). The alluvium was typically more clayey in the northern section of the alignment (Milepost 97.5 to 107.1), and sandier in the southern section of the alignment (Milepost 108.9 through 115.6). The alluvium extended to a depth of at least 46.5 feet, the maximum depth of the borings.

The consistency of the clayey alluvium varied from very stiff to hard and the relative density of the sandy alluvium varied from loose to very dense.

Selected index properties of the alluvium are summarized below.

The fines content of the clayey alluvium varied between approximately 31 percent and 64 percent.

The Plasticity Index (PI) of the clayey alluvium varied between approximately 10 and 17.

The fines content of the clayey alluvium varied between approximately 9 percent and 33 percent.

The in-place moisture content of the alluvium varied between approximately 2 percent and 17 percent. A plot of the moisture content versus depth within the alluvium is presented in Appendix B.

The percent saturation of the alluvium varied between approximately 6 percent and 99 percent. The majority of the data had percent saturation between approximately 30 and 80 percent. A plot of the percent saturation versus depth within the alluvium is presented in Appendix B.

The SPT N60 blow counts within the alluvium varied between 9 and 53. A plot of the SPT N60 blow counts versus depth within the alluvium is presented in Appendix B.

4.2.2.1 Alluvium Shear Strength

The shear strength of the alluvium was evaluated from in situ testing such as SPT blow counts from the borings, correlations from CPT data, and from laboratory direct shear testing of samples from the borings.

An estimate of the peak effective stress friction angle was made based on a correlation by Hatanaka & Uchida (1996) using the hammer energy and overburden pressure corrected blow counts (N160) from the borings. The peak effective stress friction angle using this correlation varies between approximately 35° and 45° for the sandy portion of the alluvium. A plot of the peak effective stress friction angle of the sandy portion of the alluvium is presented in Appendix B.

The undrained shear strength (S_u) of the clayey portion of the alluvium based on CPT data correlations varies between approximately 1,000 pounds per square foot (psf) to greater than 4,000 psf. Effective stress peak friction angles based on CPT data correlations varies between approximately 32° and 50° for the sandy portion of the alluvium. Parameter interpretations from the CPT's including undrained shear strength and effective stress peak friction angles are provided in Appendix C.

Ultimate or post-peak effective stress friction angles from the laboratory direct shear tests vary from 29° to 33°, with cohesion varying between 50 psf to 300 psf. Plots of the laboratory direct shear test data is provided in Appendix B.

From our evaluation of the shear strength data above, we selected an effective stress shear strength with a friction angle of 30° and cohesion of 100 psf for use in the slope stability analyses described later. The selected shear strength envelope is essentially the lower bound from the 7 direct shear tests performed on the alluvium. We believe this is a reasonably conservative shear strength for use in the slope stability evaluations based on the current geotechnical information.

4.2.3 Compacted Fill

The compacted fill was not encountered in the explorations since the compacted fill zone is located on the canal side of the embankment. In order to evaluate the shear strength of the compacted fill, we remolded soil from the upper 5 feet of the uncompacted embankment soil at two borings (B-4 and B-7).

The bulk sample from Boring B-4 is a clayey sand (SC) with 44 percent fines, and a PI of 15. The bulk sample from Boring B-7 is a sandy lean clay (CL) with 59 percent fines, and a PI of 9. These 2 samples were judged to be relatively representative of the range of fill material encountered in the borings.

4.2.3.1 Compacted Fill Shear Strength

The shear strength of the compacted fill was evaluated by performing laboratory direct shear testing of the two remolded samples described above. These 2 samples were remolded to 95 percent of the maximum density and optimum moisture content based on ASTM D698 (Standard Proctor).

The ultimate or post-peak effective stress shear strength of the clayey sand from Boring B-4 had a friction angle of 30 degrees and a cohesion of 150 psf. The ultimate or post-peak effective stress shear strength of the sandy lean clay from Boring B-7 had a friction angle of 30 degrees and a cohesion of 300 psf. Plots of the laboratory direct shear test data is provided in Appendix B.

We selected an effective stress shear strength with a friction angle of 30° and cohesion of 100 psf for use in the slope stability analyses described later. This shear strength envelope is slightly lower than the lower bound from the two direct shear tests performed on the remolded samples. We believe this is a reasonably conservative shear strength for use in the evaluations based on the current geotechnical information.

4.2.4 Groundwater

Groundwater was not observed in the borings or CPTs performed for the Phase 1 geotechnical investigation. Possible perched ground water was observed in boring B-1 at a depth of approximately 25 feet as the sampler and sample were wet. However, the hole was dry upon completion of soil augering. The moisture content of a sample from boring B-8 at a depth of approximately 30 feet is close to saturation, which may also indicate perched groundwater at this location.

We understand the regional groundwater level is at least 100 feet below the ground surface. The seepage from the canal into the embankment likely travels vertically and horizontally in an unsaturated condition. Some of the seepage may also be lost through evapotranspiration.

Concrete is permeable and there is likely leakage into the embankment from the canal through both the intact concrete and the joints and cracks within the concrete lining. However, the leakage appears to be sufficiently small such that extensive saturated soil layers do not develop within the embankment.

5.0 SEEPAGE ANALYSES

5.1 GENERAL

Seepage analyses were performed on a cross-section with the conditions/configuration observed at the Boring B-2/CPT-2 (Milepost 104.1) location in the Immediate Repair Area (Milepost 104.1 to 107.1). The purpose of the seepage analyses was to assist in developing mitigation options for on-going toe seepage issues which have occurred at several locations within the Immediate Repair Area. However, we understand that implementation of mitigation for seepage control is no longer being considered. A secondary purpose for performing seepage analyses was to better understand flows during toe seepage events for a temporary raised canal level. This information has been used in the slope stability analyses.

We understand that a temporary liner raise in the Immediate Repair Area using HDPE is currently being implemented. The HDPE liner would extend approximately 18 inches above the top of the current concrete liner. This liner raise is being performed to allow an approximate 18-inch raise in the high-water canal level. The resulting high-water canal level would be approximately 6 inches below the current top of canal concrete lining.

5.2 METHODOLOGY

Based on our discussions with FWA, we understand relatively significant seepage has occurred at multiple locations at the land side toe of the embankment within the Immediate Repair Area. FWA has observed toe seepage at mileposts 99.5, 104.9, and 105.63. The seepage problems occur when the canal water level is raised above the joint in the concrete liner between the original liner and embankment raise liner installed in the 1970s. The seepage volume at the toe of the embankment is estimated by FWA to be approximately 1 to 10 gallons per minute (GPM) over a length of approximately 80 feet, parallel to the canal alignment.

The methodology for performing the seepage studies included the following steps:

Perform a steady state seepage analysis with the canal level 2 feet above the concrete liner joint using best estimates of soil permeability from the Phase 1 Geotechnical Investigation and laboratory permeability testing. The concrete liner was modeled as a homogenous layer with a low permeability. A 1-inch thick soil layer within the concrete liner was modeled between the original and 1970s raised liner to represent the joint.

Calibrate the seepage analysis by adjusting the permeabilities to obtain the estimated seepage volumes provided by FWA.

Perform a seepage analysis using the calibrated permeabilities to develop a groundwater level through the embankment using the proposed canal water level for the temporary HDPE liner raise. This groundwater level will then be used in subsequent slope stability analysis.

5.3 SEEPAGE ANALYSIS RESULTS

The seepage analyses were performed using the software program SEEP/W (Geo-Studio, 2018). The initial seepage analysis using our best estimate of permeabilities resulted in seepage volumes at the toe of the embankment of less than 0.5 percent of the seepage volume estimated by FWA. The permeabilities in the seepage model were adjusted



until the calculated seepage volume approximately matched the FWA lower bound estimate of 1 GPM. The permeability of the concrete liner also was significantly increased from what would typically be assumed in order to match the estimated seepage volume. The permeabilities required to match the estimated seepage volume were significantly higher than what the encountered soil characteristics would indicate and what the laboratory permeability test results indicated. The estimated soil permeability based on the soil type and permeability testing is similar to clayey sand or sandy clay, whereas the calibrated permeability adjusted to match the FWA observed seepage volume for both the soil and the concrete liner is approximately that of a silty sand material.

The results of this calibration indicate that there may be relatively significant voids or piping channels (created by internal soil erosion) in the embankment soils that are resulting in large seepage volumes that would be unlikely for a homogenous embankment with the observed clayey material types. The implications of the presence of these potential voids and piping channels are discussed in the slope stability section of this report.

A summary of the resulting seepage volume and permeabilities used in the analyses are presented in the table below. Figures showing the seepage analyses are provided in Appendix D.

Table 5. Seepage Analysis Results

Material	Current High-Water Level Best Estimate Permeability – K_x (ft./sec)	Current High-Water Level Calibrated Permeability – K_x (ft./sec)	Raised High-Water Level Calibrated Permeability – K_x (ft./sec)
Compacted Fill	$4x10^{-7}$	$1x10^{-4}$	$4x10^{-7}$
Un-Compacted Fill	$4x10^{-7}$	$4x10^{-7}$	$4x10^{-7}$
Alluvium	$4x10^{-7}$	$4x10^{-7}$	$4x10^{-7}$
Concrete/HDPE Liner	$1x10^{-8}$	$1x10^{-5}$	$1x10^{-5}/1x10^{-8}$
Seepage Volume* (GPM)	0.004	1.0	1.0

Note:
*Based on a seepage length of 80 feet parallel to the canal axis at the toe of one embankment.

6.0 SLOPE STABILITY ANALYSES

6.1 Loading Conditions and Criteria

Slope stability analyses have been performed at the Immediate Repair Area to evaluate stability of the current embankment with higher canal water levels, and at other areas of the existing canal alignment to evaluate stability of an enlarged canal geometry. Two cross-sections (Mileposts 104.1 and 106.1) have been evaluated in the Immediate Repair Area for the existing geometry and seven cross-sections (Mileposts 97.5, 104.1, 106.1, 107.1, 108.9, 110.3, and 115.6) have been evaluated for the enlarged canal geometry.

Slope stability factor of safety and seismic loading criteria have been provided to us by Reclamation and are presented below.

Table 6. Static Factor of Safety Criteria (From Reclamation)

Loading Condition	Required Factor of Safety
Steady State (Normal Water Level)	1.5
Rapid Drawdown	1.2
End of Construction	1.3
Temporary Conditions during Construction	1.3

Table 7. Seismic Factor of Safety Criteria (From Reclamation)

Loading Condition	Criteria*
Liquefaction Triggering	2,475 Year Return Period
Post Liquefaction Factor of Safety	>1.2
Pseudo-Static Stability	>1.2 (1/2 of 2,475 Year PGA)

Notes:
*All seismic analysis should be performed under normal water level conditions.
*Deformation analysis are not necessary if above criteria is met.

Several of the loading conditions in the tables above are not considered applicable to the existing canal embankment or the proposed enlarged canal embankment. The following sections discuss details of the loading conditions used in our analyses.

6.1.1 Steady-State (Normal Water Level)

As discussed previously, groundwater was not present in any of the explorations performed. There was one wet sample and one sample which had a moisture content close to 100 percent saturation, but in general, there was no groundwater within the embankment. In addition to the existing longitudinal and transverse joints which may not be water tight, concrete is permeable so there is likely leakage into the embankment from the canal. However, the leakage appears to be sufficiently small such that extensive saturated soil layers do not develop within the embankment. Accordingly, the steady-state loading condition we evaluated does not include a groundwater level through the embankment. In our analyses, the water level in the canal is applied as a load (pressure) to the upstream face of the embankment, which acts as a stabilizing force for potential upstream failure surfaces.



We understand the regional groundwater level is at least 100 feet below the ground surface. The seepage from the canal into the embankment likely travels vertically and horizontally in an unsaturated condition. Some of the seepage may also be lost through evapotranspiration.

6.1.2 Rapid Drawdown

The rapid drawdown condition is not considered applicable to the existing canal embankment or proposed enlarged canal embankment since a groundwater level does not appear to be present within the embankment based on our current explorations as discussed above.

There is a groundwater level within the embankment at the locations and for the duration of the toe seepage events observed within the Immediate Repair Area. However, these appear to be relatively isolated events at several specific locations in the Immediate Repair Area and are not considered to be an overall loading condition for the proposed enlarged canal. Accordingly, conventional geotechnical rapid drawdown analyses have not been performed.

Localized rapid drawdown relating to hydrostatic water pressure developing behind the concrete liner is an important loading condition to be considered. This loading condition is being managed by FWA by limiting the rate at which the canal water level can be lowered. However, this is not considered a conventional geotechnical rapid drawdown condition where a groundwater level is present through the embankment. Figure 4 shows the conventional geotechnical rapid drawdown condition versus the localized condition described above.

6.1.3 End of Construction and Temporary Conditions

For the enlarged canal option, the current consensus is that the canal water level would be lowered to the approximate original ground elevation to provide freeboard for removal of uncompacted fill and placement of new compacted fill. The reduced stabilizing force from this lowered canal level is considered to apply the critical End of Construction and Temporary Loading Condition.

In addition to the lowered canal level condition described above, we also evaluated a dry canal condition which we consider to be the most critical condition since the stabilizing water force within the canal is not present. However, this condition is not currently proposed as an element of the planned construction.

6.1.4 Liquefaction Triggering and Post Liquefaction

Since there is not expected to be a groundwater level in the embankment or in the near surface foundation soils, liquefaction triggering and post liquefaction are not considered loading conditions for the proposed enlarged canal.

6.1.5 Seismic Slope Stability

Pseudo-static stability analyses were performed by applying a horizontal seismic coefficient equal to one-half of the 2,475-Year Peak Ground Acceleration (PGA) based on Seismic Site Class D. The 2014 United States Geological Survey (USGS) PGA values based on Seismic Site Class D vary between approximately 0.4g to 0.46g within the canal subsidence area.

Pseudo-static criteria typically include using 1/3 to 1/2 of the PGA as a horizontal seismic coefficient with a factor of safety greater than 1.0 (Marcuson, Hynes-Griffin, USACE). The criteria provided by Reclamation recommends using 1/2 of the PGA with a factor of safety greater than 1.2, which we consider to be very conservative.

One of the cross sections we evaluated had a pseudo-static factor of safety of approximately 1.0. For this cross-section, we evaluated seismic deformation as recommended in the criteria provided by Reclamation. We used a simplified seismic deformation model developed by Bray and Travasarou (2007) which is a commonly used method in California.

The 2,475-year PGA and horizontal seismic coefficients used in the pseudo-static analyses are provided in the table below.

Table 8. PGA and Horizontal Seismic Coefficient

Milepost (Boring/CPT)	2,475-Year PGA (g)	Horizontal Seismic Coefficient (g)
97.5 (B-1/CPT-1)	0.40	0.20
104.1 (B-2/CPT-2)	0.42	0.21
106.1 (B-3/CPT-3)	0.43	0.22
107.1 (B-4/CPT-4)	0.44	0.22
108.9 (B-5)	0.44	0.22
110.3 (B-7/CPT-5)	0.46	0.23

Key:
CPT = Cone Penetration Testing
g =
PGA = Peak Ground Acceleration

6.2 METHODOLOGY

Stantec conducted static and seismic slope stability analyses to evaluate the stability of the existing embankment in the Immediate Repair Area, and the proposed embankments for the enlarged canal.

The analyses were completed to assess the factor of safety against instability using a limit equilibrium slope stability method (Spencer method of slices) incorporated into the software program Slope/W (Geo-Slope, 2018).

The drained shear strength envelope is generally more conservative than the undrained shear strengths from the CPT data for the confining stress range of the canal slopes. In addition, the embankment soils are unsaturated and saturation levels are relatively low. Therefore, drained strengths are considered to be more appropriate for these stability evaluations. Accordingly, drained shear strengths have been used in the static and seismic slope stability analyses. The parameters used in the slope stability analyses are presented in the table below.

Table 9. Slope Stability Parameters

Material	Unit Weight (pcf)	Drained Friction Angle (Degrees)	Drained Cohesion (psf)
Uncompacted Fill	125	29	50
Compacted Fill	125	30	100
Alluvium	125	30	100
Concrete Lining	150	0	100

Key:
pcf = pounds per cubic feet

6.3 IMMEDIATE REPAIR AREA

Two cross-sections were evaluated in the Immediate Repair Area; Milepost 104.1 and 106.1. The three loading conditions evaluated are as follows:

Steady-state downstream stability with a canal water level 2 feet below the top of the proposed HDPE liner, and groundwater level through the embankment with toe seepage based on the seepage analysis.

Upstream stability with a dry canal. No groundwater level in the embankment.

Upstream stability with a lowered canal water level at approximate original ground elevation. No groundwater level in the embankment.

The factors of safety for these three loading conditions are provided in the table below and the slope stability figures are presented in Appendix E.

Table 10. Immediate Repair Area – Factors of Safety

Loading Condition	Milepost 104.1	Milepost 106.1
Steady State Downstream	1.6	1.5
Dry Canal Upstream	1.2	1.2
Lowered Canal Upstream	1.4	1.6

As discussed previously, the seepage analyses performed in the area where toe seepage was observed by FWA indicates there may be voids and piping channels in the embankment at these locations. While there has not been any reported slope instability at these toe seepage areas, piping channels and voids in the embankment can potentially cause slope instability. Some options to mitigate the potential instability include construction of a seepage barrier such as a slurry wall, or by removing the uncompacted material and increasing the width of the embankment such as what is proposed for the enlarged canal. We recommend that Stantec geotechnical personnel be contacted when future toe seepage areas are observed so that we can evaluate implications relating to embankment stability and develop remedial measures if necessary.

The static factors of safety calculated for the existing canal in the Immediate Repair Area generally meet Reclamation criteria. The dry canal condition may potentially be considered a temporary condition. The calculated factor of safety for this dry canal is lower than Reclamation criteria (1.2 calculated versus 1.3 Reclamation criteria). These analyses indicate that the existing canal in the Immediate Repair Area is considered grossly stable for static conditions.

6.4 PROPOSED ENLARGED CANAL

The proposed enlarged canal includes widening of the canal and raising the height of the embankment. With this option, the existing lower 1.25H:1V portion of the concrete lined canal slope would remain, a flat concrete lined section would be constructed above the lower slope, and a new raised 1.5H:1V concrete lined section would be constructed above the flat section. The flat section of the canal slope would be located approximately 5 feet below the current top of the concrete lining, although this location will likely vary. The slope stability cross-section locations are shown on Figure 1. The magnitude of the widening for this option would vary by location but is typically on the order of 30 to 50 feet on each side of the canal at the geotechnical exploration locations that have been evaluated. Similarly, the height of the embankment raise for this option would vary by location but is typically on the order of 6 to

10 feet at the geotechnical exploration locations that were evaluated. The land-side slopes of the canal would be inclined at 2H:1V. A typical cross-section of the enlarged canal cross-section is shown in the sketch below.

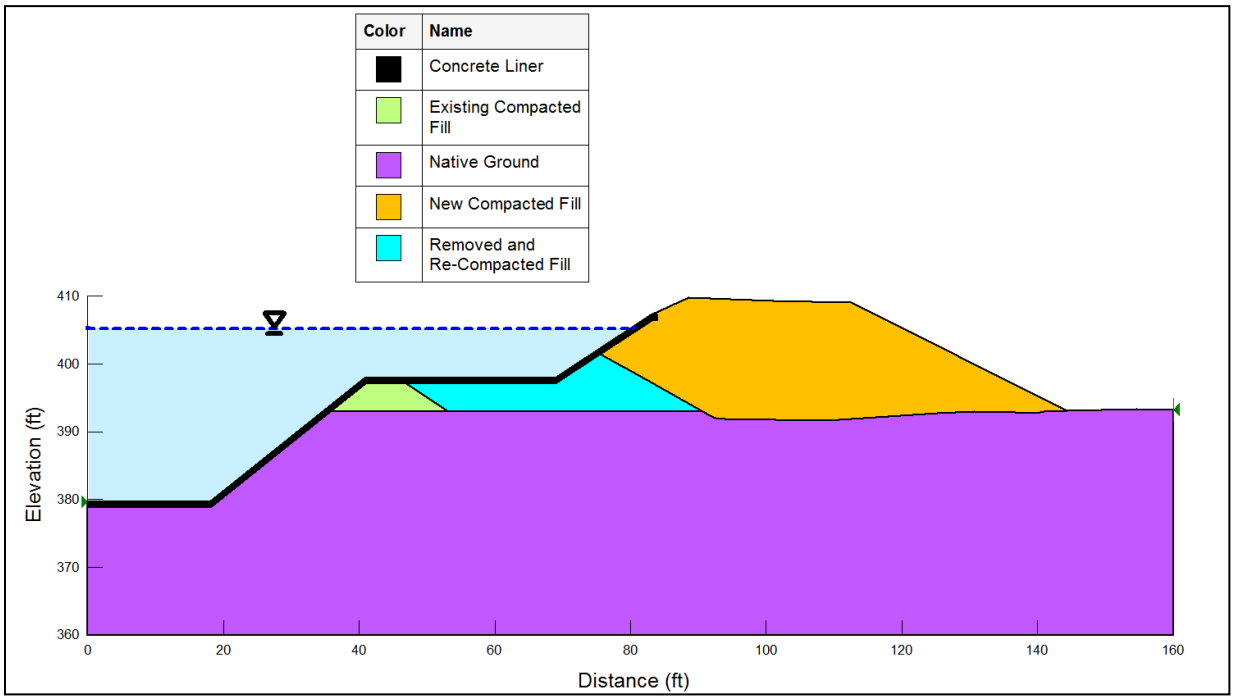


Figure 2. Typical Enlarged Canal Embankment Section

With regard to construction of the enlarged canal, all of the uncompacted fill in the existing embankment would be removed and recompacted. Compaction would typically be to at least 95 percent of the maximum dry density based on ASTM 698 (Standard Proctor). The compacted fill portion of the existing embankment would remain in place. These embankment zones are shown in the sketch above. The uncompacted portion of the existing embankment is shown in a different color from the other zones to provide an understanding of the portion of the existing embankment that will need to be removed and recompacted for this option.

Our investigation indicated that there are typically soft and loose soil zones at the contact between the uncompacted fill and alluvium. The soft and loose soil zones appear to be several feet thick and they should be removed as part of the removal of uncompacted fill as described above. It is assumed that the adjacent existing compacted fill zone consists of well compacted material. The competency of the existing compacted fill should be evaluated by the geotechnical engineer during the removal of the uncompacted fill material to determine if the existing compacted fill is suitable to be left in place. Additional earthwork recommendations will be provided in subsequent reports. These will include recommendations relating to excavation, benching, compaction and moisture, material types, testing and observation, and other related earthwork recommendations.

6.4.1 Slope Stability Analysis

The loading conditions evaluated and the corresponding factor of safety from the slope stability analyses are presented in the table below. The slope stability cross sections are presented in Appendix B.

Table 11. Enlarged Canal – Factors of Safety

Loading Condition	Downstream Normal	Downstream Seismic	Upstream Dry	Upstream Low Water	Upstream Normal	Upstream Seismic
Reclamation Min. Criteria	**1.5**	**>1.2**	**1.3**	**1.3**	**1.5**	**>1.2**
Milepost 97.5 (B-1/CPT-1)	1.8	1.2/1.3*	1.9	2.7	3.2	1.9
Milepost 104.1 (B-2/CPT-2)	1.9	1.2/1.3*	1.5	2.0	3.2	1.9
Milepost 106.1 (B-3/CPT-3)	2.0	1.3	1.4	2.8	3.2	1.8
Milepost 107.1 (B-4/CPT-4)	1.5	1.0/1.1*	1.4	2.2	3.3	1.9
Milepost 108.9 (B-5)	2.5	1.4	1.7	3.1	3.2	1.8
Milepost 110.3 (B-8/CPT-6)	2.2	1.4	2.1	2.2	3.5	1.9

Note:
* The 2nd factor of safety for the Downstream Seismic loading condition pertains to a slip surface that is forced to extend laterally at least to the canal side embankment crest.

As shown in the table above, all the static loading conditions meet or exceed the Reclamation criteria. The Downstream Seismic loading at Mileposts 97.5, 104.1, and 107.1 do not meet criteria from Reclamation. However, at Mileposts 97.5 and 104.1, the factors of safety do meet criteria when the slip surfaces are forced to extend laterally to at least the canal side of the embankment crest. As noted previously, Reclamation's pseudo-static factor of safety of greater than 1.2 is considered very conservative.

The reason the pseudo-static factor of safety at Milepost 107.1 is lower than the other cross sections is due to an approximate 20-foot deep excavation on the west side of the canal over an approximate 700-foot length at this location. This excavation results in an approximate 40-foot high embankment slope at this location.

Due to the low pseudo-static factor of safety at Milepost 107.1, we performed a simplified seismic deformation analysis at this location as described in the following section.

6.4.2 Seismic Deformation Analysis

We evaluated seismic deformation for the Milepost 107.1 cross section using the simplified seismic deformation model developed by Bray and Travasarou (2007), which is a commonly used method in California.

The Bray and Travasarou procedure estimates seismically induced deformations based on the earthquake demand including magnitude and spectral acceleration, site geometry and dynamic properties including slope height and shear wave velocity, and dynamic slope capacity characterized by the yield acceleration. The earthquake characteristics were obtained from the 2014 USGS deaggregation using a 2,475-year return period with a Seismic Site Class D soil. The parameters used in the analyses are presented in the table below.

Table 12. Seismic Deformation Parameters

Input Parameter	Value
Yield Coefficient (k_y)	0.205
Initial Fundamental Period (Ts)	0.13 seconds
Degraded Fundamental Period (1.5Ts)	0.20 seconds
Moment Magnitude (Mw)	5.1
Spectral Acceleration at Degraded Period (Sa@1.5Ts)	1.05g

The calculated median and plus one standard deviation seismic deformation using the parameters above is 4 inches and 8 inches, respectively. The results are presented in Appendix C. At the time of this report, Reclamation has not provided criteria for seismic deformation. However, the calculated values are considered to be indicators that seismic deformations will be relatively small, and that the embankment is likely to perform adequately if subjected to the design seismic event. Similarly, the other cross sections at Mileposts 97.5 and 104.1 will have lower estimated seismic deformations than those calculated above. Accordingly, these cross-sections are also likely to perform adequately if subjected to the design seismic event.

6.5 CONCLUSIONS

The slope stability analyses performed for the proposed enlarged canal indicate that the modified canal embankments will meet factor of safety criteria provided by Reclamation. Some of the assumptions and qualifications associated with this conclusion and with the evaluations performed are provided below.

The evaluations in this report are based on geotechnical information obtained from The Phase 1 geotechnical investigation performed on the O&M Road. The Phase 1 geotechnical investigation will be supplemented by a Phase 2 investigation that will focus on explorations at the toe of the existing embankments and at other locations where canal modifications are proposed. Accordingly, the results and recommendations provided in this report should be considered preliminary and subject to revision based on the findings from the Phase 2 investigation. Scheduling of the Phase 2 investigation is currently awaiting environmental approval.

The scope of the current investigation and evaluations is based on a 30 percent design level deliverable. Additional investigations and evaluations beyond the Phase 1 and Phase 2 efforts will need to be performed to support the project final design.

The evaluations assume that all of the uncompacted fill in the existing embankment will be removed and replaced as compacted fill. Additional earthwork recommendations will be provided in subsequent reports. These will include recommendations relating to excavation, benching, compaction and moisture, material types, testing and observation, and other related earthwork recommendations.

The shear strength of the compacted fill used in the analyses was based on limited laboratory testing. Relatively large volumes of imported fill will be needed to construct the enlarged canal. Shear strength testing of the imported fill will need to be performed to ensure minimum shear strengths equal to or greater than those used in the analyses are obtained.As discussed previously, the seepage analyses performed in the area where toe seepage was observed by FWA indicates there may be voids and piping channels in the embankment at these locations. While there has not been any reported slope instability at these toe seepage areas, piping channels and voids in the embankment can potentially cause slope instability. Some options to mitigate the potential instability include construction of a seepage barrier such as a slurry wall, or by removing the uncompacted material and increasing the width of the embankment such as what is proposed for the enlarged canal. We recommend that Stantec geotechnical personnel be contacted when future toe seepage areas are observed so that we can evaluate implications relating to embankment stability and develop remedial measures if necessary.

The slope stability analyses performed indicate that the existing canal in the Immediate Repair Area is considered grossly stable for static conditions.

The slope stability analyses performed indicate that the proposed enlarged canal will be grossly stable in both static and seismic conditions.

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7.0 CLOSURE

This report was prepared for the exclusive use of FWA and their agents for specific application to the FKC Subsidence Correction Project. Any use of this report or the material contained herein by third parties, or for other than the intended purpose, should first be approved in writing by Stantec.

We trust that this report meets your present requirements. If you have any questions or require additional information, please do not hesitate to contact our office.

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8.0 REFERENCES

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APPENDIX A

Statement of General Conditions

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APPENDIX B

Summary of Blow-Count-Friction Angle Correlation and Laboratory Testing Results

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APPENDIX C

Cone Penetration Testing (CPT) Interpretation

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APPENDIX D

Seepage Analysis Cross-Sections

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APPENDIX E

Slope Stability Analyses and Cross Sections

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APPENDIX F

Canal Photographs

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APPENDIX A

Statement of General Conditions

Stantec

USE OF THIS REPORT: This report has been prepared for the sole benefit of the Client or its agent and may not be used by any third party without the express written consent of Stantec and the Client. Any use which a third party makes of this report is the responsibility of such third party.

BASIS OF THE REPORT: The information, opinions, and/or recommendations made in this report are in accordance with Stantec's present understanding of the site specific project as described by the Client. The applicability of these is restricted to the site conditions encountered at the time of the investigation or study. If the proposed site specific project differs or is modified from what is described in this report or if the site conditions are altered, this report is no longer valid unless Stantec is requested by the Client to review and revise the report to reflect the differing or modified project specifics and/or the altered site conditions.

STANDARD OF CARE: Preparation of this report, and all associated work, was carried out in accordance with the normally accepted standard of care in the state or province of execution for the specific professional service provided to the Client. No other warranty is made.

INTERPRETATION OF SITE CONDITIONS: Soil, rock, or other material descriptions, and statements regarding their condition, made in this report are based on site conditions encountered by Stantec at the time of the work and at the specific testing and/or sampling locations. Classifications and statements of condition have been made in accordance with normally accepted practices which are judgmental in nature; no specific description should be considered exact, but rather reflective of the anticipated material behavior. Extrapolation of in situ conditions can only be made to some limited extent beyond the sampling or test points. The extent depends on variability of the soil, rock and groundwater conditions as influenced by geological processes, construction activity, and site use.

VARYING OR UNEXPECTED CONDITIONS: Should any site or subsurface conditions be encountered that are different from those described in this report or encountered at the test locations, Stantec must be notified immediately to assess if the varying or unexpected conditions are substantial and if reassessments of the report conclusions or recommendations are required. Stantec will not be responsible to any party for damages incurred as a result of failing to notify Stantec that differing site or sub-surface conditions are present upon becoming aware of such conditions.

PLANNING, DESIGN, OR CONSTRUCTION: Development or design plans and specifications should be reviewed by Stantec, sufficiently ahead of initiating the next project stage (property acquisition, tender, construction, etc), to confirm that this report completely addresses the elaborated project specifics and that the contents of this report have been properly interpreted. Specialty quality assurance services (field observations and testing) during construction are a necessary part of the evaluation of sub-subsurface conditions and site preparation works. Site work relating to the recommendations included in this report should only be carried out in the presence of a qualified geotechnical engineer; Stantec cannot be responsible for site work carried out without being present.

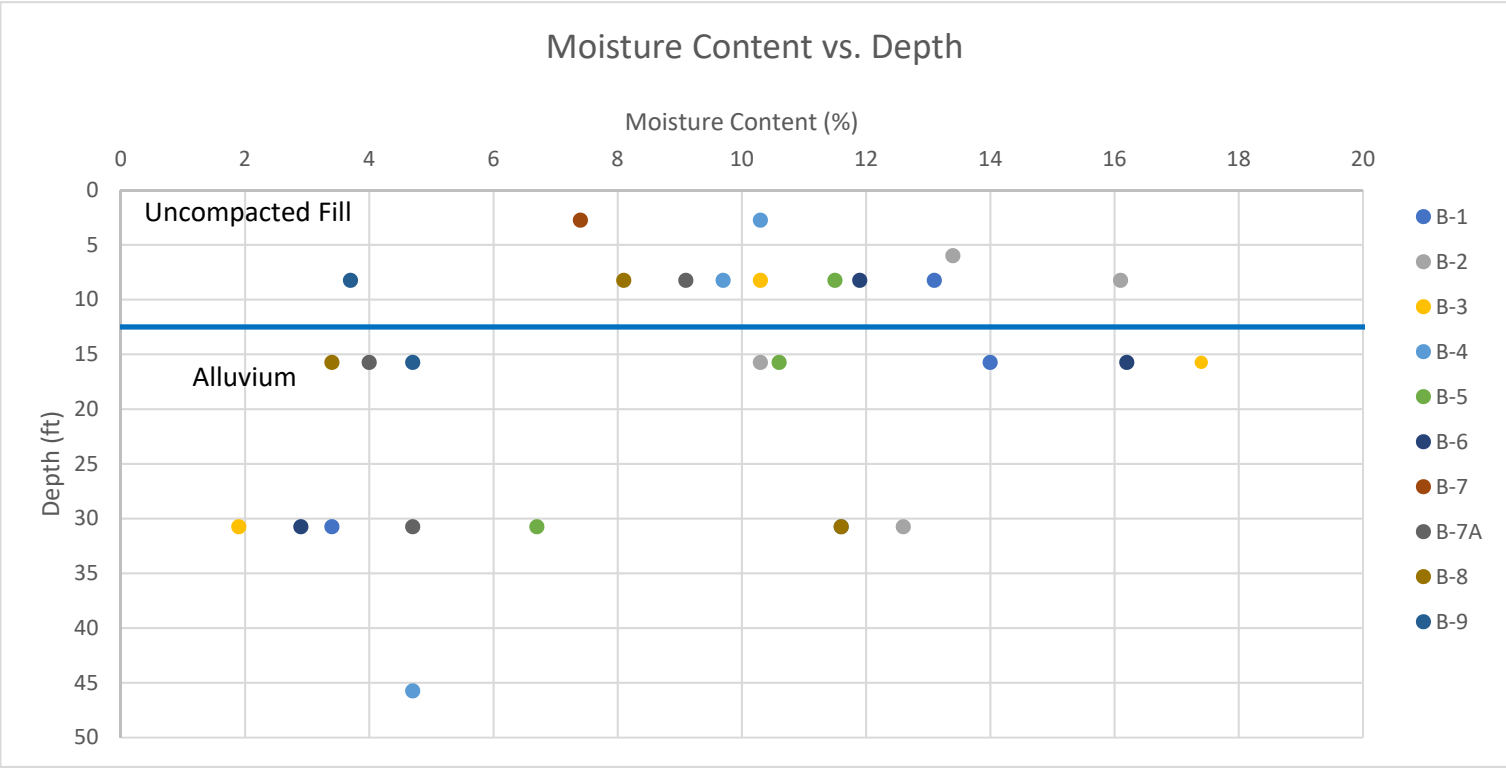
APPENDIX B

Summary of Blow-Count-Friction Angle Correlation and Laboratory Testing Results

Stantec

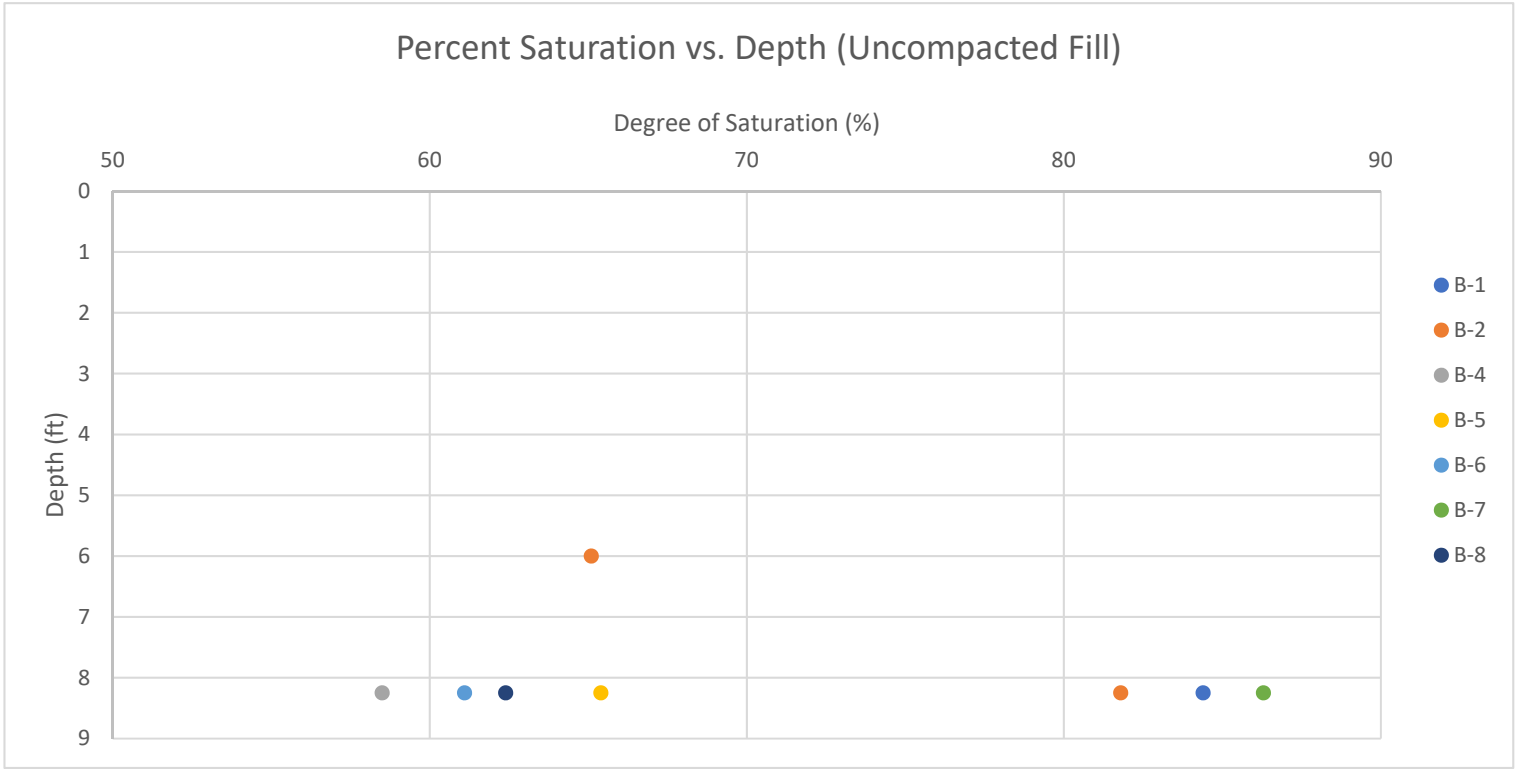
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Project Name	Friant Kern Canal capacity correction Project
Project Location	Tulare County, CA
Figure	B1

Figure B1: Moisture Content vs. Depth



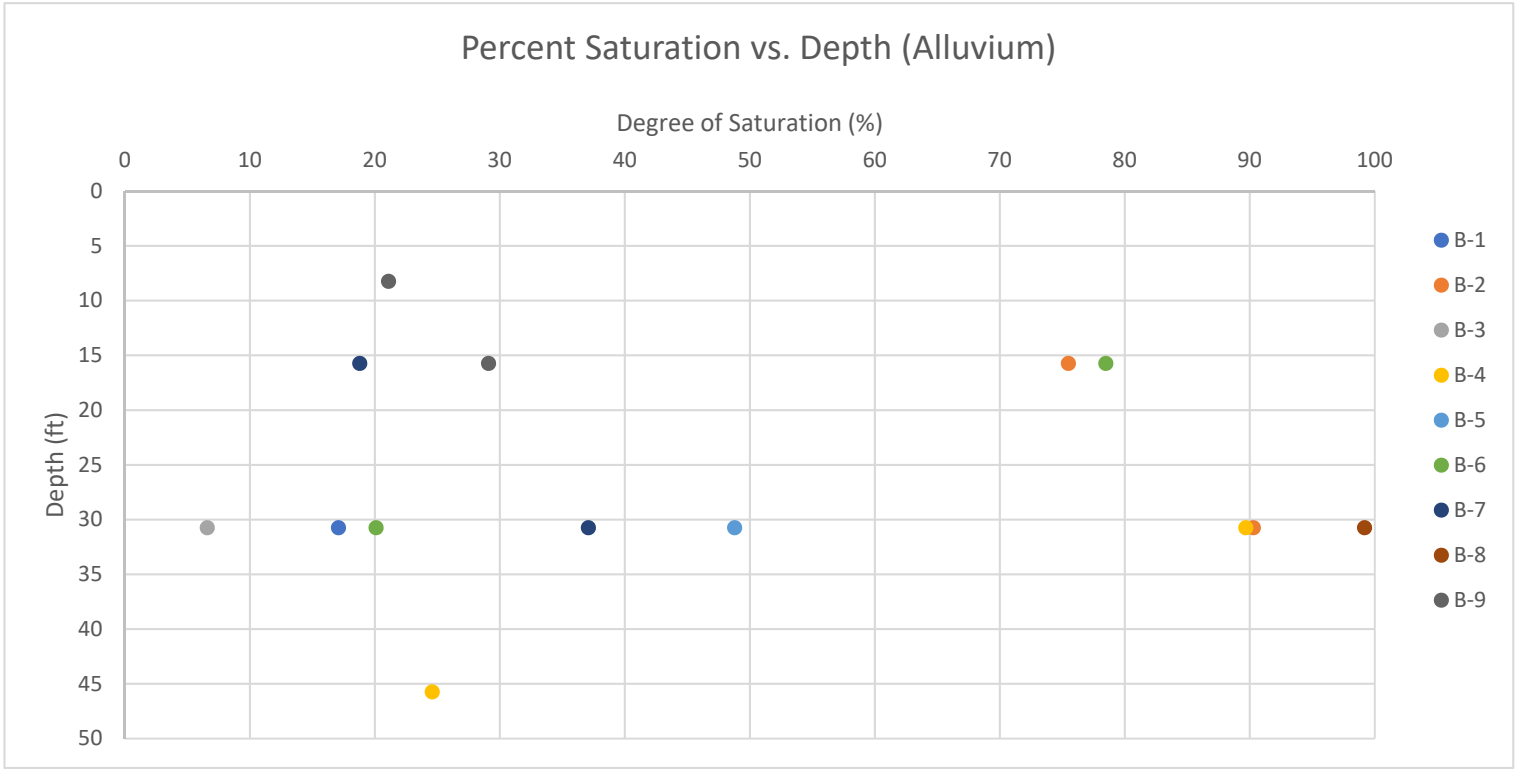
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Project Name	Friant Kern Canal capacity correction Project
Project Location	Tulare County, CA
Figure	B2

Figure B2: Percent Saturation vs. Depth - Uncompacted Fill



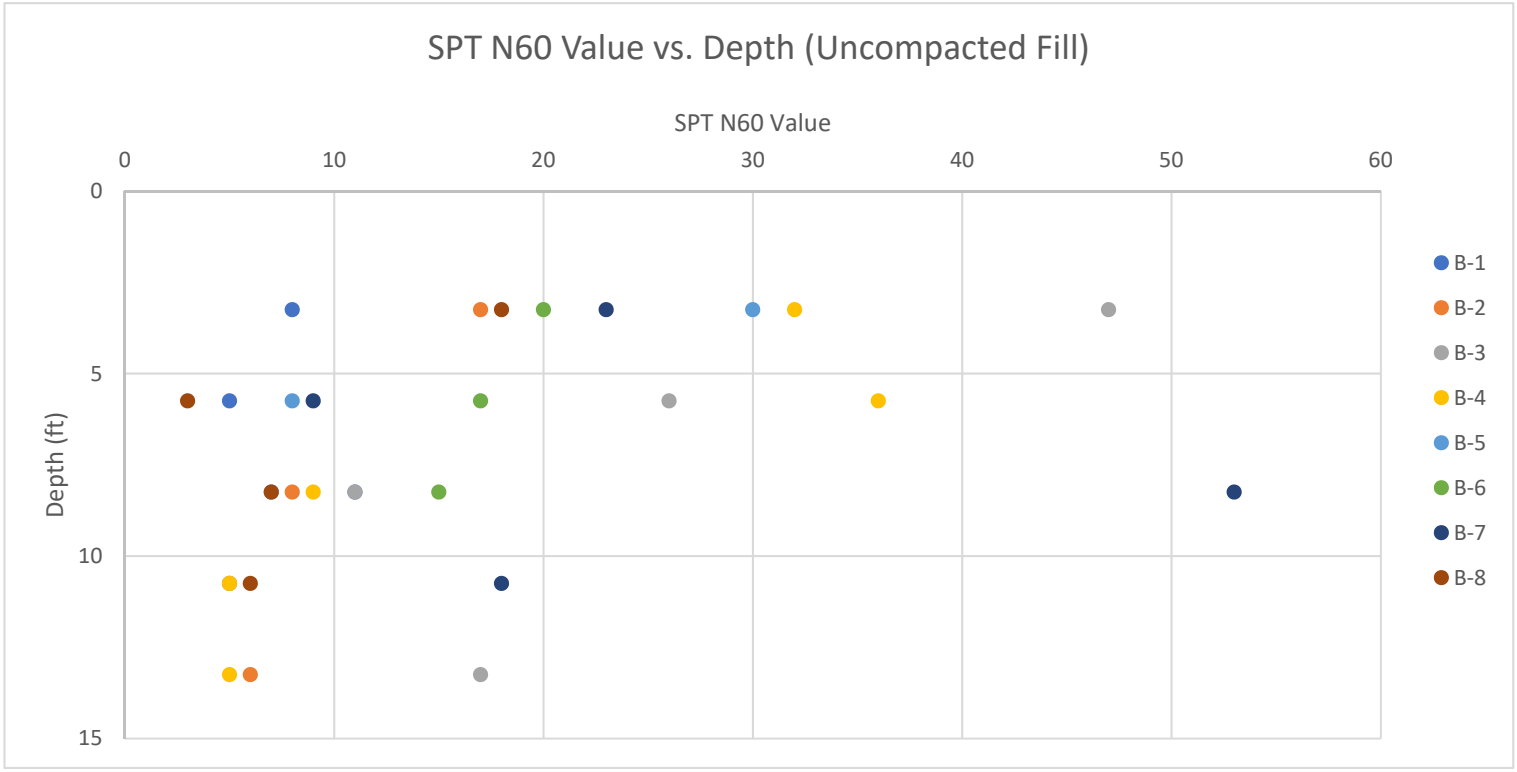
Project Number	184031016
Project Name	Friant Kern Canal Capacity Correction Project
Project Location	Tulare County, CA
Figure	B3

Figure B3: Percent Saturation vs. Depth - Alluvium



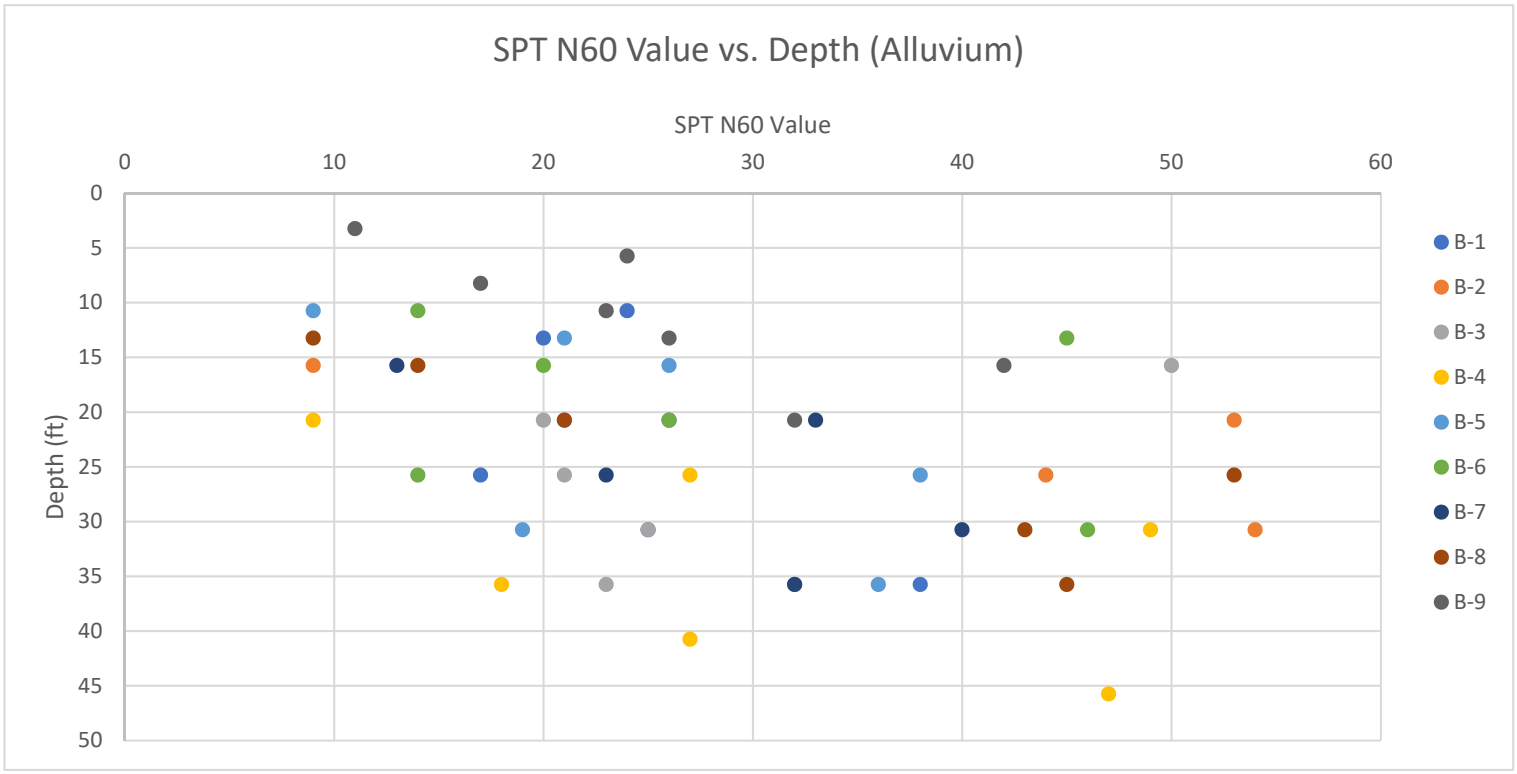
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Project Name	Friant Kern Canal Capacity Correction Project
Project Location	Tulare County, CA
Figure	B4

Figure B4: SPT N60 Value vs. Depth - Uncompacted Fill



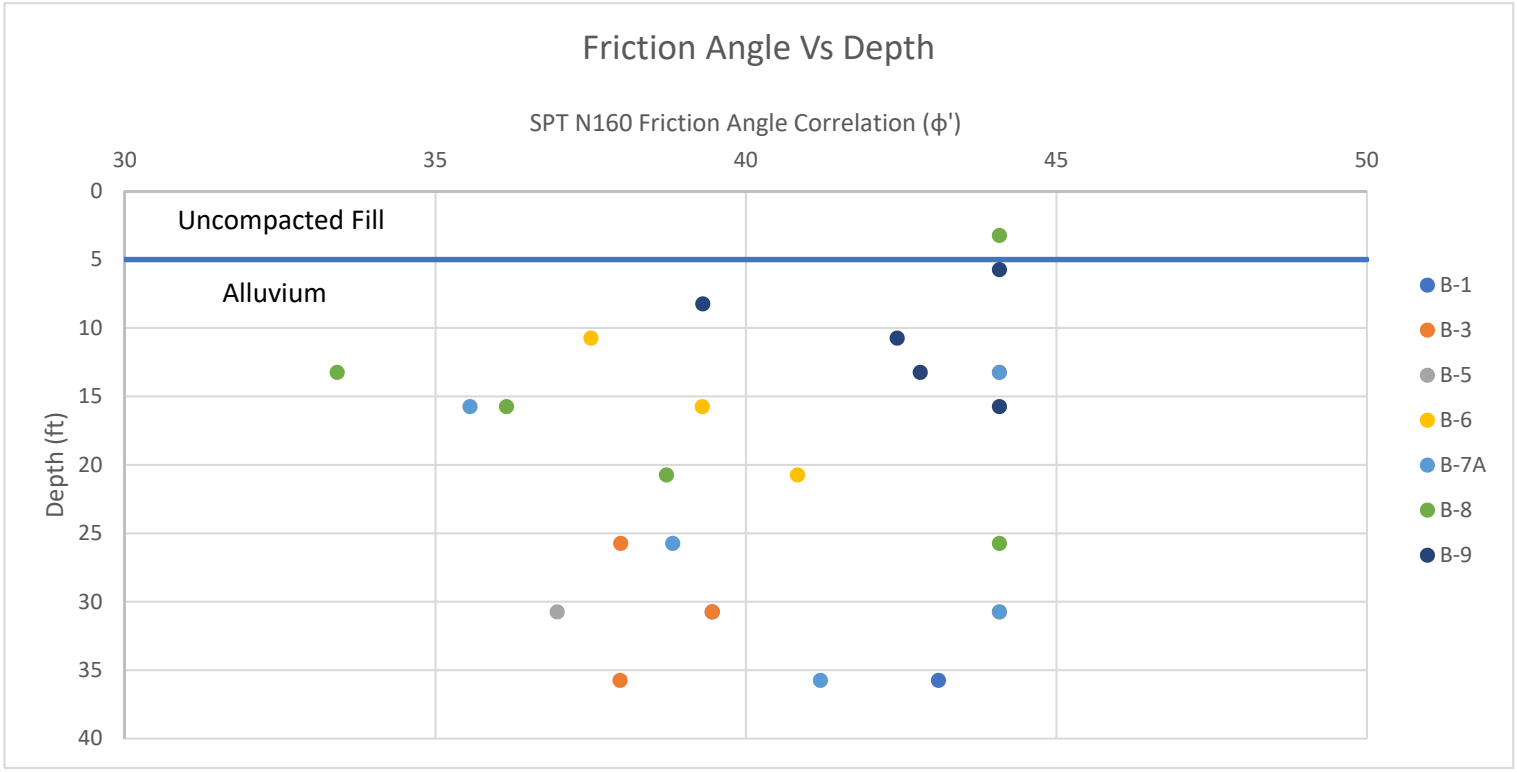
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Project Name	Friant Kern Canal Capacity Correction Project
Project Location	Tulare County, CA
Figure	B5

Figure B5: SPT N60 Value vs. Depth - Alluvium



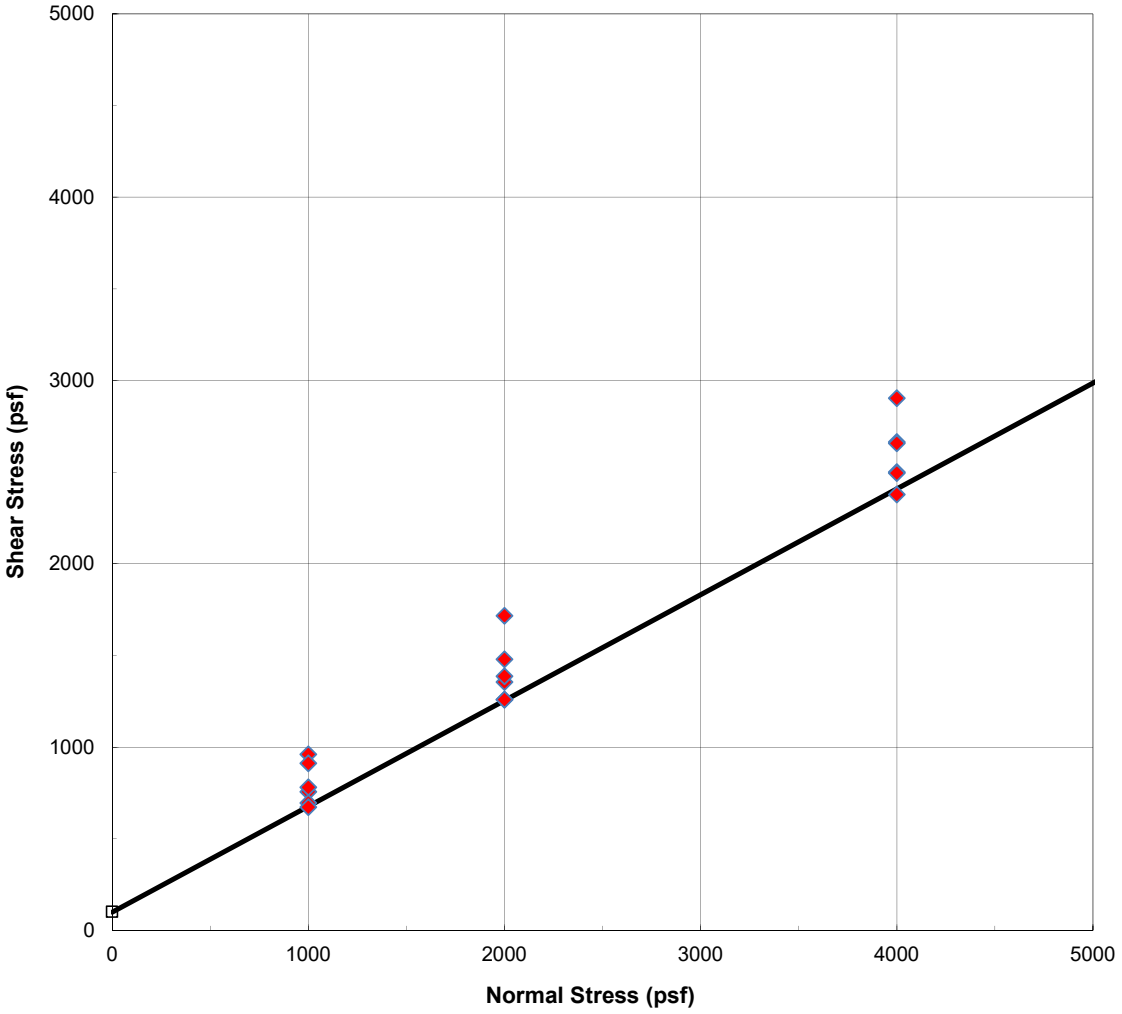
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Project Name	Friant Kern Canal Capacity Correction Project
Project Location	Tulare County, CA
Figure	B6

Figure B6: Friction Angle vs. Depth



Project Number	184031016
Project Name	Friant Kern Canal Capacity Correction Project
Project Location	Tulare County, CA
Figure	B7

Figure B7: Drained Shear Strength - Alluvium



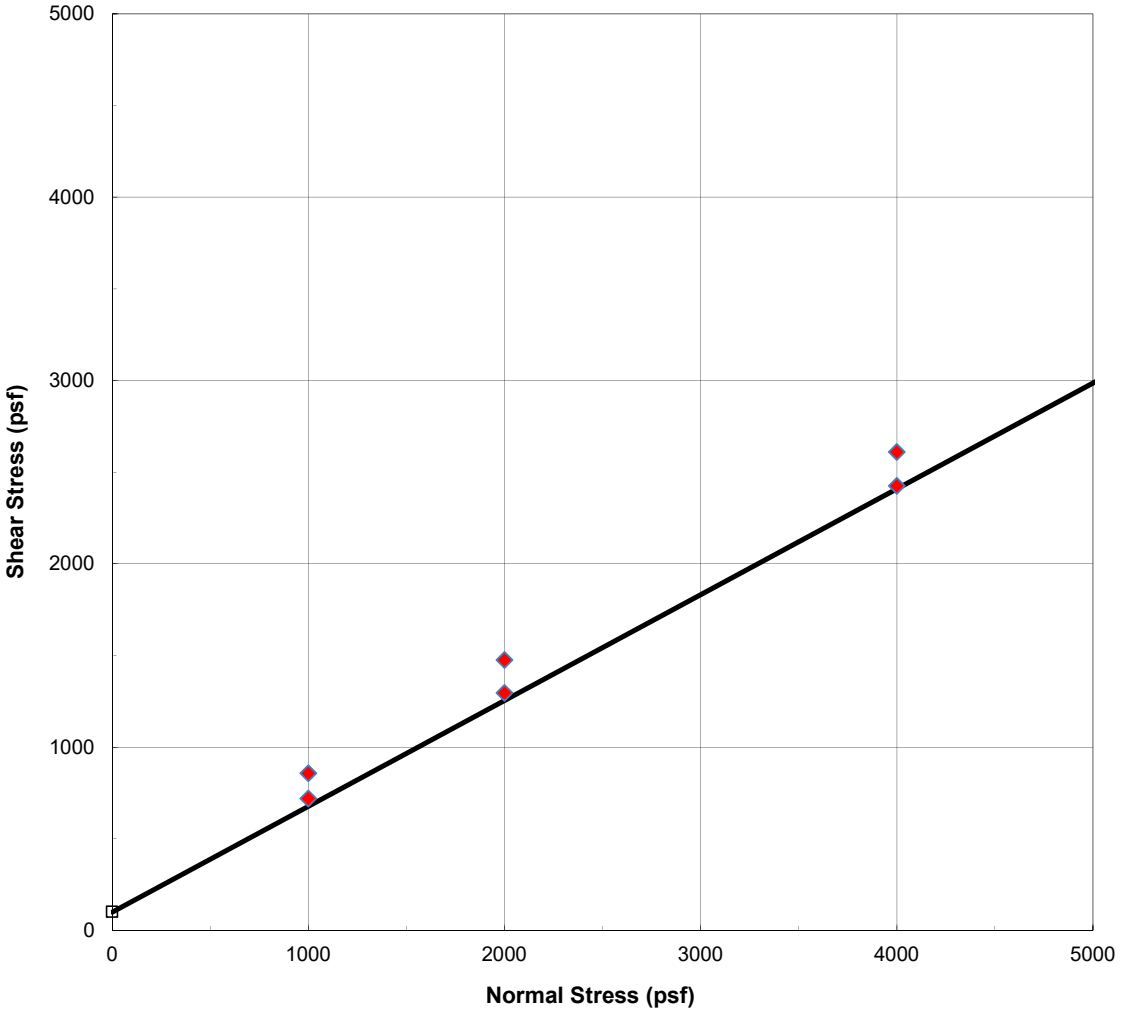
Ultimate Direct Shear Strength Data Point

Strength Envelope Used in Analysis

Drained Shear Strength Parameters Used in Analysis for Alluvium		
Parameter	Value	
Effective Phi Angle, ϕ'	**30**	**Degrees**
Effective Cohesion, c'	**100**	**psf**

Project Number	184031016
Project Name	Friant Kern Canal Capacity Correction Project
Project Location	Tulare County, CA
Figure	B8

Figure B8: Drained Shear Strength - Compacted Fill



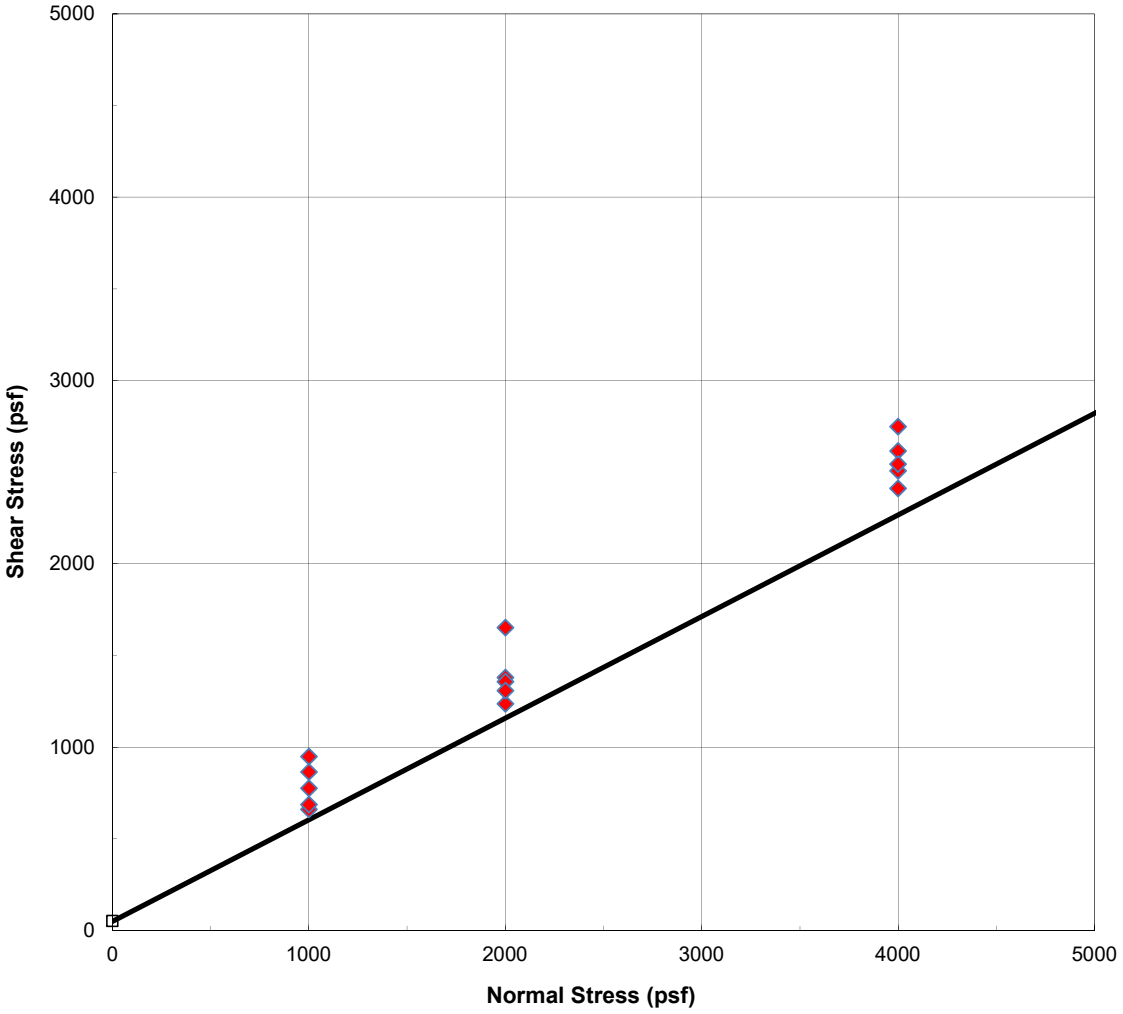
Ultimate Direct Shear Strength Data Point

Strength Envelope Used in Analysis

Drained Shear Strength Parameters Used in Analysis for Compacted Fill		
Parameter	Value	Units
Effective Phi Angle, ϕ'	**30**	**Degrees**
Effective Cohesion, c'	**100**	**psf**

Project Number	184031016
Project Name	Friant Kern Canal Capacity Correction Project
Project Location	Tulare County, CA
Figure	B9

Figure B9: Drained Shear Strength - Uncompacted Fill



Ultimate Direct Shear Strength Data Point

Strength Envelope Used in Analysis

Drained Shear Strength Parameters Used in Analysis for Uncompacted Fill		
Parameter	Value	Units
Effective Phi Angle, ϕ'	**29**	**Degrees**
Effective Cohesion, c'	**50**	**psf**

APPENDIX C

Cone Penetration Testing (CPT) Interpretation

Stantec

CPT: CPT-01

Total depth: 38.06 ft, Date: 9/25/2018

Surface Elevation: 409.70 ft

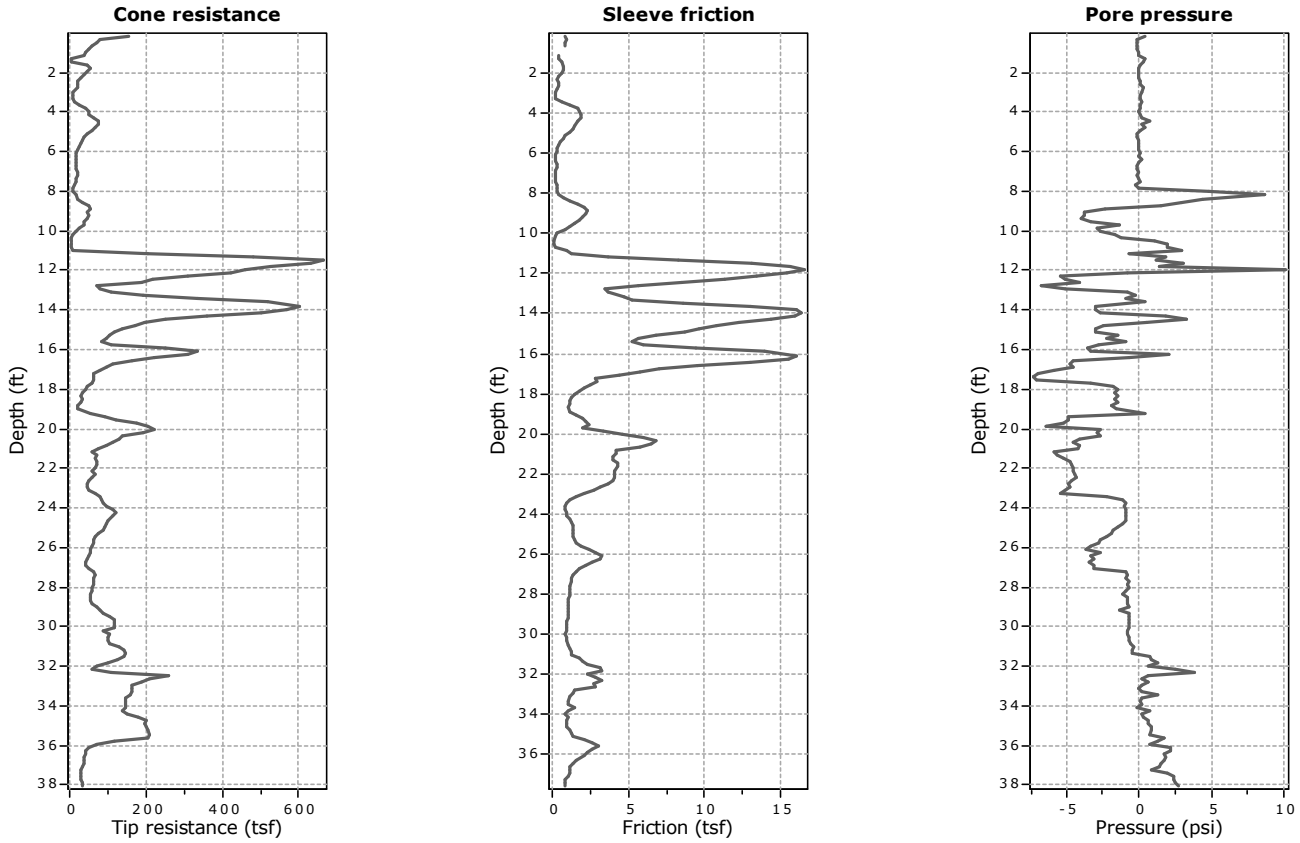
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

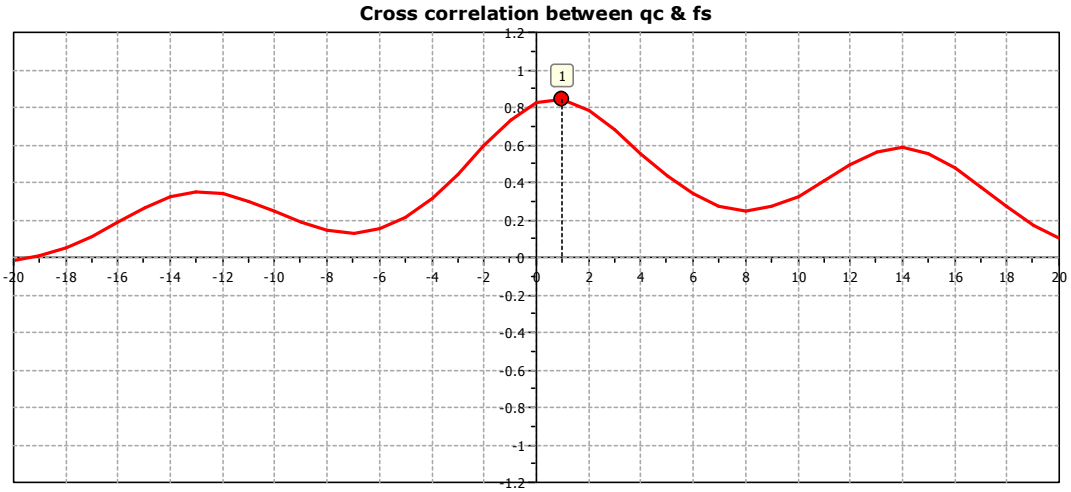
Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



Stantec

CPT: CPT-01

Total depth: 38.06 ft, Date: 9/25/2018

Surface Elevation: 409.70 ft

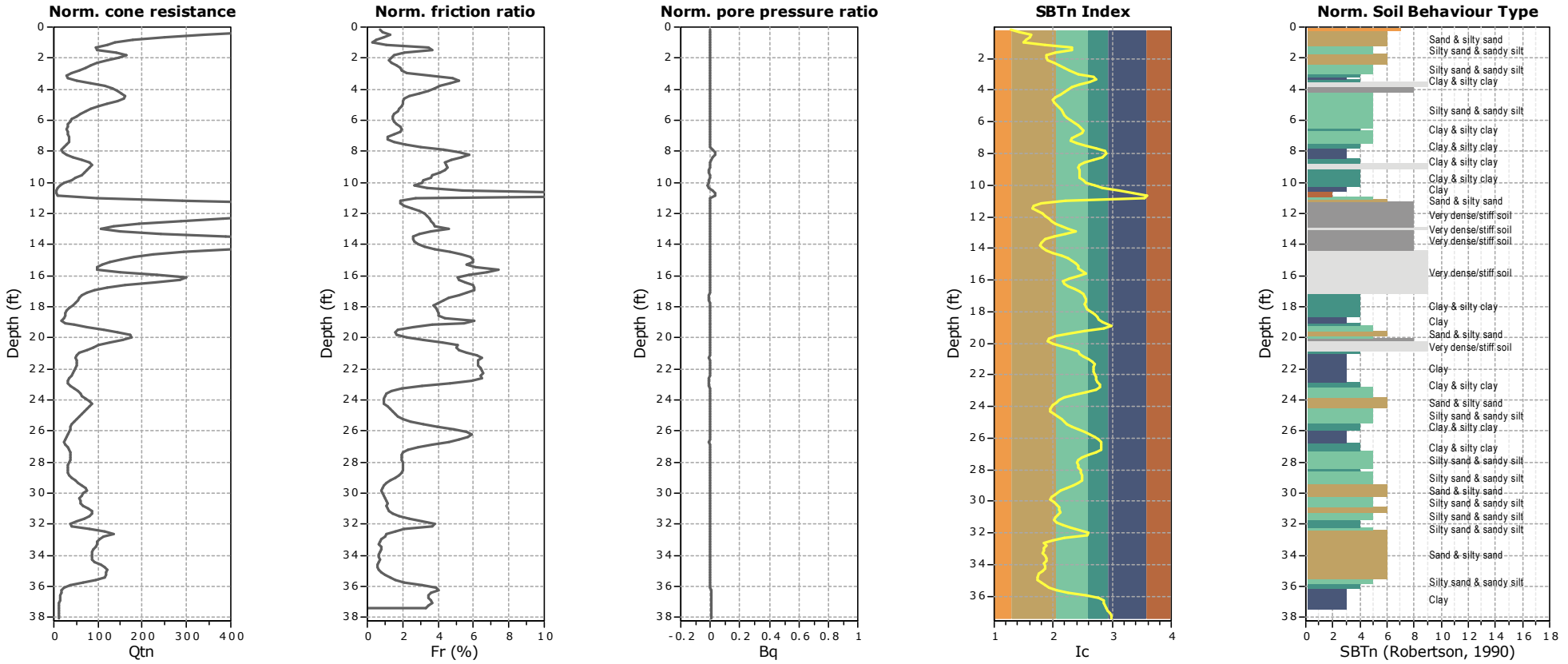
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

CPT: CPT-01

Total depth: 38.06 ft, Date: 9/25/2018

Surface Elevation: 409.70 ft

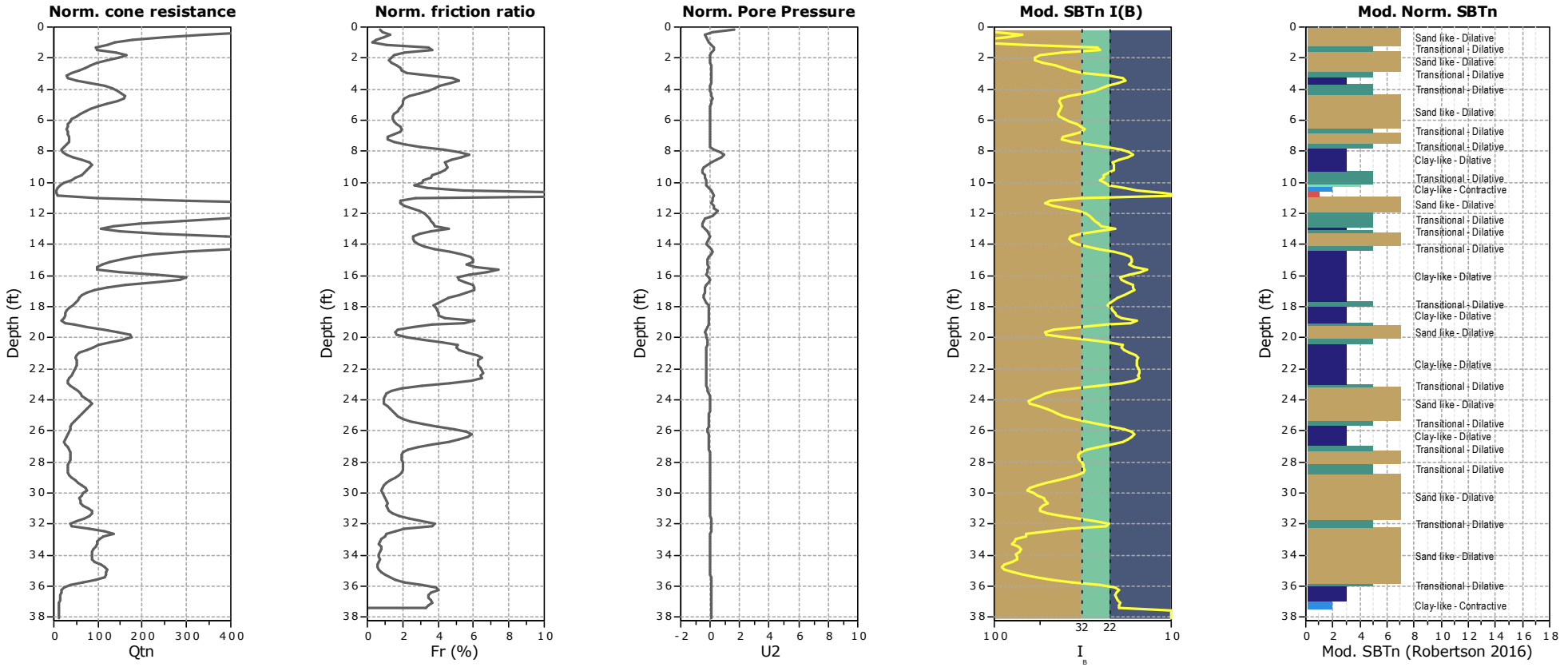
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Mod. SBTn legend

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

CPT: CPT-01

Total depth: 38.06 ft, Date: 9/25/2018

Surface Elevation: 409.70 ft

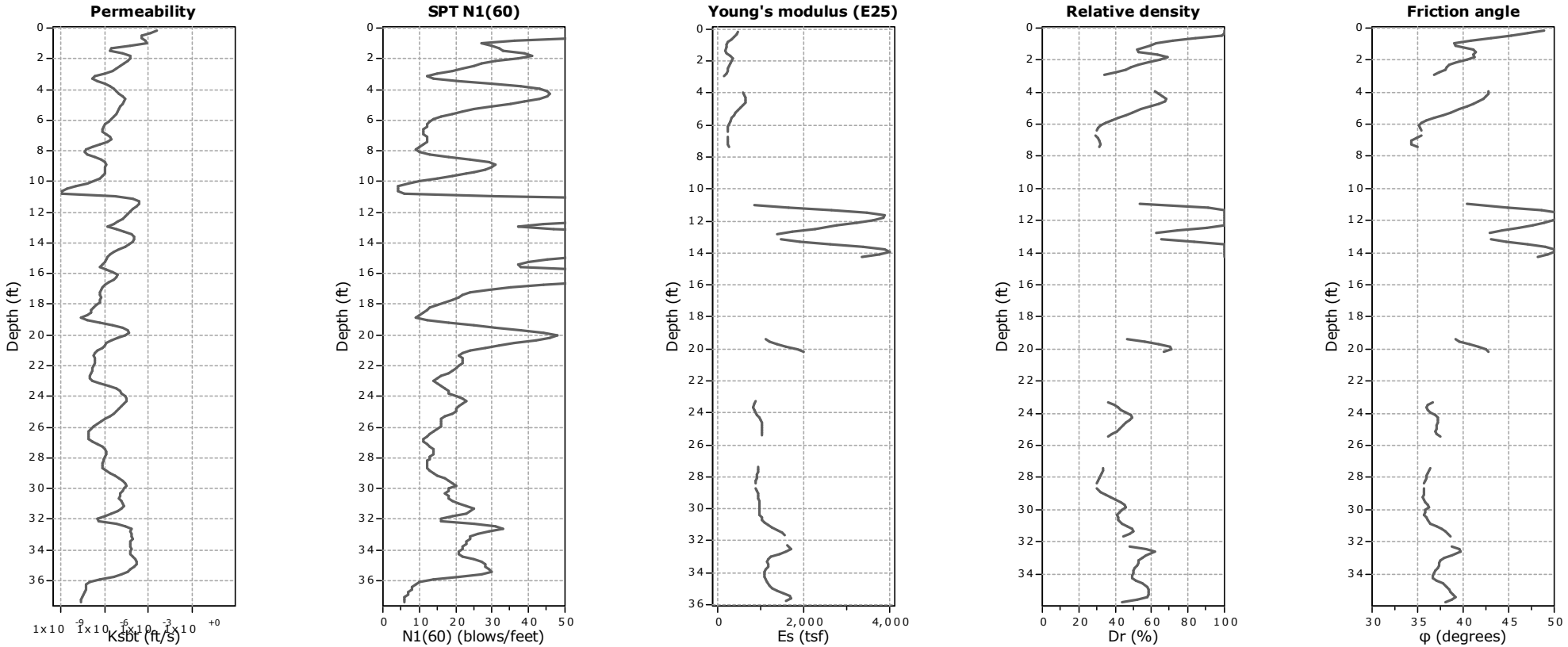
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Permeability: Based on SBT_n

SPT N_{60}: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

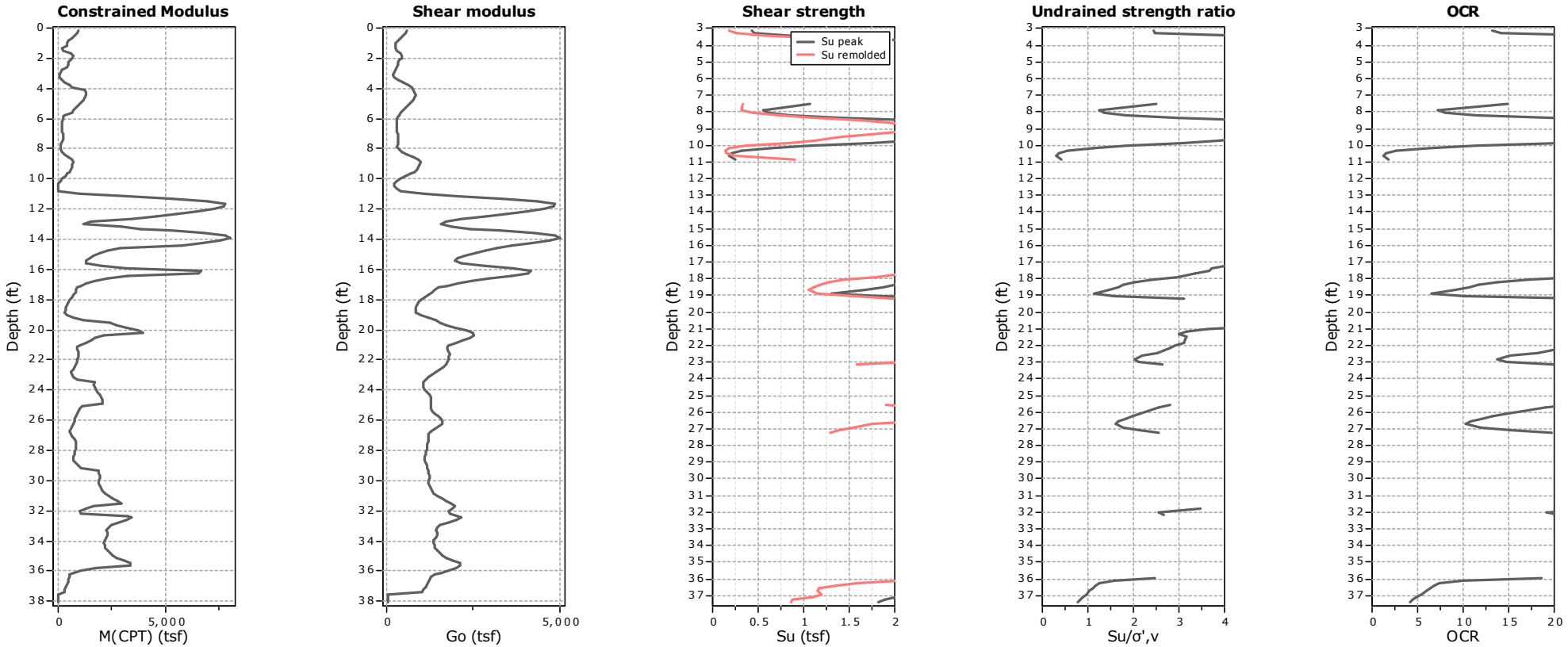
Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

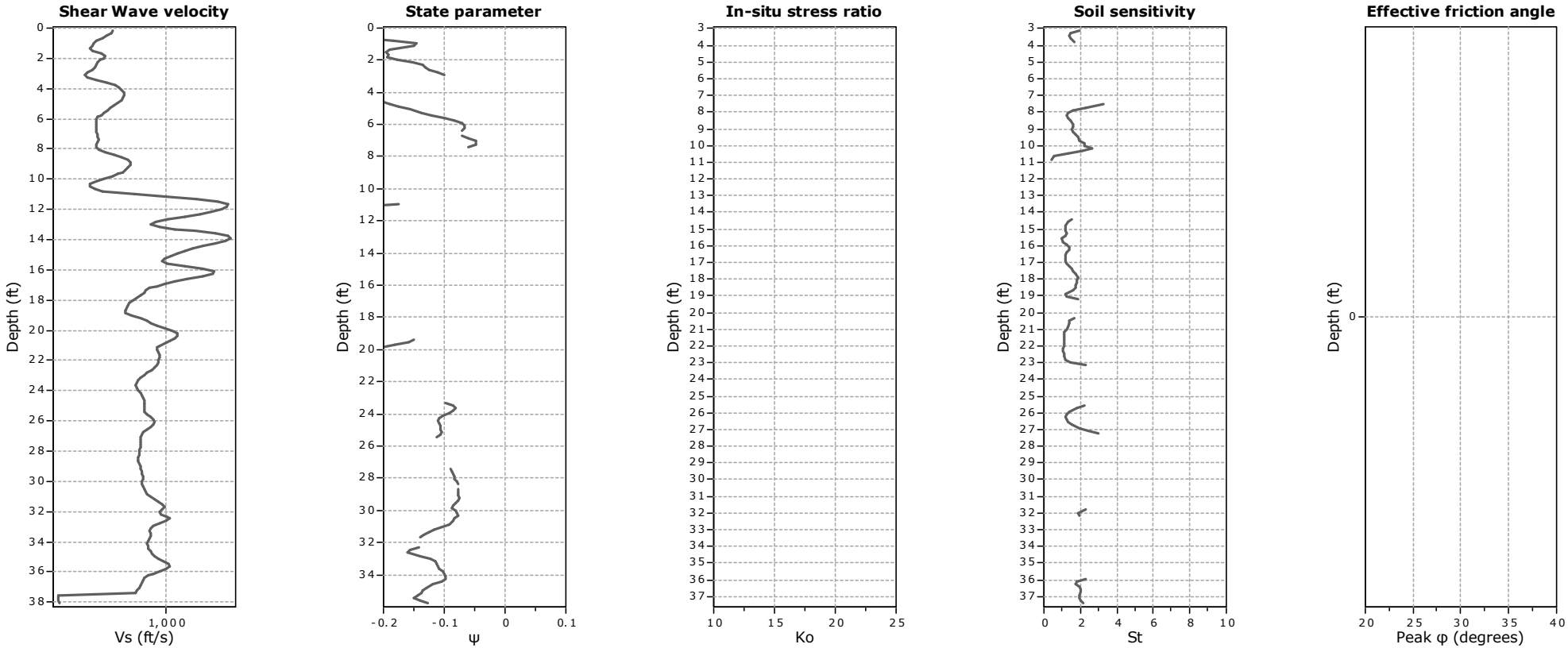
CPT: CPT-01
Total depth: 38.06 ft, Date: 9/25/2018
Surface Elevation: 409.70 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 cm
Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: Auto
OCR factor for clays, N_{kt}: Auto
User defined estimation data
Flat Dilatometer Test data

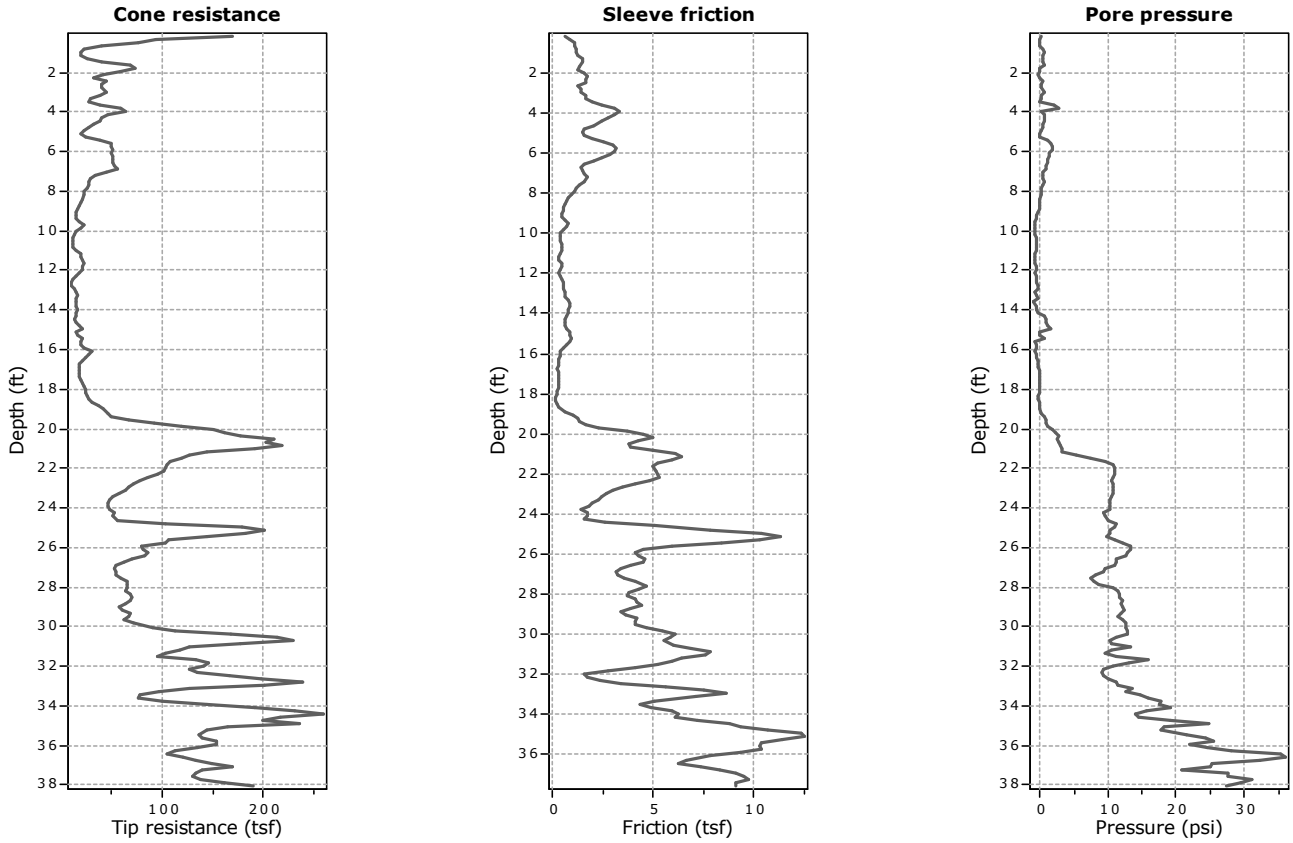


Calculation parameters

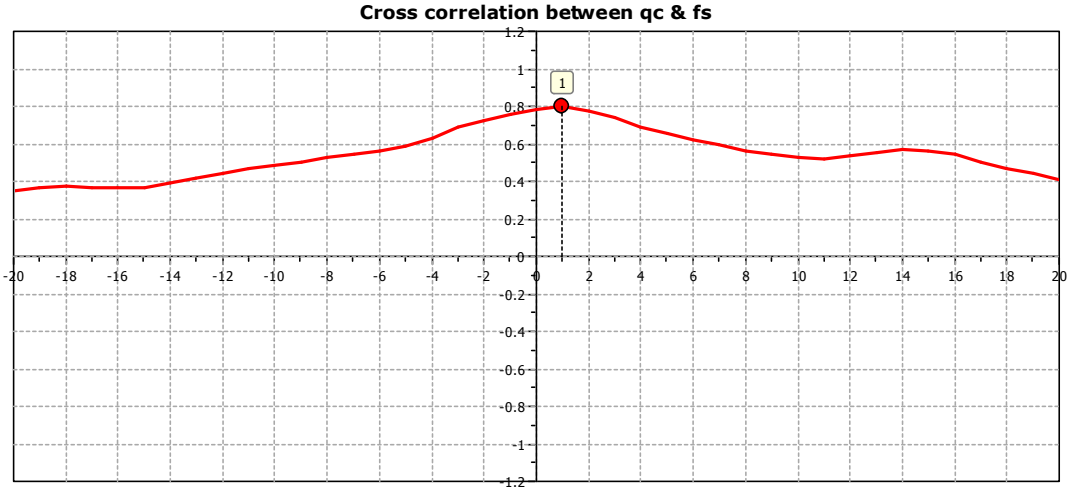
Soil Sensitivity factor, N_S: 7.00

User defined estimation data

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



CPT: CPT-02

Total depth: 38.06 ft, Date: 9/25/2018

Surface Elevation: 404.40 ft

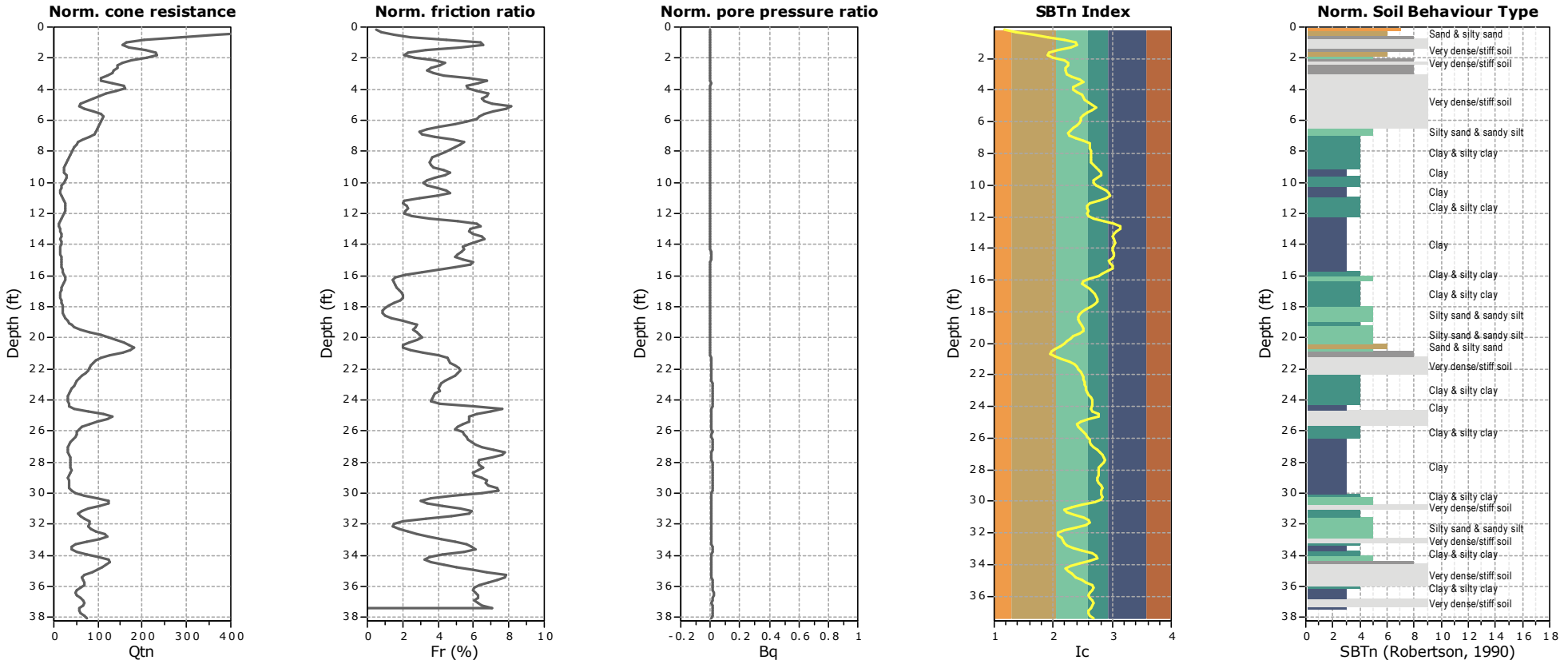
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**

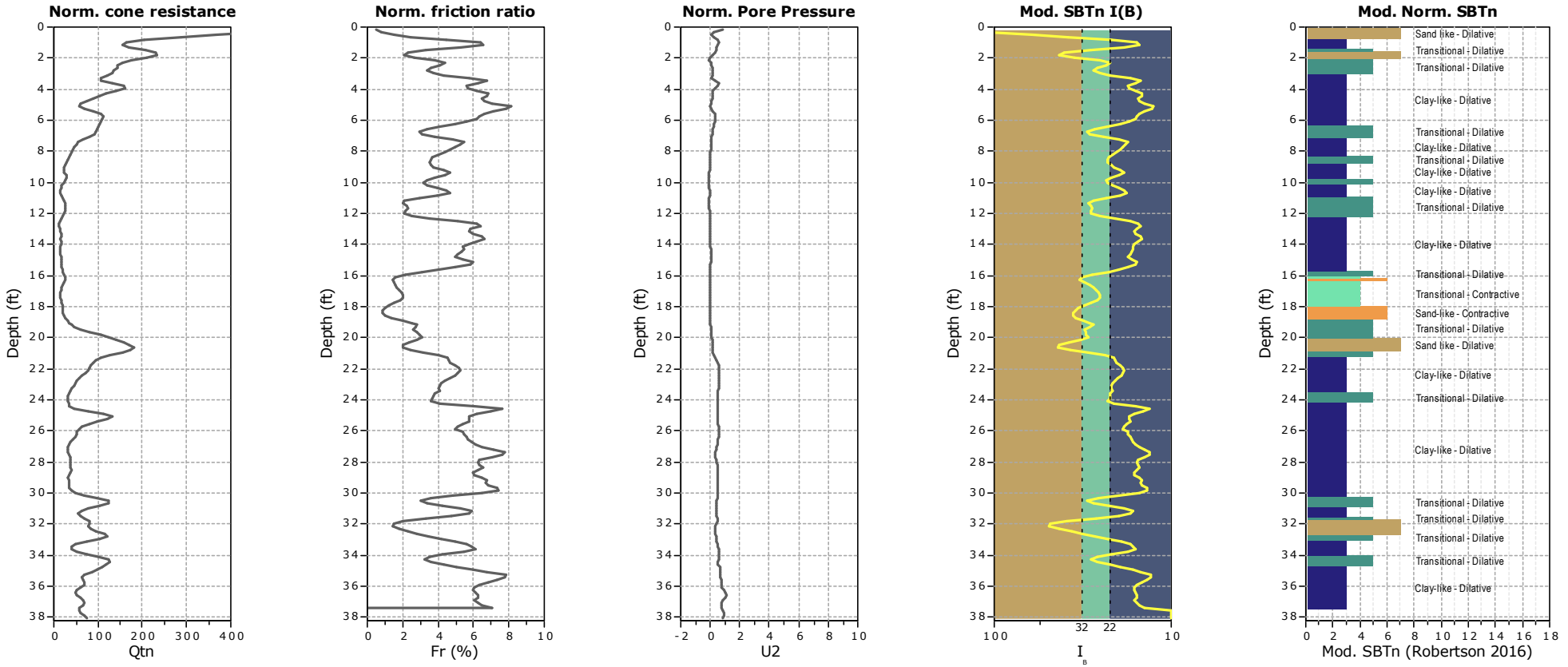


SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

CPT: CPT-02
Total depth: 38.06 ft, Date: 9/25/2018
Surface Elevation: 404.40 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 cm
Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



Mod. SBTn legend

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

CPT: CPT-02

Total depth: 38.06 ft, Date: 9/25/2018

Surface Elevation: 404.40 ft

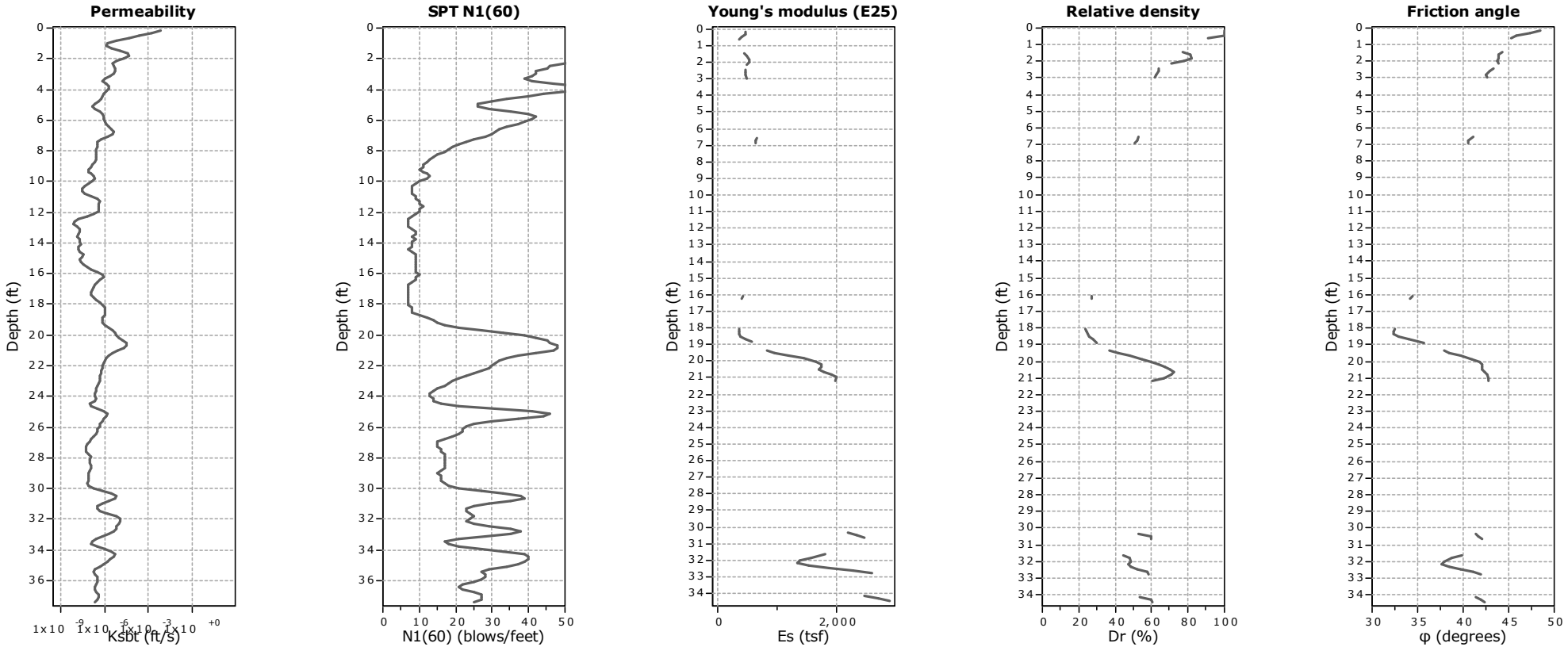
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Permeability: Based on SBT_n

SPT N_{60}: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

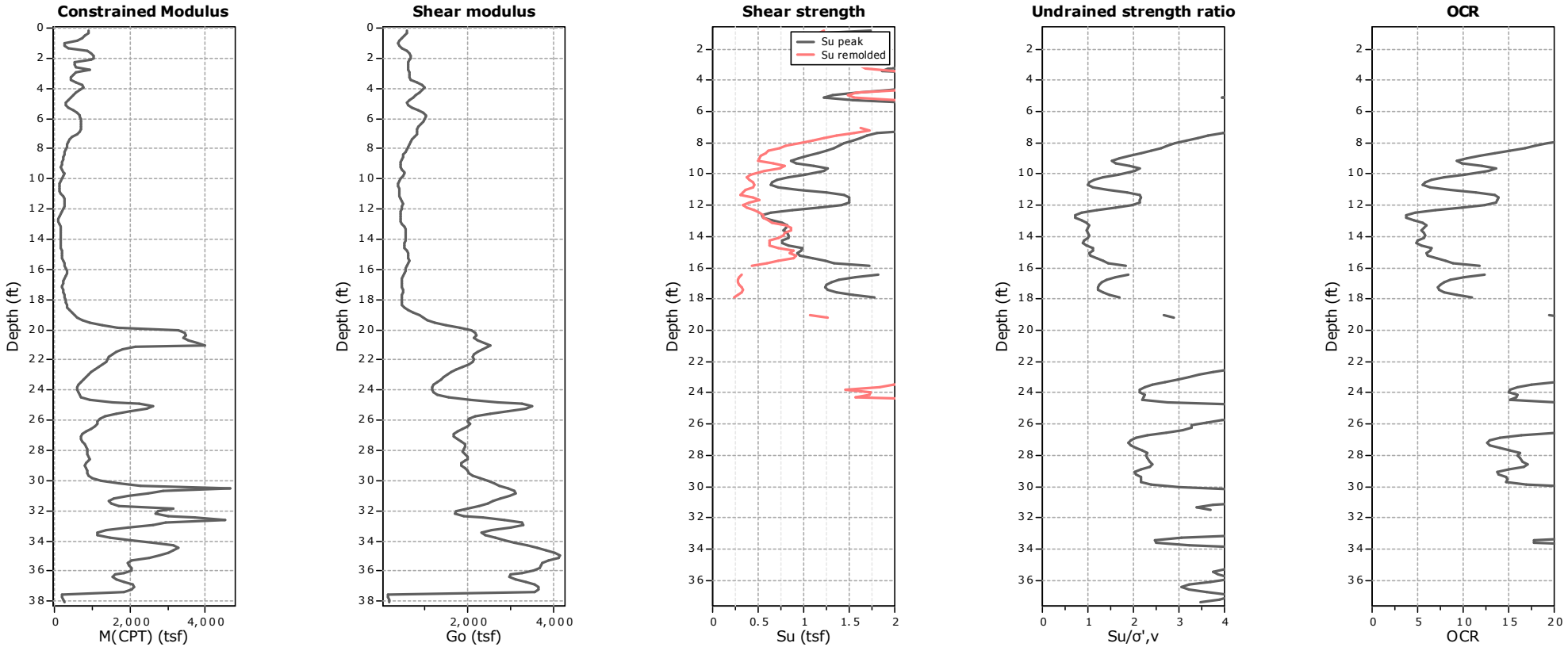
Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

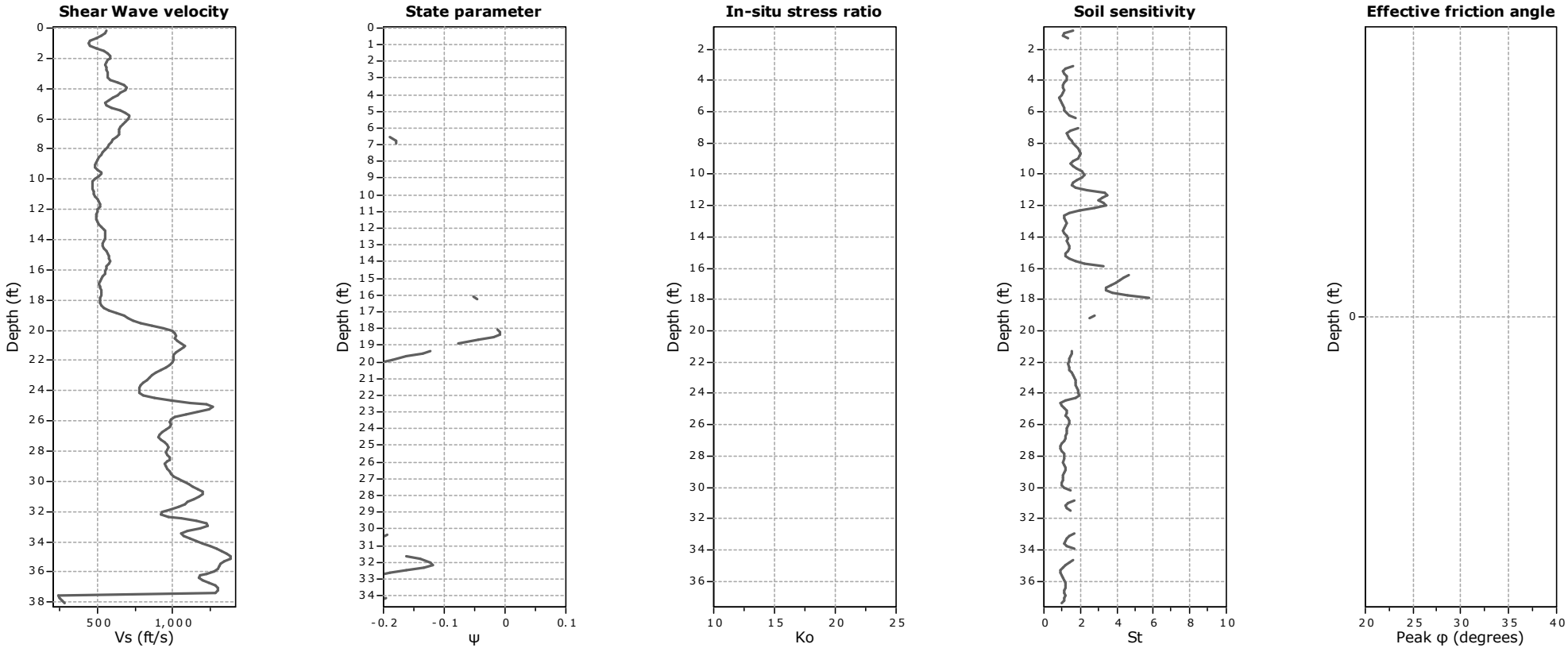
CPT: CPT-02
Total depth: 38.06 ft, Date: 9/25/2018
Surface Elevation: 404.40 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 cm
Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: Auto
OCR factor for clays, N_{kt}: Auto
User defined estimation data
Flat Dilatometer Test data

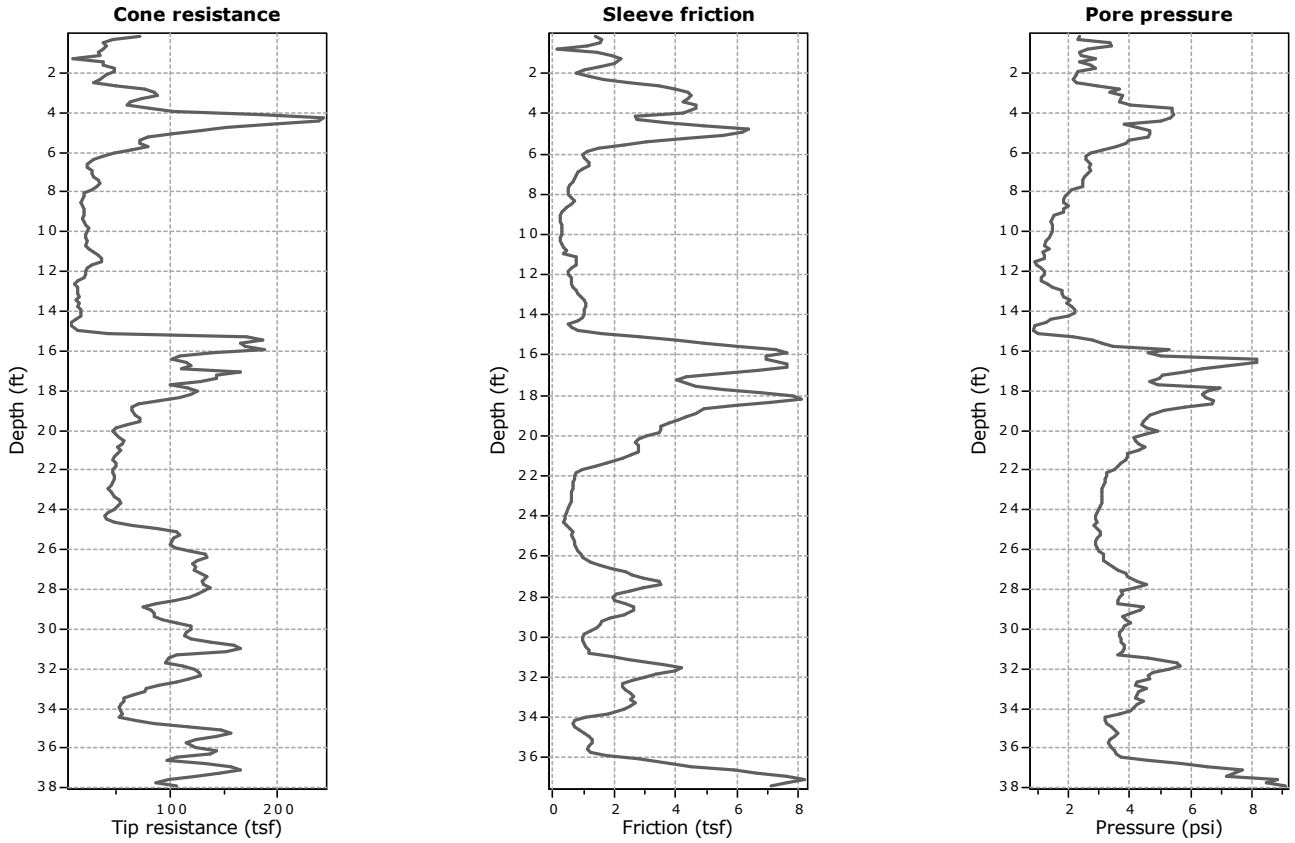


Calculation parameters

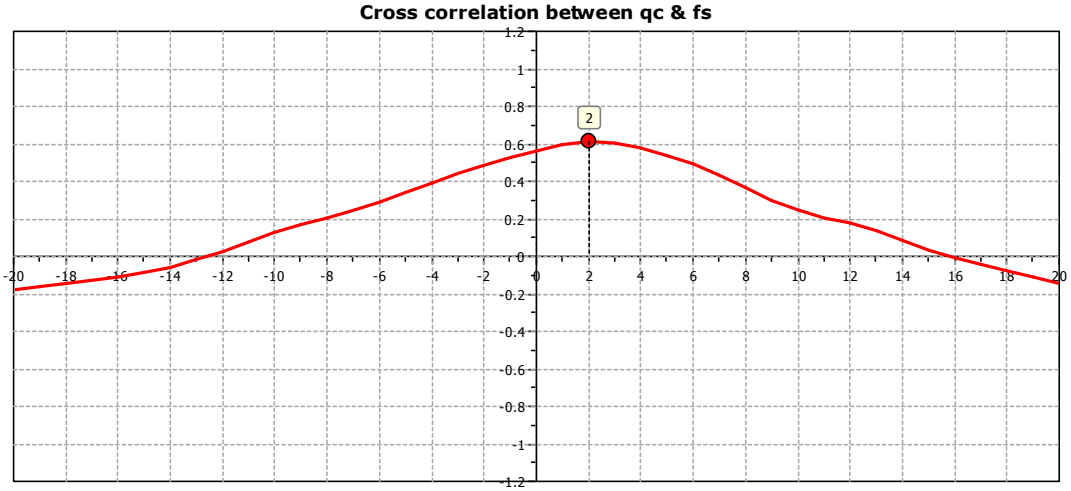
Soil Sensitivity factor, N_S: 7.00

User defined estimation data

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



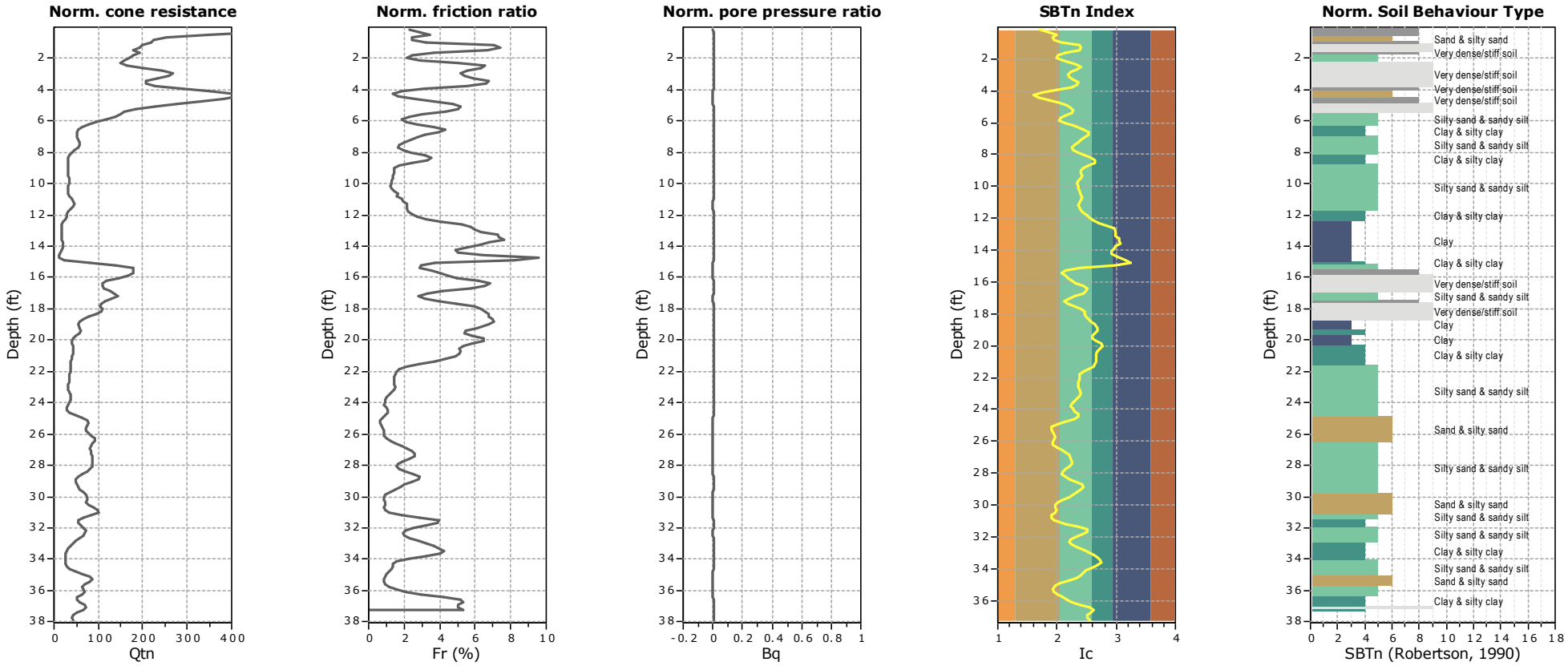
The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



Stantec

CPT: CPT-03
Total depth: 37.89 ft, Date: 9/25/2018
Surface Elevation: 404.80 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 cm
Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

CPT: CPT-03

Total depth: 37.89 ft, Date: 9/25/2018

Surface Elevation: 404.80 ft

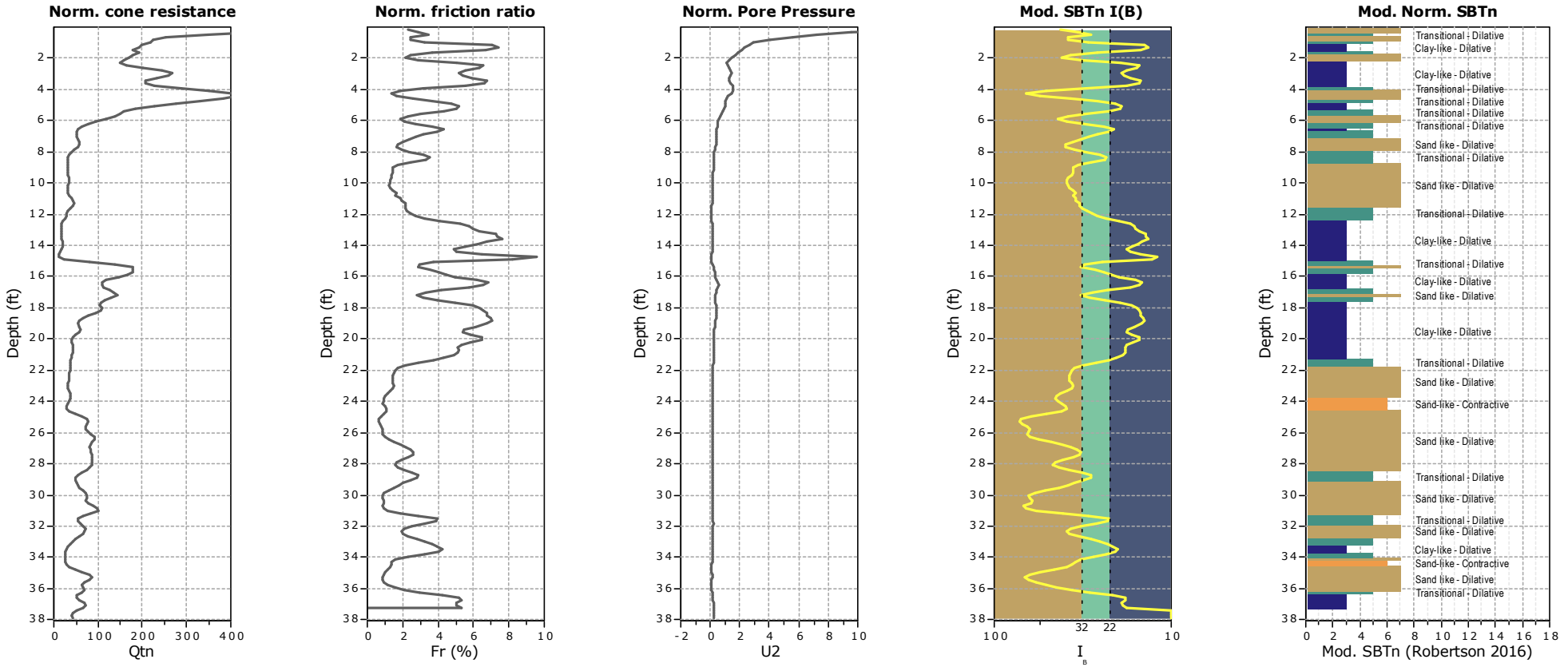
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Mod. SBTn legend

1. CCS: ClayLike - Contractive, Sensitive
2. CC: Clay-like - Contractive
3. CD: Clay-Like: Dilative
4. TC: Transitional - Contractive
5. TD: Transitional - Dilative
6. SC: Sand-like - Contractive
7. SD: Sand-like - Dilative

CPT: CPT-03

Total depth: 37.89 ft, Date: 9/25/2018

Surface Elevation: 404.80 ft

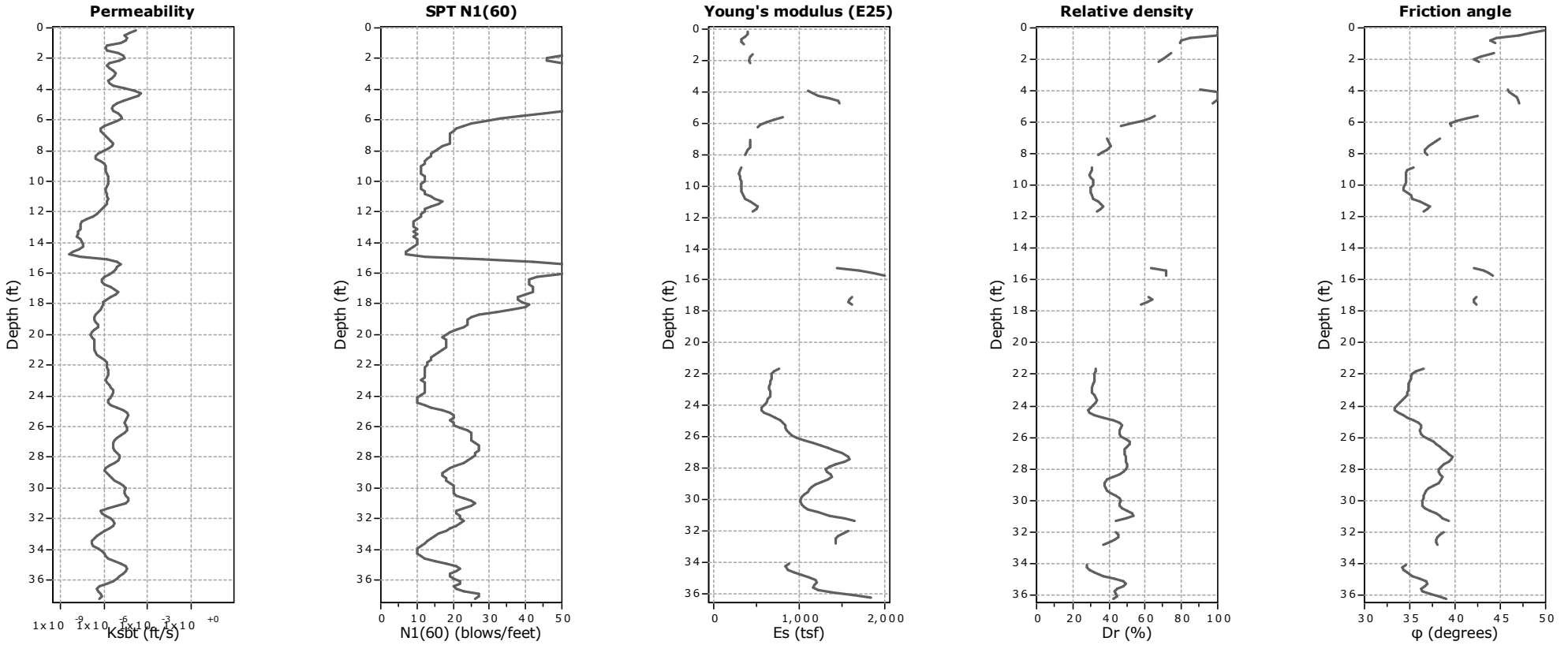
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Permeability: Based on SBT_n

SPT N_{60}: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

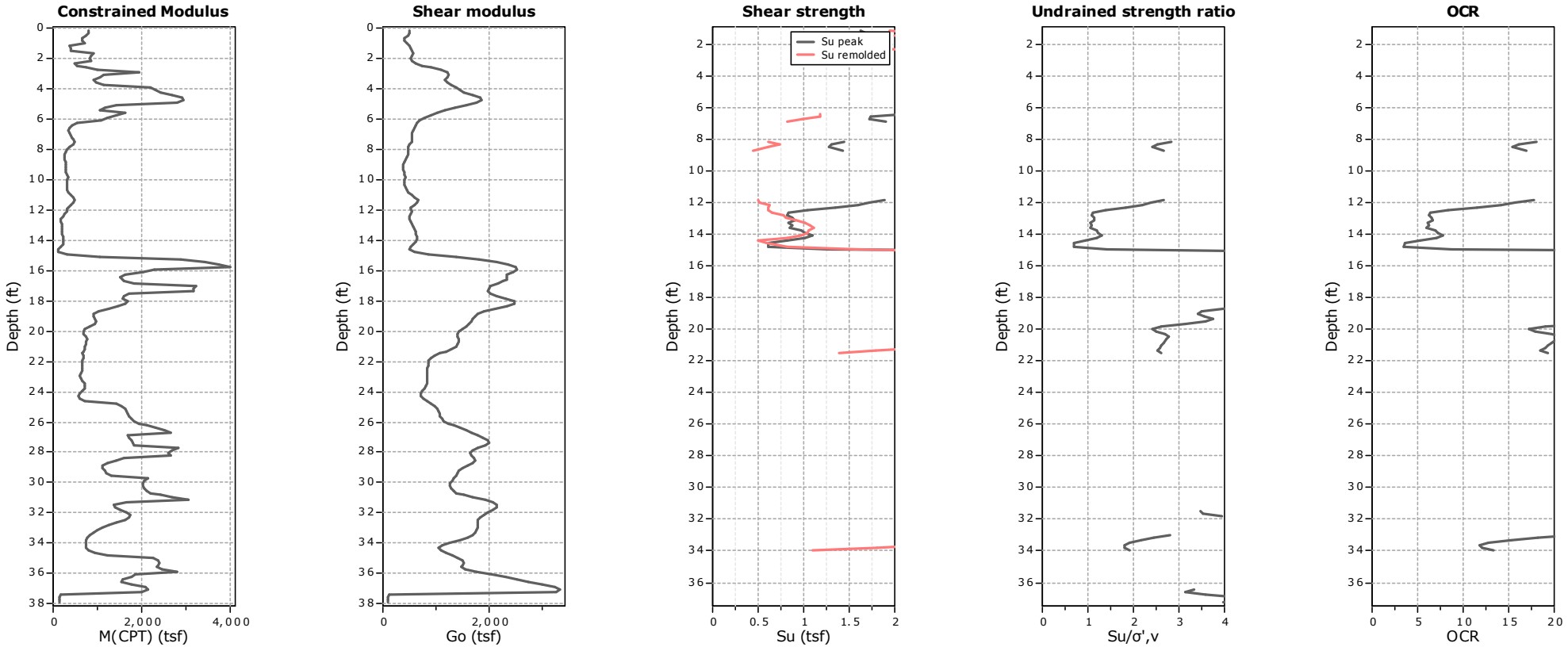
Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

CPT: CPT-03
Total depth: 37.89 ft, Date: 9/25/2018
Surface Elevation: 404.80 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 cm
Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: Auto
OCR factor for clays, N_{kt}: Auto
User defined estimation data
Flat Dilatometer Test data

CPT: CPT-03

Total depth: 37.89 ft, Date: 9/25/2018

Surface Elevation: 404.80 ft

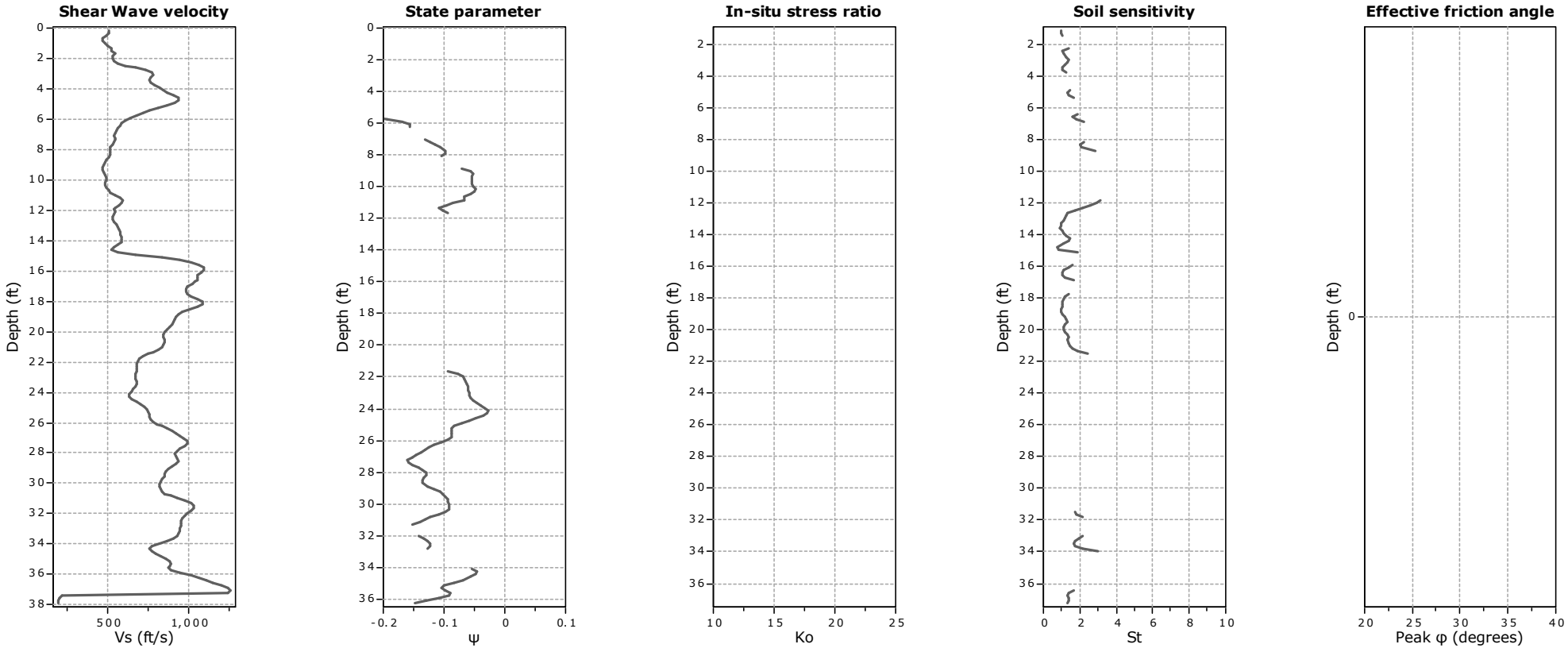
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

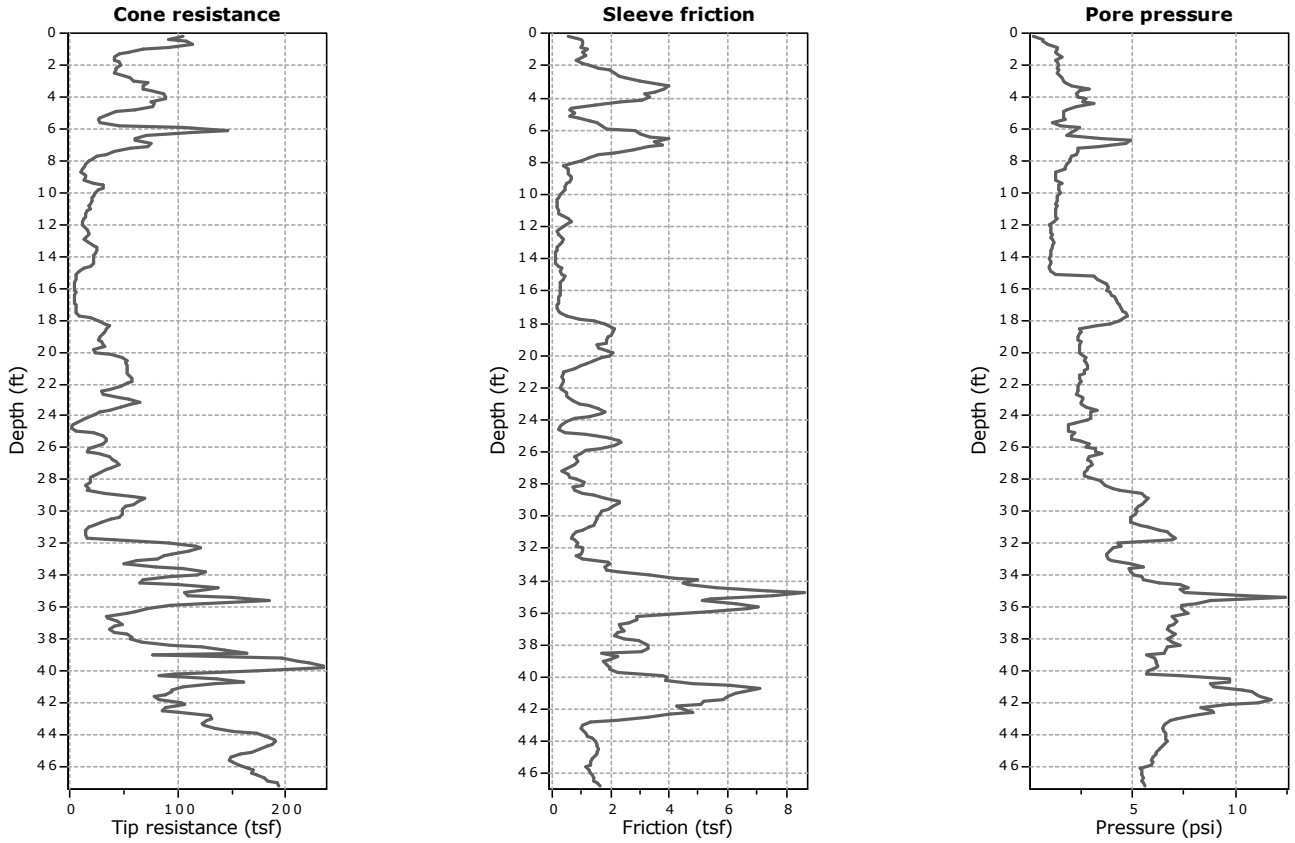
Location: **Tulare County, CA**



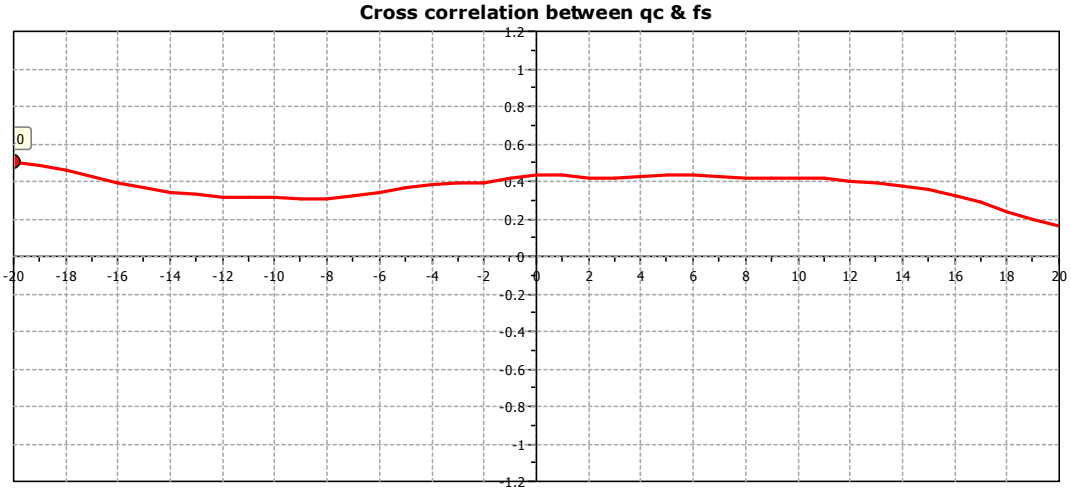
Calculation parameters

Soil Sensitivity factor, N_S: 7.00

User defined estimation data



The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



CPT: CPT-04

Total depth: 47.24 ft, Date: 9/25/2018

Surface Elevation: 404.90 ft

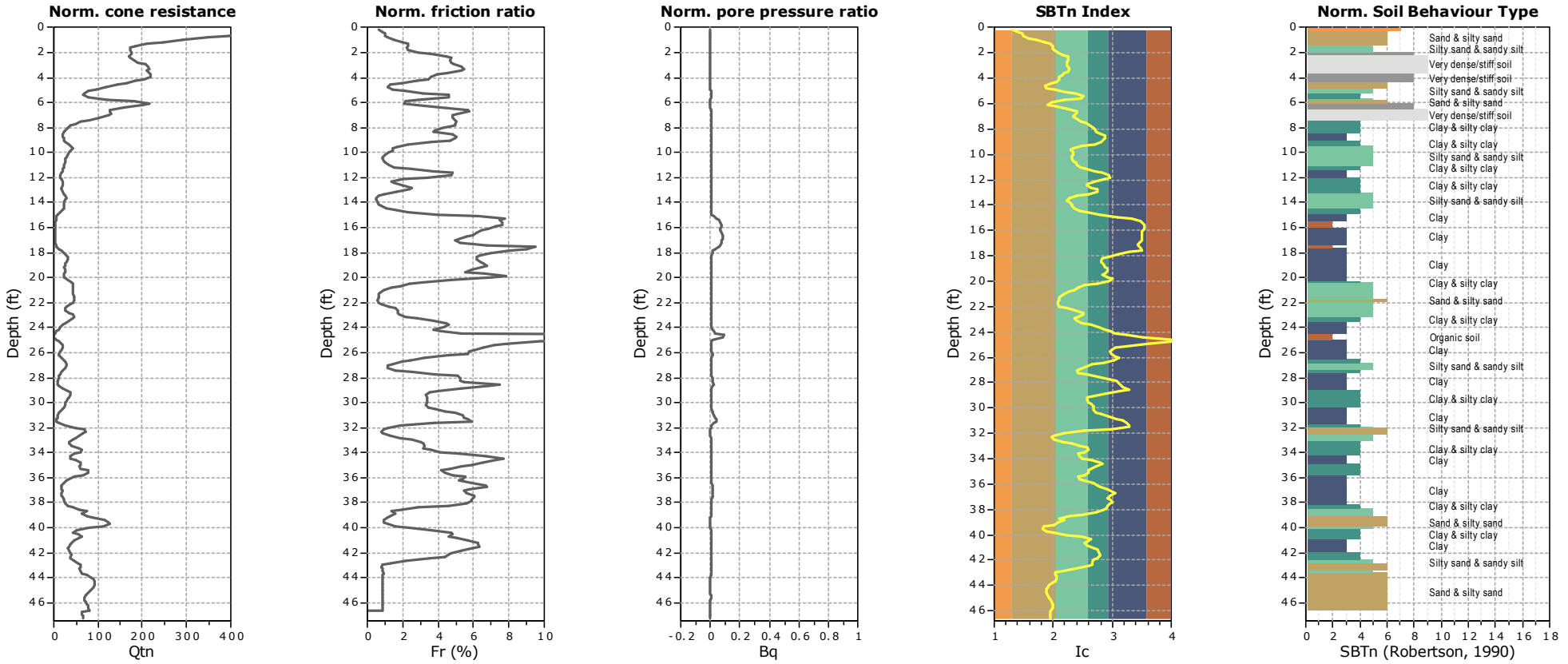
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

CPT: CPT-04

Total depth: 47.24 ft, Date: 9/25/2018

Surface Elevation: 404.90 ft

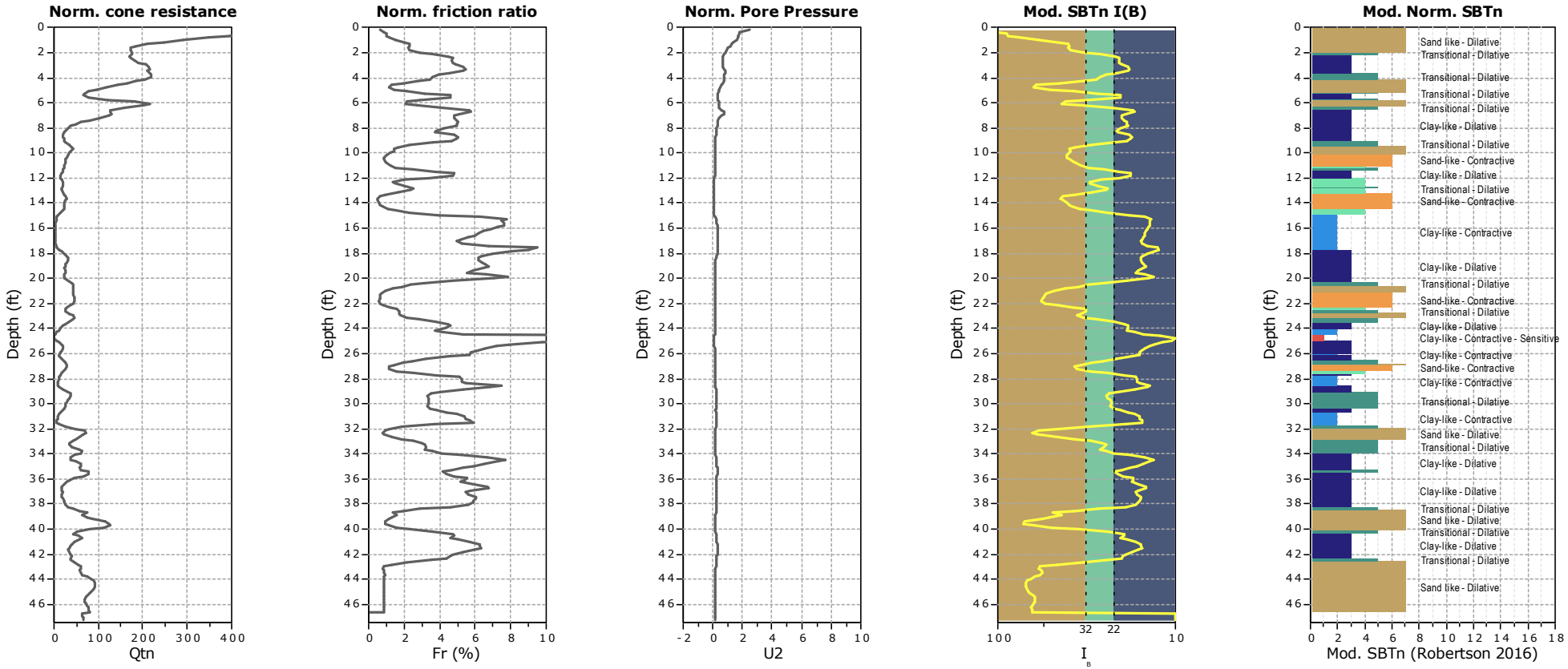
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Mod. SBTn legend

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

CPT: CPT-04

Total depth: 47.24 ft, Date: 9/25/2018

Surface Elevation: 404.90 ft

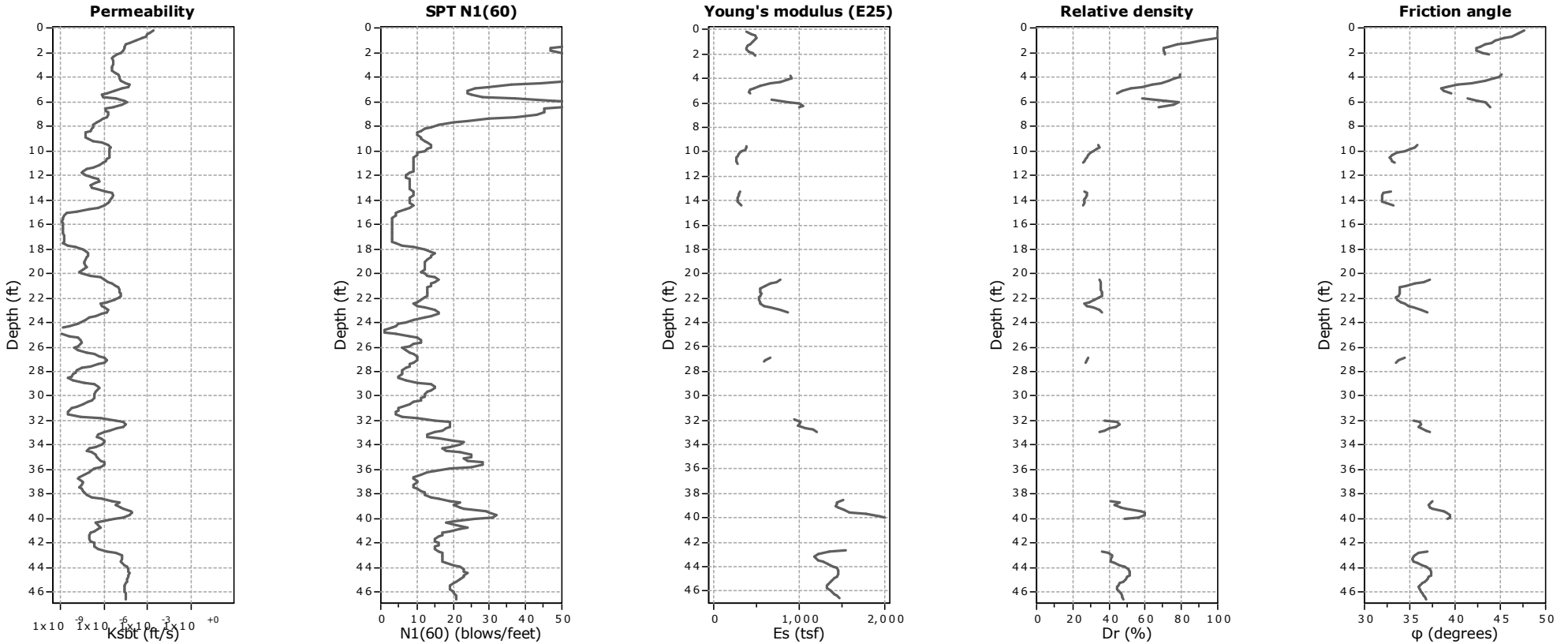
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Permeability: Based on SBT_n

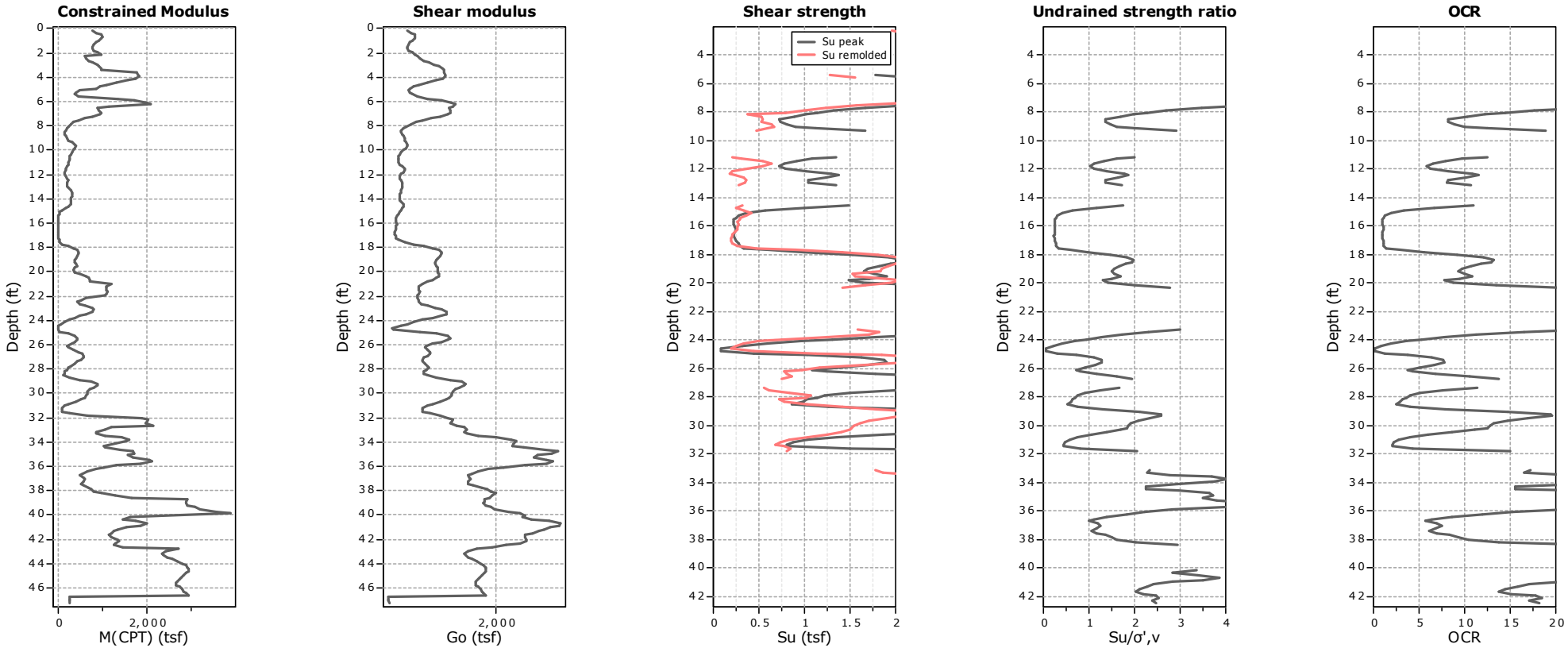
SPT N_{60}: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: Auto
OCR factor for clays, N_{kt}: Auto
User defined estimation data
Flat Dilatometer Test data

CPT: CPT-04

Total depth: 47.24 ft, Date: 9/25/2018

Surface Elevation: 404.90 ft

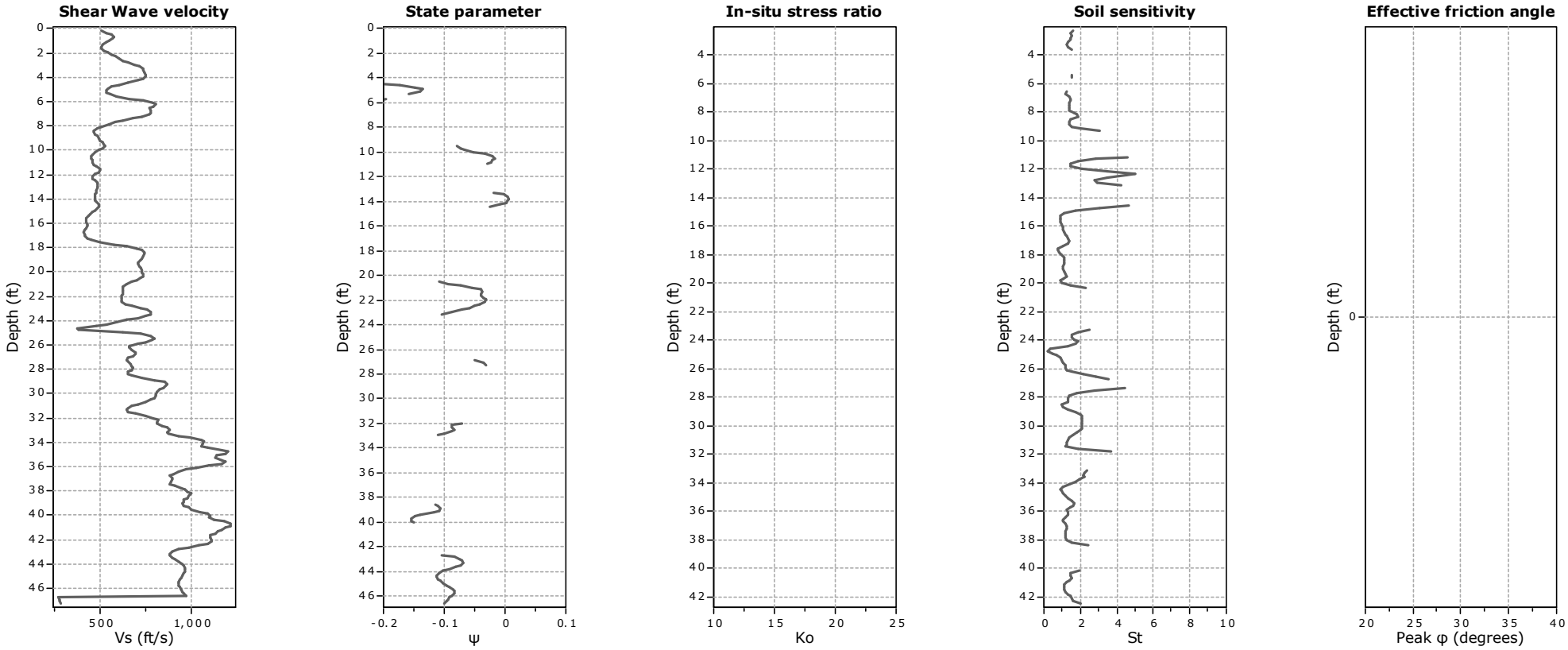
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**

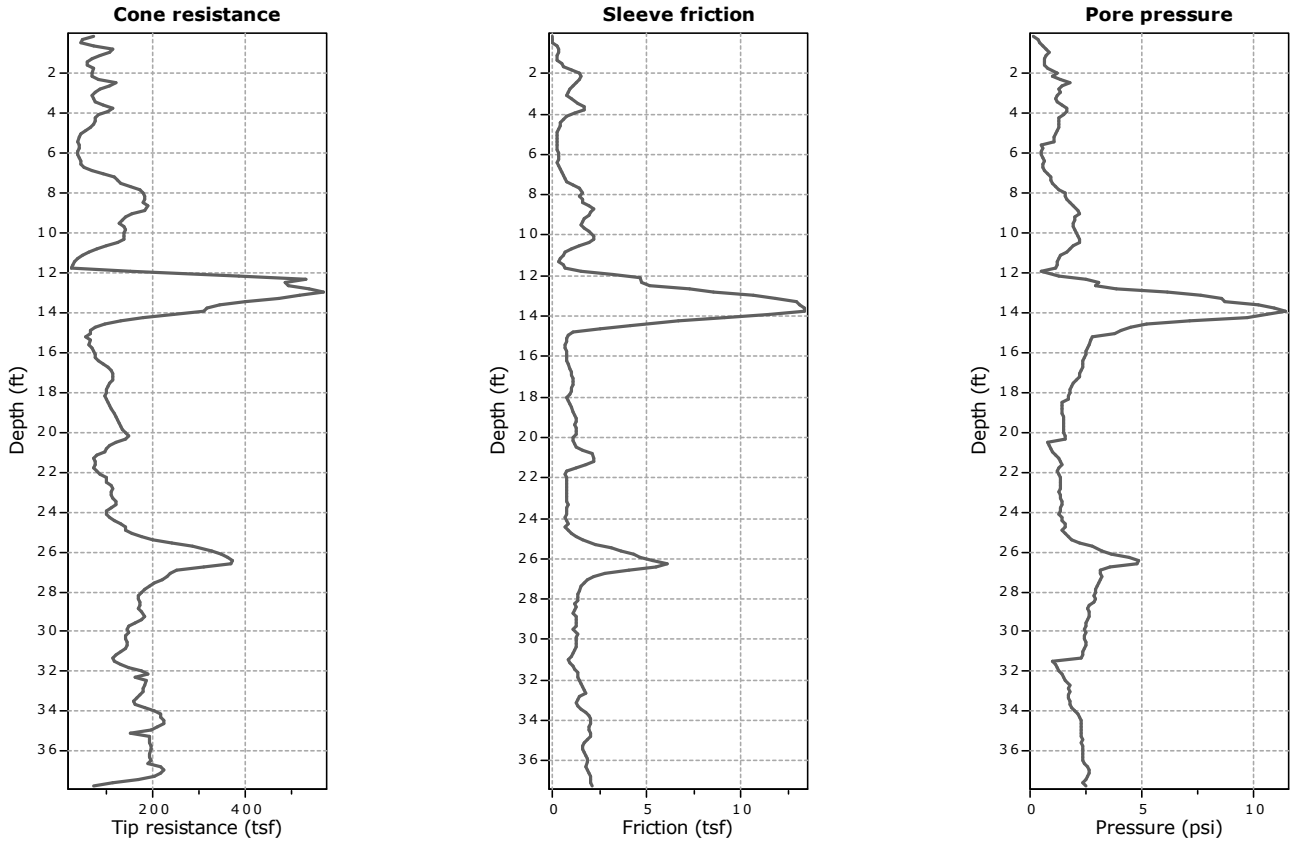


Calculation parameters

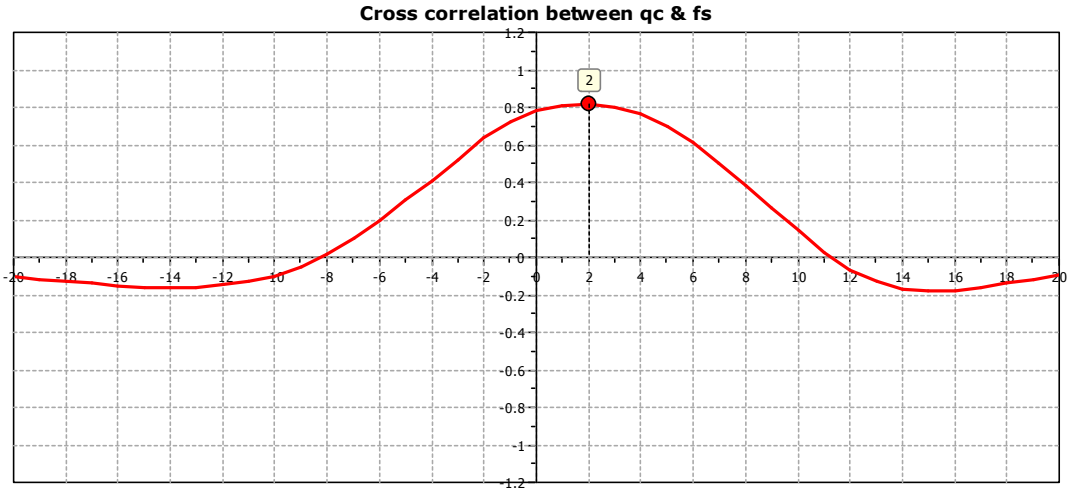
Soil Sensitivity factor, N_S: 7.00

User defined estimation data

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



Stantec

CPT: CPT-05

Total depth: 37.73 ft, Date: 9/25/2018

Surface Elevation: 407.60 ft

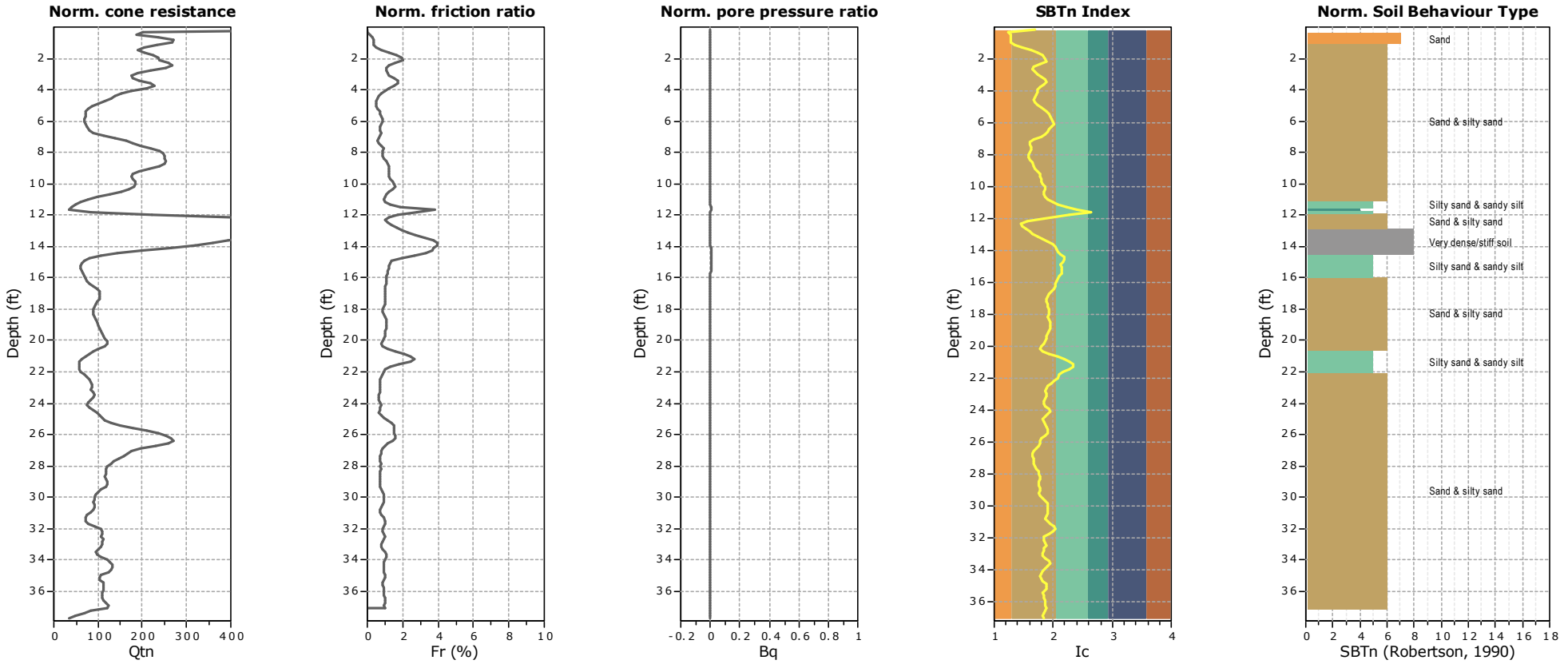
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**

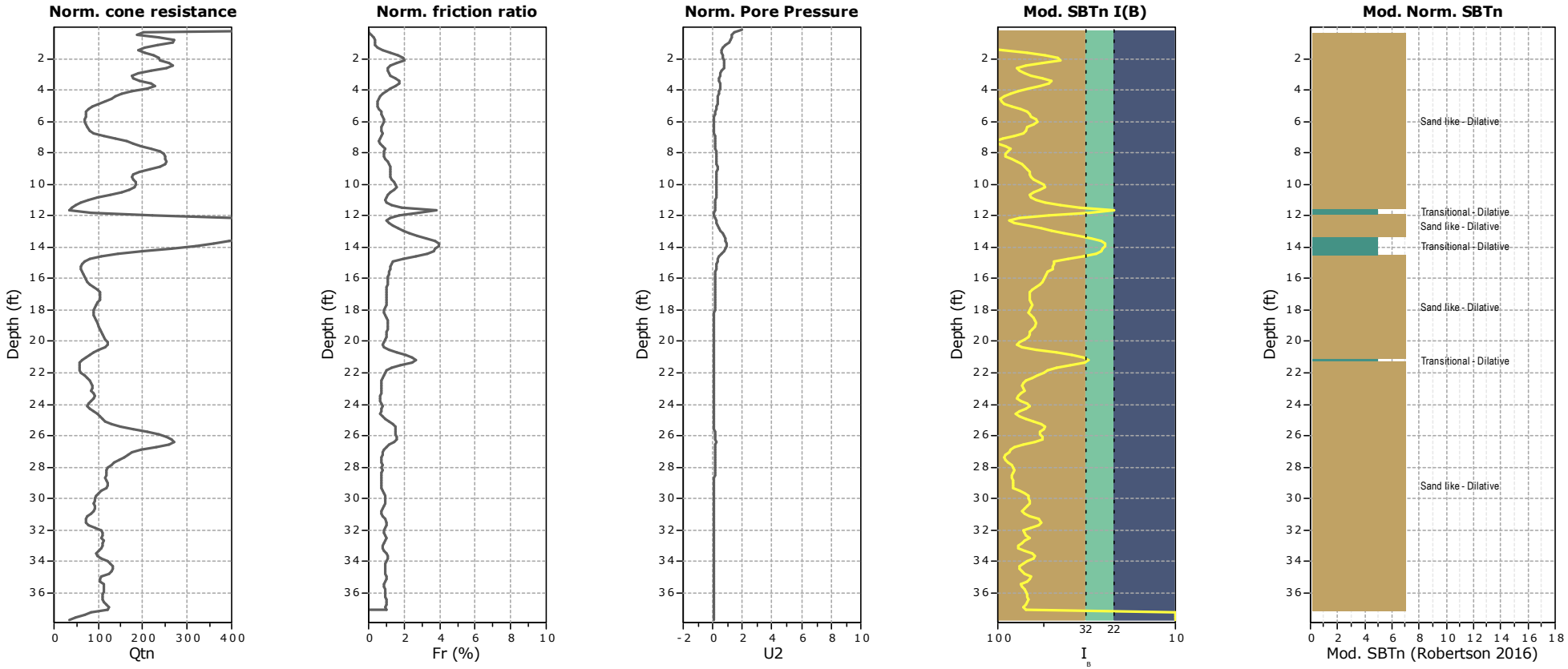


SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

CPT: CPT-05
Total depth: 37.73 ft, Date: 9/25/2018
Surface Elevation: 407.60 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 cm
Cone Operator: Middle Earth Geo Testing

Project: Friant Kern Canal Capacity Correction Project
Location: Tulare County, CA



Mod. SBTn legend

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

CPT: CPT-05

Total depth: 37.73 ft, Date: 9/25/2018

Surface Elevation: 407.60 ft

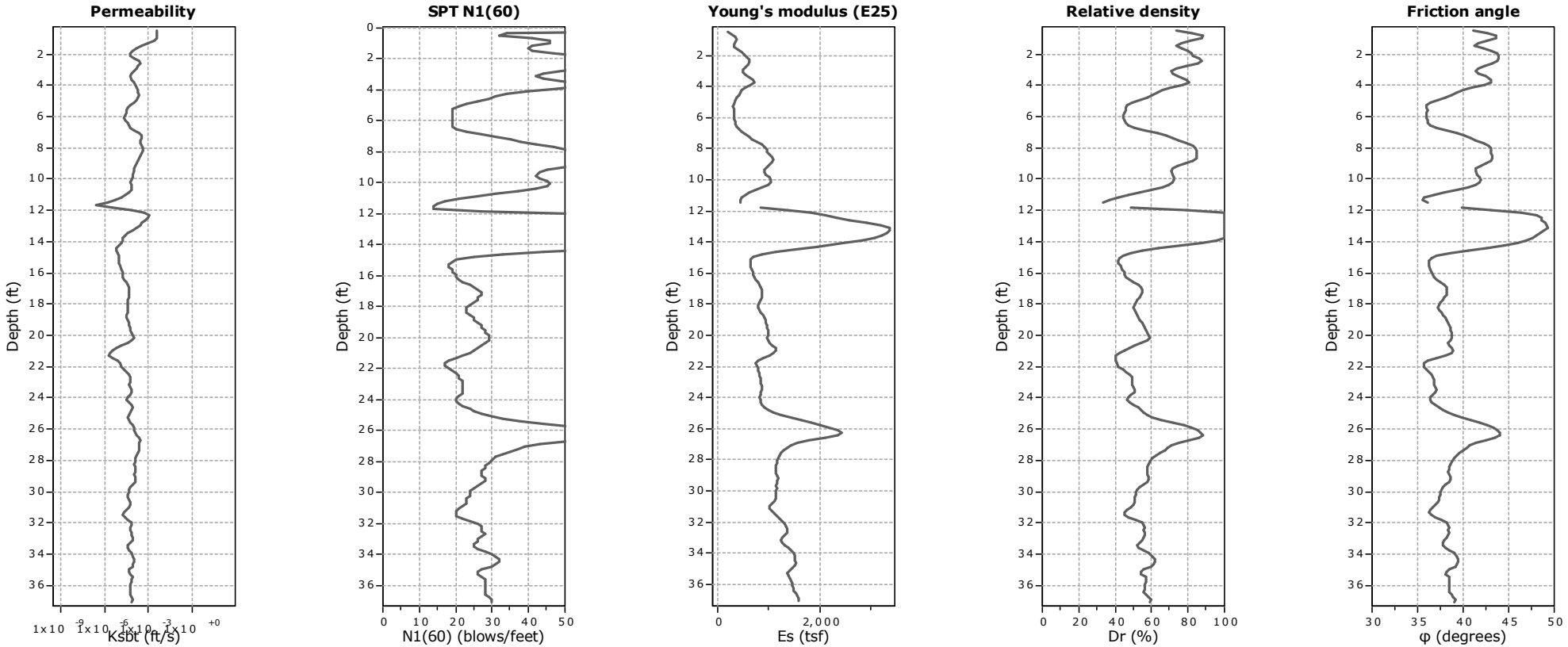
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Permeability: Based on SBT_n

SPT N_{60}: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

CPT: CPT-05

Total depth: 37.73 ft, Date: 9/25/2018

Surface Elevation: 407.60 ft

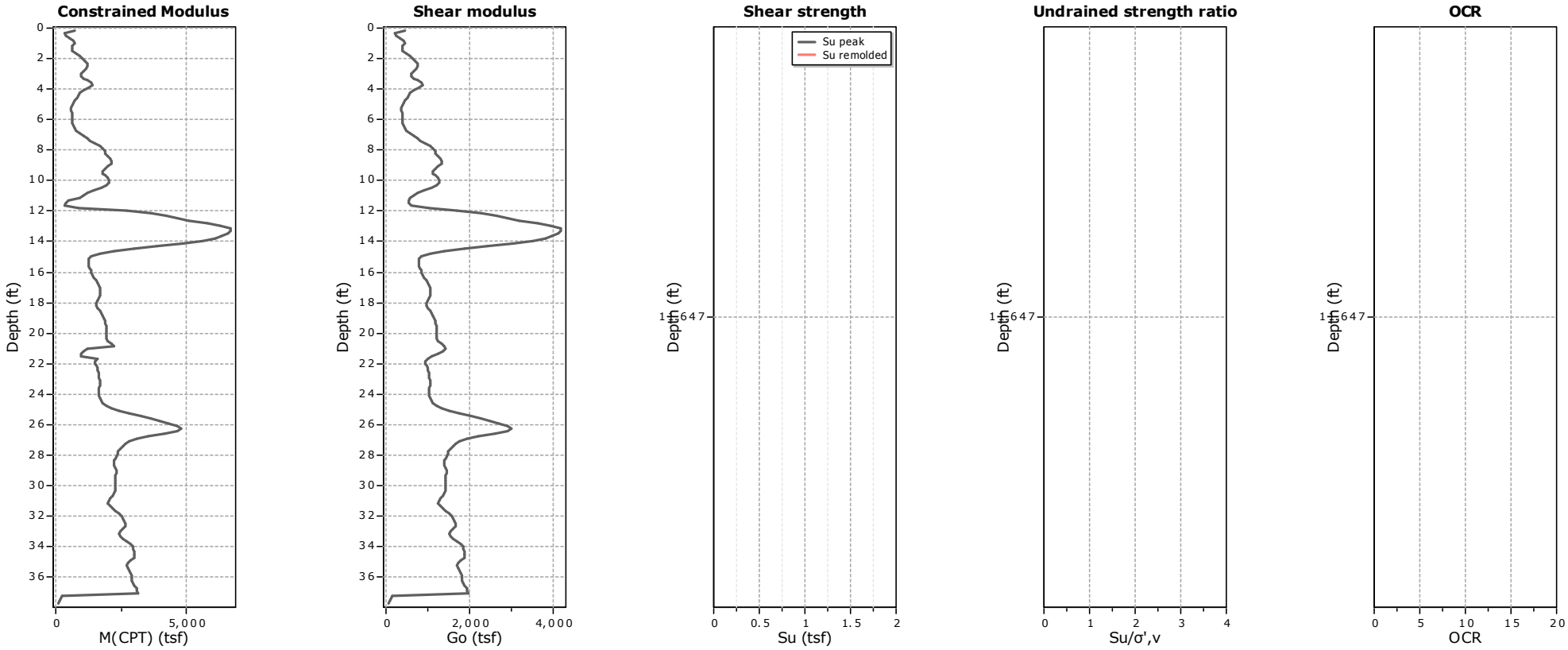
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)

Go: Based on variable alpha using I_c (Robertson, 2009)

Undrained shear strength cone factor for clays, N_{kt}: Auto

OCR factor for clays, N_{kt}: Auto

User defined estimation data

Flat Dilatometer Test data

CPT: CPT-05

Total depth: 37.73 ft, Date: 9/25/2018

Surface Elevation: 407.60 ft

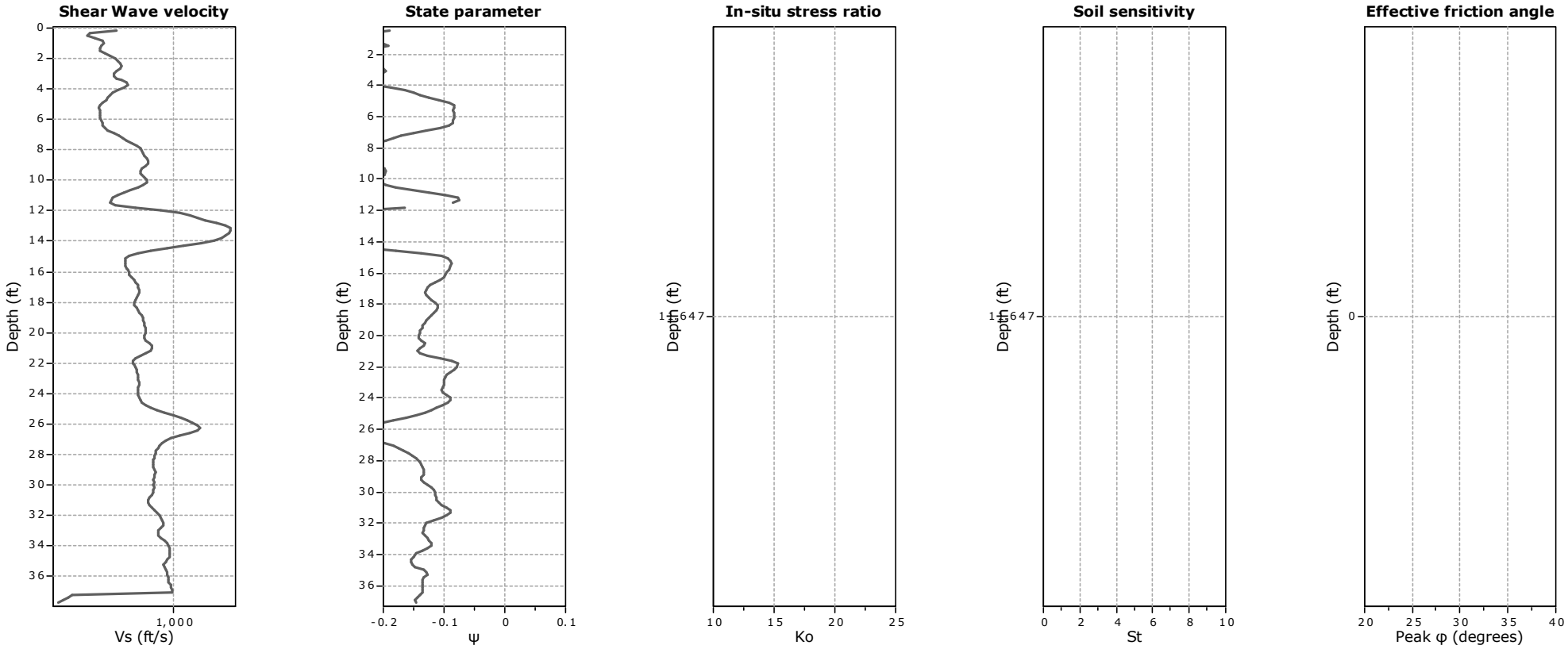
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

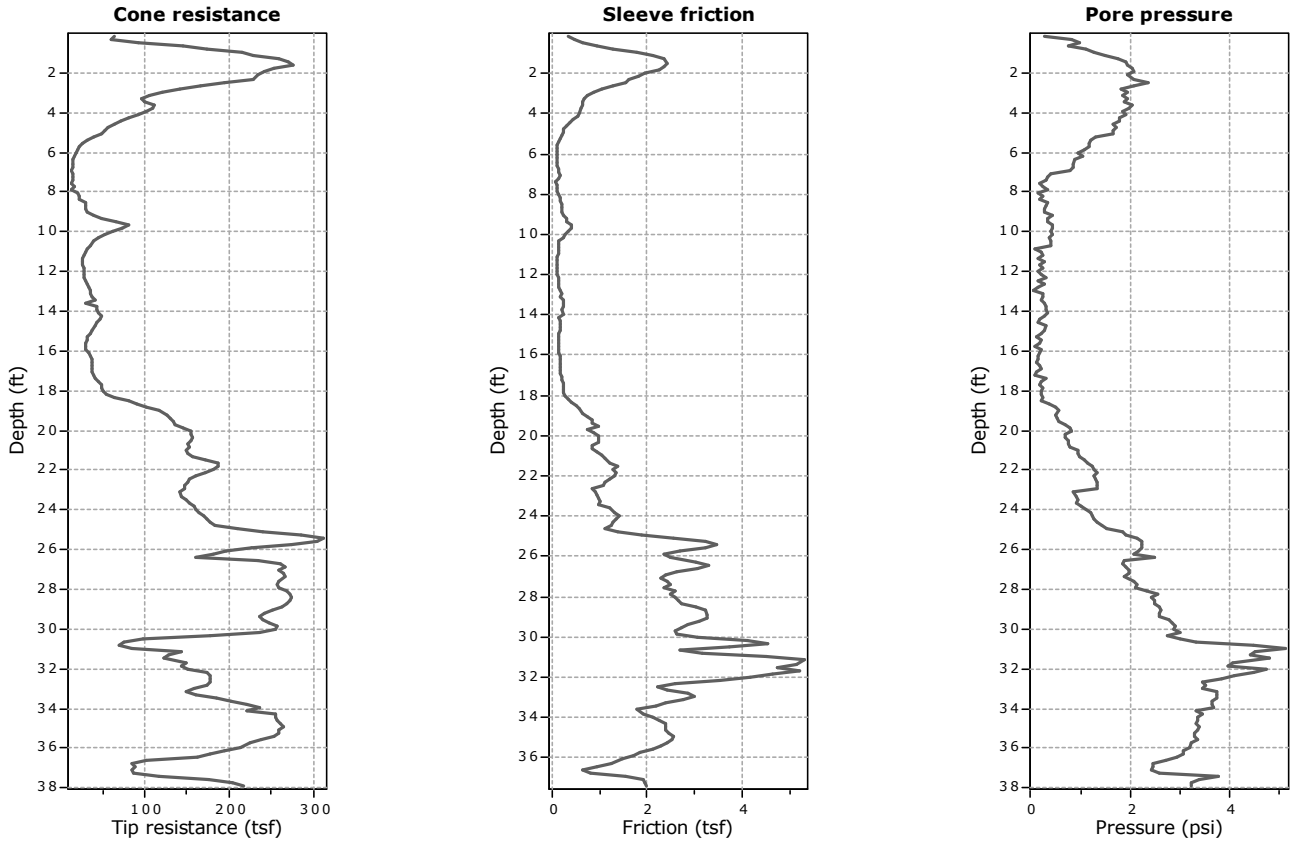
Location: **Tulare County, CA**



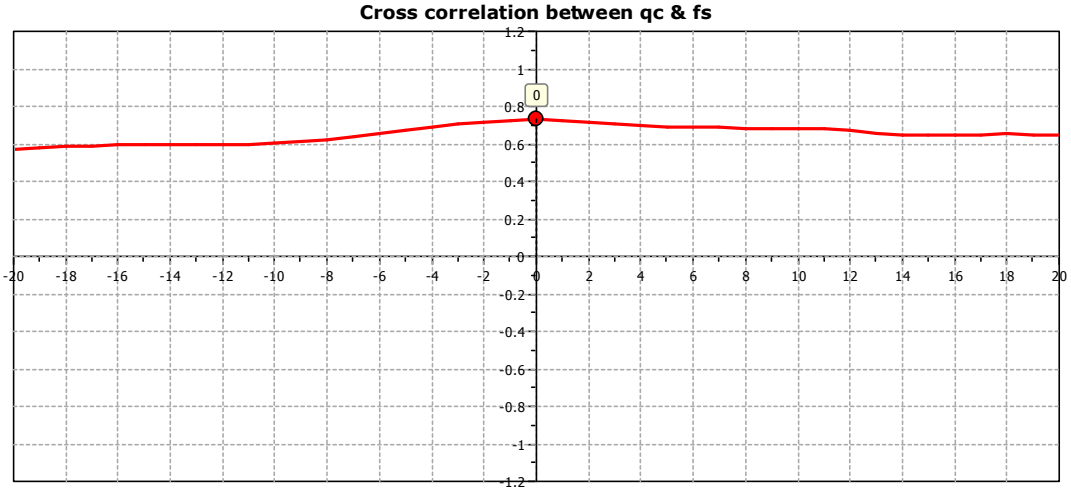
Calculation parameters

Soil Sensitivity factor, N_S: 7.00

User defined estimation data



The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



CPT: CPT-06

Total depth: 37.89 ft, Date: 9/25/2018

Surface Elevation: 407.40 ft

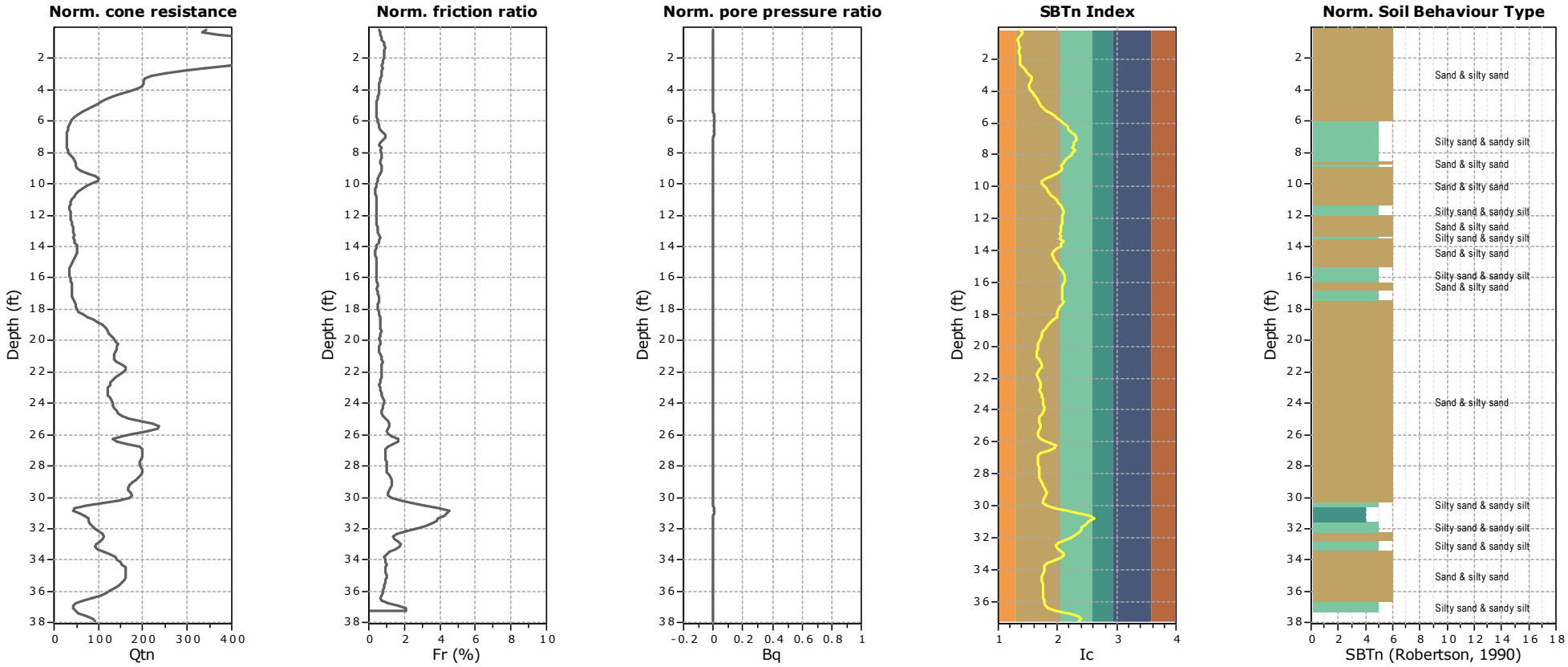
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



SBTn legend

1. Sensitive fine grained
2. Organic material
3. Clay to silty clay
4. Clayey silt to silty clay
5. Silty sand to sandy silt
6. Clean sand to silty sand
7. Gravely sand to sand
8. Very stiff sand to clayey sand
9. Very stiff fine grained

CPT: CPT-06

Total depth: 37.89 ft, Date: 9/25/2018

Surface Elevation: 407.40 ft

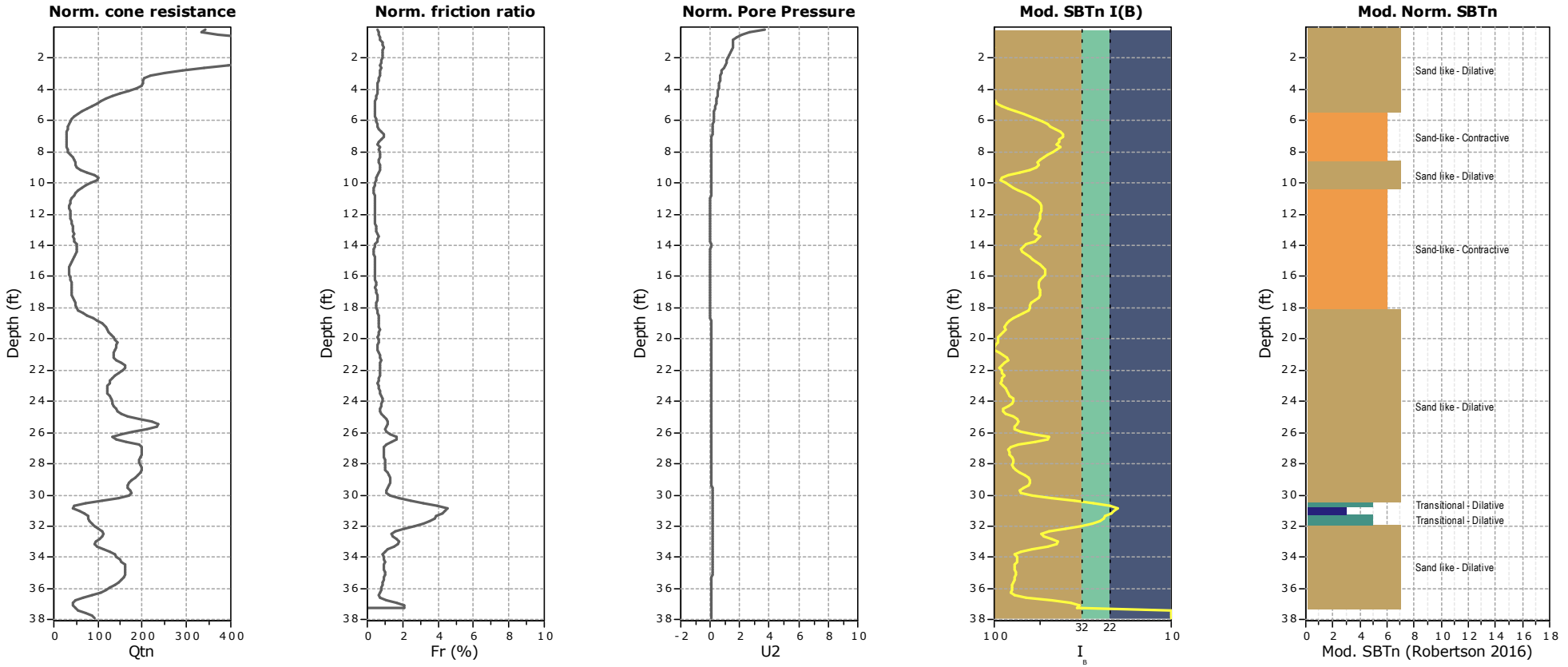
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Mod. SBTn legend

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

CPT: CPT-06

Total depth: 37.89 ft, Date: 9/25/2018

Surface Elevation: 407.40 ft

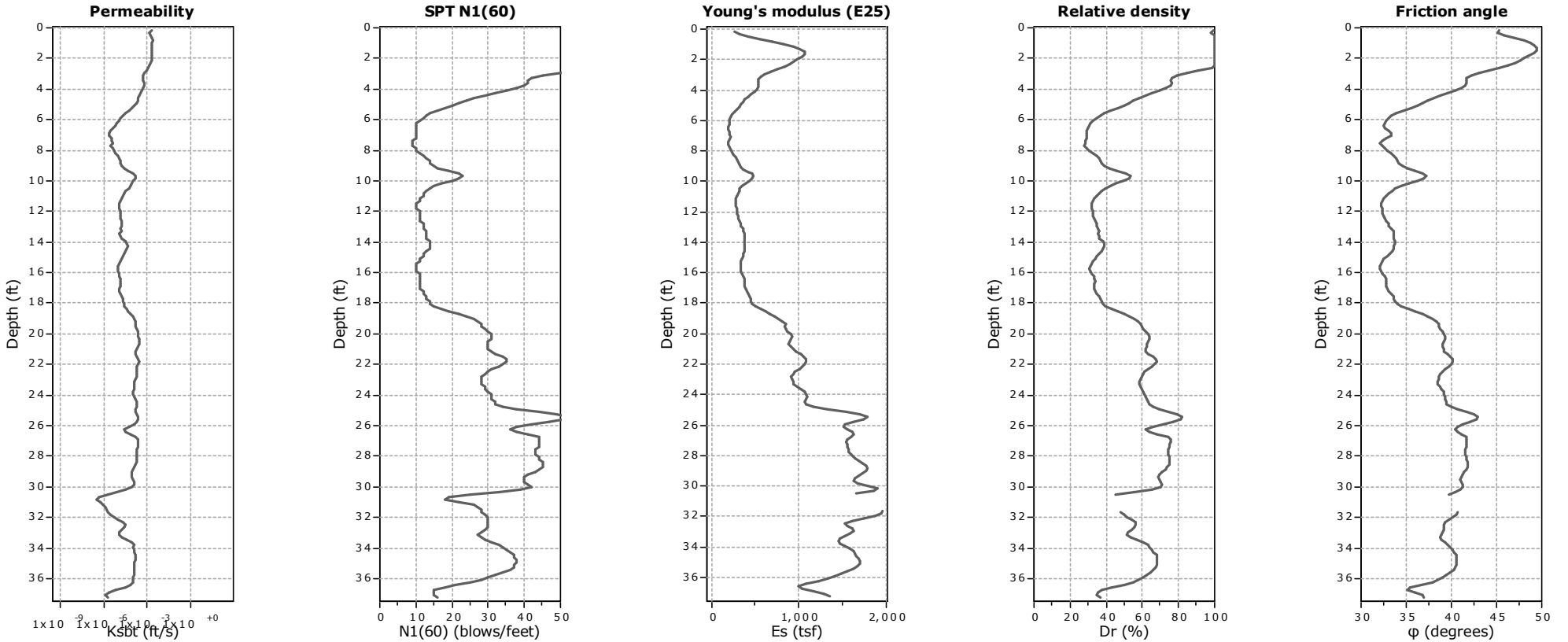
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Permeability: Based on SBT_n

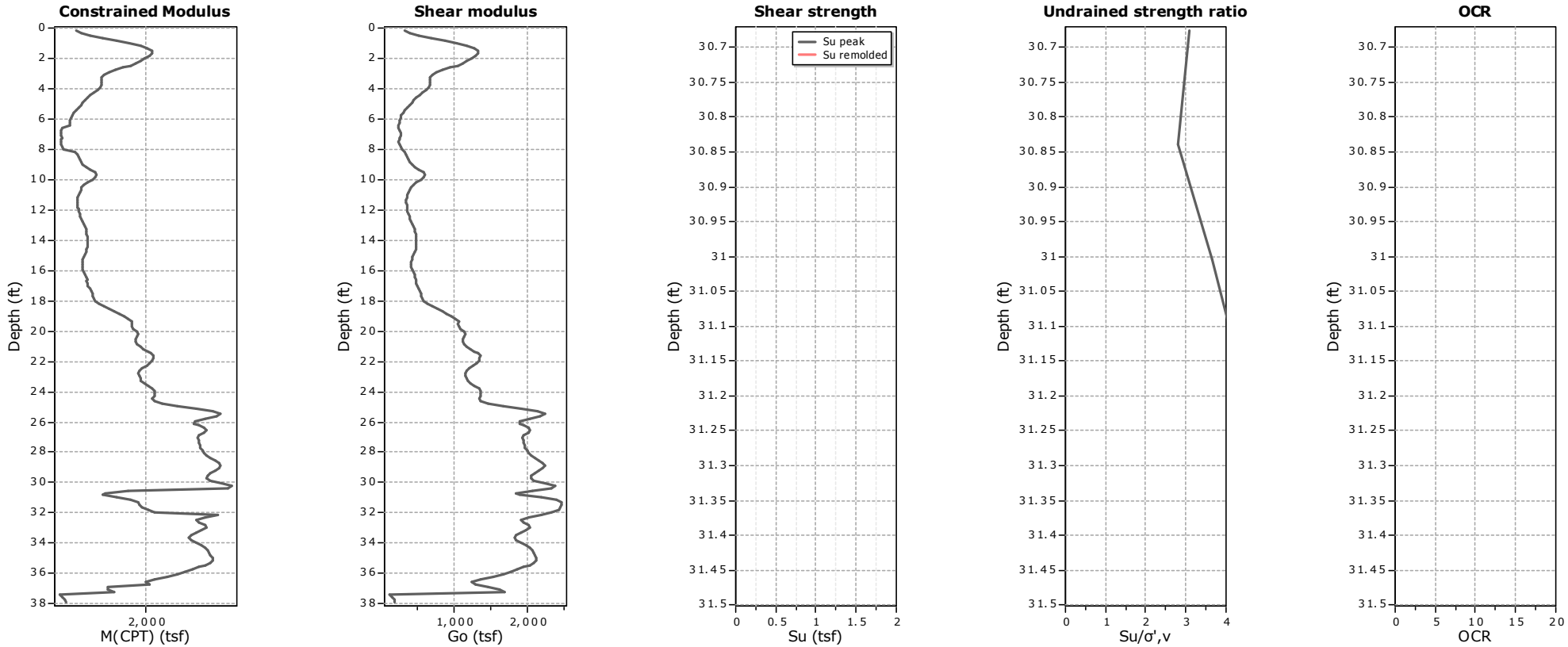
SPT N_{60}: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative desnisty constant, C_{Dr}: 350.0

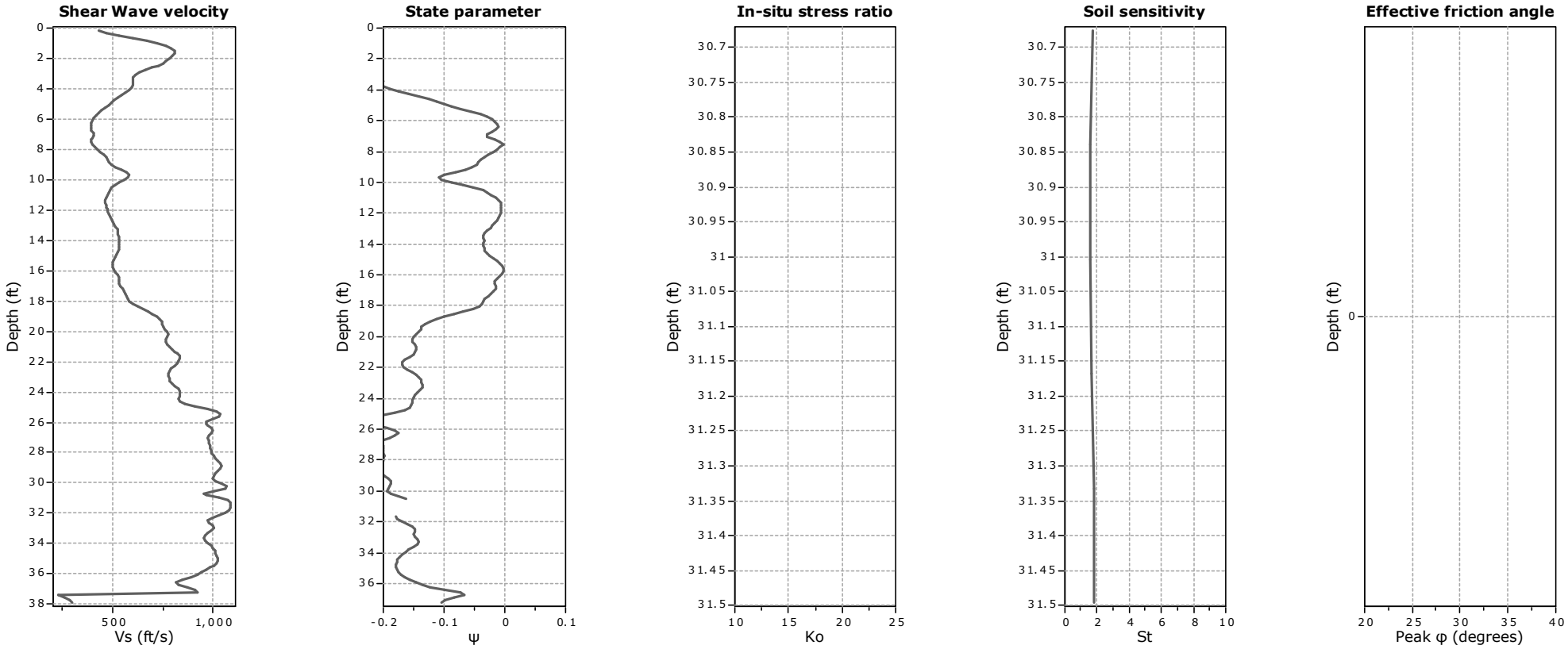
Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data



Calculation parameters

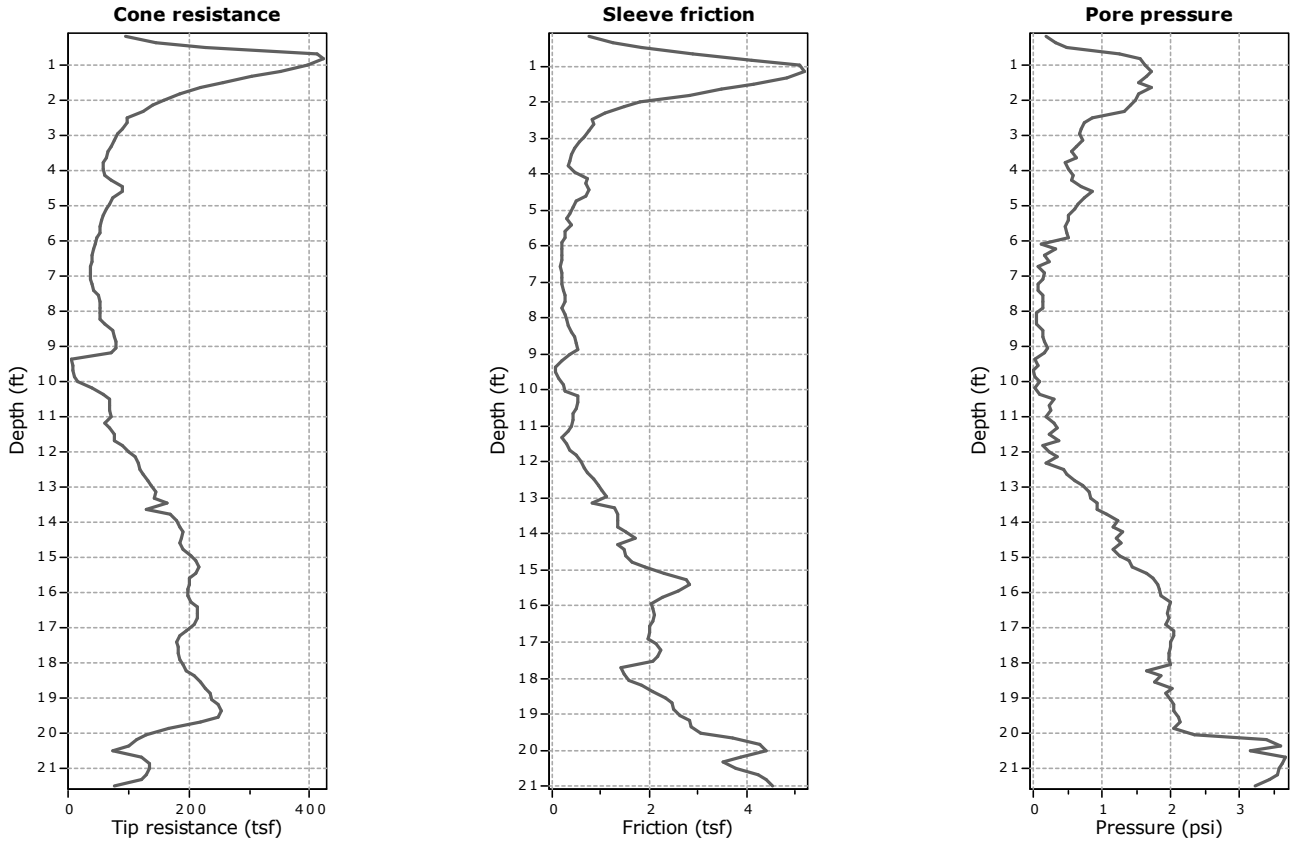
Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)
Go: Based on variable alpha using I_c (Robertson, 2009)
Undrained shear strength cone factor for clays, N_{kt}: Auto
OCR factor for clays, N_{kt}: Auto
User defined estimation data
Flat Dilatometer Test data



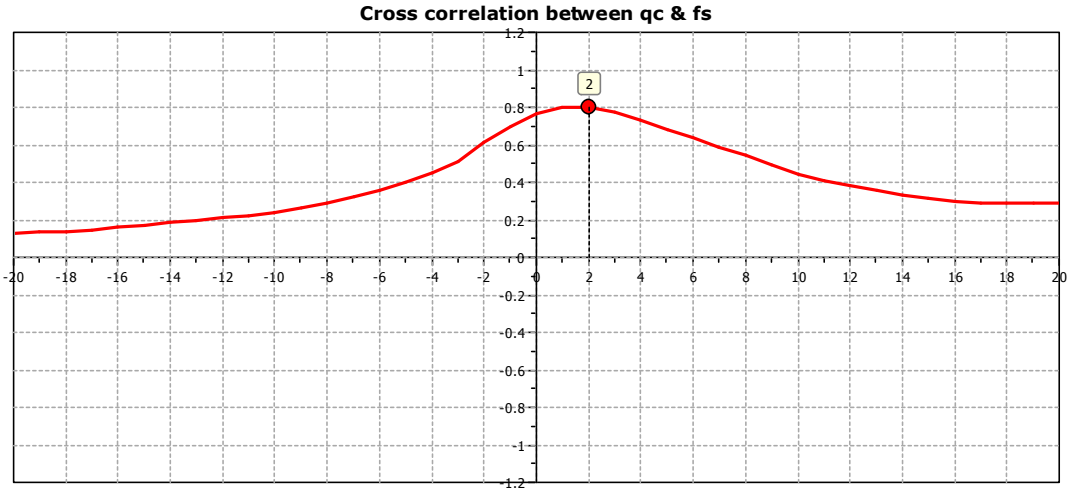
Calculation parameters

Soil Sensitivity factor, N_S: 7.00

User defined estimation data



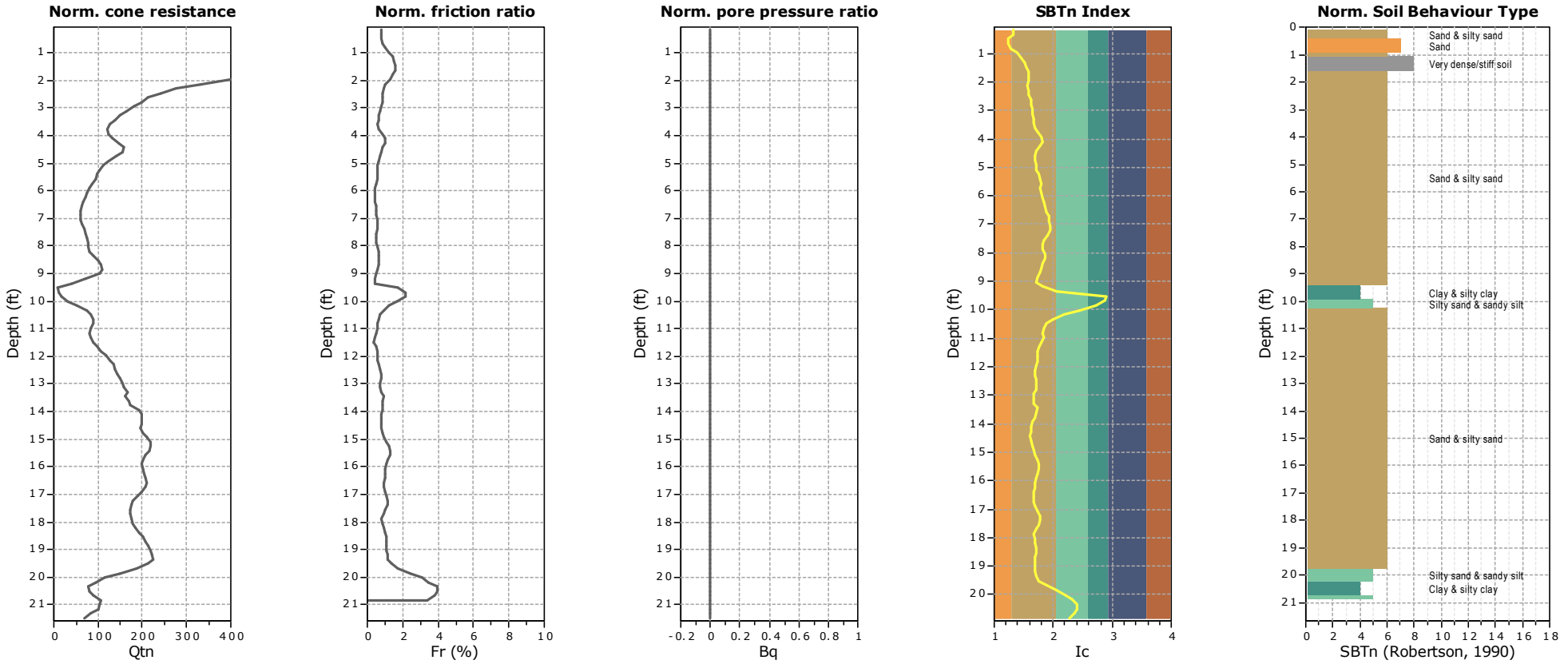
The plot below presents the cross correlation coeficient between the raw qc and fs values (as measured on the field). X axes presents the lag distance (one lag is the distance between two sucessive CPT measurements).



Stantec

CPT: CPT-07
Total depth: 21.49 ft, Date: 9/25/2018
Surface Elevation: 397.90 ft
Coords: X:0.00, Y:0.00
Cone Type: 15 cm
Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**
Location: **Tulare County, CA**



SBTn legend

- 1. Sensitive fine grained
- 2. Organic material
- 3. Clay to silty clay
- 4. Clayey silt to silty clay
- 5. Silty sand to sandy silt
- 6. Clean sand to silty sand
- 7. Gravely sand to sand
- 8. Very stiff sand to clayey sand
- 9. Very stiff fine grained

CPT: CPT-07

Total depth: 21.49 ft, Date: 9/25/2018

Surface Elevation: 397.90 ft

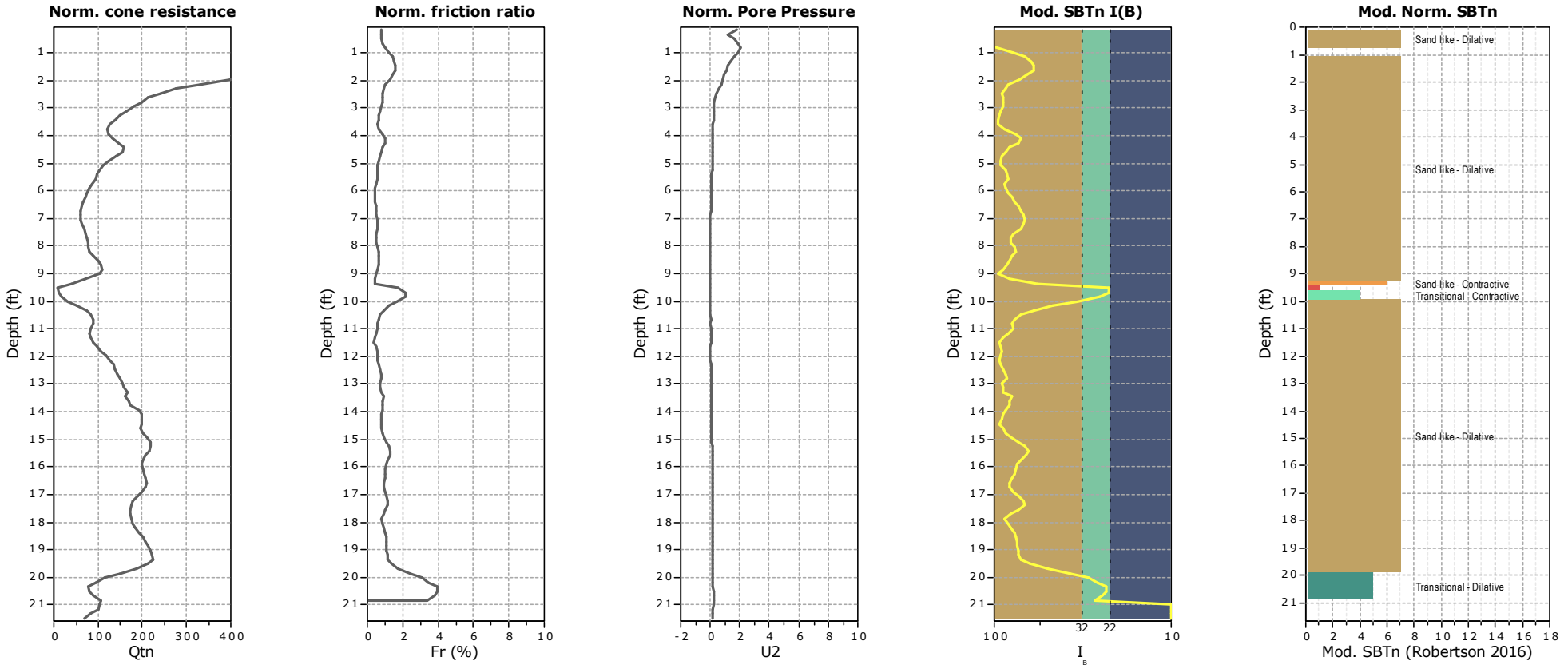
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Mod. SBTn legend

- 1. CCS: ClayLike - Contractive, Sensitive
- 2. CC: Clay-like - Contractive
- 3. CD: Clay-Like: Dilative
- 4. TC: Transitional - Contractive
- 5. TD: Transitional - Dilative
- 6. SC: Sand-like - Contractive
- 7. SD: Sand-like - Dilative

Stantec

CPT: CPT-07

Total depth: 21.49 ft, Date: 9/25/2018

Surface Elevation: 397.90 ft

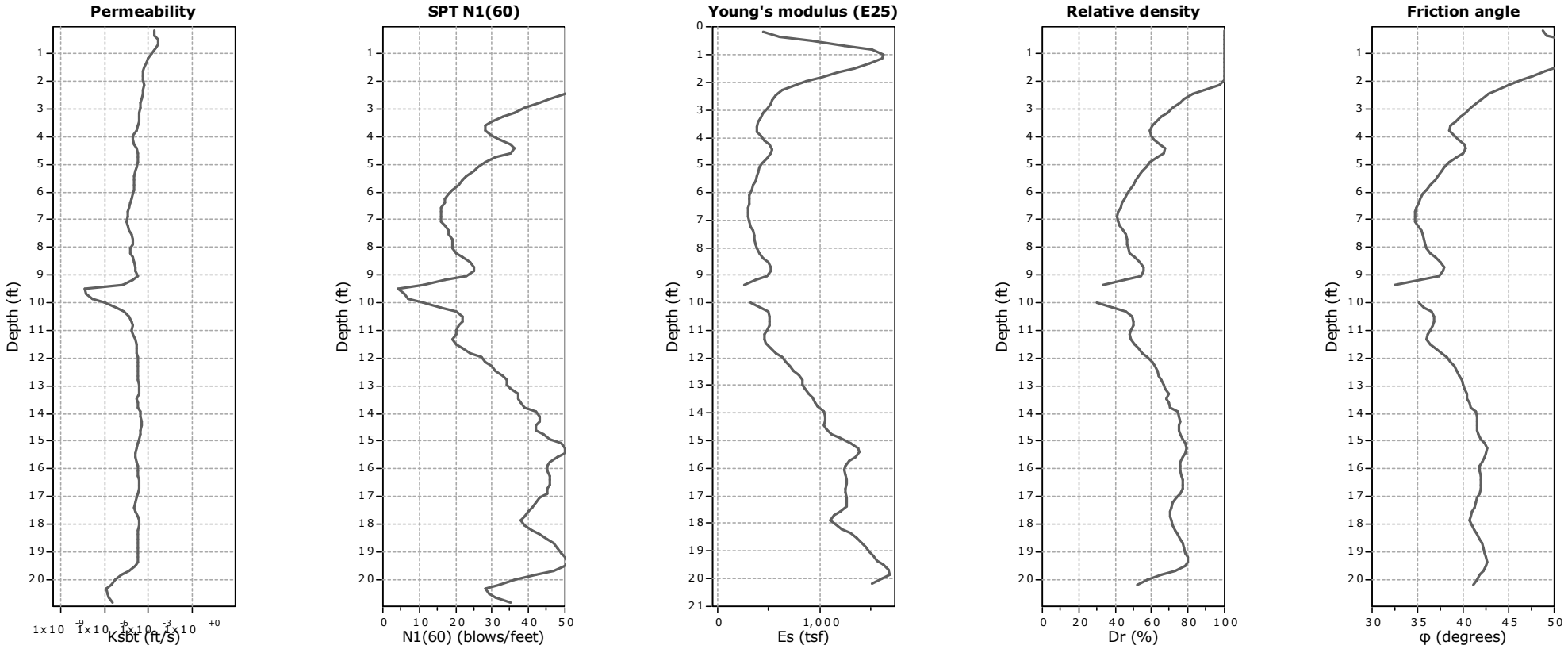
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Permeability: Based on SBT_n

SPT N_{60}: Based on I_c and q_t

Young's modulus: Based on variable alpha using I_c (Robertson, 2009)

Relative desnisty constant, C_{Dr}: 350.0

Phi: Based on Kulhawy & Mayne (1990)

User defined estimation data

CPT: CPT-07

Total depth: 21.49 ft, Date: 9/25/2018

Surface Elevation: 397.90 ft

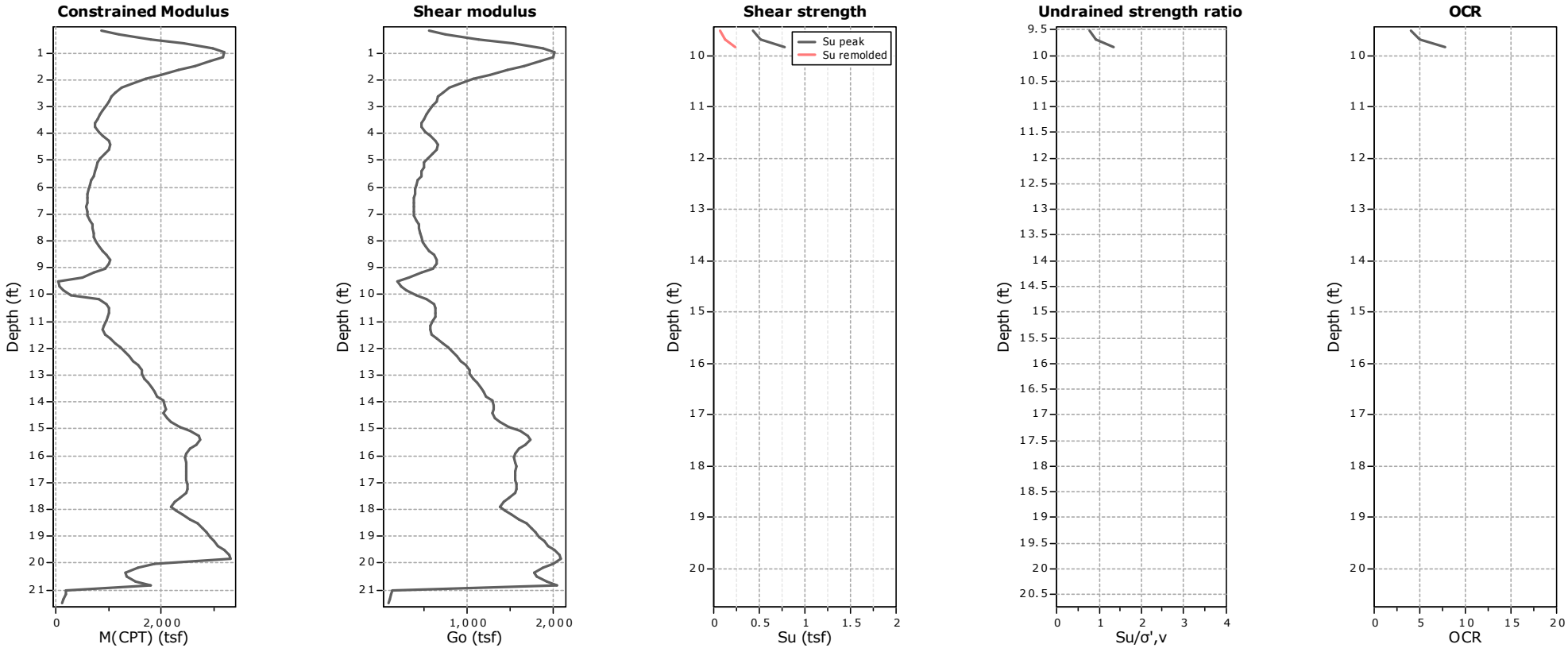
Coords: X:0.00, Y:0.00

Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**



Calculation parameters

Constrained modulus: Based on variable alpha using I_c and Q_{tn} (Robertson, 2009)

Go: Based on variable alpha using I_c (Robertson, 2009)

Undrained shear strength cone factor for clays, N_{kt}: Auto

OCR factor for clays, N_{kt}: Auto

User defined estimation data

Flat Dilatometer Test data

CPT: CPT-07

Total depth: 21.49 ft, Date: 9/25/2018

Surface Elevation: 397.90 ft

Coords: X:0.00, Y:0.00

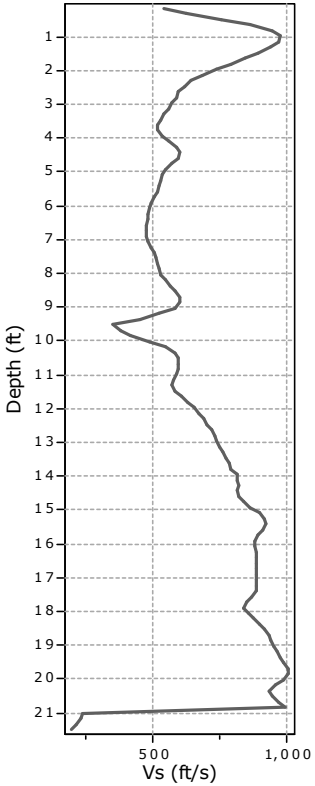
Cone Type: 15 cm

Cone Operator: Middle Earth Geo Testing

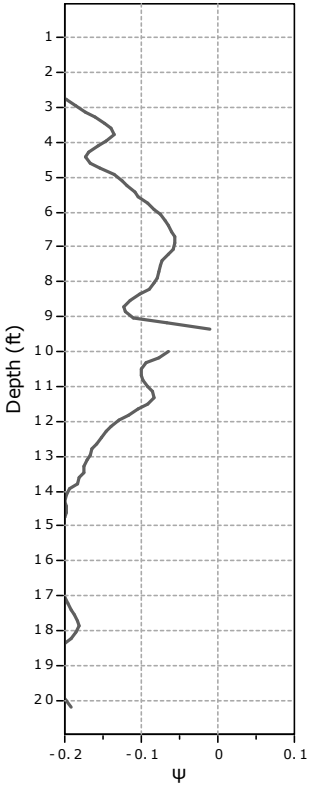
Project: **Friant Kern Canal Capacity Correction Project**

Location: **Tulare County, CA**

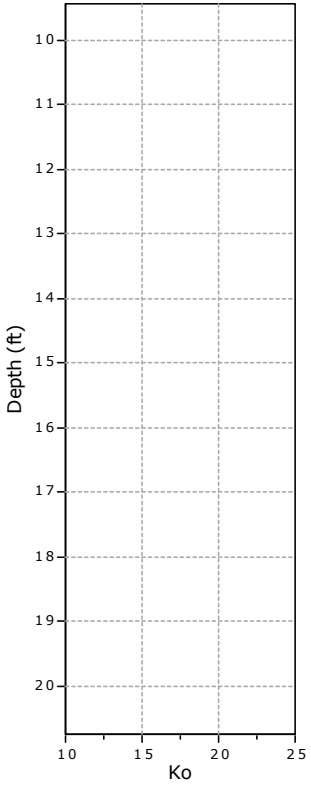
Shear Wave velocity



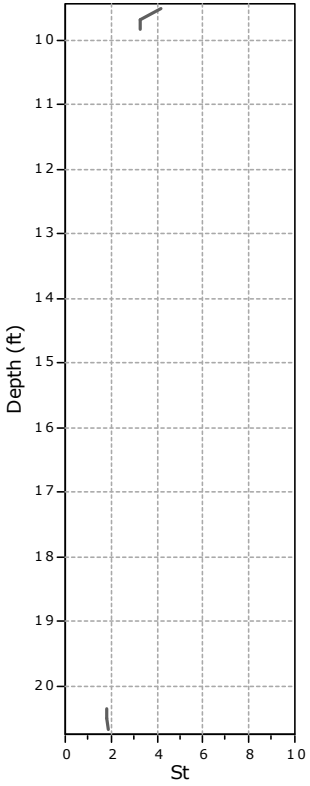
State parameter



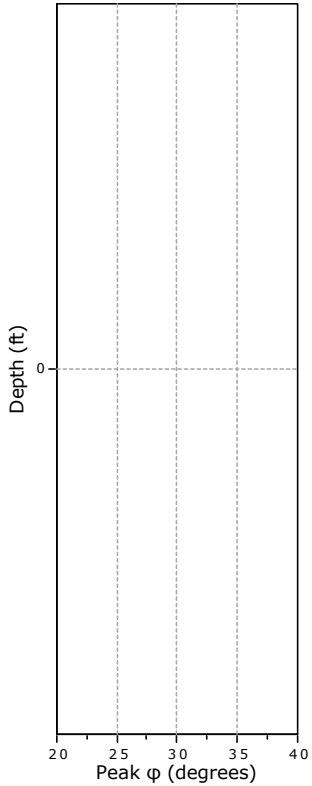
In-situ stress ratio



Soil sensitivity



Effective friction angle



Calculation parameters

Soil Sensitivity factor, N_S: 7.00

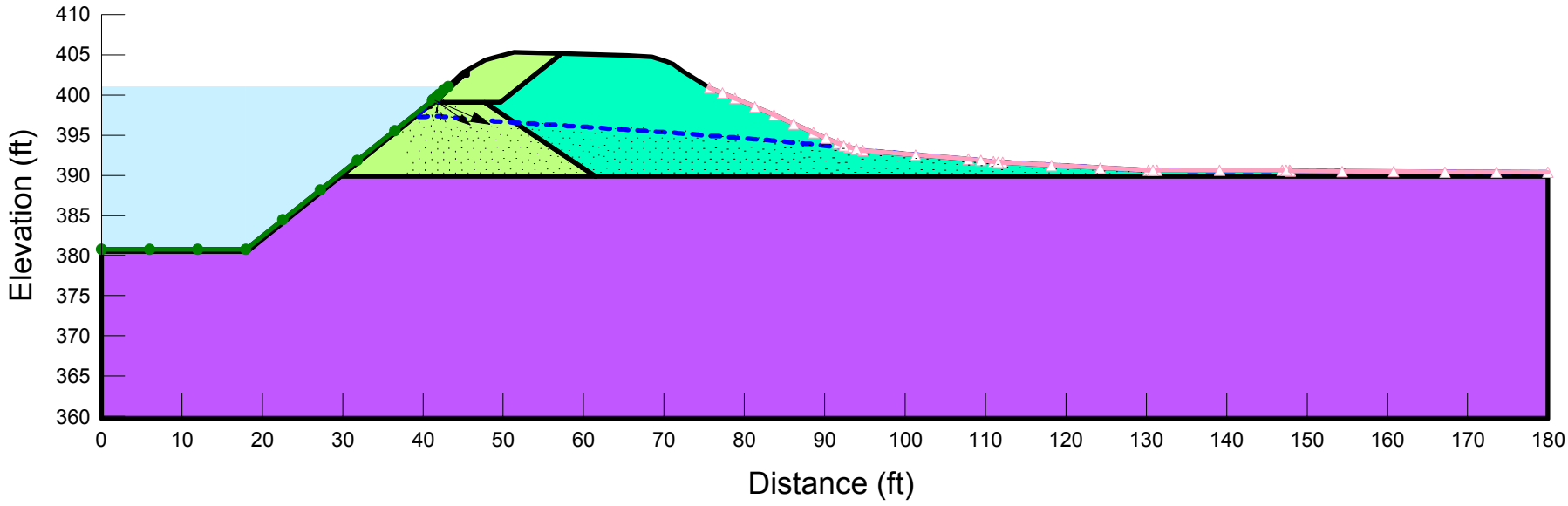
User defined estimation data

APPENDIX D

Seepage Analysis Cross-Sections

Stantec

Color	Name	K-Function	Ky'/Kx' Ratio
	Compacted Fill	Kx - 4e-7 ft/sec	0.5
	Concrete Liner	Kx = 1e-10 ft/sec	0.5
	Native Ground	Kx = 1e-9 ft/sec	0.5
	Uncompacted Fill	Kx = 4e-7 ft/sec	0.5

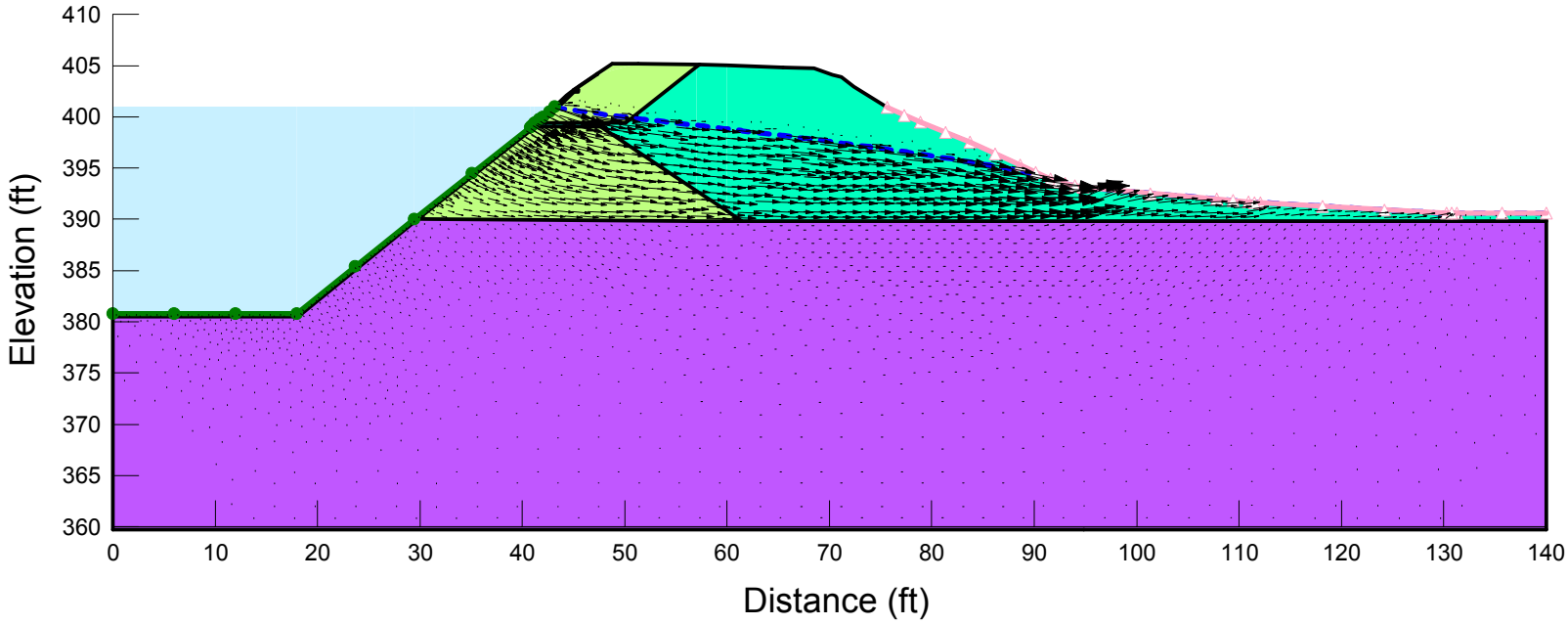


B-2 2 ft. above concrete joint best estimate

B-2 Immediate Repair Milepost 104.1 Best Estimate.gsz

11/30/2018 1:250

Color	Name	K-Function	Ky'/Kx' Ratio
	Compacted Fill	kx = 1e-4 ft/s	0.5
	Concrete Liner	kx = 1e-4 ft/s	0.5
	HDPE Liner	kx = 1e-10 ft/s	0.5
	Native Ground	kx = 1e-5 ft/s	0.5
	Uncompacted Fill	kx = 1e-4 ft/s	0.5

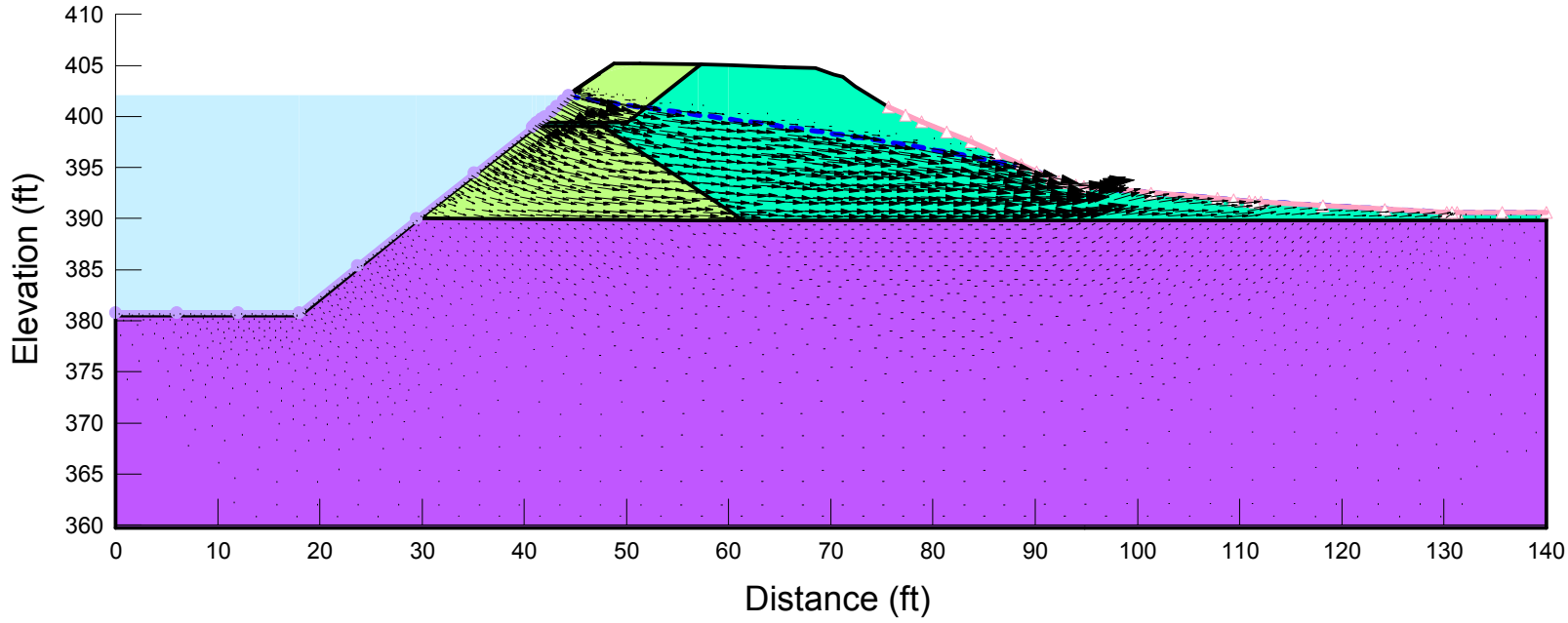


B-2 2 ft. above concrete joint calibrated

B-2 Immediate Repair Milepost 104.1.gsz

11/27/2018 1:220

Color	Name	K-Function	Ky'/Kx' Ratio
	Compacted Fill	kx = 1e-4 ft/s	0.5
	Concrete Liner	kx = 1e-4 ft/s	0.5
	HDPE Liner	kx = 1e-10 ft/s	0.5
	Native Ground	kx = 1e-5 ft/s	0.5
	Uncompacted Fill	kx = 1e-4 ft/s	0.5



B-2 2 ft. below HDPE calibrated

B-2 Immediate Repair Milepost 104.1.gsz

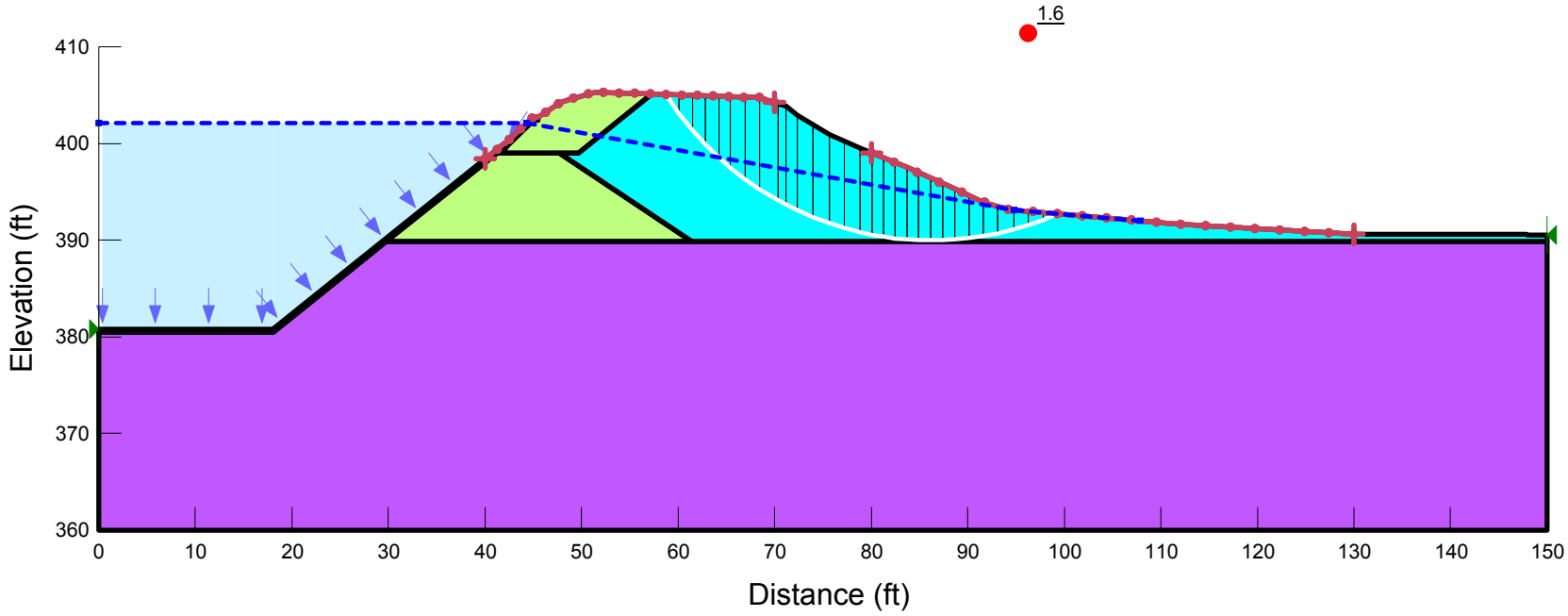
11/27/2018 1:220

APPENDIX E

Slope Stability Analyses and Cross Sections

Stantec

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	Uncompacted Fill	Mohr-Coulomb	125	50	29

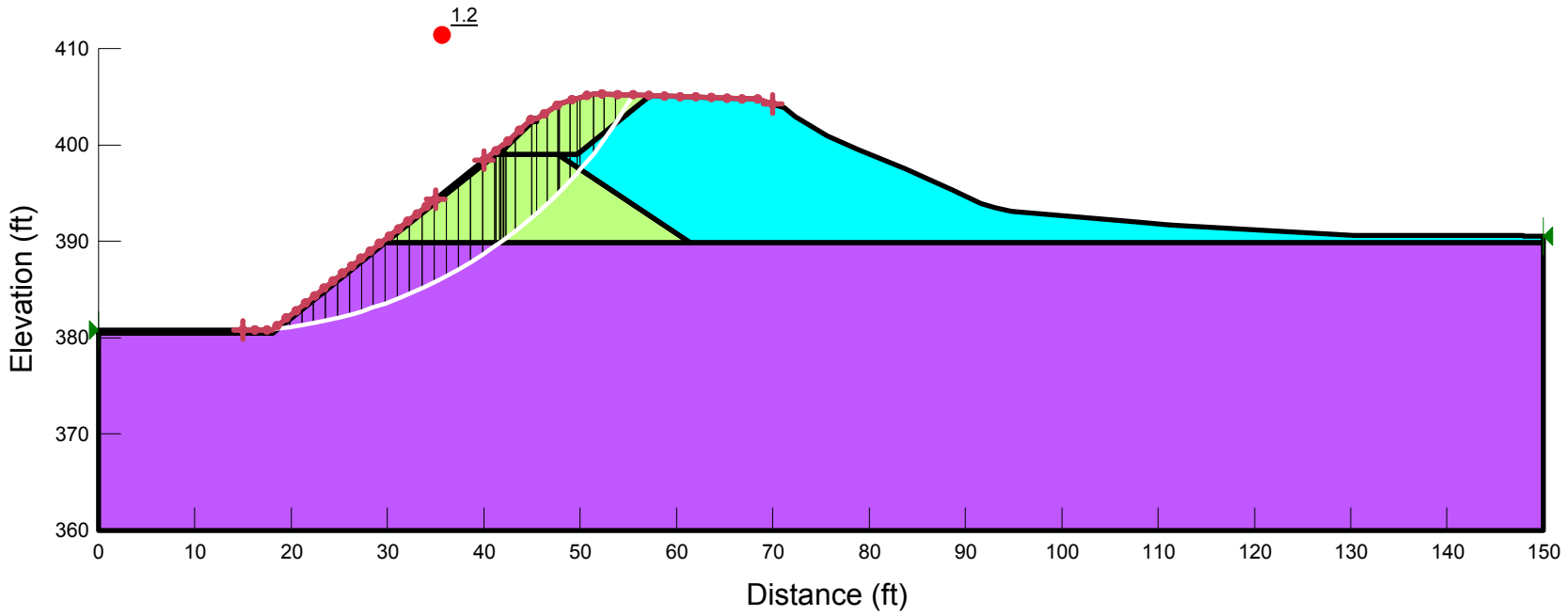


B-2 Downstream Canal 2 ft. below top of HDPE Liner

B-2 Immediate Repair Milepost 104.1.gsz

12/17/2018 1:225

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	Uncompacted Fill	Mohr-Coulomb	125	50	29

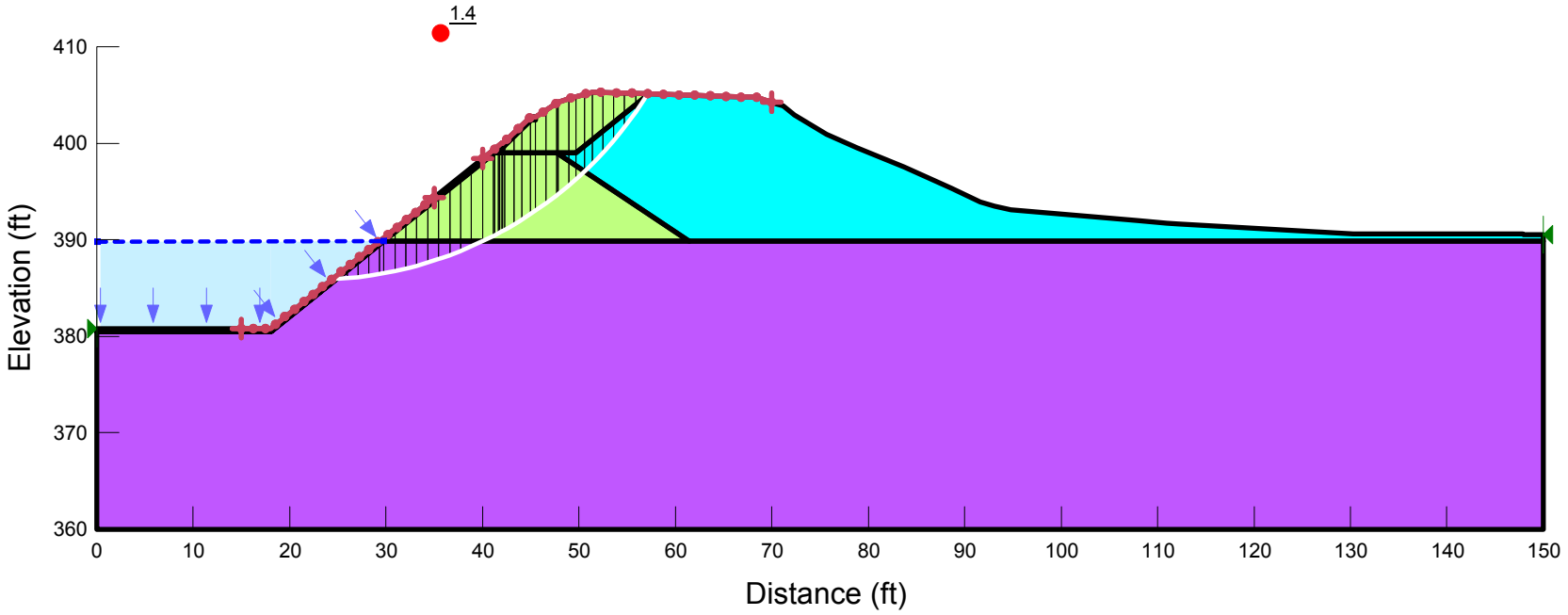


B-2 Upstream Dry

B-2 Immediate Repair Milepost 104.1.gsz

12/17/2018 1:225

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	Uncompacted Fill	Mohr-Coulomb	125	50	29

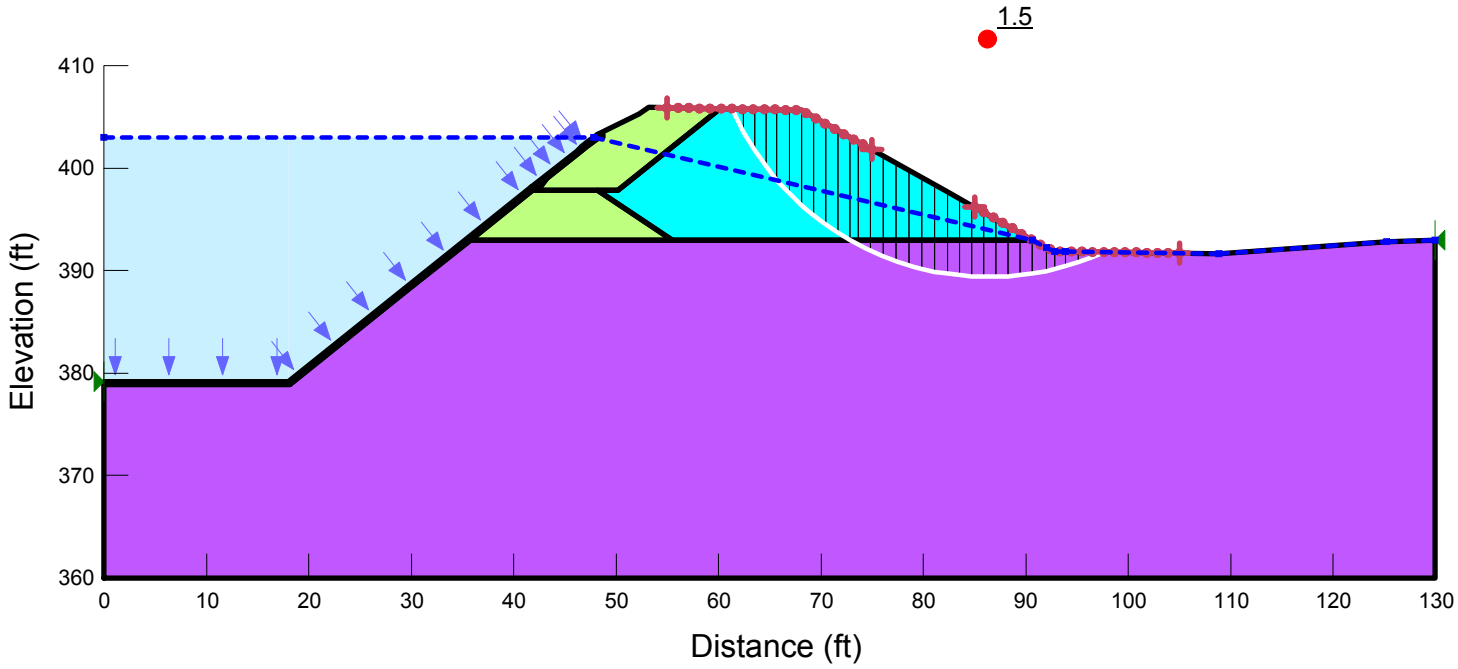


B-2 Upstream Lowered Canal

B-2 Immediate Repair Milepost 104.1.gsz

12/17/2018 1:225

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Compacted Fill	Mohr-Coulomb	125	100	30
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	Uncompacted Fill	Mohr-Coulomb	125	50	29

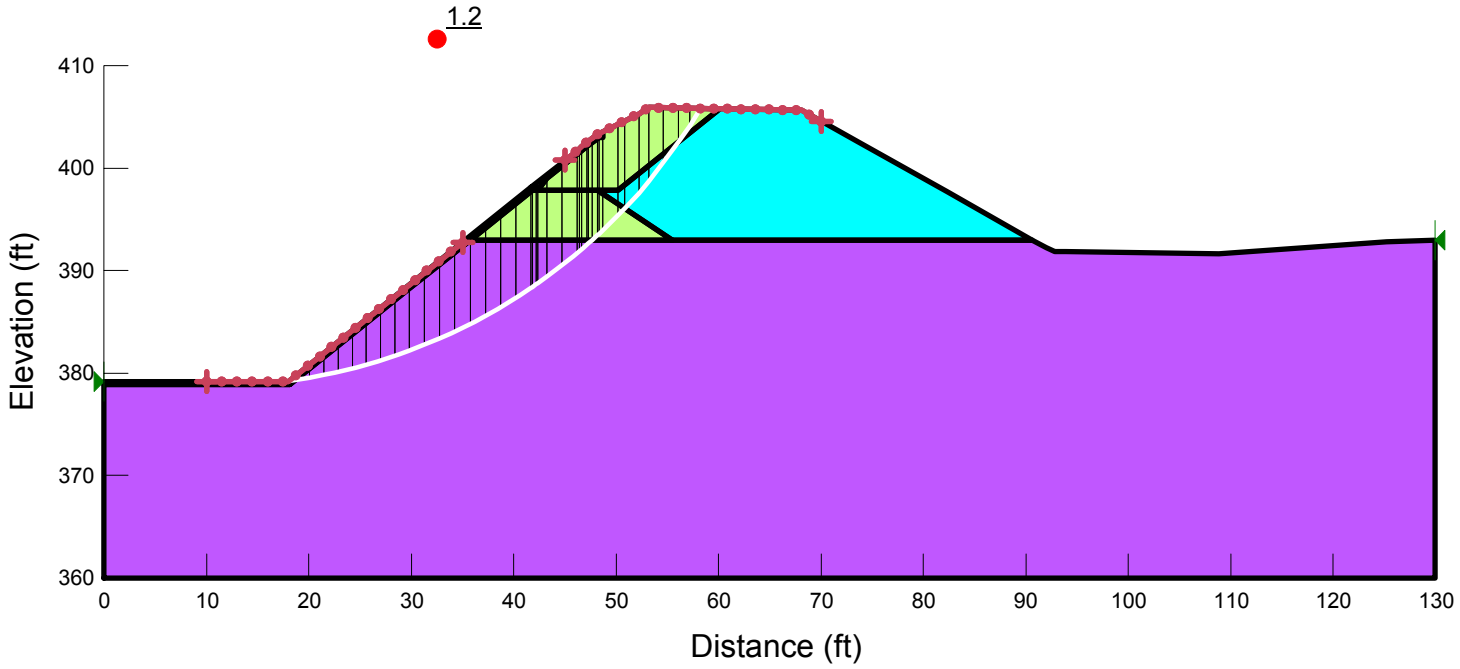


B-3 Downstream WT 2 ft below top HDPE

B-3_Immediate Repair Milepost 106.1.gsz

11/08/2018 1:225

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Compacted Fill	Mohr-Coulomb	125	100	30
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	Uncompacted Fill	Mohr-Coulomb	125	50	29

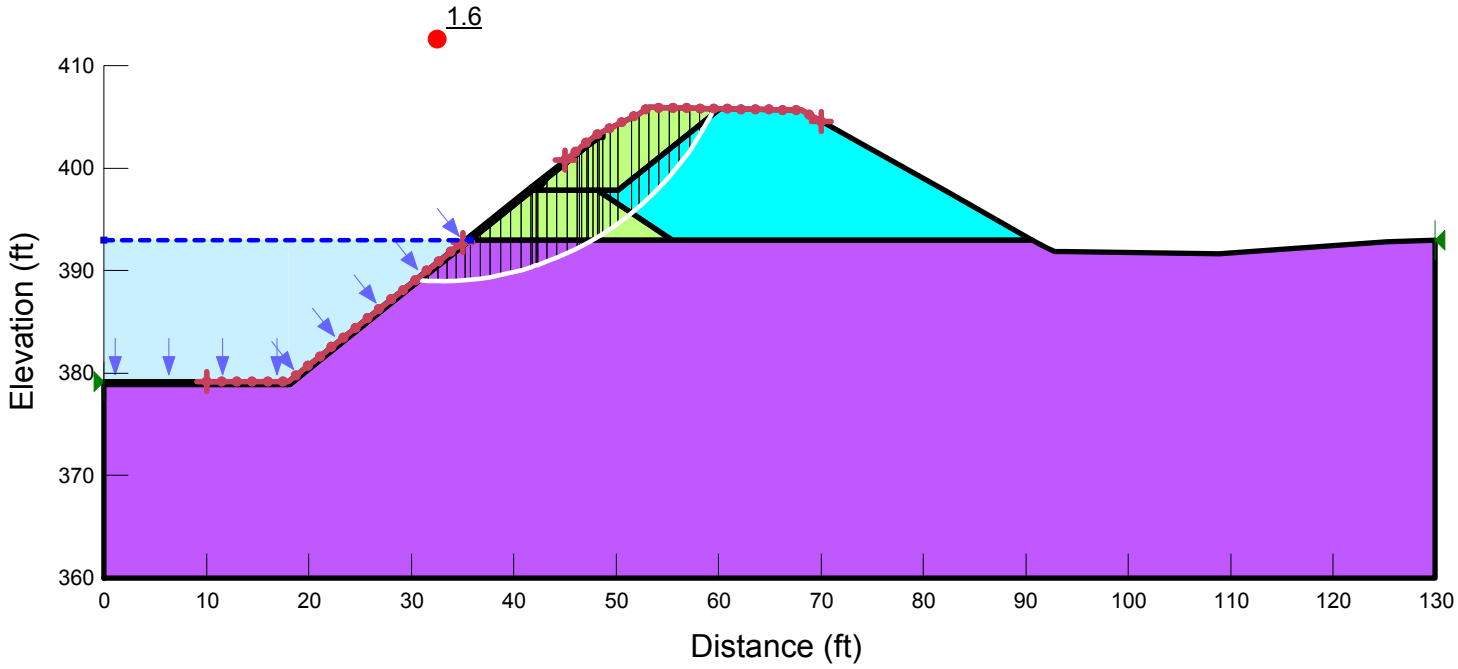


B-3 Upstream Dry

B-3_Immediate Repair Milepost 106.1.gsz

11/08/2018 1:225

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Compacted Fill	Mohr-Coulomb	125	100	30
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	Uncompacted Fill	Mohr-Coulomb	125	50	29

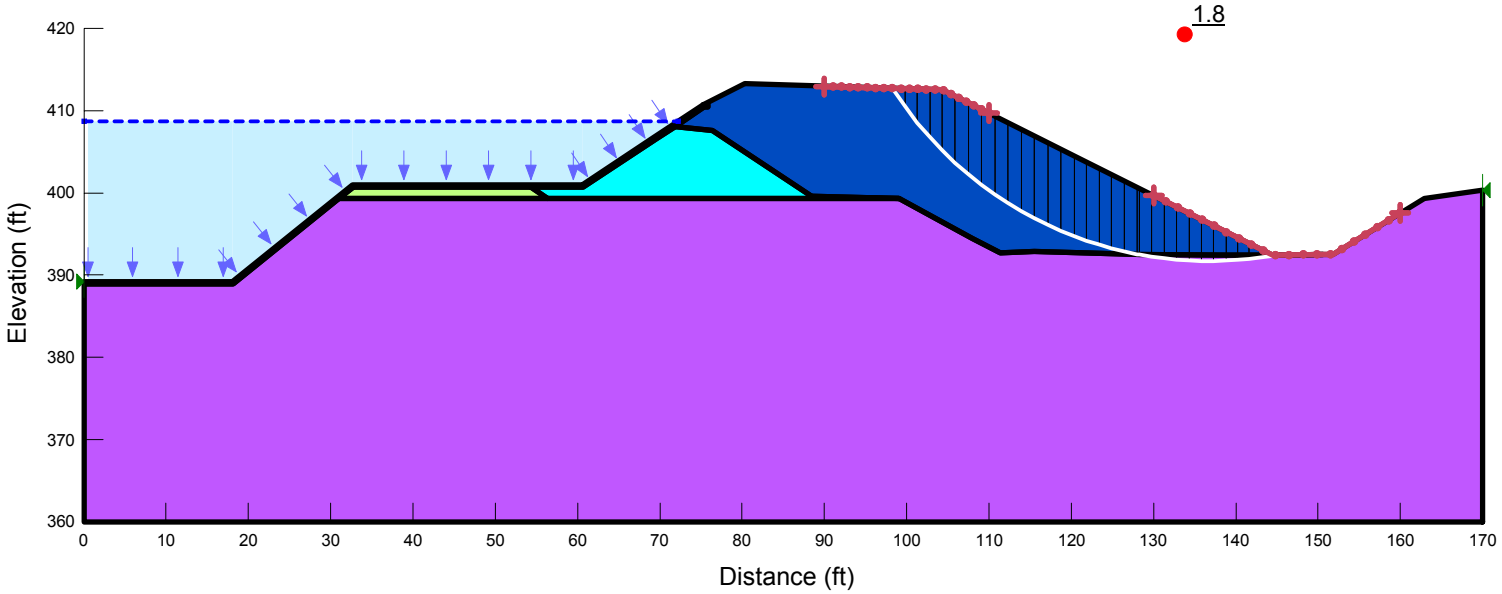


B-3 Upstream Lowered Canal Level

B-3_Immediate Repair Milepost 106.1.gsz

11/08/2018 1:225

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

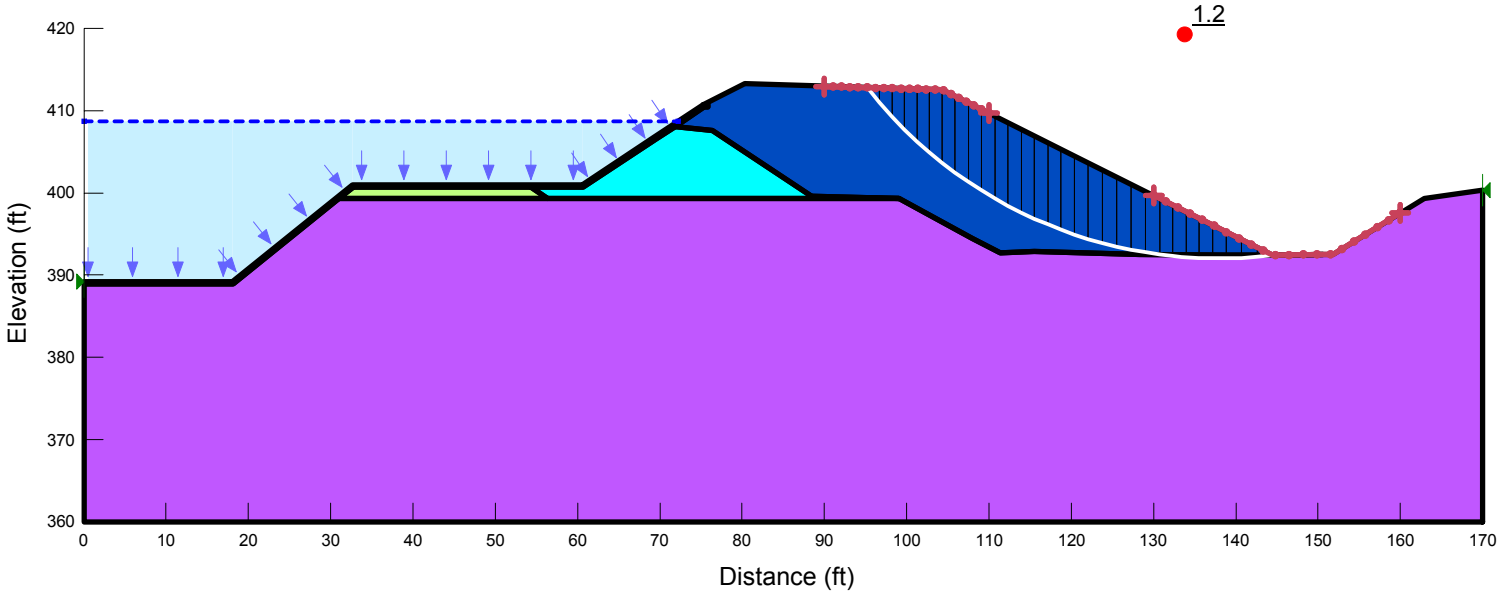


B-1 Downstream Normal

B-1 Milepost 97.5.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

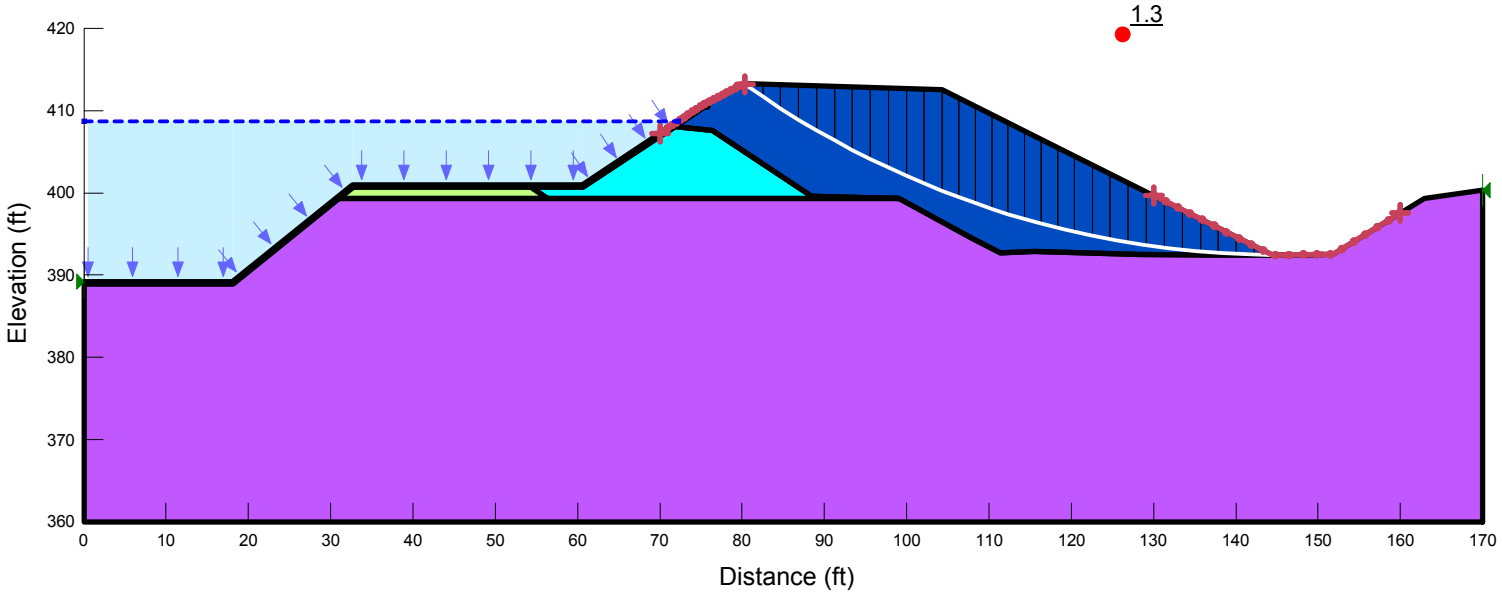


B-1 Seismic Downstream

B-1 Milepost 97.5.gsz

11/06/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

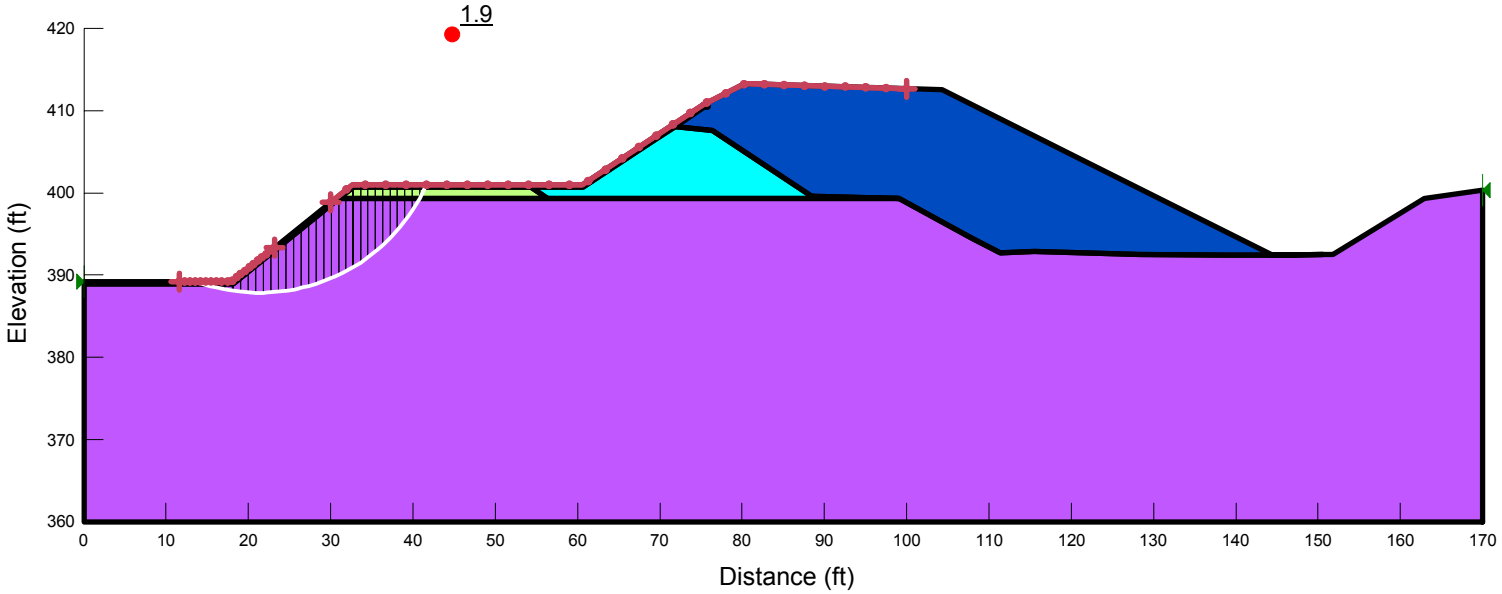


Seismic Downstream Crest Failure Surface

B-1 Milepost 97.5.gsz

11/09/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

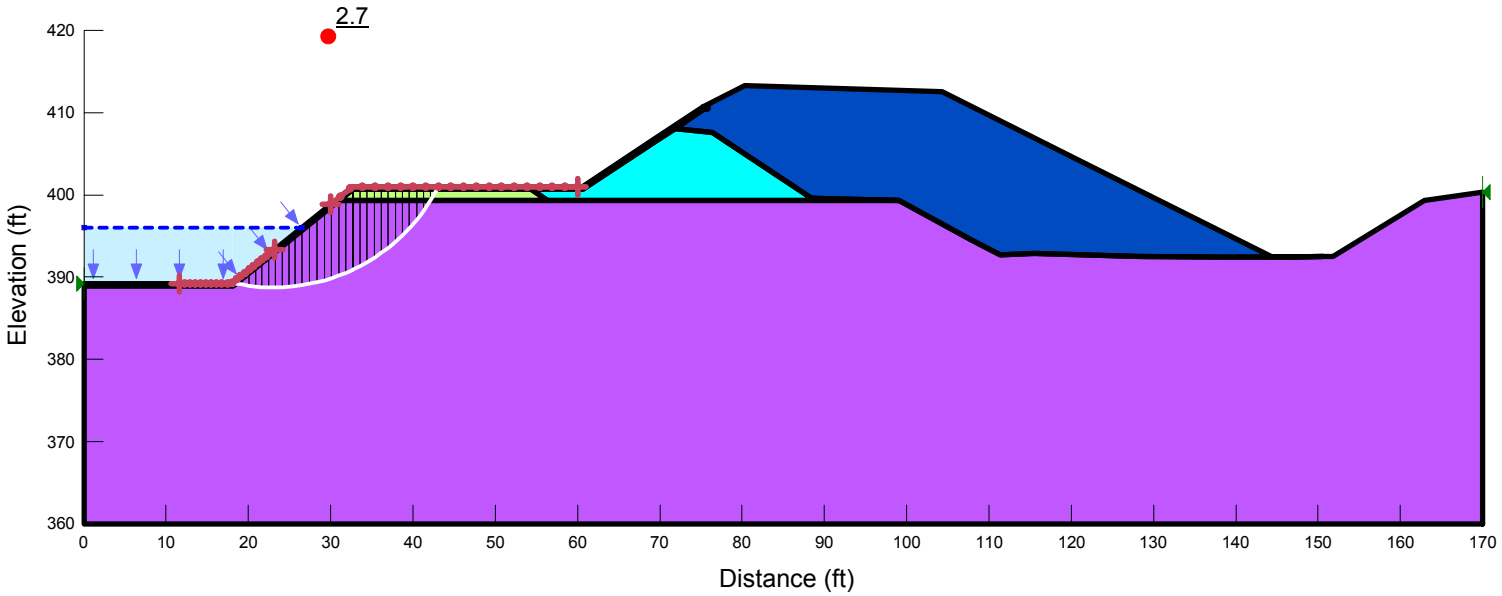


B-1 Upstream Dry

B-1 Milepost 97.5.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

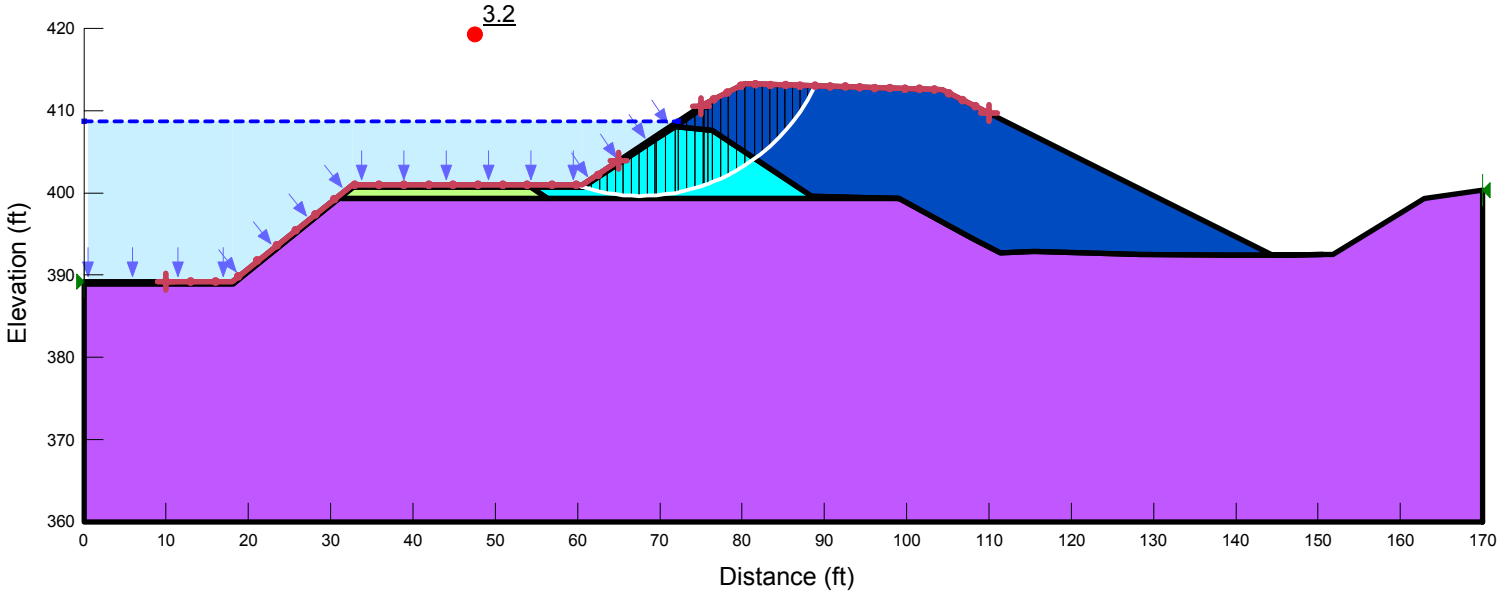


B-1 Upstream EOC Low Water

B-1 Milepost 97.5.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

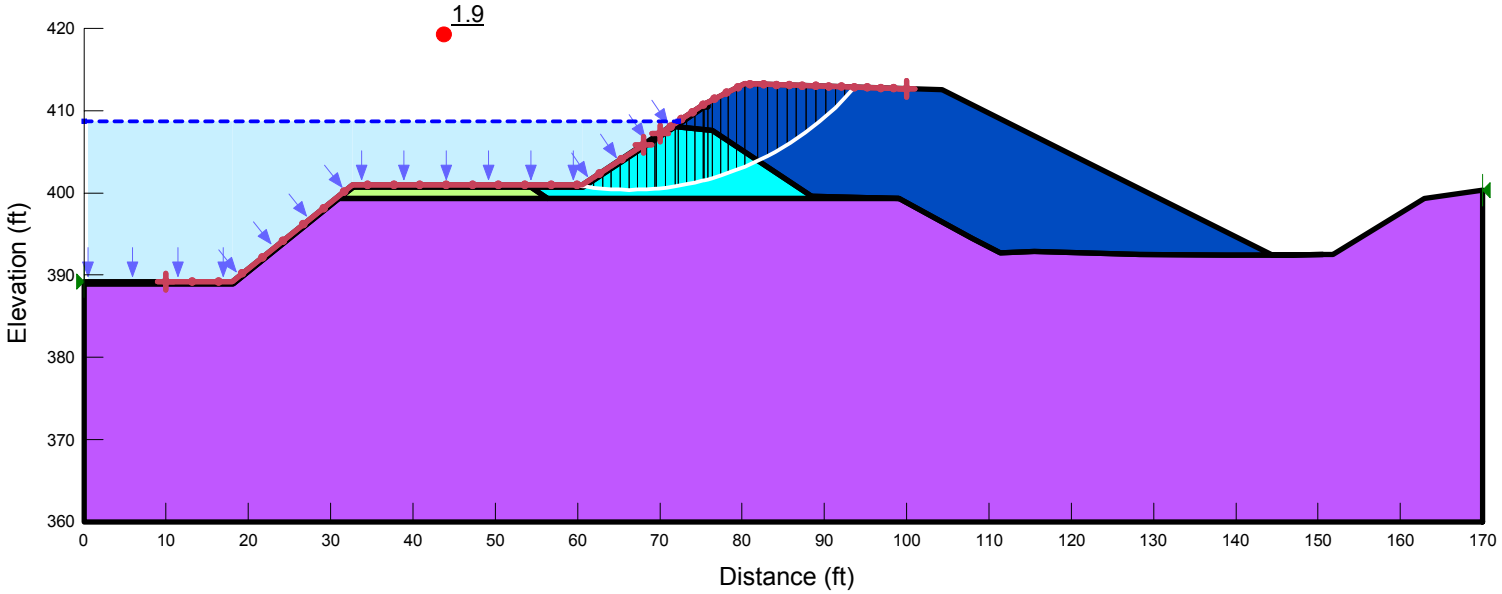


B-1 Upstream Normal

B-1 Milepost 97.5.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

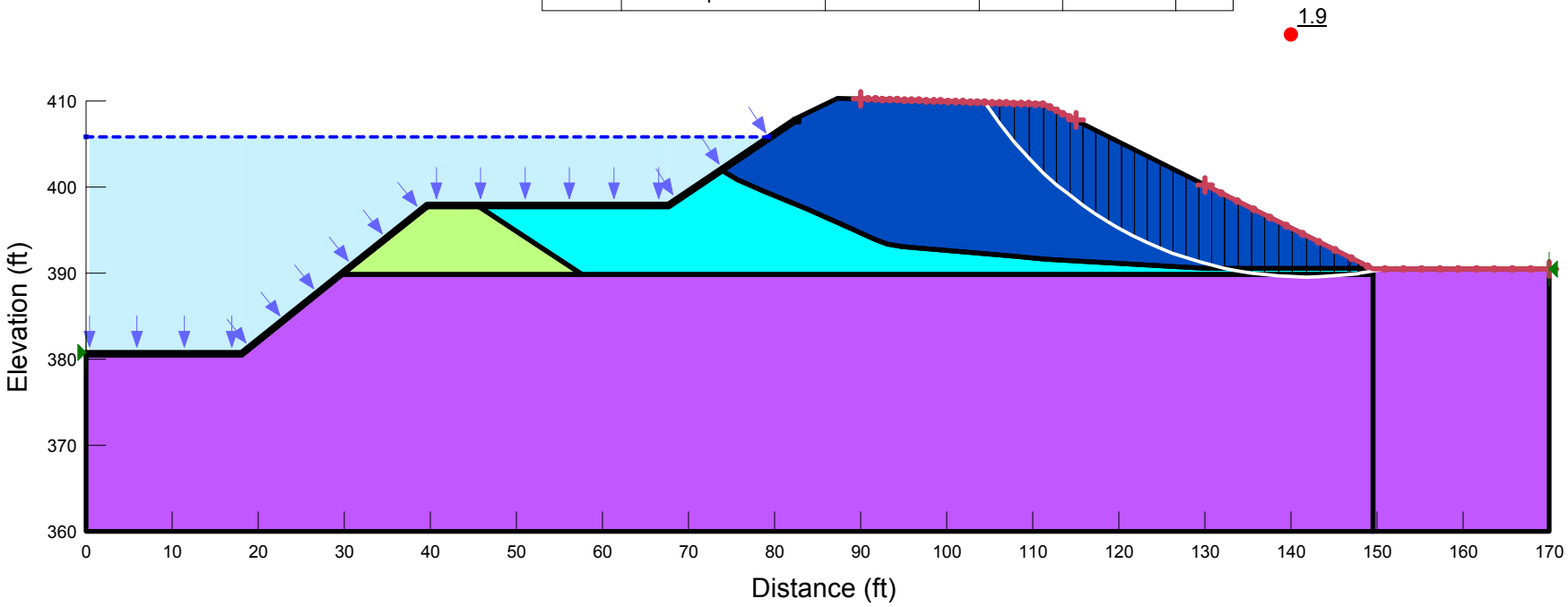


B-1 Upstream Seismic

B-1 Milepost 97.5.gsz

11/06/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

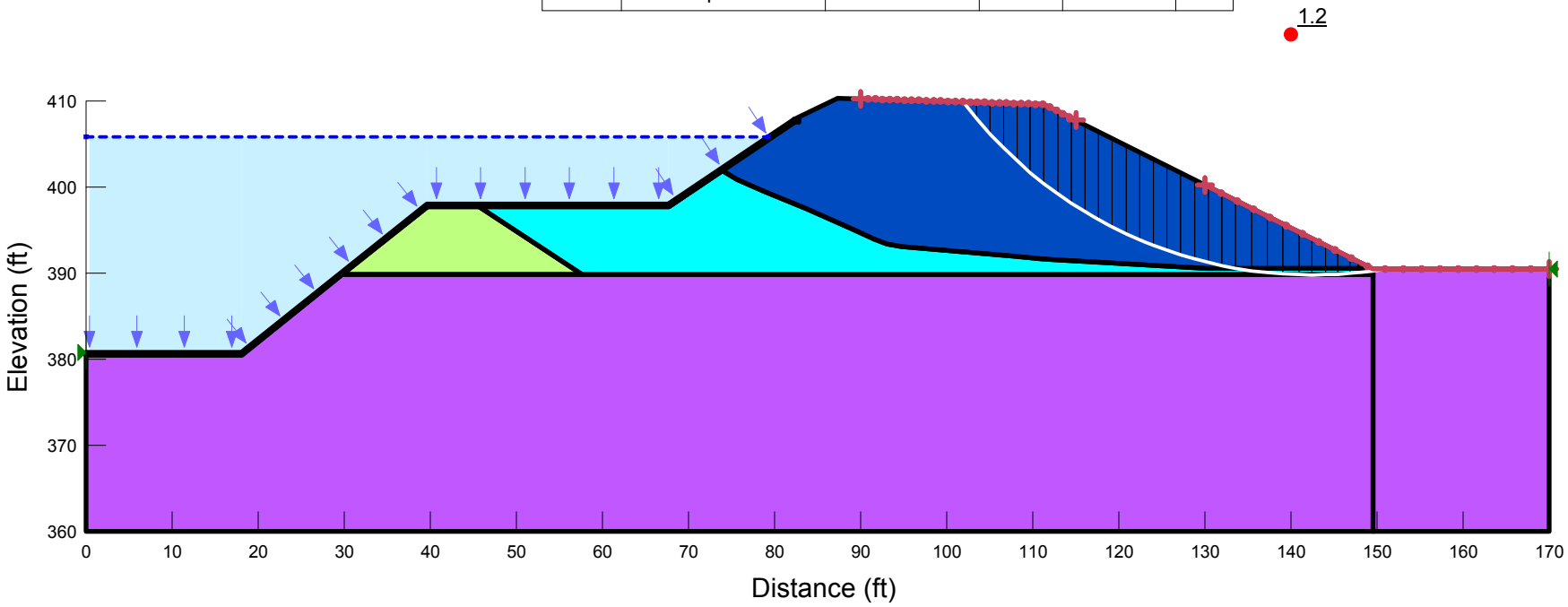


B-2 Downstream Normal

B-2 Milepost 104.1.gsz

11/01/2018 1:240

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30



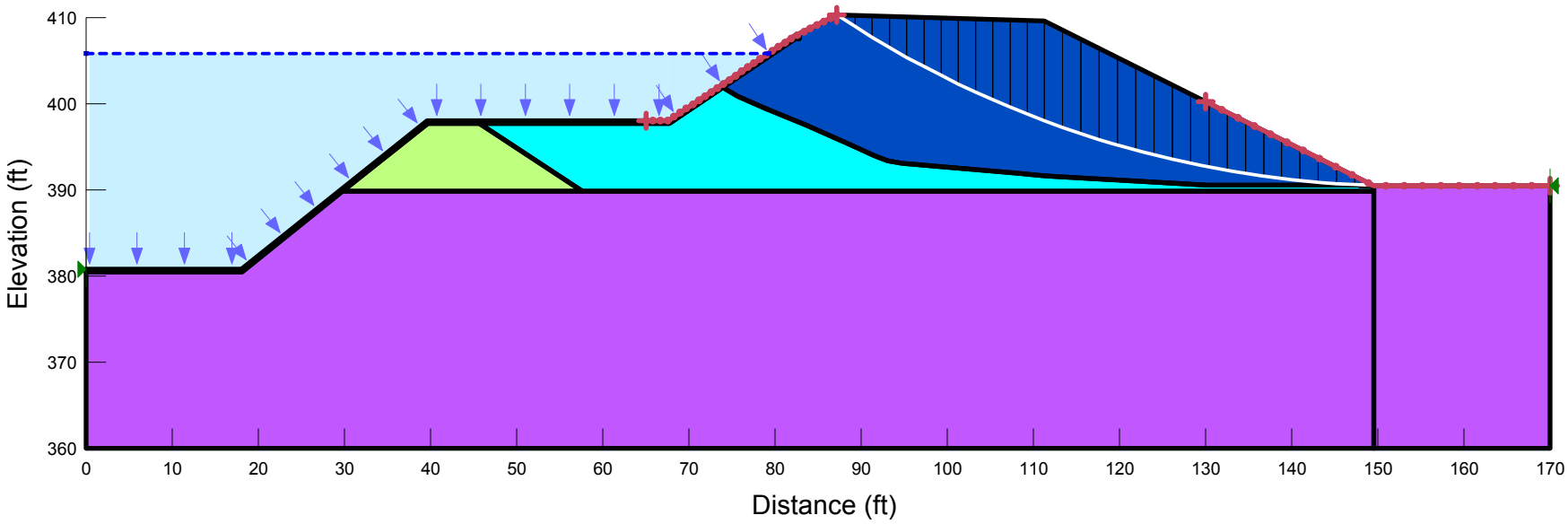
B-2 Downstream Seismic

B-2 Milepost 104.1.gsz

11/01/2018 1:240

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

1.3

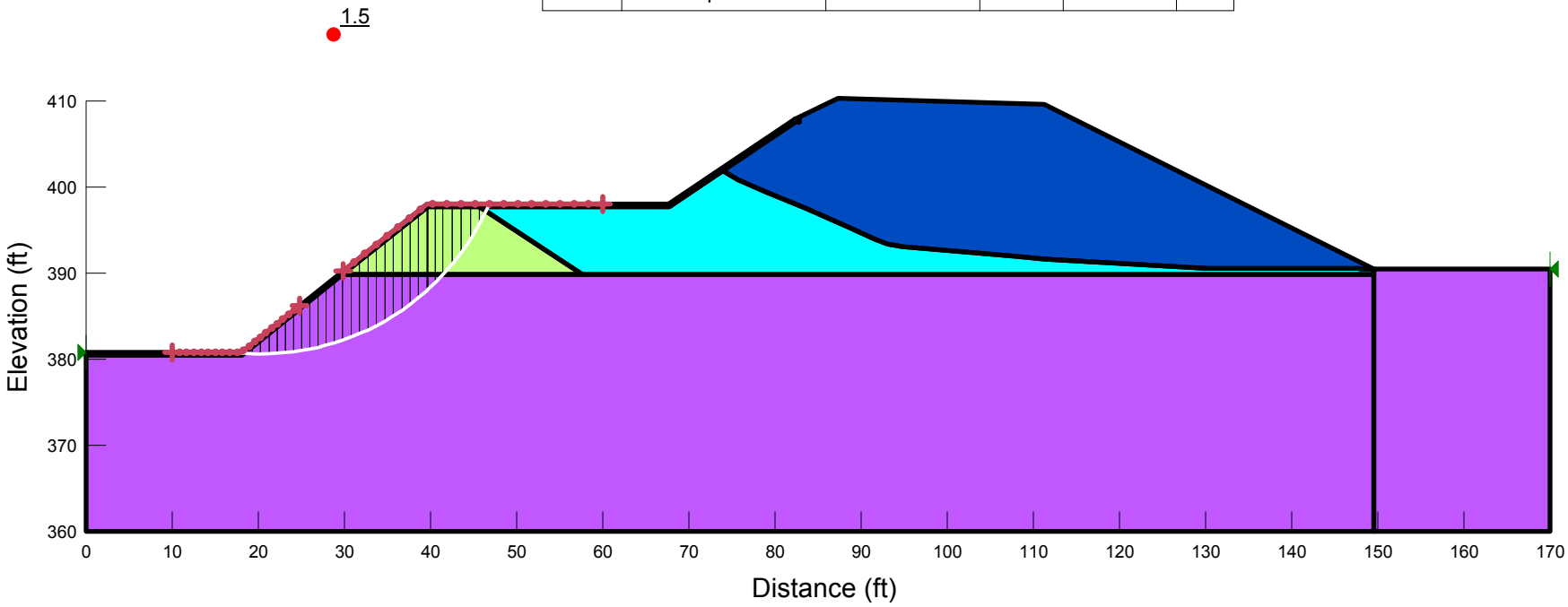


Seismic Downstream Crest Failure Surface

B-2 Milepost 104.1.gsz

11/09/2018 1:240

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

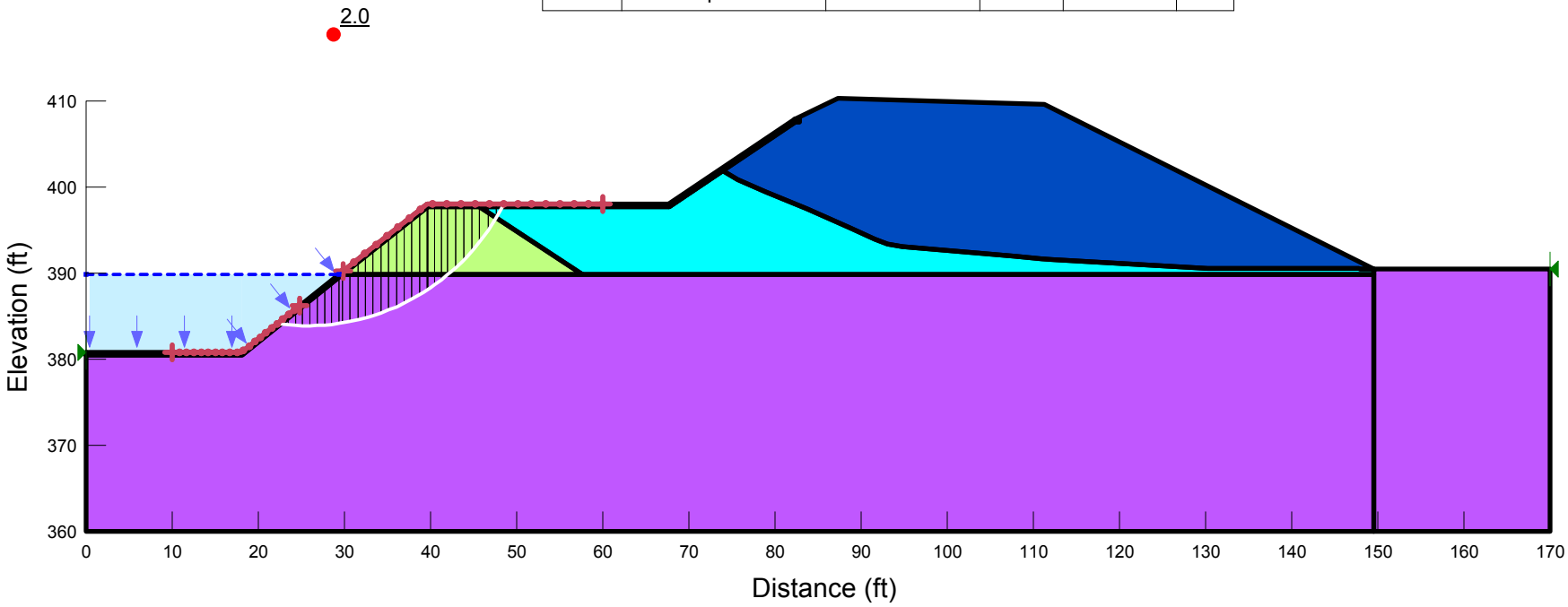


B-2 Upstream Dry

B-2 Milepost 104.1.gsz

11/01/2018 1:240

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

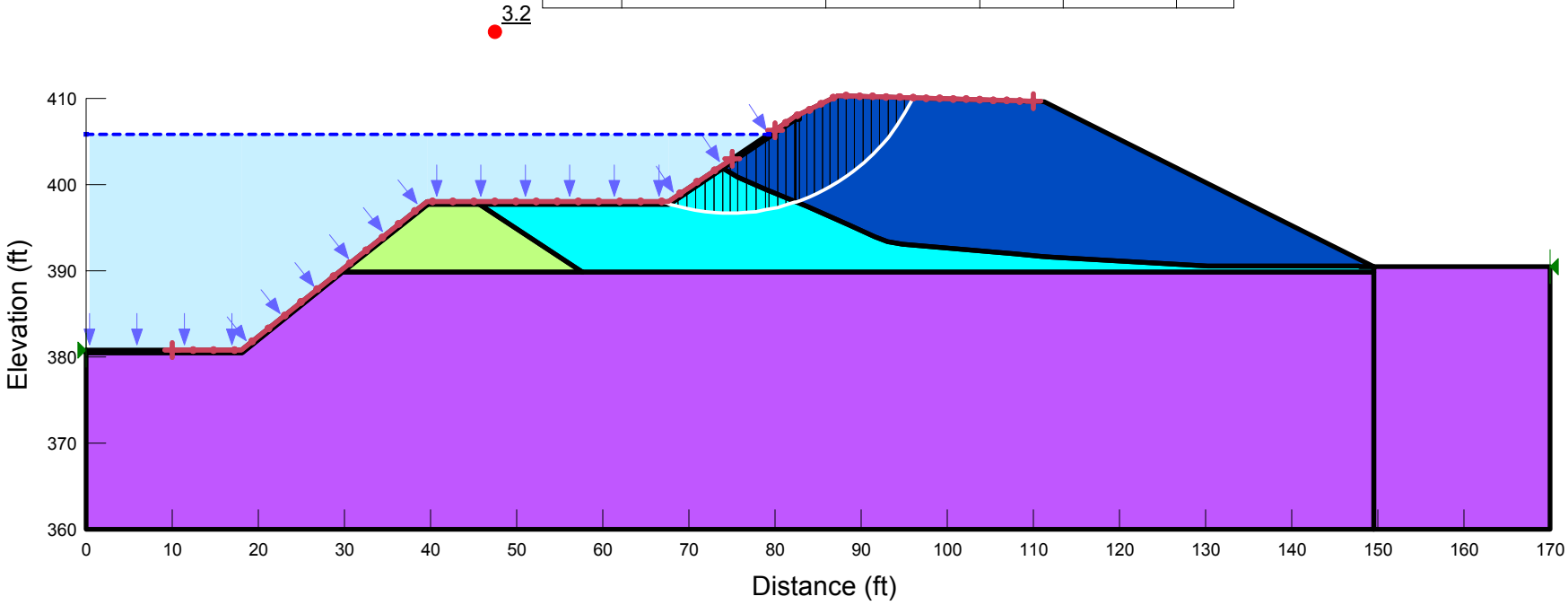


B-2 Upstream EOC Low Water

B-2 Milepost 104.1.gsz

11/01/2018 1:240

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

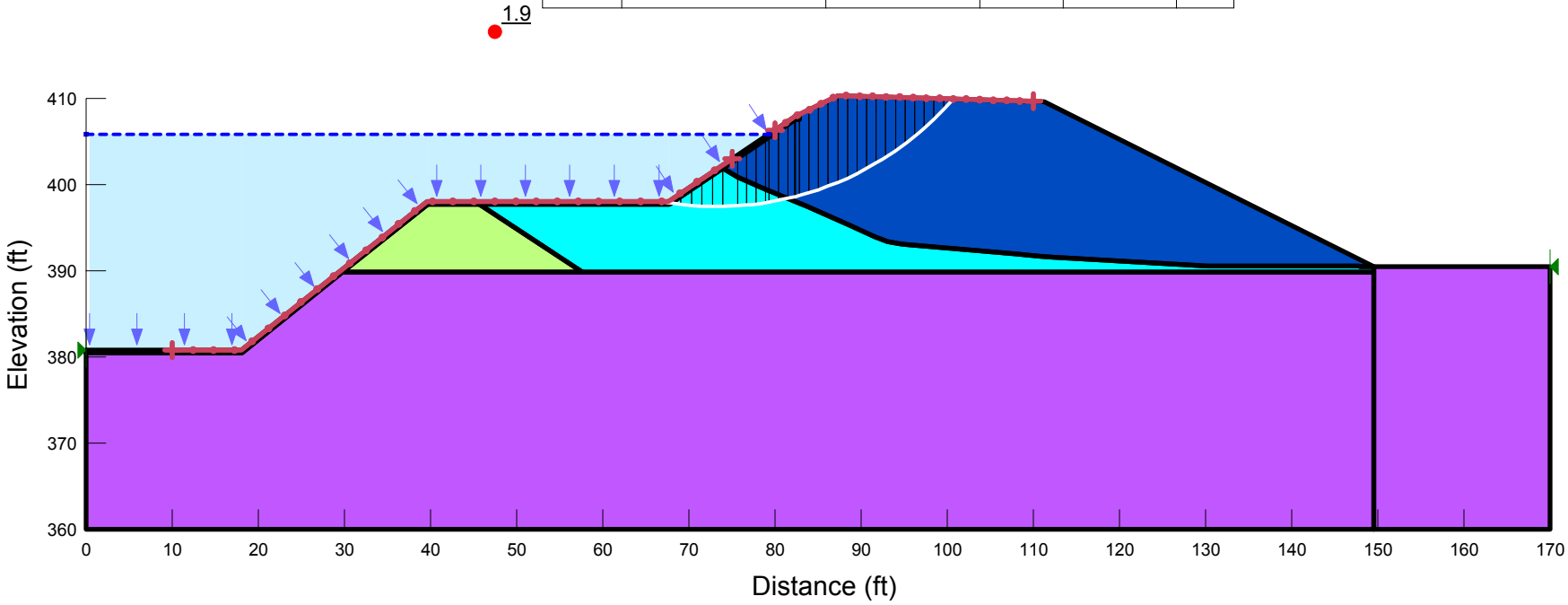


B-2 Upstream Normal

B-2 Milepost 104.1.gsz

11/01/2018 1:240

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

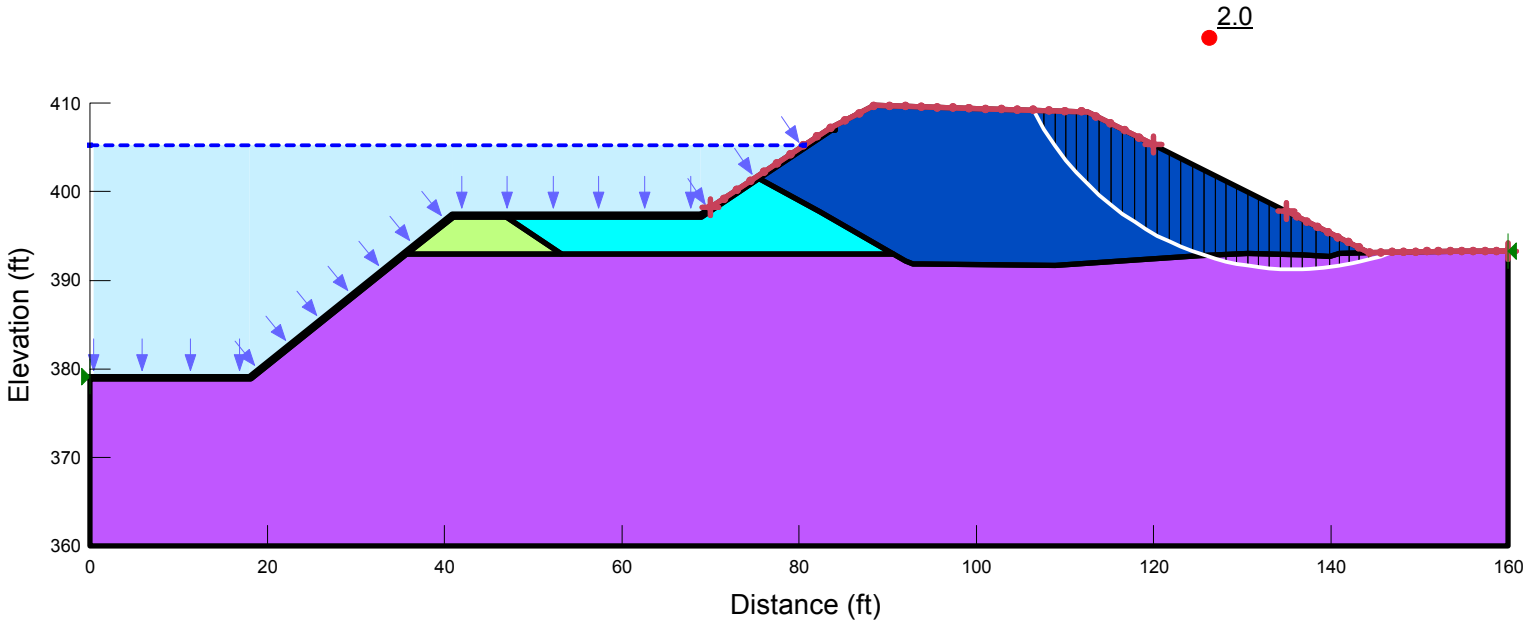


B-2 Upstream Seismic

B-2 Milepost 104.1.gsz

11/01/2018 1:240

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

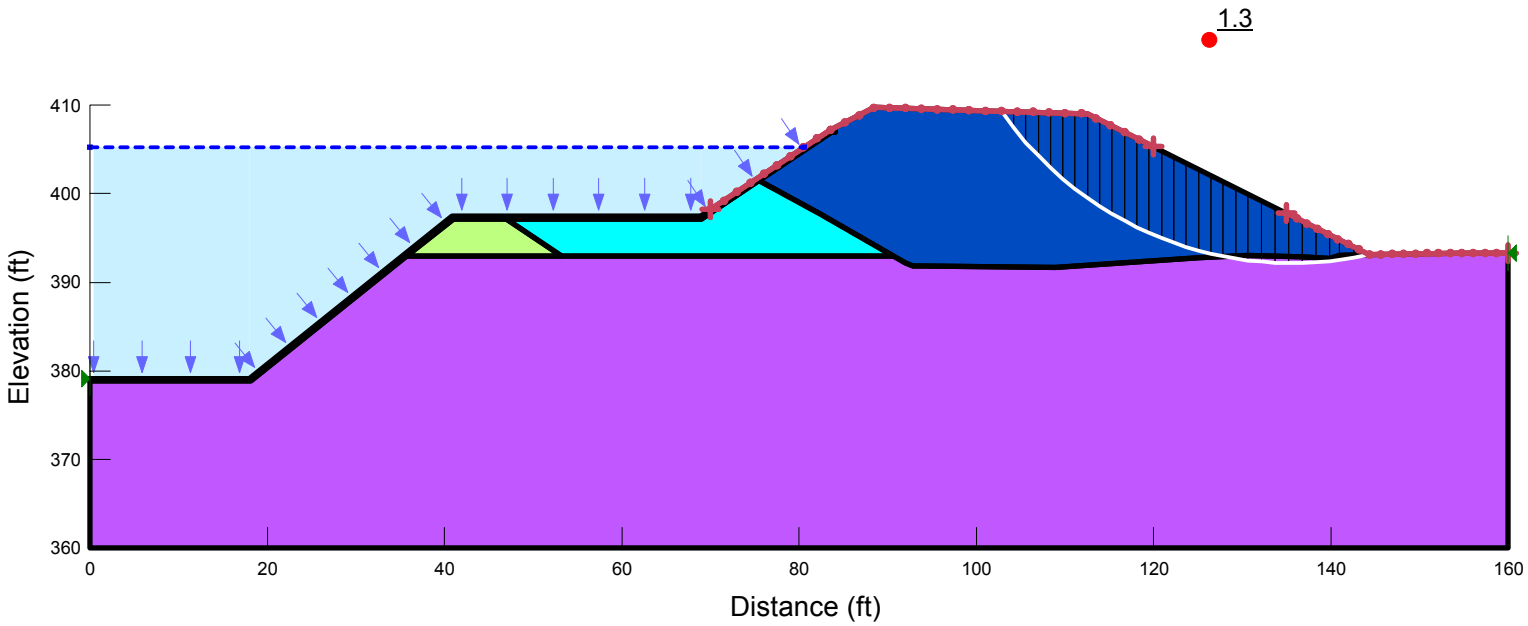


B-3 Downstream Normal

B-3 Milepost 106.1.gsz

12/17/2018 1:260

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

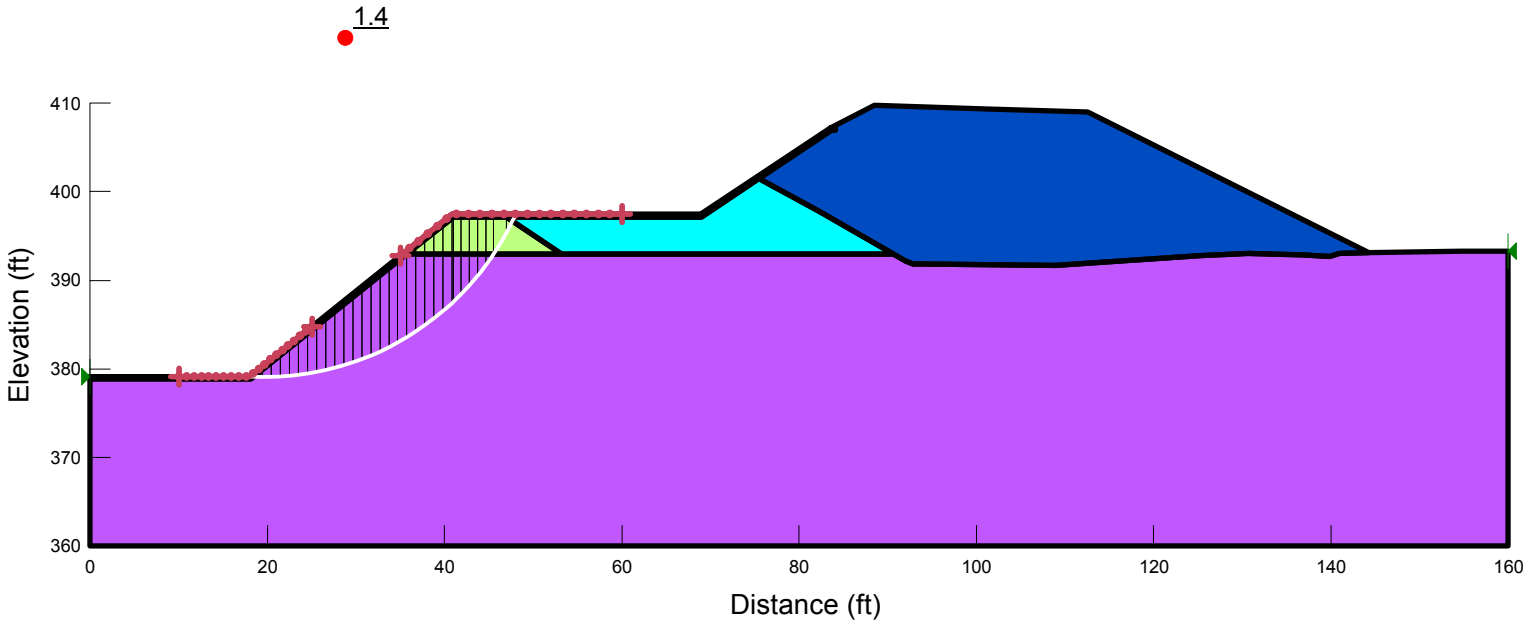


B-3 Downstream Seismic

B-3 Milepost 106.1.gsz

12/17/2018 1:260

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

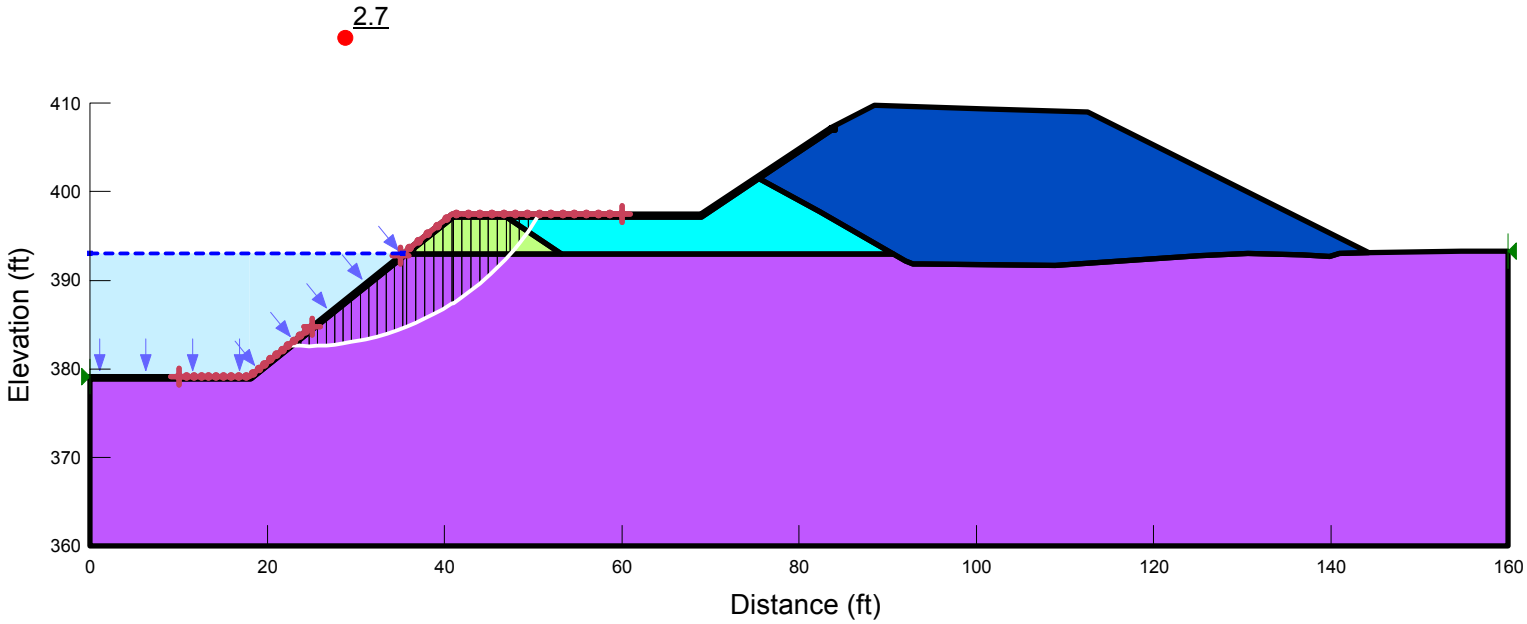


B-3 Upstream Dry

B-3 Milepost 106.1.gsz

12/17/2018 1:260

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

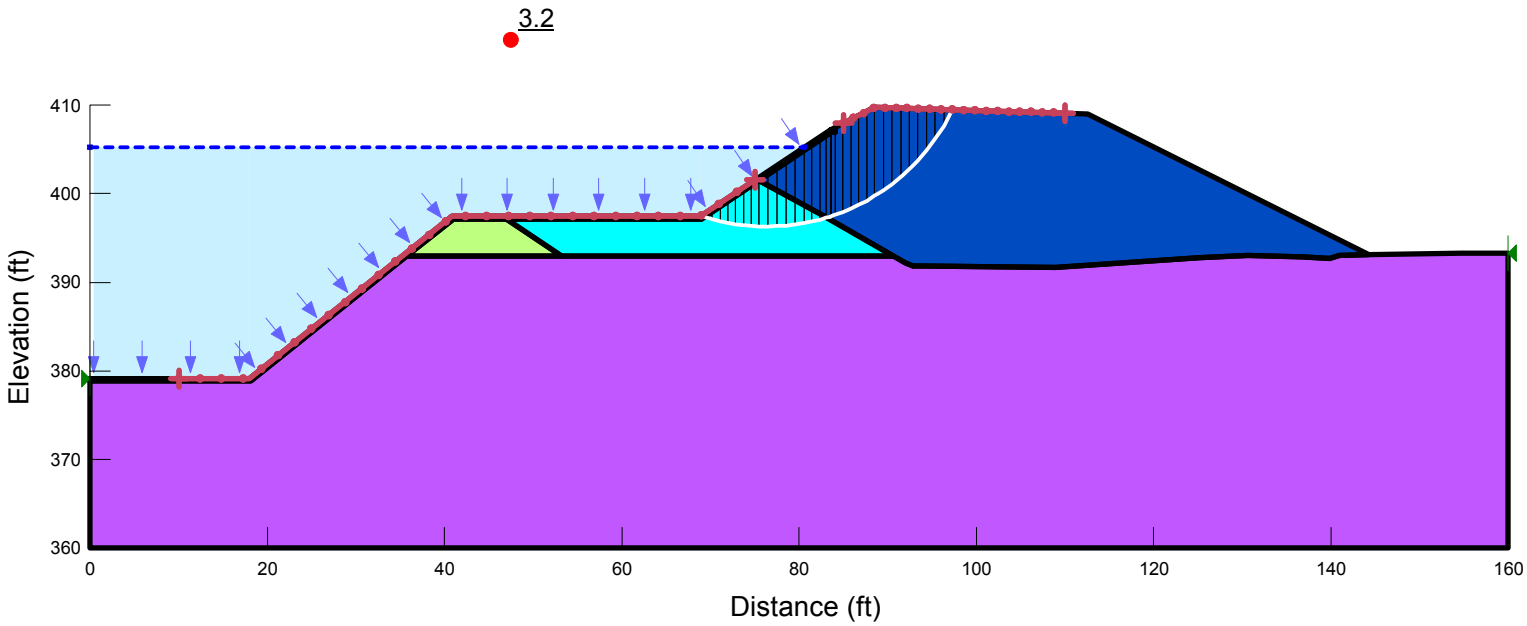


B-3 Upstream EOC Low Water

B-3 Milepost 106.1.gsz

12/17/2018 1:260

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

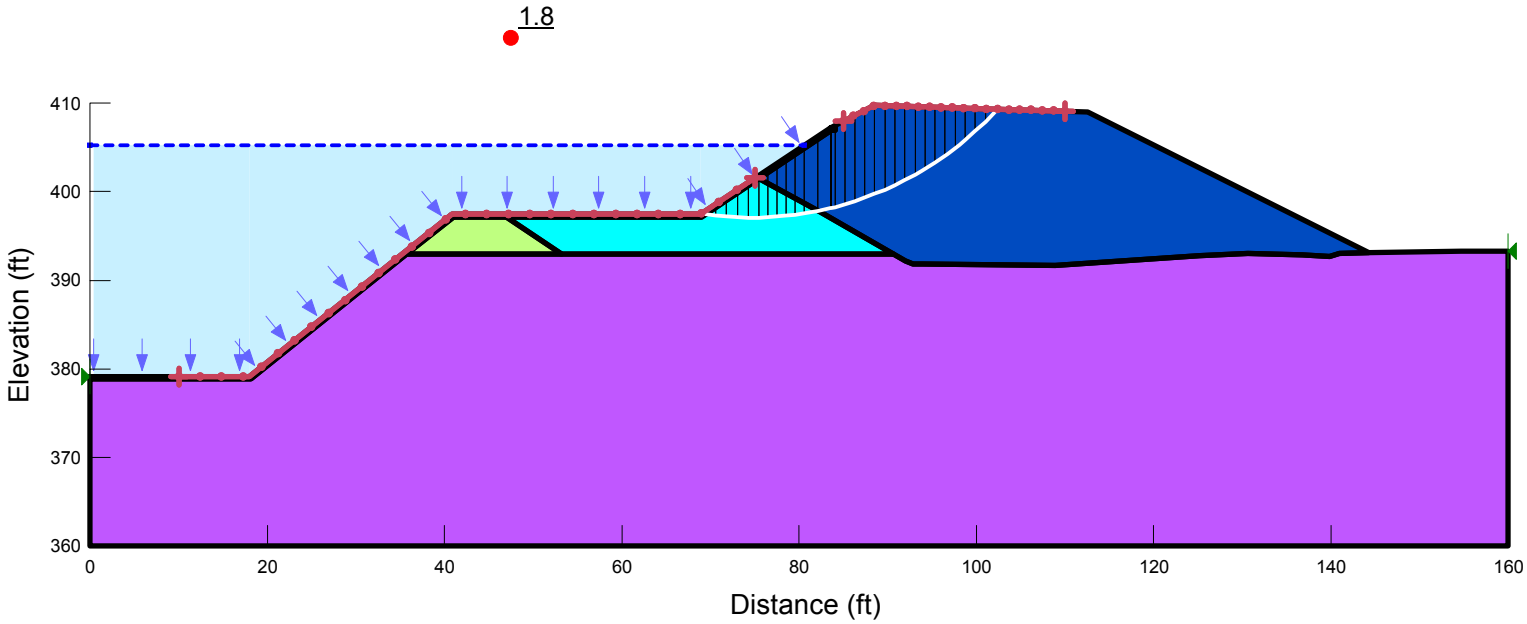


B-3 Upstream Normal

B-3 Milepost 106.1.gsz

12/17/2018 1:260

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

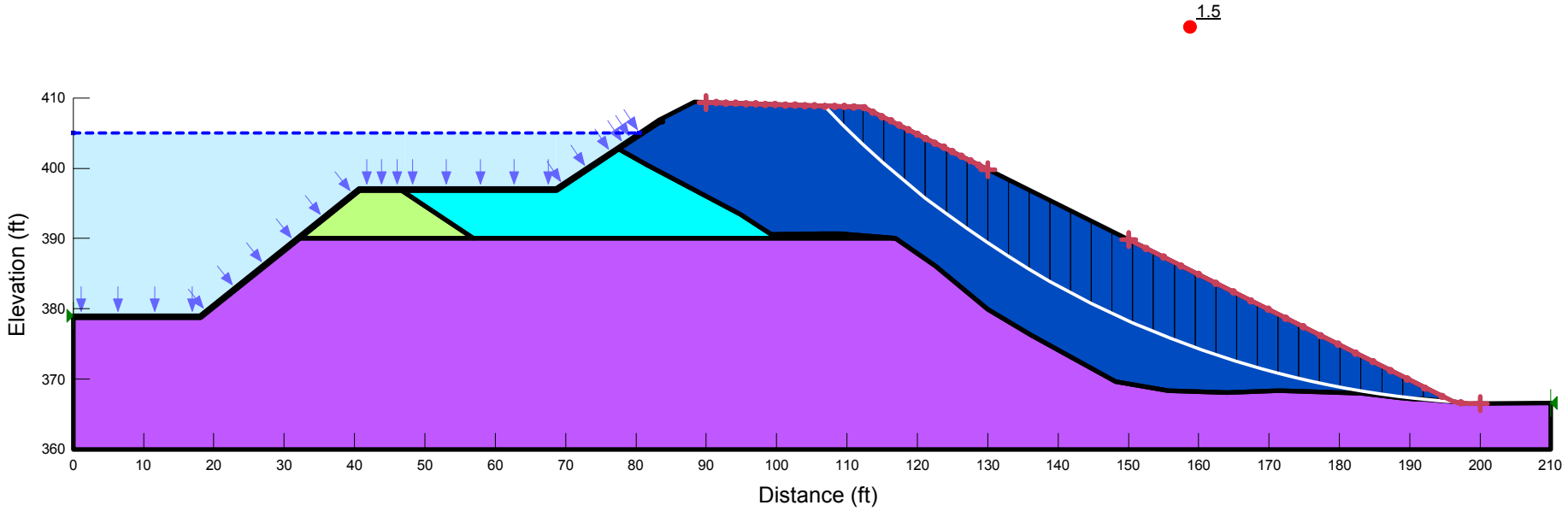


B-3 Upstream Seismic

B-3 Milepost 106.1.gsz

12/17/2018 1:260

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

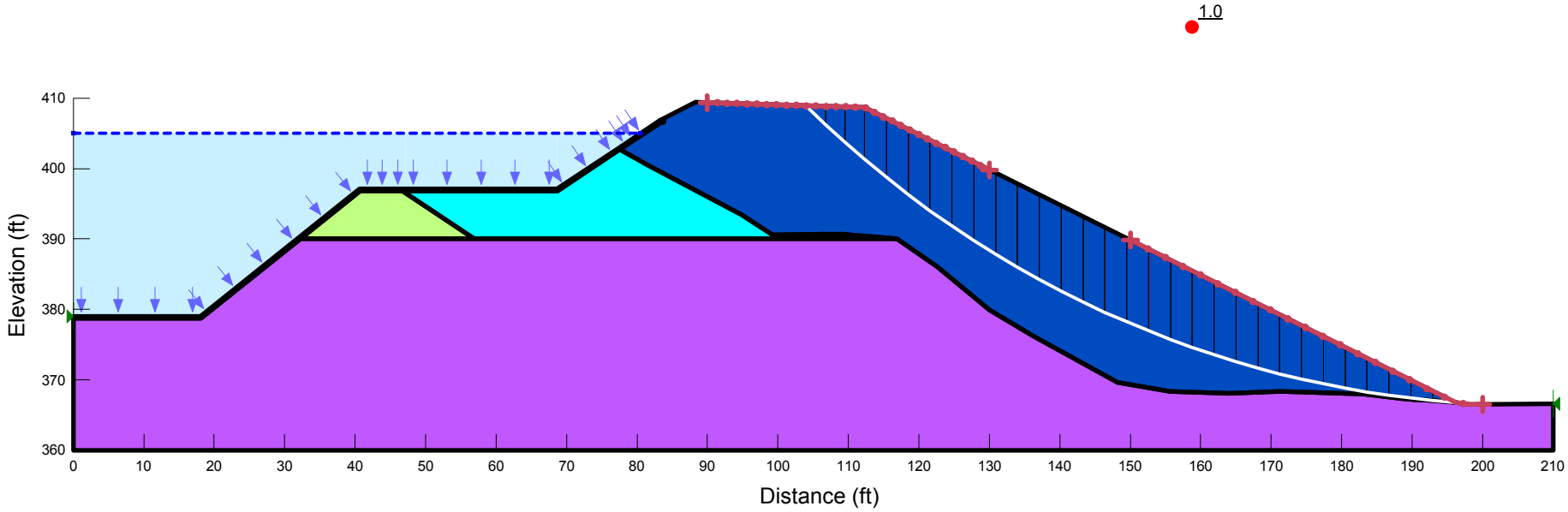


B-4 Downstream Normal

B-4 Milepost 107.1.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

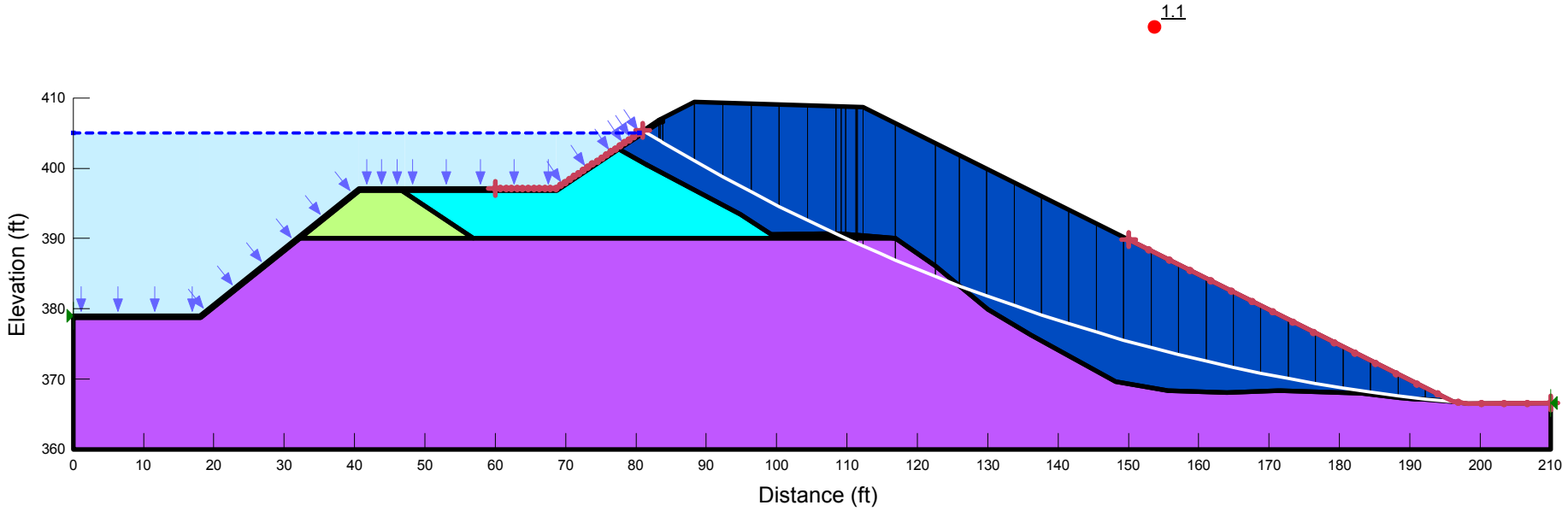


B-4 Downstream Seismic

B-4 Milepost 107.1.gsz

11/06/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

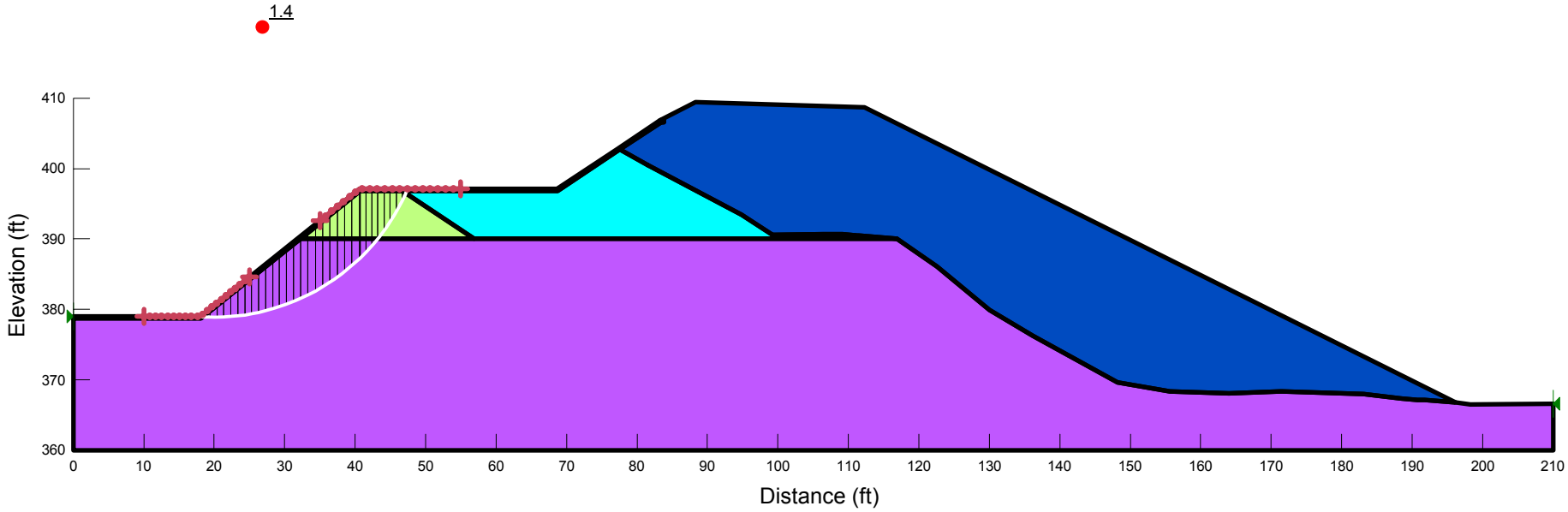


B-4 Downstream Seismic Canal Intersect

B-4 Milepost 107.1.gsz

11/06/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

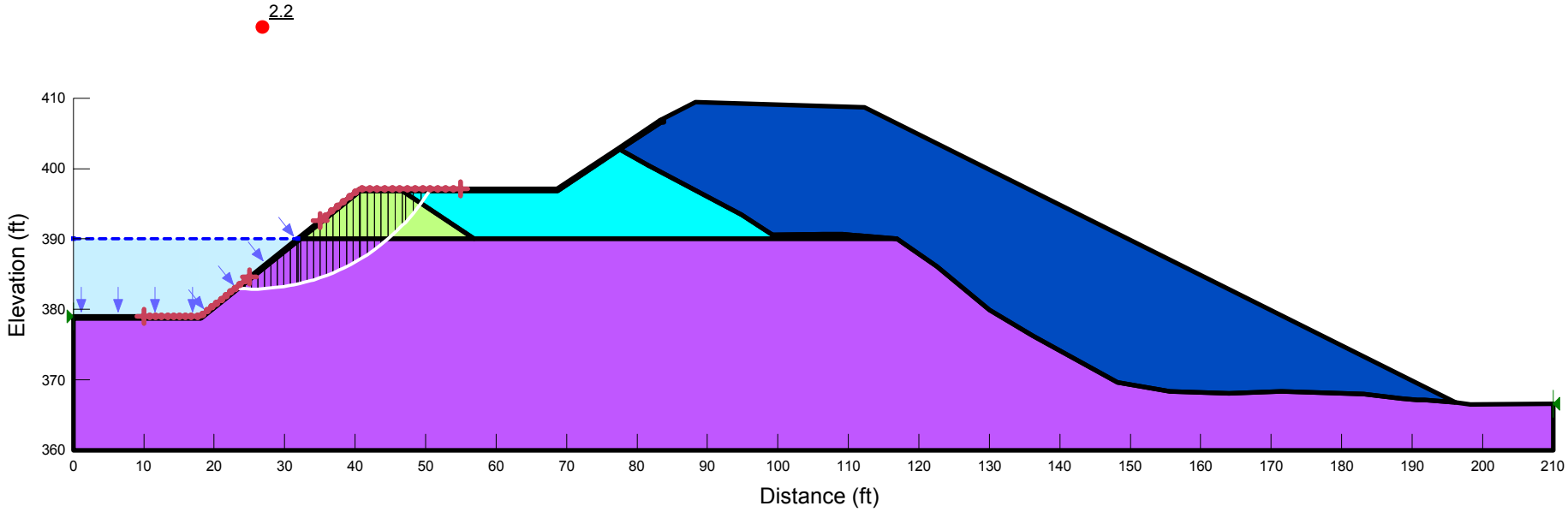


B-4 Upstream Dry

B-4 Milepost 107.1.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

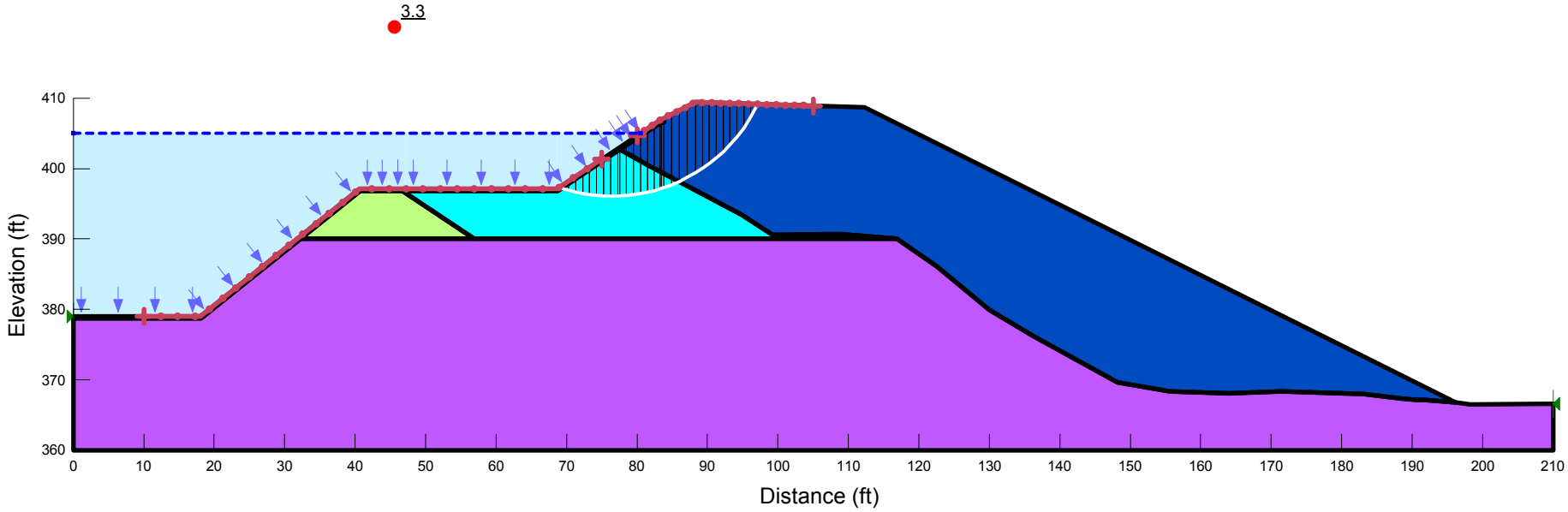


B-4 Upstream EOC Low Water

B-4 Milepost 107.1.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

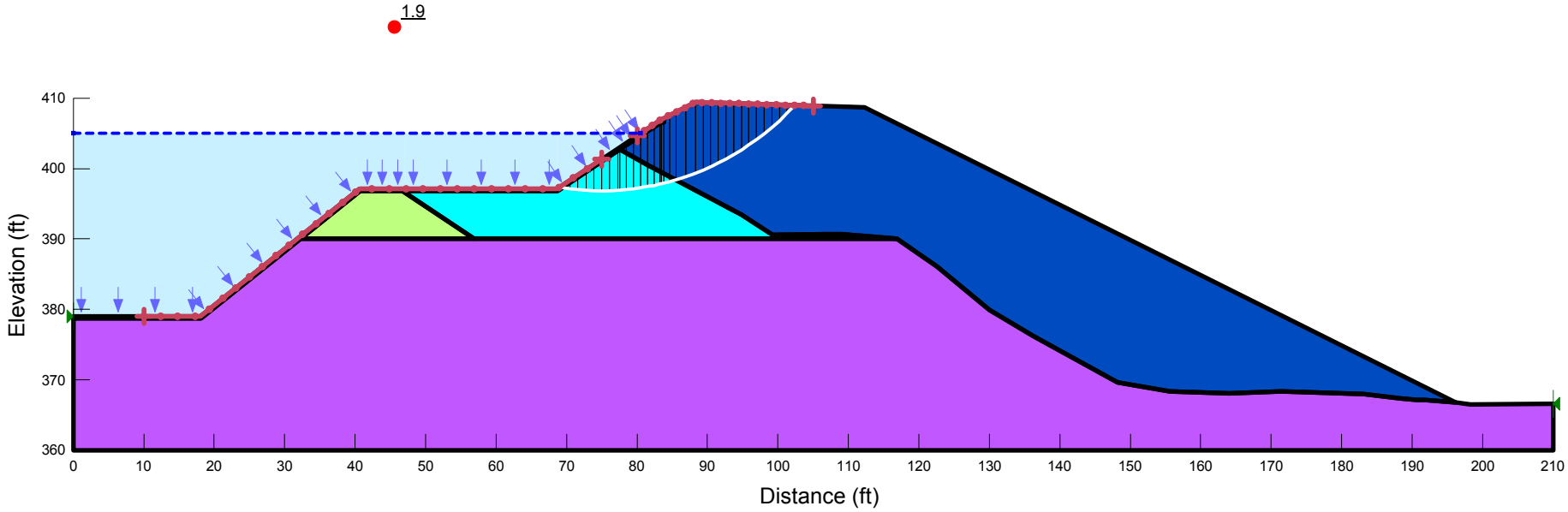


B-4 Upstream Normal

B-4 Milepost 107.1.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

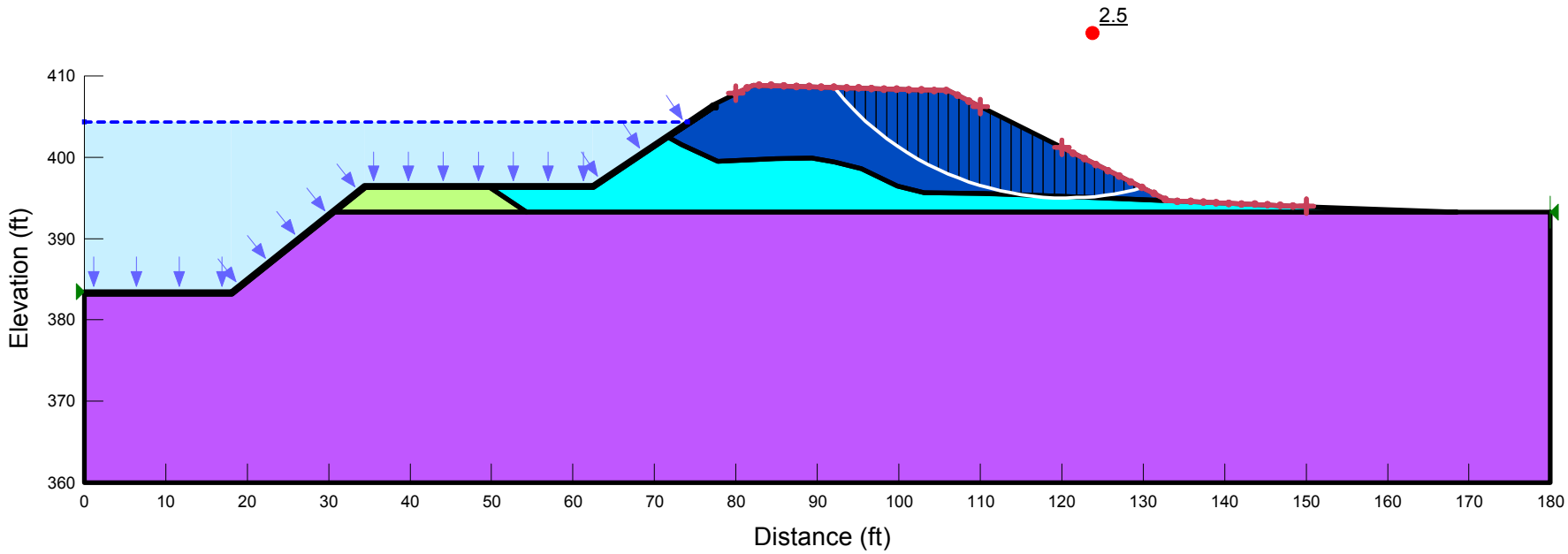


B-4 Upstream Seismic

B-4 Milepost 107.1.gsz

11/01/2018 1:280

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

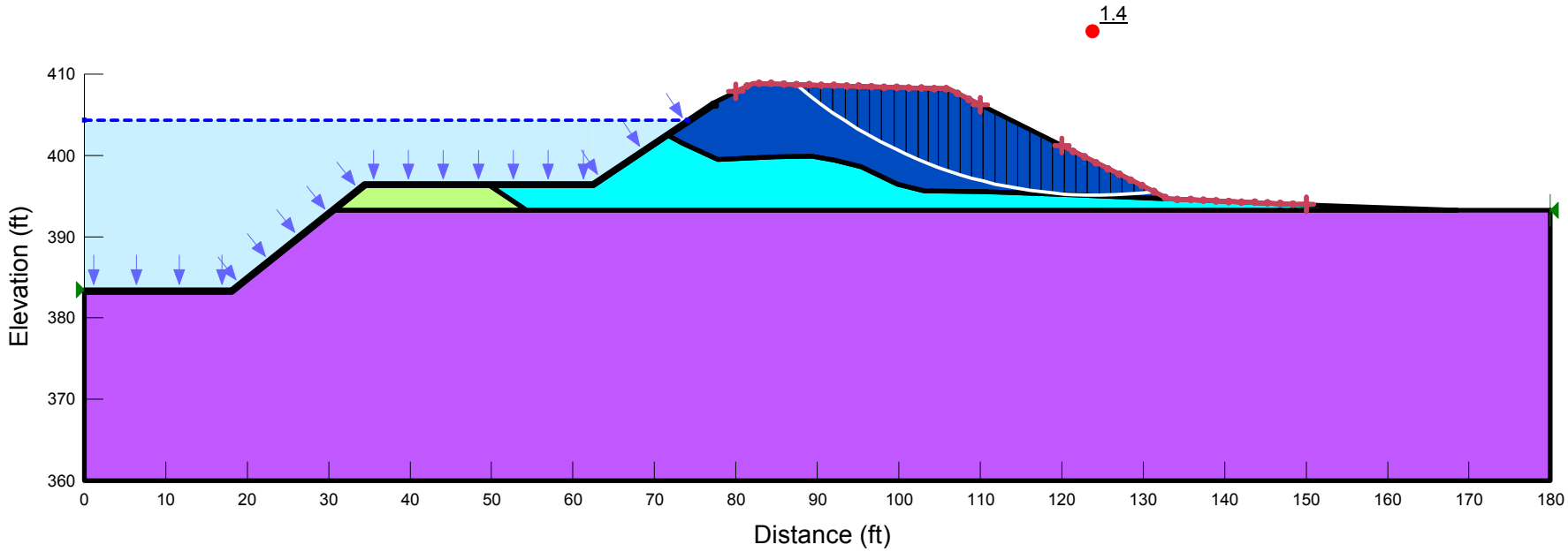


B-5 Downstream Normal

B-5 Milepost 108.9.gsz

11/01/2018 1:250

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

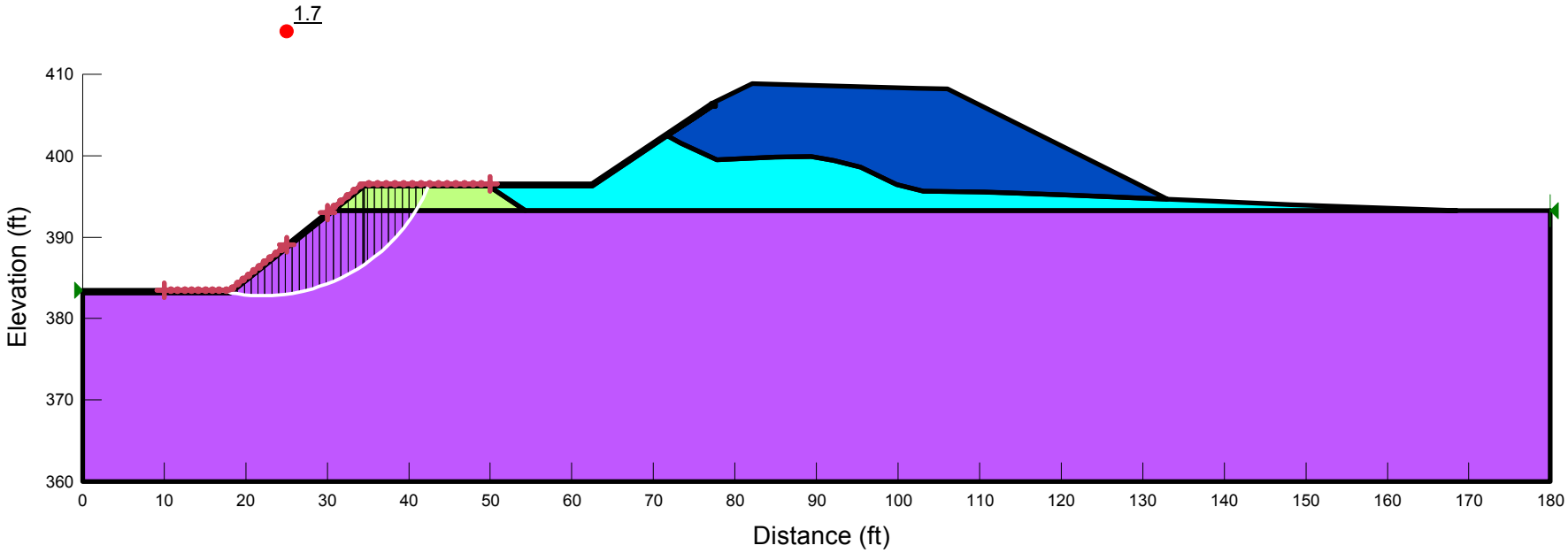


B-5 Downstream Seismic

B-5 Milepost 108.9.gsz

11/06/2018 1:250

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

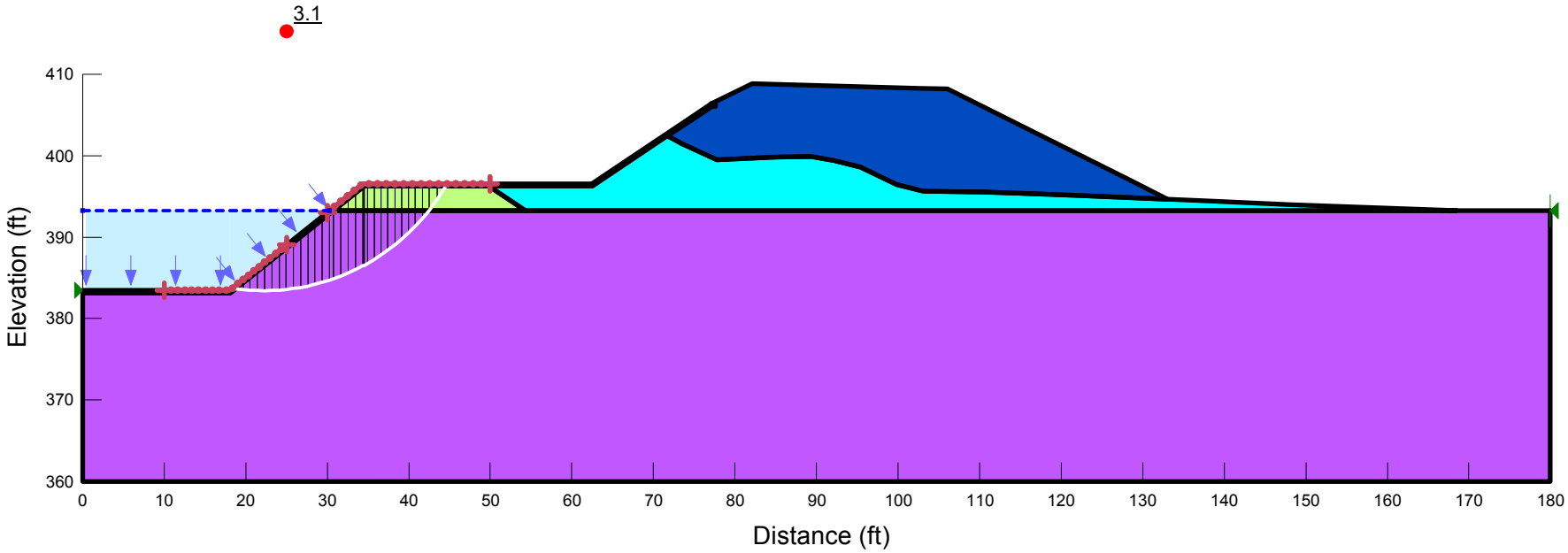


B-5 Upstream Dry

B-5 Milepost 108.9.gsz

11/01/2018 1:250

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

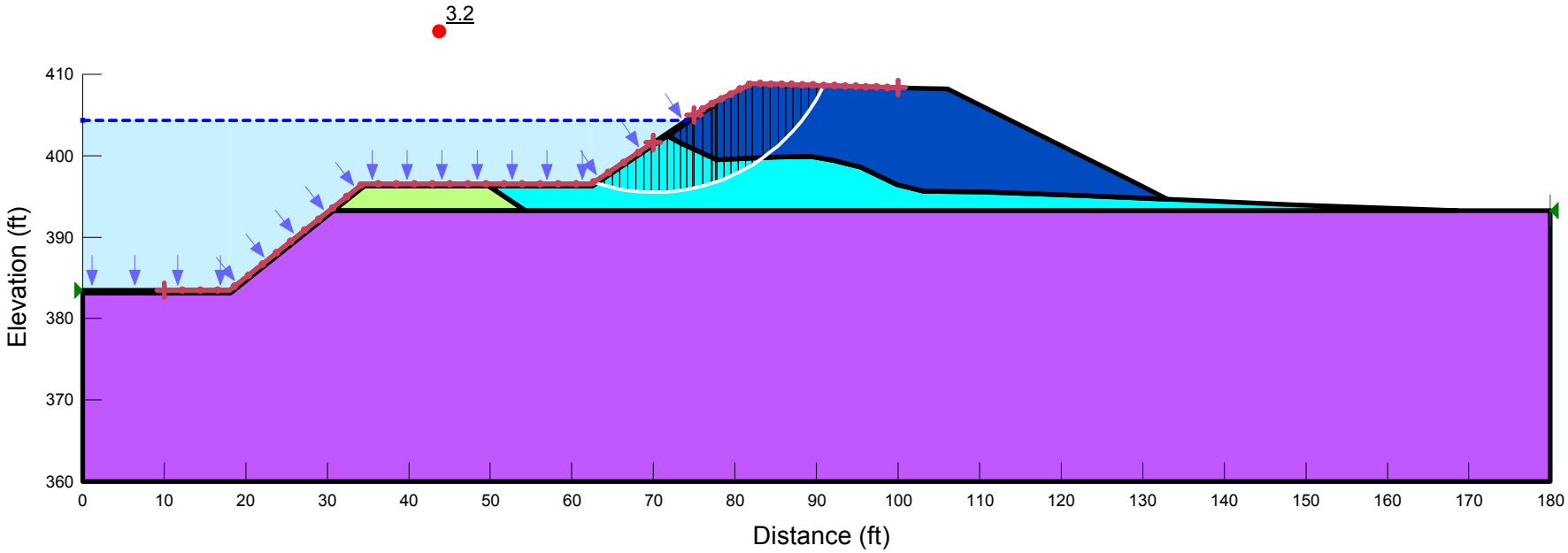


B-5 Upstream EOC Low Water

B-5 Milepost 108.9.gsz

11/01/2018 1:250

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

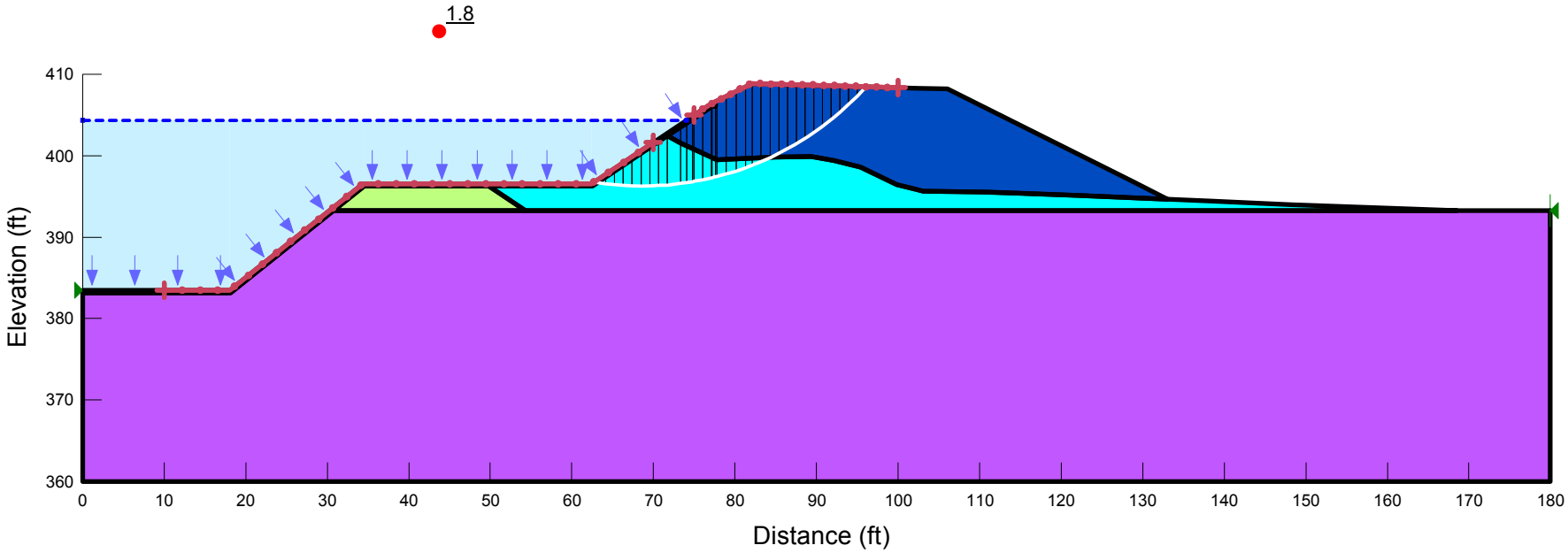


B-5 Upstream Normal

B-5 Milepost 108.9.gsz

11/01/2018 1:250

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Existing Compacted Fill	Mohr-Coulomb	125	100	30
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

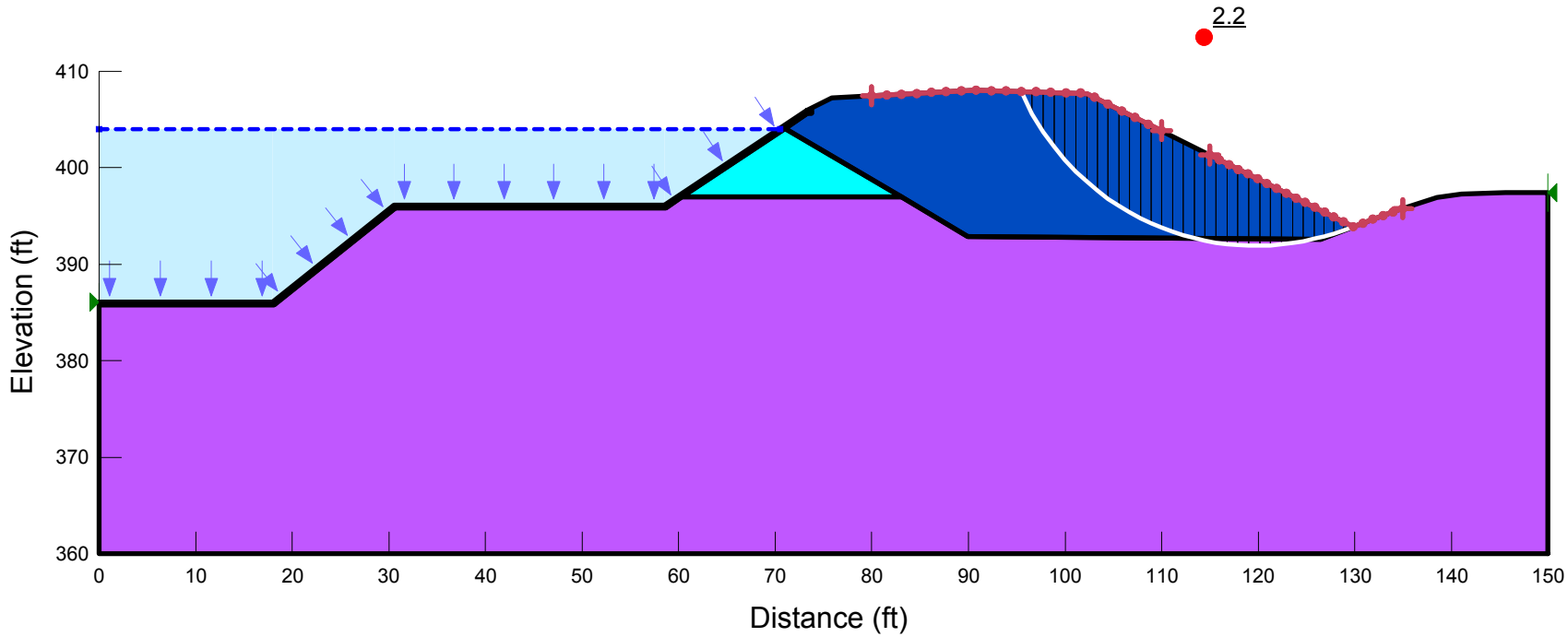


B-5 Upstream Seismic

B-5 Milepost 108.9.gsz

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Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

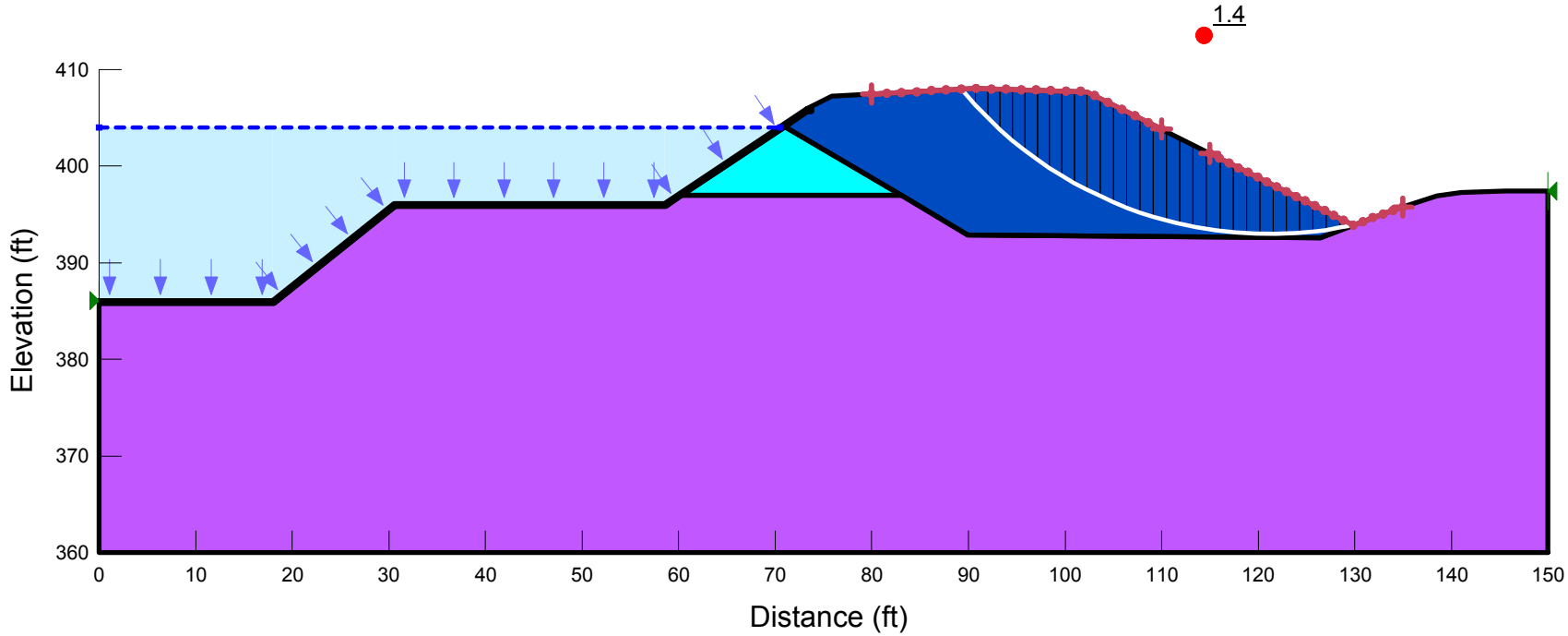


B-7 Downstream Normal

B-7 Milepost 110.3.gsz

11/01/2018 1:220

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

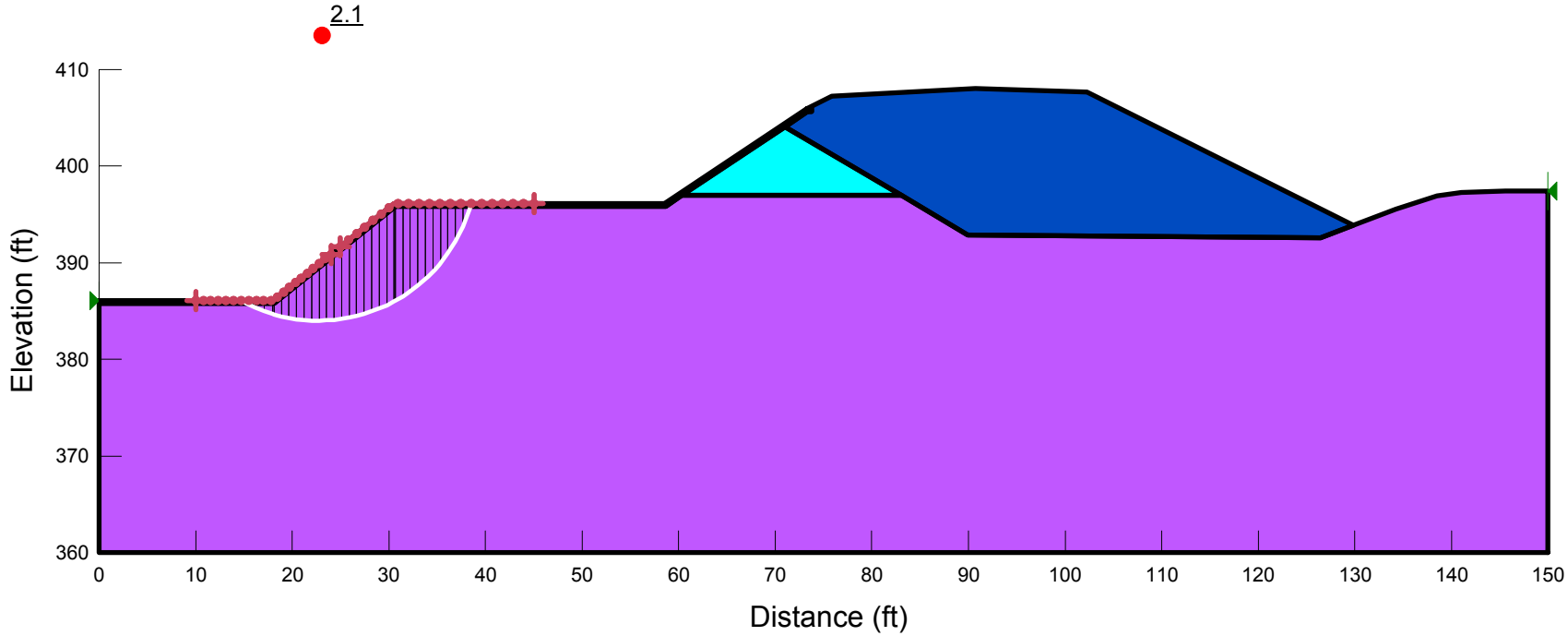


B-7 Downstream Seismic

B-7 Milepost 110.3.gsz

11/06/2018 1:220

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30

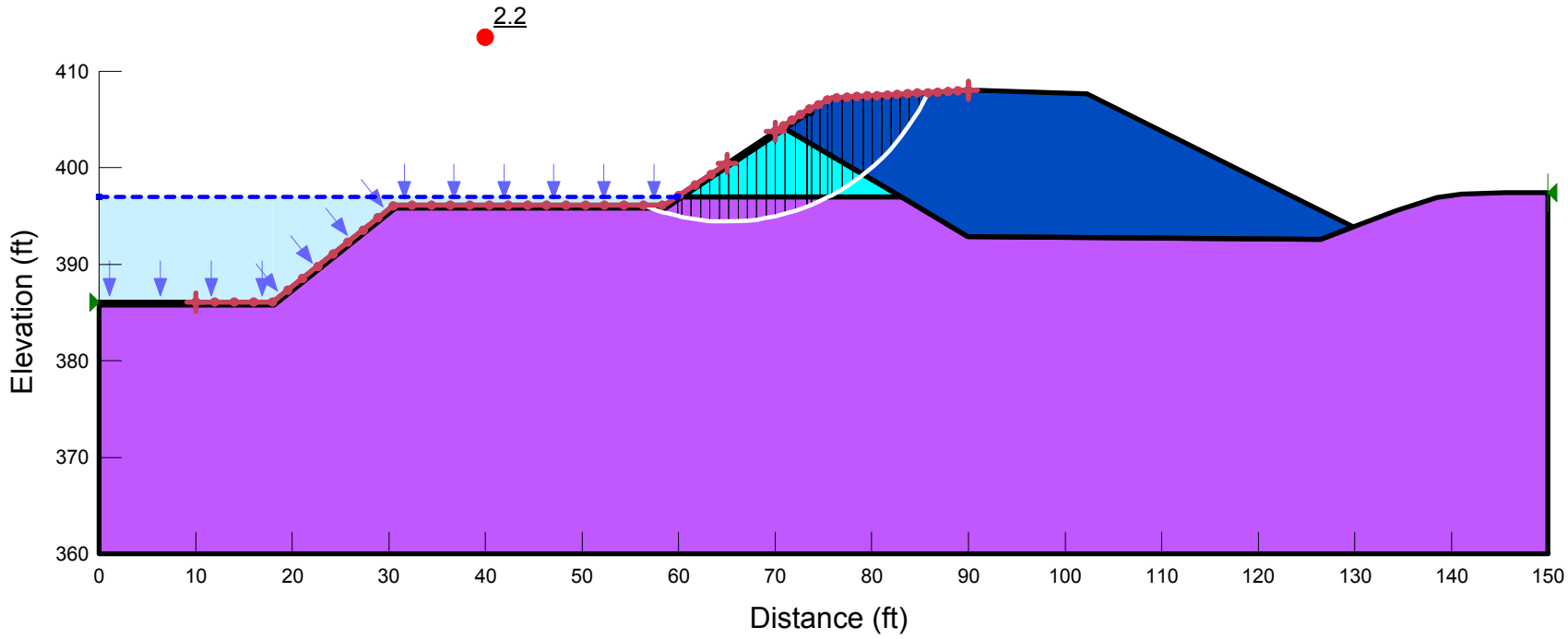


B-7 Upstream Dry

B-7 Milepost 110.3.gsz

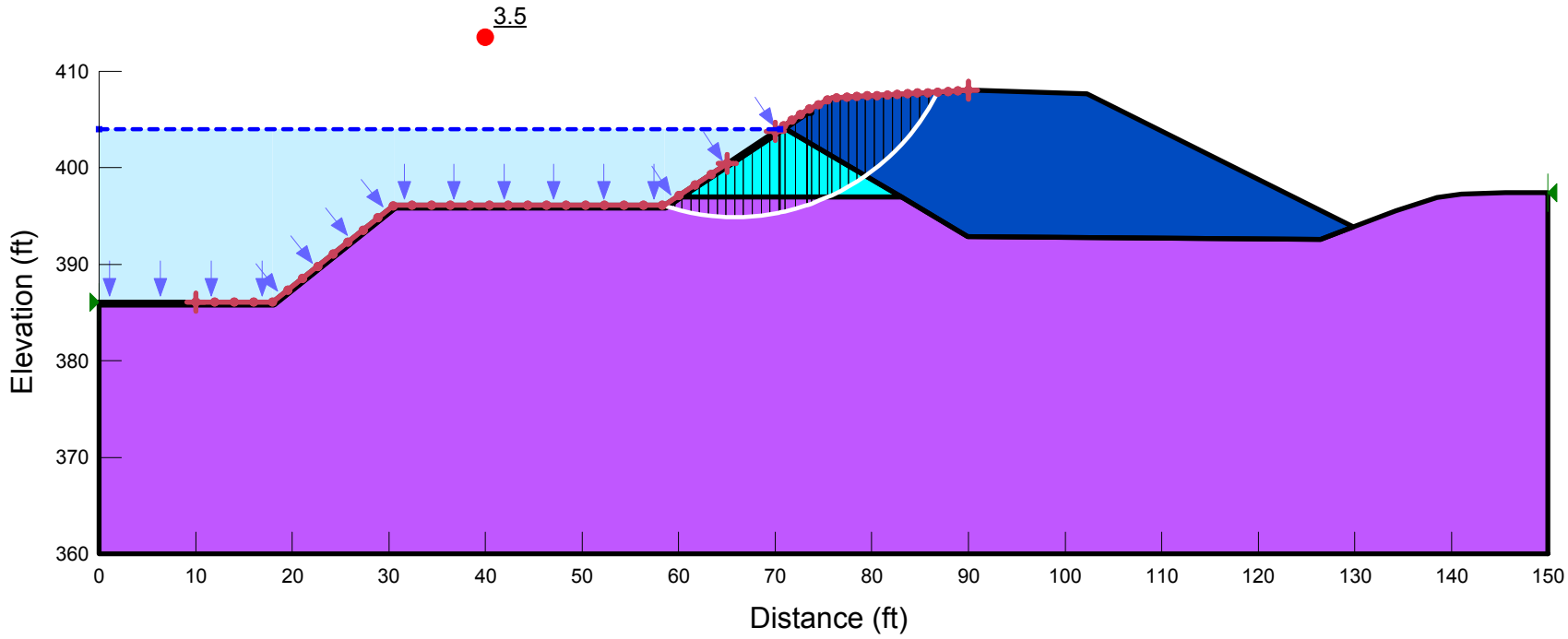
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Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30



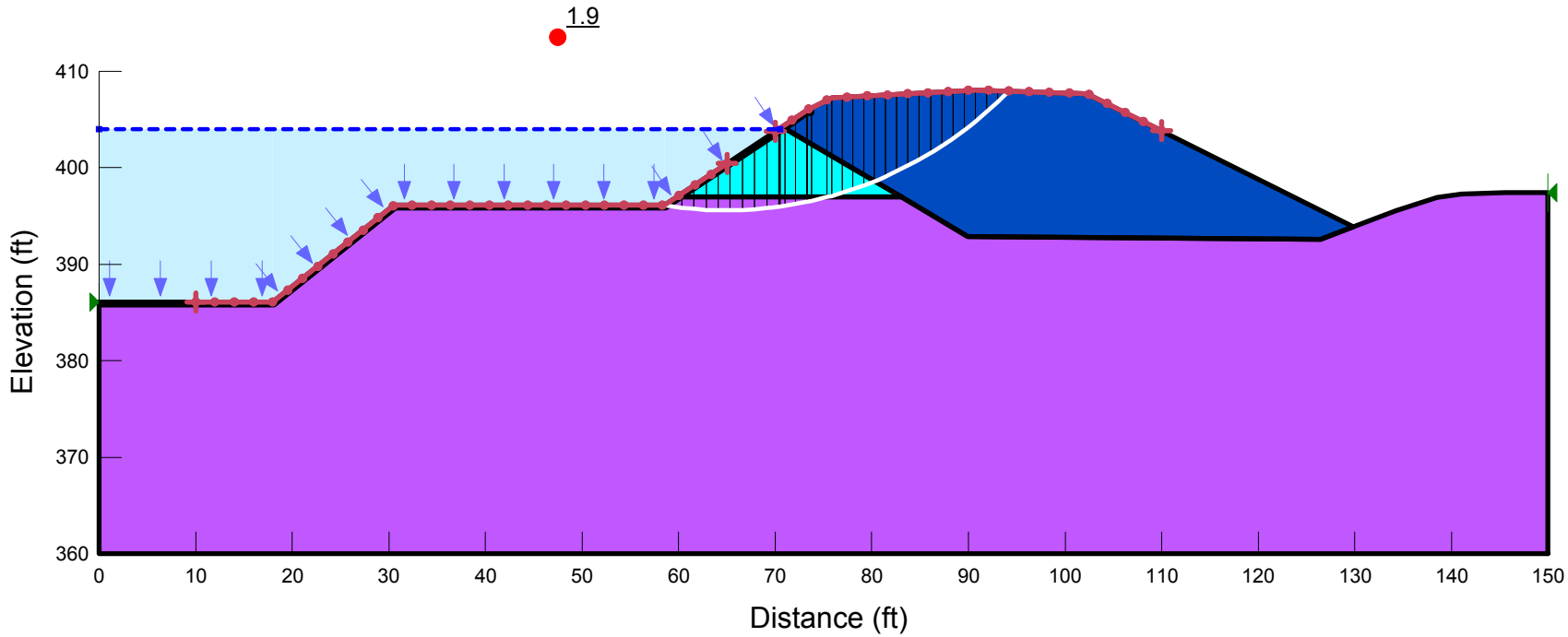
B-7 Upstream EOC Low Water	
B-7 Milepost 110.3.gsz	
11/01/2018	1:220

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30



B-7 Upstream Normal	
B-7 Milepost 110.3.gsz	
11/01/2018	1:220

Color	Name	Model	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Concrete Liner	Mohr-Coulomb	150	100	0
	Native Ground	Mohr-Coulomb	125	100	30
	New Compacted Fill	Mohr-Coulomb	125	100	30
	Removed and Re-Compacted Fill	Mohr-Coulomb	125	100	30



B-7 Upstream Seismic

B-7 Milepost 110.3.gsz

11/06/2018 1:220

Simplified Procedure for Estimating Earthquake Induced Deviatoric Slope Displacements
by Jonathan D. Bray and Thaleia Travasarou
Journal of Geotechnical and Geonvironmental Engineering, ASCE, V. 133(4), pp. 381-392, April 2007

SEE NOTES BELOW FOR GUIDANCE IN THE USE OF SPREADSHEET

Input Parameters			
Yield Coefficient (ky)	0.205		Based on pseudostatic analysis
Initial Fundamental Period (Ts)	0.13	seconds	1D: Ts=4H/Vs 2D: Ts=2.6H/Vs
Degraded Period (1.5Ts)	0.20	seconds	
Moment Magnitude (M_w)	5.1		
Spectral Acceleration (Sa(1.5Ts))	1.0534	g	

Additional Input Parameters		
Probability of Exceedance #1 (P1)	84	%
Probability of Exceedance #2 (P2)	50	%
Probability of Exceedance #3 (P3)	16	%
Displacement Threshold (d_threshold)	15	cm

Intermediate Calculated Parameters			
Non-Zero Seismic Displacement Est (D)	10.24	cm	eq. (5) or (6)
Standard Deviation of Non-Zero Seismic D	0.66		

Results			
Probability of Negligible Displ. (P(D=0))	0.00		eq. (3)
D1	5.3	cm	calc. using eq. (7)
D2	10.2	cm	calc. using eq. (7)
D3	19.7	cm	calc. using eq. (7)
P(D>d_threshold)	0.28		eq. (7)

Notes

1. Values highlighted in blue are input parameters and results are presented in the table with the yellow heading.
2. Probability of Exceedance is the desired probability of exceeding a particular displacement value.
3. Displacements D1, D2, and D3 correspond to P1, P2, and P3, respectively.
   (e.g., the probability of exceeding displacement D1 is P1)
4. Calculated seismic displacements are due to deviatoric deformation only (add in volumetrically induced movement).
5. ky may range between 0.01 and 0.5, Ts between 0 and 2 s, Sa between 0.002 and 2.7 g, M between 4.5 and 9
6. Rigid slope is assumed for Ts < 0.05 s
7. When a value for D is not calculated, D is < 1cm
8. ky may be estimated using the simplified equations shown below.
9. Examples of how Ts is estimated are shown below.
10. Vs = weighted avg. shear wave velocity for the sliding mass, e.g., for 2 layers, Vs = [(h1)(Vs1) + (h2)(Vs2)]/(h1 + h2)

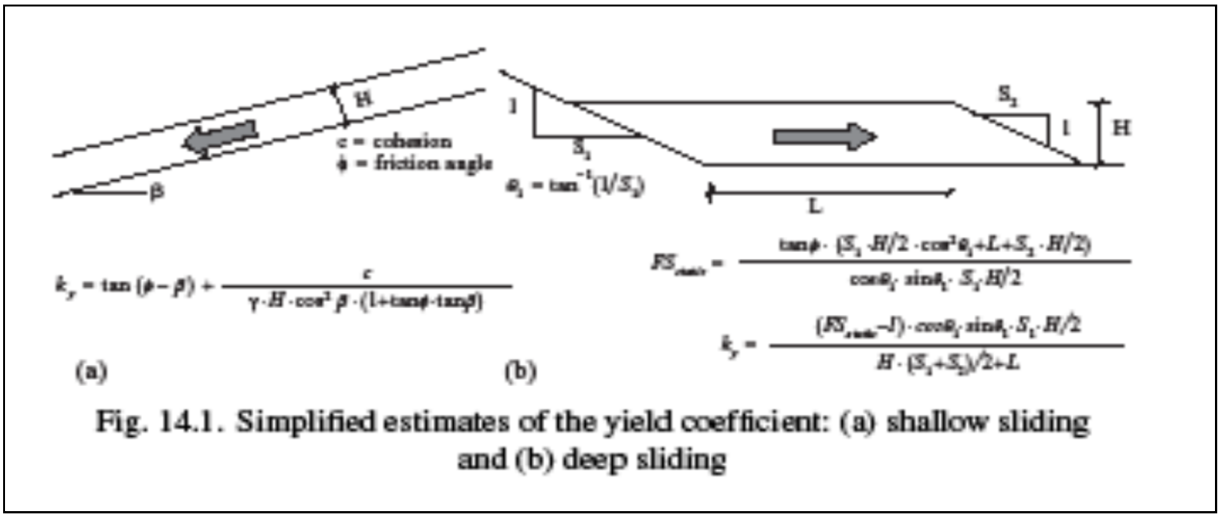


Fig. 14.1. Simplified estimates of the yield coefficient: (a) shallow sliding and (b) deep sliding

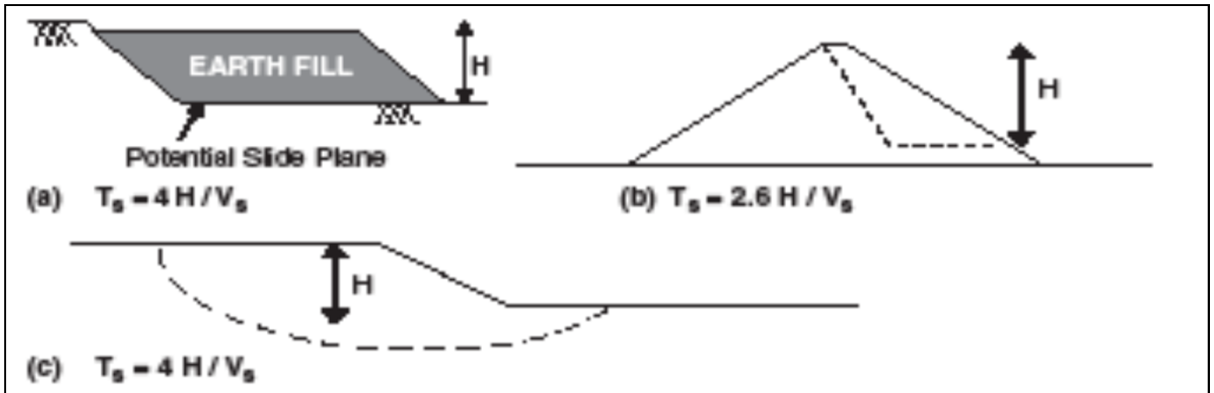
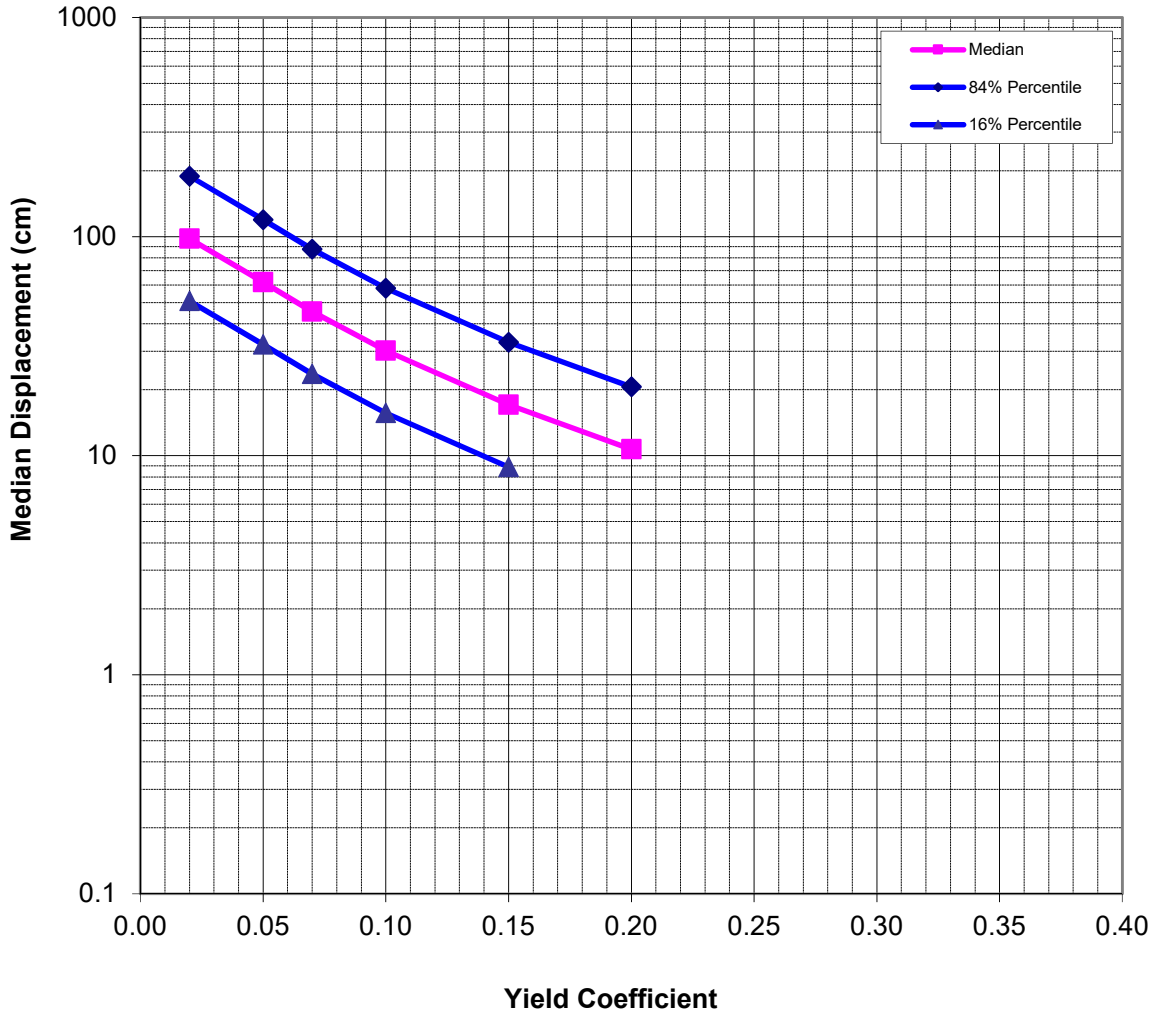


Fig. 14.4. Estimating the initial fundamental period of potential sliding blocks

Figures from Bray, J.D. (2007) "Chapter 14: Simplified Seismic Slope Displacement Procedures," Earthquake Geotechnical Engineering, 4th Inter. Conf. on Earthquake Geotechnical Engineering - Invited Lectures, in Geotechnical, Geological, and Earthquake Engineering Series, Vol. 6, Pitilakis, Kyriazis D., Ed., Springer, Vol. 6, pp. 327-353.

Dependence on ky

ky	P(D="0")	D (cm)	Dmedian (cm)	D1 (cm)	D3 (cm)
0.020	0.00	97.9	97.9	188.7	50.8
0.05	0.00	61.9	61.9	119.3	32.1
0.07	0.00	45.5	45.5	87.6	23.6
0.1	0.00	30.2	30.2	58.2	15.7
0.15	0.00	17.1	17.1	33.0	8.9
0.2	0.00	10.7	10.7	20.6	5.5
0.3	0.01	5.0	5.0	9.6	2.6
0.4	0.08	2.7	2.6	5.1	1.1



Simplified Procedure for Estimating Earthquake Induced Deviatoric Slope Displacements
by Jonathan D. Bray and Thaleia Travasarou
Journal of Geotechnical and Geonvironmental Engineering, Vol 133, No. 4, pp. 381-392, April 2007

APPENDIX F

Canal Photographs

Stantec



Photo #1 Aerial Photo Near the North End of the Immediate Repair Area and Boring B-2 Looking South



Photo #2 Aerial Photo of Boring B-2 Looking North



Photo #3 Aerial Photo of the South End of the Immediate Repair Area and Boring B-4 Looking Southeast.



Photo #4 Aerial Photo of Boring B-5 Looking Northeast



Photo #5 Aerial Photo of Boring B-7 Looking South



Photo #6 Aerial Photo of Boring B-8 Looking Northeast



Photo #7 Photo of CPT-2 Looking North

GEOTECHNICAL DATA REPORT-Phase 1 Friant-Kern Canal Capacity Correction Project Tulare County, CA

March 2019

Prepared for:

Friant Water Authority
854 N. Harvard Avenue
Lindsay, CA 93247

Prepared by:

Stantec Consulting Services Inc.
3301 C Street, Suite 1900
Sacramento, CA 95816

Stantec
3301 C St #1900
Sacramento, CA 95816

March 2019

Attention: Mr. Doug DeFlitch
Friant Water Authority
854 N. Harvard Avenue
Lindsay, CA 93247

Dear Mr. DeFlitch,

Reference: Geotechnical Data Report - Phase 1
Friant-Kern Capacity Correction Project
Tulare County, California

Stantec Consulting Services Inc. (Stantec) is pleased to provide the following Geotechnical Data Report (GDR) for the ongoing geotechnical investigation at the above referenced site. This report presents the data and other factual information for the Phase 1 geotechnical investigation.

Stantec appreciates the opportunity to provide these engineering services for Friant Water Authority. If you have any questions or require additional information, please contact our office.

Regards,

Stantec Consulting Services Inc.

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cc. Janet Atkinson

Sign-off Sheet

This document entitled GEOTECHNICAL DATA REPORT – Phase 1 Friant-Kern Canal Capacity Correction Project was prepared by Stantec Consulting Services Inc. (“Stantec”) for the account of Friant Water Authority (the “Client”). Any reliance on this document by any third party is strictly prohibited. The material in it reflects Stantec’s professional judgment in light of the scope, schedule and other limitations stated in this report and in the contract between Stantec and the Client. The opinions in the document are based on conditions and information existing at the time the document was published and do not take into account any subsequent changes. In preparing the document, Stantec did not verify information supplied to it by others. Any use which a third party makes of this document is the responsibility of such third party. Such third party agrees that Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other third party as a result of decisions made or actions taken based on this document.

Prepared by _____

(signature)

Jordan T. Keeney, EIT

Reviewed by _____

(signature)

Maurice Amendolagine, PE, GE

Approved by _____

(signature)

Dan Back, PE, GE

Sign-off Sheet

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PERMEABILITY TESTS

CHEMICAL TESTING

Abbreviations (Use Style Contents/ES)

cfs	Cubic Feet Per Second
CDMG	California Division of Mines and Geology
Cl	Chloride
CME	Central Mine Equipment Company
CPT	Cone Penetration Testing
CSDS RTN	California Surveying and Drafting Supply Real-Time Network
CTM	California Test Method
DGPS	Differential Global Positioning System
FKC	Friant-Kern Canal
FWA	Friant Water Authority
GIR	Geotechnical Interpretive Report
HSA	Hollow Stem Auger
LL	Liquid Limit
MC	Modified California Sampler
MP	Milepost
NP	Non-Plastic
PI	Plasticity Index
PL	Plastic Limit
Reclamation	United States Bureau of Reclamation
RTK	Real Time Kinematic
SO4	Sulphate
SPT	Standard Penetration Test
USA North	Northern California Underground Service Alert

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1.0 INTRODUCTION

Stantec Consulting Inc. (Stantec) has prepared this Geotechnical Data Report (GDR) as part of the deliverables for the geotechnical investigation services outlined in the contract between the Friant Water Authority (FWA) and Stantec (Professional Services Agreement for FKC Capacity Correction – Task Order No. 1 dated June 6, 2018). This report provides factual data for the Phase 1 portion of the investigation only. The Phase 2 portion of the geotechnical investigation and the Geotechnical Interpretive Report (GIR) will be provided under separate covers.

This report includes a summary of the geotechnical investigation activities, description of sampling procedures, description of field tests and test results, laboratory test results, and groundwater conditions. In addition, boring and Cone Penetration Testing (CPT) location plans, and boring and CPT logs are presented.

The Phase 1 geotechnical investigation will be supplemented by a Phase 2 investigation that will focus on explorations at the toe of the existing embankments and at other locations where canal modifications are proposed. Scheduling of the Phase 2 investigation is currently awaiting environmental approval.

1.1 PROJECT DESCRIPTION

The primary goal of the Friant-Kern Canal (FKC) Capacity Correction Project (Project) is to restore the FKC capacity through the subsidence area, approximately 33 miles of canal (Milepost 88 to 121). Mitigation alternatives are currently being developed for a 30 percent design level deliverable.

The Phase 1 geotechnical investigation was performed to provide an initial characterization of the geotechnical conditions along the approximate 30-mile stretch of the Friant-Kern Canal. Information obtained from this Phase 1 geotechnical investigation will be used to perform geotechnical analyses and provide preliminary geotechnical recommendations for 30 percent design level corrective measures. Additional investigations and analyses will be needed to provide final design recommendations for the selected corrective action.

1.2 CANAL HISTORY AND DESCRIPTION

The FKC is a 152-mile canal owned by the United States Bureau of Reclamation (Reclamation) and operated by Friant Water Authority (Friant) to convey water to augment irrigation capacity in Fresno, Tulare, and Kern counties. The FKC was constructed between 1945 to 1951 with a canal lining raise in some areas in the 1970s.

The regional setting generally consists of rural agricultural farming communities, with the canal traversing open farmland, with few associated structures. There is an assortment of County bridges that cross over the FKC.

The typical canal section varies throughout its length (depending on whether in cut or fill areas, or combination). The canal is a concrete lined (3.5 inches thick) trapezoidal channel with longitudinal and transverse joints. The canal includes numerous check structures for flow control and checking the water surface for deliveries to the various irrigation districts, cities, and farms. The check structures are generally multi-bay concrete structures with radial gates.

The inner concrete lining of the canal has a slope of approximately 1.25H:1V (1.25 horizontal to 1 vertical) and the canal has a base width of approximately 36 feet. The canal within the subsidence area consists of embankment heights that range from approximately 5 feet to 16 feet above the original ground with the western side of the canal generally being taller than the eastern side. The outer slopes within the subsidence area generally range from approximately 1.75H:1V to 2H:1V with some isolated areas that are as steep as 1.5H:1V.

Based on a review of the original canal construction documents and the 1970's canal raise, the canal embankment consists partially of compacted (i.e. engineered) fill and partially uncompacted (i.e. common) fill. A typical section showing approximate zones of the compacted and uncompacted fill in relation to a typical Phase 1 boring location and depth is presented below. The typical section below is located in a 1970's canal raise area.

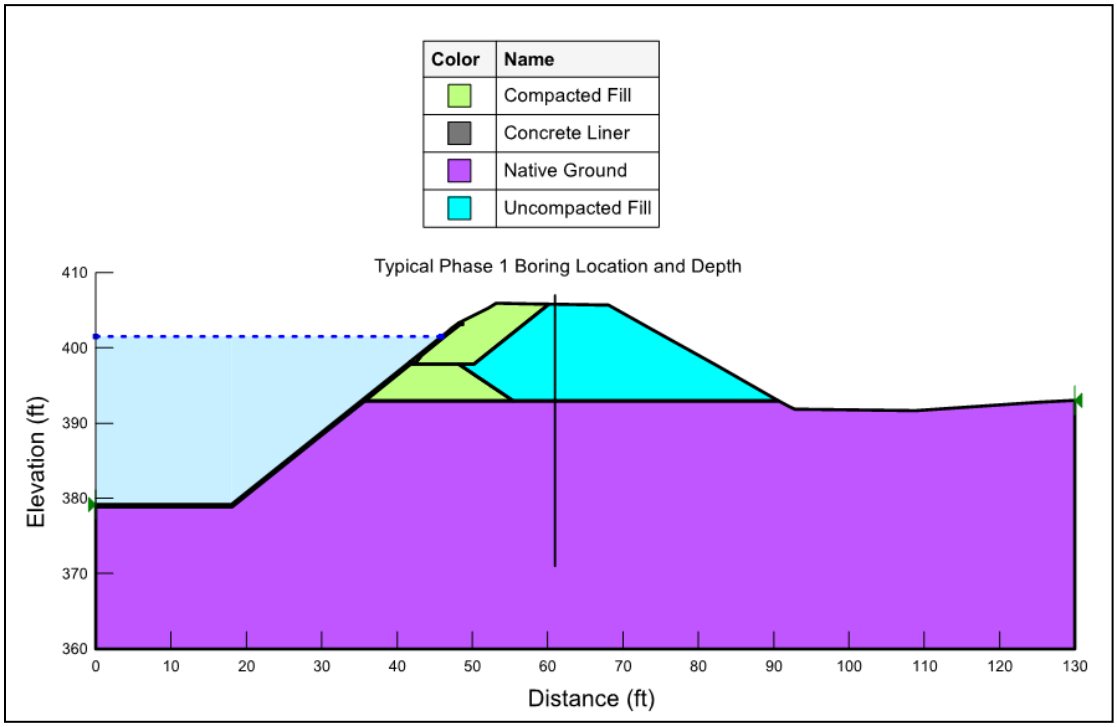


Figure 1. Canal Embankment Section Showing a Typical Phase 1 Boring

2.0 SUBSURFACE INVESTIGATION

2.1 GENERAL

The geotechnical field investigation for the FKC Capacity Correction Project was performed between September 11 and September 25, 2018, and consisted of the following:

Nine (9) hollow-stem auger (HSA) borings with Standard Penetration Testing (SPT), Modified California Sampling (MC), and Shelby tube sampling

Seven Cone Penetration Tests (CPTs)

With the exceptions of Boring B-9 and CPT-7, all of the borings and CPTs were located in the middle of the Operations and Maintenance Road (O & M Road). The Programmatic Agreement between Reclamation and the California State Historic Preservation Office area of potential effect is limited to the area from the outside toe to the outside toe of each canal embankment. Selection of boring and CPT locations outside this area for the Phase 1 field investigations was not possible because the schedule for obtaining approvals was longer than the time available to conduct the field investigations in the project schedule.

The geotechnical borings were performed by Moore Twining Associates out of Fresno, California with a truck-mounted Central Mine Equipment Company (CME) 75 auger drill rigs.

The CPT's were performed by Middle Earth Geo Testing out of Orange, California using a 25-ton direct push truck.

A summary of the type of in-situ testing, sampling method and number of samples obtained from the borings are shown in Table 1.

Table 1. In-Situ Testing and Sampling Quantities

Test	Number of Tests/Samples
Cone Penetration Test (CPT)	7 soundings
Shelby Tube (ST)	3 samples
Standard Penetration Test (SPT)	61 tests
Modified California Sampling (MC)	26 tests
Grab Sample (GS)	8 samples

A boring and CPT location plan depicting the approximate boring and CPT locations is presented in Appendix B. A geologic map of the project area, prepared by the California Division of Mines and Geology (CDMG) is presented in Appendix C. Boring logs, CPT results, and lab testing results are presented in Appendices D, E, and F respectively.

2.2 BORING/CPT SURVEY

Subsurface exploration locations and their approximate real-world (California State Plane Zone 4) coordinates were predetermined by Stantec based on observed embankment heights, embankment slopes, historical embankment seepage areas, and project alternative infrastructure characteristics. Stantec visited the project site on Monday, July

16, 2018 and staked the proposed subsurface exploration locations. After the initial staking, several borings and CPTs were moved to avoid environmental setback zones. The final subsurface exploration locations were located by a Stantec field engineer with the use of a survey grade Real Time Kinematic (RTK) Differential Global Positioning System (DGPS) referencing the California Surveying and Drafting Supply Real-Time Network (CSDS RTN). Due to ongoing regional subsidence in the project area, exploration elevations presented in this report may not match elevations at the same locations in the future.

The locations and elevations of the borings and CPTs are presented in Tables 2 and 3 of this report and on the boring logs in Appendix D.

2.3 UTILITY CLEARANCE

After the staking of the proposed boring and CPT locations and prior to commencing field work, Stantec contacted the Northern California Underground Service Alert (USA North) to have underground utility locations marked at the site at least 48-hours prior to mobilization. All of the staked boring and CPT locations were then checked by the relevant public utility locators and no underground utility conflicts were reported to us.

2.4 DRILLING, SAMPLING, AND LOGGING

A field crew comprised of Stantec, Moore Twining Associates and Middle Earth Geo Testing personnel executed the drilling, sampling and CPT operations. The field crew included a driller and driller's helper for both Moore Twining Associates and Middle Earth Geo Testing, and a Stantec field engineer to log soil materials and supervise drilling/testing operations. The field engineer monitored the drilling, CPT soundings, and backfilling operations and communicated subsurface conditions encountered with the geotechnical project team to facilitate appropriate revisions to the exploration program.

The field engineer collected, logged, and secured samples from the drilling operations and recorded the information on Stantec subsurface logs in general accordance with ASTM D2488 and D5434, as applicable.

2.5 DRILLING

Borings were completed using HSA techniques. Hollow-stem augers were used to advance through the subsurface materials. Three-and-a-quarter-inch inner diameter hollow-stem augers were used for this project.

At the desired depth, the drill string was withdrawn, and a sampler (such as an SPT, MC, or Shelby Tube) was lowered down to the drilled depth.

The boring coordinates and elevations as collected by Stantec field personnel are presented in Table 2. The boring logs are presented in Appendix D.

Table 1. Summary of Borings

Boring ID	Approximate Canal Milepost	Northing[1] (feet)	Easting[1] (feet)	Ground Elevation[1] (feet)	Depth (feet)
B-1	97.5	1900360.6	6532885.5	409.8	36.5
B-2	104.1	1868950.1	6528579.2	404.4	36.5
B-3	106.1	1860141.7	6522388.5	404.7	36.5
B-4	107.1	1854660.1	6519363.2	404.9	41.5
B-5	108.9	1846567.7	6517622.3	405.8	36.5
B-6	108.9	1846561.2	6517736.5	405.5	36.5
B-7	110.3	1839679.2	6514773.4	407.7	11.5
B-7A[2]	110.3	1839674.0	6514772.1	407.6	36.5
B-8	115.6	1813875.7	6508707.8	397.9	36.5
B-9	115.6	1813873.9	6508666.8	397.9	21.5

Notes:
[1] Coordinates and elevations were collected by the Stantec field engineer with the use of a survey grade RTK DGPS referencing the CSDS RTN.
[2] Boring B-7A was advanced approximately 5 feet south of boring B-7 after Boring B-7 was terminated due to drill rig mechanical issues.

2.6 SAMPLING PROCEDURES

Disturbed SPT and relatively undisturbed MC samples were collected during the advancement of borings B-1 through B-9. A total of 61 SPT and 26 MC samples were collected. Additionally, eight (8) grab samples were collected in the upper five feet of all borings, with the exception of boring B-3. The SPT and MC sampling was performed in general accordance with ASTM D1586 and D3550, respectively. SPT and MC samples were completed at approximately 1.5-foot intervals for the top 15 feet, and approximately 5-foot intervals thereafter. The SPT and MC samples were driven approximately 18 inches with a 140-pound automatic hammer with a drop height of 30-inches

Hammer energy calibrations are periodically performed on the drill rigs that were used on this project. The hammers were last calibrated on April 18, 2017. A Pile Driving Analyzer (PDA) was used to measure SPT hammer energy transfer efficiencies for sampling depths ranging from 10 to 25 feet. The average hammer efficiencies were reported to be 89% and 96% for Rig ID 181067 and Rig ID 156, respectively. Based on our prior experience, variations in hammer energy, and typical auto hammer efficiencies in the industry, we selected a hammer efficiency of 90% for calculating N60 values presented on the boring logs.

Three (3) undisturbed Shelby tube samples were obtained at specified intervals in three borings (B-2, B-4, and B-7A) for subsequent laboratory shear strength and permeability testing. Shelby tube sampling was performed within the uncompacted fill and alluvial soils in accordance with ASTM D1587 by mechanically pushing a 30-inch long stainless steel, thin-walled Shelby tube with sharpened cutting edges. Once the tube was removed from the boring, the Stantec field engineer measured the recovery, visually inspected the soil, and recorded the information on the boring log.

2.7 SAMPLE HANDLING AND STORAGE PROCEDURES

Handling, transportation and storage of soil samples was undertaken with care to reduce disturbance in general accordance with ASTM D4220. The three Shelby tube samples were capped and sealed at both ends with expansion seals and electrical tape. The Shelby tube samples were kept in the vertical position during transportation and storage. Samples obtained from the SPT and MC samplers were immediately stored in sealed glass sample jars and

plastic MC sample containers, respectively, to reduce the potential for drying. All samples were transported to a Stantec sample storage location in San Diego, CA and samples assigned for testing were then taken to AP Engineering and Testing, Inc. in Pomona, CA.

2.8 CONE PENETRATION TESTING

Cone Penetration Testing (CPT) was performed in accordance with ASTM D5778. The CPT involves hydraulically pushing a 15 cm^2 stainless steel cone attached to 38 mm. diameter rods into the ground at a rate of 2 cm/s. The CPTs were advanced using a 25-ton truck. Relatively continuous tip, side friction, and dynamic pore pressure data were collected at each CPT sounding. A summary of information pertaining to the CPTs are presented in Table 3. The CPT logs are presented in Appendix E.

Table 3. CPT Information

CPT ID	Approximate Canal Milepost	Northing[1] (feet)	Easting[1] (feet)	Ground Elevation[1] (feet)	Depth (feet)
CPT-1	97.5	1900369.3	6532885.9	409.7	38.1
CPT-2	104.1	1868953.8	6528582.6	404.4	38.1
CPT-3	106.1	1860147.3	6522392.1	404.8	37.9
CPT-4	107.1	1854665.2	6519370.1	404.9	47.2
CPT-5	110.3	1839690.7	6514775.9	407.6	37.7
CPT-6	115.6	1813882.4	6508707.4	407.4	37.9
CPT-7	115.6	1813882.9	6508666.3	397.9	21.5

Notes:
[1] Coordinates and elevations were collected by the Stantec field engineer with the use of a survey grade RTK DGPS referencing the CSDS RTN.

2.9 OBSERVED GROUNDWATER CONDITIONS

Groundwater was not observed in the borings or CPTs during this Phase 1 investigation. Possible perched ground water was observed in boring B-1 at a depth of approximately 25 feet as the sampler and sample were wet. However, the hole was dry upon the completion of soil augering. The moisture content of a sample from boring B-8 at a depth of approximately 30 feet is close to saturation, which also may indicate perched groundwater at this location.

2.10 COMPLETION AND BACKFILLING

Borings were backfilled with neat cement grout and the CPTs were backfilled with bentonite pellets immediately upon completion of the borings and CPT's. Borings and CPTs were completed at the surface with either cold patch asphalt where pavement was present, or auger cuttings (B-6 and B-9) to match existing and surrounding surface conditions.

2.11 SOIL DISPOSAL

Investigation derived soil materials (auger cuttings) were spread along the canal embankment in a thin layer near each boring location as directed by Friant personnel.

3.0 LABORATORY TESTING

3.1 GENERAL

The primary objectives of the laboratory testing program were to supplement the visual classification of the soil samples and to measure pertinent engineering properties of soil for the FKC Capacity Correction project. Geotechnical laboratory testing was performed in accordance with applicable ASTM International procedures and/ or laboratory equipment manufacturer's recommended test procedures. The laboratory test results are presented in Appendix F.

A summary of laboratory testing completed for the borings is presented in Table 4.

Table 2. Summary of Laboratory Tests

Laboratory Test	Number of Tests
In-Situ Water Content	29
In-Situ Unit Weight of Soil	22
Remolded Moisture Density Relationships	2
Grain Size - Sieve	19
Grain Size – Hydrometer	5
Atterberg Limits	18
Direct Shear	13
Permeability	3
pH	2
Conductivity	2
Sulphate	2
Chloride	2

The laboratory testing results in Appendix F also refer to the MC samples as "Cal" samples with a J, R, or S suffix referring to a jar, ring, or sleeve as the type of container used for the MC sample. Grab samples are also referred to as "Bulk" samples in the laboratory testing results in Appendix F. Shelby tube samples are identified in Appendix D as "ST" as noted in Table 1 of this report.

3.2 SAMPLE QUALITY AND DISTURBANCE

The three Shelby tube samples from the investigation typically achieved good recovery (approximately 1.5 to 2.0 feet of recovery). The majority of SPT and CM samples had moderate to full recovery.

3.3 LABORATORY TEST SUMMARY

3.3.1 In-Situ Moisture Content and Dry Unit Weight

Measurement of in-situ moisture content was performed in general accordance with the procedures described in ASTM D2216. The results of the moisture content testing indicate that the moisture content of the uncompacted fill ranged from approximately 3.7 percent to 16.1 percent. The moisture contents of the alluvium ranged from approximately 1.9 percent to 17.4 percent.

Dry unit weights were obtained from relatively undisturbed MC and undisturbed Shelby tube samples tested in accordance with ASTM D7263, Method B. Dry unit weights of the uncompacted fill ranged from approximately 108.1 pounds per cubic foot (pcf) to 131.2 pcf. The dry unit weights of the alluvium ranged from 94.2 pcf to 128.1 pcf.

3.3.2 Remolded Moisture-Density Relationships

Two bulk samples of the uncompacted fill obtained from the upper five feet of borings B-4 and B-7 were subjected to remolded moisture-density relationship testing. The remolded moisture-density samples were tested with respect to the Standard Proctor procedures in general accordance with ASTM D698 to determine the maximum dry density and optimum moisture content.

3.3.3 Grain Size Analyses

Sieve and Hydrometer analyses were performed to obtain particle size and gradations of the materials collected. Fourteen sieve analyses and five sieve and hydrometer analyses were performed to determine the grain size distribution for coarse and fine-grained portions of the samples. The sieve test and hydrometer test procedures are described in detail in ASTM D6913 and D7928, respectively.

3.3.4 Atterberg Limits Testing

Atterberg Limits describe the consistency and plasticity of fine-grained soils with varying degrees of moisture. Atterberg Limits tests are used to determine the water content at which soil behavior becomes liquid or brittle.

Eighteen (18) Atterberg Limits tests were performed on the samples obtained during this Phase 1 investigation. The Atterberg Limits were determined using the test procedures described in ASTM D4318 following the multi-point method (Method A).

The Atterberg Limits testing indicated a range of plasticity indexes from 9 to 21 in the uncompacted fill. The Atterberg Limits testing indicated a range of plasticity indexes from non-plastic (NP) to 17 in the alluvium.

3.3.5 Direct Shear Testing

Select Shelby tube and MC samples were subjected to direct shear (DS) testing. The DS samples were tested in general accordance with ASTM D3080.

3.3.6 Permeability Testing

Select Shelby tube and MC samples were subjected to flexible wall hydraulic conductivity testing. The permeability samples were tested in general accordance with ASTM D5084 Method A (constant head).

3.3.7 Chemical Testing

Select soil samples were tested for soluble Chloride (Cl), Sulphate (SO4), resistivity, and pH to assess the potential for sulphate attack on concrete or corrosion of metal due to soil chemistry. The testing was completed in general accordance with the laboratory methods summarized in Table 5.

Table 5. Laboratory Methods for Chemical Testing

Analysis	Laboratory Method
Chloride	CA DOT #422
Resistivity	CA DOT #643
pH	CA DOT #643
Sulphate (Soluble)	CA DOT #417

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4.0 CLOSURE

This report was prepared for the exclusive use of Friant and their agents for specific application to the FKC Capacity Correction Project. Any use of this report or the material contained herein by third parties, or for other than the intended purpose, should first be approved in writing by Stantec.

We trust that this report meets your present requirements. If you have any questions or require additional information, please do not hesitate to contact our office.

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5.0 REFERENCES

American Society for Testing and Materials (ASTM), 2008, Annual Book of ASTM Standards, Volume 04.08, Construction: Soil and Rock (I), Standards D 420 - D 5876.

California Department of Transportation. “California Test 417 - Method of Testing Soils and Waters for Sulfate Content” (2014)

California Department of Transportation. “California Test 422 - Method of Testing Soils and Waters for Chloride Content” (2014)

California Department of Transportation. “California Test 643 - Method for Determining Field and Laboratory Resistivity and pH Measurements for Soil and Water” (2007)

California Division of Mines and Geology. “Geologic Map of California: Bakersfield Sheet” (1964)

California Division of Mines and Geology. “Geologic Map of California: Fresno Sheet” (1965)

United States Department of Agriculture. “Tulare County, Western Part, California (CA659)” (2018)

United States Department of the Interior Bureau of Reclamation - Central Valley Project -California. “Friant-Kern Canal – STA. 4646+06 to STA 4870+00” (1947)

United States Department of the Interior Bureau of Reclamation - Central Valley Project -California. “Friant-Kern Canal – Lining Rehabilitation at Bridges and Bridge Raise” (1975)

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APPENDIX A

Statement of General Conditions

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APPENDIX B

Boring and CPT Location Plan

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APPENDIX C

Geologic Map

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APPENDIX D

Boring Logs

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APPENDIX E

Cone Penetration Testing (CPT)

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APPENDIX F

Laboratory Soil Testing Results – AP Engineering and Testing

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IN-SITU MOISTURE CONTENT AND DRY DENSITY

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REMOLDED MOISTURE-DENSITY RELATIONSHIPS

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GRAIN SIZE ANALYSIS – SEIVE AND HYDROMETER

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ATTERBERG LIMITS

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DIRECT SHEAR TESTS

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PERMEABILITY TESTS

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CHEMICAL TESTING

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RECLAMATION

Managing Water in the West

SAN JOAQUIN RIVER RESTORATION PROGRAM

Friant WATER AUTHORITY

Feasibility Report
Exhibit A1d Cost Estimates
Friant-Kern Canal Middle Reach Capacity Correction Project

March 2019



BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 1 - Widen Existing Canal
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		175,824	lf	$4.05	$712,773
	3	Strip/Clear Vegetation at New Embankment Areas		182	ac	$3,598	$653,580
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		800	dys	$6,430	$5,144,052
	6	Excavation to Embankment					
	7	Disk/Pre-Wet Excavation Areas		1,172,160	sy	$2.02	$2,373,223
	8	Excavation to Embankment - Scraper/Dozer (60% of balance)		1,871,401	cys	$4.79	$8,971,769
	9	Excavation to Embankment - Short Truck Haul (40% of balance)		1,247,601	cys	$8.68	$10,830,331
	10	Excavation to Embankment - Long Truck Haul		590,000	cys	$12.35	$7,285,951
	11	Embankment Construction from Borrow Pits					
	12	Load/Haul/Dump Clean Fill From Borrow Pits to Embankment - Balance		728,060	cys	$9.32	$6,786,229
	13	Load/Haul/Dump Clean Fill to Embankment Areas - Long Truck Haul		900,000	cys	$10.05	$9,047,375
	14	Place & Compact Imported Clean Fill at Embankment Areas		1,628,060	cys	$4.55	$7,401,048
	15	Concrete Canal Liner					
	16	Trim/Compact Excavated Areas		1,692,000	sys	$3.25	$5,504,877
	17	Place 3.5" Concrete Liner		1,692,000	sys	$40.90	$69,200,598
	18	Final Cure for Concrete Liner		1,692,000	sys	$0.28	$478,159
	19	Trim/Point/Patch at (e) Liner Joint		351,648	lf	$2.83	$993,757
		Feature Subtotal =>					**$135,383,722**
		Subtotal Page 1 =>					**$135,383,722**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 1 - Widen Existing Canal
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID: | **ESTIMATE LEVEL:** Appraisal

REGION: MP | **UNIT PRICE LEVEL:** 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	**Ancillary Facilities**					
	1	Canal					
	2	New Ladders		469	ea	$4,946	$2,319,440
	3	Check Structure - Modify		1	ea	$1,413,000	$1,413,000
	4	Check Structure - New		2	ea	$3,532,500	$7,065,000
	5	Transition to (e) Bridges		24	ea	$70,650	$1,695,600
	6	Transitions to (e) Turnouts		39	ea	$35,325	$1,377,675
	7	Bridges					
	8	Demo (e) County or State Bridge		16	ea	$353,250	$5,652,000
	9	Demo (e) Farm Bridge		5	ea	$35,325	$176,625
	10	New County or State Bridges - 90' span		16	ea	$1,909,951	$30,559,212
	11	Replace (e) Farm Bridges		5	ea	$176,625	$883,125
	12	O&M Road					
	13	Prep/Compact Subgrade		470,000	sys	$2.44	$1,146,849
	14	Purchase/Deliver Aggregate Base Course - 4"		100,000	tns	$28.26	$2,826,000
	15	Place & Compact Aggregate Base		100,000	tns	$4.24	$423,900
	16	Blue top Aggregate Base		470,000	sys	$1.22	$573,425
	17	Miscellaneous					
	18	Seeding		5,250,000	sf	$0.07	$370,913
		Feature Subtotal =>					**$56,482,764**
	4	**Construction Allowances**					
	1	Contractor Quality Control		1	ls	1.06%	$2,033,305
	2	Flaggers		1,000	hr	$84.78	$84,780
	3	Rent Traffic Message Board		1,000	dys	$70.65	$70,650
	4	Cathodic Protection		1	ls	$0.00	$0
	5	Crew / Mgt Per-diems & Travel		1	ls	$0.00	$0
	6	Labor Overtime		1	ls	$0.00	$0
	7	Liquated Damages		1	ls	$0.00	$0
		Feature Subtotal =>					**$2,188,735**
		Subtotal Page 2 =>					**$58,671,499**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 1 - Widen Existing Canal
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization					
	1	Submittals/Procurement/POs/Resource Coordination		2	mo	$35,325	$70,650.00
	2	Establish Survey Controls		1	ls	$0.00	$0.00
	3	Establish Baseline Survey / Alignment / As-builts		500	hr	$353.25	$176,625.00
	4	Install/Maintain BMPs, SWPPP		1	ls	$141,300	$141,300.00
	5	Initial Equipment Mobilization		20	lds	$2,826	$56,520.00
	6	Initial Labor Mobilization		1	ls	$0.00	$0.00
	7	Third Party Design Services / Outside Consultants		1	ls	$0.00	$0.00
	8	Develop & Maintain Water Supply		1	ls	$247,275	$247,275.00
	9	Create & Maintain Access / Cofferdams, Crane Pads, etc.		1	ls	$353,250	$353,250.00
	10	Create & Maintain Access to Borrow or Dump Areas		8	ea	$35,325	$282,600.00
	11	Clear/Prep Borrow or Dump Areas		8	ea	$14,130	$113,040.00
	12	Reclaim Borrow Areas		8	ea	$70,650	$565,200.00
	13	Build New Haul Roads to Facilitate Earthwork Hauling		23	mi	$70,650	$1,646,145.00
	14	Reclaim Temporary Haul Roads		23	mi	$28,260	$658,458.00
		Feature Subtotal =>					**$4,311,063.00**
		Startup/Commission/Owner Training					
	1	Pre-commissioning		350	hrs	$211.95	$74,183
	2	Vendor Support		1	ls	$0.00	$0
	3	Commissioning		350	hrs	$211.95	$74,183
	4	Training		0	hrs	$141.30	$0
	5	Startup Expendables		1	ls	$0.00	$0
		Feature Subtotal =>					**$148,365**
		Subtotal Page 3 =>					**$4,459,428**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 1 - Widen Existing Canal
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: **Appraisal**

REGION: **MP**

UNIT PRICE LEVEL: **9/1/2018**

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal from Page 1					**$135,383,722**
		Subtotal from Page 2					**$58,671,499**
		Subtotal from Page 3					**$4,459,428**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$198,514,648**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		CONTRACT COST					**$200,000,000**
		Construction Contingencies	20%	+/-			$40,000,000
		FIELD COST (Unit Price Level September 2018)					**$240,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 1 - Widen Existing Canal
MP 88.2 to 121.5
With Future Subsidence

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Additional Embankment Construction from Borrow Pits		1,440,000	cys	$15.54	$22,381,920
	2	Additional Concrete Canal Liner		98,638	sys	$44.44	$4,383,359
		Feature Subtotal =>					**$26,765,279**
	3	**Ancillary Facilities**					
	1	Bridges		16	ea	$190,995	$3,055,921
		Feature Subtotal =>					**$3,055,921**
		Subtotal					**$29,821,200**
		Additional Mobilization, Startup/Commission/Owner Training	0%	+/-			
		Feature Subtotal =>					**$0**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$29,821,200**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		ADDITIONAL CONTRACT COST					**$30,000,000**
		Construction Contingencies	20%	+/-			$6,000,000
		ADDITIONAL FIELD COST (Unit Price Level September 2018)					**$36,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		ADDITIONAL CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 2 - Widen Existing Canal & Pump Station at MP 109
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		114,690	lf	$4.02	$460,993
	3	Strip/Clear Vegetation at New Embankment Areas (Incls Temp Haul Rds)		118	ac	$3,568	$422,710
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		650	dys	$6,375	$4,144,048
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		764,600	sy	$2.01	$1,534,907
	8	Excavation to Embankment - Scraper/Dozer (60% of balance)		1,069,913	cys	$4.75	$5,085,758
	9	Excavation to Embankment - Short Truck Haul (40% of balance)		713,275	cys	$8.61	$6,139,306
	10	Excavation to Embankment - Long Truck Haul		1,391,220	cys	$10.27	$14,284,200
	11	Import to Embankment		800,000	cys	$7.75	$6,197,186
	12	Excavation & Haul to Waste - Short Truck Haul		250,000	cys	$4.42	$1,104,570
	13	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		250,000	cys	$2.83	$707,828
	14	Concrete Canal Liner					
	15	Trim/Compact Excavated Areas		936,956	sys	$3.23	$3,022,473
	16	Place 3.5" Concrete Liner		936,956	sys	$40.55	$37,994,843
	17	Final Cure for Concrete Liner		936,956	sys	$0.28	$262,535
	18	Trim/Point/Patch at (e) Liner Joint		229,380	lf	$2.80	$642,723
		Feature Subtotal =>					**$82,004,080**
		Subtotal Page 1 =>					**$82,004,080**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE:
Alternative 2 - Widen Existing Canal & Pump Station at MP 109
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID: | **ESTIMATE LEVEL:** **Appraisal**
REGION: **MP** | **UNIT PRICE LEVEL:** **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	**Ancillary Facilities**					
	1	Canal					
	2	New Ladders		417	ea	$4,904	$2,044,759.50
	3	Check Structure - Modify		2	ea	$1,401,000	$2,802,000.00
	4	Check Structure - New		2	ea	$3,502,500	$7,005,000.00
	5	Transition to (e) Bridges		24	ea	$70,050	$1,681,200.00
	6	Transitions to (e) Turnouts		63	ea	$35,025	$2,206,575.00
	7	Bridges					
	8	Demo (e) County or State Bridge		14	ea	$350,250	$4,903,500.00
	9	Demo (e) Farm Bridge		0	ea	$35,025	$0.00
	10	New County or State Bridges - 90' span		14	ea	$1,893,730	$26,512,225.46
	11	Replace (e) Farm Bridges		0	ea	$175,125	$0.00
	12	O&M Road					
	13	Prep/Compact Subgrade		292,667	sys	$2.42	$708,073.37
	14	Purchase/Deliver Aggregate Base Course - 4"		63,000	tns	$28.02	$1,765,260.00
	15	Place & Compact Aggregate Base		63,000	tns	$4.20	$264,789.00
	16	Blue top Aggregate Base		292,667	sys	$1.21	$354,036.69
	17	Miscellaneous					
	18	Seeding		3,440,700	sf	$0.07	$241,021.04
		Feature Subtotal =>					**$50,488,440**
	4	**Pump Station At MP 109.0**					
	1	Complete-in-Place		4,800	hp	$3,503	$16,812,000
		Feature Subtotal =>					**$16,812,000**
		Subtotal Page 2 =>					**$67,300,440**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
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DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 2 - Widen Existing Canal & Pump Station at MP 109
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID: | **ESTIMATE LEVEL:** Appraisal

REGION: MP | **UNIT PRICE LEVEL:** 9/1/2018

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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	5	**Pump Station Overflow Reservoir at MP 109**					
	1	Permanent Land Acquisition for Overflow Reservoir		0	ac	$35,025	$0
	2	Excavation to Embankment or Waste					
	3	Disk/Pre-Wet Excavation Areas		0	sy	$0.67	$0
	4	Excavation to Embankment - Scraper/Dozer		210,500	cys	$4.75	$1,000,597
	7	Excavation & Haul to Waste - Medium Truck Haul		1,789,500	cys	$7.89	$14,125,569
	8	Purchase Land for Stockpiling of Waste Excavation		0	ac	$35,025	$0
	9	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		1,789,500	cys	$2.83	$5,066,636
	10	O&M Road at Berm Perimeter		288,000	sys	$10.57	$3,042,850
		Feature Subtotal =>					**$23,235,652**
	6	**Construction Allowances**					
	1	Contractor Quality Control		1	ls	1.05%	$1,812,966
	2	Flaggers		1,000	hr	$84.06	$84,060
	3	Rent Traffic Message Board		1,000	dys	$70.05	$70,050
	4	Cathodic Protection		1	ls	$0.00	$0
	5	Crew / Mgt Per-diems & Travel		1	ls	$0.00	$0
	6	Labor Overtime		1	ls	$0.00	$0
	7	Liquated Damages		1	ls	$0.00	$0
		Feature Subtotal =>					**$1,967,076**
		Subtotal Page 3 =>					**$25,202,728**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE:
Alternative 2 - Widen Existing Canal & Pump Station at MP 109
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID: | **ESTIMATE LEVEL:** **Appraisal**
REGION: **MP** | **UNIT PRICE LEVEL:** **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization					
	1	Submittals/Procurement/POs/Resource Coordination		2	mo	$0.00	$0
	2	Establish Survey Controls		1	ls	$0.00	$0
	3	Establish Baseline Survey / Alignment / As-builts		500	hr	$350.25	$175,125
	4	Install/Maintain BMPs, SWPPP		1	ls	$140,100	$140,100
	5	Initial Equipment Mobilization		20	lds	$2,802	$56,040
	6	Initial Labor Mobilization		1	ls	$0.00	$0
	7	Third Party Design Services / Outside Consultants		1	ls	$0.00	$0
	8	Develop & Maintain Water Supply		1	ls	$245,175	$245,175
	9	Create & Maintain Access / Cofferdams, Crane Pads, etc.		1	ls	$350,250	$350,250
	10	Create & Maintain Access to Borrow or Dump Areas		4	ea	$35,025	$140,100
	11	Clear/Prep Borrow or Dump Areas		4	ea	$28,020	$112,080
	12	Reclaim Borrow Areas		4	ea	$70,050	$280,200
	13	Build New Haul Roads to Facilitate Earthwork Hauling		33	mi	$70,050	$2,311,650
	14	Reclaim Temporary Haul Roads		33	mi	$28,020	$924,660
		Feature Subtotal =>					**$4,735,380**
		Startup/Commission/Owner Training					
	1	Pre-commissioning		350	hrs	$210.15	$73,553
	2	Vendor Support		1	ls	$0.00	$0
	3	Commissioning		350	hrs	$210.15	$73,553
	4	Training		0	hrs	$140.10	$0
	5	Startup Expendables		1	ls	$0.00	$0
		Feature Subtotal =>					**$147,105**
		Subtotal Page 4 =>					**$4,882,485**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 2 - Widen Existing Canal & Pump Station at MP 109 MP 88.2 to 121.5	**PROJECT:** Friant-Kern Canal Middle Reach Capacity Correction (MRCC)
	WOID: **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** 9/1/2018
	FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal from Page 1					**$82,004,080**
		Subtotal from Page 2					**$67,300,440**
		Subtotal from Page 3					**$25,202,728**
		Subtotal from Page 4					**$4,882,485**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$179,389,734**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		CONTRACT COST					**$180,000,000**
		Construction Contingencies	20%	+/-			$36,000,000
		FIELD COST (Unit Price Level September 2018)					**$220,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 2 - Widen Existing Canal & Pump Station at MP 109
MP 88.2 to 121.5
With Future Subsidence

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Additional Embankment Construction - Haul from Waste		330,000	cys	$9.81	$3,236,310
	2	Additional Concrete Canal Liner		38,531	sys	$44.06	$1,697,732
		Feature Subtotal =>					**$4,934,042**
	3	**Ancillary Facilities**					
	1	Bridges		14	ea	$189,373	$2,651,222
		Feature Subtotal =>					**$2,651,222**
	4	**Pump Station At MP 109.0**					
		Capacity Increase - Added Pumps/ Motors		4	ea	$1,120,800	**$4,483,200**
		Subtotal					**$12,068,464**
		Additional Mobilization, Startup/Commission/Owner Training	0%	+/-			
		Feature Subtotal =>					**$0**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$12,068,464**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		ADDITIONAL CONTRACT COST					**$12,000,000**
		Construction Contingencies	20%	+/-			$2,400,000
		ADDITIONAL FIELD COST (Unit Price Level September 2018)					**$14,500,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		ADDITIONAL CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 3 - Widen Existing Canal + IL Pump Station at MP 119.5
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		101,342	lf	$4.03	$408,213
	3	Strip/Clear Vegetation at New Embankment Areas (Incls Temp Haul Rds)		105	ac	$3,575	$374,313
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		800	dys	$6,389	$5,111,288
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		675,613	sy	$2.01	$1,359,173
	8	Excavation to Embankment - Scraper/Dozer (60% of balance)		271,022	cys	$4.76	$1,291,042
	9	Excavation to Embankment - Short Truck Haul (40% of balance)		180,681	cys	$8.63	$1,558,490
	10	Excavation to Embankment - Med Truck Haul		490,879	cys	$9.60	$4,714,116
	11	Excavation to Embankment - Long Truck Haul		1,075,000	cys	$10.84	$11,657,251
	12	Excavation & Haul to Waste - Short Truck Haul		0	cys	$4.43	$0
	13	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		0	cys	$2.84	$0
	14	Concrete Canal Liner					
	15	Trim/Compact Excavated Areas		937,309	sys	$3.23	$3,030,086
	16	Place 3.5" Concrete Liner		937,309	sys	$40.64	$38,090,548
	17	Final Cure for Concrete Liner		937,309	sys	$0.28	$263,196
	18	Trim/Point/Patch at (e) Liner Joint		202,684	lf	$2.81	$569,137
		Feature Subtotal =>					**$68,426,853**
		Subtotal Page 1 =>					**$68,426,853**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 3 - Widen Existing Canal + IL Pump Station at MP 119.5
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	**New Canal Bypass**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		55,439	lf	$0.00	$0
	3	Strip/Clear Vegetation at New Embankment Areas		57	ac	$84.24	$4,825
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		400	dys	$126.36	$50,544
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		369,593	sy	$2.01	$743,534
	8	Excavation to Embankment - Scraper/Dozer (balance)		1,092,590	cys	$4.76	$5,204,672
	9	Excavation to Embankment - Long Truck Haul		1,075,000	cys	$10.84	$11,657,251
	10	Excavation & Haul to Waste - Medium Truck Haul		900,000	cys	$9.18	$8,262,193
	11	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		900,000	cys	$2.84	$2,553,639
	12	Concrete Canal Liner					
	13	Trim/Compact Excavated Areas		646,157	sys	$3.23	$2,088,865
	14	Place 3.5" Concrete Liner		646,157	sys	$40.64	$26,258,656
	15	Final Cure for Concrete Liner		646,157	sys	$0.28	$181,441
	16	Trim/Point/Patch at (e) Liner Joint		0	lf	$2.81	$0
		Feature Subtotal =>					**$57,005,617**
		Subtotal Page 2 =>					**$57,005,617**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 3 - Widen Existing Canal + IL Pump Station at MP 119.5
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	4	**Ancillary Facilities**					
	1	Canal					
	2	New Ladders		389	ea	$4,914	$1,911,546
	3	Check Structure - Modify		0	ea	$1,404,000	$0.00
	4	Check Structure - New		2	ea	$3,510,000	$7,020,000
	5	Transition to (e) Bridges		17	ea	$70,200	$1,193,400
	6	Transitions to (e) Turnouts		20	ea	$35,100	$702,000
	7	Bridges					
	8	Demo (e) County or State Bridge		11	ea	$351,000	$3,861,000
	9	Demo (e) Farm Bridge		1	ea	$35,100	$35,100
	10	New County or State Bridges - 90' span		23	ea	$1,897,785	$43,649,066
	11	Replace (e) Farm Bridges		1	ea	$175,500	$175,500
	12	O&M Road					
	13	Prep/Compact Subgrade		418,083	sys	$2.42	$1,013,669
	14	Purchase/Deliver Aggregate Base Course - 4"		89,000	tns	$28.08	$2,499,120
	15	Place & Compact Aggregate Base		89,000	tns	$4.21	$374,868
	16	Blue top Aggregate Base		418,083	sys	$1.21	$506,834
	17	Miscellaneous					
	18	Seeding		3,040,260	sf	$0.07	$213,426
		Feature Subtotal =>					**$63,155,529**
	5	**Pump Station At MP 109.0**					
	1	Complete-in-Place		5,600	hp	$3,510	$19,656,000
		Feature Subtotal =>					**$19,656,000**
	6	**Pump Station Overflow Reservoir at MP 109**					
	1	Permanent Land Acquisition for Overflow Reservoir		0	ac	$35,100	$0
	2	Excavation to Embankment or Waste		2,000,000	cys	$10.12	$20,236,042
	3	Disk/Pre-Wet Excavation Areas		0	sy	$0.67	$0
	4	Excavation to Embankment - Scraper/Dozer		210,500	cys	$4.76	$1,002,740
	5	Excavation & Haul to Waste - Medium Truck Haul		1,789,500	cys	$7.91	$14,155,816
	6	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		1,789,500	cys	$2.84	$5,077,486
	7	O&M Road at Berm Perimeter		288,000	sys	$10.51	$3,027,182
		Feature Subtotal =>					**$43,499,265**
		Subtotal Page 3 =>					**$126,310,795**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 3 - Widen Existing Canal + IL Pump Station at MP 119.5
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	7	**Construction Allowances**					
	1	Contractor Quality Control		1	ls	1.05%	$2,650,857
	2	Flaggers		1,000	hr	$84.24	$84,240
	3	Rent Traffic Message Board		1,000	dys	$70.20	$70,200
	4	Cathodic Protection		1	ls	$0.00	$0
	5	Crew / Mgt Per-diems & Travel		1	ls	$0.00	$0
	6	Labor Overtime		1	ls	$0.00	$0
	7	Liquated Damages		1	ls	$0.00	$0
		Feature Subtotal =>					**$2,805,297**
		Mobilization					
	1	Submittals/Procurement/POs/Resource Coordination		2	mo	$35,100.00	$70,200
	2	Establish Survey Controls		1	ls	$0.00	$0
	3	Establish Baseline Survey / Alignment / As-builts		500	hr	$351.00	$175,500
	4	Install/Maintain BMPs, SWPPP		1	ls	$140,400.00	$140,400
	5	Initial Equipment Mobilization		20	lds	$2,808.00	$56,160
	6	Initial Labor Mobilization		1	ls	$0.00	$0
	7	Third Party Design Services / Outside Consultants		1	ls	$0.00	$0
	8	Develop & Maintain Water Supply		1	ls	$245,700.00	$245,700
	9	Create & Maintain Access / Cofferdams, Crane Pads, etc.		1	ls	$351,000.00	$351,000
	10	Create & Maintain Access to Borrow or Dump Areas		6	ea	$35,100.00	$210,600
	11	Clear/Prep Borrow or Dump Areas		6	ea	$28,080.00	$168,480
	12	Reclaim Borrow Areas		6	ea	$70,200.00	$421,200
	13	Build New Haul Roads to Facilitate Earthwork Hauling		33	mi	$70,200.00	$2,316,600
	14	Reclaim Temporary Haul Roads		33	mi	$28,080.00	$926,640
		Feature Subtotal =>					**$5,082,480**
		Subtotal Page 4 =>					**$7,887,777**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 3 - Widen Existing Canal + IL Pump Station at MP 119.5
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Startup/Commission/Owner Training					
	1	Pre-commissioning		350	hrs	$210.60	$73,710
	2	Vendor Support		1	ls	$0.00	$0
	3	Commissioning		350	hrs	$210.60	$73,710
	4	Training		0	hrs	$140.40	$0
	5	Startup Expendables		1	ls	$0.00	$0
		Feature Subtotal =>					**$147,420**
		Subtotal from Page 1					**$68,426,852.89**
		Subtotal from Page 2					**$57,005,617.17**
		Subtotal from Page 3					**$126,310,794.82**
		Subtotal from Page 4					**$7,887,776.58**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$259,778,461**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		CONTRACT COST					**$260,000,000**
		Construction Contingencies	20%	+/-			$52,000,000
		FIELD COST (Unit Price Level September 2018)					**$310,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 3 - Widen Existing Canal + IL Pump Station at MP 119.5
MP 88.2 to 121.5
With Future Subsidence

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Additional Embankment Construction - Haul from Waste		1,380,000	cys	$9.83	$13,562,640
	2	Additional Concrete Canal Liner		98,635	sys	$44.16	$4,355,307
		Feature Subtotal =>					**$17,917,947**
	3	**Ancillary Facilities**					
	1	Bridges		23	ea	$189,779	$4,364,906
		Feature Subtotal =>					**$4,364,906**
	4	**Pump Station At MP 109.0**					
		Capacity Increase - Added Pumps/ Motors		4	ea	$1,123,200	**$4,492,800**
		Subtotal					**$26,775,654**
		Additional Mobilization, Startup/Commission/Owner Training	0%	+/-			
		Feature Subtotal =>					**$0**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$26,775,654**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		ADDITIONAL CONTRACT COST					**$27,000,000**
		Construction Contingencies	20%	+/-			$5,400,000
		ADDITIONAL FIELD COST (Unit Price Level September 2018)					**$32,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		ADDITIONAL CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
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BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 4A - Widen Existing Canal + Bypass from Tule River to White River
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		84,385	lf	$4.07	$343,299
	3	Strip/Clear Vegetation at New Embankment Areas		87	ac	$3,611	$314,789
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		400	dys	$6,453	$2,581,128
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		562,567	sy	$2.03	$1,143,036
	8	Excavation to Embankment - Scraper/Dozer (balance)		1,056,585	cys	$4.81	$5,083,345
	9	Excavation & Haul to Waste - Medium Truck Haul		1,371,399	cys	$9.27	$12,715,277
	10	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		1,371,399	cys	$2.87	$3,929,977
	11	Concrete Canal Liner					
	12	Trim/Compact Excavated Areas		768,899	sys	$3.26	$2,510,445
	13	Place 3.5" Concrete Liner		768,899	sys	$41.04	$31,558,246
	14	Final Cure for Concrete Liner		768,899	sys	$0.28	$218,060
	15	Trim/Point/Patch at (e) Liner Joint		168,770	lf	$2.84	$478,632
		Feature Subtotal =>					**$60,876,232**
		Subtotal Page 1 =>					**$60,876,232**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
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BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 4A - Widen Existing Canal + Bypass from Tule River to White River
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	**New Canal Bypass**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		90,403	lf	$0.00	$0
	3	Strip/Clear Vegetation at New Embankment Areas		93	ac	$3,611	$337,239
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		400	dys	$6,453	$2,581,128
	6	Excavation to Embankment or Waste		2,984,661			
	7	Disk/Pre-Wet Excavation Areas		602,687	sy	$2.03	$1,224,552
	8	Excavation to Embankment - Scraper/Dozer (balance)		1,835,428	cys	$4.81	$8,830,445
	9	Excavation to Embankment - Long Truck Haul		849,233	cys	$10.95	$9,300,872
	10	Excavation & Haul to Waste - Medium Truck Haul		300,000	cys	$9.27	$2,781,526
	11	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		300,000	cys	$2.87	$859,701
	12	Concrete Canal Liner		1,146,222			
	13	Trim/Compact Excavated Areas		1,146,222	sys	$3.26	$3,742,399
	14	Place 3.5" Concrete Liner		1,146,222	sys	$41.04	$47,044,872
	15	Final Cure for Concrete Liner		1,146,222	sys	$0.28	$325,069
	16	Trim/Point/Patch at (e) Liner Joint		0	lf	$2.84	$0
		Feature Subtotal =>					**$77,027,803**
		Subtotal Page 2 =>					**$77,027,803**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 4A - Widen Existing Canal + Bypass from Tule River to White River
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	4	**Ancillary Facilities - Both**					
	1	Canal					
	2	New Ladders		440	ea	$4,963	$2,183,720
	3	Check Structure - Modify		1	ea	$1,418,000	$1,418,000.00
	4	Check Structure - New		2	ea	$3,545,000	$7,090,000
	5	Transition to (e) Bridges		26	ea	$70,900	$1,843,400
	6	Transitions to (e) Turnouts		32	ea	$35,450	$1,134,400
	7	Bridges					
	8	Demo (e) County or State Bridge		2	ea	$354,500	$709,000
	9	Demo (e) Farm Bridge		2	ea	$35,450	$70,900
	10	New County or State Bridges - 90' span		18	ea	$1,916,709	$34,500,767
	11	Replace (e) Farm Bridges		2	ea	$177,250	$354,500
	12	O&M Road					
	13	Prep/Compact Subgrade		466,101	sys	$2.45	$1,141,360
	14	Purchase/Deliver Aggregate Base Course - 4"		100,000	tns	$28.36	$2,836,000
	15	Place & Compact Aggregate Base		100,000	tns	$4.25	$425,400
	16	Blue top Aggregate Base		466,101	sys	$1.22	$570,680
	17	Miscellaneous					
	18	Seeding		5,243,640	sf	$0.07	$371,774
		Feature Subtotal =>					**$54,649,901**
	7	**Construction Allowances**					
	1	Contractor Quality Control		1	ls	1.06%	$2,047,811
	2	Flaggers		1,000	hr	$85.08	$85,080
	3	Rent Traffic Message Board		1,000	dys	$70.90	$70,900
	4	Cathodic Protection		1	ls	$0.00	$0
	5	Crew / Mgt Per-diems & Travel		1	ls	$0.00	$0
	6	Labor Overtime		1	ls	$0.00	$0
	7	Liquated Damages		1	ls	$0.00	$0
		Feature Subtotal =>					**$2,203,791**
		Subtotal Page 3 =>					**$56,853,692**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 4A - Widen Existing Canal + Bypass from Tule River to White River
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization					
	1	Submittals/Procurement/POs/Resource Coordination		2	mo	$35,450	$70,900
	2	Establish Survey Controls		1	ls	$0.00	$0
	3	Establish Baseline Survey / Alignment / As-builts		500	hr	$354.50	$177,250
	4	Install/Maintain BMPs, SWPPP		1	ls	$141,800	$141,800
	5	Initial Equipment Mobilization		20	lds	$2,836	$56,720
	6	Initial Labor Mobilization		1	ls	$0.00	$0
	7	Third Party Design Services / Outside Consultants		1	ls	$0.00	$0
	8	Develop & Maintain Water Supply		1	ls	$248,150	$248,150
	9	Create & Maintain Access / Cofferdams, Crane Pads, etc.		1	ls	$354,500	$354,500
	10	Create & Maintain Access to Borrow or Dump Areas		10	ea	$35,450	$354,500
	11	Clear/Prep Borrow or Dump Areas		10	ea	$28,360	$283,600
	12	Reclaim Borrow Areas		10	ea	$70,900	$709,000
	13	Build New Haul Roads to Facilitate Earthwork Hauling		33	mi	$70,900	$2,339,700
	14	Reclaim Temporary Haul Roads		33	mi	$28,360	$935,880
		Feature Subtotal =>					**$5,672,000**
		Startup/Commission/Owner Training					
	1	Pre-commissioning		350	hrs	$212.70	$74,445
	2	Vendor Support		1	ls	$0.00	$0
	3	Commissioning		350	hrs	$212.70	$74,445
	4	Training		0	hrs	$141.80	$0
	5	Startup Expendables		1	ls	$0.00	$0
		Feature Subtotal =>					**$148,890**
		Subtotal Page 4 =>					**$5,820,890**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE: Alternative 4A - Widen Existing Canal + Bypass from Tule River to White River MP 88.2 to 121.5	**PROJECT:** Friant-Kern Canal Middle Reach Capacity Correction (MRCC)
	WOID:
	ESTIMATE LEVEL: Appraisal
	REGION: MP
	UNIT PRICE LEVEL: 9/1/2018
	FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal from Page 1					**$60,876,231.72**
		Subtotal from Page 2					**$77,027,802.78**
		Subtotal from Page 3					**$56,853,692.07**
		Subtotal from Page 4					**$5,820,890.00**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$200,578,617**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		CONTRACT COST					**$200,000,000**
		Construction Contingencies	20%	+/-			$40,000,000
		FIELD COST (Unit Price Level September 2018)					**$240,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 4A - Widen Existing Canal + Bypass from Tule River to White River
MP 88.2 to 121.5
With Future Subsidence

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Additional Embankment Construction - Haul from Waste		1,100,000	cys	$9.93	$10,918,600
	2	Additional Concrete Canal Liner		102,950	sys	$44.60	$4,591,168
		Feature Subtotal =>					**$15,509,768**
	3	**Ancillary Facilities**					
	1	Bridges		18	ea	$191,671	$3,450,077
		Feature Subtotal =>					**$3,450,077**
		Subtotal					**$18,959,845**
		Additional Mobilization, Startup/Commission/Owner Training	0%	+/-			
		Feature Subtotal =>					**$0**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$18,959,845**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		ADDITIONAL CONTRACT COST					**$19,000,000**
		Construction Contingencies	20%	+/-			$3,800,000
		ADDITIONAL FIELD COST (Unit Price Level September 2018)					**$23,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		ADDITIONAL CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE: Alternative 4B - Widen Existing Canal + Bypass from Tule River to Woollomes Reservoir MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		126,532	lf	$4.06	$513,311
	3	Strip/Clear Vegetation at New Embankment Areas		131	ac	$3,601	$470,683
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		300	dys	$6,435	$1,930,385
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		843,547	sy	$2.03	$1,709,102
	8	Excavation to Embankment - Scraper/Dozer (balance)		602,177	cys	$4.80	$2,888,965
	9	Excavation & Haul to Waste - Medium Truck Haul		806,814	cys	$9.25	$7,459,475
	10	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		806,814	cys	$2.86	$2,305,539
	11	Concrete Canal Liner					
	12	Trim/Compact Excavated Areas		403,475	sys	$3.26	$1,313,624
	13	Place 3.5" Concrete Liner		403,475	sys	$40.93	$16,513,281
	14	Final Cure for Concrete Liner		403,475	sys	$0.28	$114,103
	15	Trim/Point/Patch at (e) Liner Joint		253,064	lf	$2.83	$715,665
		Feature Subtotal =>					**$35,934,132**
		Subtotal Page 1 =>					**$35,934,132**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 4B - Widen Existing Canal + Bypass from Tule River to Woollomes Reservoir
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	**New Canal Bypass**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		126,532	lf	$0.00	$0
	3	Strip/Clear Vegetation at New Embankment Areas		131	ac	$3,601	$470,683
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		500	dys	$6,435	$3,217,308
	6	Excavation to Embankment or Waste		4,764,631			
	7	Disk/Pre-Wet Excavation Areas		843,547	sy	$2.03	$1,709,102
	8	Excavation to Embankment - Scraper/Dozer (balance)		1,913,200	cys	$4.80	$9,178,648
	9	Excavation to Embankment - Long Truck Haul		1,913,200	cys	$9.25	$17,688,680
	10	Excavation & Haul to Waste - Medium Truck Haul		938,232	cys	$10.92	$10,246,605
	11	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		1,913,200	cys	$2.86	$5,467,133
	12	Concrete Canal Liner		1,559,908			
	13	Trim/Compact Excavated Areas		1,559,908	sys	$3.26	$5,078,711
	14	Place 3.5" Concrete Liner		1,559,908	sys	$40.93	$63,843,358
	15	Final Cure for Concrete Liner		1,559,908	sys	$0.28	$441,142
	16	Trim/Point/Patch at (e) Liner Joint		0	lf	$2.83	$0
		Feature Subtotal =>					**$117,341,369**
		Subtotal Page 2 =>					**$117,341,369**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 4B - Widen Existing Canal + Bypass from Tule River to Woollomes Reservoir MP 88.2 to 121.5

PROJECT: Friant-Kern Canal Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	4	**Ancillary Facilities - Both**					
	1	Canal					
	2	New Ladders		442	ea	$4,949	$2,187,458
	3	Check Structure - Modify		0	ea	$1,414,000	$0.00
	4	Check Structure - New		2	ea	$3,535,000	$7,070,000
	5	Transition to (e) Bridges		17	ea	$70,700	$1,201,900
	6	Transitions to (e) Turnouts		11	ea	$35,350	$388,850
	7	Bridges					
	8	Demo (e) County or State Bridge		0	ea	$353,500	$0
	9	Demo (e) Farm Bridge		1	ea	$35,350	$35,350
	10	New County or State Bridges - 90' span		24	ea	$1,911,302	$45,871,259
	11	Replace (e) Farm Bridges		1	ea	$176,750	$176,750
	12	O&M Road					
	13	Prep/Compact Subgrade		478,976	sys	$2.44	$1,169,579
	14	Purchase/Deliver Aggregate Base Course - 4"		102,000	tns	$28.28	$2,884,560
	15	Place & Compact Aggregate Base		102,000	tns	$4.24	$432,684
	16	Blue top Aggregate Base		478,976	sys	$1.22	$584,789
	17	Miscellaneous					
	18	Seeding		7,591,920	sf	$0.07	$536,749
		Feature Subtotal =>					**$62,539,929**
	7	**Construction Allowances**					
	1	Contractor Quality Control		1	ls	1.06%	$2,288,722.64
	2	Flaggers		1,000	hr	$84.84	$84,840
	3	Rent Traffic Message Board		1,000	dys	$70.70	$70,700
	4	Cathodic Protection		1	ls	$0.00	$0
	5	Crew / Mgt Per-diems & Travel		1	ls	$0.00	$0
	6	Labor Overtime		1	ls	$0.00	$0
	7	Liquated Damages		1	ls	$0.00	$0
		Feature Subtotal =>					**$2,444,263**
		Subtotal Page 3 =>					**$64,984,191**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 4B - Widen Existing Canal + Bypass from Tule River to Woollomes Reservoir
MP 88.2 to 121.5

PROJECT: Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:

ESTIMATE LEVEL: Appraisal

REGION: MP

UNIT PRICE LEVEL: 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization					
	1	Submittals/Procurement/POs/Resource Coordination		2	mo	$35,350	$70,700
	2	Establish Survey Controls		1	ls	$0.00	$0
	3	Establish Baseline Survey / Alignment / As-builts		500	hr	$353.50	$176,750
	4	Install/Maintain BMPs, SWPPP		1	ls	$141,400	$141,400
	5	Initial Equipment Mobilization		20	lds	$2,828	$56,560
	6	Initial Labor Mobilization		1	ls	$0.00	$0
	7	Third Party Design Services / Outside Consultants		1	ls	$0.00	$0
	8	Develop & Maintain Water Supply		1	ls	$247,450	$247,450
	9	Create & Maintain Access / Cofferdams, Crane Pads, etc.		1	ls	$353,500	$353,500
	10	Create & Maintain Access to Borrow or Dump Areas		10	ea	$35,350	$353,500
	11	Clear/Prep Borrow or Dump Areas		10	ea	$28,280	$282,800
	12	Reclaim Borrow Areas		10	ea	$70,700	$707,000
	13	Build New Haul Roads to Facilitate Earthwork Hauling		33	mi	$70,700	$2,333,100
	14	Reclaim Temporary Haul Roads		33	mi	$28,280	$933,240
		Feature Subtotal =>					**$5,656,000**
		Startup/Commission/Owner Training					
	1	Pre-commissioning		350	hrs	$212.10	$74,235
	2	Vendor Support		1	ls	$0.00	$0
	3	Commissioning		350	hrs	$212.10	$74,235
	4	Training		0	hrs	$141.40	$0
	5	Startup Expendables		1	ls	$0.00	$0
		Feature Subtotal =>					**$148,470**
		Subtotal Page 3 =>					**$5,804,470**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 4B - Widen Existing Canal + Bypass from Tule River to Woollomes Reservoir MP 88.2 to 121.5	**PROJECT:** Friant-Kern Canal Middle Reach Capacity Correction (MRCC)
	WOID: **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** 9/1/2018
	FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal from Page 1					**$35,934,131.96**
		Subtotal from Page 2					**$117,341,369.45**
		Subtotal from Page 3					**$64,984,191.24**
		Subtotal from Page 4					**$5,804,470.00**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$224,064,163**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		CONTRACT COST					**$220,000,000**
		Construction Contingencies	20%	+/-			$44,000,000
		FIELD COST (Unit Price Level September 2018)					**$260,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE: Alternative 4B - Widen Existing Canal + Bypass from Tule River to Woollomes Reservoir MP 88.2 to 121.5 With Future Subsidence	**PROJECT:** Friant-Kern Canal Middle Reach Capacity Correction (MRCC)
	WOID: **ESTIMATE LEVEL:** Appraisal
	REGION: MP **UNIT PRICE LEVEL:** 9/1/2018
	FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Additional Embankment Construction - Haul from Waste		1,110,000	cys	$9.90	$10,986,780
	2	Additional Concrete Canal Liner		101,313	sys	$44.47	$4,505,420
		Feature Subtotal =>					**$15,492,200**
	3	**Ancillary Facilities**					
	1	Bridges		24	ea	$191,130	$4,587,126
		Feature Subtotal =>					**$4,587,126**
		Subtotal					**$20,079,325**
		Additional Mobilization, Startup/Commission/Owner Training	0%	+/-			
		Feature Subtotal =>					**$0**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$20,079,325**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		ADDITIONAL CONTRACT COST					**$20,000,000**
		Construction Contingencies	20%	+/-			$4,000,000
		ADDITIONAL FIELD COST (Unit Price Level September 2018)					**$24,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		ADDITIONAL CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 5A - Widen Existing Canal + Parallel Canal from Tule River to White River
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		85,792	lf	$4.05	$347,546
	3	Strip/Clear Vegetation at New Embankment Areas		89	ac	$3,596	$318,684
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		400	dys	$6,426	$2,570,206
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		571,947	sy	$2.02	$1,157,177
	8	Excavation to Embankment - Scraper/Dozer (balance)		1,028,084	cys	$4.79	$4,925,295
	9	Excavation & Haul to Waste - Medium Truck Haul		1,369,899	cys	$9.23	$12,647,625
	10	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		1,369,899	cys	$2.85	$3,909,068
	11	Concrete Canal Liner					
	12	Trim/Compact Excavated Areas		756,411	sys	$3.25	$2,459,221
	13	Place 3.5" Concrete Liner		756,411	sys	$40.87	$30,914,331
	14	Final Cure for Concrete Liner		756,411	sys	$0.28	$213,610
	15	Trim/Point/Patch at (e) Liner Joint		171,584	lf	$2.82	$484,553
		Feature Subtotal =>					**$59,947,317**
		Subtotal Page 1 =>					**$59,947,317**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE: Alternative 5A - Widen Existing Canal + Parallel Canal from Tule River to White River MP 88.2 to 121.5

PROJECT: Friant-Kern Canal Middle Reach Capacity Correction (MRCC)

WOID: | **ESTIMATE LEVEL:** Appraisal

REGION: MP | **UNIT PRICE LEVEL:** 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	**New Canal Bypass**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		90,403	lf	$0.00	$0
	3	Strip/Clear Vegetation at New Embankment Areas		93	ac	$3,596	$335,812
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		400	dys	$6,426	$2,570,206
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		602,687	sy	$2.02	$1,219,371
	8	Excavation to Embankment - Scraper/Dozer (50% balance)		795,256	cys	$4.79	$3,809,875
	9	Excavation to Embankment - Truck (50% balance)		795,256	cys	$8.67	$6,898,674
	10	Excavation to Embankment - Long Truck Haul		773,185	cys	$10.91	$8,432,155
	11	Excavation & Haul to Waste - Medium Truck Haul		1,100,000	cys	$11.08	$12,186,930
	12	Import to Embankment					
	13	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		1,100,000	cys	$2.85	$3,138,898
	14	Concrete Canal Liner					
	15	Trim/Compact Excavated Areas		1,144,273	sys	$3.25	$3,720,227
	16	Place 3.5" Concrete Liner		1,144,273	sys	$40.87	$46,766,156
	17	Final Cure for Concrete Liner		1,144,273	sys	$0.28	$323,143
	18	Trim/Point/Patch at (e) Liner Joint		0	lf	$2.82	$0
		Feature Subtotal =>					**$89,401,447**
		Subtotal Page 2 =>					**$89,401,447**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION **ESTIMATE WORKSHEET** SHEET 3 OF 5

FEATURE: Alternative 5A - Widen Existing Canal + Parallel Canal from Tule River to White River MP 88.2 to 121.5

PROJECT: Friant-Kern Canal Middle Reach Capacity Correction (MRCC)

WOID: **ESTIMATE LEVEL:** Appraisal

REGION: MP **UNIT PRICE LEVEL:** 9/1/2018

FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	4	**Ancillary Facilities - Both**					
	1	Canal					
	2	New Ladders		442	ea	$4,942	$2,184,364
	3	Check Structure - Modify		0	ea	$1,412,000	$0.00
	4	Check Structure - New		1	ea	$3,530,000	$3,530,000
	5	Transition to (e) Bridges		26	ea	$70,600	$1,835,600
	6	Transitions to (e) Turnouts		32	ea	$35,300	$1,129,600
	7	Bridges					
	8	Demo (e) County or State Bridge		2	ea	$353,000	$706,000
	9	Demo (e) Farm Bridge		2	ea	$35,300	$70,600
	10	New County or State Bridges - 90' span		18	ea	$1,908,599	$34,354,783
	11	Replace (e) Farm Bridges		2	ea	$176,500	$353,000
	12	O&M Road					
	13	Prep/Compact Subgrade		471,179	sys	$2.44	$1,148,913
	14	Purchase/Deliver Aggregate Base Course - 4"		101,000	tns	$28.24	$2,852,240
	15	Place & Compact Aggregate Base		101,000	tns	$4.24	$427,836
	16	Blue top Aggregate Base		471,179	sys	$1.22	$574,456
	17	Miscellaneous					
	18	Seeding		5,285,850	sf	$0.07	$373,181
		Feature Subtotal =>					**$49,540,573**
	7	**Construction Allowances**					
	1	Contractor Quality Control		1	ls	1.06%	$2,106,238
	2	Flaggers		1,000	hr	$84.72	$84,720
	3	Rent Traffic Message Board		1,000	dys	$70.60	$70,600
	4	Cathodic Protection		1	ls	$0.00	$0
	5	Crew / Mgt Per-diems & Travel		1	ls	$0.00	$0
	6	Labor Overtime		1	ls	$0.00	$0
	7	Liquated Damages		1	ls	$0.00	$0
		Feature Subtotal =>					**$2,261,558**
		Subtotal Page 2 =>					**$51,802,131**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE:
Alternative 5A - Widen Existing Canal + Parallel Canal from Tule River to White River
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID: | **ESTIMATE LEVEL:** **Appraisal**
REGION: **MP** | **UNIT PRICE LEVEL:** **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization					
	1	Submittals/Procurement/POs/Resource Coordination		2	mo	$35,300	$70,600
	2	Establish Survey Controls		1	ls	$0.00	$0
	3	Establish Baseline Survey / Alignment / As-builts		500	hr	$353.00	$176,500
	4	Install/Maintain BMPs, SWPPP		1	ls	$141,200	$141,200
	5	Initial Equipment Mobilization		20	lds	$2,824	$56,480
	6	Initial Labor Mobilization		1	ls	$0.00	$0
	7	Third Party Design Services / Outside Consultants		1	ls	$0.00	$0
	8	Develop & Maintain Water Supply		1	ls	$247,100	$247,100
	9	Create & Maintain Access / Cofferdams, Crane Pads, etc.		1	ls	$353,000	$353,000
	10	Create & Maintain Access to Borrow or Dump Areas		4	ea	$35,300	$141,200
	11	Clear/Prep Borrow or Dump Areas		4	ea	$28,240	$112,960
	12	Reclaim Borrow Areas		4	ea	$70,600	$282,400
	13	Build New Haul Roads to Facilitate Earthwork Hauling		33	mi	$70,600	$2,329,800
	14	Reclaim Temporary Haul Roads		33	mi	$28,240	$931,920
		Feature Subtotal =>					**$4,843,160**
		Startup/Commission/Owner Training					
	1	Pre-commissioning		350	hrs	$211.80	$74,130
	2	Vendor Support		1	ls	$0.00	$0
	3	Commissioning		350	hrs	$211.80	$74,130
	4	Training		0	hrs	$141.20	$0
	5	Startup Expendables		1	ls	$0.00	$0
		Feature Subtotal =>					**$148,260**
		Subtotal Page 2 =>					**$4,991,420**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal from Page 1					**$59,947,316.84**
		Subtotal from Page 2					**$89,401,446.89**
		Subtotal from Page 3					**$51,802,131.44**
		Subtotal from Page 4					**$4,991,420.00**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$206,142,315**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		CONTRACT COST					**$210,000,000**
		Construction Contingencies	20%	+/-			$42,000,000
		FIELD COST (Unit Price Level September 2018)					**$250,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
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DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 5A - Widen Existing Canal + Parallel Canal from Tule River to White River
MP 88.2 to 121.5
With Future Subsidence

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Additional Embankment Construction from Borrow Pits		680,000	cys	$15.53	$10,561,760
	2	Additional Concrete Canal Liner		100,915	sys	$44.41	$4,481,373
		Feature Subtotal =>					**$15,043,133**
	3	**Ancillary Facilities**					
	1	Bridges		18	ea	$190,860	$3,435,478
		Feature Subtotal =>					**$3,435,478**
		Subtotal					**$18,478,611**
		Additional Mobilization, Startup/Commission/Owner Training	0%	+/-			
		Feature Subtotal =>					**$0**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$18,478,611**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		ADDITIONAL CONTRACT COST					**$18,500,000**
		Construction Contingencies	20%	+/-			$3,700,000
		ADDITIONAL FIELD COST (Unit Price Level September 2018)					**$22,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		ADDITIONAL CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

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BUREAU OF RECLAMATION

ESTIMATE WORKSHEET

FEATURE:
Alternative 5B - Widen Existing Canal + Parallel Canal from Tule River to Woollomes Reservoir
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID:
ESTIMATE LEVEL: **Appraisal**
REGION: **MP**
UNIT PRICE LEVEL: **9/1/2018**
FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		50,142	lf	$4.07	$203,846
	3	Strip/Clear Vegetation at New Embankment Areas		52	ac	$3,608	$186,918
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		300	dys	$6,448	$1,934,480
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		334,280	sy	$2.03	$678,719
	8	Excavation to Embankment - Scraper/Dozer (balance)		597,457	cys	$4.81	$2,872,404
	9	Excavation & Haul to Embankment - Medium Truck Haul		717,145	cys	$10.94	$7,848,693
	10	Purchase Land for Stockpiling of Waste Excavation		0	ac	$35,425.00	$0
	11	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		0	cys	$2.86	$0
	12	Concrete Canal Liner					
	13	Trim/Compact Excavated Areas		403,475	sys	$3.26	$1,316,411
	14	Place 3.5" Concrete Liner		403,475	sys	$41.01	$16,548,316
	15	Final Cure for Concrete Liner		403,475	sys	$0.28	$114,345
		Trim/Point/Patch at (e) Liner Joint		100,284	lf	$2.83	$284,205
		Feature Subtotal =>					**$31,704,132**
		Subtotal Page 1 =>					**$31,704,132**

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	3	**New Canal Bypass**					
	1	Removals					
	2	Score/Remove (e) Concrete Liner (Top 7' - Both Sides)		126,532	lf	$0.00	$0
	3	Strip/Clear Vegetation at New Embankment Areas		131	ac	$3,608	$471,681
	4	Maintenance of Temporary Works					
	5	Maintain Haul Roads & Dust Controls for All Earthworks		500	dys	$6,448	$3,224,134
	6	Excavation to Embankment or Waste					
	7	Disk/Pre-Wet Excavation Areas		843,547	sy	$2.03	$1,712,728
	8	Excavation to Embankment - Scraper/Dozer (balance)		1,022,358	cys	$4.81	$4,915,207
	9	Excavation to Embankment - Long Truck Haul		1,022,358	cys	$9.27	$9,472,367
	10	Excavation & Haul to Waste - Medium Truck Haul		1,791,827	cys	$10.94	$19,610,403
	11	Spread/Shape/Compact Waste Matls at Dump or Stockpile Site		1,022,358	cys	$2.86	$2,927,674
	12	Concrete Canal Liner					
	13	Trim/Compact Excavated Areas		1,546,717	sys	$3.26	$5,046,448
	14	Place 3.5" Concrete Liner		1,546,717	sys	$41.01	$63,437,788
	15	Final Cure for Concrete Liner		1,546,717	sys	$0.28	$438,340
	16	Trim/Point/Patch at (e) Liner Joint		0	lf	$2.83	$0
		Feature Subtotal =>					**$111,256,771**
		Subtotal Page 2 =>					**$111,256,771**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
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FEATURE:
Alternative 5B - Widen Existing Canal + Parallel Canal from Tule River to Woollomes Reservoir
MP 88.2 to 121.5

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Friant-Kern Canal
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	4	**Ancillary Facilities - Both**					
	1	Canal					
	2	New Ladders		440	ea	$4,960	$2,182,180
	3	Check Structure - Modify		0	ea	$1,417,000	$0.00
	4	Check Structure - New		1	ea	$3,542,500	$3,542,500
	5	Transition to (e) Bridges		17	ea	$70,850	$1,204,450
	6	Transitions to (e) Turnouts		11	ea	$35,425	$389,675
	7	Bridges					
	8	Demo (e) County or State Bridge		0	ea	$354,250	$0
	9	Demo (e) Farm Bridge		1	ea	$35,425	$35,425
	10	New County or State Bridges - 90' span		23	ea	$1,915,358	$44,053,224
	11	Replace (e) Farm Bridges		1	ea	$177,125	$177,125
	12	O&M Road					
	13	Prep/Compact Subgrade		468,565	sys	$2.45	$1,146,585
	14	Purchase/Deliver Aggregate Base Course - 4"		102,000	tns	$28.34	$2,890,680
	15	Place & Compact Aggregate Base		102,000	tns	$4.25	$433,602
	16	Blue top Aggregate Base		478,976	sys	$1.22	$586,030
	17	Miscellaneous					
	18	Seeding		5,300,220	sf	$0.07	$375,521
		Feature Subtotal =>					**$57,016,996**
	7	**Construction Allowances**					
	1	Contractor Quality Control		1	ls	1.06%	$942,883.79
	2	Flaggers		1,000	hr	$85.02	$85,020
	3	Rent Traffic Message Board		1,000	dys	$70.85	$70,850
	4	Cathodic Protection		1	ls	$0.00	$0
	5	Crew / Mgt Per-diems & Travel		1	ls	$0.00	$0
	6	Labor Overtime		1	ls	$0.00	$0
	7	Liquated Damages		1	ls	$0.00	$0
		Feature Subtotal =>					**$1,098,754**
		Subtotal Page 3 =>					**$58,115,750**

QUANTITIES		**PRICES**	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

FEATURE:
Alternative 5B - Widen Existing Canal + Parallel Canal from Tule River to Woollomes Reservoir
MP 88.2 to 121.5

PROJECT:
Friant-Kern Canal
Middle Reach Capacity Correction (MRCC)

WOID: **ESTIMATE LEVEL:** **Appraisal**
REGION: **MP** **UNIT PRICE LEVEL:** **9/1/2018**
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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Mobilization					
	1	Submittals/Procurement/POs/Resource Coordination		2	mo	$35,425	$70,850
	2	Establish Survey Controls		1	ls	$0.00	$0
	3	Establish Baseline Survey / Alignment / As-builts		500	hr	$354.25	$177,125
	4	Install/Maintain BMPs, SWPPP		1	ls	$141,700	$141,700
	5	Initial Equipment Mobilization		20	lds	$2,834	$56,680
	6	Initial Labor Mobilization		1	ls	$0.00	$0
	7	Third Party Design Services / Outside Consultants		1	ls	$0.00	$0
	8	Develop & Maintain Water Supply		1	ls	$247,975	$247,975
	9	Create & Maintain Access / Cofferdams, Crane Pads, etc.		1	ls	$354,250	$354,250
	10	Create & Maintain Access to Borrow or Dump Areas		10	ea	$35,425	$354,250
	11	Clear/Prep Borrow or Dump Areas		10	ea	$28,340	$283,400
	12	Reclaim Borrow Areas		10	ea	$70,850	$708,500
	13	Build New Haul Roads to Facilitate Earthwork Hauling		33	mi	$70,850	$2,338,050
	14	Reclaim Temporary Haul Roads		33	mi	$28,340	$935,220
		Feature Subtotal =>					**$5,668,000**
		Startup/Commission/Owner Training					
	1	Pre-commissioning		350	hrs	$212.55	$74,393
	2	Vendor Support		1	ls	$0.00	$0
	3	Commissioning		350	hrs	$212.55	$74,393
	4	Training		0	hrs	$141.70	$0
	5	Startup Expendables		1	ls	$0.00	$0
		Feature Subtotal =>					**$148,785**
		Subtotal Page 4 =>					**$5,816,785**

QUANTITIES		PRICES	
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FEATURE: Alternative 5B - Widen Existing Canal + Parallel Canal from Tule River to Woollomes Reservoir MP 88.2 to 121.5	**PROJECT:** Friant-Kern Canal Middle Reach Capacity Correction (MRCC)
	WOID:
	ESTIMATE LEVEL: Appraisal
	REGION: MP
	UNIT PRICE LEVEL: 9/1/2018
	FILE: https://stantec.sharepoint.com/teams/184031016/Shared Documents/4.0 Draft and Final Reports/Subtask 2.6 Federal Feasibility Report/MRCC/Plan Formulation Report/Engr_Appx/Supporting Files/[FKC_BlueSheets_20181204_1216.xlsx]ALT 5B

PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
		Subtotal from Page 1					**$31,704,131.74**
		Subtotal from Page 2					**$111,256,771.29**
		Subtotal from Page 3					**$58,115,750.29**
		Subtotal from Page 4					**$5,816,785.00**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$206,893,438**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		CONTRACT COST					**$210,000,000**
		Construction Contingencies	20%	+/-			$42,000,000
		FIELD COST (Unit Price Level September 2018)					**$250,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

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BUREAU OF RECLAMATION

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PLANT ACCOUNT	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT
	2	**Canal Widening**					
	1	Additional Embankment Construction from Borrow Pits		680,000	cys	$15.59	$10,599,160
	2	Additional Concrete Canal Liner		101,039	sys	$44.56	$4,502,768
		Feature Subtotal =>					**$15,101,928**
	3	**Ancillary Facilities**					
	1	Bridges		23	ea	$191,536	$4,405,322
		Feature Subtotal =>					**$4,405,322**
		Subtotal					**$19,507,250**
		Additional Mobilization, Startup/Commission/Owner Training	0%	+/-			
		Feature Subtotal =>					**$0**
		Subtotal with Mobilization, Startup, Commission, & Owner Training					**$19,507,250**
		Contract Cost Allowances (Sum of):	0%	+/-			$0
		Design Contingencies, 0% (+/-)					
		APS, 0% (+/-). Type of Procurement: Full and Open Request for Proposal					
		ADDITIONAL CONTRACT COST					**$19,500,000**
		Construction Contingencies	20%	+/-			$3,900,000
		ADDITIONAL FIELD COST (Unit Price Level September 2018)					**$23,000,000**
		Escalation to Notice to Proceed (NTP) from Unit Price Level not included here. Will be included in the Construction Cost Estimate (CCE)/					
		Project Cost Estimate (PCE) generated by the appropriate responsible office.					
		Non-Contract Costs		**To be determined by the appropriate responsible office.**			
		ADDITIONAL CONSTRUCTION COST		**To be determined by the appropriate responsible office.**			
		Ref: For appropriate use and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02, and 09-03.					

QUANTITIES		PRICES	
BY	**CHECKED**	**BY**	**CHECKED**
M. Carpenter, J. Loucks		J. Loucks, E. Hersh	M. Carpenter, E. Perez
DATE PREPARED	**PEER REVIEW / DATE**	**DATE PREPARED**	**PEER REVIEW / DATE**
09/18/18		12/14/18	

RECLAMATION

Managing Water in the West

SAN JOAQUIN RIVER RESTORATION PROGRAM

Friant WATER AUTHORITY

Feasibility Report
Attachment A2 - Environmental Constraints Analysis Summary

Friant-Kern Canal Middle Reach Capacity Correction Project

October 2019



Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Abbreviations and Acronyms

ATC	Authority to Construct
Basin	San Joaquin Valley Air Basin
Caltrans	California Department of Transportation
CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CFR	Code of Federal Regulations
CMP	Congestion Management Program
CNDDB	California Natural Diversity Database
CO	Carbon Monoxide
COG	Kern Council of Governments
Corps	U.S. Army Corps of Engineers
CRPR	California Rare Plant Rank
CWA	Clean Water Act
DOC	California Department of Conservation
EA	Environmental Assessment
EIR	Environmental Impact Report
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FESA	Federal Endangered Species Act
FKC	Friant-Kern Canal
FMMP	Farmland Mapping and Monitoring Program

Abbreviations and Acronyms

FONSI	Finding of No Significant Impact
FPPA	Federal Farmland Protection Policy Act
FTM	Farm to Market
FWA	Friant Water Authority
GC	General Conformity
GSA	Groundwater Sustainability Agencies
GSP	Groundwater Sustainability Plan
HAER	Historic American Engineering Record
IS	Initial Study
LOS	Level of Service
MND	Mitigated Negative Declaration
N/A	Not Applicable
NAAQS	Federal National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act Section 106
NO_2	Nitrogen Dioxide
NO_x	Oxides of Nitrogen
Pb	Lead
PM_{10}	Particulate Matter 10 Microns or Smaller
$PM_{2.5}$	Particulate Matter 2.5 Microns or Smaller
PRC	California Public Resources Code
ROG	Reactive Organic Gases

Abbreviations and Acronyms

RTPA	Regional Transportation Planning Agency
RWQCB	Regional Water Quality Control Board
SGMA	Sustainable Groundwater Management Act
SHPO	State Historic Preservation Officer
SJVAPCD	San Joaquin Valley Air Pollution Control District
SO_2	Sulfur Dioxides
SO_x	Sulfur Oxides
SR	State Route
TCAG	Tulare County Association of Governments
USFWS	U.S. Fish and Wildlife Service
VA	Valley Agricultural

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Chapter 1.
Introduction

This technical memorandum has been prepared to support comparisons of Friant Water Authority (FWA) Friant-Kern Canal (FKC) Middle Reach Subsidence and Capacity Correction Project (MRSCC) initial concepts for long-term corrective actions in terms of their environmental constraints and the associated environmental regulatory requirements. Long term corrective actions comprise combinations of one or more specific structural measures including an in-line pump station and associated off-canal surge reservoir, canal enlargement, parallel bypass canal, and offset bypass canal. Non-structural measures (i.e., modifications to water delivery schedules), while not currently considered, could be incorporated into future comparisons. Seven initial concepts for long-term corrective actions labeled Alternative 1, Alternative 2, Alternative 3, Alternative 4A, Alternative 4B, Alternative 5A, and Alternative 5B are compared. In addition to its number designation each alternative has been assigned a name that communicates its primary structural measures and location.

The following sections of this technical memorandum (1) describe the local, state, and federal frameworks for environmental decision-making for the project; (2) describe the seven alternatives; (3) identify metrics for the evaluations and comparison of environmental constraints and regulatory requirements; (4) assign a constraint ranking for each of the metrics to each of the alternatives; and (5) identify additional design detail that would be needed to further evaluate and contrast the alternatives in terms of environmental constraints and regulatory requirements.

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Chapter 2.
Regulatory Framework

CEQA and NEPA Compliance

Discretionary approvals made by local, state, and federal agencies for the project will require documentation of compliance with the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA), with FWA and the Bureau of Reclamation (Reclamation) acting as the CEQA and NEPA lead agencies respectively. Additionally, one or more construction permits issued by federal and non-federal agencies following completion of the CEQA and NEPA processes are likely to be needed.

CEQA and NEPA stipulate the overarching processes that lead agencies are required to follow to document their consideration of the environmental implications of their discretionary decisions, including whether and how to approve a project. Both statutes set forth procedural and analytical steps to achieve the fundamental goals and purposes of environmental review: information, public and stakeholder participation, mitigation of impacts, and accountability. Both statutes provide for documentation of compliance via one of two procedural and written formats, depending on the context and intensity of impacts, and degree of public and stakeholder engagement.

Both CEQA and NEPA use the concept of "significance" to characterize the environmental consequences of the actions being evaluated. However the two statutes differ in how "significance" is applied to inform findings and decisions. CEQA encourages agencies to establish thresholds of significance that are used to compare environmental impacts of projects, and to provide consistency in determining whether impacts require mitigation. CEQA requires each "significant effect" to be identified and mitigated where feasible. NEPA uses the concept of "significance" to characterize how a particular action as a whole will affect the quality of the human environment. Thresholds of significance are not codified under NEPA as they are under CEQA. Instead significance is assessed based on consideration of the geographic, social, and other settings, or "context", where the actions being contemplated would occur, and on the severity or "intensity" of the impact.

Under CEQA, complex projects are commonly subjected to an initial, relatively straightforward analytical process, termed an "initial study" (IS). The IS reveals the potential significant impacts and can be used to define mitigation measures that would avoid, minimize, or provide compensatory mitigation to render the impacts less than significant. The CEQA lead agency memorializes revisions or enhancements to the project plan that would mitigate impacts to a less-than-significant level in a "mitigated negative declaration" (MND) that is attached to the IS and circulated for public review prior to adopting the IS/MND and approving the project. If the IS

reveals significant unmitigable impacts the more rigorous environmental impact report (EIR) process is required.

The analytical process under an EIR is similar to the IS. The EIR process requires more rigorous comparison of project alternatives in terms of their environmental impacts and provides for greater public and stakeholder participation as the CEQA process proceeds. Importantly, whereas an IS/MND cannot be used as a basis for approving projects that may result in significant unmitigated impacts, an EIR can be so applied when it is accompanied by a finding by the CEQA lead agency (i.e., FWA) of "overriding considerations" that is supported by substantial evidence that the economic, social, or other benefits of the project outweigh the unavoidable adverse environmental impacts.

Like CEQA, NEPA distinguishes between projects with and without the potential to significantly affect the environment. Under NEPA, complex projects are commonly subjected to an initial environmental assessment (EA). If the EA concludes that the project, including environmental commitments incorporated into the project description to avoid or minimize impacts, would not result in significant impacts, the NEPA lead agency (i.e., Reclamation) may complete a finding of no significant impact (FONSI). If the EA reveals significant impacts then a FONSI is not possible, and the more rigorous environmental impact statement (EIS) process is required. The analytical process under an EIS is similar to the EA, but as with CEQA it requires more rigorous comparison of project alternatives in terms of their environmental impacts and provides for greater public and stakeholder participation as the NEPA process proceeds.

This constraints analysis identifies five resource topics for comparing the seven initial conceptual alternatives in terms of their potential environmental impacts. These resource topics have been distilled from more than a dozen resource topics that will be evaluated under CEQA and NEPA. The five resource topics applied in this analysis comprise resources that have elevated potential to incur impacts that exceed approval thresholds under ISs or EAs.

Interconnected Statutes and Requirements

Interconnected statues and requirements are other environmental laws and procedures that must be closely coordinated with the CEQA and NEPA processes to avoid duplication and delays in evaluating the environmental impacts of proposed projects. While several interconnected statutes and requirements may require coordination for the MRSCC, three merit special discussion because of their potential impact on the timelines for completing CEQA and NEPA documentation. These are the state and federal Endangered Species Acts (respectively CESA and ESA), and the federal National Historic Preservation Act (NHPA).

As described in sections 4.2 and 5.2 of this report, regulatory concerns will arise during the IS/EA processes regarding project effects on the San Joaquin kit fox, a protected species under the ESA and CESA. The ESA and CESA establish procedures whereby lead agencies, as applicable, consult with the U.S. Fish and Wildlife Service (USFWS) and the California

Department of Fish and Wildlife (CDFW) to ensure decisions reached under NEPA and CEQA comport with the mandates of the ESA and CESA. Consultations focus on the potential effects of the project on the species, and on the reasonable and prudent measures that can be implemented to avoid or minimize "take". Where take is unavoidable, the consultations can authorize take—an otherwise illegal activity—under closely regulated terms and conditions that typically include providing compensatory mitigation.

The ESA establishes a 135-day timeline for completing formal consultation (i.e., issuance of a Biological Opinion), which begins upon receipt of an adequate description of the project, including an initial evaluation of potential effects on listed species and proposed mitigation measures. Take under CESA can sometimes be authorized via a finding by CDFW that the Biological Opinion issued by the USFWS is consistent with the CESA; otherwise a separate Incidental Take Permit must be issued by CDFW.

The USFWS and CDFW can provide technical assistance to lead agencies prior to engaging in formal consultation to aid in compiling project description information, assessing take, and formulating mitigation proposals that fully anticipate agency requirements at the initiation of formal consultation.

Similarly, as described in sections 4.3 and 5.3, regulatory concerns will arise regarding project effects on the FKC itself and closely associated built environment due to its eligibility for inclusion in the National Register of Historic Places (NRHP), or on buried archaeological resources. Like the ESA, the NHPA establishes a procedure whereby the NHPA lead federal agency consults with the State Historic Preservation Officer (SHPO) to ensure decisions reached under NEPA comport with the mandates of the NHPA. The consultation focuses on the occurrences of potential historic properties in the project area, the eligibility status of those properties that meet the HRHP eligibility criteria, the effects of the project on the attributes that render properties eligible for inclusion in the NRHP, and measures that can be implemented to avoid or minimize adverse effects on a historic property. Where adverse effects on a historic property are unavoidable, measures are negotiated and implemented in order to resolve the adverse effects under the NHPA and reduce those impacts under NEPA to less than significant. These commitments may include detailed documentation prior to construction of each affected resource, in the form of a Historic American Engineering Record (HAER), for example. The NHPA establishes 30-day timelines for review of the various elements of the consultation (e.g., historic property survey, eligibility evaluation, effects determination).

It is important to note that approvals via the IS/MND and EA/FONSI rely on findings that the proposed project will not result in significant unmitigated impacts. For the ESA, CESA, and NHPA, and potentially for other interconnected statues and requirements, certainty regarding the absence of significant impacts will not likely be reached by the CEQA and NEPA lead agencies until completion of the consultation process.

Permitting

In addition to documenting compliance with CEQA and NEPA for project approval by the lead agencies, environmental permits may be required prior to construction. The permits needed will depend on the alternative selected for implementation. Examples of permits that may be needed include Clean Water Act (CWA) section 404 authorization for discharge of dredged or fill material into waters of the United States (issued by the U.S. Army Corps of Engineers [Corps]), CWA section 401 water quality certification (Regional Water Quality Control Board [RWQCB]), and CDFW streambed alteration agreement. Because issuance of these and other permits by local, state, and federal agencies are discretionary actions with potential to affect the environment, the decisions whether to issue the permits must also comport with the requirements of CEQA and NEPA. Because authorizing agencies (e.g., "responsible" and "cooperating" agencies) typically tier their decisions from the CEQA and NEPA documents adopted by the lead agencies, permitting processes must be closely coordinated with the CEQA and NEPA processes to avoid duplication and delays in the evaluation of impacts by the responsible and cooperating agencies following completion of CEQA and NEPA.

Chapter 3.
Project Description

Purpose and Need

Alternatives 1–5B are being developed and evaluated to identify a preferred alternative to restore the conveyance capacity of the FKC along an approximately 33-mile reach from mile post (MP) 88.2 to MP 121.5 in Tulare and Kern counties (project area) (Appendix A, Figure 1 and Figure 2). The current conveyance capacity of the FKC is severely compromised because of deficiency in the original design and subsequent land subsidence.

Project Alternatives

Alternatives 1–5B are illustrated in Figures 3-1 to 3-7 (Appendix A) and are described below.

Alternative 1: Canal Enlargement. Alternative 1 involves enlarging the canal from MP 88.2 to the Lake Woollomes check at MP 121.5.

Alternative 2: Pump Station at MP 109. Alternative 2 involves construction of a pump station and associated off-canal surge reservoir at approximately MP 109 and the following modifications to the FKC:

- MP 88.2–MP 105.5: Enlarge canal.
- MP 105.5–MP 108.7: No modifications.
- MP 108.7–MP121.5: Enlarge canal.

Alternative 3: Woollomes Pump Station. Alternative 3 involves constructing a bypass canal beginning at MP 108.7 on the FKC and continuing to a pump station and associated off-canal surge reservoir just north of Lake Woollomes at MP 119.5. The bypass canal would include a siphon below White River. In addition, Alternative 3 includes the following modifications to the FKC:

- MP 88.2–MP 95.7: Enlarge canal.
- MP 95.7–MP 96.4: No modifications.
- MP 96.4–MP 108.7: Enlarge canal.

- MP 119.5–MP 121.5: Enlarge canal.

Alternative 4A: Offset Bypass Canal from Tule River to White River. Alternative 4A includes constructing an offset bypass canal beginning at MP 95.7 of the FKC (just downstream from Tule River) and reconnecting with the FKC at MP 112.9 (just upstream of White River). The bypass canal will require the construction of a new siphon below Deer Creek. In addition, Alternative 4A includes the following modifications to the FKC:

- MP 88.2–MP 95.7: Enlarge canal.
- MP 112.9–MP 121.5: Enlarge canal.

Alternative 4B: Offset Bypass Canal from Tule River to Lake Woollomes. Alternative 4B includes constructing an offset bypass canal beginning at MP 95.7 (just upstream of Tule River) and reconnecting with the FKC at MP 119.5 (Lake Woollomes' northern edge). The bypass canal will require the construction of two new siphons, one below Deer Creek and one below White River. In addition, Alternative 4A includes the following modifications to the FKC:

- MP 88.2–MP 95.7: Enlarge canal.
- MP 119.5–MP 121.5: Enlarge canal.

Alternative 5A: Parallel Bypass Canal from Tule River to White River. Alternative 5A includes constructing a parallel bypass canal beginning at MP 95.7 (just upstream of Tule River) and reconnecting with the FKC at MP 112.9 (just upstream White River). No new siphons would be constructed, rather the parallel bypass canal would tie into the FKC at the existing check structures. In addition, Alternative 5A includes the following modifications to the FKC:

- MP 88.2–MP 95.7: Enlarge canal.
- MP 112.9–MP 121.5: Enlarge canal.

Alternative 5B: Parallel Bypass Canal from Tule River to Lake Woollomes. Alternative 5B includes constructing a parallel bypass canal beginning at MP 95.7 (just upstream of Tule River) and reconnecting with the FKC at MP 119.5 (Lake Woollomes' northern edge). No new siphons would be constructed, rather the parallel bypass canal would tie into the FKC at the existing check structures. In addition, Alternative 5B includes the following modifications to the FKC:

- MP 88.2–MP 95.7: Enlarge canal.
- MP 119.5–MP 121.5: Enlarge canal.

Chapter 4.
Environmental Setting

The project area that encompasses all alternatives is located along an approximately 33-mile reach of the FKC from MP 88.2 to MP 121.5 in Tulare and Kern counties. This location can be found on the *Porterville, Decor, Sausalito School, and Delano East* 7.5-minute U.S. Geological Survey quadrangles (Appendix A, Figure 1 and Figure 2).

Air Quality

The project is located in the San Joaquin Valley Air Basin (Basin) under the jurisdiction of the San Joaquin Valley Air Pollution Control District (SJVAPCD). The Basin is designated as non-attainment for the 8-hour ozone standard and the particulate matter 2.5 microns or smaller ($PM_{2.5}$) standard under the Federal National Ambient Air Quality Standards (NAAQS) and non-attainment for particulate matter 10 microns in size or smaller (PM_{10}), $PM_{2.5}$, and 8-hour ozone standards under the California Ambient Air Quality Standards.

The primary pollutants of concern in the project vicinity are ozone [including Reactive Organic Gases (ROG) and oxides of nitrogen (NO_x)], PM_{10}, and $PM_{2.5}$.

Each of the alternatives for the project has the potential to generate significant construction emissions from on-road and off-road vehicles and equipment and localized PM emissions from fugitive dust.

The proposed in-line pump stations included in certain alternatives would be powered by electricity and would therefore not require Authority to Construct (ATC) permits from the Air District. Each of the alternatives would disturb more than 5 acres and move more than 2,500 cubic yards per day, therefore compliance with the Air District's Regulation VIII Fugitive PM_{10} Dust Prohibitions will be required. Compliance with Regulation VIII will require the preparation of a Dust Control Plan. A Dust Control Plan identifies the fugitive dust sources at the construction site and describes all the dust control measures to be implemented before, during, and after any dust-generating activity for the duration of the project. The Air District will review and approve, conditionally approve, or disapprove the Dust Control Plan within 30 days of submittal. Construction activities may not commence until the Dust Control Plan has been approved or conditionally approved by the Air District.

The Air District is committed to providing technical assistance to Lead Agencies in addressing air quality issues in environmental documents. The Air District provides comments on air quality impacts and suggests mitigation measures to reduce air quality impacts from development projects.

The Air District has established the following thresholds with regards to criteria air pollutants during construction to determine a project's significance:

- ROG – 10 tons per year
- NO_x – 10 tons per year
- PM_{10} – 15 tons per year
- $PM_{2.5}$ – 15 tons per year
- Carbon Monoxide (CO) – 100 tons per year
- Sulfur Oxides (SO_x) – 27 tons per year

Pursuant to NEPA regulations (40 Code of Federal Regulations [CFR] 1500–1508), project effects are evaluated based on the criteria of context and intensity. Context means the affected environment in which a proposed project occurs. Intensity refers to the severity of the effect, which is examined in terms of the type, quality, and sensitivity of the resource involved, location and extent of the effect, duration of the effect (short or long term), and other considerations of context. Beneficial effects are identified and described. When there is no measurable effect, impact is found not to occur. The intensity of the adverse effects is summarized as the degree or magnitude of a potential adverse effect, where the adverse effect is thus determined to be negligible, moderate, or substantial. It is possible that a significant adverse effect may still exist when, on balance, the impact is negligible or even beneficial.

Per NEPA and the Clean Air Act regulations, regional project emissions are compared with the general conformity *de minimis* (GC) thresholds on a calendar-year basis. If the GC thresholds are exceeded for any calendar year in which emissions occur, a GC determination is required. In addition, project emissions may not cause new violations or exacerbate an existing violation of NAAQS. Table 1 presents the *de minimis* thresholds applicable to the project.

If the project pollutant emissions are below the corresponding GC thresholds and expected to cause pollutant emissions that do not exceed other applicable emissions, air quality, or health risk thresholds (such as those in SJVAPCD CEQA guidelines), the intensity of the impact is considered negligible. Air quality impacts of moderate intensity are defined as pollutant emissions below corresponding GC thresholds, but having the potential to exceed other applicable emissions, air quality, or health risk thresholds. Impacts of substantial intensity are defined as pollutant emissions that are greater than the corresponding GC threshold and have the potential to exceed other applicable emissions, air quality, or health risk thresholds.

Table 1. General Conformity *de minimis* Thresholds

Pollutant	Federal Attainment Status	Threshold Values (tons per year)
NO_2	Attainment	N/A
Ozone precursor (NO_x)	Nonattainment: Extreme	10
Ozone precursor (ROG)	Nonattainment: Extreme	10
CO	Maintenance	100
SO_x	Attainment	N/A
$PM_{2.5}$	Nonattainment	100
$PM_{2.5}$ precursor (SO_2)	Nonattainment	100
PM_{10}	Maintenance	100
Pb	No designation	N/A

Notes:

Thresholds from 40 C.F.R. Parts 51 and 93

Ozone reclassifications were made by U.S. Environmental Protection Agency on May 5, 2010.

Only the urban portions of Fresno County and Kern County are maintenance areas for CO.

SO_2 has a GC threshold of 100 tpy. Due to the stringent requirement of using ultra-low sulfur content diesel in California, emissions of SO_2 anticipated from the project are expected to be negligible compared to the threshold.

Acronyms:

CO carbon monoxide

GC General Conformity

N/A not applicable

NO_2 nitrogen dioxide

NO_x nitrogen oxide

Pb lead

PM_{10} particulate matter smaller than or equal to 10 microns in diameter

$PM_{2.5}$ particulate matter smaller than or equal to 2.5 microns in diameter

ROG reactive organic gases

SO_2 sulfur dioxide

SO_x sulfur oxide tpy ton(s) per year

Biological Resources

Vegetation Communities/Aquatic Features

Vegetation communities in the project area were classified based on habitat descriptions provided in *A Guide to Wildlife Habitats of California* (Mayer and Laudenslayer 1988) and the results of a desktop-review and field assessments of portions of the project area. Vegetation communities present in the project area include annual grassland, barren, vineyard, orchard, irrigated hayfield, and agricultural canal (i.e., FKC). Aquatic features in the project area include the FKC, intermittent streams, and wetlands. A description of each of these vegetation communities and aquatic features is provided below.

Annual Grassland

Annual grassland occurs throughout the project area, mostly on the landside slopes of the FKC embankment and generally consists of a moderate herbaceous layer. Typical plant species present within the annual grassland community include wild oat (*Avena fatua*), ripgut brome (*Bromus diandrus*), medusa head (*Elymus caput-medusae*), Jimson weed (*Datura discolor*), and turkey mullein (*Croton setiger*).

Barren

Barren areas are present on the dirt and paved roads and associated road shoulders. Vegetation is generally not present.

Vineyard

Vineyards occur throughout the project area. The vineyards consist of grape vines (*Vitis* sp.) planted in rows and supported by wood and wire trellises. The vines are intertwined in the rows and open areas are present between the rows. The understory of the vineyard is open and the ground is generally barren of vegetation.

Orchard

Both evergreen and deciduous orchards occur throughout the project area. The orchards consist of a single species, mostly commonly almonds and pistachios planted in rows. Some orchards within the project area have sparse herbaceous vegetation growing in the understory while others are barren.

Irrigated Hayfield

Irrigated hayfields consisting of hay crops and alfalfa (*Medicago sativa*) are present in the northeastern portion of the project area. The fields are monocrops of fairly low growing, dense vegetation.

Agricultural Canal (FKC)

The project area includes approximately 33 miles of the FKC. The FKC is an agricultural canal that was completed in 1951. The canal is owned by Reclamation and is operated and maintained by FWA. The canal supplies San Joaquin River water stored at Millerton Lake to more than 30 irrigation districts and cities, and to 15,000 family farms. The FKC and the operations and maintenance (O&M) roads are regularly maintained pursuant to an existing O&M Biological Opinion from the USFWS (U.S. Fish and Wildlife Service 2005).

Intermittent Streams

Porter Slough, Tule River, Deer Creek, and White River bisect the project area. All of these features appear to be intermittent streams. Based on the desktop review, riparian vegetation may also be associated with these features.

Wetlands

Based on the desktop review, there appears to be some wetlands within the project area that are hydrologically connected to Deer Creek and Porter Slough (Figure 4). These features are considered potential waters of the United States.

Special-Status Species and Other Sensitive Biological Resources

Special-status plant and animal species that may occur in the project area were determined by performing reconnaissance-level surveys of limited portions of the project area (approximately 3 miles) and a preliminary desktop review of natural resource agency databases, literature, aerial imagery, and other relevant sources. These sources include: (1) the USFWS list of endangered and threatened species for Kern and Tulare counties (U.S. Fish and Wildlife Service 2018); (2) the CDFW California Natural Diversity Database (California Department of Fish and Wildlife 2018); and (3) the California Native Plant Society online Inventory of Rare and Endangered Plants (California Native Plant Society 2018) records for the Porterville, Ducor, Sausalito School, and Delano East, California 7.5-minute quadrangles.

For the purpose of this evaluation, special-status plant species include plants that are (1) listed as threatened or endangered under the CESA or the ESA, (2) proposed for federal listing as threatened or endangered, (3) state or federal candidate species, (4) designated as rare by the CDFW, and (5) California Rare Plant Rank (CRPR) 1A, 1B, 2A or 2B species. Special-status animal species include species that are (1) listed as threatened or endangered under CESA or ESA, (2) proposed for federal listing as threatened or endangered, (3) state or federal candidate species, and (4) identified by CDFW as species of special concern (SSC) or fully protected.

Based on the preliminary desktop and field review, 15 special-status animal species were determined to have potential to occur include in the vicinity of the project area. The species are identified in Table 2 below. The preliminary list of species shown in Table 2 will be revised as additional biological investigations are completed during the environmental review process.

Because of a general lack of suitable habitat, no federal- or state-listed plant species are anticipated to occur within the project area, although there may be suitable habitat for non-listed species-status plant species. The assessment of habitat suitability for special-status plants will be revised as additional biological investigations are completed during the environmental review process.

Other sensitive biological resources in the vicinity of the project area include nesting habitat for raptors and migratory birds, wetlands and streams, and riparian habitats. Most of the bridges in the project area are used by cliff swallows for nesting during the breeding season.

Table 2. Special-Status Species with a Potential to Occur in Vicinity of the Project Area

Common Name Scientific Name	Listing Status[1] Fed/State	Habitat Requirements	Potential for Occurrence
Kern brook lamprey *Entosphenus hubbsi*	–/SSC	Silty backwaters of large rivers. In summer, found in shallow pools along stream edges with minimal flow. Needs gravel-bottomed areas for spawning and muddy-bottomed areas where ammocoetes (larval stage) can burrow and feed. Has been documented in the FKC canal.	**High.** Species was first discovered in siphons of the FKC. Potential habitat is present in the streams in the project area. Non-typical habitat is present in the FKC, however given the general absence of spawning habitat species is not likely to reproduce in the FKC. There is one CNDDB occurrence located within the FKC.
San Joaquin roach *Lavinia symmetricus ssp. 1*	–/SSC	Found in a variety of streams; well adapted to small, intermittent streams.	**Moderate.** Potential habitat is present in the streams in the project area.
Western spadefoot *Spea hammondii*	–/SSC	Requires shallow, temporary pools or streams during the breeding season and adjacent upland habitat (primarily in grasslands) for burrowing during the non-breeding season.	**High.** There are two CNDDB-reported occurrences located adjacent to the FKC embankment. Potential breeding habitat may be present in small pools and streams throughout the project area.

Table 2. Special-Status Species with a Potential to Occur in Vicinity of the Project Area

Common Name Scientific Name	Listing Status[1] Fed/State	Habitat Requirements	Potential for Occurrence
White-tailed kite *Elanus leucurus*	–/FP	Nests in tall shrubs and trees, forages in grasslands, agricultural fields and marshes.	**Moderate**. Trees and annual grassland habitat present in the project area provide potential nesting and foraging habitat for the species.
Northern harrier *Circus cyaneus*	–/SSC	Breen and forages in a wide variety of open habitats. Nests on the ground in and near wet habitats such as freshwater marsh, wet meadows, weedy borders of lakes, rivers and streams, grasslands, lightly grazed pastures, and some croplands (e.g., alfalfa, tomatoes, melons).	**Moderate**. Wetlands, grasslands, and cropland habitat present within and adjacent to the project area may provide potential nesting and foraging habitat for the species.
Burrowing owl *Athene cunicularia*	–/SSC	Grasslands and ruderal habitats. Uses mammal burrows or other suitable underground cavities.	**Low**. Small mammal burrows present along the canal banks provide potential nesting habitat for the species.
Cliff Swallow *Petrochelidon pyrrhonota*	MBTA/–	Builds mud nests on the edge of a sheltered cliff, under an eave, or bridge.	**High.** During 2018 field surveys of portions of the FKC, cliff swallow nests were abundant under bridges crossing the FKC.
Yellow warbler *Setophaga petechia*	–/SSC	Breeds in riparian woodlands, particularly those dominated by willows and cottonwoods.	**Moderate**. The riparian habitat in the project area provides potential nesting and foraging habitat for the species.
Yellow-breasted chat *Icteria virens*	–/SSC	Breeds in riparian habitats having dense understory vegetation, such as willow and blackberry.	**Moderate**. The riparian habitat in the project area provides potential nesting and foraging habitat for the species.

Table 2. Special-Status Species with a Potential to Occur in Vicinity of the Project Area

Common Name Scientific Name	Listing Status[1] Fed/State	Habitat Requirements	Potential for Occurrence
Grasshopper sparrow *Ammodramus savannarum*	–/SSC	Breeds and forages in moderately open grasslands with scattered shrubs and croplands.	**Moderate**. Grasslands and cropland habitat present within and adjacent to the project area provide potential nesting and foraging habitat for the species.
Hoary bat *Lasiurus cinereus*	–/SSC	Migratory. Present in California from September to May. Roosts in the foliage of trees near ends of branches.	**Moderate**. Trees within the project area may provide potential roosting habitat. There is one CNDDB occurrence within five miles of the project area.
Pallid bat *Antrozous pallidus*	–/SSC	Forages over many habitats; roosts in buildings, large oaks or redwoods, rocky outcrops and rocky crevices in mines and caves.	**Moderate**. Trees and annual grassland habitat present in the project area provide potential roosting and foraging habitat for the species.
Townsend's big-eared bat *Corynorhinus townsendii*	–/SSC	Hibernation roosts are typically in abandoned mines or caves.	**Moderate**. Large culverts that go under the FKC may provide potential roosting habitat during hibernation. There is one CNDDB occurrence within five miles of the project area.
Western red bat *Lasiurus blossevillii*	–/SSC	Typically roost solitarily in dense tree foliage, particularly in willows, cottonwoods, and sycamores. Strongly associated with riparian habitats, particularly mature stands of cottonwood/sycamore.	**Moderate.** Riparian habitat within the project area provides roosting habitat.

Table 2. Special-Status Species with a Potential to Occur in Vicinity of the Project Area

Common Name Scientific Name	Listing Status[1] Fed/State	Habitat Requirements	Potential for Occurrence
San Joaquin kit fox *Vulpes macrotis mutica*	E/T	Inhabits dens with openings ranging from 4 to 12 inches diameter within grassland and scrubland habitats. May utilize several dens, especially during the summer months. Also utilizes atypical dens such as culverts, pipes, and holes under concrete slabs. Agricultural lands such as orchards, vineyards, and irrigated pastures are also used.	**High.** Burrows (4–12 inches in diameter) and other features (e.g., pipes, culverts) on the FKC embankments provide potential denning habitat for San Joaquin kit fox. There are six CNDDB-reported occurrences of San Joaquin kit fox that intersect the project alignment and several others within 5 miles of the project alignment (Figure 5). During biological surveys for the immediate repairs project, approximately 58 burrows (potential dens) 4–12 inches in diameter were observed along an approximately 3.68-mile reach of the FKC.
[1] Status Codes: Federal and State Codes: E = Endangered; T = Threatened; CT= Candidate Threatened; CE= Candidate Endangered; FP = Fully Protected; SSC= Species of Special Concern; MBTA= Migratory Bird Treaty Act.			

Because of a general lack of suitable habitat, no federal- or state-listed plant species are anticipated to occur within the project area. Other sensitive biological resources in the vicinity of the project area include nesting habitat for raptors and migratory birds, wetlands and streams, and riparian habitats.

Cultural Resources

Regulatory Setting

National Historic Preservation Act of 1966 as Amended

The NHPA of 1966 was passed to acknowledge the importance of recognizing resources that are historically significant. The NHPA created federal policy for preservation of the nation's heritage, established a federal-state and federal-tribal partnership, required selection of qualified State Historic Preservation Officers and created the Advisory Council on Historic Preservation. Further it charged federal agencies to be responsible stewards and established the NRHP. The MRSCC is considered an undertaking subject to compliance with Section 106 of the NHPA and its implementing regulations (36 CFR 800) as the FKC is owned by Reclamation and the project will be partially funded by federal grant money. All resources that are over 50 years of age and could potentially be affected, directly or indirectly, are studied as part of a federal undertaking for the NHPA. To be eligible for the NRHP a resource must be determined significant under at least one of the four criteria and retain integrity to its period of significance. The criteria for the NRHP are paraphrased below.

- **Criteria A:** Resources that are associated with events that have made a significant contribution to the broad patterns of our history.

- **Criteria B:** Resources that are associated with the lives of significant persons in our past.

- **Criteria C:** Resources that embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction.

- **Criteria D:** Resources that have yielded or may be likely to yield, information important in history or prehistory.

In addition to significance under one or more of the criteria listed above, a resource must possess integrity, defined by seven aspects as follows:

- **Location:** The place where the historic property was constructed or the place where the historic event took place.

- **Design:** The composition of elements that constitute the form, plan, space, structure, and style of a property.

- **Setting:** The physical environment of a historic property that illustrates the character of the place.

- **Materials:** The physical elements combined in a particular pattern or configuration.

- **Workmanship:** The physical evidence of the crafts of a particular culture or people during any given period of history.

- **Feeling:** The quality that a historic property has in evoking the aesthetic or historic sense of a past period of time.

- **Association:** The direct link between a property and the event or person for which the property is significant.

NRHP analysis is based upon all pertinent cultural resources guidance and best practices including that of 36 CFR Part 800 and technical bulletins including National Register Bulletin 15: How to Apply the National Register Criteria for Evaluation.

Prehistoric Context

There is a long history of regional archaeological research in the San Joaquin Valley. The earliest archaeological surveys in the San Joaquin Valley date to the 1920s, and were accomplished by Gifford and Schenck (1926) and Schenck and Dawson (1929). This work was followed in 1941 by Hewes' survey of a 160-mile-long stretch of the central San Joaquin Valley and the adjacent the foothills of the Sierra Nevada. Subsequent research broadened both the scope of earlier work, and became more systematic and intensive. Some of this more recent research includes work: near Porterville (cf., Schiffman 1974; Gehr 1981; Gehr et al 1979); at Pine Flat Lake (Meighan et al 1988a); at Lake Success (Meighan et al 1988b); at Hensley Lake (also known as Hidden Reservoir) (Fenega 1973; Wallace 1968, 1970); Kerkoff Lake (Varner and McCormick 1977); on the Fresno Plains (Lagenwalter et al 1989; Meighan and Dillon 1987); in Mountain Home State Forest (Wallace et al 1989); at Buchanan Reservoir (also known as Eastman Lake) (King 1976; Moratto 1972; Peak 1976); in the Owens Valley (cf., Bettinger 1975, 1976, 1980, 1982; Basgall et al 1986); in the Yokohl Valley (Varner and Stuart 1975); near Tulare and Buena Vista Lakes (cf., Wedel 1941; Riddell and Olson 1969; Fredrickson and Grossman 1977); at Isabella Lake (Schiffman 1976; Glassow and Moore 1978; Meighan and Dillon 1988); and on the Kern Plateau (cf., Garfinkel et al 1980; McGuire and Garfinkel 1980).

There are few recent archaeological investigations in the San Joaquin Valley, particularly across the valley floor (Jones and Klar 2007). Most of the research in the general project area was conducted to the east of the project area in the foothills. Regardless, archaeological research for the construction of Terminus Dam and Lake Kaweah (also known as Terminus Reservoir) and Lake Isabella can provide archaeological information relevant to the project area. The investigations near Lake Isabella primarily occurred at an elevation of approximately 3,000 feet and are not as relevant to the project area as the investigations at Terminus Dam and near Lake Kaweah (cf., Fenenga 1947, 1948). The archaeological surveys associated with the construction of Terminus Dam and Lake Kaweah identified 19 habitation sites, 14 bedrock milling stations, and 4 rock art sites (Fenenga 1947, 1948). Two of these archaeological sites, CA-TUL-1 and CA-TUL-10 were excavated in the 1950s.

Greasy Creek, CA-TUL-1, is a stratified site extending to a depth of two meters (Pendergast and Meighan 1959). Features and artifacts identified in the upper 40 centimeters of the site are similar to artifacts recovered at CA-TUL-10, Slick Rock Village. Pendergast and Meighan (1959) associated the upper level at the site with the protohistoric Wukchumni Yokuts. The lower levels of the site, however, revealed a quite different assemblage. The lower component of the site contains large projectile points, core choppers, and cobble mortars which predate the occupation of Wukchumni Yokuts. A date has not been assigned to this earlier assemblage.

Fenenga (1952) excavated CA-TUL-10, Slick Rock Village, and identified 14 house pits, 3 bedrock milling stations with 21–48 mortar holes, tubular clay pipes, steatite disk beads, and sherds of Tule Plain Ware. Fenenga (1952) concluded that the site was associated with the protohistoric Wukchumni Yokuts. Rock art studies at the sites near or inundated by Lake Kaweah by Berryman and Elsasser (1966) support this hypothesis.

A third site at Lake Kaweah and Terminus Dam, CA-TUL-145, was excavated by von Werlhof (1961) in 1960. Site CA-TUL-145, the Cobble Lodge Site, is located at the Terminus Dam borrow pit. Local residents maintain that Native Americans lived at Cobble Lodge until the 1860s, when their community was decimated by a smallpox epidemic (Moratto 1984:331). The remains of houses are reported to have existed until the 1930s, when they were destroyed by agricultural activity. Excavations at Cobble Lodge identified a large cemetery and a single pit containing 50 individuals (von Werlhof 1961). The individuals buried in the pit may represent the effects of the smallpox epidemic on the Native American population at the site. The earliest use of the cemetery probably dates to the protohistoric Wukchumni Yokuts, but the site lacks radiocarbon dates to substantiate this assumption. In addition, there is an earlier component at the site consisting of a large projectile point and cobble mortars. This assemblage is similar to the artifacts excavated from the lower levels of CA-TUL-1. Unfortunately, all of the sites at Lake Kaweah and the Terminus Dam lack radiometric dates. This shortcoming severely limits discussion and placement of these assemblages in a regional chronology.

The lack of an adequate chronology for the area surrounding the project is an unresolved archaeological research issue. Regardless, the prehistory of the project area and the San Joaquin Valley may be divided into three periods (Wallace 1978; Moratto 1984; Jones and Klar 2007). The first period is characterized by big game hunting and dates to approximately 8,000 years ago. Occupation of the valley during this time period is very sparse, with a correspondingly very low site density. The second period dates from approximately 5,000 years ago to A.D. 1200, and is characterized by a shift in subsistence strategy from hunting to the collection of plant resources. This shift in economic pursuits is evidenced in typical artifact assemblages from this period that include seed-grinding implements. Occupation of the valley during this time period is sparse, with a correspondingly low site density. The third period dates from approximately A.D. 1200–1700, and represents habitation of the area by Yokuts. Occupation of the valley increase during this time period, with sites typically located near the foothills and along rivers and their major tributaries.

Ethnographic Context

Prior to Euroamericans arrival in the region, California was inhabited by groups of Native Americans speaking more than 100 different languages and occupying a variety of ecological settings. Kroeber (1925, 1936) acknowledged this diversity, but also identified regional similarities and divided California into four subculture areas, Northwestern, Northeastern, Southern, and Central. The Central area encompasses the current project area and includes the Yokuts. Yokuts inhabit the San Joaquin Valley and are members of the Penutian language family (Latta 1949; Wallace 1978, 1981). Yokuts are generally divided into three groups, Northern Yokuts, Foothill Yokuts, and Southern Yokuts. The Southern Yokuts occupied the project area.

Tribelets were the principal political units of Yokuts (Latta 1949; Wallace 1978, 1981). These groups were organized around a male chief or headman. The role of chief was a hereditary position passed from father to son. Chiefs exercised considerable authority in coordinating and implementing various cultural activities. Tribelets consisted of family groups that were organized into moieties, which were identified by totem symbols. Yokuts generally built circular, or oval, thatched frame houses (Latta 1949; Wallace 1978, 1981). The typical house was built by digging a shallow pit approximately ten to twelve feet in diameter and one to two feet in depth and securing long slender poles, usually green willows, in holes around the inside of the pit. The poles were bent downward to meet each other and were lashed together, forming a hemispheric dome. The top was secured by lashing a willow ring to all of the poles. Willows were then lashed in larger rings around the exterior of the structure, making a solid framework. The house was made weather tight by thatching it with tules. Mud would then be applied to the outside of the tule thatch for additional insulation. The doorway was usually oriented to the south and had an animal skin flap at the entrance. Yokuts also built mat-covered buildings as granaries. These structures were owned by the entire community and usually were elevated to keep them dry and free of pests.

Yokuts subsistence patterns included hunting, fishing, and collecting plant resources (Latta 1949; Wallace 1978, 1981). Yokuts hunted a variety of game using an un-backed bow and arrows with simple, hardened wood points. Prey species included tule elk, antelope, rabbits, and squirrels. Waterfowl also were netted or trapped, and fish were netted or speared. In addition, lakes, sloughs, and marshes were exploited for other resources such as fresh-water mussels and turtles. Yokuts also harvested acorns and a wide variety of other plant resources, particularly roots and seeds, for food. Yokuts exploited rivers, sloughs, and lakes for food resources and also for transportation using a canoe made from tules (Latta 1949; Wallace 1978, 1981). The tules were harvested when dry, tied into three long bundles and then lashed together, forming a base and two sides with a pointed bow and stern. Tule canoes were built to hold six people and their gear. Yokuts culture prospered until the arrival of Euroamericans in their territory. Contact with Euroamericans affected and dramatically altered the Yokuts culture. As the Euroamerican population increased in California, Yokuts and other Native American groups and their traditional cultures declined across California.

Southern Yokuts occupied the project area, including the Telamni, Wo'lasi, and Choynok that occupied the Lower Kaweah River; Koyeti who inhabited an area near Porterville along the Tule River; and the Chunut who inhabited the area east of former Tulare Lake (Latta 1949, Wallace 1978). There are known Telamni, Wo'lasi, and Choynok villages located approximately 10 miles east of the project area along the Kaweah River near the edge of the San Joaquin Valley and the foothills. These villages include Waitatshulu, Dawaw Nashid, and Chunto Choynuk (Wallace 1978). A Chunut village, Yimel, which is translated as 'catch fish by hand' is located approximately 15 miles to the west of the project area (Wallace 1978). There are no identified ethnographic villages in close proximity to the project area, which is described in the ethnographic record as an area of swampy sloughs (cf., Latta 1949, Wallace 1978).

Historic Context

At the time when California received statehood in 1850, the south-central portion of Tulare County was largely devoid of western settlement. However, the overnight population boom in California that was spurred by the Gold Rush eventually spilled into the expanses of the state beyond the gold fields. The Euro-American settlers began arriving in the region in the 1850s, moving along the foothills of the Sierra Nevada in search of new and unexploited gold fields. These routes evolved into stage lines, such as the Butterfield Overland Stage Line, which in turn prompted the founding of stops with general stores, hotels, and other simple amenities (City of Porterville 2018). The region was quickly established as a center of agricultural activity. The readily available expanses of grasslands were first utilized by ranchers, who drove their herds of sheep and cattle throughout the San Joaquin Valley and the foothills of the Sierra Nevada. Farmers also began to acquire land and produced a variety of crops. During the initial phase of agricultural development, grains were the most common, but the Mediterranean climate and rich soils of southern Tulare County proved a suitable location to experiment with a wide variety of crops and agricultural products. By the late 19th and early 20th centuries, the south-central area of Tulare County became increasingly known for a number of exotic crops, including citrus, olives, and grapes. To increase agricultural production in the largely arid region, first farmers and later irrigation districts constructed networks of simple water conveyance systems. These earthen canals and ditches traversed Tulare County and provided the necessary access to water to increase production (County of Tulare Resource Management Agency 2015).

By 1872, the Southern Pacific Railroad was extended into Tulare County, providing the agricultural industry with direct access to the markets in California and beyond. In 1888, a new railroad line, known as the Stockton Tulare Railroad, was constructed to the east of the project area and served the communities of Porterville, Terra Bella, and Plano, and further increased the transportation of both people and goods (County of Tulare Resource Management Agency 2015). People continued to arrive in the region and the established townsites continued to experience modest growth throughout the early 20th century. Some real estate companies purchased large tracts of land, particularly near the established center of Porterville, and began to subdivide it into parcels. However, this form of development remained rare and the region remained largely rural with family-owned farms.

Agriculture continued to be the predominant industry through the turn of the century and crops, such as citrus, olives, and grapes, were among the most common. Increases in agricultural production around California were catalyzed through the development of expanded irrigation networks and systems, which were often governed by cooperatives like mutual water companies, and eventually through irrigation districts. By 1930, there were 94 irrigation districts operating in California, the vast majority of which were serving the Central Valley. A handful of districts served Tulare County, but the overall conveyance systems and output in the Porterville continued to be serviced by those early 19th century irrigation canals, and agricultural development was modest in relation to other areas of the state (Biagio 2018; JRP Historical Consulting 2000).

In the 1930s, following the onset of the Great Depression, the region saw a population influx as migrants from other regions of the country moved to California in search of opportunity and economic stability. The south-central region of Tulare County was particularly attractive for the availability of inexpensive land and agricultural jobs. This period, synonymous with the New Deal of the Roosevelt Administration, also marked the beginning of largescale, publicly funded infrastructure projects. Over the following decades, new and modern irrigation networks were constructed throughout the San Joaquin Valley to provide increasing access to water, including the Central Valley Water Project and the Friant-Kern Canal. The Friant-Kern Canal was a significant catalyst for the expansion of the agricultural industry in the Porterville-Terra Bella area in Southern Tulare County. Following the completion of the canal in 1948, the Porterville Irrigation District was established and immediately oversaw a rapid expansion of irrigated acreage in the region (Biagio 2018; JRP Historical Consulting 2000).

Throughout the remainder of the 20th century, the region continued to be a center of agricultural activity. Some of the urban centers, like Porterville and Visalia, experienced noteworthy growth during this post-war period due to the accessibility of affordable housing and established highway systems. However, much of the surrounding region remained predominantly rural and defined by the agricultural industry. In the later parts of the 20th century, farmland became increasingly consolidated by large agricultural businesses and organizations. This nation-wide trend continued to shift the overall aesthetic of the rural Tulare landscape, moving away from residentially scaled agricultural structures to more industrial expansive warehouses, packing facilities, and shipment centers (County of Tulare Resource Management Agency 2015).

Friant-Kern Canal

The FKC was constructed between 1945 and 1951 as part of the Central Valley Project (CVP), which included several advanced hydrological engineering projects that would provide both power and water conveyance throughout California. Although the FKC and other portions of the CVP were largely constructed in the post-war years of the 20th century, it was initially conceived decades earlier. In the late 19th century, the U.S. Army Corps of Engineers began studying the concept of a massive water infrastructure project throughout Central California. Over the following decades, major projects, such as the Los Angeles Aqueduct and the Hetch-Hetchy Reservoir systems had been constructed to bring increased water supplies to the urban centers of the state. However, it was not until the 1920s that the concept of a massive central water

conveyance system gained traction. Starting in 1927, the State Engineer of California, Edward Hyatt, began studying the possibility of dams and canals that would deliver water throughout the California. In 1931, Hyatt released his studies and plan for the system of dams, reservoirs, and canals that would ultimately become the CVP; however, the country had entered the Great Depression and California was unable to market the bonds required to finance the project (JRP Historical Consulting 2000).

By 1935, the Roosevelt administration had enacted policies of the New Deal, which supplied funding for new infrastructure projects around the country as a strategy for providing employment to average Americans, as well as improving various services and systems throughout the nation. Federal emergency funds were allocated to the construction of the CVP and Reclamation was tasked with overseeing the construction and operation of the broad network. Reclamation relied on the plans developed by Hyatt in the late 1920s and divided the project into five primary units: Shasta Dam, the Delta-Mendota Canal, the Contra Costa Canal, the Friant Dam, and Friant-Kern Canal (JRP Historical Consulting 2000).

The Friant Dam and Friant-Kern Canal divisions of the CVP were paired together. The designs of both projects worked in tandem to store water from the San Joaquin River near Fresno at the Millerton Reservoir, set behind the Friant Dam, and divert it throughout the southern Central Valley through Tulare and Kern counties via the canal network. Construction of Friant Dam began in 1939 and was ultimately completed in 1944. Reclamation officially began constructing the 152-mile canal in 1945 and moved downstream to finish construction near Bakersfield in 1951. The concrete-lined canal was constructed by a series of crawler tractors that created the embankment of the canal, which were then followed by a moving construction machine, called a "Jumbo," which both shaped the canal, as well as provided scaffolding and slips for the immaculate finishing of the concrete lining. The construction efforts were divided into segments, which were contracted to separate companies that in turn hired numerous local contractors (Water Education Foundation 2018).

At completion in June 1951, the FKC was considered a major feat in engineering. The largely uniform 152-mile canal had a varied bottom width of 15–36 feet with steep bank slopes, and had a maximum capacity of 5,000 cubic feet per second (cfs). It also featured 29 major canal siphons, over 100 bridges, 49 culverts, several waste ways and over chutes, dozens of laterals, one equalization reservoir, and hundreds of power and telephone lines relocated underground. New irrigation districts throughout the three counties were formed to administer the marketing and distribution of the water to the surrounding agricultural lands (Autobee 1994).

Since its completion in 1951, the FKC has been providing water for irrigation throughout the southern counties of the Central Valley. However, it has not been without controversy. Issues related to the riparian environment of the San Joaquin River and fishery stocks, the continued growth of regional population centers in the Central Valley, and the widespread use of underground aquifers for agriculture have all resulted in complications in the operation of the canal. The latter of these issues has notably resulted in the subsidence of the central valley floor, which has significantly impacted the ability of the carefully engineered canal to deliver water. As

of 2017, emergency repairs of the canal in order to increase and regulate flows are being implemented (Autobee 1994; Elkins 2017).

Land Use and Agricultural Resources

Regulatory Setting

Federal Agencies and Regulations

Federal Farmland Protection Policy Act

The Federal Farmland Protection Policy Act (FPPA) is intended to minimize the unnecessary and irreversible conversion of farmland to nonagricultural use that could result from implementation of a project having a federal nexus. It ensures that federal programs are administered to be compatible with state, local, and private programs and policies to protect farmlands. Every two years, federal agencies are required to review, revise, and develop their policies and procedures to maintain consistency with the FPPA. It does not authorize the federal government to regulate the use of private or nonfederal land or, in any way, affect the property rights of owners. For the purposes of FPPA, farmland includes prime farmland, unique farmland, and land of statewide or local importance. FPPA does not require that designated farmland be actively cultivated or be limited to croplands to be afforded protection. Lands included in FPPA can be forest land, pastureland, cropland, or other land, but not water or urban built-up land. Projects that may irreversibly convert farmland to a non-agricultural use, either directly or indirectly, and are completed by a federal agency or with the assistance of a federal agency, may be subject to FPPA requirements. Projects not subject to FPPA include, but are not limited to, projects planned and completed without the assistance of a federal agency, projects on land already used for water storage, and construction within an existing right-of-way purchased on or before August 4, 1984 (Natural Resources Conservation Service 2018).

State Agencies and Regulations

California Important Farmland Inventory System and Farmland Mapping and Monitoring Program.

The California Department of Conservation (DOC), under the Division of Land Resource Protection, administers the Farmland Mapping and Monitoring Program (FMMP), which monitors conversion of the state's farmland to and from agricultural use. DOC sponsors the FMMP and is also responsible for establishing agricultural easements in accordance with California Public Resources Code (PRC) Sections 10250–10255 (California Legislative Information 2018a). Every two years these maps are updated with the use of aerial photographs, computer mapping systems, public review, and field reconnaissance. As part of this effort to map agricultural land uses, the Natural Resources Conservation Service (NRCS) developed a series of definitions known as Land Inventory and Monitoring criteria. These criteria classify the land's suitability for agricultural production that includes both the physical and chemical characteristics of soils and the actual land use. Important Farmland maps are derived from NRCS soil survey maps using the Land Inventory and Monitoring criteria and are available by county. The maps

prepared by NRCS classify land into one of nine categories, defined as follows (California Department of Conservation 2018a):

- **Prime Farmland** – Land that has the best combination of physical and chemical characteristics for crop production. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields of crops when treated and managed.

- **Farmland of Statewide Importance** – Land other than Prime Farmland that has a good combination of physical and chemical characteristics for crop production. This land has minor shortcomings, such as greater slopes or less ability to store soil moisture than Prime Farmland.

- **Unique Farmland** – Land that does not meet the criteria for Prime Farmland or Farmland of Statewide Importance, but that has been used for the production of specific crops with high economic value. This land is usually irrigated but may include non-irrigated orchards or vineyards as found in some climatic zones in California.

- **Farmland of Local Importance** – Land that either is currently producing crops or has the capability of production but does not meet the criteria of the categories above. Farmland of Local Importance is defined by each county's local advisory committee and adopted by its board of supervisors.

- **Grazing Land** – Land on which the vegetation is suited to the grazing of livestock. The minimum mapping unit for Grazing Land is 40 acres.

- **Urban and Built-Up Lands** – Land occupied by structures with a density of at least one dwelling unit per 1.5 acres.

- **Other Land** – Land not included in any other mapping category. Common examples include low density rural developments; brush, timber, wetland, and riparian areas not suitable for livestock grazing; confined livestock; and water bodies smaller than forty acres. Vacant and non-agricultural land surrounded on all sides by urban development and greater than 40 acres is mapped as Other Land.

- **Water** – Perennial water bodies with an extent of at least 40 acres.

- **Land Committed to Nonagricultural Use** – Vacant areas; existing lands that have a permanent commitment to development but have an existing land use of agricultural or grazing lands. Use of this designation is optional.

Important Farmland is classified by DOC as Prime Farmland, Farmland of Statewide Importance, Unique Farmland, or Farmland of Local Importance. The designations are defined together under the terms "Agricultural Land" and "Important Farmland" in CEQA (PRC

Sections 21060.1 and 21095) (FindLaw 2018) and Appendix G of the State CEQA Guidelines. The conversion of these types of farmland could be considered an environmental impact.

Williamson Act: California Land Conservation Act of 1965

The California Land Conservation Act of 1965, Sections 51200 et seq., of the California Government Code, commonly known as the Williamson Act, enables local governments to enter into contracts with private landowners for the purpose of restricting specific parcels of land to agricultural or related open space use. Agreements are made under a 10-year rolling contract. In return, restricted parcels are assessed for property tax purposes at a rate consistent with their actual use, rather than potential market value (California Department of Conservation 2018b). Contract cancellation must be done by a landowner petition that may be tentatively approved by the local government who must make specific findings that are supported by substantial evidence. Existence of an opportunity for another land use is not sufficient reason for cancellation (California Department of Conservation 2018b). Local governments may identify compatible uses permitted with a use permit.

Farmland Security Zones

Farmland Security Zones (FSZ), also known as Super Williamson Act lands, were established by DOC with the same general intent as Williamson Act contracts, but for 20-year contract periods with additional tax benefits over and above the standard Williams Act contract. An FSZ must be located in an agricultural preserve area (i.e., eligible for a Williamson Act contract) and designated as Prime Farmland, Farmland of Statewide Importance, Unique Farmland, or Farmland of Local Importance.

An FSZ contract can be terminated through nonrenewal or cancellation. The nonrenewal allows a rollout process to occur over the remainder of the contract term, when the tax rates would gradually rise to the full rate by the end of the 20-year term. A cancellation must be applied for and approved by the DOC director and must meet specific criteria. The cancellation must be in the public interest and consistent with Williamson Act criteria. If a cancellation is approved, fees equal to 25 percent of the full market value of the property must be paid.

Regional and Local

Tulare and Kern Counties

The general plans of Tulare and Kern counties contain goals, policies, and implementation measures to protect agricultural lands, as summarized below.

- **Tulare County General Plan.** The Tulare County General Plan (County of Tulare Resource Management Agency 2012) identifies goals, policies, and implementation measures aimed at conserving large contiguous areas of productive agricultural land. It provides opportunities for the future expansion of such uses and identifies protection measures to alleviate development pressures that would adversely affect or hinder existing or future agricultural operations. This includes the objectives and policies to protect water resources and supply systems critical to agriculture. The entirety of the FKC in Tulare County passes through areas zoned as Valley Agricultural (VA). This land

use designation applicable to all agricultural lands on the valley floor below the 600-foot elevation that are located outside of urban areas.

- **Kern County General Plan.** The Kern County General Plan (Kern County Planning Department 2009) encourages and supports agricultural resources and land use in Kern County. The goals and policies in the Land Use, Open Space and Conservation Element provide for a variety of land uses for future economic growth while also assuring the conservation of Kern County's agricultural, natural, and resource attributes. In Kern County, designated land use zoning for lands adjacent to the FKC is for intensive agriculture.

Tulare County Resource Management Agency

The Tulare County Resource Management Agency oversees actions in the unincorporated areas of the county, providing inspection services, permits, and oversight of the Tulare County General Plan, and zoning codes and entitlements. Permits that it issues include encroachment permits, which are required for improvements in public rights-of-way and building permits. Parcels affected by the project may need to be rezoned to maintain compatibility with Tulare County's zoning codes. The Tulare County Resource Management Agency would be responsible for the review of petitions for land use rezoning.

Kern County Planning and Natural Resources Department

The Kern County Planning and Natural Resources Department provides consolidated land use planning, including administration of the Kern County General Plan, effectuating General Plan policies and goals; administration of the county's zoning and land division ordinances; and administration of the Agricultural Preserve Program. The County's Planning Director, or delegate, would be responsible for the approval of any discretionary land use-related permits or rezoning actions needed to allow for project construction.

Agricultural Water Management Plans

The Sustainable Groundwater Management Act (SGMA) of 2014 is a combination of three bills passed by State Legislature and signed by California Governor Jerry Brown: Assembly Bill 1739, and Senate Bills 1168 and 1319. This legislation provides local agencies with the framework to manage groundwater basins in a sustainable manner. Local agencies are tasked with forming groundwater sustainability agencies (GSA) that will develop and implement groundwater sustainability plans (GSP) to achieve and manage groundwater sustainability by 2040. The FKC is aligned through the portion of Tulare County managed by the East Kaweah Groundwater Sustainability Agency. In Kern County, the Poso Creek and Kern Integrated Regional Water Management Plans are comprehensive plans that address region-wide water management and related issues. The local planning direction of each of these agencies should be considered in the design and implementation of the FKC project. The GSPs developed by each agency would be used to identify baseline conditions and integrate water management with land use planning.

Land Use

Land uses in Tulare and Kern counties range from high density urban cities to mountainous and high desert open spaces. In the project area, the linear FKC is the dominant existing land use feature. As it flows south through both counties, land use zoning immediately adjacent to the canal is wholly agricultural. Following are preliminary discussions of the land use settings of each county in greater detail.

Tulare County

The primary land use in Tulare County, particularly in the valley region, is agriculture (County of Tulare Resource Management Agency 2012). The entirety of the FKC in Tulare County is aligned through valley agricultural (VA) lands, a resource land use designation used by Tulare County to identify areas of intensive agricultural activities on prime valley agricultural soils and other productive or potentially productive valley lands where commercial agricultural uses can exist without conflicting with other uses, or where conflicts can be mitigated (County of Tulare Resource Management Agency 2012). Among the uses typically allowed on VA-designated lands are resource facilities that directly support agricultural operations, including public utilities.

Where it passes near the unincorporated community of Strathmore (approximately MP 89 to MP 90.7), the FKC is used to delineate the community's eastern boundary (i.e., urban development boundary). It similarly forms much of the southwestern urban development boundary of the city of Porterville.

Rural residential and commercial (i.e., agricultural industrial) are infrequent in the project area, although they do occur. Currently, dominant crops adjacent to the project area include grapes, nuts, and alfalfa.

Kern County

Kern County land uses are predominantly for natural resources, open space, and productive farmland (Kern Council of Governments 2018). Designated land use for lands in Kern County adjacent to the FKC are zoned for intensive agriculture (Kern County Assessor 2018). There a no residential land uses in or immediately adjacent to the project area between County Line Road and the north end of Lake Woollomes.

Agricultural Resources

The San Joaquin Valley of central California is one of the most important agricultural areas in the world, with Tulare County being the leading producer of agricultural commodities in the United States (Tulare County Association of Governments 2018a). Similarly, Kern County is also one of the richest agricultural areas in the world growing more than 88 different crops, many of which are not grown anywhere else in the nation, grown on over 740,000 acres of cultivated farmland (Kern Council of Governments 2018). In Tulare County, agricultural uses, which include row crops, orchards, dairies, and grazing lands on the valley floor and in the foothills

occupy over 2,080 square miles or approximately 43 percent of the entire county (Tulare County Association of Governments 2018a). Currently, in Tulare County the main crops adjacent to the project area include grapes, nuts, and alfalfa. In Kern County, grapes are currently the dominant cultivated crop grown on lands along the project alignment. In addition to producing agricultural commodities, agricultural lands benefit biological habitats, flood control efforts, groundwater recharge, and energy production.

In the project area, lands are wholly zoned for agricultural use. Agricultural preserves are adjacent to the FKC (Conservation Biology Institute 2018; County of Tulare Resource Management Agency 2018). These preserves consist of designated areas protected for agricultural use by either contract (such as a Williamson Act[1] contract), easement (such as a conservation easement, or other mechanism designed to protect the agricultural use of land for 10 or more years, renewed annually (County of Tulare Resource Management Agency 2012). In Tulare County, one FSZ parcel is currently mapped adjacent to the FKC (Yale Framework 2018). This parcel is located on the west side of the canal and is at the southeast corner of the intersection of Avenue 16 and Road 176. In Kern County, all agricultural lands adjacent to the FKC from the county line to the northern end of Lake Woollomes (MPs 116.8 to 119.5) are zoned as Exclusive Agriculture and are designated prime farmlands under active Williamson Act contracts (Kern County 2018). The minor exception is a grouping of six parcels located at the southwest corner of the SR 155/FKC intersection. These parcels are, however, designated prime farmlands.

Along the FKC alignment are several driveway entrances used for both rural residential and agricultural/industrial facility and cultivated field access.

Transportation and Circulation

Federal

Although the project would have no impact on the interstate highway system, and is not necessarily a transit project, its federal nexus will require compliance with several federal statutes and regulations that pertain to transportation projects in general. The following Federal legislative statutes may apply to surface transportation and transportation aspects of the project:

- Federal Clean Air Act
- Federal Transit Act
- Americans with Disabilities Act – Civil Rights Act

[1] The Williamson Act (aka the California Land Conservation Act of 1965) is a California law that provides property tax relief to owners of farmland and open-space land in exchange for a 10-year (typically renewable) agreement that the land will not be developed or otherwise converted to another use.

- Safe, Accountable, Flexible, Efficient Transportation Equity Act

State

The California Department of Transportation (Caltrans) plans, designs, constructs, and maintains State-owned roadways. Caltrans's standard specifications establish uniform design and construction procedures for California highways and local roads. The highway design criteria and policies in the standard specifications ensure minimum design, contract, and construction standards for projects. The project is in Caltrans District 6, headquartered in Fresno. District 6 includes Tulare and Kern counties. Caltrans' Division of Transportation Planning, System Planning Branch, conducts long-range transportation plans in cooperation with local agencies to identify future highway improvements; the Division of Transportation Programming sets priorities for various Federal and State transportation funding programs.

Regional and Local

Transportation and circulation elements in the general plans of California counties address the movement of people and goods. California Government Code Section 65302(b) requires that circulation elements address the general location and extent of existing and proposed major thoroughfares, transportation routes, terminals, and other local public utilities and facilities (California Legislative Information 2018b).

Circulation elements establish goals and policies that pertain to transportation related activities on county-maintained roads. Most general plans contain circulation goals related to levels of service that are used to describe the efficiency of road segments and intersections in terms of traffic delays. Level of service guidelines address long-term planning objectives rather than temporary conditions such as temporary, short-term traffic delays resulting from construction activities.

In California, counties classify county-maintained roads according to their intended function and connection to land uses. Major roads such as highways and arterials are generally defined as primary carriers of intercity and intracounty travel. Collector roads are intended to provide subregional access and circulation by linking major roads with residential streets.

The Tulare County Association of Governments (TCAG) is the agency responsible for developing the transportation and circulation plan in Tulare County. TCAG is a regional agency governed by the eight cities and the County of Tulare. Those cities are Dinuba, Exeter, Farmersville, Lindsay, Porterville, Tulare, Visalia, and Woodlake. The regional transportation plan planning period is required to be a minimum of 20 years; the current plan covers the years 2014–2040. In 2014, TCAG adopted the Regional Transportation Plan and Sustainable Communities Strategy (Tulare County Association of Governments 2018b) for Tulare County in accordance with California Government Code Section 65080 et seq. The plan discusses regional transportation issues, problems, and solutions and includes goals and objectives for each transportation mode and area of concern.

The Kern Council of Governments (COG) is a state-designated Regional Transportation Planning Agency (RTPA). Preparing a Regional Transportation Plan is one of Kern COG's primary statutory responsibilities under federal and state law. Kern COG understands that land use is one of the most important elements of effective transportation planning. Although it does not have jurisdiction over land use planning, the agency does advise and encourage dialogue among those involved in the decision-making process. The 2018 Regional Transportation Plan and Sustainable Communities Strategy (Kern Council of Governments 2018) was prepared by Kern COG for Kern County. It serves as a 24-year blueprint that establishes a set of regional transportation goals, policies, and actions intended to guide development of the planned multimodal transportation systems in Kern County. Also included in the Kern County Regional Transportation Plan is the Congestion Management Program (CMP), which is designed to ensure that a balanced transportation system is developed relating population and traffic growth, land use decisions, performance standards, and air quality improvements.

Existing Conditions

Roadway Network

Most travel throughout Tulare and Kern counties involves movement through a network of roads. Regional streets and highways are used by nearly all modes of transportation, including automobiles, intra- and inter-regional trucking, bicyclists, pedestrians, and public transit. The mobility of people and goods are one of the most important issues to both Tulare and Kern county governments. There is a total of 48 road crossings over the FKC including 38 improved road crossings in Tulare County and four improved road crossings in Kern County; and six agricultural crossings (i.e., used for direct access into agricultural fields), five in Tulare County and one in Kern County. Most of these roads are county-owned, undivided, narrow two-lane collector and local roads used primarily to distribute traffic between local streets and arterials, and for agricultural and residential land access. A preliminary review of these roads found essentially all of them to have little or no paved shoulders. Two unnamed roads crossing the FKC in Tulare County (one south of MP 102 and the other east of Road 176) and one unnamed road in Kern County (near the north end of Lake Woollomes) appear to be specifically for agricultural land access; crossings at these locations are via single-lane, unpaved, (potentially) moveable bridge structure types. State highways that cross the FKC include state route (SR) 65 and SR 190 in Tulare County and SR 155 (Garces Highway) in Kern County. These highways and their bridges are administered by the California Department of Transportation (Caltrans). The counties manage bridges associated with their respective roads.

Traffic Levels

Traffic operations are commonly classified using a level of service (LOS) ranking. This qualitative ranking considers factors such as speed, travel time, traffic interruptions, safety, convenience, and operation costs under a particular volume condition. LOS rankings range from A to F, representing various levels of traffic flow from free-flow for A to stop-and-go gridlock for F. In Kern County, roads must meet and LOS of E or better (Kern Council of Governments

2018). In Tulare County, the goal is to meet a LOS of D or better (County of Tulare Resource Management Agency 2012). Roads also are designated by their function type, such as major or minor arterial, major or minor collector, or local. The FKC does not intersect any interstates, or other classified freeways or expressways (California Department of Transportation 2018). However, throughout its reach, it is crossed over by several arterials, including SR 65 and SR 190 (both principal arterials), and major and minor collectors. The rural nature of Tulare and Kern counties through which the FKC is aligned allows for LOS ratings to be based on uninterrupted traffic flows, thus arterials and collectors may operate as LOS A and B, while local roads may be LOS C, D, and in some cases, E.

The importance of regional agriculture has led the Tulare County Association of Governments to identify specific routes, or Farm to Market Routes (FTM) throughout the county. This network of roads is subject to at least 300 truck trips per day (Tulare County Association of Governments 2018). FTMs connect local farms to the state highway system and ultimately, national and international markets. FTM roads that cross the FKC include Avenue 196, Avenue 128, Road 192, East Terra Bella Avenue (J24), Avenue 56, Avenue 24, and Avenue 8 (Tulare County Association of Governments 2018) (Figure 6). Improvements and maintenance of FTMs are funded in part by ballot initiatives. A preliminary review for Kern County did not find any such similar route designations.

Transit and Aviation Services

Public transportation services in Tulare and Kern counties include public transit, Amtrak, and private carriers such as Greyhound. However, there are no rail service facilities near the FKC project area, nor do any private transportation carriers have routes that cross the FKC. Fixed routes for Tulare County public transit systems near the FKC are limited to the Porterville area (Tulare County Association of Governments 2017). In Kern County, there are no public transit systems operating in the part of the county through which the FKC is aligned (Kern Transit 2018).

In Tulare County, Eckert Field, a privately owned public airfield, is less than 0.5 mile east of the upper end of the FKC (MPs 88.2 and 89), and the Porterville Municipal Airport is approximately 1.5 miles east of the FKC (MPs 98 and 99). In Kern County, the Delano Municipal Airport is approximately 3 miles west of the north end of Lake Woollomes. There are no known private airstrips near the FKC.

Bicycle and Pedestrian Facilities

Most roads and bridge crossing over the FKC are narrow, with little or no shoulders, thus separate bike lanes and sidewalks are not feasible. Although there are no sidewalks or designated bike lanes within the project alignment, SR 65 and SR 155 are deemed state highway accessible bikeways (Kern Council of Governments 2012; California Department of Transportation 2015). Because of the rural nature of the area through which the FKC passes, bicycle and pedestrian use of local and arterial roads is often shared with motor vehicle traffic.

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Chapter 5.
Potential Constraints and Comparison of Alternatives

Potential environmental constraints for air quality, biological resources, cultural resources, land use and agricultural resources, and transportation and circulation are discussed below. Comparisons of Alternatives 1–5B are also provided below.

Air Quality

Preliminary emissions estimates were prepared for each of the Alternatives. The Alternatives were assumed to be constructed over a multi-year construction period. As a preliminary analysis, the maximum year is presented in Table 3; however, multiple years may have exceedances of the Air District thresholds. The assumptions used for air quality modeling for each of the Alternatives is provided in Appendix B.

Table 3. Maximum Yearly Air Quality Emissions Estimates

	Maximum Tons per Year					
Alternative	**ROG**	**NO_x**	**CO**	**SO_x**	**PM_{10}**	**$PM_{2.5}$**
1	5.57	77.24	36.23	0.17	16.02	8.90
2	5.78	83.64	37.28	0.18	17.71	9.37
3	5.62	77.56	36.39	0.16	15.87	8.91
4A	5.62	78.45	36.48	0.16	16.22	8.97
4B	5.49	79.70	35.03	0.18	16.46	9.01
5A	5.45	72.97	35.58	0.17	14.67	8.56
5B	5.28	73.07	33.94	0.15	14.58	8.20

Sources: CalEEMOD, 2016.3.2 and Sacramento Metropolitan Air Quality Management District Roadway Model, version 9.0.

Notes:

Air District Threshold Exceedances shown in bold.

For information on the schedule and equipment assumptions please refer to Appendix B.

PM_{10} emissions assumes compliance with Regulation VIII

As shown above, each of the alternatives will have an exceedance of NO_x and all alternatives except for 5A and 5B will have PM_{10} exceedances. Note that not all sources of emissions are

accounted for, such as potential stockpiles, soil-loading, etc. The emissions are a factor of the quantity of soil movement, construction schedule, and equipment usage, therefore refining the schedule and equipment list for each project alternative will be critical as the project progresses.

Based on the preliminary estimates above, all the alternatives have the potential to result in a significant impact on air quality. Mitigation will be required to reduce air quality impacts to a less-than-significant level. If the air quality impacts cannot be reduced to a less-than-significant level, then an Environmental Impact Report may be required for compliance with the California Environmental Quality Act. Potential mitigation measures include the use of Tier 4 off-road equipment and cleaner on-road haul trucks to reduce emissions or the purchase of offsets through a Voluntary Emission Reduction Agreement with the Air District.

No Authority to Construct permits will be required from the Air District for pump stations if they are powered by electricity. All of the alternatives will be required to comply with the Air District's Regulation VIII – Fugitive Dust Prohibitions through the preparation of a Dust Control Plan.

With regard to NEPA, the General Conformity regulations incorporate a stepwise process, beginning with an applicability analysis. According to the U.S. Environmental Protection Agency (EPA) General Conformity Guidance: Questions and Answers, before any approval is given for a Federal Action to go forward, the federal agency must apply the applicability requirements found at 40 CFR § 93.153 to the Federal Action and/or determine on a pollutant-by-pollutant basis, whether a determination of General Conformity is required. During the applicability analysis, the federal agency determines the following:

- Whether the action will occur in a nonattainment or maintenance area;
- Whether one or more of the specific exemptions apply to the action;
- Whether the federal agency has included the action on its list of presumed-to-conform actions;
- Whether the total direct and indirect emissions are below or above the *de minimis* levels; and/or
- Where a facility has an emissions budget approved by the State or Tribe as part of the SIP or TIP, the federal agency determines that the emissions from the proposed action are within the budget.

The EPA Guidance states that the applicability analysis can be (but is not required to be) completed concurrently with any analysis required under the NEPA.

If through the applicability analysis process the responsible federal agency determines that the General Conformity regulations do not apply to the Federal Action, no further analysis or documentation is required. If, however, the General Conformity regulations do apply to the

Federal Action, the responsible federal agency must conduct a conformity evaluation in accordance with the criteria and procedures in the implementing regulations; publish a draft determination of General Conformity for public review; and then publish the final determination of General Conformity. In general, the General Conformity determination is completed as part of the NEPA process.

To make a conformity determination, the federal agency must demonstrate conformity by one or more of several prescribed methods. These methods include:

- demonstrating that the direct and indirect emissions are specifically identified in the relevant implementation plan;
- obtaining a written statement from the entity responsible for the implementation plan that the total indirect and direct emissions from the action, along with other emissions in the area, will not exceed the total implementation plan emission budget; or
- fully offsetting the total direct and indirect emissions by reducing emissions of the same pollutant in the same nonattainment or maintenance area.

Based on the preliminary estimates, all alternatives will exceed the General Conformity *de minimis* threshold for NO_x and will require a conformity determination. Given that the alternatives are not contained within the emissions budget of State Implementation Plan offsets may need to be considered.

Biological Resources

The potential impacts on the non-listed special-species identified in Table 2 would generally be similar for all alternatives. Potential mitigation measures would likely include standard practices like avoiding work during nesting/breeding seasons or installing exclusionary devices (e.g., netting bridges to prevent swallow nesting); conducting preconstruction surveys for nesting birds, roosting bats, and other special-status species where suitable habitat would be affected (e.g., removal of bridges or vegetation, disturbance to streams or wetlands); and establishing buffers or conducting biological monitoring if species are determined to be present. Additionally, coordination with the CDFW may be necessary to determination the disposition of freshwater native and game fishes during dewatering of the FKC and any stream reaches. Also, project alternatives may require a streambed alteration agreement with the CDFW for modifications to the existing FKC that involve stream crossings, as applicable; and may potentially require Corps and RWQCB authorization under the CWA. Coordination with these agencies may be needed to confirm regulatory permitting requirements for modification of the existing FKC, and such coordination should occur as early in the environmental review and approval process as practicable.

Based on the preliminary review of biological resources, San Joaquin kit fox is the primary species of concern within the project area. San Joaquin kit fox was listed as endangered under the ESA on March 11, 1967; and was listed as threatened under the CESA on June 27, 1971. Throughout the project area, burrows on the FKC embankments provide potential denning habitat for San Joaquin kit fox in a landscape where most of their natural habitat has been converted to agricultural use. There are six CNDDB-reported occurrences of San Joaquin kit fox that intersect the project alignment and several others within 5 miles of the project alignment (Figure 5). Most of the CNDDB records date back to 1975, with the most recent observation (CNDDB Occurrence Number 376) of a known den recorded in 2005, located less than one mile west of the FKC MP 120.35. Another occurrence (CNDDB Occurrence Number 148) from 1993 was recorded along the FKC at MP 129.07 (California Department of Fish and Wildlife 2018).

During reconnaissance-level field surveys conducted in August 2018 for the immediate repairs project, Stantec biologists identified approximately 58 potential dens (e.g., burrows 4 to 12 inches in diameter) along an approximately 3.68-mile reach of the FKC between the Avenue 96 bridge (MP 103.66) and the Road 192 bridge (MP 107.34). Scat and prey remains were observed at three of the 58 potential dens. While it is not known if the scat and prey remains are attributable to San Joaquin kit fox, it is an indicator of possible use by this species. It is anticipated that potential dens are present along the entire alignment of the FKC within the project area.

Given that all the project alternatives would disturb potential dens along the FKC, all the project alternatives have a potential to adversely affect San Joaquin kit fox. Such project-related effects could potentially result in “take” under the ESA and CESA. Therefore, consultation with the USFWS under section 7 of the ESA and CESA incidental take permitting with CDFW is anticipated to be required for all project alternatives. Mitigation measures would need to be developed to avoid or minimize potential project-related impacts.

For this assessment, it is assumed that canal enlargement will not require modification of the existing siphons and will not have any impact on wetlands or waters of the United States at the stream crossings. For offset bypass canal stream crossings, it is assumed that a new siphon will be constructed and trenching through the stream will be required. Work within wetlands and waters of the United States will likely require CWA section 404 authorization from the Corps, CWA 401 authorization from the RWQCB, and a CDFW section 1600 streambed alteration agreement.

Two metrics were identified for the purposes of comparing the biological resources constraints among the project alternatives. These metrics include: (1) the potential for impacts on federal- and state-listed species (i.e., San Joaquin kit fox); and (2) the potential for impacts on wetlands and other waters of the United States and associated riparian habitat.

To assess the magnitude of potential impacts for each alternative, a ranking of 1 (high), 2 (moderately high), 3 (moderate), 4 (moderately low), or 5 (low) was assigned for each of the metrics. To provide a comparison among the alternatives within each ranking, a second number

was assigned. The second number identifies which alternatives would have the greatest (e.g., 1) or least impact (e.g., 7) within the ranking. For instance, an alternative ranked 1.1 and an alternative ranked 1.7 would both have a high magnitude of potential impact, but the alternative ranked 1.7 would have less of an impact than the alternative ranked 1.1. A discussion of each alternative is provided below.

Alternative 1: Canal Enlargement

Given that Alternative 1 would enlarge the entire reach of the FKC within the project area, it has the most potential to adversely affect San Joaquin kit fox and is assigned a rank of 1.1 (high) for potential impacts on federal- and state-listed species. It is anticipated that Alternative 1 would temporarily remove potential San Joaquin kit fox dens on both sides of the FKC from MP 88.2 to MP 121.5 (33.3 miles of canal or 66.6 miles of embankment). It is anticipated that potential dens would become reestablished over time after construction activities are completed.

Alternative 1 spans White River, Deer Creek, Tule River, and Porter Slough. It is anticipated that the existing siphons at these locations would not require modification and no disturbance to streams or riparian habitats would occur. There are two wetland areas within the project area, one north of Deer Creek and one north of Porter Slough. It is anticipated that Alternative 1 would not result in disturbance to these wetlands. As such, Alternative 1 is assigned a rank of 5.1 (low) for potential impacts on wetlands and other waters of the United States and associated riparian habitat.

Alternative 2: Pump Station at MP 109

Canal enlargement under Alternative 2 would temporarily remove potential San Joaquin kit fox dens on both sides of the FKC from MP 88.2 to MP 105.5 and MP 108.7 to MP 121.5 (30.1 miles of canal or 60.2 miles of embankment). Alternative 2 would temporarily remove most potential San Joaquin kit fox dens along the FKC, but the extent of loss is slightly less than under Alternative 1). It is anticipated that potential dens would become reestablished over time after construction activities are completed. Alternative 2 is assigned a rank of 1.2 (high) for potential impacts on federal- and state-listed species.

Alternative 2 spans White River, Deer Creek, Tule River, and Porter Slough. It is anticipated that the existing siphons at these locations would not require modification and no disturbance to streams or riparian habitats would occur. There are two wetland areas within the project area, one north of Deer Creek and one north of Porter Slough. It is anticipated that Alternative 2 would not result in disturbance to these wetlands. As such, Alternative 2 is assigned a rank of 5.1 (low) for potential impacts on wetlands and other waters of the United States and associated riparian habitat.

Alternative 3: Woollomes Pump Station

Canal enlargement under Alternative 3 would temporarily remove potential San Joaquin kit fox dens on both sides of the FKC from MP 88.2 to 95.7, MP 96.4 to MP 108.7, and MP 119.5 to

121.5 (21.8 miles of canal or 43.6 miles of embankment). It is anticipated that potential dens would become reestablished over time after construction activities are completed.

Due to the offset bypass, a 10.8-mile reach of the FKC between MP 108.7 and MP 119.5 would remain unchanged. The FKC would also remain unchanged for the 3.2-mile reach from MP 105.5 to MP 108.7 where no modifications are proposed. Alternative 3 would temporarily remove a majority of the potential San Joaquin kit fox dens along the FKC, but less than under Alternative 1 and Alternative 2. Alternative 3 is assigned a rank of 1.3 (high) for potential impacts on federal- and state-listed species.

Alternative 3 crosses White River and Deer Creek. Construction of a new siphon at White River would be required. It is anticipated that the Deer Creek crossing would utilize the existing siphon, and would not require disturbance to the streambed, riparian habitat, or wetland area north of Deer Creek. Alternative 3 is assigned a rank of 3.1 (moderate) for potential impacts on wetlands and other waters of the United States and associated riparian habitat.

Alternative 4A: Offset Bypass Canal from Tule River to White River and 4B: Offset Bypass Canal from Tule River to Lake Woollomes

Alternatives 4A and 4B both have potential to adversely affect San Joaquin kit fox. Canal enlargement under Alternative 4A would temporarily remove potential San Joaquin kit fox dens on both sides of the FKC canal from MP 88.2 to MP 95.7 and MP 112.9 to 121.5 (16.1 miles of canal or 32.2 miles of embankment). For Alternative 4B, canal enlargement would temporarily remove potential dens on both sides of the FKC from MP 88.2 to MP 95.7 and MP 119.5 to 121.5 (9.5 miles of canal or 19.0 miles of embankment). It is anticipated that potential dens would become reestablished over time after construction activities are completed.

It is anticipated that the alignment for the offset bypass canal segments would not contain a significant number of potential San Joaquin kit fox dens, but field surveys have not been conducted in these areas. Given that construction of offset bypass canals would leave relatively large segments of the existing FKC unchanged, Alternatives 4A and 4B would temporarily remove less potential San Joaquin kit fox dens along the FKC than Alternatives 1–3. However, the lower magnitude of impact is still considered potentially significant (i.e., loss of potential dens along 16.1 miles [Alternative 4A] or 9.5 miles [Alternative 4B] of FKC). Alternative 4A is assigned a rank of 1.6 (high) for potential impacts on federal- and state-listed species, and Alternative 4B is assigned a rank of 1.7 (high).

The offset bypass canal segments for Alternative 4A and Alternative 4B both begin at Tule River in the north (MP 95.7) and cross Deer Creek. While the Alternative 4A bypass ends at White River, the Alternative 4B bypass crosses White River and continues south to Lake Woollomes. Both alternatives would require construction of a new siphon at Deer Creek, and Alternative 4B would also require a new siphon at White River. It is anticipated that trenching across the streambed and removing riparian vegetation would be required for siphon construction. In addition, there is a wetland area north of Deer Creek that is likely to be impacted by construction

of a bypass canal under both alternatives. Based on a preliminary desktop-level review, it is estimated that construction of the bypass canal would result in a loss of approximately 8 acres of wetlands. There could also be temporary impacts on wetlands associated with staging areas necessary for project construction. Given the stream/riparian impacts that would be associated with construction of new siphons (1 siphon for Alternative 4A and 2 siphons for Alternative 4B) and the loss of wetland habitat for bypass canal construction, Alternative 4A is assigned a rank of 1.2 (high) for potential impacts on wetlands and other waters of the United States and associated riparian habitat; and Alternative 4B is assigned a rank of 1.1 (high).

Alternative 5A: Parallel Bypass Canal from Tule River to White River

Canal enlargement under Alternative 5A would temporarily remove potential San Joaquin kit fox dens on both sides of the FKC from MP 88.2 to MP 95.7 and MP 112.9 to MP 121.5 (16.1 miles of canal or 32.2 miles of embankment), and the parallel bypass canal would temporarily remove potential San Joaquin kit fox dens on the east side of FKC from MP 95.7 to MP 113 (17.3 miles of embankment). It is anticipated that potential dens would become reestablished over time after construction activities are completed. Alternative 5A would have less impact on potential San Joaquin kit fox dens than Alternatives 1–2, but a greater impact than Alternatives 3, 4A, 4B, and 5B. Alternative 5A is assigned a rank of 1.3 (high) for potential impacts on federal- and state-listed species.

The parallel bypass canal for Alternative 5A begins at Tule River in the north (MP 95.7), crosses Deer Creek, and ends at White River in the south (MP 113). Rather than construct a new siphon, Alternative 5A would tie back into the existing infrastructure at Deer Creek. Based on a preliminary desktop-level review, it is estimated that construction of the bypass canal would result in a loss of up to 4 acres of wetlands just north of Deer Creek. There could also be temporary impacts on wetlands associated with staging areas necessary for project construction. Alternative 5A would result in a greater impact on wetlands/other waters/riparian habitat than Alternatives 1 and 2 (no impact under these alternatives) and Alternative 3, but a lesser impact than under Alternatives 4A and 4B (8 acres of wetland loss under these alternatives). Given the loss of wetland habitat for bypass canal construction, Alternative 5A is assigned a rank of 1.3 (high) for potential impacts on wetlands and other waters of the United States and associated riparian habitat.

Alternative 5B: Parallel Bypass Canal from Tule River to Lake Woollomes

Canal enlargement under Alternative 5B would temporarily remove potential San Joaquin kit fox dens on both sides of the FKC from MP 88.2 to MP 95.7 and MP 119.5 to MP 121.5 (9.5 miles of canal or 19 miles of embankment), and the parallel bypass canal would temporarily remove potential San Joaquin kit fox dens on the east side of the FKC from MP 95.7 to MP 119.5 (23.8 miles of embankment). It is anticipated that potential dens would become reestablished over time after construction activities are completed. Alternative 5B is anticipated to have less impact on potential San Joaquin kit fox dens than Alternatives 1–3 and 5A, but a greater impact than

Alternatives 4A, and 4B. As such, Alternative 5B is assigned a rank of 1.5 (high) for potential impacts on federal- and state-listed species.

The parallel bypass canal for Alternative 5B begins at Tule River in the north (MP 95.7), crosses Deer Creek and White River, and ends at Lake Woollomes in the south (MP 119.5). Rather than construct new siphons, Alternative 5B would tie back into the existing infrastructure at Deer Creek and White River. There is a wetland area north of Deer Creek that is likely to be impacted by construction of a bypass canal. Based on a preliminary desktop-level review, it is estimated that construction of the bypass canal would result in a loss of up to 4 acres of wetlands. There could also be temporary impacts on wetlands associated with staging areas necessary for project construction.). Alternative 5B would result in a greater impact on wetlands/other waters/riparian habitat than Alternatives 1 and 2 (no impact under these alternatives) and Alternative 3, but a lesser impact than under Alternatives 4A and 4B (8 acres of wetland loss under these alternatives). Given the loss of wetland habitat for bypass canal construction, Alternative 5B is assigned a rank of 1.3 (high) for potential impacts on wetlands and other waters of the United States and associated riparian habitat.

Cultural Resources

The FKC and contributing resources (e.g., bridges) is a cultural resource constraint that is common to all alternatives. All alternatives will likely have a significant adverse effect on the FKC and mitigation, potentially in the in the form of a HAER, to further document the FKC and all of its affected contributing elements may be required. A HAER is a mitigation measure with standards outlined by the Library of Congress and the National Park Service. The effort would involve a detailed historic context noting the canals development and operation, 5 x 4 film photography of a selection of key features, overviews, and details, and identification of key engineering drawings.

All project alternatives will require Reclamation to conduct Native American outreach/consultation; complete cultural resources field surveys of any areas within and outside of the Reclamation parcel boundaries; and complete NHPA Section 106 consultation with the SHPO. In addition, FWA will conduct AB-52 consultation to comply with CEQA. The project alternatives primarily differ in the extent of the FKC that would be enlarged, the extent of new rights-of-way and temporary construction easements that would be needed, and the number of bridges that would need to be replaced.

In general, archaeological sensitivity in and near the project area and is indeterminate because there have not been many large-scale surveys conducted in these areas. Archaeological resources that may be encountered are primarily historical refuse scatters associated with agriculture and settlement and prehistoric archaeological resources associated with subsistence activities. Prehistoric archaeological resources may be buried by recent soil sediments; therefore, subsurface excavation may encounter archaeological resources that are not identifiable solely through surface survey. Built environment resources (buildings and structures) over the 50-year

age threshold are located along the FKC corridor, the number of properties that would require study varies depending on the alternative. The rankings provided take into account three constraints aspects. These are (1) number and presence of known resources and areas of high sensitivity for the presence of archaeological resources; (2) the level of effort and analysis required to complete the resource management process through the mitigation phase by action type and location; and (3) the level of effort required to document resources and the resulting analysis of effect, or potential effect, on project schedule.

To assess the magnitude of potential impacts for each alternative, a ranking of 1 (high), 2 (moderately high), 3 (moderate), 4 (moderately low), or 5 (low) was assigned for each of the metrics. To provide a comparison among the alternatives within each ranking, a second number was assigned. The second number identifies which alternatives would have the greatest (e.g., 1) or least impact (e.g., 7) within the ranking. For instance, an alternative ranked 1.1 and an alternative ranked 1.7 would both have a high magnitude of potential impacts, but the alternative ranked 1.7 would have less of an impact than the alternative ranked 1.1. A discussion of each alternative is provided below.

Alternative 1: Canal Enlargement

Alternative 1 would enlarge the FKC from MP 88.2 to MP 121.5 and would require the replacement of 16 state or county road bridges and 5 farm bridges; 27 existing bridges would be unaffected. Intensive-level cultural resources surveys would be required for approximately 550 acres located outside the current Reclamation parcel boundaries. This survey area roughly extends 35 miles per side of the canal at approximately 275 acres per side. Alternative 1 would also require inventory and NRHP evaluation of upwards of 48 historic-age buildings and structures.

Alternative 1 is assigned a rank of 1.3 (high) as there is a high likelihood of effects because of the number of historic age properties that will need to be studied and the acreage for cultural resources surveys. However, when compared to the other alternatives, Alternative 1 has the mid to low magnitude of potential impacts aside from those related to canal enlargement.

Alternative 2: Pump Station at MP 109

Canal enlargement associated with Alternative 2 would require the replacement of 14 state or county road bridges and no farm bridges; 34 existing bridges would be unaffected. Intensive-level cultural resources surveys would be required for approximately 900 acres located outside the current Reclamation parcel boundaries (500 for canal enlargement and 400 for surge reservoir). In addition, Alternative 2 would require inventory and NRHP evaluation of upwards of 48 historic-age buildings and structures.

Alternative 2 is assigned a rank of 1.1 (high) because of the number of historic age properties that will need to be studied and the acreage for cultural resources surveys. While the likelihood of encountering archaeological and paleontological resources is still likely low, the likelihood of

finding resources increases with larger acreages and depth of excavation (e.g., depth of excavation for surge reservoir) is unknown.

Alternative 3: Woollomes Pump Station

Canal enlargement associated with Alternative 3 would require the replacement of 11 state or county road bridges and 1 farm bridge; 36 existing bridges would be unaffected. Intensive-level cultural resources surveys would be required for approximately 870 acres located outside the current Reclamation parcel boundaries (500 for canal enlargement, 55 for bypass canal, and 315 for surge reservoir). In addition, Alternative 3 would require inventory and NRHP evaluation of upwards of 48 historic-age buildings and structures.

Alternative 3 is assigned a rank of 1.2 (high) because of the number of historic age properties that will need to be studied and the acreage for cultural resources surveys. While the likelihood of encountering archaeological and paleontological resources is still likely low, the likelihood of finding resources increases with larger acreages and depth of excavation (e.g., depth of excavation for surge reservoir is unknown).

Alternative 4A: Offset Bypass Canal from Tule River to White River

Canal enlargement associated with Alternative 4A would require the replacement of 2 state or county road bridges and 2 farm bridges; 44 existing bridges would be unaffected. Intensive-level cultural resources surveys would be required for approximately 1,300 acres located outside the current Reclamation parcel boundaries (300 for canal enlargement, 1,000 for bypass canal). In addition, Alternative 4A would require inventory and NRHP evaluation of approximately 34 historic-age buildings and structures.

Alternative 4A is assigned the rank of 3.1 (moderate) because construction of the offset bypass canal would result in a substantial portion of the FKC (17.3 miles) remaining unchanged (i.e. not enlarged) in comparison to other alternatives without an offset bypass canal. Although Alternative 4A would require a larger cultural resources survey area than other alternatives, the survey area has been largely farmland for the last century and this decreases the likelihood of historic archaeological resources and the number of built environment resources.

Alternative 4B: Offset Bypass Canal from Tule River to Lake Woollomes

Canal enlargement associated with Alternative 4B would require the replacement of 1 state or county road bridges and 1 farm bridge; 46 existing bridges would be unaffected. Intensive-level cultural resources surveys would be required for approximately 1,200 acres located outside the current Reclamation parcel boundaries (200 for canal enlargement, 1,000 for bypass canal). In addition, Alternative 4B would require inventory and NRHP evaluation of approximately 34 historic-age buildings and structures.

Alternative 4B is assigned the rank of 3.2 (moderate) because construction of the offset bypass canal would result in a substantial portion of the FKC (23.8 miles) remaining unchanged (i.e. not

enlarged) in comparison to other alternatives without an offset bypass canal. Alternative 4B would also have a lesser extent of canal enlargement than Alternative 4A. Although Alternative 4B would require a larger cultural resources survey area than other alternatives, the survey area has been largely farmland for the last century and this decreases the likelihood of historic archaeological resources and the number of built environment resources.

Alternative 5A: Parallel Bypass Canal from Tule River to White River

Canal enlargement associated with Alternative 5A would require the replacement of 2 state or county road bridges and 2 farm bridges; 44 existing bridges would be unaffected. Intensive-level cultural resources surveys would be required for approximately 400 acres located outside the current Reclamation parcel. In addition, Alternative 5A would require inventory and NRHP evaluation of upwards of 48 historic-age buildings and structures.

Alternative 5A is assigned the rank of 1.5 (high) because of the number of historic age properties that will need to be studied and the acreage for cultural resources surveys. While the likelihood of encountering archaeological and paleontological resources is still likely low, the likelihood of finding resources increases with larger acreages and unknown depths of excavation.

Alternative 5B: Parallel Bypass Canal from Tule River to Lake Woollomes

Canal enlargement associated with Alternative 5B would require the replacement of 1 state or county road bridges and 1 farm bridge; 46 existing bridges would be unaffected. Intensive-level cultural resources surveys would be required for approximately 550 acres located outside the current Reclamation parcel boundaries. In addition, Alternative 5B would require inventory and NRHP evaluation of upwards of 48 historic-age buildings and structures.

Alternative 5B is assigned the rank of 1.4 (high) because of the number of historic age properties that will need to be studied and the acreage for cultural resources surveys. While the likelihood of encountering archaeological and paleontological resources is still likely low, the likelihood of finding resources increases with larger acreages and unknown depths of excavation.

Land Use and Agricultural Resources

Three metrics were identified for the purposes of comparing the land use and agricultural resources constraints among the project alternatives. These metrics include: (1) the potential for encroachment onto important farmlands, including Williamson Act lands; (2) the potential for agricultural and land use impacts as a result of road crossing modifications; and (3) the potential for land use zoning changes.

To assess the magnitude of potential impacts for each alternative, a ranking of 1 (high), 2 (moderately high), 3 (moderate), 4 (moderately low), or 5 (low) was assigned for each of the metrics. To provide a comparison among the alternatives within each ranking, a second number was assigned. The second number identifies which alternatives would have the greatest (e.g., 1)

or least impact (e.g., 7) within the ranking. For instance, an alternative ranked 1.1 and an alternative ranked 1.7 would both have a high magnitude of potential impacts, but the alternative ranked 1.7 would have less of an impact than the alternative ranked 1.1. A discussion of each alternative is provided below.

Based on a preliminary review of environmental conditions in the project area, the following land use and agricultural resources constraints were identified for the proposed project alternatives and could require specific design features or mitigation measures:

Alternative 1: Canal Enlargement

New road crossings needed to span the enlarged canal are anticipated to follow the general alignment of the existing bridge and roadway approaches (i.e., occur within the existing right-of-way) and are not anticipated to substantially affect agricultural lands. However, preliminary layout files for Alternative 1 (i.e., kmz files [October 5, 2018]) show canal enlargement to require approximately 40 linear feet of encroachment onto existing land uses on adjacent properties. A review of the current alignment found this encroachment to occur mainly on the east side of the canal between MP 90 and MP 93.5, MP 96 and MP 98.3, MP 100.3 and MP 100.6, MP 102.7 and MP 105, MP 108 and MP 108.7, MP 109.5 and MP 110.2, MP 111 and MP 111.6, and MP 115 and MP 115 and MP 116. Many of the potentially impacted areas are designated prime farmland, some of which are under Williamson Act contracts. This could be considered a land use conflict and may require cancellation of the Williamson Act contract or other relevant agreement(s), which could include payment of a significant valuation for the affected property(ies).

- Enlarging the canal between MP 88.2 and MP 121.5 would require the replacement of 16 state or county road bridges and 5 farm bridges under Alternative 1. This alternative includes transitioning the newly enlarged canal back to its existing width at some bridge crossings. Thus, 27 existing bridges would be unaffected by the canal enlargement. Although no permanent removal of bridge crossings is anticipated under Alternative 1, if permanent removal does occur, it would directly affect agricultural operations by interfering with the movement of equipment between fields.

- Conversion of existing farmland to a utility land use could require changes in zoning; however, the project's relationship to agricultural land use may be considered consistent with both counties' general plans. Consultation with the respective county is recommended.

- Potential impacts on existing facilities, such as an electrical substation near MP 108 and irrigation pumps like the one at the northeast corner of FKC and East Bella Avenue will require further assessment.

- Permanent land acquisition needed for new right-of-way under Alternative 1 is anticipated to total approximately 170 acres.

- County and regional land use plans will need to be reviewed and consistency determinations made in the project's environmental impacts decision document for this proposed alternative.

Enlargement of the FKC would largely occur within the existing easement; however, there would be some minor encroachment onto designated important farmlands immediately adjacent to the canal. Some of these farmlands are under Williamson Act contracts so project encroachment would conflict with land use and may require cancellation of the Williamson Act contract or other relevant agreement(s). These impacts may require payment of a significant valuation for the affected property(ies), although the affected area would be small relative to the other project alternatives. Alternative 1 is assigned a rank of 3.3 (moderate) for potential impacts on important farmlands, including Williamson Act lands.

Under Alternative 1, the temporary closure of bridge crossings during construction would affect agricultural equipment access, but the County's network of roads provides reasonable, although in some cases lengthy, detour routes. Alternative routes would need to be identified to avoid significant impacts on agricultural operations and other land uses. Compared to the other proposed project alternatives, Alternative 1 would affect fewer roads than the other alternatives, including agricultural access roads. Alternative 1 is assigned a rank of 3.3 (moderate) for potential impacts on agriculture and land use because of road crossing modifications.

Encroachment onto adjacent farmlands as a result of Alternative 1 would be minor relative to other project alternatives but would necessitate a review of county zoning policies to ensure that the project will be consistent with county and regional land use plans. Alternative 1 is assigned a rank of 3.3 (moderate) for potential to require land use rezoning.

Alternative 2: Pump Station at MP 109

- Set-aside for the off-canal surge reservoir at MP 109 would inundate approximately 400 acres of prime farmland, including Williamson Act lands. The proposed off-canal surge reservoir set-aside also currently includes a residence, cultivated fields, and two detention basins. This could be considered a land use conflict and may require cancellation of the Williamson Act contract or other relevant agreement(s), which could include payment of a significant valuation for the affected property(ies). In addition, consideration of impacts on the existing residence will be required.

- New road crossings needed to span the enlarged canal are anticipated to follow the general alignment of the existing bridge and roadway approaches (i.e., occur within the existing right-of-way).

- Enlarging the canal between MP 88.2 and MP 105.5, and MP 108.7 and MP 121.5 would require the replacement of a total of 14 state or county road bridges and no farm bridges under Alternative 2. This alternative includes transitioning the newly enlarged canal back to its existing width at some bridge crossings. Thus, 34 existing bridges would be

unaffected by the canal enlargement. Although no permanent removal of bridge crossings is anticipated under Alternative 2, if permanent removal does occur, it would directly affect agricultural operations by interfering with the movement of equipment between fields.

- Conversion of existing farmland to a utility land use could require changes in zoning; however, the project's relationship to agricultural land use may be considered consistent with both counties' general plans. Consultation with the respective county is recommended.

- Potential impacts on existing facilities, such as irrigation pump stations like the one at the northeast corner of FKC and East Terra Bella Avenue will require further assessment.

- Permanent land acquisition needed for new right-of-way under Alternative 2 is anticipated to total approximately 122 acres, plus an additional 400 acres for the emergency reservoir.

- County and regional land use plans will need to be reviewed and consistency determinations made in the project's environmental impacts decision document for this proposed alternative.

The magnitude of potential impacts on important farmlands under Alternative 2 would be high, relative to the extent of land use and agricultural resource impacts anticipated under most of the other proposed project alternatives. Permanent land acquisition needed for new right-of-way under Alternative 2 is anticipated to total approximately 122 acres, in addition to an approximately 400-acre off-canal surge reservoir that is located on cultivated agricultural land that is currently under a Williamson Act contract. Impacts of Alternative 2 on important farmland, including Williamson Act lands, may require payment of a significant valuation for the affected property(ies). Alternative 2 is assigned a rank of 1.3 (high) for potential impacts on important farmlands, including Williamson Act lands.

Alternative 2 would require the fewest new bridge replacements of the proposed alternatives. Under Alternative 2, the temporary closure of bridge crossings during construction would affect agricultural equipment access, but the County's network of roads provides reasonable, although in some cases lengthy, detour routes. Alternative routes would need to be identified to avoid significant impacts on agricultural operations and other land uses. Numerous agricultural field access roads and cultivated fields are within the approximately 122-acre area needed for new right-of-way, and the 400 acres that would be set aside for the off-canal emergency surge reservoir. There is also a rural residence located on the western edge of the proposed reservoir that may be impacted. Alternative 2 is assigned a rank of 1.1 (high) for potential impacts on agriculture and land use because of road crossing modifications.

Encroachment onto adjacent farmlands as a result of Alternative 2 would be substantial, primarily due to the inclusion of new right-of-way and the off-canal emergency surge reservoir

in this alternative. Although it is anticipated that this project will be consistent with county and regional land use plans, the approximately 122-acre area needed for new right-of-way and the 400 acres of prime farmland proposed for the off-canal emergency surge reservoir may require rezoning to allow for the new land use. Alternative 2 is assigned a rank of 1.3 (high) for potential to require land use rezoning.

Alternative 3: Woollomes Pump Station

- Set-aside for the off-canal surge reservoir just north of Lake Woollomes (at MP 119.5) would inundate approximately 400 acres of prime farmland, including Williamson Act lands. The proposed off-canal surge reservoir set-aside currently includes cultivated fields, three detention basins, and two pump stations. This could be considered a land use conflict and may require cancellation of the Williamson Act contract or other relevant agreement(s), which could include payment of a significant valuation for the affected property(ies).

- New road crossings needed to span the enlarged canal are anticipated to follow the general alignment of the existing bridge and roadway approaches (i.e., occur within the existing right-of-way) and would not substantially affect agricultural lands.

- Under Alternative 3, enlarging the canal between MP 88.2 and MP 95.7, MP 96.4 and MP 108.7, and MP 119.5 and MP 121.5, and construction of a canal bypass between MP 108.7 and MP 119.5 would require the replacement of 11 state or county road bridges and 1 farm bridge, and new construction of 12 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 36 existing bridges would be unaffected by the canal enlargement. Although no permanent removal of bridge crossings is anticipated under Alternative 3, if permanent removal does occur, it would directly affect agricultural operations by interfering with the movement of equipment between fields.

- Conversion of existing farmland to a utility land use could require changes in zoning; however, the project's relationship to agricultural land use may be considered consistent with both counties' general plans. Consultation with the respective county is recommended.

- Construction of a parallel bypass canal on the east side of the existing FKC, beginning at MP 108.7 to Lake Woollomes at MP 119.5, would impact utilities facility stations and agricultural staging yards near the Avenue 24/Road 181 intersection (MP 113.5), north of County Road J44 (County Line Road/Avenue 0) (MP 116.8), and south of Cecil Avenue (MP 118). Costs of relocating these facilities should be considered.

- Construction of a bypass as proposed under Alternative 3 could also result in the permanent loss of prime farmland and land under a Williamson Act or other relevant

agreement(s), which could require payment of a significant valuation for the affected property(ies).

- Permanent land acquisition needed for new right-of-way under Alternative 3 is anticipated to total approximately 223 acres, plus an additional 400 acres for the emergency reservoir.

- County and regional land use plans will need to be reviewed and consistency determinations made in the project's environmental impacts decision document for this proposed alternative.

The magnitude of potential impacts on important farmlands under Alternative 3 would be high, relative to the extent of agricultural resource impacts anticipated under the other project alternatives. Permanent land acquisition needed for new right-of-way under Alternative 3 is anticipated to total approximately 223 acres in addition to an approximately 400-acre off-canal surge reservoir would have the potential to inundate a sizable area of cultivated agricultural land that is currently under a Williamson Act contract. Impacts of Alternative 3 on important farmland, including Williamson Act lands, may require payment of a significant valuation for the affected property(ies). Alternative 3 is assigned a rank of 1.2 (high) for potential impacts on important farmlands, including Williamson Act lands.

Alternative 3 would require a substantial number of bridge replacements (all roadway bridges) and new bridge construction to create crossings over the parallel bypass canal. This would correspond to the need for additional right-of-way, which could encroach onto adjacent agricultural lands. The County's network of roads would provide reasonable, although in some cases lengthy, detour routes. Numerous agricultural field access roads and cultivated fields are within the 223 acres needed for new right-of-way, in addition to the 400 acres that would be set aside for the off-canal surge reservoir. Alternative routes would need to be identified to avoid significant impacts on agricultural operations and other land uses. Alternative 3 is assigned a rank of 1.2 (high) for potential impacts on agriculture and land use because of road crossing modifications.

Encroachment onto adjacent farmlands as a result of Alternative 3 would be substantial, primarily due to the inclusion of the off-canal surge reservoir in this alternative. Although it is anticipated that this project will be consistent with county and regional land use plans, the area proposed for the off-canal surge reservoir and new right-of-way may require rezoning of a total of approximately 623 acres of prime farmland to allow for the new land use. Alternative 3 is assigned a rank of 1.2 (high) for potential to require land use rezoning.

Alternative 4A: Offset Bypass Canal from Tule River to White River

- New road crossings needed to span the enlarged canal sections between MP 88.2 and MP 95.7, and MP 112.9 and MP 121.5 are anticipated to follow the general alignment of the

existing bridge and roadway approaches (i.e., occur within the existing right-of-way) and would not substantially affect agricultural lands.

- Under Alternative 4A, enlarging the canal between MP 88.2 and MP 95.7, and MP 112.9 and MP 121.5, and construction of a canal bypass between MP 95.7 and MP 112.9 (i.e., Tule River to White River) would require the replacement of 2 state or county road bridges and 1 farm bridge, and new construction of 16 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 45 existing bridges would be unaffected by the canal enlargement. Although no permanent removal of bridge crossings is anticipated under Alternative 4A, if permanent removal does occur, it would directly affect agricultural operations by interfering with the movement of equipment between fields.

- Conversion of existing farmland to a utility land use could require changes in zoning; however, the project's relationship to agricultural land use may be considered consistent with both counties' general plans. Consultation with the respective county is recommended.

- Construction of a bypass as proposed under this alternative would result in the permanent loss of prime farmland and land under a Williamson Act or other relevant agreement(s), which could require payment of a significant valuation for the affected property(ies).

- Construction of an offset bypass between MP 95.7 (Tule River) and MP 112.9 (White River) would split numerous agricultural properties and obstruct access to fragmented fields. It is anticipated that suitable agricultural equipment crossings would be needed at strategic intervals identified through consultation with land owners. Creation of these crossings may be a significant project expense.

- Permanent land acquisition needed for new right-of-way under Alternative 4A is anticipated to total approximately 506 acres.

- County and regional land use plans will need to be reviewed and consistency determinations made in the project's environmental impacts decision document for this proposed alternative.

The magnitude of potential impacts on land use and agricultural resources under Alternative 4A would be high, relative to the extent of land use and agricultural resource impacts anticipated under the other project alternatives, but not as high as Alternative 4B, which would have a greater overall area of impact both in number of affected parcels and total impacted acreage. Permanent land acquisition needed for new right-of-way under Alternative 4A is anticipated to total approximately 506 acres. The proposed offset bypass would fragment agricultural land, much of which is currently under Williamson Act contracts. Impacts of Alternative 4A on important farmland, including Williamson Act lands, may require payment of a significant

valuation for the affected property(ies). Alternative 4A is assigned a rank of 1.4 (high) for potential impacts on important farmlands, including Williamson Act lands.

Alternative 4A would require a number of bridge replacements (all roadway bridges) and new bridge construction to create crossings over the offset bypass canal. This would correspond to the need for additional right-of-way, which could encroach onto adjacent agricultural lands. The proposed offset bypass would fragment agricultural land, much of which is currently under a Williamson Act contract. The County's network of roads would provide reasonable, although in some cases lengthy, detour routes. Alternative routes would need to be identified to avoid significant impacts on agricultural operations and other land uses. Alternative 4A is assigned a rank of 2.1 (moderately high) for potential impacts on agriculture and land use because of road crossing modifications.

The offset bypass proposed under Alternative 4A would fragment a sizable are of agricultural land, much of which is currently under a Williamson Act contract. Although it is anticipated that the project will be consistent with county and regional land use plans, this encroachment would necessitate a review of county zoning policies, Williamson Act contracts, and potential impacts on agricultural facilities such as irrigation pump stations. Alternative 4A is assigned a rank of 1.4 (high) for potential to require land use rezoning.

Alternative 4B: Offset Bypass Canal from Tule River to Lake Woollomes

- New road crossings needed to span the enlarged canal sections between MP 88.2 and MP 95.7, and MP 119.5 and MP 121.5 are anticipated to follow the general alignment of the existing bridge and roadway approaches (i.e., occur within the existing right-of-way) and would not substantially affect agricultural lands.

- Under Alternative 4B, enlarging the canal between MP 88.2 and MP 95.7, and MP 119.5 and MP 121.5, and construction of a canal bypass between MP 95.7 and MP 119.5 (i.e., Tule River to Lake Woollomes) would require the replacement of 1 state or county road bridge and 1 farm bridge and new construction of 23 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 46 existing bridges would be unaffected by the canal enlargement. Although no permanent removal of bridge crossings is anticipated under Alternative 4B, if permanent removal does occur, it would directly affect agricultural operations by interfering with the movement of equipment between fields.

- New road crossings would be needed where existing roads intersect the offset bypass canal. Impacts on agricultural operations could be significant if existing transportation routes are affected.

- Conversion of existing farmland to a utility land use could require changes in zoning; however, the project's relationship to agricultural land use may be considered consistent

with both counties' general plans. Consultation with the respective county is recommended.

- Construction of a bypass as proposed under this alternative would also result in the permanent loss of prime farmland and land under a Williamson Act or other relevant agreement(s), which could require payment of a significant valuation for the affected property(ies).

- Construction of an offset bypass between MP 95.7 and MP 119.5 (i.e., Tule River to Lake Woollomes) would split numerous agricultural properties and obstruct access to fragmented fields. It is anticipated that suitable agricultural equipment crossings would be needed at strategic intervals identified through consultation with land owners. Creation of these crossings may be a significant project expense.

- Permanent land acquisition needed for new right-of-way under Alternative 4B is anticipated to total approximately 650 acres.

- County and regional land use plans will need to be reviewed and consistency determinations made in the project's environmental impacts decision document for this proposed alternative.

- Alternative 4B would have the greatest impact on land use of the project alternatives under consideration. Extensive prime agricultural lands, many of which are under Williamson Act contracts, would be permanently removed from agricultural production under this alternative. In addition, field and road fragmentation resulting from the bypass alignment could hinder agricultural operations. It should be anticipated that potential zoning changes, Williamson Act contract cancellation penalties, and mitigation needed to offset agricultural and land use impacts would be significant both in time and money.

The magnitude of potential impacts on land use and agricultural resources under Alternative 4B would be the highest of the proposed alternatives, relative to the extent of land use and agricultural resource impacts anticipated under the other proposed project alternatives. Alternative 4B would have a greater overall area of impact both in number of affected parcels and total impacted acreage. The proposed offset bypass would fragment agricultural land, much of which is currently under a Williamson Act contract. Permanent land acquisition needed for new right-of-way under Alternative 4B is anticipated to total approximately 650 acres. Impacts of Alternative 4B on important farmland, including Williamson Act lands, may require payment of a significant valuation for the affected property(ies). Alternative 4B is assigned a rank of 1.1 (high) for potential impacts on important farmlands, including Williamson Act lands.

The proposed offset bypass proposed under Alternative 4B would fragment agricultural land. Alternative 4B would require a substantial number of bridge replacements (both roadway and agricultural access bridges) and new bridge construction to create crossings over the parallel bypass canal: however, no new farm bridges would be needed under this alternative. Additional

right-of-way would be needed to accommodate the bridge replacements. This right-of-way would likely encroach onto adjacent agricultural lands. The County's network of roads would provide reasonable, although in some cases lengthy, detour routes. Alternative routes would need to be identified to avoid significant impacts on agricultural operations and other land uses. Alternative 4B is assigned a rank of 1.3 (high) for potential impacts on agriculture and land use because of road crossing modifications.

The proposed offset bypass would fragment agricultural land, much of which is currently under a Williamson Act contract. Although it is anticipated that the project will be consistent with county and regional land use plans, this encroachment would necessitate a review of county zoning policies, Williamson Act contracts, and potential impacts on agricultural facilities such as irrigation pump stations. Alternative 4B is assigned a rank of 1.1 (high) for potential impacts requiring land use zoning changes.

Alternative 5A: Parallel Bypass Canal from Tule River to White River

- New road crossings needed to span the enlarged canal sections between MP 88.2 and MP 95.7, and MP 112.9 and MP 121.5 are anticipated to follow the general alignment of the existing bridge and roadway approaches (i.e., occur within the existing right-of-way) and would not substantially affect agricultural lands.

- Under Alternative 5A, enlarging the canal between MP 88.2 and MP 95.7, and MP 112.9 and MP 121.5, and construction of a parallel canal bypass between MP 95.7 and MP 112.9 (i.e., Tule River to White River) would require the replacement of 2 state or county road bridges and 2 farm bridges, and new construction of 16 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 44 existing bridges would be unaffected by the canal enlargement. Although no permanent removal of bridge crossings is anticipated under Alternative 5A, if permanent removal does occur, it would directly affect agricultural operations by interfering with the movement of equipment between fields.

- Conversion of existing farmland to a utility land use could require changes in zoning; however, the project's relationship to agricultural land use may be considered consistent with both counties' general plans. Consultation with the respective county is recommended.

- Construction of a parallel bypass between MP 95.7 and MP 112.9 (i.e., Tule River to White River) as proposed under this alternative could also result in the permanent loss of prime farmland and land under a Williamson Act or other relevant agreement(s), which could require payment of a significant valuation for the affected property(ies).

- Permanent land acquisition needed for new right-of-way under Alternative 5A is anticipated to total approximately 320 acres.

- County and regional land use plans will need to be reviewed and consistency determinations made in the project's environmental impacts decision document for this proposed alternative.

The magnitude of potential impacts on land use and agricultural resources under Alternative 5A would be moderate, relative to the extent of land use and agricultural resource impacts anticipated under the other project alternatives. Permanent land acquisition needed for new right-of-way under Alternative 5A is anticipated to total approximately 320 acres. Alternative 5A would require a number of bridge replacements (all roadway bridges) and new bridge construction to create crossings over the parallel bypass canal but would not fragment agricultural fields like alternatives 4A and 4B. Alternative 5A would require additional right-of-way, which could encroach onto adjacent agricultural lands. Impacts of Alternative 5A on important farmland, including Williamson Act lands, may require payment of a significant valuation for the affected property(ies). Alternative 5A is assigned a rank of 3.2 (moderate) for potential impacts on important farmlands, including Williamson Act lands.

Alternative 5A would require a substantial number of bridge replacements (all roadway bridges) and new bridge construction to create crossings over the parallel bypass canal but would not fragment agricultural fields like alternatives 4A and 4B. Alternative 5A would require additional right-of-way, which could encroach onto adjacent agricultural lands. Enlargement of the FKC would largely occur within the existing easement. Alternative routes would need to be identified to avoid significant impacts on agricultural operations. Alternative 5A is assigned a rank of 3.2 (moderate) for potential impacts on agriculture and land use because of road crossing modifications.

Enlargement portions of the FKC would largely occur within the existing easement but bypass sections would encroach onto adjacent farmlands. Although it is anticipated that the project will be consistent with county and regional land use plans, this encroachment would necessitate a review of county zoning policies, Williamson Act contracts, and potential impacts on agricultural facilities such as irrigation pump stations. Alternative 5A is assigned a rank of 3.2 (moderate) for potential impacts requiring land use zoning changes.

Alternative 5B: Parallel Bypass Canal from Tule River to Lake Woollomes

- New road crossings needed to span the enlarged canal sections are anticipated to follow the general alignment of the existing bridge and roadway approaches (i.e., occur within the existing right-of-way) and would not substantially affect agricultural lands.

- Under Alternative 5B, enlarging the canal between MP 88.2 and MP 95.7, and MP 119.5 and MP 121.5, and construction of a parallel canal bypass between MP 95.7 and MP 119.5 (i.e., Tule River to Lake Woollomes) would require the replacement of 1 state or county road bridge and 1 farm bridge and new construction of 23 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 46 existing bridges would be unaffected

by the canal enlargement. Although no permanent removal of bridge crossings is anticipated under Alternative 5B, if permanent removal does occur, it would directly affect agricultural operations by interfering with the movement of equipment between fields.

- Conversion of existing farmland to a utility land use could require changes in zoning; however, the project's relationship to agricultural land use may be considered consistent with both counties' general plans. Consultation with the respective county is recommended.

- Construction of a bypass between MP 95.7 and MP 119.5 (i.e., Tule River to Lake Woollomes) as proposed under this alternative could also result in the permanent loss of prime farmland and land under a Williamson Act or other relevant agreement(s), which could require payment of a significant valuation for the affected property(ies).

- County and regional land use plans will need to be reviewed and consistency determinations made in the project's environmental impacts decision document for this proposed alternative.

- Permanent land acquisition needed for new right-of-way under Alternative 5B is anticipated to total approximately 386 acres.

- Because Alternative 5B would involve more extensive canal enlargement than Alternative 5A, it should be assumed that although similar in nature, the constraints described under Alternative 5B would be quantitatively greater.

The magnitude of potential impacts on land use and agricultural resources under Alternative 5B would be moderate relative to the extent of land use and agricultural resource impacts anticipated under the other project alternatives, but not as high as other alternatives. Permanent land acquisition needed for new right-of-way under Alternative 5B is anticipated to total approximately 386 acres. Alternative 5B would require a substantial number of bridge replacements (all roadway bridges) and new bridge construction to create crossings over the parallel bypass canal but would not fragment agricultural fields like alternatives 4A and 4B. Alternative 5B would require additional right-of-way, which could encroach onto adjacent agricultural lands. Enlargement of the FKC would largely occur within the existing easement. Impacts of Alternative 5B on important farmland, including Williamson Act lands, may require payment of a significant valuation for the affected property(ies). Alternative 5B is assigned a rank of 3.1 (moderate) for potential impacts on important farmlands, including Williamson Act lands.

Alternative 5B would require a substantial number of bridge replacements (all roadway bridges) and new bridge construction to create crossings over the parallel bypass canal but would not fragment agricultural fields like alternatives 4A and 4B. Alternative 5B would require additional right-of-way for the proposed bypass, which could encroach onto adjacent agricultural lands,

although sections of enlargement of the FKC would largely occur within the existing easement. Alternative routes would need to be identified to avoid significant impacts on agricultural operations and land use. Alternative 5B is assigned a rank of 3.1 (moderate) for potential impacts on agriculture and land use.

Enlargement portions of the FKC would largely occur within the existing easement but bypass sections would encroach onto adjacent farmlands. Although it is anticipated that the project will be consistent with county and regional land use plans, this encroachment would necessitate a review of county zoning policies, Williamson Act contracts, and potential impacts on agricultural facilities such as irrigation pump stations. Alternative 5B is assigned a rank of 3.1 (moderate) for potential impacts requiring land use zoning changes.

Transportation and Circulation

Two metrics were identified for the purposes of comparing the transportation and circulation constraints among the project alternatives. These metrics include: (1) potential conflicts with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation; and (2) the potential for traffic circulation impacts, including impacts on agricultural-related traffic and emergency vehicle access, due to possible modifications of existing bridges and routes.

To assess the magnitude of potential impacts for each alternative, a ranking of 1 (high), 2 (moderately high), 3 (moderate), 4 (moderately low), or 5 (low) was assigned for each of the metrics. To provide a comparison among the alternatives within each ranking, a second number was assigned. The second number identifies which alternatives would have the greatest (e.g., 1) or least impact (e.g., 7) within the ranking. For instance, an alternative ranked 1.1 and an alternative ranked 1.7 would both have a high magnitude of potential impact, but the alternative ranked 1.7 would have less of an impact than the alternative ranked 1.1. A discussion of each alternative is provided below.

Alternative 1: Canal Enlargement

- Enlarging the canal between MP 88.2 and MP 121.5 would require the replacement of 16 state or county road bridges and 5 farm bridges under Alternative 1. This alternative includes transitioning the newly enlarged canal back to its existing width at some bridge crossings. Thus, 27 existing bridges would be unaffected by the canal enlargement. In addition to numerous local roads, depending on the final project design, the following major and minor regional roads may be impacted by canal enlargement proposed under Alternative 1:

– SR 65 – a major regional arterial

– Avenue 196 H-20 (Tulare County Road J28 or Frazier Highway) – major collector

- Avenue 152 (Olive Avenue) – major collector
- Avenue 96 (Tulare County Road J24 or East Terra Bella Avenue) – major collector
- Avenue 56 (Tulare County Road J22 or Ducor Highway) – major collector
- State Highway 190 (Avenue 144) – minor arterial
- SR 155 (Garces Highway) – major collector

Temporary impacts would include the use of temporary detours for all modes of transportation during canal enlargement. Permanent impacts would occur if bridges are not replaced. Regional traffic circulation patterns would be forced to operate within the limited east/west crossing options, which could result in safety and maintenance hazards. It should be anticipated that important highway crossings such as these would require full bridge replacement.

- Costs to replace bridge crossings should be considered in the context of anticipated increased maintenance costs for roads subjected to increased traffic volumes and concentrated use by various vehicle weight classes.
- Although no permanent removal of bridge crossings is anticipated under Alternative 1, if permanent removal does occur, it would directly affect traffic circulation patterns and agricultural operations by removing through access.
- Up to four designated FTM routes in Tulare County—Avenue 192, Avenue 128, Avenue 96, and County Line Road—could be affected by temporary road closures during construction.
- SRs 65 and 155 are state highway accessible bikeways. Impacts on crossings of the FKC could affect bicycle transit but the impact is anticipated to be temporary (if bridge work is required) and alternate routes would be available.
- Pedestrian use of roads included in the Alternative 1 alignment is likely infrequent given the region's rural nature and dispersed population. Some temporary and permanent pedestrian inconvenience could occur under this alternative.
- Considerations of the potential effects of temporary and permanent road closures on emergency response vehicle access through the project area will be required.
- County and regional transportation plans will need to be reviewed and consistency determinations made in the project's environmental document for this proposed alternative.

- A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended.

It is anticipated that any project-related roadway construction implemented under Alternative 1 will be consistent with County and regional transportation plans. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Because Alternative 1 would potentially impact fewer state and county roads, but a higher number of farm bridges than many of the other proposed project alternatives, the potential for conflicts with existing plans and established levels of effectiveness would be moderate. Alternative 1 is assigned a rank of 5.2 (low) for its low potential to conflict with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation.

The magnitude of potential impacts on transportation and circulation under Alternative 1 would be moderate, but less than many of the other project alternatives. Temporary closure of bridge crossings during construction would affect traffic circulation for all modes of transportation, including emergency vehicles, agricultural equipment access, bicycles, pedestrian use, and designated FTM routes, but the County's network of roads provides reasonable, although in some cases lengthy, detour routes. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 1 is assigned a rank of 3.4 (moderate) for potential impacts on traffic circulation patterns because of possible modifications to existing bridges and routes, and the ability to phase construction.

Alternative 2: Pump Station at MP 109

- Set-aside for the off-canal surge reservoir at MP 109 would not impact county roads but would interfere with agricultural access to the affected area during inundation.

- The proposed off-canal surge reservoir would not interfere with any existing FKC road crossings.

- Enlarging the canal between MP 88.2 and MP 105.5, and MP 109 and MP 121.5 would require the replacement of a total of 14 state or county road bridges and no farm bridges under Alternative 2. This alternative includes transitioning the newly enlarged canal back to its existing width at some bridge crossings. Thus, 34 existing bridges would be unaffected by the canal enlargement. In addition to the numerous local roads, depending on the final project design, the following major and minor regional roads may be impacted by canal enlargement proposed under Alternative 2:

– SR 65 – a major regional arterial

– Avenue 196 H-20 (Tulare County Road J28 or Frazier Highway) – major collector

  - Avenue 152 (Olive Avenue) – major collector
  - Avenue 96 (Tulare County Road J24 or East Terra Bella Avenue) – major collector
  - Avenue 56 (Tulare County Road J22 or Ducor Highway) – major collector
  - State Highway 190 (Avenue 144) – minor arterial
  - SR 155 (Garces Highway) – major collector

- Costs to replace bridge crossings should be considered in the context of anticipated increased maintenance costs for roads subjected to increased traffic volumes and concentrated use by various vehicle weight classes.

- Although no permanent removal of bridge crossings is anticipated under Alternative 2, if permanent removal does occur, it would directly affect traffic circulation patterns and agricultural operations by removing through access.

- Up to four designated FTM routes in Tulare County—Avenue 192, Avenue 128, Avenue 96, and County Line Road—could be affected by temporary road closures during construction.

- SR 155 is a state highway accessible bikeway. Impacts on this crossing of the FKC could affect bicycle transit but the impact is anticipated to be temporary (if bridge work is required) and alternate routes would be available.

- Pedestrian use of roads included in the Alternative 2 alignment is likely infrequent given the region's rural nature and dispersed population. Some temporary and permanent pedestrian inconvenience could occur under this alternative.

- Considerations of the potential effects of temporary and permanent road closures on emergency response vehicle access through the project area will be required.

- County and regional transportation plans will need to be reviewed and consistency determinations made in the project's environmental document for this proposed alternative.

- A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended.

It is anticipated that any project-related roadway construction implemented under Alternative 2 will be consistent with County and regional transportation plans. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Because Alternative 2 would potentially impact the fewest number of state and county roads, and no farm bridges, the potential for conflicts with

existing plans and established levels of effectiveness would be low. Alternative 2 is assigned a rank of 5.1 (low) for its low potential to conflict with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation.

The magnitude of potential impacts on transportation and circulation under Alternative 2 would be low compared to the other proposed project alternatives. Alternative 2 would require the least amount of bridge replacement or new construction of the proposed alternatives. Temporary closure of bridge crossings during construction would affect traffic circulation, including emergency vehicles, agricultural equipment access, bicycles, pedestrian use, and designated FTM routes, but the County's network of roads provides reasonable, although in some cases lengthy, detour routes. Numerous agricultural field access roads within the area that would be set aside for the off-canal surge reservoir may be inundated. Set-aside for the off-canal surge reservoir at MP 109 would not impact county roads but would interfere with agricultural access to the affected area during inundation. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 2 is assigned a rank of 5.1 (low) for its low potential for impacts on traffic circulation patterns.

Alternative 3: Woollomes Pump Station

- Under Alternative 3, enlarging the canal between MP 88.2 and MP 92.9, MP 96.4 and MP 109, and MP 119.5 and MP 121.5, and construction of a canal bypass between MP 109 and MP 119.5 would require the replacement of 11 state or county road bridges, 1 farm bridge, and new construction of 12 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 36 existing bridges would be unaffected by the canal enlargement. In addition to the numerous local roads, depending on the final project design, the following major and minor regional roads may be impacted by canal enlargement and the parallel bypass proposed under Alternative 3:

– SR 65 – a major regional arterial

– Avenue 196 H-20 (Tulare County Road J28 or Frazier Highway) – major collector

– Avenue 152 (Olive Avenue) – major collector

– Avenue 96 (Tulare County Road J24 or East Terra Bella Avenue) – major collector

– Avenue 56 (Tulare County Road J22 or Ducor Highway) – major collector

– State Highway 190 (Avenue 144) – minor arterial

– SR 155 (Garces Highway) – major collector

Temporary impacts would include the use of temporary detours for all modes of transportation during canal enlargement. Permanent impacts would occur if bridges are not replaced. Regional traffic circulation patterns would be forced to operate within the limited east/west crossing options, which could result in safety and maintenance hazards. It should be anticipated that important highway crossings such as these would require full bridge replacement.

- Costs to replace bridge crossings should be considered in the context of anticipated increased maintenance costs for roads subjected to increased traffic volumes and concentrated use by various vehicle weight classes.

- Although no permanent removal of bridge crossings is anticipated under Alternative 3, if permanent removal does occur, it would directly affect traffic circulation patterns and agricultural operations by removing through access.

- Up to four designated FTM routes in Tulare County—Avenue 192, Avenue 128, Avenue 96, and County Line Road—could be affected by temporary road closures during construction.

- Construction of a parallel bypass canal on the east side of the existing FKC, beginning at MP 109 to Lake Woollomes at MP 119.5, would impact 15 road crossings, including 2 agricultural access roads. Although the affected crossings would be primarily along local roads, this segment of proposed bypass canal would impact SR 155 (Garces Highway) in Kern County, a designated major collector.

- Set-aside for the off-canal surge reservoir just north of Lake Woollomes near MP 119.5 would require closure of an approximately 0.5-mile stretch of Wallace Road, a north/south aligned local road, as well as several agricultural access roads in the proposed surge reservoir footprint. Although closure of Wallace Road may be inconvenient for some motorists, the maximum detour would be approximately 1.5 miles for north/south traffic circulation.

- The proposed off-canal surge reservoir would not interfere with any existing FKC road crossings.

- SR 65 and SR 155 are state highway accessible bikeways. Impacts on either of these crossings of the FKC could affect bicycle transit but the impact is anticipated to be temporary (if bridge work is required) and alternate routes would be available.

- Pedestrian use of roads included in the Alternative 3 alignment is likely infrequent given the region's rural nature and dispersed population. Some temporary and permanent pedestrian inconvenience could occur under this alternative.

- Considerations of the potential effects of temporary and permanent road closures on emergency response vehicle access through the project area will be required.

- County and regional transportation plans will need to be reviewed and consistency determinations made in the project's environmental document for this proposed alternative.

- A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended.

It is anticipated that any project-related roadway construction implemented under Alternative 3 will be consistent with County and regional transportation plans. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Because Alternative 2 would potentially impact the fewest number of state and county roads, but the highest potential to impact farm bridges of the other project alternatives, the potential for conflicts with existing plans and established levels of effectiveness would be moderate. Alternative 3 is assigned a rank of 2.1 (moderately high) for its potential to conflict with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation.

The magnitude of potential impacts on transportation and circulation under Alternative 3 would be high but would affect slightly fewer area roads than other off-canal project alternatives. However, this determination is preliminary pending determination of project actions between MP 92.9 and MP 96.4. Alternative 3 would require a substantial number of bridge replacements (both roadway and agricultural access bridges) and new bridge construction to create crossings over the parallel bypass canal. Temporary closure of bridge crossings and roads during construction would affect traffic circulation, including emergency vehicles, agricultural equipment access, bicycles, pedestrian uses, and designated FTM routes, but the County's network of roads provides reasonable, although in some cases lengthy, detour routes. Set-aside for the off-canal surge reservoir just north of Lake Woollomes near MP 119.5 would require closure of an approximately 0.5-mile stretch of Wallace Road, a north/south aligned local road, as well as several agricultural access roads in the proposed surge reservoir footprint. Although closure of Wallace Road may be inconvenient for some motorists, the maximum detour would be approximately 1.5 miles for north/south traffic circulation. Numerous agricultural field access roads within the area that would be set aside for the off-canal surge reservoir may be inundated. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 3 is assigned a rank of 1.2 (high) for potential impacts on traffic circulation patterns because of possible modifications to existing bridges and routes.

Alternative 4A: Offset Bypass Canal from Tule River to White River

- Under Alternative 4A, enlarging the canal between MP 88.2 and MP 95.7, and MP 112.9 and MP 121.5, and construction of a canal bypass between MP 95.7 and MP 112.9 (i.e., Tule River to White River) would require the replacement of 2 state or county road bridges and 2 farm bridges, and new construction of 16 bridges. This alternative includes

transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 44 existing bridges would be unaffected by the canal enlargement. In addition to the numerous local roads, depending on the final project design, the following major and minor regional roads may be impacted by canal enlargement or construction of the offset bypass canal proposed under Alternative 4A:

- SR 65 – a major regional arterial
- Avenue 196 H-20 (Tulare County Road J28 or Frazier Highway) – major collector
- Avenue 152 (Olive Avenue) – major collector
- Avenue 96 (Tulare County Road J24 or East Terra Bella Avenue) – major collector
- Avenue 56 (Tulare County Road J22 or Ducor Highway) – major collector
- State Highway 190 (Avenue 144) – minor arterial
- SR 155 (Garces Highway) – major collector

Temporary impacts would include the use of temporary detours for all modes of transportation during canal enlargement. Permanent impacts would occur if bridges are not replaced. Regional traffic circulation patterns would be forced to operate within the limited east/west crossing options, which could result in safety and maintenance hazards. It should be anticipated that important highway crossings such as these would require full bridge replacement.

- Costs to replace bridge crossings should be considered in the context of anticipated increased maintenance costs for roads subjected to increased traffic volumes and concentrated use by various vehicle weight classes.
- Although no permanent removal of bridge crossings is anticipated under Alternative 4A, if permanent removal does occur, it would directly affect traffic circulation patterns and agricultural operations by removing through access.
- Up to four designated FTM routes in Tulare County—Avenue 192, Avenue 128, Avenue 96, and County Line Road—could be affected by temporary road closures during construction.
- SRs 65 and 155 are state highway accessible bikeways. Impacts on crossings of the FKC could affect bicycle transit but the impact is anticipated to be temporary (if bridge work is required) and alternate routes would be available.

- Pedestrian use of roads included in the Alternative 4A alignment is likely infrequent given the region's rural nature and dispersed population. Some temporary and permanent pedestrian inconvenience could occur under this alternative.

- Considerations of the potential effects of temporary and permanent road closures on emergency response vehicle access through the project area will be required.

- County and regional transportation plans will need to be reviewed and consistency determinations made in the project's environmental document for this proposed alternative.

- A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended.

It is anticipated that any project-related roadway construction implemented under Alternative 4A will be consistent with County and regional transportation plans. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Because Alternative 4A would potentially impact the greatest total number of state, county, and farm roads of the project alternatives, the potential for conflicts with existing plans and established levels of effectiveness would be the highest. Alternative 4A is assigned a rank of 4.2 (moderately low) for its potential to conflict with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation.

The magnitude of potential impacts on transportation and circulation under Alternative 4A would be moderate compared to the other project alternatives. Alternative 4A would require fewer total bridge replacements (both roadway and agricultural access bridges) and new bridge construction to create crossings over the offset bypass canal than other alternatives, but more than some. Temporary closure of bridge crossings and roads during construction would affect traffic circulation, including emergency vehicles, agricultural equipment access, bicycles, pedestrian uses, and designated FTM routes, but the County's network of roads provides reasonable, although in some cases lengthy, detour routes. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 4A is assigned a rank of 3.3 (moderate) for potential impacts on traffic circulation patterns because of possible modifications to existing bridges and routes.

Alternative 4B: Offset Bypass Canal from Tule River to Lake Woollomes

- Under Alternative 4B, enlarging the canal between MP 88.2 and MP 95.7, and MP 119.5 and MP 121.5, and construction of a canal bypass between MP 95.7 and MP 119.5 (i.e., Tule River to Lake Woollomes) would require the replacement of 1 state or county road bridge and 1 farm bridge and new construction of 23 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 46 existing bridges would be unaffected by the canal

enlargement. In addition to the numerous local roads, depending on the final project design, the following major and minor regional roads may be impacted by canal enlargement or construction of the offset bypass canal proposed under Alternative 4B:

- SR 65 – a major regional arterial
- Avenue 196 H-20 (Tulare County Road J28 or Frazier Highway) – major collector
- Avenue 152 (Olive Avenue) – major collector
- Avenue 96 (Tulare County Road J24 or East Terra Bella Avenue) – major collector
- Avenue 56 (Tulare County Road J22 or Ducor Highway) – major collector
- State Highway 190 (Avenue 144) – minor arterial
- SR 155 (Garces Highway) – major collector

Temporary impacts would include the use of temporary detours for all modes of transportation during canal enlargement. Permanent impacts would occur if bridges are not replaced. Regional traffic circulation patterns would be forced to operate within the limited east/west crossing options, which could result in safety and maintenance hazards. It should be anticipated that important highway crossings such as these would require full bridge replacement.

- Costs to replace bridge crossings should be considered in the context of anticipated increased maintenance costs for roads subjected to increased traffic volumes and concentrated use by various vehicle weight classes.
- Although no permanent removal of bridge crossings is anticipated under Alternative 4B, if permanent removal does occur, it would directly affect traffic circulation patterns and agricultural operations by removing through access.
- Up to four designated FTM routes in Tulare County—Avenue 192, Avenue 128, Avenue 96, and County Line Road—could be affected by temporary road closures during construction.
- SRs 65 and 155 are state highway accessible bikeways. Impacts on crossings of the FKC could affect bicycle transit but the impact is anticipated to be temporary (if bridge work is required) and alternate routes would be available.
- Pedestrian use of roads included in the Alternative 4B alignment is likely infrequent given the region's rural nature and dispersed population. Some temporary and permanent pedestrian inconvenience could occur under this alternative.

- Considerations of the potential effects of temporary and permanent road closures on emergency response vehicle access through the project area will be required.

- County and regional transportation plans will need to be reviewed and consistency determinations made in the project's environmental document for this proposed alternative.

- A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended.

It is anticipated that any project-related roadway construction implemented under Alternative 4B will be consistent with County and regional transportation plans. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Because Alternative 4B would potentially have one of the greatest impacts on state and county roads of the project alternatives (although no impact on farm roads) and fewer impacts on area roads than Alternative 4A, the potential for conflicts with existing plans and established levels of effectiveness would be high. Alternative 4B is assigned a rank of 1.1 (high) for its potential to conflict with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation.

The magnitude of potential impacts on transportation and circulation under Alternative 4B would be one of the highest of the project alternatives, but not quite as high as Alternative 4A. Under Alternative 4B the total number of bridge replacements and new bridge construction required would be 24. In comparison, Alternative 4A would require a total of 18 replacements and new construction. Although road closures during construction would be temporary, the number of roads impacted by project construction at any given time could be significant. Temporary closure of bridge crossings and roads during construction would affect traffic circulation, including emergency vehicles, agricultural equipment access, bicycles, pedestrian use, and designated FTM routes despite the County's network of available detours. Many detours would be lengthy. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 4B is assigned a rank of 1.1 (high) for potential impacts on traffic circulation patterns because of possible modifications to existing bridges and routes.

Alternative 5A: Parallel Bypass Canal from Tule River to White River

Under Alternative 5A, enlarging the canal between MP 88.2 and MP 95.7, and MP 112.9 and MP 121.5, and construction of a parallel canal bypass between MP 95.7 and MP 112.9 (i.e., Tule River to White River) would require the replacement of 2 state or county road bridges and 2 farm bridges, and new construction of 16 bridges. This alternative includes transitioning the segments of newly enlarged canal back to their existing width at some bridge crossings. Thus, 44 existing bridges would be unaffected by the canal enlargement. In addition to the numerous local roads, depending on the final project design, the following major and minor regional roads may be

impacted by canal enlargement or construction of the parallel bypass canal proposed under Alternative 5A:

- SR 65 – a major regional arterial
- Avenue 196 H-20 (Tulare County Road J28 or Frazier Highway) – major collector
- Avenue 152 (Olive Avenue) – major collector
- Avenue 96 (Tulare County Road J24 or East Terra Bella Avenue) – major collector
- Avenue 56 (Tulare County Road J22 or Ducor Highway) – major collector
- State Highway 190 (Avenue 144) – minor arterial
- SR 155 (Garces Highway) – major collector

Temporary impacts would include the use of temporary detours for all modes of transportation during canal enlargement. Permanent impacts would occur if bridges are not replaced. Regional traffic circulation patterns would be forced to operate within the limited east/west crossing options, which could result in safety and maintenance hazards. It should be anticipated that important highway crossings such as these would require full bridge replacement.

- Costs to replace bridge crossings should be considered in the context of anticipated increased maintenance costs for roads subjected to increased traffic volumes and concentrated use by various vehicle weight classes.
- Although no permanent removal of bridge crossings is anticipated under Alternative 5A, if permanent removal does occur, it would directly affect traffic circulation patterns and agricultural operations by removing through access.
- Up to four designated FTM routes in Tulare County—Avenue 192, Avenue 128, Avenue 96, and /County Line Road—could be affected by temporary road closures during construction.
- SRs 65 and 155 are state highway accessible bikeways. Impacts on crossings of the FKC could affect bicycle transit but the impact is anticipated to be temporary (if bridge work is required) and alternate routes would be available.
- Pedestrian use of roads included in the Alternative 5A alignment is likely infrequent given the region's rural nature and dispersed population. Some temporary and permanent pedestrian inconvenience could occur under this alternative.

- Considerations of the potential effects of temporary and permanent road closures on emergency response vehicle access through the project area will be required.

- County and regional transportation plans will need to be reviewed and consistency determinations made in the project's environmental document for this proposed alternative.

- A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended.

It is anticipated that any project-related roadway construction implemented under Alternative 5A will be consistent with County and regional transportation plans. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Because Alternative 5A would potentially have one of the greatest impacts on state, county, and farm roads of the project alternatives, although in a more concise area (i.e., immediately adjacent to the existing FKC alignment) than Alternatives 4A and 4B, the potential for conflicts with existing plans and established levels of effectiveness would be high but slightly less. Alternative 5A is assigned a rank of 3.1 (moderate) for its potential to conflict with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation.

The magnitude of potential impacts on transportation and circulation under Alternative 5A would be high. Alternative 5A would require a similar total number of bridge replacements (both roadway and agricultural access bridges) and new bridge construction to create crossings over the bypass canal as Alternative 4A but would affect slightly less total area than other off-canal project alternatives. Temporary closure of bridge crossings and roads during construction would affect traffic circulation, including emergency vehicles, agricultural equipment access, bicycles, pedestrian use, and designated FTM routes despite the County's network of available detours. Many detours would be lengthy. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 5A is assigned a rank of 3.2 (moderate) for potential impacts on traffic circulation patterns because of possible modifications to existing bridges and routes.

Alternative 5B: Parallel Bypass Canal from Tule River to Lake Woollomes

- Under Alternative 5B, enlarging the canal between MP 88.2 and MP 95.7, and MP 119.5 and MP 121.5, and construction of a parallel canal bypass between MP 95.7 and MP 119.5 (i.e., Tule River to Lake Woollomes) would require the replacement of 1 state or county road bridge and 1 farm bridge and new construction of 23 bridges. This alternative includes transitioning the segments of newly widened canal back to their existing width at some bridge crossings. Thus, 46 existing bridges would be unaffected by the canal widening. In addition to the numerous local roads, depending on the final

project design, the following major and minor regional roads may be impacted by canal enlargement or construction of the parallel bypass canal proposed under Alternative 5B:

- SR 65 – a major regional arterial
- Avenue 196 H-20 (Tulare County Road J28 or Frazier Highway) – major collector
- Avenue 152 (Olive Avenue) – major collector
- Avenue 96 (Tulare County Road J24 or East Terra Bella Avenue) – major collector
- Avenue 56 (Tulare County Road J22 or Ducor Highway) – major collector
- State Highway 190 (Avenue 144) – minor arterial
- SR 155 (Garces Highway) – major collector

Temporary impacts would include the use of temporary detours for all modes of transportation during canal enlargement. Permanent impacts would occur if bridges are not replaced. Regional traffic circulation patterns would be forced to operate within the limited east/west crossing options, which could result in safety and maintenance hazards. It should be anticipated that important highway crossings such as these would require full bridge replacement.

- Costs to replace bridge crossings should be considered in the context of anticipated increased maintenance costs for roads subjected to increased traffic volumes and concentrated use by various vehicle weight classes.
- Although no permanent removal of bridge crossings is anticipated under Alternative 5B, if permanent removal does occur, it would directly affect traffic circulation patterns and agricultural operations by removing through access.
- Up to four designated FTM routes in Tulare County—Avenue 192, Avenue 128, Avenue 96, and County Line Road—could be affected by temporary road closures during construction.
- SRs 65 and 155 are state highway accessible bikeways. Impacts on crossings of the FKC could affect bicycle transit but the impact is anticipated to be temporary (if bridge work is required) and alternate routes would be available.
- Pedestrian use of roads included in the Alternative 5B alignment is likely infrequent given the region's rural nature and dispersed population. Some temporary and permanent pedestrian inconvenience could occur under this alternative.

- Considerations of the potential effects of temporary and permanent road closures on emergency response vehicle access through the project area will be required.

- County and regional transportation plans will need to be reviewed and consistency determinations made in the project's environmental document for this proposed alternative.

- A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended.

- Because Alternative 5B would involve more extensive canal enlargement than Alternative 5A, it should be assumed that although similar in nature, the constraints described under Alternative 5B would be quantitatively greater.

It is anticipated that any project-related roadway construction implemented under Alternative 5B will be consistent with County and regional transportation plans. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 5B would potentially have one of the lesser total impacts on state roads but a higher level of total impact on county roads (and no impact on farm roads) and would be constructed in a more concise area (i.e., immediately adjacent to the existing FKC alignment) than Alternatives 4A and 4B, the potential for conflicts with existing plans and established levels of effectiveness would be moderate. Alternative 5B is assigned a rank of 4.1 (moderately low) for its potential to conflict with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation.

The magnitude of potential impacts on transportation and circulation under Alternative 5B would be high but would affect slightly fewer area roads than other off-canal project alternatives. Temporary closure of bridge crossings and roads during construction would affect traffic circulation, including emergency vehicles, agricultural equipment access, bicycles, pedestrian use, and designated FTM routes despite the County's network of available detours. Many detours would be lengthy. A traffic study that fully assesses the LOS of affected roads, traffic circulation patterns, and the proposed alternative's impacts on these roads is recommended. Alternative 5B is assigned a rank of 3.1 (moderate) for potential impacts on traffic circulation patterns because of possible modifications to existing bridges and routes.

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Chapter 6.
Additional Information Required

Additional information needed to further evaluate and contrast the alternatives in terms of environmental constraints and regulatory requirements is summarized in Table 4 below.

Table 4. Information Needs to Further Evaluate Alternatives

Environmental Resource	Data Needs
General	For Alternative 2 and 3, need power alignment. For canal enlargement, need to determine which specific bridges need to be replaced and which will remain intact. For Alternative 1, confirm that no new permanent right-of-way is needed or provide detail on new permanent right-of-way. For the alternatives that have bypasses, what is planned for the existing canal in the reaches where a bypass will be constructed?
Air Quality	The following are needed for each alternative: • Construction equipment quantities and hours of operation. • Soil quantities for import/export. • Acreage of soil disturbance impacts. • Construction worker numbers. • Soil hauling truck trips (can be estimated using 20 cubic yards per trip if quantities are provided). • Types of impacts made to bridges.
Biological Resources	Description for construction of siphons for the bypass canal alternatives. Discussion of how canal enlargement and bypass construction would be sequenced. Is it practicable to incorporate burrow replacement (e.g., artificial dens) into project design? How will dewatering be addressed during the construction of canal enlargement and bypass tie-in? What is the timeline of construction? Is there a certain time of year work must occur due to water delivery to farmers? Will there be phases? How long is it anticipated to take? What is the plan for demolition of bridges? Will it take place while the canal has water present?

Table 4. Information Needs to Further Evaluate Alternatives

Environmental Resource	Data Needs
Cultural Resources	What will be the depth of excavation at MP 109 and Woollomes surge reservoirs? What are depths of excavation for the bypass canal alternatives? Need to confirm number of bridges replaced under each alternative and identify the specific bridges. For the parallel and bypass alternatives where will the soil be sourced? Will the embankment soil come solely from excavations in the footprint, or will it be sourced from an alternate location and if so, where? For the pump locations of Alternative 2 and 3, where will the electricity come from? Will it require additional electrical connections? If so, these routes will need to be identified. Aside from the bridges, what other features of the canal infrastructure will be altered? Will river crossing infrastructure or gates be modified? Will the alternatives require reconstruction of irrigation laterals or intakes? Will the canal be enlarged its entire length for Alternatives 5A and 5B? Or just one side of the canal?
Land Use and Agricultural Resources	Need a description of what will occur in the areas identified for surge reservoirs associated with pump station alternatives. How often will inundation occur and for how long. Will these areas be permanently set-aside and no other use will occur, or would other uses be accommodated? One of them includes a residence. The surge reservoir footprints do not seem to be include in the right-of-way needed for Alternatives 2 and 3. Should they be included in the total impacted acreage needed for the project?
Transportation and Circulation	The table provided that identifies number of replaced and retained bridges under the alternatives needs to be updated. Some of the bridges do not seem to be accounted for in the table. Analysis in this memorandum used the vales in the table provided. Kmz file that includes the bridge crossings labeled by type (e.g., road vs farm).

Chapter 7. Summary

A summary of the environmental constraints metrics rankings for Alternatives 1–5B is provided in Table 5 below.

Table 5. Summary of Environmental Constraints Metrics Rankings by Alternative

Environmental Constraints and Regulatory Permits/Approvals**	Alternative 1	Alternative 2	Alternative 3	Alternative 4A	Alternative 4B	Alternative 5A	Alternative 5B
Air Quality							
Exceedances of SJVAPCD Thresholds and GC Thresholds	1.2	1.1	1.2	1.2	1.2	1.3	1.3
Biological Resources							
Impacts on federal- and state-listed species	1.1	1.2	1.4	1.6	1.7	1.3	1.5
Impacts on wetlands/waters of the U.S./riparian habitat	5.1	5.1	3.1	1.2	1.1	1.3	1.3
Cultural Resources							
Number and presence of known resources and areas of high sensitivity for the presence of resources	1.3	1.1	1.2	3.1	3.2	1.5	1.4
Level of effort and analysis required to complete the resource management process through the mitigation phase	1.3	1.1	1.2	3.1	3.2	1.5	1.4
Level of effort required to document resources and the resulting effect, or potential effect, on project schedule	1.3	1.1	1.2	3.1	3.2	1.5	1.4
Land Use and Agricultural Resources							
Potential for encroachment onto important farmlands, including Williamson Act lands	3.3	1.3	1.2	1.4	1.1	3.2	3.1
Potential for agricultural and land use impacts as a result of road crossing modifications	3.3	1.1	1.2	2.1	1.3	3.2	3.1
Potential for land use zoning changes	3.3	1.3	1.2	1.4	1.1	3.2	3.1

Environmental Constraints and Regulatory Permits/Approvals**	Alternative 1	Alternative 2	Alternative 3	Alternative 4A	Alternative 4B	Alternative 5A	Alternative 5B
Transportation and Circulation							
Potential conflicts with an applicable traffic congestion management program, ordinance, or policy establishing measures of effectiveness for area roads, considering all modes of transportation	5.2	5.1	2.1	4.2	1.1	3.1	4.1
Potential for traffic circulation impacts, including impacts on agricultural-related traffic and emergency vehicle access, due to possible modifications of existing bridges and routes	3.4	5.1	1.2	3.3	1.1	3.2	3.1
Note** Assessment Value: 1 = High; 2 = Moderately High; 3 = Moderate; 4 = Moderately Low; 5 = Low							

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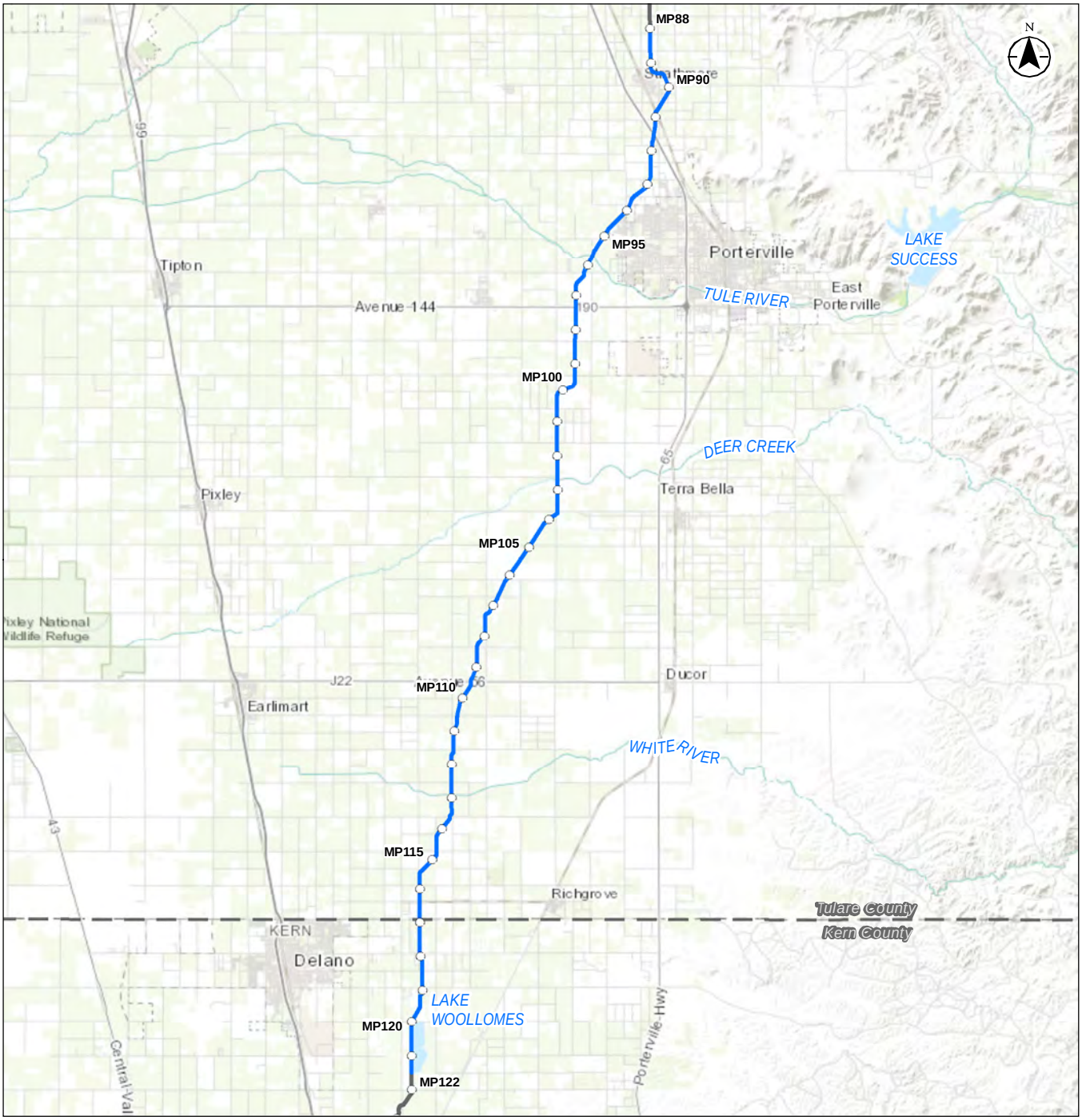
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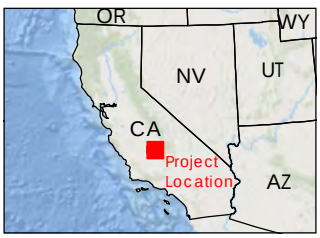
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APPENDIX A

Figures

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Legend

- Existing Canal
- Canal Mile Posts

Alternative 1

- Canal Enlargement (MPs 88.2-121.5)

0 4 8 Miles

1 inch = 4.5 miles (At page size of 8.5"x11")

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FRIANT WATER AUTHORITY

Project Location
Tulare and Kern Counties, California

184031016 REVA
Prepared by NE on 2018-09-12

Client/Project
Friant Water Authority
Friant-Kern Canal Capacity Correction Project

Figure No.
3-1

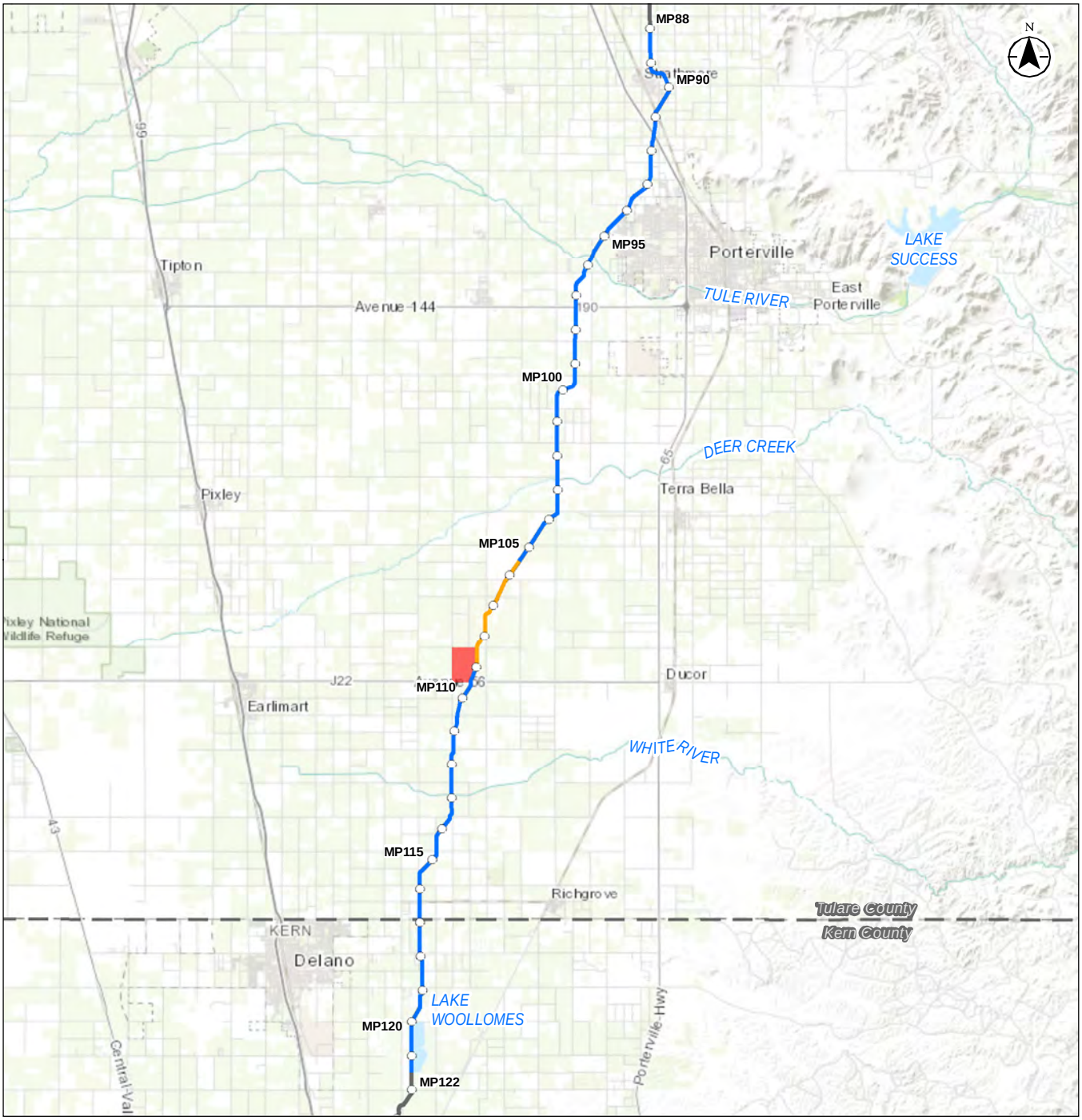
Alternative 1 – Canal Enlargement

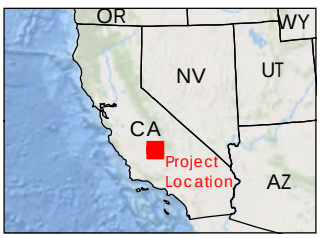
Title
Friant-Kern Canal Middle Rach Subsidence and Capacity Correction Project
Preliminary Constraints Analysis

Notes
1. Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
2. Base map: ESRI World Topo Map web mapping service

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Legend

- Existing Canal
- Canal Mile Posts

Alternative 2

- Canal Enlargment (MPs 88.2-105.5 and 108.7-121.5)
- No Modifications (MPs 105.5-108.7)
- Pump Station/Surge Reservoir (MP 109)

0 4 8 Miles

1 inch = 4.5 miles (At page size of 8.5"x11")

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FRIANT WATER AUTHORITY

Project Location
Tulare and Kern Counties, California

184031016 REVA
Prepared by NE on 2018-09-12

Client/Project
Friant Water Authority
Friant-Kern Canal Capacity Correction Project

Figure No.
3-2

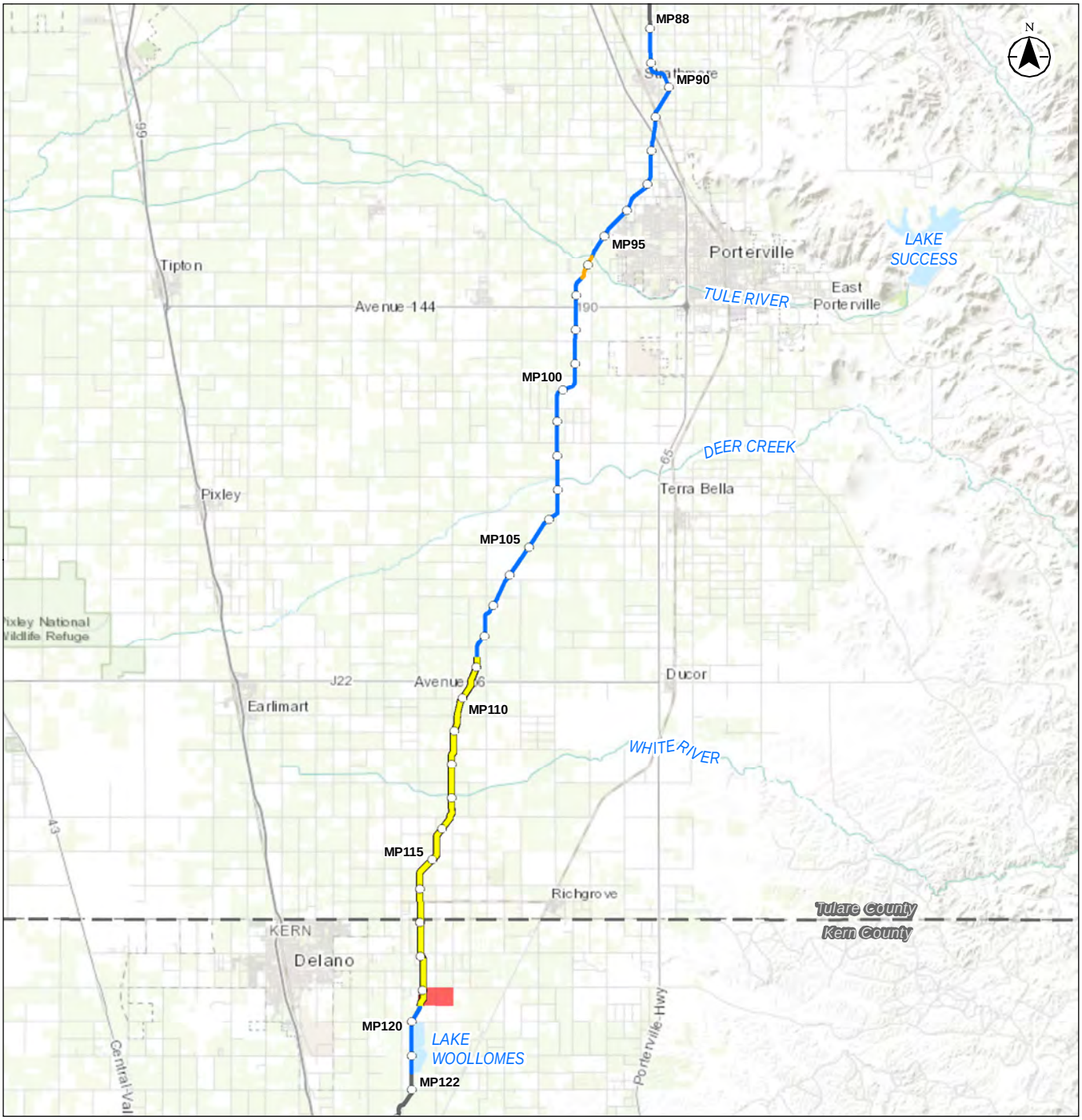
Alternative 2 – Pump Station at MP 109

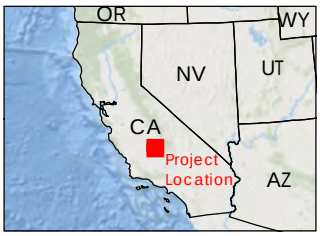
Title
Friant-Kern Canal Middle Rach Subsidence and Capacity Correction Project
Preliminary Constraints Analysis

Notes
1. Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
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Legend

- Existing Canal
- Canal Mile Posts

Alternative 3

- No Modifications (MPs 95.7-96.4)
- Canal Enlargement (MPs 88.2-95.7, 96.4-108.7, and 119.5-121.5)
- Full Capacity Bypass to Lake Woollomes (MPs 108.7-119.5)
- Pump Station/Surge Reservoir (MP 119.5)

0 4 8 Miles

1 inch = 4.5 miles (At page size of 8.5"x11")

Stantec

FRIANT WATER AUTHORITY

Project Location
Tulare and Kern Counties, California

184031016 REVA
Prepared by NE on 2018-09-12

Client/Project
Friant Water Authority
Friant-Kern Canal Capacity Correction Project

Figure No.
3-3

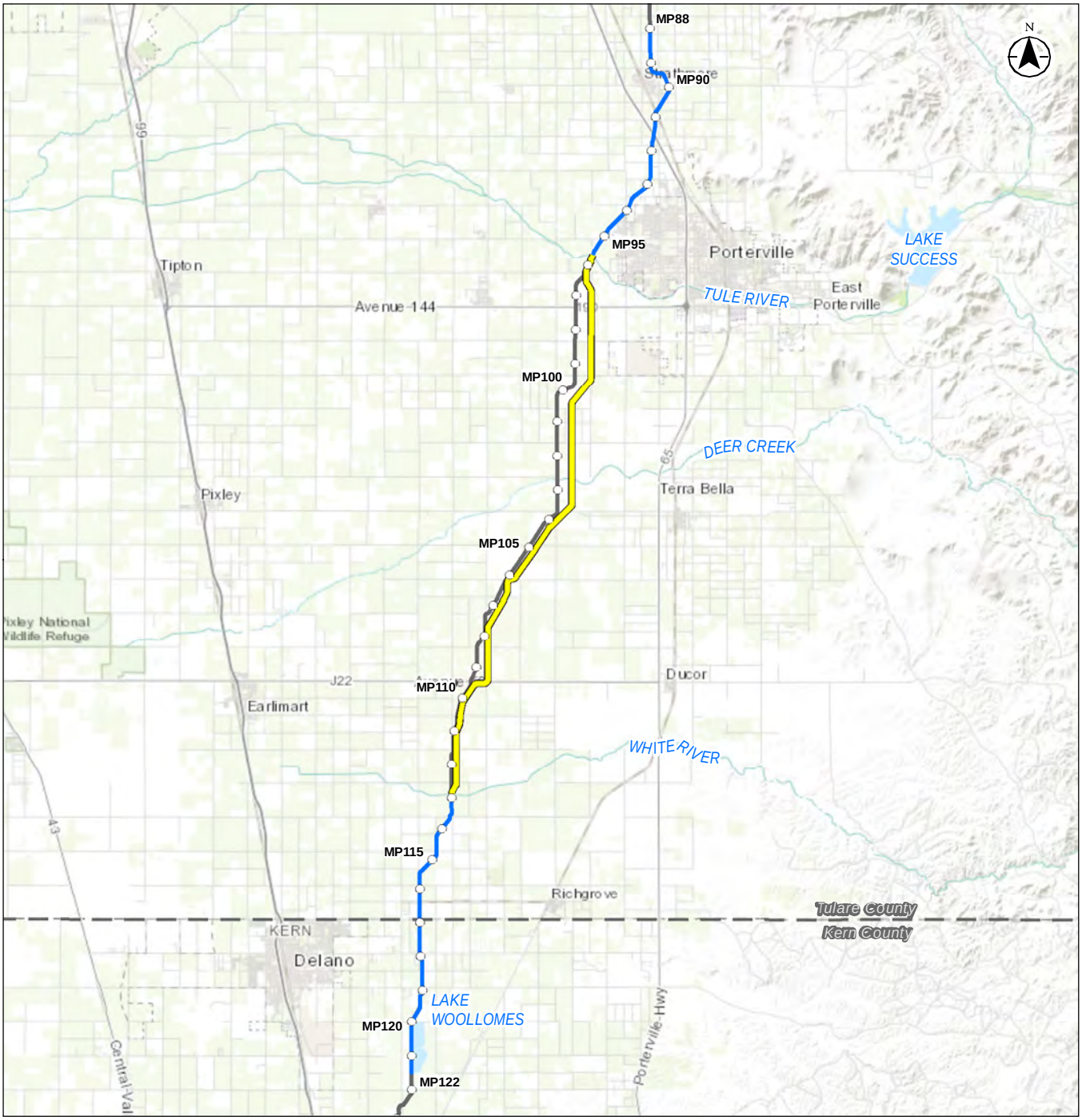
Alternative 3 – Woollomes Pump Station

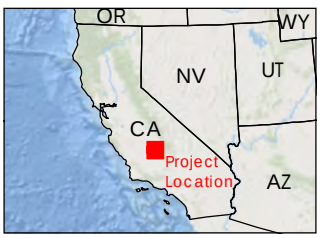
Title
Friant-Kern Canal Middle Rach Subsidence and Capacity Correction Project
Preliminary Constraints Analysis

Notes
1. Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
2. Base map: ESRI World Topo Map web mapping service

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Legend

- Existing Canal
- Canal Mile Posts

Alternative 4A

- Canal Enlargment (MPs 88.2-95.7 and 112.9-121.5)
- Bypass Tule River to White River (MPs 95.7-112.9)

0 4 8 Miles

1 inch = 4.5 miles (At page size of 8.5"x11")

Stantec

FRIANT WATER AUTHORITY

Project Location
Tulare and Kern Counties, California

184031016 REVA
Prepared by NE on 2018-09-12

Client/Project
Friant Water Authority
Friant-Kern Canal Capacity Correction Project

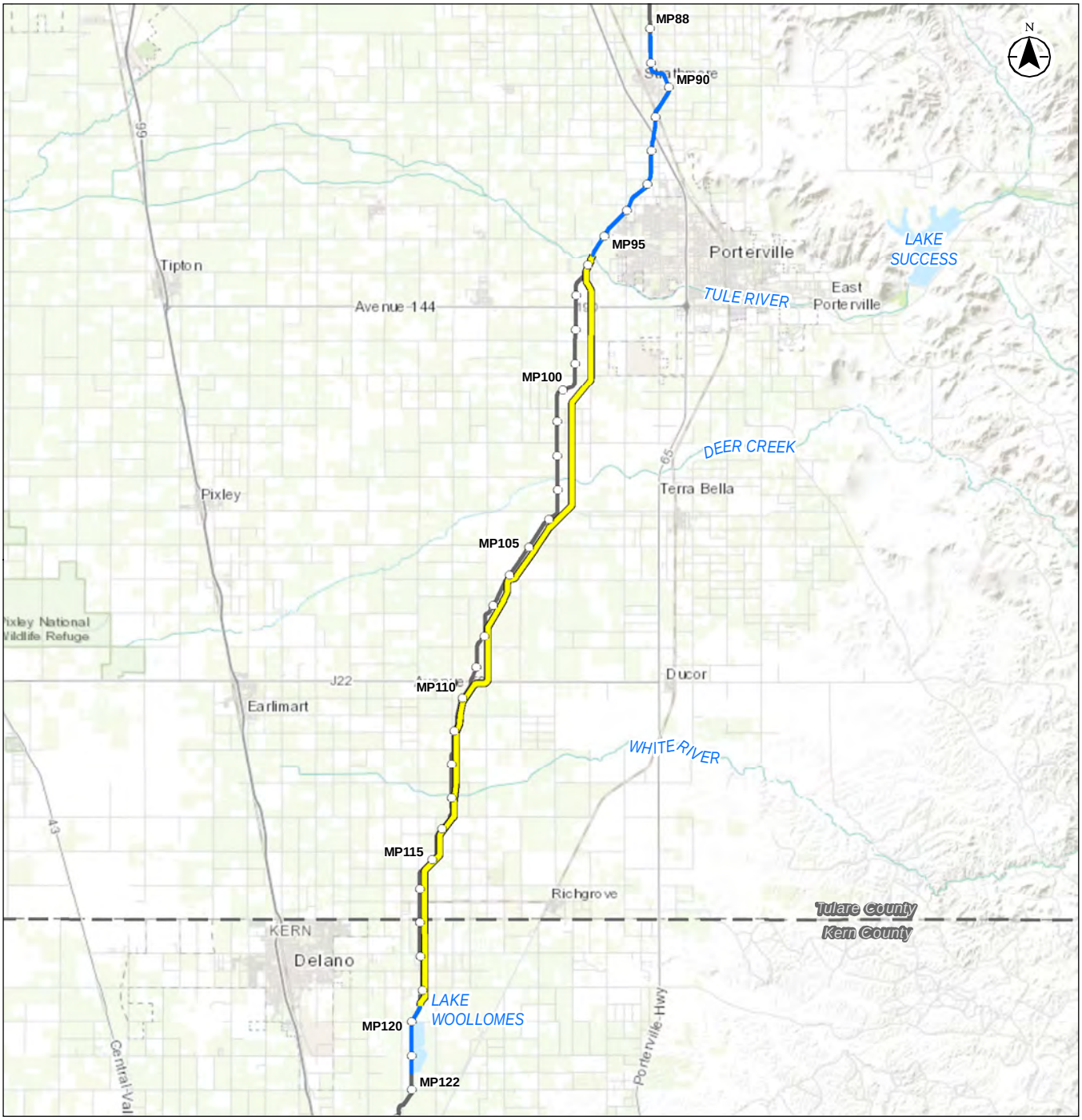
Figure No.
3-4
Alternative 4A – Offset Bypass Canal from Tule River to White River

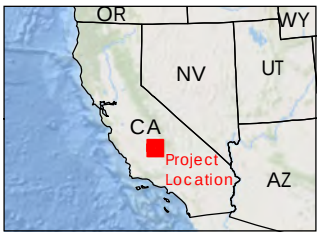
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Friant-Kern Canal Middle Rach Subsidence and Capacity Correction Project
Preliminary Constraints Analysis

Notes
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Legend

- Existing Canal
- Canal Mile Posts

Alternative 4B

- Canal Enlargement (MPs 88.2-95.7 and 119.5-121.5)
- Full Capacity Bypass Tule River to Lake Woollomes (MPs 95.7-119.5)

0 4 8 Miles

1 inch = 4.5 miles (At page size of 8.5"x11")

Stantec

FRIANT WATER AUTHORITY

Project Location
Tulare and Kern Counties, California

184031016 REVA
Prepared by NE on 2018-09-12

Client/Project
Friant Water Authority
Friant-Kern Canal Capacity Correction Project

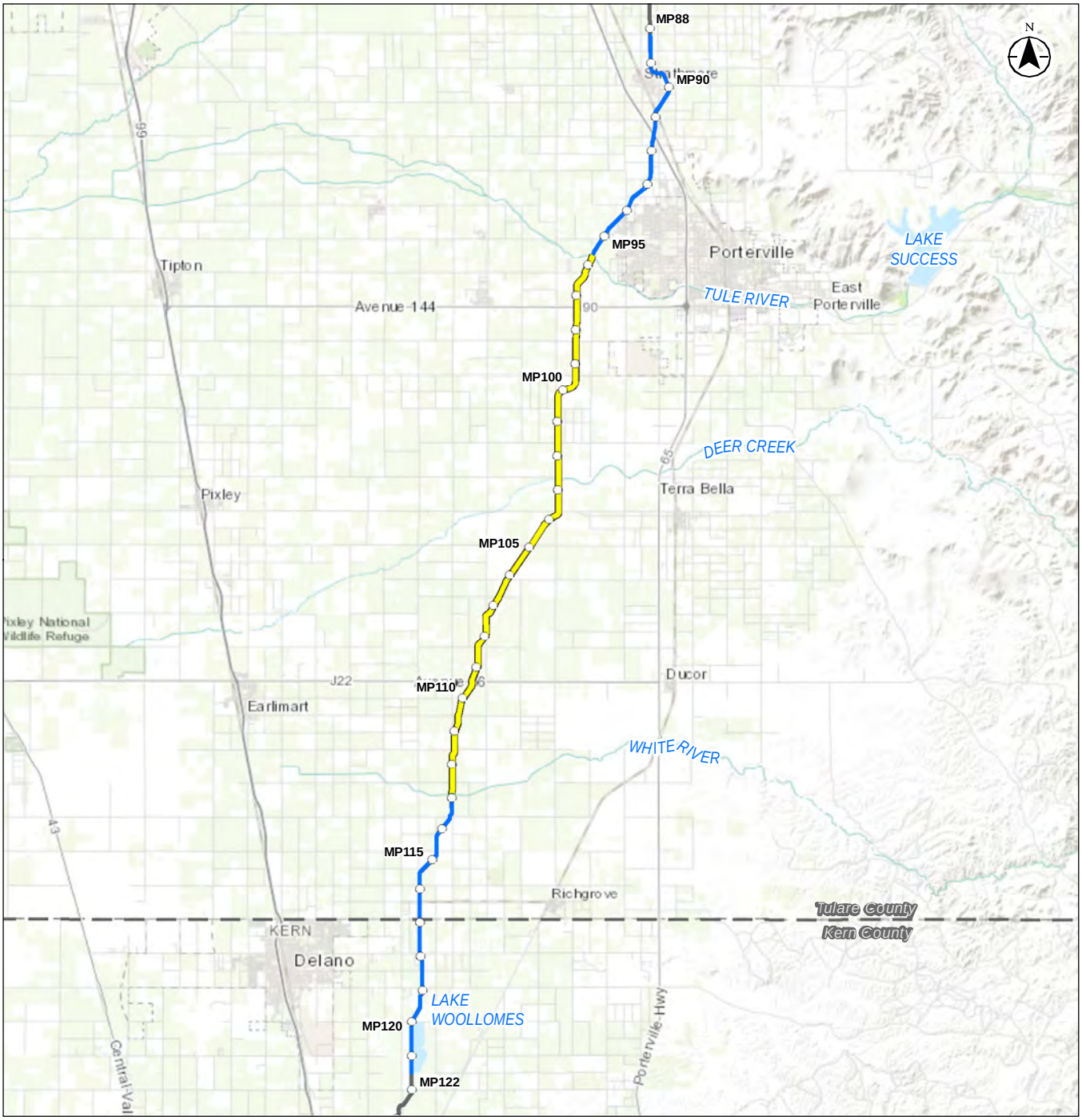
Figure No.
3-5
Alternative 4B -Offset Bypass Canal from Tule River to Lake Woollomes

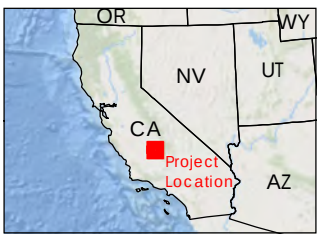
Title
Friant-Kern Canal Middle Rach Subsidence and Capacity Correction Project
Preliminary Constraints Analysis

Notes
1. Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
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Legend

- Existing Canal
- Canal Mile Posts

Alternative 5A

- Canal Enlargment (MPs 88.2-95.7 and 112.9-121.5)
- Parallel Bypass Tule River to White River (MPs 95.7-112.9)

0 4 8 Miles

1 inch = 4.5 miles (At page size of 8.5"x11")

Stantec

FRIANT WATER AUTHORITY

Project Location
Tulare and Kern Counties, California

184031016 REVA
Prepared by NE on 2018-09-12

Client/Project
Friant Water Authority
Friant-Kern Canal Capacity Correction Project

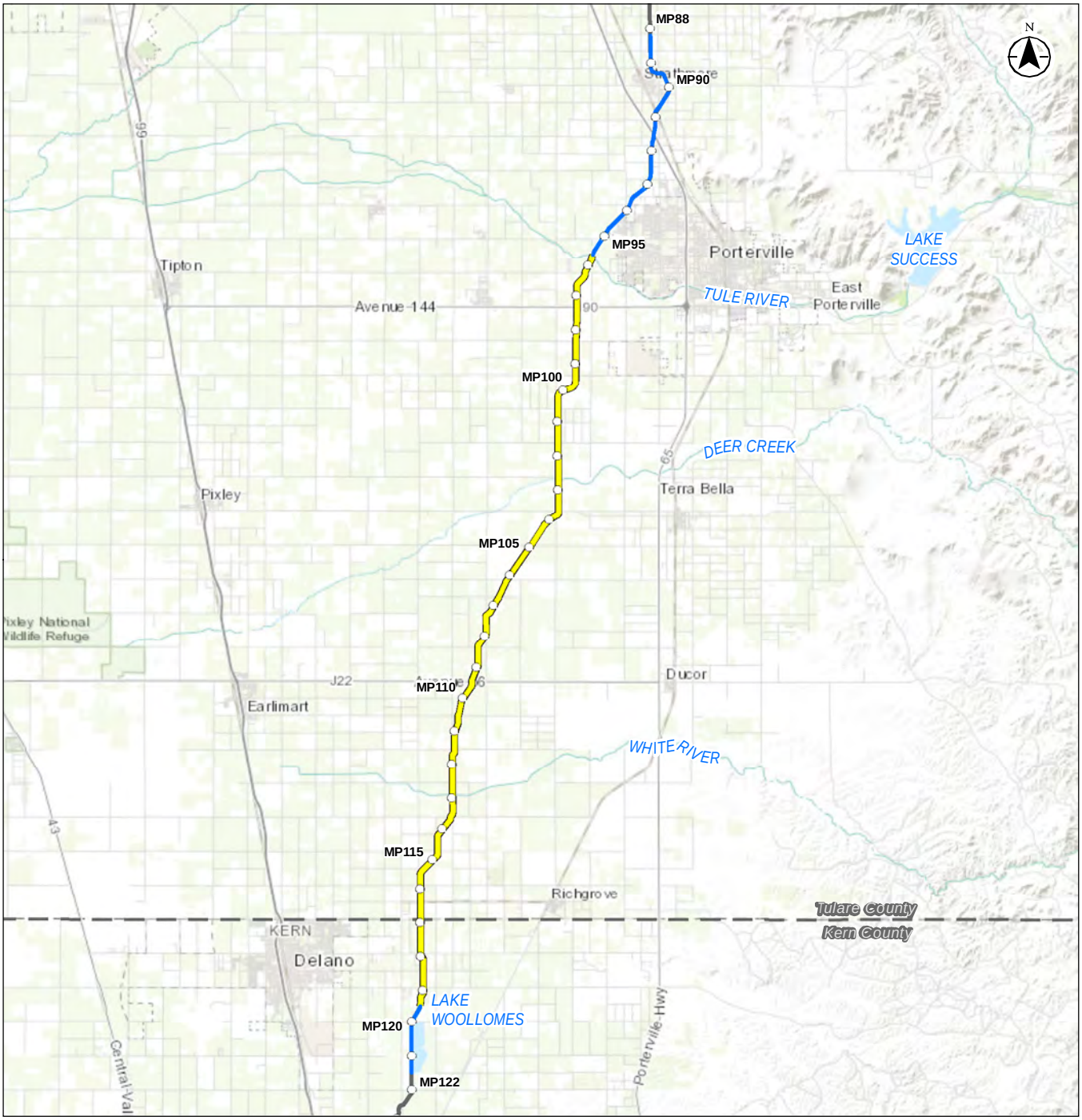
Figure No.
3-6
Alternative 5A - Parallel Bypass Canal from Tule River to White River

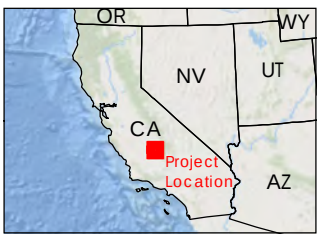
Title
Friant-Kern Canal Middle Rach Subsidence and Capacity Correction Project
Preliminary Constraints Analysis

Notes
1. Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
2. Base map: ESRI World Topo Map web mapping service

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Legend

- Existing Canal
- Canal Mile Posts

Alternative 5B

- Canal Enlargment (MPs 88.2-95.7 and 119.5-121.5)
- Parallel Bypass Canal Tule River to Lake Woollomes (MPs 95.7-119.5)

0 4 8 Miles

1 inch = 4.5 miles (At page size of 8.5"x11")

Notes
1. Coordinate System: NAD 1983 StatePlane California IV FIPS 0404 Feet
2. Base map: ESRI World Topo Map web mapping service

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Stantec

FRIANT WATER AUTHORITY

Project Location
Tulare and Kern Counties, California

184031016 REVA
Prepared by NE on 2018-09-12

Client/Project
Friant Water Authority
Friant-Kern Canal Capacity Correction Project

Figure No.
3-7
Alternative 5B - Parallel Bypass Canal from Tule River to Lake Woollomes

Title
Friant-Kern Canal Middle Rach Subsidence and Capacity Correction Project
Preliminary Constraints Analysis

APPENDIX B

Air Quality Modeling Assumptions

Air Quality Assumptions

The following assumptions were used in the California Emissions Estimator Model (CalEEMod) version 2016.3.2 and the Sacramento Metropolitan Air Quality Management District Roadway Model version 9.0 (approved by the San Joaquin Valley Air Pollution Control District).

Table 1: Construction Quantities

Item	Unit	Alternative 1	Alternative 2	Alternative 3	Alternative 4A	Alternative 4B	Alternative 5A	Alternative 5B
Clearing and grubbing	AC	161	97	0	0	0	0	346
Excavation	CY	3,709,002	4,883,336	5,085,172	5,412,645	6,173,621	4,335,338	4,871,372
Embankment construction	CY	5,259,535	6,439,178	4,140,544	3,663,231	3,756,076	4,420,056	4,459,047
Trimming	SY	1,685,073	1,501,777	1,583,466	1,915,121	1,963,383	1,900,684	1,950,193
3-1/2" thick conrete lining	SY	1,685,073	1,501,777	1,583,466	1,915,121	1,963,383	1,900,684	1,950,193
Furnish and Place Transverse Canal Joints	LF	1,011,044	901,066	950,080	1,149,072	1,178,030	1,140,410	1,170,116
Furnish and Place Longitudinal Canal Joints	LF	1,305,752	1,164,336	1,166,144	1,322,096	1,318,839	1,311,120	1,310,618
Ladders	EA	469	417	389	441	442	442	440
Aggregate base O&M road surfacing	SY	468,864	389,496	418,083	466,101	478,976	471,179	468,565
Check Structure	EA	3	2	2	3	3	1	1
Canal Transitions to Existing Bridges	EA	24	24	17	26	17	26	17
New Bridge Construction On Bypass Canals	EA	0	0	20	20	28	20	28

Table 1: Construction Quantities - continued

Item	Unit	Alternative 1	Alternative 2	Alternative 3	Alternative 4A	Alternative 4B	Alternative 5A	Alternative 5B
Bridge Replacement - County or State Bridges	EA	17	7	2	12	1	12	1
Bridge Replacement - Farm Bridges	EA	4	2	18	2	0	2	0
Canal Transitions to Existing Turnouts	EA	39	24	11	32	11	32	11
Permanent Land Acquisition (R.O.W.)	AC	170	116	223	566	650	380	386

Notes:
AC = acres
EA = each
LF = linear feet
SY = square yards
Source: Stantec, October 2, 2018

Table 2: Construction Schedule Assumptions

Alternative	Assumptions
1	48 months of construction. Assumed excavated soil would be reused for embankment construction and any deficits would need to be imported. Assumed excavated soil would be reused for embankment construction and any deficit would need to be imported.
2	48 months of construction. Assumed excavated soil would be reused for embankment construction Assumed excavated soil would be reused for embankment construction and any deficit would need to be imported.
3	48 months of construction. Assumed excavated soil would be reused for embankment construction Assumed excavated soil would be reused for embankment construction and any surplus would need to be exported.
4A	48 months of construction. Assumed excavated soil would be reused for embankment construction

	Assumed excavated soil would be reused for embankment construction and any surplus would need to be exported.
4B	48 months of construction. Assumed excavated soil would be reused for embankment construction Assumed excavated soil would be reused for embankment construction and any surplus would need to be exported.
5A	48 months of construction. Assumed excavated soil would be reused for embankment construction Assumed excavated soil would be reused for embankment construction and any surplus would need to be exported.
5B	48 months of construction. Assumed excavated soil would be reused for embankment construction Assumed excavated soil would be reused for embankment construction and any surplus would need to be exported.
Notes: 20 cubic yards of soil per truckload CalEEMod land use category – User Defined Industrial was used in the model because CalEEMod does not have a land use category for this type of project. The land use category does not impact the construction emissions, those are determined by the estimated soil movement and equipment usage.	

Preliminary Modeling Results

CalEEMod Version: CalEEMod.2016.3.2

 Date: 10/19/2018 10:32 AM

FKC - Alternative 1 - San Joaquin Valley Unified APCD Air District, Annual

FKC - Alternative 1

San Joaquin Valley Unified APCD Air District, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
User Defined Industrial	61.00	User Defined Unit	161.00	0.00	0

1.2 Other Project Characteristics

Urbanization	Urban	**Wind Speed (m/s)**	2.7	**Precipitation Freq (Days)**	45
Climate Zone	3			**Operational Year**	2020
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - Total acreage cleared and grubbed

Construction Phase - 4 years of construction

Off-road Equipment - est

Off-road Equipment - est

Trips and VMT - est

Grading - est

Construction Off-road Equipment Mitigation -

Table Name	Column Name	Default Value	New Value
tblConstDustMitigation	WaterUnpavedRoadMoistureContent	0	6.1

tblConstDustMitigation	WaterUnpavedRoadVehicleSpeed	0	15
tblConstructionPhase	NumDays	310.00	1,056.00
tblGrading	AcresOfGrading	15,840.00	161.00
tblGrading	MaterialExported	0.00	3,709,002.00
tblGrading	MaterialImported	0.00	1,550,533.00
tblLandUse	LotAcreage	0.00	161.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblTripsAndVMT	HaulingTripLength	20.00	40.00
tblTripsAndVMT	HaulingTripNumber	657,441.00	525,954.00
tblTripsAndVMT	WorkerTripLength	10.80	40.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9634	43.6432	18.2029	0.0887	12.4634	1.2011	13.6644	4.4660	1.1076	5.5736	0.0000	8,217.2528	8,217.2528	1.0330	0.0000	8,243.0772
2021	4.7468	68.2451	29.7332	0.1491	16.1115	1.8732	17.9847	6.3725	1.7272	8.0997	0.0000	13,802.5774	13,802.5774	1.7393	0.0000	13,846.0609
2022	4.1338	58.5475	27.8153	0.1472	16.0775	1.5334	17.6109	6.3547	1.4140	7.7686	0.0000	13,621.3043	13,621.3043	1.7215	0.0000	13,664.3425
2023	3.5566	45.4691	26.0915	0.1439	16.0776	1.2695	17.3471	6.3547	1.1692	7.5239	0.0000	13,313.2357	13,313.2357	1.6349	0.0000	13,354.1082
2024	1.6112	20.1878	11.9728	0.0666	11.3384	0.5589	11.8973	3.8781	0.5148	4.3929	0.0000	6,162.2783	6,162.2783	0.7614	0.0000	6,181.3123
Maximum	**4.7468**	**68.2451**	**29.7332**	**0.1491**	**16.1115**	**1.8732**	**17.9847**	**6.3725**	**1.7272**	**8.0997**	**0.0000**	**13,802.5774**	**13,802.5774**	**1.7393**	**0.0000**	**13,846.0609**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9634	43.6431	18.2028	0.0887	9.6526	1.2011	10.8537	3.0267	1.1076	4.1343	0.0000	8,217.2497	8,217.2497	1.0330	0.0000	8,243.0741
2021	4.7468	68.2451	29.7331	0.1491	11.5287	1.8732	13.4019	3.9591	1.7272	5.6863	0.0000	13,802.5721	13,802.5721	1.7393	0.0000	13,846.0556
2022	4.1338	58.5475	27.8152	0.1472	11.5113	1.5334	13.0447	3.9505	1.4140	5.3644	0.0000	13,621.2991	13,621.2991	1.7215	0.0000	13,664.3372
2023	3.5566	45.4691	26.0915	0.1439	11.5113	1.2695	12.7809	3.9505	1.1692	5.1197	0.0000	13,313.2305	13,313.2305	1.6349	0.0000	13,354.1029
2024	1.6112	20.1878	11.9728	0.0666	9.0741	0.5589	9.6330	2.7392	0.5148	3.2540	0.0000	6,162.2759	6,162.2759	0.7614	0.0000	6,181.3099
Maximum	**4.7468**	**68.2451**	**29.7331**	**0.1491**	**11.5287**	**1.8732**	**13.4019**	**3.9591**	**1.7272**	**5.6863**	**0.0000**	**13,802.5721**	**13,802.5721**	**1.7393**	**0.0000**	**13,846.0556**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**26.07**	**0.00**	**23.94**	**35.73**	**0.00**	**29.38**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**6-1-2020**	**8-31-2020**	19.6353	19.6353
2	**9-1-2020**	**11-30-2020**	19.6431	19.6431
3	**12-1-2020**	**2-28-2021**	18.5597	18.5597
4	**3-1-2021**	**5-31-2021**	18.2535	18.2535
5	**6-1-2021**	**8-31-2021**	18.1545	18.1545
6	**9-1-2021**	**11-30-2021**	18.1520	18.1520
7	**12-1-2021**	**2-28-2022**	16.4147	16.4147
8	**3-1-2022**	**5-31-2022**	15.7336	15.7336
9	**6-1-2022**	**8-31-2022**	15.6477	15.6477
10	**9-1-2022**	**11-30-2022**	15.6467	15.6467
11	**12-1-2022**	**2-28-2023**	13.3262	13.3262
12	**3-1-2023**	**5-31-2023**	12.3309	12.3309
13	**6-1-2023**	**8-31-2023**	12.2835	12.2835
14	**9-1-2023**	**11-30-2023**	12.2433	12.2433

15	**12-1-2023**	**2-29-2024**	11.9279	11.9279
16	**3-1-2024**	**5-31-2024**	11.7806	11.7806
17	**6-1-2024**	**8-31-2024**	2.1684	2.1684
		Highest	19.6431	19.6431

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Grading	Grading	6/1/2020	6/17/2024	5	1056	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 161

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 0; Non-Residential Outdoor: 0; Striped Parking Area: 0

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Grading	Excavators	10	8.00	158	0.38
Grading	Graders	10	8.00	187	0.41
Grading	Rubber Tired Dozers	10	8.00	247	0.40
Grading	Scrapers	10	8.00	367	0.48
Grading	Tractors/Loaders/Backhoes	10	8.00	97	0.37

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Grading	50	125.00	0.00	525,954.00	40.00	7.30	40.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

Water Exposed Area

Water Unpaved Roads

Reduce Vehicle Speed on Unpaved Roads

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Alternative 1 Project Phases (Pounds)	ROG (lbs/day)	CO (lbs/day)	NOx (lbs/day)	Total PM10 (lbs/day)	Exhaust PM10 (lbs/day)	Fugitive Dust PM10 (lbs/day)	Total PM2.5 (lbs/day)	Exhaust PM2.5 (lbs/day)	Fugitive Dust PM2.5 (lbs/day)	SOx (lbs/day)	CO2 (lbs/day)	CH4 (lbs/day)	N2O (lbs/day)	CO2e (lbs/day)
Grubbing/Land Clearing	1.24	10.52	13.38	20.58	0.58	20.00	4.68	0.52	4.16	0.02	2,237.07	0.59	0.05	2,266.12
Grading/Excavation	9.45	70.78	106.12	24.38	4.38	20.00	8.12	3.96	4.16	0.16	15,555.66	4.70	0.18	15,727.10
Drainage/Utilities/Sub-Grade	5.68	47.90	58.75	22.43	2.43	20.00	6.38	2.22	4.16	0.11	10,557.81	2.73	0.12	10,663.27
Paving	0.99	13.23	9.27	0.48	0.48	0.00	0.42	0.42	0.00	0.02	2,211.63	0.57	0.05	2,239.67
Maximum (pounds/day)	9.45	70.78	106.12	24.38	4.38	20.00	8.12	3.96	4.16	0.16	15,555.66	4.70	0.18	15,727.10
Total (tons/construction project)	3.29	26.01	35.96	10.47	1.49	8.98	3.22	1.35	1.87	0.06	5,661.66	1.62	0.07	5,722.85

Notes:

Project Start Year ->	2020
Project Length (months) ->	48
Total Project Area (acres) ->	25
Maximum Area Disturbed/Day (acres) ->	2
Water Truck Used? ->	Yes

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	280	40
Grading/Excavation	0	0	0	0	1,160	40
Drainage/Utilities/Sub-Grade	0	0	0	0	760	40
Paving	0	0	0	0	360	40

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Alternative 1 Project Phases (Tons for all except CO2e. Metric tonnes for CO2e)	ROG (tons/phase)	CO (tons/phase)	NOx (tons/phase)	Total PM10 (tons/phase)	Exhaust PM10 (tons/phase)	Fugitive Dust PM10 (tons/phase)	Total PM2.5 (tons/phase)	Exhaust PM2.5 (tons/phase)	Fugitive Dust PM2.5 (tons/phase)	SOx (tons/phase)	CO2 (tons/phase)	CH4 (tons/phase)	N2O (tons/phase)	CO2e (MT/phase)
Grubbing/Land Clearing	0.07	0.56	0.71	1.09	0.03	1.06	0.25	0.03	0.22	0.00	118.12	0.03	0.00	108.55
Grading/Excavation	2.25	16.82	25.21	5.79	1.04	4.75	1.93	0.94	0.99	0.04	3,696.02	1.12	0.04	3,389.96
Drainage/Utilities/Sub-Grade	0.90	7.59	9.31	3.55	0.38	3.17	1.01	0.35	0.66	0.02	1,672.36	0.43	0.02	1,532.31
Paving	0.08	1.05	0.73	0.04	0.04	0.00	0.03	0.03	0.00	0.00	175.16	0.05	0.00	160.92
Maximum (tons/phase)	2.25	16.82	25.21	5.79	1.04	4.75	1.93	0.94	0.99	0.04	3696.02	1.12	0.04	3,389.96
Total (tons/construction project)	3.29	26.01	35.96	10.47	1.49	8.98	3.22	1.35	1.87	0.06	5661.66	1.62	0.07	5,191.74

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

CalEEMod Version: CalEEMod.2016.3.2

FKC - Alternative 2 - San Joaquin Valley Unified APCD Air District, Annual

FKC - Alternative 2

San Joaquin Valley Unified APCD Air District, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
User Defined Industrial	97.00	User Defined Unit	97.00	0.00	0

1.2 Other Project Characteristics

Urbanization	Rural	**Wind Speed (m/s)**	2.7	**Precipitation Freq (Days)**	45
Climate Zone	3			**Operational Year**	2025
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - 97 acres cleared and grubbed

Construction Phase - 4 year constuction schedule

Off-road Equipment - est

Trips and VMT - est

Grading - est

Construction Off-road Equipment Mitigation -

Table Name	Column Name	Default Value	New Value
tblConstDustMitigation	WaterUnpavedRoadMoistureContent	0	6.1
tblConstDustMitigation	WaterUnpavedRoadVehicleSpeed	0	15

tblConstructionPhase	NumDays	155.00	1,056.00
tblGrading	AcresOfGrading	15,840.00	97.00
tblGrading	MaterialExported	0.00	4,883,336.00
tblGrading	MaterialImported	0.00	1,555,842.00
tblLandUse	LotAcreage	0.00	97.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblProjectCharacteristics	UrbanizationLevel	Urban	Rural
tblTripsAndVMT	HaulingTripLength	20.00	40.00
tblTripsAndVMT	HaulingTripNumber	804,898.00	643,918.00
tblTripsAndVMT	VendorTripLength	6.60	7.30
tblTripsAndVMT	WorkerTripLength	16.80	40.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	3.0829	47.5516	18.8117	0.1014	14.1018	1.2169	15.3187	4.8733	1.1228	5.9961	0.0000	9,418.4392	9,418.4392	1.0738	0.0000	9,445.2833
2021	4.9370	74.2571	30.7240	0.1702	17.8011	1.8967	19.6979	6.7983	1.7497	8.5480	0.0000	15,813.8267	15,813.8267	1.8062	0.0000	15,858.9814
2022	4.3114	63.9397	28.7652	0.1679	17.7667	1.5531	19.3198	6.7804	1.4328	8.2132	0.0000	15,598.8480	15,598.8480	1.7857	0.0000	15,643.4905
2023	3.6784	48.8929	26.8972	0.1640	17.7667	1.2772	19.0439	6.7804	1.1766	7.9570	0.0000	15,225.0336	15,225.0336	1.6799	0.0000	15,267.0305
2024	1.6674	21.7430	12.3417	0.0759	12.9610	0.5625	13.5235	4.2797	0.5182	4.7978	0.0000	7,046.1214	7,046.1214	0.7825	0.0000	7,065.6846
Maximum	**4.9370**	**74.2571**	**30.7240**	**0.1702**	**17.8011**	**1.8967**	**19.6979**	**6.7983**	**1.7497**	**8.5480**	**0.0000**	**15,813.8267**	**15,813.8267**	**1.8062**	**0.0000**	**15,858.9814**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	3.0829	47.5516	18.8117	0.1014	11.2618	1.2169	12.4787	3.4288	1.1228	4.5516	0.0000	9,418.4361	9,418.4361	1.0738	0.0000	9,445.2802
2021	4.9370	74.2571	30.7240	0.1702	13.1892	1.8967	15.0859	4.3798	1.7497	6.1295	0.0000	15,813.8215	15,813.8215	1.8062	0.0000	15,858.9761
2022	4.3114	63.9397	28.7652	0.1679	13.1712	1.5531	14.7244	4.3709	1.4328	5.8038	0.0000	15,598.8427	15,598.8427	1.7857	0.0000	15,643.4852
2023	3.6784	48.8929	26.8972	0.1640	13.1713	1.2772	14.4485	4.3710	1.1766	5.5475	0.0000	15,225.0284	15,225.0284	1.6799	0.0000	15,267.0252
2024	1.6674	21.7430	12.3417	0.0759	10.6675	0.5625	11.2300	3.1356	0.5182	3.6537	0.0000	7,046.1190	7,046.1190	0.7825	0.0000	7,065.6821
Maximum	**4.9370**	**74.2571**	**30.7240**	**0.1702**	**13.1892**	**1.8967**	**15.0859**	**4.3798**	**1.7497**	**6.1295**	**0.0000**	**15,813.8215**	**15,813.8215**	**1.8062**	**0.0000**	**15,858.9761**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**23.55**	**0.00**	**21.79**	**33.29**	**0.00**	**27.67**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**6-1-2020**	**8-31-2020**	21.2976	21.2976
2	**9-1-2020**	**11-30-2020**	21.3354	21.3354
3	**12-1-2020**	**2-28-2021**	20.1545	20.1545
4	**3-1-2021**	**5-31-2021**	19.7866	19.7866
5	**6-1-2021**	**8-31-2021**	19.6661	19.6661
6	**9-1-2021**	**11-30-2021**	19.6894	19.6894
7	**12-1-2021**	**2-28-2022**	17.8558	17.8558
8	**3-1-2022**	**5-31-2022**	17.1164	17.1164
9	**6-1-2022**	**8-31-2022**	17.0119	17.0119
10	**9-1-2022**	**11-30-2022**	17.0326	17.0326
11	**12-1-2022**	**2-28-2023**	14.3828	14.3828
12	**3-1-2023**	**5-31-2023**	13.2130	13.2130

13	**6-1-2023**	**8-31-2023**	13.1556	13.1556
14	**9-1-2023**	**11-30-2023**	13.1256	13.1256
15	**12-1-2023**	**2-29-2024**	12.8060	12.8060
16	**3-1-2024**	**5-31-2024**	12.6422	12.6422
17	**6-1-2024**	**8-31-2024**	2.3259	2.3259
		Highest	21.3354	21.3354

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Grading	Grading	6/1/2020	6/17/2024	5	1056	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 97

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 0; Non-Residential Outdoor: 0; Striped Parking Area: 0

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Grading	Excavators	10	8.00	158	0.38
Grading	Graders	10	8.00	187	0.41
Grading	Rubber Tired Dozers	10	8.00	247	0.40
Grading	Scrapers	10	8.00	367	0.48
Grading	Tractors/Loaders/Backhoes	10	8.00	97	0.37

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Grading	50	125.00	0.00	643,918.00	40.00	7.30	40.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

Water Exposed Area

Water Unpaved Roads

Reduce Vehicle Speed on Unpaved Roads

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Alternative 2 Project Phases (Pounds)	ROG (lbs/day)	CO (lbs/day)	NOx (lbs/day)	Total PM10 (lbs/day)	Exhaust PM10 (lbs/day)	Fugitive Dust PM10 (lbs/day)	Total PM2.5 (lbs/day)	Exhaust PM2.5 (lbs/day)	Fugitive Dust PM2.5 (lbs/day)	SOx (lbs/day)	CO2 (lbs/day)	CH4 (lbs/day)	N2O (lbs/day)	CO2e (lbs/day)
Grubbing/Land Clearing	1.17	9.98	12.99	20.56	0.56	20.00	4.66	0.50	4.16	0.02	2,125.20	0.58	0.05	2,153.40
Grading/Excavation	9.63	71.25	109.39	24.51	4.51	20.00	8.25	4.09	4.16	0.16	15,483.43	4.69	0.18	15,654.58
Drainage/Utilities/Sub-Grade	5.97	49.00	63.69	22.65	2.65	20.00	6.59	2.43	4.16	0.11	10,490.97	2.73	0.12	10,596.43
Paving	0.99	12.91	9.65	0.52	0.52	0.00	0.46	0.46	0.00	0.02	2,144.14	0.56	0.05	2,172.00
Maximum (pounds/day)	9.63	71.25	109.39	24.51	4.51	20.00	8.25	4.09	4.16	0.16	15,483.43	4.69	0.18	15,654.58
Total (tons/construction project)	2.53	19.68	28.15	7.90	1.17	6.73	2.46	1.06	1.40	0.04	4,217.00	1.22	0.05	4,262.79

Notes:

Project Start Year ->	2020
Project Length (months) ->	36
Total Project Area (acres) ->	18
Maximum Area Disturbed/Day (acres) ->	2
Water Truck Used? ->	Yes

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	200	40
Grading/Excavation	0	0	0	0	1,120	40
Drainage/Utilities/Sub-Grade	0	0	0	0	720	40
Paving	0	0	0	0	320	40

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Alternative 2 Project Phases (Tons for all except CO2e. Metric tonnes for CO2e)	ROG (tons/phase)	CO (tons/phase)	NOx (tons/phase)	Total PM10 (tons/phase)	Exhaust PM10 (tons/phase)	Fugitive Dust PM10 (tons/phase)	Total PM2.5 (tons/phase)	Exhaust PM2.5 (tons/phase)	Fugitive Dust PM2.5 (tons/phase)	SOx (tons/phase)	CO2 (tons/phase)	CH4 (tons/phase)	N2O (tons/phase)	CO2e (MT/phase)
Grubbing/Land Clearing	0.05	0.40	0.51	0.81	0.02	0.79	0.18	0.02	0.16	0.00	84.16	0.02	0.00	77.36
Grading/Excavation	1.72	12.70	19.49	4.37	0.80	3.56	1.47	0.73	0.74	0.03	2,759.15	0.84	0.03	2,530.75
Drainage/Utilities/Sub-Grade	0.71	5.82	7.57	2.69	0.31	2.38	0.78	0.29	0.49	0.01	1,246.33	0.32	0.01	1,142.03
Paving	0.06	0.77	0.57	0.03	0.03	0.00	0.03	0.03	0.00	0.00	127.36	0.03	0.00	117.04
Maximum (tons/phase)	1.72	12.70	19.49	4.37	0.80	3.56	1.47	0.73	0.74	0.03	2759.15	0.84	0.03	2,530.75
Total (tons/construction project)	2.53	19.68	28.15	7.90	1.17	6.73	2.46	1.06	1.40	0.04	4217.00	1.22	0.05	3,867.18

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

CalEEMod Version: CalEEMod.2016.3.2

FKC - Alternative 3 - San Joaquin Valley Unified APCD Air District, Annual

FKC - Alternative 3

San Joaquin Valley Unified APCD Air District, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
User Defined Industrial	97.00	User Defined Unit	97.00	0.00	0

1.2 Other Project Characteristics

Urbanization	Rural	**Wind Speed (m/s)**	2.7	**Precipitation Freq (Days)**	45
Climate Zone	3			**Operational Year**	2025
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - 97 acres cleared and grubbed

Construction Phase - 4 year constuction schedule

Off-road Equipment - est

Trips and VMT - est

Grading - est

Construction Off-road Equipment Mitigation -

Table Name	Column Name	Default Value	New Value
tblConstDustMitigation	WaterUnpavedRoadMoistureContent	0	6.1
tblConstDustMitigation	WaterUnpavedRoadVehicleSpeed	0	15

tblConstructionPhase	NumDays	155.00	1,056.00
tblGrading	AcresOfGrading	15,840.00	387.50
tblGrading	MaterialExported	0.00	5,085,172.00
tblLandUse	LotAcreage	0.00	97.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblProjectCharacteristics	UrbanizationLevel	Urban	Rural
tblTripsAndVMT	HaulingTripLength	20.00	40.00
tblTripsAndVMT	HaulingTripNumber	804,898.00	508,517.00
tblTripsAndVMT	VendorTripLength	6.60	7.30
tblTripsAndVMT	WorkerTripLength	16.80	40.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9457	43.0654	18.1129	0.0869	12.3363	1.1987	13.5350	4.4182	1.1054	5.5236	0.0000	8,039.6979	8,039.6979	1.0270	0.0000	8,065.3716
2021	4.7186	67.3564	29.5867	0.1460	15.9768	1.8697	17.8466	6.3219	1.7239	8.0458	0.0000	13,505.2820	13,505.2820	1.7295	0.0000	13,548.5184
2022	4.1075	57.7505	27.6748	0.1441	15.9429	1.5305	17.4734	6.3042	1.4112	7.7154	0.0000	13,328.9912	13,328.9912	1.7120	0.0000	13,371.7922
2023	3.5386	44.9630	25.9724	0.1410	15.9429	1.2684	17.2114	6.3042	1.1682	7.4723	0.0000	13,030.6408	13,030.6408	1.6283	0.0000	13,071.3472
2024	1.6030	19.9579	11.9183	0.0653	11.2136	0.5584	11.7720	3.8312	0.5143	4.3455	0.0000	6,031.6319	6,031.6319	0.7582	0.0000	6,050.5877
Maximum	**4.7186**	**67.3564**	**29.5867**	**0.1460**	**15.9768**	**1.8697**	**17.8466**	**6.3219**	**1.7239**	**8.0458**	**0.0000**	**13,505.2820**	**13,505.2820**	**1.7295**	**0.0000**	**13,548.5184**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9457	43.0654	18.1128	0.0869	9.4665	1.1987	10.6652	2.9729	1.1053	4.0782	0.0000	8,039.6948	8,039.6948	1.0270	0.0000	8,065.3685
2021	4.7186	67.3564	29.5867	0.1460	11.3351	1.8697	13.2048	3.9026	1.7239	5.6264	0.0000	13,505.2767	13,505.2767	1.7295	0.0000	13,548.5131
2022	4.1075	57.7504	27.6748	0.1441	11.3177	1.5305	12.8482	3.8939	1.4112	5.3051	0.0000	13,328.9859	13,328.9859	1.7120	0.0000	13,371.7869
2023	3.5386	44.9630	25.9724	0.1410	11.3178	1.2684	12.5862	3.8939	1.1682	5.0621	0.0000	13,030.6356	13,030.6356	1.6283	0.0000	13,071.3419
2024	1.6029	19.9579	11.9183	0.0653	8.8904	0.5584	9.4488	2.6862	0.5143	3.2005	0.0000	6,031.6295	6,031.6295	0.7582	0.0000	6,050.5852
Maximum	**4.7186**	**67.3564**	**29.5867**	**0.1460**	**11.3351**	**1.8697**	**13.2048**	**3.9026**	**1.7239**	**5.6264**	**0.0000**	**13,505.2767**	**13,505.2767**	**1.7295**	**0.0000**	**13,548.5131**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**26.73**	**0.00**	**24.52**	**36.17**	**0.00**	**29.70**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**6-1-2020**	**8-31-2020**	19.3896	19.3896
2	**9-1-2020**	**11-30-2020**	19.3929	19.3929
3	**12-1-2020**	**2-28-2021**	18.3239	18.3239
4	**3-1-2021**	**5-31-2021**	18.0269	18.0269
5	**6-1-2021**	**8-31-2021**	17.9310	17.9310
6	**9-1-2021**	**11-30-2021**	17.9247	17.9247
7	**12-1-2021**	**2-28-2022**	16.2017	16.2017
8	**3-1-2022**	**5-31-2022**	15.5292	15.5292
9	**6-1-2022**	**8-31-2022**	15.4461	15.4461
10	**9-1-2022**	**11-30-2022**	15.4418	15.4418
11	**12-1-2022**	**2-28-2023**	13.1700	13.1700
12	**3-1-2023**	**5-31-2023**	12.2005	12.2005

13	**6-1-2023**	**8-31-2023**	12.1546	12.1546
14	**9-1-2023**	**11-30-2023**	12.1129	12.1129
15	**12-1-2023**	**2-29-2024**	11.7981	11.7981
16	**3-1-2024**	**5-31-2024**	11.6533	11.6533
17	**6-1-2024**	**8-31-2024**	2.1452	2.1452
		Highest	19.3929	19.3929

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Grading	Grading	6/1/2020	6/17/2024	5	1056	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 387.5

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 0; Non-Residential Outdoor: 0; Striped Parking Area: 0

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Grading	Excavators	10	8.00	158	0.38
Grading	Graders	10	8.00	187	0.41
Grading	Rubber Tired Dozers	10	8.00	247	0.40
Grading	Scrapers	10	8.00	367	0.48
Grading	Tractors/Loaders/Backhoes	10	8.00	97	0.37

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Grading	50	125.00	0.00	508,517.00	40.00	7.30	40.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

Water Exposed Area

Water Unpaved Roads

Reduce Vehicle Speed on Unpaved Roads

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Alternative 3 Project Phases (Pounds)	ROG (lbs/day)	CO (lbs/day)	NOx (lbs/day)	Total PM10 (lbs/day)	Exhaust PM10 (lbs/day)	Fugitive Dust PM10 (lbs/day)	Total PM2.5 (lbs/day)	Exhaust PM2.5 (lbs/day)	Fugitive Dust PM2.5 (lbs/day)	SOx (lbs/day)	CO2 (lbs/day)	CH4 (lbs/day)	N2O (lbs/day)	CO2e (lbs/day)
Grubbing/Land Clearing	1.17	9.98	12.99	20.56	0.56	20.00	4.66	0.50	4.16	0.02	2,125.20	0.58	0.05	2,153.40
Grading/Excavation	9.95	72.53	114.27	24.73	4.73	20.00	8.45	4.29	4.16	0.16	15,496.68	4.69	0.18	15,668.23
Drainage/Utilities/Sub-Grade	6.86	52.96	75.97	23.24	3.24	20.00	7.14	2.98	4.16	0.11	10,515.69	2.74	0.13	10,622.36
Paving	1.22	13.19	11.97	0.70	0.70	0.00	0.62	0.62	0.00	0.02	2,163.49	0.56	0.05	2,191.98
Maximum (pounds/day)	9.95	72.53	114.27	24.73	4.73	20.00	8.45	4.29	4.16	0.16	15,496.68	4.69	0.18	15,668.23
Total (tons/construction project)	0.90	6.80	10.20	2.67	0.43	2.24	0.86	0.39	0.47	0.01	1,407.81	0.41	0.02	1,423.16

Notes:

Project Start Year ->	2020
Project Length (months) ->	12
Total Project Area (acres) ->	9
Maximum Area Disturbed/Day (acres) ->	2
Water Truck Used? ->	Yes

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	200	40
Grading/Excavation	0	0	0	0	1,120	40
Drainage/Utilities/Sub-Grade	0	0	0	0	720	40
Paving	0	0	0	0	320	40

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Alternative 3 Project Phases (Tons for all except CO2e. Metric tonnes for CO2e)	ROG (tons/phase)	CO (tons/phase)	NOx (tons/phase)	Total PM10 (tons/phase)	Exhaust PM10 (tons/phase)	Fugitive Dust PM10 (tons/phase)	Total PM2.5 (tons/phase)	Exhaust PM2.5 (tons/phase)	Fugitive Dust PM2.5 (tons/phase)	SOx (tons/phase)	CO2 (tons/phase)	CH4 (tons/phase)	N2O (tons/phase)	CO2e (MT/phase)
Grubbing/Land Clearing	0.02	0.13	0.17	0.27	0.01	0.26	0.06	0.01	0.05	0.00	28.05	0.01	0.00	25.79
Grading/Excavation	0.59	4.31	6.79	1.47	0.28	1.19	0.50	0.25	0.25	0.01	920.50	0.28	0.01	844.32
Drainage/Utilities/Sub-Grade	0.27	2.10	3.01	0.92	0.13	0.79	0.28	0.12	0.16	0.00	416.42	0.11	0.01	381.61
Paving	0.02	0.26	0.24	0.01	0.01	0.00	0.01	0.01	0.00	0.00	42.84	0.01	0.00	39.37
Maximum (tons/phase)	0.59	4.31	6.79	1.47	0.28	1.19	0.50	0.25	0.25	0.01	920.50	0.28	0.01	844.32
Total (tons/construction project)	0.90	6.80	10.20	2.67	0.43	2.24	0.86	0.39	0.47	0.01	1407.81	0.41	0.02	1,291.09

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

CalEEMod Version: CalEEMod.2016.3.2

FKC - Alternative 4A - San Joaquin Valley Unified APCD Air District, Annual

FKC - Alternative 4A

San Joaquin Valley Unified APCD Air District, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
User Defined Industrial	0.00	User Defined Unit	0.00	0.00	0

1.2 Other Project Characteristics

Urbanization	Rural	**Wind Speed (m/s)**	2.7	**Precipitation Freq (Days)**	45
Climate Zone	3			**Operational Year**	2025
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - 0 acres cleared and grubbed

Construction Phase - 4 year constuction schedule

Off-road Equipment - est

Grading - est

Trips and VMT - est

Construction Off-road Equipment Mitigation -

Table Name	Column Name	Default Value	New Value
tblConstDustMitigation	WaterUnpavedRoadMoistureContent	0	6.1

tblConstDustMitigation	WaterUnpavedRoadVehicleSpeed	0	15
tblConstructionPhase	NumDays	155.00	1,056.00
tblConstructionPhase	PhaseEndDate	1/1/2021	6/17/2024
tblGrading	AcresOfGrading	15,840.00	0.00
tblGrading	MaterialExported	0.00	5,412,645.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblProjectCharacteristics	UrbanizationLevel	Urban	Rural
tblTripsAndVMT	HaulingTripLength	20.00	40.00
tblTripsAndVMT	HaulingTripNumber	804,898.00	541,265.00
tblTripsAndVMT	VendorTripLength	6.60	7.30
tblTripsAndVMT	WorkerTripLength	16.80	40.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9789	44.1504	18.2819	0.0904	12.5950	1.2031	13.7982	4.5101	1.1096	5.6197	0.0000	8,373.1594	8,373.1594	1.0383	0.0000	8,399.1162
2021	4.7714	69.0254	29.8618	0.1518	16.2498	1.8763	18.1261	6.4190	1.7301	8.1491	0.0000	14,063.6252	14,063.6252	1.7480	0.0000	14,107.3255
2022	4.1568	59.2474	27.9386	0.1499	16.2158	1.5360	17.7517	6.4012	1.4164	7.8176	0.0000	13,877.9773	13,877.9773	1.7299	0.0000	13,921.2237
2023	3.5725	45.9135	26.1961	0.1465	16.2158	1.2705	17.4864	6.4012	1.1702	7.5714	0.0000	13,561.3753	13,561.3753	1.6407	0.0000	13,602.3938
2024	1.6185	20.3897	12.0207	0.0678	11.4680	0.5594	12.0274	3.9215	0.5152	4.4367	0.0000	6,276.9957	6,276.9957	0.7641	0.0000	6,296.0984
Maximum	**4.7714**	**69.0254**	**29.8618**	**0.1518**	**16.2498**	**1.8763**	**18.1261**	**6.4190**	**1.7301**	**8.1491**	**0.0000**	**14,063.6252**	**14,063.6252**	**1.7480**	**0.0000**	**14,107.3255**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9789	44.1504	18.2819	0.0904	9.8250	1.2031	11.0281	3.0750	1.1096	4.1845	0.0000	8,373.1563	8,373.1563	1.0383	0.0000	8,399.1130
2021	4.7714	69.0254	29.8617	0.1518	11.7078	1.8763	13.5841	4.0098	1.7301	5.7399	0.0000	14,063.6199	14,063.6199	1.7480	0.0000	14,107.3202
2022	4.1568	59.2473	27.9385	0.1499	11.6903	1.5360	13.2263	4.0011	1.4164	5.4175	0.0000	13,877.9721	13,877.9721	1.7299	0.0000	13,921.2184
2023	3.5725	45.9135	26.1961	0.1465	11.6904	1.2705	12.9609	4.0011	1.1702	5.1713	0.0000	13,561.3700	13,561.3700	1.6407	0.0000	13,602.3885
2024	1.6185	20.3897	12.0207	0.0678	9.2445	0.5594	9.8039	2.7867	0.5152	3.3020	0.0000	6,276.9933	6,276.9933	0.7641	0.0000	6,296.0959
Maximum	**4.7714**	**69.0254**	**29.8617**	**0.1518**	**11.7078**	**1.8763**	**13.5841**	**4.0098**	**1.7301**	**5.7399**	**0.0000**	**14,063.6199**	**14,063.6199**	**1.7480**	**0.0000**	**14,107.3202**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**25.55**	**0.00**	**23.47**	**35.36**	**0.00**	**29.11**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**6-1-2020**	**8-31-2020**	19.8510	19.8510
2	**9-1-2020**	**11-30-2020**	19.8627	19.8627
3	**12-1-2020**	**2-28-2021**	18.7667	18.7667
4	**3-1-2021**	**5-31-2021**	18.4525	18.4525
5	**6-1-2021**	**8-31-2021**	18.3507	18.3507
6	**9-1-2021**	**11-30-2021**	18.3515	18.3515
7	**12-1-2021**	**2-28-2022**	16.6018	16.6018
8	**3-1-2022**	**5-31-2022**	15.9131	15.9131
9	**6-1-2022**	**8-31-2022**	15.8248	15.8248
10	**9-1-2022**	**11-30-2022**	15.8265	15.8265
11	**12-1-2022**	**2-28-2023**	13.4633	13.4633
12	**3-1-2023**	**5-31-2023**	12.4454	12.4454

13	**6-1-2023**	**8-31-2023**	12.3967	12.3967
14	**9-1-2023**	**11-30-2023**	12.3578	12.3578
15	**12-1-2023**	**2-29-2024**	12.0419	12.0419
16	**3-1-2024**	**5-31-2024**	11.8925	11.8925
17	**6-1-2024**	**8-31-2024**	2.1889	2.1889
		Highest	19.8627	19.8627

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Grading	Grading	6/1/2020	6/17/2024	5	1056	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 0

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 0; Non-Residential Outdoor: 0; Striped Parking Area: 0

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Grading	Excavators	10	8.00	158	0.38
Grading	Rubber Tired Dozers	10	8.00	247	0.40
Grading	Graders	10	8.00	187	0.41
Grading	Tractors/Loaders/Backhoes	10	8.00	97	0.37
Grading	Scrapers	10	8.00	367	0.48

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Grading	50	125.00	0.00	541,265.00	40.00	7.30	40.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

Water Exposed Area

Water Unpaved Roads

Reduce Vehicle Speed on Unpaved Roads

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Alternative 4A Project Phases (Pounds)	ROG (lbs/day)	CO (lbs/day)	NOx (lbs/day)	Total PM10 (lbs/day)	Exhaust PM10 (lbs/day)	Fugitive Dust PM10 (lbs/day)	Total PM2.5 (lbs/day)	Exhaust PM2.5 (lbs/day)	Fugitive Dust PM2.5 (lbs/day)	SOx (lbs/day)	CO2 (lbs/day)	CH4 (lbs/day)	N2O (lbs/day)	CO2e (lbs/day)
Grubbing/Land Clearing	1.24	10.52	13.38	20.58	0.58	20.00	4.68	0.52	4.16	0.02	2,237.07	0.59	0.05	2,266.12
Grading/Excavation	9.70	71.66	109.76	24.53	4.53	20.00	8.27	4.11	4.16	0.16	15,563.55	4.70	0.18	15,735.23
Drainage/Utilities/Sub-Grade	6.04	49.41	64.06	22.66	2.66	20.00	6.60	2.44	4.16	0.11	10,569.97	2.74	0.13	10,675.94
Paving	1.06	13.31	10.02	0.54	0.54	0.00	0.47	0.47	0.00	0.02	2,222.74	0.57	0.05	2,251.10
Maximum (pounds/day)	9.70	71.66	109.76	24.53	4.53	20.00	8.27	4.11	4.16	0.16	15,563.55	4.70	0.18	15,735.23
Total (tons/construction project)	2.56	19.85	28.29	7.91	1.18	6.73	2.47	1.07	1.40	0.04	4,249.75	1.22	0.05	4,295.77

Notes:

Project Start Year ->	2020
Project Length (months) ->	36
Total Project Area (acres) ->	27
Maximum Area Disturbed/Day (acres) ->	2
Water Truck Used? ->	Yes

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	280	40
Grading/Excavation	0	0	0	0	1,160	40
Drainage/Utilities/Sub-Grade	0	0	0	0	760	40
Paving	0	0	0	0	360	40

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Alternative 4A Project Phases (Tons for all except CO2e. Metric tonnes for CO2e)	ROG (tons/phase)	CO (tons/phase)	NOx (tons/phase)	Total PM10 (tons/phase)	Exhaust PM10 (tons/phase)	Fugitive Dust PM10 (tons/phase)	Total PM2.5 (tons/phase)	Exhaust PM2.5 (tons/phase)	Fugitive Dust PM2.5 (tons/phase)	SOx (tons/phase)	CO2 (tons/phase)	CH4 (tons/phase)	N2O (tons/phase)	CO2e (MT/phase)
Grubbing/Land Clearing	0.05	0.42	0.53	0.82	0.02	0.79	0.19	0.02	0.16	0.00	88.59	0.02	0.00	81.41
Grading/Excavation	1.73	12.77	19.56	4.37	0.81	3.56	1.47	0.73	0.74	0.03	2,773.42	0.84	0.03	2,543.79
Drainage/Utilities/Sub-Grade	0.72	5.87	7.61	2.69	0.32	2.38	0.78	0.29	0.49	0.01	1,255.71	0.32	0.01	1,150.60
Paving	0.06	0.79	0.60	0.03	0.03	0.00	0.03	0.03	0.00	0.00	132.03	0.03	0.00	121.31
Maximum (tons/phase)	1.73	12.77	19.56	4.37	0.81	3.56	1.47	0.73	0.74	0.03	2773.42	0.84	0.03	2,543.79
Total (tons/construction project)	2.56	19.85	28.29	7.91	1.18	6.73	2.47	1.07	1.40	0.04	4249.75	1.22	0.05	3,897.10

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

CalEEMod Version: CalEEMod.2016.3.2

FKC - Alternative 4B - San Joaquin Valley Unified APCD Air District, Annual

FKC - Alternative 4B

San Joaquin Valley Unified APCD Air District, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
User Defined Industrial	0.00	User Defined Unit	0.00	0.00	0

1.2 Other Project Characteristics

Urbanization	Rural	**Wind Speed (m/s)**	2.7	**Precipitation Freq (Days)**	45
Climate Zone	3			**Operational Year**	2025
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - 0 acres cleared and grubbed

Construction Phase - 4 year constuction schedule

Off-road Equipment - est

Grading - est

Trips and VMT - est

Construction Off-road Equipment Mitigation -

Table Name	Column Name	Default Value	New Value
tblConstDustMitigation	WaterUnpavedRoadMoistureContent	0	6.1

tblConstDustMitigation	WaterUnpavedRoadVehicleSpeed	0	15
tblConstructionPhase	NumDays	155.00	1,056.00
tblConstructionPhase	PhaseEndDate	1/1/2021	6/17/2024
tblGrading	AcresOfGrading	15,840.00	0.00
tblGrading	MaterialExported	0.00	6,173,621.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblProjectCharacteristics	UrbanizationLevel	Urban	Rural
tblTripsAndVMT	HaulingTripLength	20.00	40.00
tblTripsAndVMT	HaulingTripNumber	804,898.00	617,363.00
tblTripsAndVMT	VendorTripLength	6.60	7.30
tblTripsAndVMT	WorkerTripLength	16.80	40.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	3.0560	46.6718	18.6747	0.0985	13.6739	1.2134	14.8872	4.7752	1.1194	5.8946	0.0000	9,148.0389	9,148.0389	1.0646	0.0000	9,174.6534
2021	4.8942	72.9038	30.5010	0.1655	17.3617	1.8914	19.2531	6.6961	1.7446	8.4407	0.0000	15,361.0723	15,361.0723	1.7911	0.0000	15,405.8507
2022	4.2714	62.7259	28.5513	0.1633	17.3273	1.5487	18.8760	6.6782	1.4286	8.1067	0.0000	15,153.6810	15,153.6810	1.7713	0.0000	15,197.9624
2023	3.6510	48.1222	26.7159	0.1595	17.3274	1.2755	18.6029	6.6782	1.1749	7.8531	0.0000	14,794.6668	14,794.6668	1.6698	0.0000	14,836.4106
2024	1.6548	21.3929	12.2587	0.0738	12.5367	0.5617	13.0983	4.1829	0.5174	4.7003	0.0000	6,847.1586	6,847.1586	0.7778	0.0000	6,866.6026
Maximum	**4.8942**	**72.9038**	**30.5010**	**0.1655**	**17.3617**	**1.8914**	**19.2531**	**6.6961**	**1.7446**	**8.4407**	**0.0000**	**15,361.0723**	**15,361.0723**	**1.7911**	**0.0000**	**15,405.8507**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	3.0560	46.6718	18.6746	0.0985	10.8729	1.2134	12.0863	3.3354	1.1194	4.4548	0.0000	9,148.0358	9,148.0358	1.0646	0.0000	9,174.6503
2021	4.8942	72.9037	30.5009	0.1655	12.7888	1.8914	14.6802	4.2822	1.7446	6.0269	0.0000	15,361.0670	15,361.0670	1.7911	0.0000	15,405.8454
2022	4.2714	62.7258	28.5513	0.1633	12.7710	1.5487	14.3197	4.2734	1.4286	5.7020	0.0000	15,153.6758	15,153.6758	1.7713	0.0000	15,197.9571
2023	3.6510	48.1222	26.7158	0.1595	12.7711	1.2755	14.0465	4.2734	1.1749	5.4484	0.0000	14,794.6615	14,794.6615	1.6698	0.0000	14,836.4053
2024	1.6547	21.3929	12.2586	0.0738	10.2822	0.5617	10.8439	3.0435	0.5174	3.5609	0.0000	6,847.1561	6,847.1561	0.7778	0.0000	6,866.6002
Maximum	**4.8942**	**72.9037**	**30.5009**	**0.1655**	**12.7888**	**1.8914**	**14.6802**	**4.2822**	**1.7446**	**6.0269**	**0.0000**	**15,361.0670**	**15,361.0670**	**1.7911**	**0.0000**	**15,405.8454**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**23.96**	**0.00**	**22.12**	**33.79**	**0.00**	**28.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**6-1-2020**	**8-31-2020**	20.9234	20.9234
2	**9-1-2020**	**11-30-2020**	20.9544	20.9544
3	**12-1-2020**	**2-28-2021**	19.7955	19.7955
4	**3-1-2021**	**5-31-2021**	19.4415	19.4415
5	**6-1-2021**	**8-31-2021**	19.3258	19.3258
6	**9-1-2021**	**11-30-2021**	19.3433	19.3433
7	**12-1-2021**	**2-28-2022**	17.5314	17.5314
8	**3-1-2022**	**5-31-2022**	16.8051	16.8051
9	**6-1-2022**	**8-31-2022**	16.7048	16.7048
10	**9-1-2022**	**11-30-2022**	16.7206	16.7206
11	**12-1-2022**	**2-28-2023**	14.1449	14.1449
12	**3-1-2023**	**5-31-2023**	13.0145	13.0145

13	**6-1-2023**	**8-31-2023**	12.9593	12.9593
14	**9-1-2023**	**11-30-2023**	12.9270	12.9270
15	**12-1-2023**	**2-29-2024**	12.6084	12.6084
16	**3-1-2024**	**5-31-2024**	12.4482	12.4482
17	**6-1-2024**	**8-31-2024**	2.2904	2.2904
		Highest	20.9544	20.9544

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Grading	Grading	6/1/2020	6/17/2024	5	1056	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 0

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 0; Non-Residential Outdoor: 0; Striped Parking Area: 0

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Grading	Excavators	10	8.00	158	0.38
Grading	Rubber Tired Dozers	10	8.00	247	0.40
Grading	Graders	10	8.00	187	0.41
Grading	Tractors/Loaders/Backhoes	10	8.00	97	0.37
Grading	Scrapers	10	8.00	367	0.48

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Grading	50	125.00	0.00	617,363.00	40.00	7.30	40.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

Water Exposed Area

Water Unpaved Roads

Reduce Vehicle Speed on Unpaved Roads

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Alternative 4B Project Phases (Pounds)	ROG (lbs/day)	CO (lbs/day)	NOx (lbs/day)	Total PM10 (lbs/day)	Exhaust PM10 (lbs/day)	Fugitive Dust PM10 (lbs/day)	Total PM2.5 (lbs/day)	Exhaust PM2.5 (lbs/day)	Fugitive Dust PM2.5 (lbs/day)	SOx (lbs/day)	CO2 (lbs/day)	CH4 (lbs/day)	N2O (lbs/day)	CO2e (lbs/day)
Grubbing/Land Clearing	1.17	9.98	12.99	20.56	0.56	20.00	4.66	0.50	4.16	0.02	2,125.20	0.58	0.05	2,153.40
Grading/Excavation	9.95	72.53	114.27	24.73	4.73	20.00	8.45	4.29	4.16	0.16	15,496.68	4.69	0.18	15,668.23
Drainage/Utilities/Sub-Grade	6.86	52.96	75.97	23.24	3.24	20.00	7.14	2.98	4.16	0.11	10,515.69	2.74	0.13	10,622.36
Paving	1.22	13.19	12.00	0.70	0.70	0.00	0.62	0.62	0.00	0.02	2,163.81	0.56	0.05	2,192.31
Maximum (pounds/day)	9.95	72.53	114.27	24.73	4.73	20.00	8.45	4.29	4.16	0.16	15,496.68	4.69	0.18	15,668.23
Total (tons/construction project)	0.60	4.53	6.80	1.78	0.29	1.50	0.57	0.26	0.31	0.01	938.55	0.27	0.01	948.78

Notes:

Project Start Year ->	2020
Project Length (months) ->	8
Total Project Area (acres) ->	9
Maximum Area Disturbed/Day (acres) ->	2
Water Truck Used? ->	Yes

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	200	40
Grading/Excavation	0	0	0	0	1,120	40
Drainage/Utilities/Sub-Grade	0	0	0	0	720	40
Paving	0	0	0	0	320	40

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Alternative 4B Project Phases (Tons for all except CO2e. Metric tonnes for CO2e)	ROG (tons/phase)	CO (tons/phase)	NOx (tons/phase)	Total PM10 (tons/phase)	Exhaust PM10 (tons/phase)	Fugitive Dust PM10 (tons/phase)	Total PM2.5 (tons/phase)	Exhaust PM2.5 (tons/phase)	Fugitive Dust PM2.5 (tons/phase)	SOx (tons/phase)	CO2 (tons/phase)	CH4 (tons/phase)	N2O (tons/phase)	CO2e (MT/phase)
Grubbing/Land Clearing	0.01	0.09	0.11	0.18	0.00	0.18	0.04	0.00	0.04	0.00	18.70	0.01	0.00	17.19
Grading/Excavation	0.39	2.87	4.52	0.98	0.19	0.79	0.33	0.17	0.16	0.01	613.67	0.19	0.01	562.88
Drainage/Utilities/Sub-Grade	0.18	1.40	2.01	0.61	0.09	0.53	0.19	0.08	0.11	0.00	277.61	0.07	0.00	254.40
Paving	0.02	0.17	0.16	0.01	0.01	0.00	0.01	0.01	0.00	0.00	28.56	0.01	0.00	26.25
Maximum (tons/phase)	0.39	2.87	4.52	0.98	0.19	0.79	0.33	0.17	0.16	0.01	613.67	0.19	0.01	562.88
Total (tons/construction project)	0.60	4.53	6.80	1.78	0.29	1.50	0.57	0.26	0.31	0.01	938.55	0.27	0.01	860.73

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

CalEEMod Version: CalEEMod.2016.3.2

FKC - Alternative 5A - San Joaquin Valley Unified APCD Air District, Annual

FKC - Alternative 5A

San Joaquin Valley Unified APCD Air District, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
User Defined Industrial	0.00	User Defined Unit	0.00	0.00	0

1.2 Other Project Characteristics

Urbanization	Rural	**Wind Speed (m/s)**	2.7	**Precipitation Freq (Days)**	45
Climate Zone	3			**Operational Year**	2025
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - 0 acres cleared and grubbed

Construction Phase - 4 year constuction schedule

Off-road Equipment - est

Grading - est

Trips and VMT - est

Construction Off-road Equipment Mitigation -

Table Name	Column Name	Default Value	New Value
tblConstDustMitigation	WaterUnpavedRoadMoistureContent	0	6.1

tblConstDustMitigation	WaterUnpavedRoadVehicleSpeed	0	15
tblConstructionPhase	NumDays	155.00	1,056.00
tblConstructionPhase	PhaseEndDate	1/1/2021	6/17/2024
tblGrading	AcresOfGrading	15,840.00	0.00
tblGrading	MaterialExported	0.00	4,335,338.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblProjectCharacteristics	UrbanizationLevel	Urban	Rural
tblTripsAndVMT	HaulingTripLength	20.00	40.00
tblTripsAndVMT	HaulingTripNumber	804,898.00	433,534.00
tblTripsAndVMT	VendorTripLength	6.60	7.30
tblTripsAndVMT	WorkerTripLength	16.80	40.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.8697	40.5810	17.7258	0.0789	11.0678	1.1886	12.2564	4.1348	1.0957	5.2305	0.0000	7,276.1721	7,276.1721	1.0010	0.0000	7,301.1976
2021	4.5977	63.5350	28.9569	0.1325	14.6758	1.8548	16.5306	6.0267	1.7096	7.7363	0.0000	12,226.8453	12,226.8453	1.6870	0.0000	12,269.0195
2022	3.9946	54.3229	27.0710	0.1309	14.6421	1.5180	16.1601	6.0090	1.3992	7.4083	0.0000	12,071.9792	12,071.9792	1.6713	0.0000	12,113.7605
2023	3.4612	42.7867	25.4603	0.1282	14.6422	1.2635	15.9057	6.0091	1.1635	7.1725	0.0000	11,815.4197	11,815.4197	1.5997	0.0000	11,855.4113
2024	1.5673	18.9694	11.6838	0.0594	9.9552	0.5562	10.5113	3.5514	0.5121	4.0635	0.0000	5,469.8232	5,469.8232	0.7448	0.0000	5,488.4426
Maximum	**4.5977**	**63.5350**	**28.9569**	**0.1325**	**14.6758**	**1.8548**	**16.5306**	**6.0267**	**1.7096**	**7.7363**	**0.0000**	**12,226.8453**	**12,226.8453**	**1.6870**	**0.0000**	**12,269.0195**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.8697	40.5810	17.7258	0.0789	8.3415	1.1886	9.5301	2.7063	1.0957	3.8020	0.0000	7,276.1690	7,276.1690	1.0010	0.0000	7,301.1945
2021	4.5977	63.5349	28.9568	0.1325	10.1775	1.8548	12.0323	3.6241	1.7096	5.3337	0.0000	12,226.8400	12,226.8400	1.6870	0.0000	12,269.0142
2022	3.9946	54.3229	27.0710	0.1309	10.1604	1.5180	11.6784	3.6156	1.3992	5.0148	0.0000	12,071.9740	12,071.9740	1.6713	0.0000	12,113.7552
2023	3.4612	42.7866	25.4603	0.1282	10.1604	1.2635	11.4240	3.6156	1.1635	4.7791	0.0000	11,815.4145	11,815.4145	1.5997	0.0000	11,855.4061
2024	1.5673	18.9694	11.6838	0.0594	7.7754	0.5562	8.3315	2.4233	0.5121	2.9354	0.0000	5,469.8208	5,469.8208	0.7448	0.0000	5,488.4401
Maximum	**4.5977**	**63.5349**	**28.9568**	**0.1325**	**10.1775**	**1.8548**	**12.0323**	**3.6241**	**1.7096**	**5.3337**	**0.0000**	**12,226.8400**	**12,226.8400**	**1.6870**	**0.0000**	**12,269.0142**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**28.27**	**0.00**	**25.74**	**37.88**	**0.00**	**30.83**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	6-1-2020	8-31-2020	18.3329	18.3329
2	9-1-2020	11-30-2020	18.3172	18.3172
3	12-1-2020	2-28-2021	17.3102	17.3102
4	3-1-2021	5-31-2021	17.0524	17.0524
5	6-1-2021	8-31-2021	16.9702	16.9702
6	9-1-2021	11-30-2021	16.9474	16.9474
7	12-1-2021	2-28-2022	15.2857	15.2857
8	3-1-2022	5-31-2022	14.6503	14.6503
9	6-1-2022	8-31-2022	14.5790	14.5790
10	9-1-2022	11-30-2022	14.5608	14.5608
11	12-1-2022	2-28-2023	12.4984	12.4984

12	**3-1-2023**	**5-31-2023**	11.6398	11.6398
13	**6-1-2023**	**8-31-2023**	11.6003	11.6003
14	**9-1-2023**	**11-30-2023**	11.5520	11.5520
15	**12-1-2023**	**2-29-2024**	11.2400	11.2400
16	**3-1-2024**	**5-31-2024**	11.1057	11.1057
17	**6-1-2024**	**8-31-2024**	2.0451	2.0451
		Highest	18.3329	18.3329

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Grading	Grading	6/1/2020	6/17/2024	5	1056	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 0

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 0; Non-Residential Outdoor: 0; Striped Parking Area: 0

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Grading	Excavators	10	8.00	158	0.38
Grading	Rubber Tired Dozers	10	8.00	247	0.40
Grading	Graders	10	8.00	187	0.41
Grading	Tractors/Loaders/Backhoes	10	8.00	97	0.37
Grading	Scrapers	10	8.00	367	0.48

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class

Grading	50	125.00	0.00	433,534.00	40.00	7.30	40.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

Water Exposed Area

Water Unpaved Roads

Reduce Vehicle Speed on Unpaved Roads

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Alternative 5A Project Phases (Pounds)	ROG (lbs/day)	CO (lbs/day)	NOx (lbs/day)	Total PM10 (lbs/day)	Exhaust PM10 (lbs/day)	Fugitive Dust PM10 (lbs/day)	Total PM2.5 (lbs/day)	Exhaust PM2.5 (lbs/day)	Fugitive Dust PM2.5 (lbs/day)	SOx (lbs/day)	CO2 (lbs/day)	CH4 (lbs/day)	N2O (lbs/day)	CO2e (lbs/day)
Grubbing/Land Clearing	1.24	10.52	13.38	20.58	0.58	20.00	4.68	0.52	4.16	0.02	2,237.07	0.59	0.05	2,266.12
Grading/Excavation	9.70	71.66	109.76	24.53	4.53	20.00	8.27	4.11	4.16	0.16	15,563.55	4.70	0.18	15,735.23
Drainage/Utilities/Sub-Grade	6.04	49.41	64.06	22.66	2.66	20.00	6.60	2.44	4.16	0.11	10,569.97	2.74	0.13	10,675.94
Paving	1.06	13.31	10.02	0.54	0.54	0.00	0.47	0.47	0.00	0.02	2,222.74	0.57	0.05	2,251.10
Maximum (pounds/day)	9.70	71.66	109.76	24.53	4.53	20.00	8.27	4.11	4.16	0.16	15,563.55	4.70	0.18	15,735.23
Total (tons/construction project)	2.56	19.85	28.29	7.91	1.18	6.73	2.47	1.07	1.40	0.04	4,249.75	1.22	0.05	4,295.77

Notes:

Project Start Year ->	2020
Project Length (months) ->	36
Total Project Area (acres) ->	27
Maximum Area Disturbed/Day (acres) ->	2
Water Truck Used? ->	Yes

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	280	40
Grading/Excavation	0	0	0	0	1,160	40
Drainage/Utilities/Sub-Grade	0	0	0	0	760	40
Paving	0	0	0	0	360	40

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Alternative 5A Project Phases (Tons for all except CO2e. Metric tonnes for CO2e)	ROG (tons/phase)	CO (tons/phase)	NOx (tons/phase)	Total PM10 (tons/phase)	Exhaust PM10 (tons/phase)	Fugitive Dust PM10 (tons/phase)	Total PM2.5 (tons/phase)	Exhaust PM2.5 (tons/phase)	Fugitive Dust PM2.5 (tons/phase)	SOx (tons/phase)	CO2 (tons/phase)	CH4 (tons/phase)	N2O (tons/phase)	CO2e (MT/phase)
Grubbing/Land Clearing	0.05	0.42	0.53	0.82	0.02	0.79	0.19	0.02	0.16	0.00	88.59	0.02	0.00	81.41
Grading/Excavation	1.73	12.77	19.56	4.37	0.81	3.56	1.47	0.73	0.74	0.03	2,773.42	0.84	0.03	2,543.79
Drainage/Utilities/Sub-Grade	0.72	5.87	7.61	2.69	0.32	2.38	0.78	0.29	0.49	0.01	1,255.71	0.32	0.01	1,150.60
Paving	0.06	0.79	0.60	0.03	0.03	0.00	0.03	0.03	0.00	0.00	132.03	0.03	0.00	121.31
Maximum (tons/phase)	1.73	12.77	19.56	4.37	0.81	3.56	1.47	0.73	0.74	0.03	2773.42	0.84	0.03	2,543.79
Total (tons/construction project)	2.56	19.85	28.29	7.91	1.18	6.73	2.47	1.07	1.40	0.04	4249.75	1.22	0.05	3,897.10

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

CalEEMod Version: CalEEMod.2016.3.2

FKC - Alternative 5B - San Joaquin Valley Unified APCD Air District, Annual

FKC - Alternative 5B

San Joaquin Valley Unified APCD Air District, Annual

1.0 Project Characteristics

1.1 Land Usage

Land Uses	Size	Metric	Lot Acreage	Floor Surface Area	Population
User Defined Industrial	0.00	User Defined Unit	0.00	0.00	0

1.2 Other Project Characteristics

Urbanization	Rural	**Wind Speed (m/s)**	2.7	**Precipitation Freq (Days)**	45
Climate Zone	3			**Operational Year**	2025
Utility Company	Pacific Gas & Electric Company				
CO2 Intensity (lb/MWhr)	641.35	**CH4 Intensity (lb/MWhr)**	0.029	**N2O Intensity (lb/MWhr)**	0.006

1.3 User Entered Comments & Non-Default Data

Project Characteristics -

Land Use - 0 acres cleared and grubbed

Construction Phase - 4 year constuction schedule

Off-road Equipment - est

Grading - est

Trips and VMT - est

Construction Off-road Equipment Mitigation -

Table Name	Column Name	Default Value	New Value
tblConstDustMitigation	WaterUnpavedRoadMoistureContent	0	6.1

tblConstDustMitigation	WaterUnpavedRoadVehicleSpeed	0	15
tblConstructionPhase	NumDays	155.00	1,056.00
tblConstructionPhase	PhaseEndDate	1/1/2021	6/17/2024
tblGrading	AcresOfGrading	15,840.00	0.00
tblGrading	MaterialExported	0.00	4,871,372.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	1.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblOffRoadEquipment	OffRoadEquipmentUnitAmount	2.00	10.00
tblProjectCharacteristics	UrbanizationLevel	Urban	Rural
tblTripsAndVMT	HaulingTripLength	20.00	40.00
tblTripsAndVMT	HaulingTripNumber	804,898.00	487,138.00
tblTripsAndVMT	VendorTripLength	6.60	7.30
tblTripsAndVMT	WorkerTripLength	16.80	40.00

2.0 Emissions Summary

2.1 Overall Construction

Unmitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9240	42.3571	18.0025	0.0846	11.8277	1.1959	13.0236	4.3216	1.1026	5.4242	0.0000	7,822.0030	7,822.0030	1.0196	0.0000	7,847.4919
2021	4.6842	66.2669	29.4071	0.1421	15.4590	1.8655	17.3245	6.2219	1.7198	7.9417	0.0000	13,140.7767	13,140.7767	1.7173	0.0000	13,183.7103
2022	4.0753	56.7732	27.5027	0.1403	15.4251	1.5269	16.9521	6.2042	1.4078	7.6119	0.0000	12,970.5945	12,970.5945	1.7004	0.0000	13,013.1048
2023	3.5166	44.3425	25.8264	0.1373	15.4252	1.2670	16.6922	6.2042	1.1668	7.3710	0.0000	12,684.1595	12,684.1595	1.6201	0.0000	12,724.6620
2024	1.5928	19.6761	11.8515	0.0636	10.7079	0.5578	11.2657	3.7355	0.5137	4.2492	0.0000	5,871.4502	5,871.4502	0.7544	0.0000	5,890.3100
Maximum	**4.6842**	**66.2669**	**29.4071**	**0.1421**	**15.4590**	**1.8655**	**17.3245**	**6.2219**	**1.7198**	**7.9417**	**0.0000**	**13,140.7767**	**13,140.7767**	**1.7173**	**0.0000**	**13,183.7103**

Mitigated Construction

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio- CO2	Total CO2	CH4	N2O	CO2e
Year	tons/yr										MT/yr					
2020	2.9240	42.3570	18.0025	0.0846	9.0796	1.1959	10.2755	2.8898	1.1026	3.9923	0.0000	7,821.9999	7,821.9999	1.0196	0.0000	7,847.4887
2021	4.6842	66.2668	29.4071	0.1421	10.9389	1.8655	12.8044	3.8160	1.7198	5.5358	0.0000	13,140.7715	13,140.7715	1.7173	0.0000	13,183.7050
2022	4.0753	56.7732	27.5027	0.1403	10.9216	1.5269	12.4486	3.8074	1.4078	5.2152	0.0000	12,970.5892	12,970.5892	1.7004	0.0000	13,013.0995
2023	3.5166	44.3425	25.8264	0.1373	10.9217	1.2670	12.1887	3.8074	1.1668	4.9742	0.0000	12,684.1542	12,684.1542	1.6201	0.0000	12,724.6567
2024	1.5928	19.6761	11.8514	0.0636	8.5064	0.5578	9.0641	2.6041	0.5137	3.1178	0.0000	5,871.4477	5,871.4477	0.7544	0.0000	5,890.3076
Maximum	**4.6842**	**66.2668**	**29.4071**	**0.1421**	**10.9389**	**1.8655**	**12.8044**	**3.8160**	**1.7198**	**5.5358**	**0.0000**	**13,140.7715**	**13,140.7715**	**1.7173**	**0.0000**	**13,183.7050**

	ROG	NOx	CO	SO2	Fugitive PM10	Exhaust PM10	PM10 Total	Fugitive PM2.5	Exhaust PM2.5	PM2.5 Total	Bio- CO2	NBio-CO2	Total CO2	CH4	N20	CO2e
Percent Reduction	**0.00**	**0.00**	**0.00**	**0.00**	**26.84**	**0.00**	**24.55**	**36.58**	**0.00**	**29.95**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

Quarter	Start Date	End Date	Maximum Unmitigated ROG + NOX (tons/quarter)	Maximum Mitigated ROG + NOX (tons/quarter)
1	**6-1-2020**	**8-31-2020**	19.0883	19.0883
2	**9-1-2020**	**11-30-2020**	19.0862	19.0862
3	**12-1-2020**	**2-28-2021**	18.0349	18.0349
4	**3-1-2021**	**5-31-2021**	17.7490	17.7490
5	**6-1-2021**	**8-31-2021**	17.6571	17.6571
6	**9-1-2021**	**11-30-2021**	17.6461	17.6461
7	**12-1-2021**	**2-28-2022**	15.9405	15.9405
8	**3-1-2022**	**5-31-2022**	15.2786	15.2786
9	**6-1-2022**	**8-31-2022**	15.1988	15.1988
10	**9-1-2022**	**11-30-2022**	15.1906	15.1906

11	**12-1-2022**	**2-28-2023**	12.9785	12.9785
12	**3-1-2023**	**5-31-2023**	12.0407	12.0407
13	**6-1-2023**	**8-31-2023**	11.9966	11.9966
14	**9-1-2023**	**11-30-2023**	11.9529	11.9529
15	**12-1-2023**	**2-29-2024**	11.6390	11.6390
16	**3-1-2024**	**5-31-2024**	11.4972	11.4972
17	**6-1-2024**	**8-31-2024**	2.1166	2.1166
		Highest	19.0883	19.0883

3.0 Construction Detail

Construction Phase

Phase Number	Phase Name	Phase Type	Start Date	End Date	Num Days Week	Num Days	Phase Description
1	Grading	Grading	6/1/2020	6/17/2024	5	1056	

Acres of Grading (Site Preparation Phase): 0

Acres of Grading (Grading Phase): 0

Acres of Paving: 0

Residential Indoor: 0; Residential Outdoor: 0; Non-Residential Indoor: 0; Non-Residential Outdoor: 0; Striped Parking Area: 0

OffRoad Equipment

Phase Name	Offroad Equipment Type	Amount	Usage Hours	Horse Power	Load Factor
Grading	Excavators	10	8.00	158	0.38
Grading	Rubber Tired Dozers	10	8.00	247	0.40
Grading	Graders	10	8.00	187	0.41
Grading	Tractors/Loaders/Backhoes	10	8.00	97	0.37
Grading	Scrapers	10	8.00	367	0.48

Trips and VMT

Phase Name	Offroad Equipment Count	Worker Trip Number	Vendor Trip Number	Hauling Trip Number	Worker Trip Length	Vendor Trip Length	Hauling Trip Length	Worker Vehicle Class	Vendor Vehicle Class	Hauling Vehicle Class
Grading	50	125.00	0.00	487,138.00	40.00	7.30	40.00	LD_Mix	HDT_Mix	HHDT

3.1 Mitigation Measures Construction

Water Exposed Area

Water Unpaved Roads

Reduce Vehicle Speed on Unpaved Roads

Road Construction Emissions Model, Version 9.0.0

Daily Emission Estimates for -> Alternative 5B Project Phases (Pounds)	ROG (lbs/day)	CO (lbs/day)	NOx (lbs/day)	Total PM10 (lbs/day)	Exhaust PM10 (lbs/day)	Fugitive Dust PM10 (lbs/day)	Total PM2.5 (lbs/day)	Exhaust PM2.5 (lbs/day)	Fugitive Dust PM2.5 (lbs/day)	SOx (lbs/day)	CO2 (lbs/day)	CH4 (lbs/day)	N2O (lbs/day)	CO2e (lbs/day)
Grubbing/Land Clearing	1.17	9.98	12.99	20.56	0.56	20.00	4.66	0.50	4.16	0.02	2,125.20	0.58	0.05	2,153.40
Grading/Excavation	9.95	72.53	114.27	24.73	4.73	20.00	8.45	4.29	4.16	0.16	15,496.68	4.69	0.18	15,668.23
Drainage/Utilities/Sub-Grade	6.86	52.96	75.97	23.24	3.24	20.00	7.14	2.98	4.16	0.11	10,515.69	2.74	0.13	10,622.36
Paving	1.22	13.19	12.00	0.70	0.70	0.00	0.62	0.62	0.00	0.02	2,163.81	0.56	0.05	2,192.31
Maximum (pounds/day)	9.95	72.53	114.27	24.73	4.73	20.00	8.45	4.29	4.16	0.16	15,496.68	4.69	0.18	15,668.23
Total (tons/construction project)	0.60	4.53	6.80	1.78	0.29	1.50	0.57	0.26	0.31	0.01	938.55	0.27	0.01	948.78

Notes:

Project Start Year ->	2020
Project Length (months) ->	8
Total Project Area (acres) ->	9
Maximum Area Disturbed/Day (acres) ->	2
Water Truck Used? ->	Yes

	Total Material Imported/Exported Volume (yd^3/day)		Daily VMT (miles/day)			
Phase	Soil	Asphalt	Soil Hauling	Asphalt Hauling	Worker Commute	Water Truck
Grubbing/Land Clearing	0	0	0	0	200	40
Grading/Excavation	0	0	0	0	1,120	40
Drainage/Utilities/Sub-Grade	0	0	0	0	720	40
Paving	0	0	0	0	320	40

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

Total Emission Estimates by Phase for -> Alternative 5B Project Phases (Tons for all except CO2e. Metric tonnes for CO2e)	ROG (tons/phase)	CO (tons/phase)	NOx (tons/phase)	Total PM10 (tons/phase)	Exhaust PM10 (tons/phase)	Fugitive Dust PM10 (tons/phase)	Total PM2.5 (tons/phase)	Exhaust PM2.5 (tons/phase)	Fugitive Dust PM2.5 (tons/phase)	SOx (tons/phase)	CO2 (tons/phase)	CH4 (tons/phase)	N2O (tons/phase)	CO2e (MT/phase)
Grubbing/Land Clearing	0.01	0.09	0.11	0.18	0.00	0.18	0.04	0.00	0.04	0.00	18.70	0.01	0.00	17.19
Grading/Excavation	0.39	2.87	4.52	0.98	0.19	0.79	0.33	0.17	0.16	0.01	613.67	0.19	0.01	562.88
Drainage/Utilities/Sub-Grade	0.18	1.40	2.01	0.61	0.09	0.53	0.19	0.08	0.11	0.00	277.61	0.07	0.00	254.40
Paving	0.02	0.17	0.16	0.01	0.01	0.00	0.01	0.01	0.00	0.00	28.56	0.01	0.00	26.25
Maximum (tons/phase)	0.39	2.87	4.52	0.98	0.19	0.79	0.33	0.17	0.16	0.01	613.67	0.19	0.01	562.88
Total (tons/construction project)	0.60	4.53	6.80	1.78	0.29	1.50	0.57	0.26	0.31	0.01	938.55	0.27	0.01	860.73

PM10 and PM2.5 estimates assume 50% control of fugitive dust from watering and associated dust control measures if a minimum number of water trucks are specified.

Total PM10 emissions shown in column F are the sum of exhaust and fugitive dust emissions shown in columns G and H. Total PM2.5 emissions shown in Column I are the sum of exhaust and fugitive dust emissions shown in columns J and K.

CO2e emissions are estimated by multiplying mass emissions for each GHG by its global warming potential (GWP), 1 , 25 and 298 for CO2, CH4 and N2O, respectively. Total CO2e is then estimated by summing CO2e estimates over all GHGs.

The CO2e emissions are reported as metric tons per phase.

RECLAMATION

Managing Water in the West

SAN JOAQUIN RIVER RESTORATION PROGRAM

Friant WATER AUTHORITY

Feasibility Report
Attachment A3 – Initial Alternatives Evaluation and Comparison

Friant-Kern Canal Middle Reach Capacity Correction Project

March 2019



Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Abbreviations and Acronyms

CDFW	California Department of Fish and Wildlife
CEQA	California Environmental Quality Act
CESA	California Endangered Species Act
CNDDB	California Natural Diversity Database
CWA	Clean Water Act
EIS/R	Environmental Impact Statement/Report
ESA	Endangered Species Act
FKC	Friant-Kern Canal
FWA	Friant Water Authority
HGL	hydraulic grade line
MP	Milepost
MRSCC	Middle Reach Subsidence and Capacity Correction
NEPA	National Environmental Policy Act
O&M	operations and maintenance
OM&R	operations, maintenance, and replacement
ROW	right of way
RWQCB	Regional Water Quality Control Board
SHPO	State Historical Preservation Officer
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Services

Evaluation and Comparison of Initial Alternatives

This Appendix describes the evaluation and comparison of Initial Alternatives for the Friant-Kern Canal (FKC) Middle Reach Subsidence and Capacity Correction (MRSCC) Project. The Initial Alternatives were developed to a preliminary level of detail that included identification of key features (canal modifications, new canals, bridges), estimated material quantities for earthwork and concrete lining, and cost estimates. To provide an outer bound on the analysis, the Initial Alternatives were developed to achieve the same capacity objectives based on the maximum design flow and standard freeboard requirements.

A set of five evaluation criteria were selected to provide a consistent framework for evaluation and comparison. The following evaluation criteria were defined: constructability, operational requirements and flexibility, cost, schedule, and environmental compliance and permitting. For each criterion, a set of three to six sub-criteria were used to score the alternatives (Table 1). The sub-criteria were based either quantitative (numerical) or qualitative information.

Table 1. Evaluation Criteria and Sub-Criteria

I. Constructability	II. Operational Requirements and Flexibility	III. Cost	IV. Schedule	V. Environmental Compliance and Permitting
CON-1. Complexity to Maintain Water Deliveries during Construction	OPS-1. Additional O&M Requirements and Expertise of FWA Staff	COST-1. Construction Cost*	SCH-1. Time to Start Construction	ENV-1. Complexity of Required Environmental Compliance
CON-2. Ability to operate and maintain during Construction	OPS-2. Operations of District Turnouts	COST-2. Non-contract Cost*	SCH-2. Construction Duration	ENV-2. Number of Stream Crossings*
CON-3. Temporary Bypasses and Tie-Ins Needed to Construct the Project	OPS-3. Ability to Accommodate Power Outages	COST-3. Present Worth Additional OM&R Costs*	SCH-3. Time Until Benefits Realized	ENV-3. Number of Bridges*
CON-4. Extent of Dewatering			SCH-4. Potential to Phase Construction	ENV- 4. Length of Modified Existing Embankment*
CON-5. Material Balance*			SCH-5. Land Acquisition*	
			SCH-6. Schedule Risk	

Note:
*Qualitative metric
Key:
FWA = Friant Water Authority
O&M = operations and maintenance
OM&R = operations, maintenance, and replacement

The scores for all sub-criteria range from one to five; a score of five was assigned to the most favorable outcome and a score of one was assigned to the least favorable outcome. For quantitative sub-criteria, as denoted with an asterisk in Table 1, assessment values were normalized to a range of one to five. Rational scores, or those with decimals, were maintained rather than rounded to the nearest integer to exemplify the differences between each alternative. For the qualitative sub-criteria, the judgement of a team of engineers, planners, and environmental compliance specialists was used to assign scores on a relative basis among the Initial Alternatives.

The evaluation was conducted using quantitative values developed for two conditions: the current land condition and a future subsided condition. The current land condition offers baseline information that is valuable for understanding what would be required to build the project in the near-term, but it does not address the project's ability to maintain conveyance capacity over time. The evaluation under a future subsided condition assumes the project would be constructed relative to a lower land elevation and would require greater material quantities to achieve the proposed hydraulic grade line (HGL). A description of the future subsided condition used in the analysis is presented in Appendix B Attachment 3 Selection of Subsidence Condition Subsidence.

The Appendix is structured by criterion and further broken down by sub-criterion. Each criterion is described in general terms and has an associated results summary table. The reasoning behind the results is described in detail under each sub-criterion.

I. Constructability

Constructability is a broad category that refers to the ability and complexity necessary to construct the project. Constructability includes staging during construction, ability operate and maintain the FKC during construction, and appurtenances needed to construct the project. The following sub-criteria were developed to evaluate alternatives under the constructability criterion:

- CON-1 — complexity to maintain water deliveries during construction,
- CON-2 — ability to operate and maintain canal during construction,
- CON-3 — temporary bypasses and tie-ins needed to construct the work,
- CON-4 — extent of dewatering, and
- CON-5 — material balance.

A summary of results for constructability sub-criteria is presented in Table 2 that depicts the scores under current land surface conditions and with future subsidence conditions. Detailed descriptions and evaluations are provided below for each constructability sub-criterion.

Table 2. Constructability Score Summary

	CON-1		CON-2		CON-3		CON-4		CON-5	
Initial Alternative	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**
1: Canal Enlargement	1.0	1.0	1.0	1.0	1.0	1.0	5.0	5.0	1.0	1.0
2: Pump Station at MP 109	2.0	2.0	2.0	2.0	1.2	1.2	4.0	4.0	4.3	5.0
3: Woollomes Pump Station	3.0	3.0	3.0	3.0	3.3	3.3	1.0	1.0	3.8	4.5
4A: Bypass Canal —Tule R. to White R.	4.0	4.0	4.0	4.0	4.5	4.5	4.0	4.0	2.7	4.7
4B: Bypass Canal —Tule R. to Woollomes	5.0	5.0	5.0	5.0	5.0	5.0	3.0	3.0	1.9	4.2
5A: Parallel Canal —Tule R. to White R.	4.0	4.0	4.0	4.0	4.2	4.2	3.0	3.0	5.0	4.1
5B: Parallel Canal —Tule R. to Woollomes	5.0	5.0	5.0	5.0	4.4	4.4	2.0	2.0	5.0	4.8

Key:
MP= Milepost
C= Current
F= Future

CON-1. Complexity to Maintain Water Deliveries during Construction

Description

This is a qualitative sub-criterion that relates to challenges associated with maintaining water deliveries during construction.

Evaluation

Scores range from the most favorable (5), indicating that operational restrictions can be avoided, to the least favorable (1) that, indicating that significant operational restrictions would apply. Table 3 describes all the assessment values and identifies scores assigned to each Initial Alternative.

Construction activities that involve work within the existing canal could impair the ability to maintain water deliveries. Canal raising and widening would require lower water levels, possibly even dewatering, in portions of the canal. The longer the section of the canal to be enlarged or facilities that need to be constructed in the FKC, the more operations could be restricted. Thus, Alternative 1 received the lowest score (1) since it involves enlarging the entire 33-mile stretch.

Table 3. Complexity to Maintain Water Deliveries During Construction Scoring

Assessment Value	Score	Alternative
Operational restrictions can be avoided	5.0	4B, 5B
Few operational restrictions	4.0	4A, 5A
Some operational restrictions expected	3.0	3
Numerous operational restrictions expected	2.0	2
Significant operational restrictions	1.0	1

Alternative 2 also would require substantial work within the existing canal, and the construction of additional control structures; yet several sections between Tule River and the proposed pump station would not require any modification. Therefore, Alternative 2 was assigned a score of 2. Alternative 3 was assigned a score of 3 because it requires some modifications within the existing canal, but the bypass canal to the pump station could be constructed without impacting deliveries.

Likewise, Alternatives 4A and 5A could be constructed without impacting canal operations. These alternatives were assigned a score of 4 rather than a 5 because they would require slightly more canal enlargement work than Alternatives 4B and 5B. Alternatives 4B and 5B would have the least amount of canal enlargement work and therefore could be constructed with minimal or no operational restrictions. Both of these alternatives were assigned the highest score. The assigned scores did not change from current land conditions to future conditions with subsidence because construction requirements and techniques would remain the same.

CON-2. Ability to Operate & Maintain Canal during Construction

Description

A qualitative sub-criterion that describes how construction activities could affect the operations and maintenance of the FKC. This sub-criterion does not address long-term O&M following completion of construction.

Evaluation

The assessment values, scoring, and justification follows a similar methodology to the previous sub-criterion, which is based on the complexity of actions required to maintain water deliveries during construction. O&M during construction would include activities such as mud-jacking, vegetation removal, sediment removal, turnout repair, or other similar actions. Construction activities contained within the canal increase the difficulty and complexity of performing O&M activities. The scoring for this sub-criterion is shown in Table 4.

Table 4. Ability to Operations and Maintenance Canal During Construction

Assessment Value	Score	Alternative
O&M restrictions can be avoided	5.0	4B, 5B
Few O&M restrictions	4.0	4A, 5A
Some O&M restrictions expected	3.0	3
Numerous O&M restrictions expected	2.0	2
Significant O&M restrictions	1.0	1

Because Alternative 1 includes the greatest length of canal enlargement, it would present the greatest restriction on O&M activities; therefore, it was assigned a score of 1. Alternative 2 similarly requires substantial work within the existing canal, but several sections between Tule River and the proposed pump station at milepost (MP) 109 would not require any modification, thus it was assigned a score of 2. Alternative 3 was assigned a score of 3 because it requires limited work within the existing canal, but the bypass canal to the pump station could be constructed without impacting O&M of the existing FKC.

Likewise, Alternatives 4A and 5A have bypass canals that could be constructed without impacting O&M of the FKC. They were assigned a score of 4 rather than a 5 because they have slightly more canal enlargement work than Alternatives 4B and 5B. Alternatives 4B and 5B have the least canal enlargement work and therefore could avoid O&M restrictions. They were assigned the highest score (5). The assigned scores did not change from current land conditions to future conditions with subsidence because the limitations on O&M activities would remain the same.

CON-3. Temporary Bypasses and Tie-ins Needed to Construct the Project

Description

A quantitative sub-criterion that is identifies the number of temporary canal re-routing features required during construction based on preliminary designs.

Evaluation

To evaluate this sub-criterion, the bypasses and tie-ins were identified on the preliminary designs and summed. The assessment values were then normalized to develop the score.

The less work is done within the existing canal, the better the score. As indicated in Table5, Alternative 1 has the most temporary bypasses and tie-ins needed to construct the work because all work is done within the existing canal. Although Alternatives 4A/B and 5A/B are both bypass canals, they differ slightly due to the alignment. Alternatives 4A and 4B do not tie-in to the existing canal at the Deer Creek check whereas Alternatives 5A and 5B do. Therefore, Alternatives 4A and 4B have a higher score than Alternative 5A and 5B. Note that the scores do not change from current land conditions to future conditions with subsidence as the requirements for constructing tie-ins would not change.

Table 5. Temporary Bypass and Tie-Ins Needed to Construct the Work Scoring

Assessment Value	Score	Alternative
11	5.0	4B
14	4.5	4A
15	4.4	5B
16	4.2	5A
22	3.3	3
36	1.2	2
37	1.0	1

CON-4. Extent of Dewatering

Description

A qualitative sub-criterion that characterizes if there is a need for dewatering, and the relative magnitude of that need. Dewatering would be expected in excavations located in areas with high groundwater, and/or adjacent to the FKC.

Evaluation

Based on expert engineering opinion, modifications to the current canal would not likely require dewatering. Therefore, Alternative 1 was assigned the highest score of 5. Similarly, the bypass canals would require shallow excavation in an uphill area and are may require few to some dewatering; therefore, Alternative 4A was also assigned a score of 4 and Alternative 4B was assigned a lower score of 3 because it involves a longer bypass canal which carries more risk. Similar reasoning was applied to the parallel canal alternatives; longer canals carry more risk and thus receive lower scores. Alternative 5A was assigned a score of 3 and Alternative 5B was assigned a score of 2 because construction of the parallel canal will likely necessitate some to numerous dewatering due to the proximity to the current canal.

Unlike Alternatives 5A/5B, the pump station alternatives vary significantly in the anticipated extent of dewatering. As shown in Table 6, Alternative 2 was assigned a score of 4 because it mainly modifies the existing canal, but there may be some dewatering required for the pump station. Alternative 3 will likely require the most dewatering because it is involves a new canal and pump station situated immediately adjacent to Lake Woollomes. During construction, it is expected that subsurface flow from the lake would require significant dewatering.

Table 6. Extent of Dewatering for Scoring

Assessment Value	Score	Alternative
No dewatering	5.0	1,
Few dewatering	4.0	2, 4A
Some dewatering	3.0	4B,5A
Numerous dewatering	2.0	5B
Significant dewatering	1.0	3

CON-5. Material Balance

Description

A quantitative sub-criterion based off the amount of earth material needed to construct the alternative. Alternatives can either have borrow, surplus, or a balance of earthwork. Borrow is the negative difference between excavation and embankment construction, meaning that there is less material excavated for construction than what is needed to construct the new canal embankments, and contractors would obtain additional material from off-site sources. Surplus is the positive difference between excavation and embankment construction, meaning that more is material available than needed, and the surplus will be disposed. Balance occurs when the excavation material and embankment construction are approximately equal.

Evaluation

From preliminary designs, estimates were developed for both excavated material to construct the canal prism and fill material required for embankment construction. As shown in Table 7, Alternatives 5A and 5B received a score of 5 under the current land surface condition because the earthwork calculations are considered balanced within the error limits. However, neither alternative is considered balanced when the earthwork calculations take future subsidence into consideration. To accommodate subsidence, Alternatives 5A and 5B would both require borrow to raise the embankments relative to a future subsided condition.

Alternative 1 also requires borrow under both the current land surface condition and with future subsidence. Because Alternative 1 does not involve any new excavation work, it requires a significant amount of borrow. Thus, it received the lowest score under both conditions. Note that in Table 7, there is a weighted assessment value which doubles the borrow quantities. The doubling was an internal weighting mechanism because borrow difficult to acquire and costly.

Table 7. Material Balance Scoring Under Current Land Surface and Future Subsidence

Alternative	Quantity (1,000 yd^3)		Weighted Assessment Value* (1,000 yd^3)		Score	
	Current	Future	Current	Future	Current	Future
1	(-) 1,550	(-) 2,991	(-) 3,101*	(-) 5,982	1.0	1.0
2	(+) 540	(+) 200	(+) 540	(+) 200	4.3	5.0
3	(+) 945	(-) 435	(+) 945	(-) 870	3.8	4.5
4A	(+) 1,750	(+) 649	(+) 1,750	(+) 649	2.7	4.7
4B	(+) 2,418	(+) 1,308	(+) 2,418	(+) 1,308	1.9	4.2
5A	Balanced	(-) 765	Balanced	(-) 1,530	5.0	4.1
5B	Balanced	(-) 268	Balanced	(-) 536	5.0	4.8

Note
*Weighted Assessment Value doubles the quantities if there was borrow
Key:
yd^3 = cubic yards
Legend: (+) Surplus; (-) Borrow

II. Operational Requirements and Flexibility

The Operational Requirements and Flexibility criterion pertains to the ability to operate and maintain the project. The following sub-criterion were identified to evaluate alternatives under the Operation Requirements and Flexibility criterion:

- OPS-1 — additional O&M requirements and expertise of FWA staff,
- OPS-2 — operations of district turnouts, and
- OPS-3 — the ability to accommodate power outages.

A summary table of results for Operations Requirements and Flexibility sub-criteria is presented in Table 8 that depicts the scores under current land surface conditions and with future subsidence conditions. Because all three sub-criteria are qualitative, the scores do not change between the two conditions, with the exception of the scores for Alternatives 2 and 3 under OPS-3. Detailed descriptions and evaluations are provided below for each sub-criterion.

Table 8. Operational Requirements and Flexibility Score Summary

	OPS-1		OPS-2		OPS-3	
Alternative	**Current**	**Future**	**Current**	**Future**	**Current**	**Future**
1: Canal Enlargement	5.0	5.0	5.0	5.0	5.0	5.0
2: Pump Station at MP 109	2.0	2.0	3.0	3.0	2.0	1.0
3: Woollomes Pump Station	1.0	1.0	3.0	3.0	2.0	1.0
4A: Bypass Canal—Tule River to White River	4.0	4.0	2.0	2.0	5.0	5.0
4B: Bypass Canal—Tule River to Woollomes	3.0	3.0	1.0	1.0	5.0	5.0
5A: Parallel—Tule River to White River	4.0	4.0	4.0	4.0	5.0	5.0
5B: Parallel Canal—Tule River to Woollomes	3.0	3.0	3.0	3.0	5.0	5.0

Key:
MP = Milepost

OPS-1. Additional O&M Requirements and Expertise of FWA Staff

Description

A qualitative sub-criterion used to distinguish how complex an alternative would affect the long-term O&M activities and required expertise of FWA O&M staff in comparison to current conditions.

Evaluation

Alternative 1 would restore capacity by enlarging the existing canal without adding a bypass canal or pump station. Alternative 1 was assigned a score of 5 because the total length of canal to be operated and maintained would not change. Although Alternative 1 has a bench that may increase some of the normal O&M in this section, it is expected to be minor changes. Alternatives 4A/4B and 5A/5B, on the other hand, require extensive changes to O&M since they include a bypass canal that would require FWA to operate and maintain two canals rather than one.

Alternatives 4A and 5A were assigned a score of 4 and Alternatives 4B and 5B were assigned a score of 3 because of the extended length of the bypass and the additional check structures. Alternatives 2 was a assigned a score of 2 because inclusion of a pump station that would require numerous to significant additional O&M requirements and expertise that exceed the current capabilities of FWA staff. Alternative 3 was assigned a score of 1 because it includes a pump station and a bypass canal. A summary of these scores are presented in Table 9. Note that the scores did not change from current land conditions to future conditions with subsidence because the O&M requirements would be similar under both conditions.

Table 9. Additional Operations and Maintenance Requirements and Expertise of Friant Water Authority Staff Scoring

Assessment Value	Score	Alternative
No additional requirements	5.0	1
Few additional requirements	4.0	4A, 5A
Some additional requirements	3.0	4B, 5B
Numerous additional requirements	2.0	2
Significant additional requirements	1.0	3

OPS-2. Operations of District Turnouts

Description

This qualitative sub-criterion characterizes the relative effect of each alternative on existing FKC turnouts. The sub-criterion highlights whether an alternative would require slight modifications, new structures to improve water surface elevations, or new turnouts to be constructed. The analysis was based on general observations from initial hydraulic model results and should not be considered a final determination of project requirements.

Evaluation

As shown in Table 10, Alternative 1 was assigned the highest score because it would not impact operations of district turnouts. The original turnouts could be used because the enlarged canal would transition to the existing canal width at the major turnouts. Alternative 2 was assigned a score of 3 because some turnouts may need to be modified to accommodate the potential lower water surface elevation caused by the pump station. Alternatives 3 was also assigned a score of 3 because the bypass canal could require construction of new turnouts to serve districts east of the FKC.

Alternatives 4A and 4B involve a bypass canal at different lengths. In general, the longer and more complex the bypass is, the more turnouts would be impacted, and the more additional canal modifications would be required to maintain water deliveries, thus resulting in lower scores. Alternative 4A was assigned a score of 2 and Alternative 4B was assigned a score of 1. Alternatives 5A and 5B involve a parallel canal at different lengths, however turnouts would be affected only on the east side of the FKC. As a result, Alternative 5A was assigned a score of 4 and Alternative 5B was assigned as score of 3. Note that the scores did not change from current land conditions to future conditions with subsidence as the turnout design elements based on the proposed HGL are independent of subsidence.

Table 10. Operations of District Turnouts Scoring

Assessment Value	Score	Alternative
No changes	5.0	1
Few changes	4.0	5A
Some changes	3.0	2, 3, 5B
Numerous changes	2.0	4A
Significant changes	1.0	4B

OPS-3. Ability to Accommodate Power Outages

Description

This is a qualitative sub-criterion that addresses how an alternative would function in the event of a power outage.

Evaluation

As shown in Table 11, Alternatives 1, 4A, 4B, 5A, and 5B were assigned a score of 5 because they are all gravity solutions, meaning that they do not require electricity to move water, and thus would be unaffected by power outages. Conversely, Alternatives 2 and 3 incorporate pump stations that require electrical power. If a power outage were to occur, the pumping plants would stop working and water deliveries would be limited to the gravity bypass flow capacity, impacting water deliveries for a period of time.

Table 11. Ability to Accommodate Power Outages Scoring

Assessment Value	Score	Alternative
Not Affected by Power Outages	5.0	1, 4A, 4B, 5A, 5B
Power Facilities Included; Deliveries Not Affected	4.0	—
Power Facilities Included; Moderate Potential to Impact Deliveries During Outage	3.0	—
Power Facilities Included; Significant Potential to Impact on Deliveries During Outage	2.0	2, 3[1]
Power Facilities Included; Extreme Potential to Impact Deliveries During Outage	1.0	2, 3[2]

Notes: 1. Current land condition 2. Future subsided condition

As subsidence continues in the future, the gravity bypass capacity will decline and the volume that would be pumped would be used will increase, thereby increasing the potential severity of water delivery impacts. In recognition of this, Alternatives 2 and 3 were assigned a score of 2 under current and future subsided conditions and a score of 1 under future subsidence conditions.

III. Cost

The Cost criterion refers to the capital and long-term annual costs associated with construction and operations and maintenance of an alternative. The following sub-criteria were developed to evaluate alternatives under the Cost criterion:

- COST-1 — construction cost,
- COST-2 — non-contract cost, and
- COST-3 — present worth of additional O&M and replacement cost.

A summary table of result for Cost sub-criteria is presented in Table 12 that depicts scores under current land surface conditions and with future subsidence conditions. Detailed descriptions and evaluations are provided below for each cost sub-criterion.

Table 12. Cost Score Summary

Alternative	COST-1		COST-2		COST-3	
	Current	Future	Current	Future	Current	Future
1: Canal Enlargement	4.1	3.2	5.0	4.8	5.0	5.0
2: Pump Station at MP 109	5.0	5.0	4.0	5.0	1.5	1.5
3: Woollomes Pump Station	1.0	1.0	1.0	1.0	1.0	1.0
4A: Bypass Canal—Tule River to White River	4.1	3.9	3.5	4.1	4.1	4.1
4B: Bypass Canal—Tule River to Woollomes	3.2	2.8	2.2	2.3	3.6	3.6
5A: Parallel—Tule River to White River	3.7	3.9	4.0	4.8	4.2	4.2
5B: Parallel Canal—Tule River to Woollomes	3.7	3.2	3.8	4.1	3.7	3.7

COST-1. Construction Cost

Description

This is a quantitative sub-criterion that details the construction cost of each alternative. Construction costs includes items such as line item buildups, mobilization, construction contingencies, and design contingencies. For a break-down of the construction costs, refer to Appendix B Engineering Cost and Design.

Evaluation

Under the current land surface condition, the alternatives range in cost from approximately $220 million to $310 million. For most of the alternatives, this range cost results primarily due to the amount of canal enlargement, bypass canal construction, and number of new or replaced bridges. As shown in Table 13, Alternatives 2 and 3, which include pump stations, represent the least and most costly alternatives, respectively. Alternative 2 has the least construction cost because it has the fewest bridge replacements and no bypass canal. Alternative 3 has the greatest construction cost because it incorporates both canal enlargement and a bypass canal, requires numerous bridge modifications, and includes a pump station at Lake Woollomes. Alternatives 2 and 3 both include costs for an emergency reservoir necessary for the diversion of water in the event of a power failure.

Table 13. Construction Cost Scoring Under Current Land Surface/Future Subsidence

	Assessment Value ($M)			Score	
Alternative	Current	Future	Additional Cost in Future ($M)	Current	Future
1	$240	$280	$40	4.1	3.2
2	$220	$230	$10	5.0	5.0
3	$310	$340	$30	1.0	1.0
4A	$240	$260	$20	4.1	3.9
4B	$260	$290	$30	3.2	2.8
5A	$250	$260	$10	3.7	3.9
5B	$250	$280	$30	3.7	3.2

Under the future subsidence condition, all alternatives would require more material to raise the lining and the embankment. Additionally, several bridges would need to be raised to maintain the HGL. Bridge raising, plus the new material, result in an additional $14 to $35 million in construction cost. Alternative 3 remains the costliest to construct under a future subsidence condition.

COST-2. Non-contract Cost

Description

Non-contract cost is a qualitative sub-criterion that refers to the costs of work or services provided in support of implementing an alternative, including environmental mitigation, planning, permitting, design, construction management, legal and administrative, and land acquisition. For a detailed breakdown of these costs, refer to Appendix B Engineering Costs and Design.

Evaluation

Non-contract costs were calculated as a percentage of the construction cost for all categories except total land purchase. Environmental mitigation was assigned 7 percent, planning/permitting/design/construction management was assigned 10 percent, and legal and administrative was assigned 2 percent of the construction cost. Total land acquisition cost was calculated using the land requirements for each alternative and an assumed cost of $25,000 per acre. The results of this evaluation are shown below in Table 14.

Table 14. Non-Contract Cost Scoring Under Current Land Surface and Future Subsidence

	Assessment Value ($M)			Score	
Alternative	Current	Future	Additional Cost in Future ($M)	Current	Future
1	$46	$55	$9	5.0	4.8
2	$52	$54	$2	4.0	5.0
3	$70	$76	$6	1.0	1.0
4A	$55	$59	$4	3.5	4.1
4B	$63	$69	$6	2.2	2.3
5A	$52	$55	$3	4.0	4.8
5B	$53	$59	$6	3.8	4.1

Even though non-contract costs are mainly a percentage of the construction costs, they are differentiated by the land acquisition cost. Alternative 1 has a high construction cost, however it requires the least amount of land; therefore, it is the most cost effective and received the most favorable score of 5. Alternative 3, on the other hand, requires significant land purchase and is the most expensive to construct, and received the lowest score of 1.

Alternative 3 would remain the most expensive when future subsidence conditions are taken into consideration. The price increase for Alternative 3, as well as the other alternatives, can largely be attributed to the additional right of way (ROW) required to construct higher embankments.

COST-3. Present Worth Additional Operations, Maintenance & Replacement Costs

Description

The operations, maintenance, and replacement (OM&R) costs for the canal represent additional costs resulting from the new structures to be built, on top of FWA's existing annual OM&R budget. For the pump station OM&R annual costs, the estimate includes power consumption, labor costs, and major equipment rehabilitation and replacement over 50 years. The pump station rehabilitation and replacement costs include mobilization, contingency, and non-contract costs. For more detailed information on the additional OM&R costs, refer to Appendix B Engineering Cost and Design.

Evaluation

The analysis reveals that more complex actions entail more OM&R costs. Alternative 1, for example, would require OM&R actions similar to those of the current FKC, and therefore has the lowest additional costs. Conversely, Alternative 3 involves modifications to the existing canal, a bypass canal, and a pump station, all of which result in higher additional OM&R costs (see Table 15). Note that the scores were not changed from current land conditions to future conditions with subsidence.

Table 15. Present Worth Additional Operations, Maintenance, and Replacement Costs Scoring

Assessment Value ($M)	Score	Alternative
$0.3	5.0	1
$0.9	4.2	5A
$1	4.1	4A
$1.3	3.7	5B
$1.4	3.6	4B
$3.1	1.5	2
$3.5	1.0	3

IV. Schedule

The Schedule criterion provides an indication of how long it will take to construct the project and realize benefits as well as the items that could affect the timeline. The following six sub-criteria were developed to evaluate alternatives under the Schedule criterion:

- SCH-1 — time to start construction,
- SCH-2 — construction duration,
- SCH-3 — time until benefits realized,
- SCH-4 — potential to phase construction,
- SCH-5 — land acquisition, and
- SCH-6 — schedule risk.

A scoring summary table for the Schedule sub-criteria is presented in Table 16. Note that only the scores in SCH-5 changed under current land surface conditions and with future subsidence conditions. Detailed descriptions and evaluations are provided below for each schedule sub-criterion.

Table 16. Schedule Score Summary

	SCH-1		SCH-2		SCH-3		SCH-4		SCH-5		SCH-6	
Initial Alternative	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**	**C**	**F**
1: Canal Enlargement	5.0	5.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0	4.0	4.0
2: Pump Station at MP 109	3.0	3.0	4.0	4.0	3.0	3.0	3.0	3.0	2.1	2.4	2.0	2.0
3: Woollomes Pump Station	2.0	2.0	3.0	3.0	2.0	2.0	2.0	2.0	1.2	1.2	1.0	1.0
4A: Bypass Canal —Tule River to White River	2.0	2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.2	2.4	3.0	3.0
4B: Bypass Canal —Tule River to Woollomes	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0
5A: Parallel Canal —Tule River to White River	3.0	3.0	2.0	2.0	3.0	3.0	4.0	4.0	3.7	4.1	5.0	5.0
5B: Parallel Canal —Tule River to Woollomes	2.0	2.0	1.0	1.0	3.0	3.0	4.0	4.0	3.2	3.5	5.0	5.0

Key:
MP = Milepost
C = Current
F = Future

SCH-1. Time to Start Construction

Description

This is a qualitative sub-criterion that assesses the time it will take to complete pre-construction actives and begin construction based on the expected schedule risks.

Evaluation

The time to start construction will be affected by the land acquisition process, and regulatory compliance requirements associated with biological and cultural resources. In general, the more ROW that is required for an alternative, the lower the assigned alternative score because of the time that will be required to secure ROW. Similarly, alternatives that affect known biological resources may require more complex environmental compliance processes and mitigation requirements, which would add to the schedule before construction could begin.

At the time this evaluation was completed, limited information was available about specific biological or cultural resources, other than the potential presence of San Joaquin kit fox habitat along existing FKC embankments and the limited extent of an existing programmatic agreement between FWA and the State Historical Preservation Officer (SHPO). A more detailed discussion of environmental resource constraints is presented in Appendix C Environmental Constraints Analysis Summary and addressed in the environmental evaluation criteria in a later section of this Appendix.

Alternative 1 was assigned a score of 5 because it requires the least amount of land acquisition for ROW. Alternative 4B was assigned the lowest score because it requires the most amount of land acquisition for ROW and would involve the construction of siphons below two streams, which may require obtaining a Section 404 permit from the U.S. Army Corps of Engineers (USACE). Note that the scores did not change from current land conditions to future conditions with subsidence as the construction schedule is independent of subsidence.

Table 17. Time to Start Construction Scoring

Assessment Value	Score	Alternative
Approx. 0-1 years	5.0	1
Approx. 1-2 years	4.0	—
Approx. 2-3 years	3.0	2, 5A
Approx. 3-4 years	2.0	3, 4A, 5B
Approx. 4+ years	1.0	4B

SCH-2. Construction Duration

Description

This is a qualitative sub-criterion that considers a generalized expected construction schedule based on the complexity of each alternative.

Evaluation

Through examining the known schedule risks, described further in SCH-6, experts determined that all alternative would take at least a year to complete. As demonstrated in Table 18, Alternatives 1 and 2, however, could likely be completed within one to two years since they mainly modify the existing canal. Conversely, Alternatives 3, 4A, 4B, 5A, and 5B include a new canal that would increase the construction timeframe. The longer and more complex the new canal, the longer experts expect the construction to last. Note that the scores did not change from current land conditions to future conditions with subsidence as the construction schedule is independent of subsidence.

Table 18. Construction Duration Scoring

Assessment Value	Score	Alternative
Approx. 0-1 years	5.0	—
Approx. 1-2 years	4.0	1, 2
Approx. 2-3 years	3.0	3
Approx. 3-4 years	2.0	4A, 5A
Approx. 4+ years	1.0	4B, 5B

SCH-3. Time Until Benefits Realized

Description

A qualitative sub-criterion that addresses when increases in capacity allowing additional water delivery, either in part or in total, is expected to begin.

Evaluation

The time until benefits are realized is primarily a function of the alternative design. Alternatives with a bypass or parallel canal will not restore capacity until the new canal is tied into the existing canal, whereas alternatives that modify the existing canal will result in more immediate benefits. As such, Alternative 1 was assigned the highest score because any modified segment could be placed into service immediately following construction completion.

Alternative 2 was assigned a score of 3 because it includes modifications to the existing canal but requires the installation of several pumps before the capacity is restored. In addition to the pumps, Alternative 3 has a bypass canal so it was assigned of a lower score of 2. Alternatives 4A and 4B also have a bypass canal but were assigned a score of 1 because neither could be put into service until the canal and tie-ins are complete. Alternatives 5A and 5B were both assigned scores of 3 because the tie-ins would need to be completed before the parallel canal can operate, but capacity would increase as soon as one segment was constructed. The scores do not change from current land conditions to future conditions with subsidence as the time until benefits are realized is independent of subsidence.

Table 19. Time Until Benefits Realized Scoring

Assessment Value	Score	Alternative
Early During Construction	5.0	1
During Construction	4.0	—
After Partial Completion	3.0	2, 5A, 5B
After Substantial Completion	2.0	3
After Completion	1.0	4A 4B

SCH-4. Potential to Phase Construction

Description

This is a qualitative sub-criterion that addresses the ability to construct an alternative in phases or to expand an alternative at a later date. A phased construction approach could accommodate potential funding constraints and future subsidence.

Evaluation

The potential for phasing is dependent upon the proposed design; modifications are easier to incorporate into some designs than others (see Table 20). Alternative 1 was assigned a score of 5 because phasing can be easily accomplished during construction or at a later date. Modifications to any canal segment could be put into service once it is complete and expanded in the future. Likewise, the parallel canal in Alternatives 5A and 5B could be constructed and expanded in segments, but the tie-ins would need to be built initially, resulting in an assigned score of 4. Alternative 2 was assigned a score of 3 because pumping units could be installed in phases as subsidence progresses, once the pumping plant structure is initially constructed.

Alternative 3 was assigned a lower score (2) than Alternative 2 because the bypass canal would also need to be constructed initially. Alternatives 4A and 4B would need to be fully constructed before they could become operational; therefore, these alternatives were assigned a score of 5.

Table 20. Potential to Phase Construction Scoring

Assessment Value	Score	Alternative
All features can be phased	5.0	1
Most project features can be phased	4.0	5A, 5B
Moderate potential for phasing	3.0	2
Most project features constructed at once	2.0	3
All project features constructed at once	1.0	4A, 4B

SCH-5. Land Acquisition

Description

This is a quantitative sub-criterion based on the amount of land acquisition for ROW expansion. Only permanent ROW that would underlie project facilities is considered in this evaluation. Additional ROW needed for construction or permanent access, or for material borrow or disposal is not considered in this evaluation.

Evaluation

The amount of land needed to extend the ROW was determined using the design drawings. Using the canal stations as a point of reference, the extent of land beyond the current ROW required for project features was calculated. Alternative 1 would enlarge the existing canal and would involve extending the embankments beyond the existing ROW, requiring an additional 170 acres of land.

As shown in Table 21, all subsequent alternatives require hundreds of more acers than Alternative 1. The significant change in land required from Alternative 1 to Alternatives 2 and 3 is predominately a factor of the 350 to 400-acre emergency reservoirs necessary should the pump stations fail. Yet, neither pump station alternative requires the most acreage. Alternative 4B, with a bypass canal from Tule River to Woollomes, in conjunction with some existing canal enlargement, requires the most acreage (650 acres) and therefore received the lowest score of 1.

Table 21. Land Acquisition Required Scoring Under Current Land Surface and Future Subsidence

	Assessment Value (Acres)			Score	
Alternative	Current	Future	Additional Acres in Future	Current	Future
1	170	261	91	5.0	5.0
2	522	534	12	2.1	2.4
3	622	671	48	1.2	1.2
4A	508	542	34	2.2	2.4
4B	650	688	38	1.0	1.0
5A	321	355	35	3.7	4.1
5B	390	423	33	3.2	3.5

SCH-6. Schedule Risk

Description

This is a qualitative sub-criterion that accounts for the foreseeable and unforeseeable schedule risks to a project. Risks refer broadly to items that involve decisions by others or items that have not been sufficiently defined to allow for a full understanding of the schedule implications. Items considered in schedule risk include land acquisition, environmental compliance, constructability, and interagency coordination.

Evaluation

Schedule risk was assigned based on the complexity of each alternative; alternatives with a greater number of actions that present potential schedule risk were assigned lower scores, particularly as it relates to ROW and environmental permitting. Although Alternative 5A and 5B require more acres for ROW than Alternative 1, both Alternatives 5A and 5B mainly disrupt the east bank of the canal, whereas Alternative 1 disrupts both sides of the canal. Land acquisition on only one side of the canal likely means fewer transactions and less schedule risk. As a result, Alternatives 5A and 5B were assigned the highest score and Alternative 1 a score of 4.

Conversely, Alternatives 2 and 3 are considered more complex, requiring more land and large lead times for mechanical manufacturing and pump installation. Alternative 3 was assigned a lower score than Alternative 2 because it also requires permitting for a new siphon at White River.

Table 22. Schedule Risk Scoring

Assessment Value	Score	Alternative
Minimal risk	5.0	5A, 5B
Some risks	4.0	1
Few risks	3.0	4A
Numerous risks	2.0	2, 4B
Significant risk	1.0	3

V. Environmental Compliance and Permitting

The Environmental Compliance and Permitting criterion addresses the complexity to complete National Environmental Policy (NEPA)/California Environmental Quality Act (CEQA) documentation and obtain necessary permits. The following four sub-criteria were developed to evaluate alternatives under the constructability Environmental Compliance and Permitting criterion:

- ENV-1 — complexity of required environmental compliance,
- ENV-2 — number of stream crossings,
- ENV-3 — number of bridges, and
- ENV-4 — total length of modified embankment.

A scoring summary table is presented below that includes both the current and future conditions score (Table 23). Note that the scores did not change for any of the sub-criterion from one condition to the other. For a detailed review of the environmental considerations and constraints, refer to Appendix C Environmental Constraints Analysis Summary.

Table 23. Environmental Compliance and Permitting Score Summary

	ENV-1		ENV-2		ENV-3		ENV-4	
Alternative	**Current**	**Future**	**Current**	**Future**	**Current**	**Future**	**Current**	**Future**
1: Canal Enlargement	3.0	3.0	5.0	5.0	3.8	3.8	1.0	1.0
2: Pump Station at MP 109	1.0	1.0	5.0	5.0	5.0	5.0	2.2	2.2
3: Woollomes Pump Station	1.0	1.0	3.0	3.0	1.4	1.4	4.4	4.4
4A: Bypass Canal—Tule River to White River	1.0	1.0	3.0	3.0	3.4	3.4	4.0	4.0
4B: Bypass Canal—Tule River to Woollomes	1.0	1.0	1.0	1.0	1.0	1.0	5.0	5.0
5A: Parallel—Tule River to White River	1.0	1.0	5.0	5.0	3.4	3.4	2.5	2.5
5B: Parallel Canal—Tule River to Woollomes	1.0	1.0	5.0	5.0	1.0	1.0	3.0	3.0

ENV-1. Complexity of Required Environmental Compliance

Description

This is a qualitative sub-criterion that captures the complexity of the expected environmental compliance activities and documentation necessary to satisfy NEPA and CEQA.

Evaluation

From preliminary conversations with the relevant federal agencies, it was determined that all alternatives will likely require an Environmental Impact Statement/Report (EIS/R). As such, no alternative was considered "not complex" as it pertains to environmental compliance (see Table 24). However, Alternative 1 is less environmentally complex than other alternatives because it requires the least land that could be environmentally or culturally significant. Additionally, Alternative 1 does not require new siphons or operations, reducing the permitting complexity. Alternatives 2 through 5B, however, require greater ROW than Alternative 1, changes to FKC operations, and some require new siphons, resulting in high environmental compliance complexity.

Table 24. Complexity of Required Environmental Compliance Scoring

Assessment Value	Score	Alternative
Not complex	5.0	—
Moderately Complex	3.0	1
Highly Complex	1.0	2, 3, 4A, 4B, 5A, 5B

ENV-2. Number of Stream Crossings

Description

This is a quantitative sub-criterion based on the number of new stream crossings included in an alternative. This sub-criterion is indicative of potential impacts to wetlands and the extent of Clean Water Act (CWA) 404, Regional Water Quality Control Board (RWQCB) 401, and California Department of Fish and Wildlife (CDWF) 1600 permit.

Evaluation

The design details reveal the number of construction features that would cross a stream. Alternatives 1, 2, 5A, and 5B would not require the construction of additional siphons or modification of the existing siphons. Therefore, none of these four alternatives are anticipated to have any impact on wetlands or waters of the United States at the stream crossings and were assigned a score of 5 (see Table 25).

Alternatives 3, 4A, and 4B include a new siphon below Deer Creek, likely necessitating instream construction. Work within waters of the United States will likely require a CWA section 404 permit from USACE, CWA 401 authorization from the RWQCB, and a CDFW section 1600 streambed alteration agreement. In addition to the permits required for Deer Creek, Alternative 4B includes a siphon at White River, and thus was assigned a score of 1.

Table 25. Number of Stream Crossings Score

Assessment Value (Number of Stream Crossings)	Score	Alternative
0	5.0	1, 2, 5A, 5B
1	3.0	3, 4A
2	1.0	4B

ENV-3. Number of Bridges

Description

This is a quantitative sub-criterion based on the number county and state bridges[1] that will need to be either constructed over a bypass canal or replaced or raised on the existing FKC. Permits will be required for replacement or alteration of county or state bridges. Modification or replacement of bridges also will earthwork, and can affect traffic access or patterns, as detailed in Appendix C Environmental Constraints Analysis Summary.

Evaluation

To accommodate a higher flow and the canal enlargement, Alternative 1 would require replacing seventeen county or state bridges. Alternative 2 would not require widening or raising a portions of the FKC and therefore would affect fewer bridges than Alternative 1. In addition to bridge replacements, alternatives with a bypass require many new bridges which lowered the scores, as demonstrated in Table 26.

Table 26. Number of Bridges Scoring

Assessment Value (Number of Affected Bridges)	Score	Alternative
14	5.0	2
17	3.8	1
18	3.4	4A, 5A
23	1.4	3
24	1.0	4B, 5B

[1] Farm bridges were not considered in the Initial Alternatives Evaluation and Comparison at the direction of FWA. Farm bridges are relatively minor structures and it is unclear at this time if they would be replaced.

ENV-4. Length of Modified Existing Embankment

Description

This is a quantitative sub-criterion based on the number of miles of existing FKC embankment that would be modified. The existing FKC embankment contains several burrows that may provide potential habitat for the endangered San Joaquin kit fox.

Based on the preliminary review of biological resources, the San Joaquin kit fox is the primary species of concern within the project area. The San Joaquin kit fox was listed as endangered under the Endangered Species Act (ESA) on March 11, 1967; and was listed as threatened under the California Endangered Species Act (CESA) on June 27, 1971. Throughout the project area, burrows on the FKC embankments provide potential denning habitat for San Joaquin kit fox in a landscape where most of their natural habitat has been converted to agricultural use. There are six California Natural Diversity Database (CNDDB)-reported occurrences of San Joaquin kit fox that intersect the project alignment and several others within 5-miles of the project alignment. Most of the CNDDB records date back to 1975, with the most recent observation (CNDDB Occurrence Number 376) of a known den recorded in 2005, located less than one mile west of the Friant-Kern Canal MP 120.35. Another occurrence (CNDDB Occurrence Number 148) from 1993 was recorded along the FKC at MP 129.07 (California Department of Fish and Wildlife 2018).

During reconnaissance-level field surveys for the Immediate Repairs project, biologists identified approximately 58 potential dens (e.g., burrows 4 to 12 inches in diameter) along an approximately 3.68-mile reach of the FKC (7.36-miles of embankment) between the Avenue 96 bridge (MP 103.66) and the Road 192 bridge (MP 107.34). Scat and prey remains were observed at three of the 58 potential dens. While it is not known if the scat and prey remains are attributable to San Joaquin kit fox, it is an indicator of possible use by this species. It is anticipated that potential dens are present along the entire alignment of the FKC within the project area.

Evaluation

Given that all the project alternatives would disturb potential dens along the FKC, all project alternatives have a potential to adversely affect San Joaquin kit fox. Such project-related effects could potentially result in “take” under the ESA and CESA, however the basis to determine “take” has not yet been established with U.S. Fish and Wildlife Services (USFWS) and CDFW. Consultation with the USFWS under section 7 of the ESA and CDFW under the CESA incidental take permitting will like be required for all project alternatives. Mitigation measures would need to be developed to avoid or minimize potential project-related impacts.

Table 27. Length of Modified Existing Embankment Scoring

Assessment Value (Affected Miles of Existing FKC Embankment)	Score	Alternative
19.9	5.0	4B
26.9	4.4	3
32.1	4.0	4A
43.5	3.0	5B
49.4	2.5	5A
52.5	2.2	2
66.6	1.0	1

Based on the assumption that the potential Kit Fox habitat is uniformly distributed along existing FKC embankments, some alternatives would affect more potential habitat than others. Alternative 4B would modify the least embankment and is therefore the least disruptive to the San Joaquin Kit Fox. Alternative 1 would modify the entire middle stretch of the canal on both sides and is considered the most disruptive to potential kit fox habitat.

Summary

Tables 28 and 29 provides a summary table for the range of scores assigned to each sub-criterion. The colors indicate the favorability of the score; green is the most favorable (5) and red is the least favorable (1).

Table 28. Current Conditions Summary Scores

Alternative	I. Constructability					II. Operational Requirements and Flexibility			III. Cost			IV. Schedule						V. Environmental Compliance and Permitting			
	CON-1. Complexity to maintain water deliveries during construction	CON-2. Ability to O&M canal during construction	CON-3. Temporary bypasses & tie-ins needed to construct the project	CON-4. Extent of dewatering	CON-5. Material Balance	OPS-1. Additional O&M requirements and expertise of FWA	OPS-2. Operations of district turnouts	OPS-3. Ability to accommodate power outages	COST-1. Construction cost	COST-2. Non-contract cost	COST-3. PV of 50 Years OM&R	SCH-1. Time to start construction	SCH-2. Construction duration	SCH-3. Time until benefits realized	SCH-4. Potential to phase construction	SCH-5. Land acquisition	SCH-6. Schedule Risk	ENV-1. Complexity of required environmental compliance	ENV-2. Number of stream crossings	ENV-3. Number of bridges	ENV-4. Length of modified existing embankment
1	1.0	1.0	1.0	5.0	1.0	5.0	5.0	5.0	4.1	5.0	5.0	5.0	4.0	5.0	5.0	5.0	4.0	3.0	5.0	3.8	1.0
2	2.0	2.0	1.2	4.0	4.3	2.0	3.0	2.0	5.0	4.0	1.5	4.0	4.0	3.0	3.0	2.1	2.0	1.0	5.0	5.0	2.2
3	3.0	3.0	3.3	1.0	3.8	1.0	3.0	2.0	1.0	1.0	1.0	2.0	3.0	3.0	2.0	1.2	1.0	1.0	3.0	1.4	4.4
4A	4.0	4.0	4.5	4.0	2.7	4.0	2.0	5.0	4.1	3.5	4.1	2.0	2.0	1.0	1.0	2.2	3.0	1.0	3.0	3.4	4.0
4B	5.0	5.0	5.0	3.0	1.9	3.0	1.0	5.0	3.2	2.2	3.6	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	5.0
5A	4.0	4.0	4.2	3.0	5.0	4.0	4.0	5.0	3.7	4.0	4.2	3.0	2.0	3.0	4.0	3.7	5.0	1.0	5.0	3.4	2.5
5B	5.0	5.0	4.4	2.0	5.0	3.0	3.0	5.0	3.7	3.8	3.7	2.0	1.0	3.0	4.0	3.2	5.0	1.0	5.0	1.0	3.0

Table 29. Future with Subsidence Condition Summary Scores

Alternative	I. Constructability					II. Operational Requirements and Flexibility			III. Cost			IV. Schedule						V. Environmental Compliance and Permitting			
	CON-1. Complexity to maintain water deliveries during construction	CON-2. Ability to O&M canal during construction	CON-3. Temporary bypasses & tie-ins needed to construct the project	CON-4. Extent of dewatering	CON-5. Material Balance	OPS-1. Additional O&M requirements and expertise of FWA staff	OPS-2. Operations of district turnouts	OPS-3. Ability to accommodate power outages	COST-1. Construction cost	COST-2. Non-contract cost	COST-3. PV of 50 Years OM&R	SCH-1. Time to start construction	SCH-2. Construction duration	SCH-3. Time until benefits realized	SCH-4. Potential to phase construction	SCH-5. Land acquisition	SCH-6. Schedule Risk	ENV-1. Complexity of required environmental compliance	ENV-2. Number of stream crossings	ENV-3. Number of bridges	ENV-4. Length of modified existing embankment
1	1.0	1.0	1.0	5.0	1.0	5.0	5.0	5.0	3.2	4.8	5.0	5.0	4.0	5.0	5.0	5.0	4.0	3.0	5.0	3.8	1.0
2	2.0	2.0	1.2	4.0	5.0	2.0	3.0	1.0	5.0	5.0	1.5	3.0	4.0	3.0	3.0	2.4	2.0	1.0	5.0	5.0	2.2
3	3.0	3.0	3.3	1.0	4.5	1.0	3.0	1.0	1.0	1.0	1.0	2.0	3.0	2.0	2.0	1.2	1.0	1.0	3.0	1.4	4.4
4A	4.0	4.0	4.5	4.0	4.7	4.0	2.0	5.0	3.9	4.1	4.1	2.0	2.0	1.0	1.0	2.4	3.0	1.0	3.0	3.4	4.0
4B	5.0	5.0	5.0	3.0	4.2	3.0	1.0	5.0	2.8	2.3	3.6	1.0	1.0	1.0	1.0	1.0	2.0	1.0	1.0	1.0	5.0
5A	4.0	4.0	4.2	3.0	4.1	4.0	4.0	5.0	3.9	4.8	4.2	3.0	2.0	3.0	4.0	4.1	5.0	1.0	5.0	3.4	2.5
5B	5.0	5.0	4.4	2.0	4.8	3.0	3.0	5.0	3.2	4.1	3.7	2.0	1.0	3.0	4.0	3.5	5.0	1.0	5.0	1.0	3.0

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