Technical Memorandum

To:	Tule Subbasin Technical Advisory Committee c/o Mr. R.L. Schafer, Coordinator
From:	Thomas Harder, P.G., C.HG. Thomas Harder & Co.
Date:	3-Jan-20
Re:	Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal within the Tule Subbasin

1 Introduction

This technical memorandum (TM) summarizes an analysis of the relative cause of future predicted land subsidence along a section of the Friant-Kern Canal (FKC) that lies within the eastern portion of the Tule Subbasin in Tulare County, California (see Figure 1). Historical land subsidence along a section of the FKC in the Tule Subbasin has resulted in a depression in the canal, which restricts the volume of water the Friant Water Authority (FWA) can deliver downstream of the affected area. The FWA is in the process of preparing design plans to repair the damage to the canal from historical land subsidence. However, additional land subsidence is predicted to occur in the future as groundwater pumping rates in the Tule Subbasin are transitioned from overdraft conditions to sustainable conditions.

The Tule Subbasin Technical Advisory Committee (TAC) desires to coordinate future groundwater management plans within the subbasin with on-going efforts by the FWA to repair the canal and restore its original flow capacity. A primary planned management action for Groundwater Sustainability Agencies (GSAs) within the Tule Subbasin whose water supply portfolio is not sustainable is the gradual reduction in groundwater pumping after 2020 to achieve a balance of recharge and discharge (i.e. sustainability) by 2040, in accordance with the Sustainable Groundwater Management Act (SGMA). As the subbasin is currently in overdraft resulting in declining groundwater levels which contribute to land subsidence, any delay in implementing the pumping reduction management action risks additional land subsidence beneath the canal, which will need to be accounted for by the FWA and their engineering design team in implementing the canal repair. The cost of the repair is related to the amount of land subsidence they need to address.

1.1 Purpose and Scope

Of the Tule Subbasin GSAs that need to reduce groundwater production in order to be sustainable, all are planning to reduce pumping gradually into the future (i.e. transitional pumping) to allow growers to plan and adjust to the new pumping requirements. Accordingly, the delay in reaching sustainable pumping levels is anticipated to result in continued declining groundwater levels and land subsidence beneath the FKC during the transitional pumping period between 2020 and 2040. The purpose of the analysis presented herein is to predict the relative contribution to land subsidence beneath the FKC between the various agencies and growers in the Tule Subbasin for the transitional pumping period between 2020 and 2040.

Agencies and white areas are represented in the groundwater flow model with distinct Water Budget Areas (WBAs). Each WBA has a unique water budget, including consumptive use volumes and surface water deliveries. WBAs in different GSAs also have different transitional pumping schedules. The scope of work to address the objective included using the existing Tule Subbasin Groundwater Flow Model to run various predictive scenarios to isolate the relative contribution of each WBA on land subsidence at the FKC.

The analysis separately accounts for potential land subsidence between 2020 and 2040 that can be attributed to "legacy" effects resulting from the ongoing equilibration of historical groundwater depressions in the western subbasin area with higher groundwater levels in the southeastern portion of the subbasin, as described in TH&Co (2019a)[1].

2 Analysis Methodology – Groundwater Flow model

2.1 Groundwater Flow Model

Predicted future land subsidence in the Tule Subbasin was analyzed using a calibrated numerical groundwater flow model (GFM). The GFM used for the analysis was previously developed to evaluate the sustainable yield, groundwater level conditions, and land subsidence for the Tule Subbasin in support of compliance with SGMA, as described in TH&Co (2019b)[2]. The GFM was developed using MODFLOW, a block-centered, finite difference groundwater flow modeling code developed by the United States Geological Survey (USGS) for simulating groundwater flow. The GFM also includes the subsidence package to estimate land subsidence based on groundwater levels and aquifer properties (e.g. elastic and inelastic storage). The GFM is calibrated to within industry standards to historical groundwater levels and land subsidence measurements.

[1] TH&Co, 2019a. Draft Detailed Analysis of Land Subsidence Along the Friant-Kern Canal in the Tule Subbasin. Prepared for the Tule Subbasin Technical Advisory Committee. Dated May 24, 2019.
[2] TH&Co, 2019b. Groundwater Flow Model of the Tule Subbasin. Prepared for the Tule Subbasin Technical Advisory Committee.

2.2 Water Budget Areas

The GFM utilizes the Farm Process Package (FMP) of MODFLOW to account for the application, consumptive use, and movement of water at the land surface in irrigated agricultural areas. The surface water budget is coupled with the groundwater flow system in the sense that the applied water demand of any given agricultural area that is not met by surface water supplies (i.e., imported water, diverted streamflow, or precipitation) is assumed to be supplied by pumped groundwater. In the Farm Process Package, agricultural areas can be subdivided to account for differences in crop type, e.g., irrigation efficiency, and available surface water supply, among others. To account for these unique water budget areas, the FMP for the Tule Subbasin model was divided into agricultural water budget areas (WBAs).

The following WBAs were analyzed (see Figure 1):

- WBA 2 – City of Porterville area
- WBA 3 – Porterville Irrigation District area
- WBA 4 – Vandalia and Tea Pot Dome Water Districts area
- WBA 5 – Eastern Tule White Area North
- WBA 6 – Saucelito Irrigation District area
- WBA 7 – Terra Bella Irrigation District area
- WBA 8 – Eastern Tule White Area South
- WBA 9 – Kern-Tulare Water District area
- WBA 10 – Lower Tule River Irrigation District area
- WBA 11 – Western Pixley Irrigation District area (within the mapped extent of the Corcoran Clay)
- WBA 12 – Delano-Earlimart Irrigation District area
- WBA 13 - Delano-Earlimart Irrigation District GSA White Lands area
- WBA 14 – Angiola Water District area
- WBA 15 – Tri-County GSA White Lands east
- WBA 16 – Tri-County GSA White Lands west
- WBA 17 – Tri-County GSA White Lands north
- WBA 18 – Alpaugh Irrigation District GSA area
- WBA 20 – Lower Tule River Irrigation District GSA White Lands area
- WBA 34 – Eastern Pixley Irrigation District area (outside the mapped extent of the Corcoran Clay)

It is noted that the areal domain of the GFM extends outside the Tule Subbasin. WBAs outside the Tule Subbasin but within the model domain were not included in the analysis, which is why not all WBAs are represented in the above list.

2.3 Transitional Pumping

A planned reduction in crop consumptive use is necessary to achieve sustainability by 2040. The reduction in crop consumptive use is directly correlated to a reduction in irrigated water demand and groundwater pumping. Each GSA provided a schedule to reduce consumptive use, starting in 2020, in order to achieve sustainable groundwater pumping by 2040. As the availability of surface water supplies from imported water and diverted streamflow is different between the GSAs, each GSA established a different consumptive use reduction, or "transitional pumping," schedule (see TH&Co, 2019c) [3]. This transitional pumping was the subject of our analysis.

3 Analysis Methodology – Relative Cause

Using the WBAs listed above, the analytical process was as follows:

1. Using the existing transitional pumping schedules for the period from 2020 to 2040 as presented in TH&Co (2019c), TH&Co analyzed cumulative model-predicted land subsidence along the canal from 2020 through 2040, as shown on Figure 2. This analysis is considered the "All Transitional Pumping" run.

2. As a separate "bookend" analysis, TH&Co assigned 2040 sustainable water budget conditions (i.e., sustainable groundwater pumping under projected recharge and available surface water deliveries) to all WBAs starting in 2020 with no transitional pumping. This analysis is considered the "No Transitional Pumping" run. Model-predicted land subsidence along the canal as a result of this simulation is shown on Figure 3.

3. In the first set of predictive model analysis scenarios, the water budget for one WBA was set at sustainable (i.e. 2040) conditions in 2020 while the water budgets for all other WBAs reflected their transitional pumping schedules from 2020 to 2040. This was repeated for each of the 19 WBAs analyzed. This set of runs is referred to herein as the "All Transitional Pumping Except One" scenarios.

4. The second set of model runs was established as the inverse of the first set, whereby the water budget for one WBA was set to reflect its transitional pumping schedule from 2020 to 2040 while the water budgets for all other WBAs reflected sustainable conditions from 2020 to 2040. This was repeated for each of the 19 WBAs analyzed. This set of scenarios is referred to herein as the "No Transitional Pumping Except One" scenarios.

5. To assess the relative contribution of land subsidence along the FKC for each scenario, TH&Co calculated the cross-sectional area (i.e. length times height) of projected land

[3] TH&Co, 2019c. Draft Tule Subbasin Setting. Prepared for the Tule Subbasin Technical Advisory Committee.

subsidence along the segment of the canal that is within the Tule Subbasin. This was conducted for each of the following conditions:

a. The All Transitional Pumping run (see Figure 4).

b. The No Transitional Pumping run (see Figure 5).

c. The difference in cross-sectional area along the FKC between the All Transitional Pumping run and the individual WBA with no transitional pumping. This difference provided one estimate of the land subsidence associated with transitional pumping within that WBA (see Figure 6 for an example).

d. The difference in cross-sectional area along the FKC between the No Transitional Pumping run and the individual WBA with transitional pumping. This difference provided a second estimate of the land subsidence associated with transitional pumping within that WBA

e. The relative percent contribution to land subsidence at the FKC from each WBA was assessed by dividing the individual contributions, as described above, by the sum of the individual contributions to land subsidence.

It is noted that WBA 12, which corresponds to the Delano-Earlimart Irrigation District (DEID) area, is not projected to require transitional pumping and therefore is excluded from the analysis.

4 Findings

Results of the All Transitional Pumping Except One model analysis scenarios show that WBAs 5, 6, 8, 11, and 34 have the greatest impact on land subsidence along the canal (see Figure 7). Results of the No Transitional Pumping Except One analysis scenarios show that WBAs 5, 8, and 11 have the greatest impact subsidence along the canal (see Figure 8). These WBAs generally correspond to agencies or agricultural areas that are close to the canal and have limited access to surface water supplies.

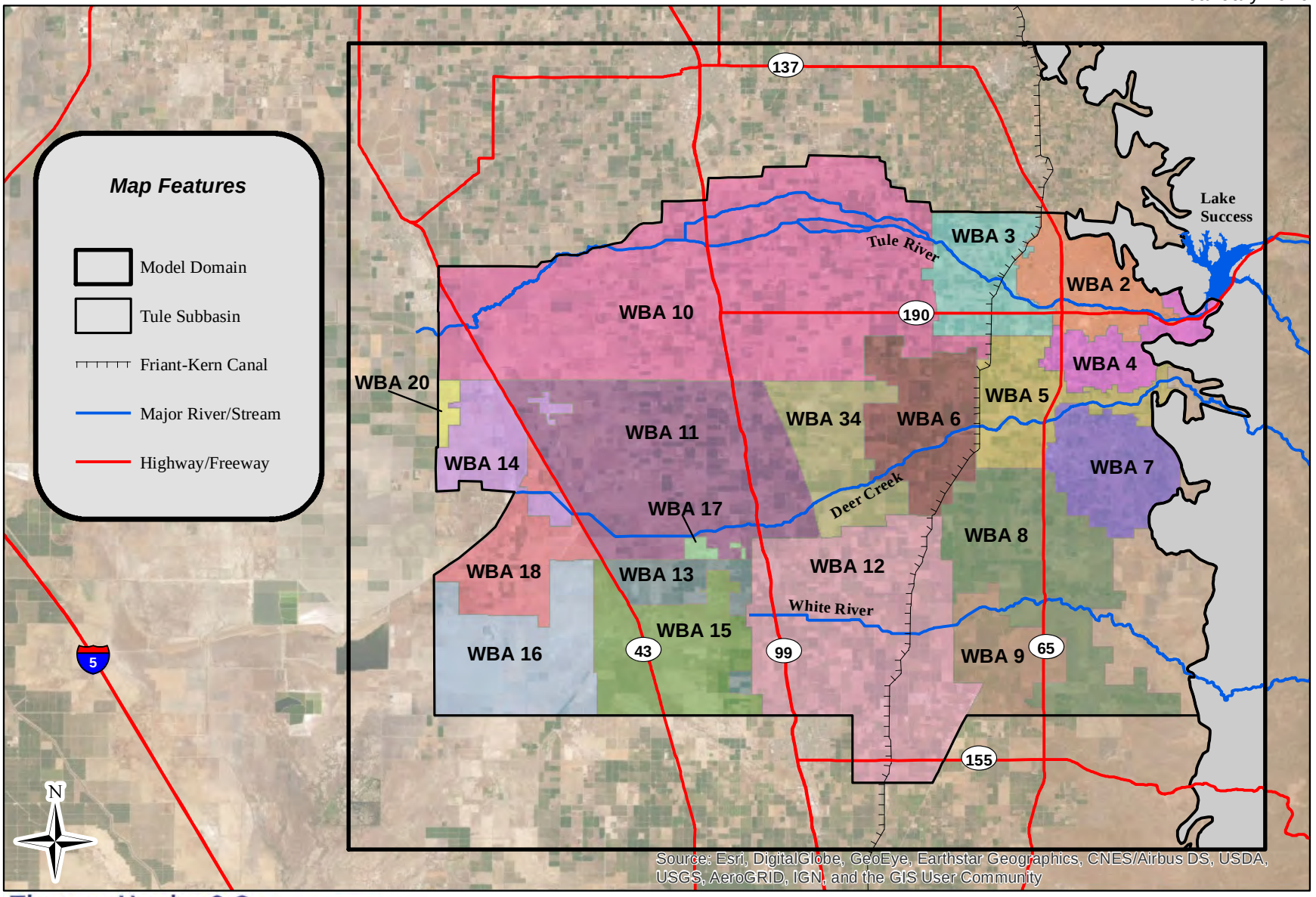
The relative contribution to land subsidence along the Friant-Kern Canal for each set of model scenarios is also represented in the pie chart on Figure 9. The average of the two sets of scenarios is shown in the large pie. The four WBAs that have the greatest impact on land subsidence are as follows:

1. WBA 8 (Eastern Tule White Area South); 56 percent
2. WBA 5 (Eastern Tule White Area North); 20 percent
3. WBA 34 (Eastern Pixley Irrigation District); 6 percent
4. WBA 11 (Western Pixley Irrigation District); 6 percent

5. WBA 6 (Saucelito Irrigation District); 5 percent

Relative contribution to land subsidence at the Friant-Kern Canal from the remaining WBAs accounts for the remaining 6 percent.

Tule Subbasin TAC



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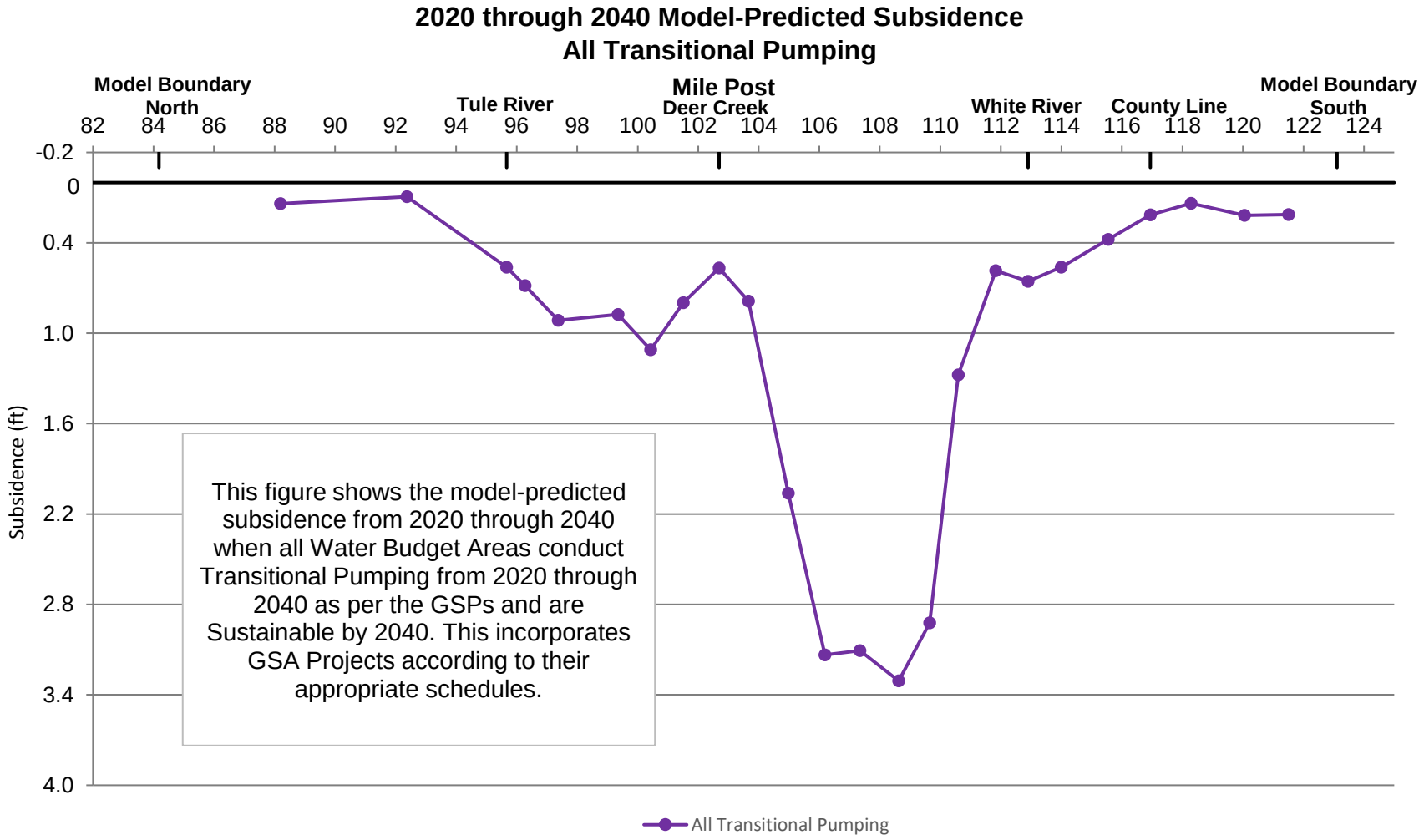
Water Budget Areas

Figure 1

Tule Subbasin TAC
Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal

Figure 2



Note: Subsidence from October 1, 2019 through September 30, 2040.

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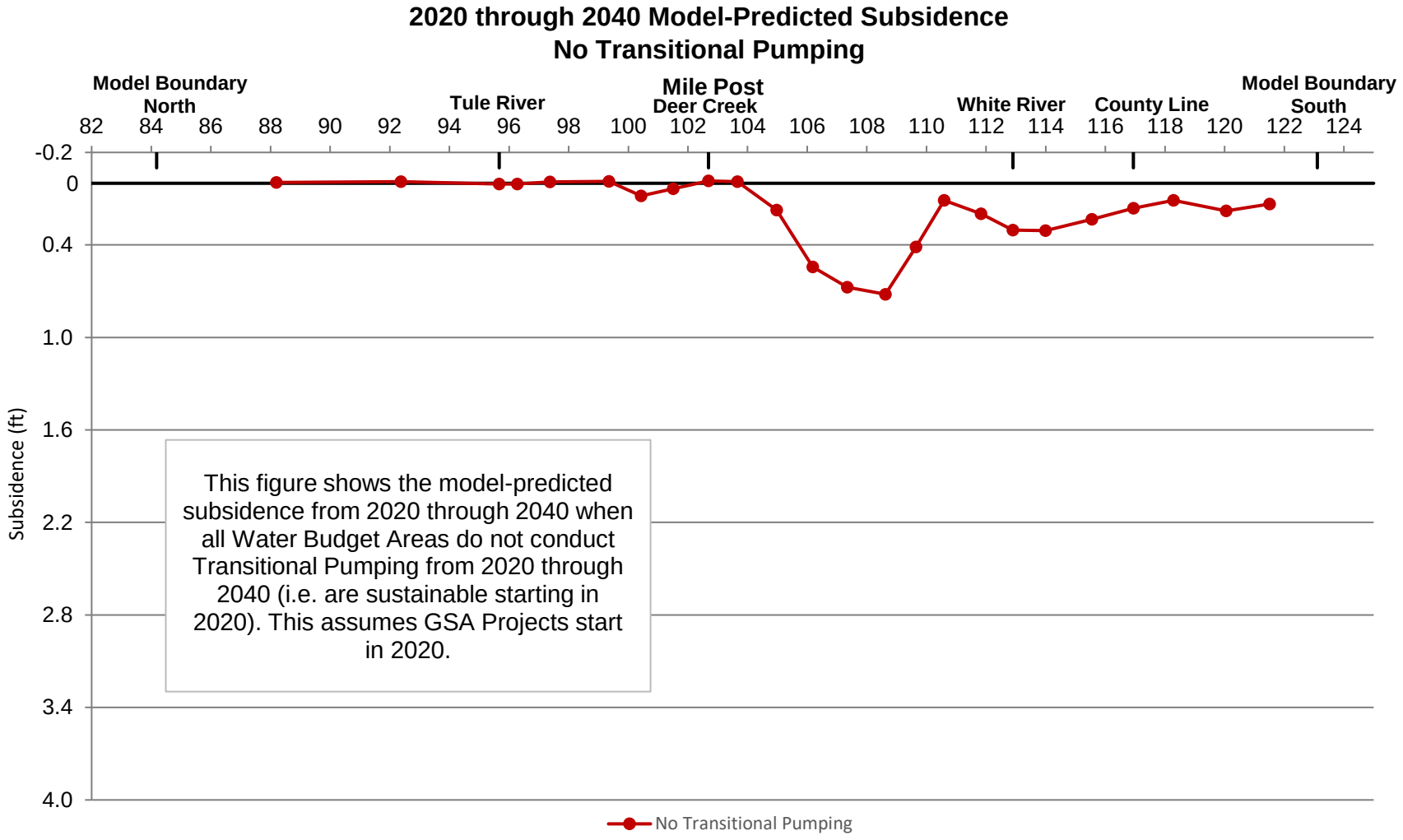
Tule Subbasin TAC
Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal

Figure 3



Note: Subsidence from October 1, 2019 through September 30, 2040.

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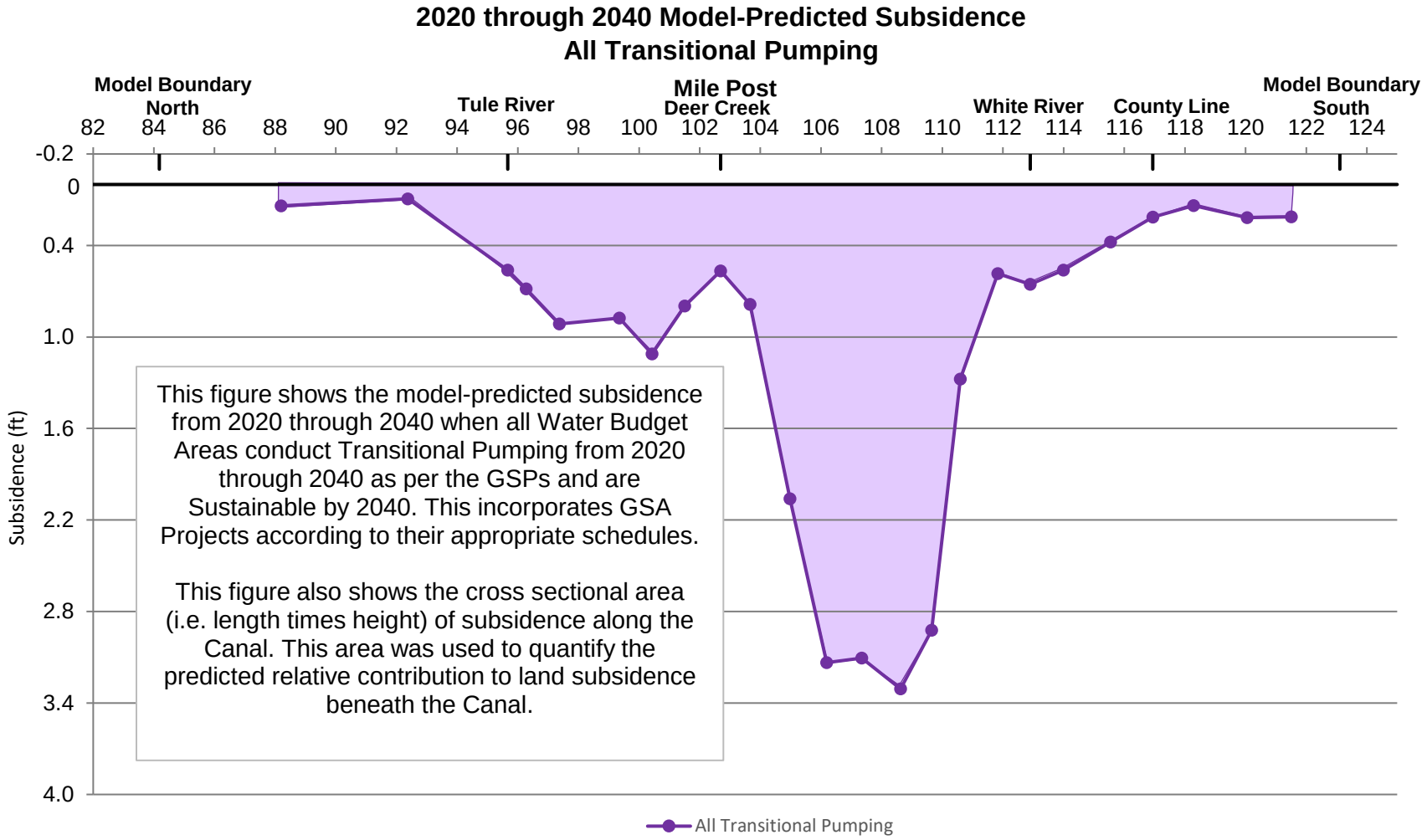
Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal

Figure 4



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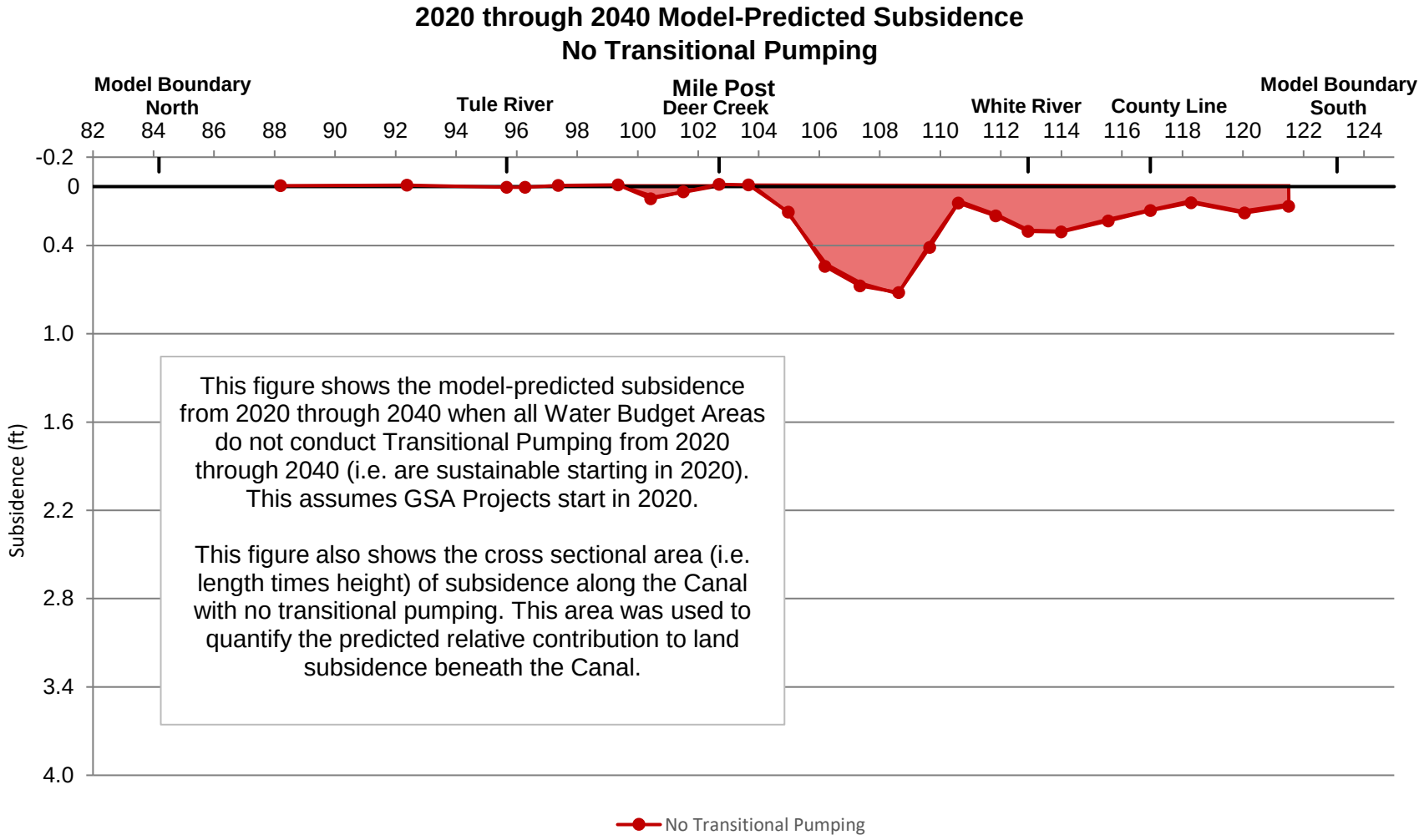
Tule Subbasin TAC
Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal

Figure 5



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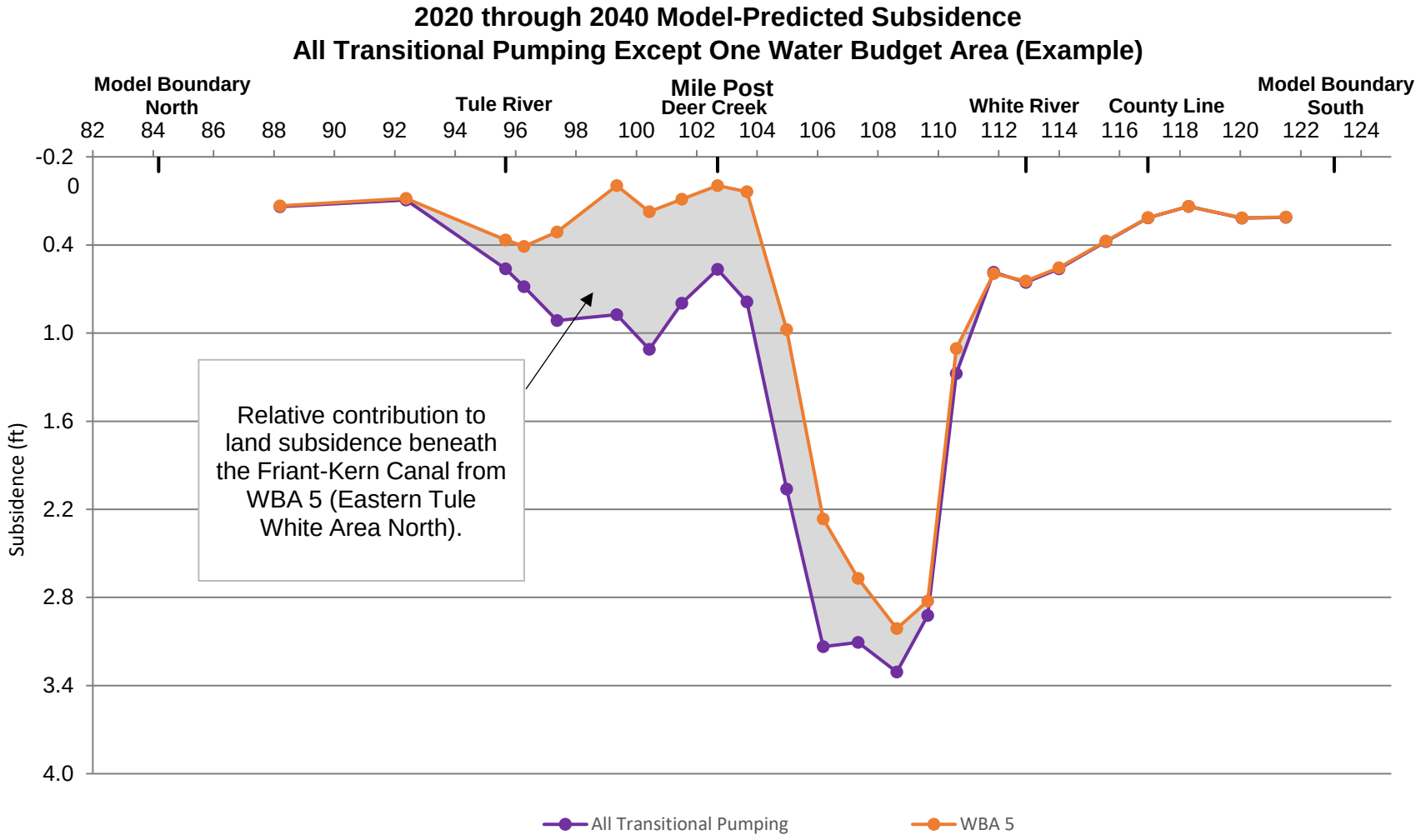
Tule Subbasin TAC
Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal

Figure 6



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Tule Subbasin TAC
Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal

Figure 7

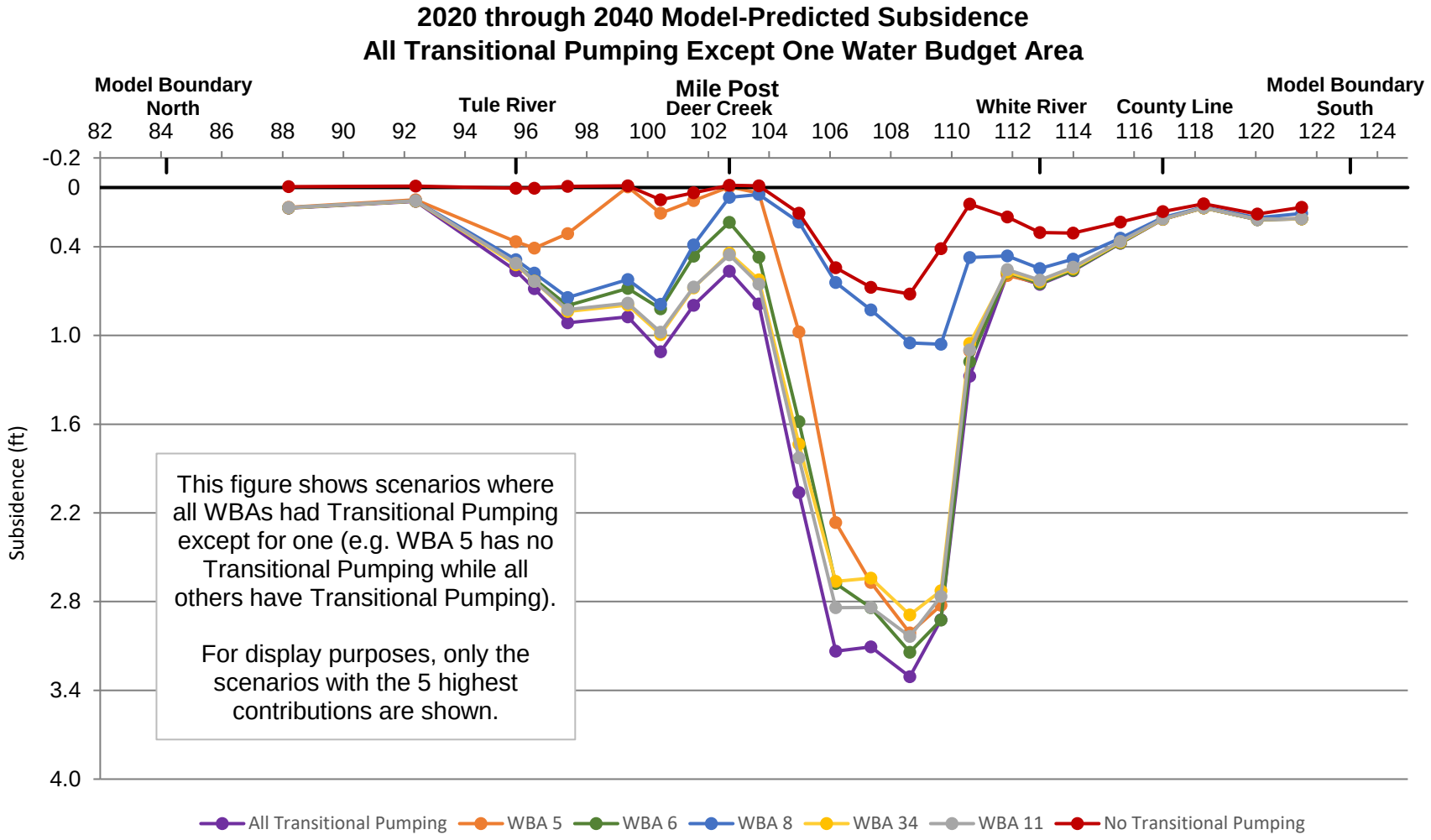

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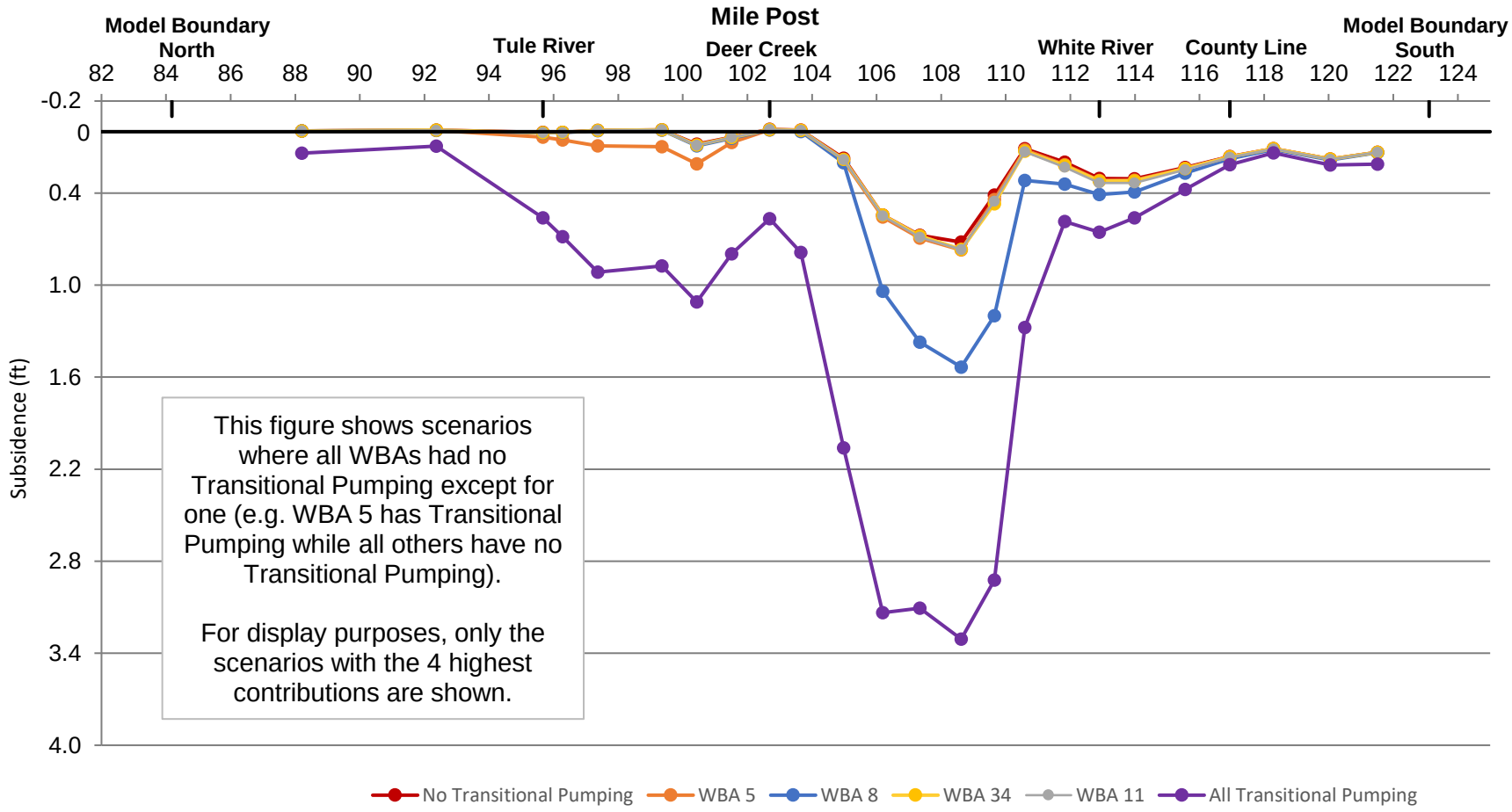
Figure 8

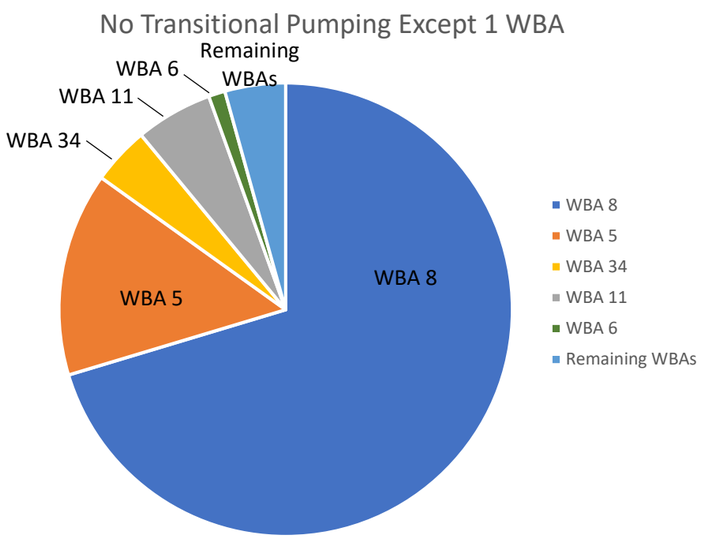
2020 through 2040 Model-Predicted Subsidence
No Transitional Pumping Except One Water Budget Area

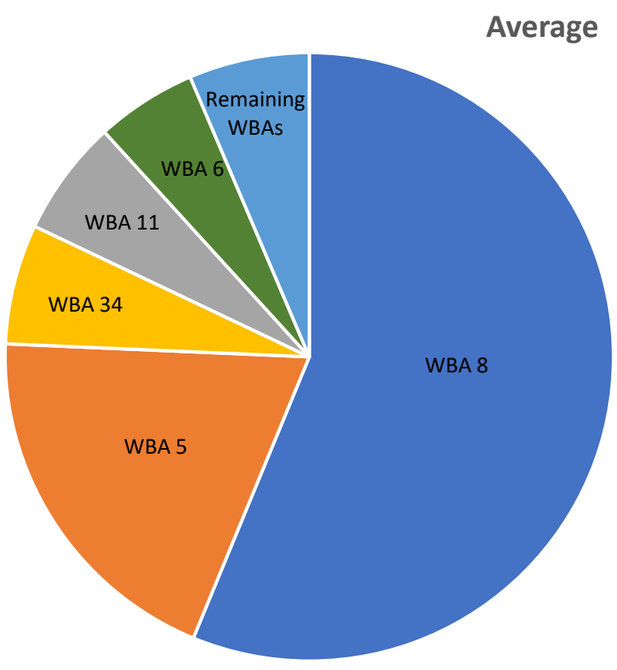


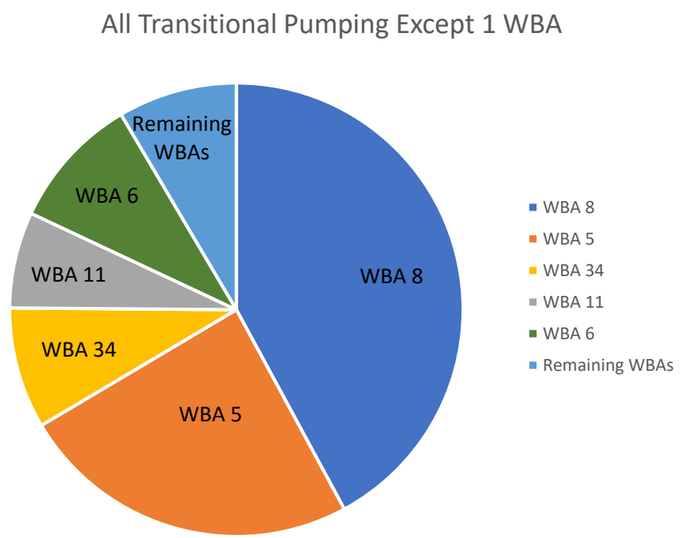
Tule Subbasin TAC
Analysis of the Relative Cause of Future Predicted Land Subsidence along the Friant-Kern Canal

Figure 9

Focused Subsidence Analysis
Predicted Relative Contribution to Land Subsidence Beneath the Friant-Kern Canal 2020 - 2040







This figure shows the relative contribution of each WBA's transitional pumping on subsidence beneath the Friant-Kern Canal. The figure shows the results of each method (i.e. No Transitional Pumping Except 1 WBA and All Transitional Pumping Except 1 WBA) and the average of the two methods.

For example, the Transitional Pumping from WBA 5 is predicted to contribute approximately 20% of the land subsidence beneath the Friant-Kern Canal from 2020 through 2040.

- WBA 8, Eastern Tule White Area South: 56%
- WBA 5, Eastern Tule White Area North: 20%
- WBA 34, Eastern Pixley Irrigation District area: 6%
- WBA 11, Western Pixley Irrigation District area: 6%
- WBA 6, Saucelito Irrigation District area: 5%
- Remaining WBAs: 6%

*Remaining WBAs include the 14 other WBAs analyzed (see Figure 1)

Thomas Harder & Co.
Groundwater Consulting

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