COUNTY OF SAN LUIS OBISPO
Department of Public Works
John Diodati, *Director*

December 13th, 2022

Technical Memorandum

Subject: Revisions to Preliminary East Fork San Luis Obispo Creek Zone A Mapping

Introduction

East Fork SLO Creek (East Fork), like Lower SLO Creek, is currently effectively mapped as Zone A Special Flood Hazard Area. FEMA's full Physical Map Revision with detailed studies for San Luis Obispo Creek will produce effective Zone AE SFHA for Lower SLO Creek. While FEMA is not performing similar detailed studies for East Fork, FEMA has preliminarily remapped the Zone A boundaries of a portion of East Fork on Preliminary Map Panel 06079C1331H. The preliminarily remapped Zone A boundaries on East Fork reflect a Base Level Engineering (BLE) analysis of East Fork.

The County is in the process of studying this portion of the East Fork watershed in detail, including production of engineered hydrologic and hydraulic models. While model development is complete, documentation is still in draft form. Despite this, the models and draft documentation still constitute more accurate information than the BLE analysis. This memo provides an overview of how this information is technically superior to the BLE analysis and demonstrates that the preliminary remapped Zone A boundaries on Map Panel 06079C1331H should instead be revised to reflect the results of the County's modeling.

County staff wish to clearly communicate to FEMA that this area is likely to face considerable development pressure in the near future. It is of the utmost importance to not underestimate flood risks in this area.

BLE Discussion

BLE consists of hydrologic and hydraulic analyses of limited detail. While BLE products are assuredly more useful than Zone A boundaries with no associated analyses, BLE products must be used with caution. County staff review of BLE products has prompted some concern, as the BLE analyses generally forgo hydrologic modeling to simply use flows calculated via the USGS Regional Regression Method. The USGS Regional Regression Method is explicitly a rough approximation with a large standard error and performs poorly in relatively developed watersheds. Via comparison with historical stage gage data in nearby watersheds, County staff have observed that the USGS Regional Regression Method appears to underestimate 1% annual chance event flows through watersheds in the vicinity of the City of San Luis Obispo.

County East Fork Study

Concurrent to FEMA's flood risk studies of San Luis Obispo Creek, County staff and Schaaf & Wheeler have been studying flood risks on East Fork. Registered professional engineers from Schaaf & Wheeler and the County have collaborated to produce hydrologic and hydraulic analyses of the East Fork watershed, with a particular emphasis on the area represented on Map Panel 06079C1331H. The hydrologic analysis includes a HEC-HMS model of the entire East Fork watershed, calibrated to nearby gaged watersheds. The hydraulic analysis includes an unsteady, two-dimensional HEC-RAS model of nearly the entire East Fork area represented on Map Panel 06079C1331H.

The hydraulic approach of the County East Fork Study is similar to the BLE hydraulic modeling but is superior in technical quality due to incorporation of field-surveyed topography. As the hydrologic approach of the County East Fork Study includes a calibrated HEC-HMS model, it is superior in technical quality to the very limited BLE hydrologic analysis.

While full documentation of the modeling analysis is still in progress, a partial draft of the report follows this memo. The associated HEC-HMS and HEC-RAS files are included separately in this appeal submittal. County staff are willing to provide further information if this documentation does not clearly demonstrate technical superiority over the BLE analysis.

In general, the County analyses predict larger flood extents associated with East Fork in the area represented on Map Panel 06079C1331H. This is assumed primarily due to higher flows generated by the County hydrologic analysis than the BLE hydrologic analysis.

Nearby Map Revisions & Workmap

Emphasizing the development pressure in this vicinity, the area represented on Map Panel 06079C1331H contains one effective LOMR, one CLOMR that has been submitted to FEMA for review, and two CLOMRs that will be submitted to FEMA in the next calendar year (per County staff discussions with project engineers).

LOMR 21-09-0731P is associated with the Avila Ranch development, immediately northeast of the Buckley Road and Vachell Lane intersection. This LOMR covers flood extents ostensibly associated with Tank Farm Creek above its confluence with East Fork. However, flooding through this area is primarily driven by backwater conditions from East Fork. Per correspondence with City of San Luis Obispo staff and project engineers, a CLOMR associated with the Avila Ranch project has at least been applied for (if not issued) for the next northernmost reach of Tank Farm Creek above the extents of LOMR 21-09-0731P. Additionally, the County anticipates issuing a Community Acknowledgement Form in 2023 for the reach of Tank Farm Creek immediately upstream of the Avila Ranch property, in support of a CLOMR associated with the Chevron Tank Farm Remediation Project which will alter flood behavior on Tank Farm Creek. For these reasons, the County does not recommend alteration of the preliminary Tank Farm Creek Zone A boundaries from the BLE results. The BLE results areas will presumably be superseded in the near future with mapping more accurate than the County East Fork Flood Study will produce for these portions of Tank Farm Creek. The attached Comparison Map of Zone A in Panel 06079C1331H Area (Workmap) identifies these areas and does not reflect County results within them.

The County also expects to issue a Community Acknowledgement Form in 2023 for another CLOMR associated with the Chevron Tank Farm Remediation Project that will address the very uppermost portion of East Fork represented on Panel 06079C1331H. This area is indicated on the Workmap. County East Fork flood extents would tie in with the BLE results at this point.

The Workmap is included separately in this appeal submittal. The first sheet identifies areas discussed in this memo and illustrates differences in the County and BLE flood extents. The second sheet depicts Zone A SFHA extents with the County East Fork Study results appropriately incorporated as detailed in this memo. The GIS shapefile of these extents is included in the HEC-RAS files.

Attached

- Excerpt from Draft Report of East Fork SLO Creek Study

Included in Submittal Package

- Comparison Map of Zone A in Panel 06079C1331H Area
- County East Fork HEC-HMS and HEC-RAS Files

Introduction

The San Luis Obispo County Flood Control and Water Conservation District, Flood Control Zone 9 (County) contracted Schaaf & Wheeler to complete a hydrologic and hydraulic analysis to investigate the cause of and possible solutions for flooding that occurs on Buckley Road at the intersection of Vachell Lane. The sources of flooding are Tank Farm Creek and East Fork San Luis Obispo Creek (East Fork), which flow parallel to and across Buckley Road and are tributaries to San Luis Obispo Creek. Buckley Road regularly floods at the intersection of Vachell Lane during larger storm events, causing the County to close the road periodically and limiting access to the horse farm located south of the intersection. The flooding also causes damage to road asphalt and shoulders. While the East Fork was included in the City & County's Waterway Management Plan (Questa Engineering, 2003), this report expands upon the previous analysis of this specific area and utilizes updated technical methods. The study area of focus is shown in Figure 1.

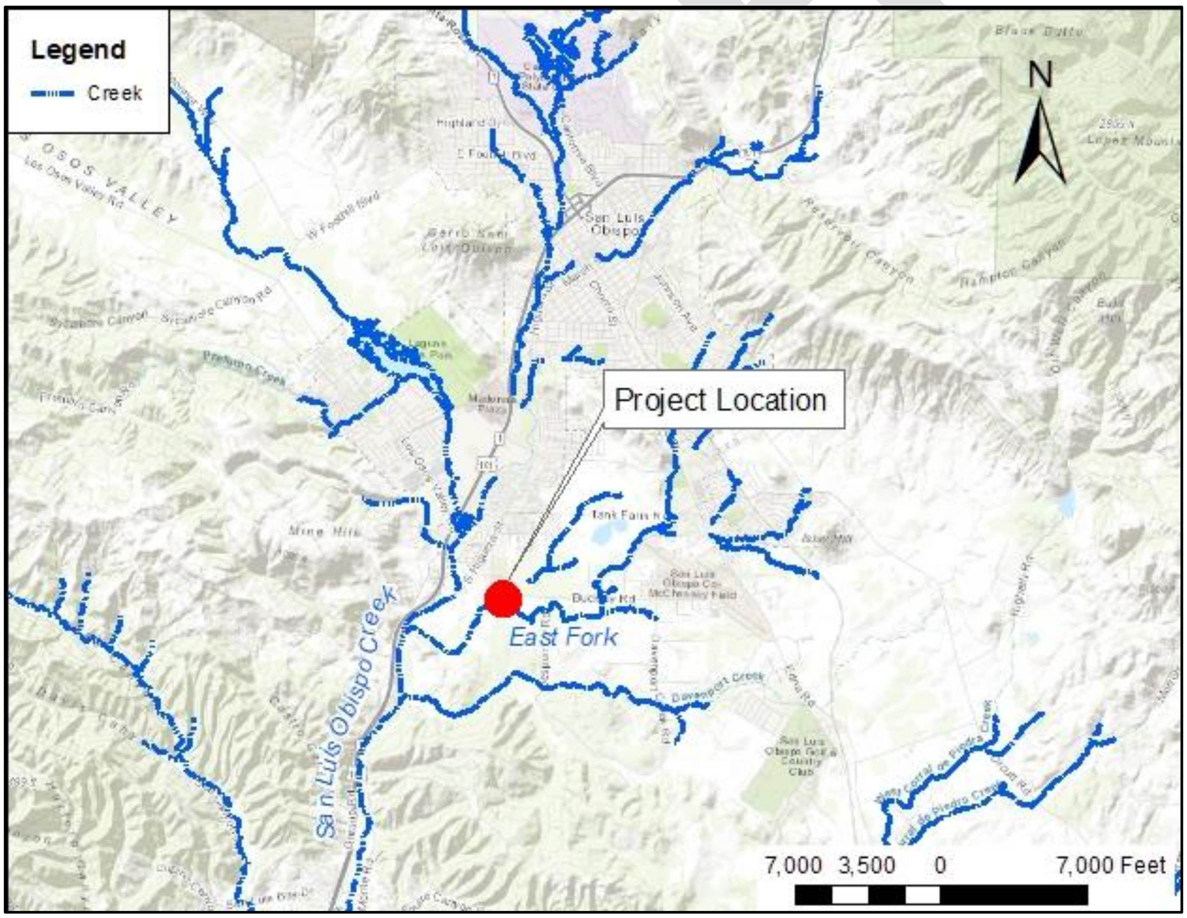

Figure 1 – Vicinity Map

Schaaf & Wheeler used data from multiple sources in this study, including field investigations, FEMA flood insurance study (FIS) data, ground survey data, LiDAR and other regional topography, regional USGS stream gage data, and previous reports by Questa Engineering and Avocet Environmental. This information was used to create a HEC-HMS hydrologic model of the East Fork watershed and a two-dimensional HEC-RAS hydraulic model of the lower East Fork. Flood risks in the study area were evaluated for 2-year, 5-year, 10-year, 25-year and 100-year flows. Four improvement concepts were then modeled to determine their potential benefits in reducing flooding in the project area.

History of Flooding

The East Fork watershed has experienced significant flooding over the past 50 years. The region's historic flooding events of this period include March 1995, February 1998, and December 2004, as well as recent events like January 2019. All the above events produced runoff that exceeded the capacity of the East Fork channel below Buckley Road. Flood impacts included road closures, property damage, and hazardous conditions for residents. With increasing urbanization within the overall watershed and in the vicinity of Buckley Road, longstanding flood risks are becoming more noticeable. Moreover, as climate change accelerates, these events have the potential to become more severe and more frequent.

Figure 2 – January 2019 Downstream of Buckley Road

Hydrologic Analysis

This report analyzes the hydrology of the East Fork watershed in detail. The analytical methodology employed follows the standardized engineering approach of characterizing the watershed then incorporating this information into a hydrologic model.

Watershed Characteristics

The East Fork San Luis Obispo Creek watershed is 12.3 square miles. The watershed starts in the hills east of the City of San Luis Obispo and converges with San Luis Obispo Creek downstream of the city limits. The only named tributary to East Fork is Tank Farm Creek which has a watershed area of 1.6 square miles. The topography of the East Fork watershed is dominated by a pattern of steep hillsides transitioning to flat valley lands. Figure 3 shows the watershed topography. This topographic regime naturally creates wetland areas that drain slowly to receiving waters. Such areas in Central California have historically been productive for agricultural uses and less desirable for urbanization, partially due to inherent flood risks.

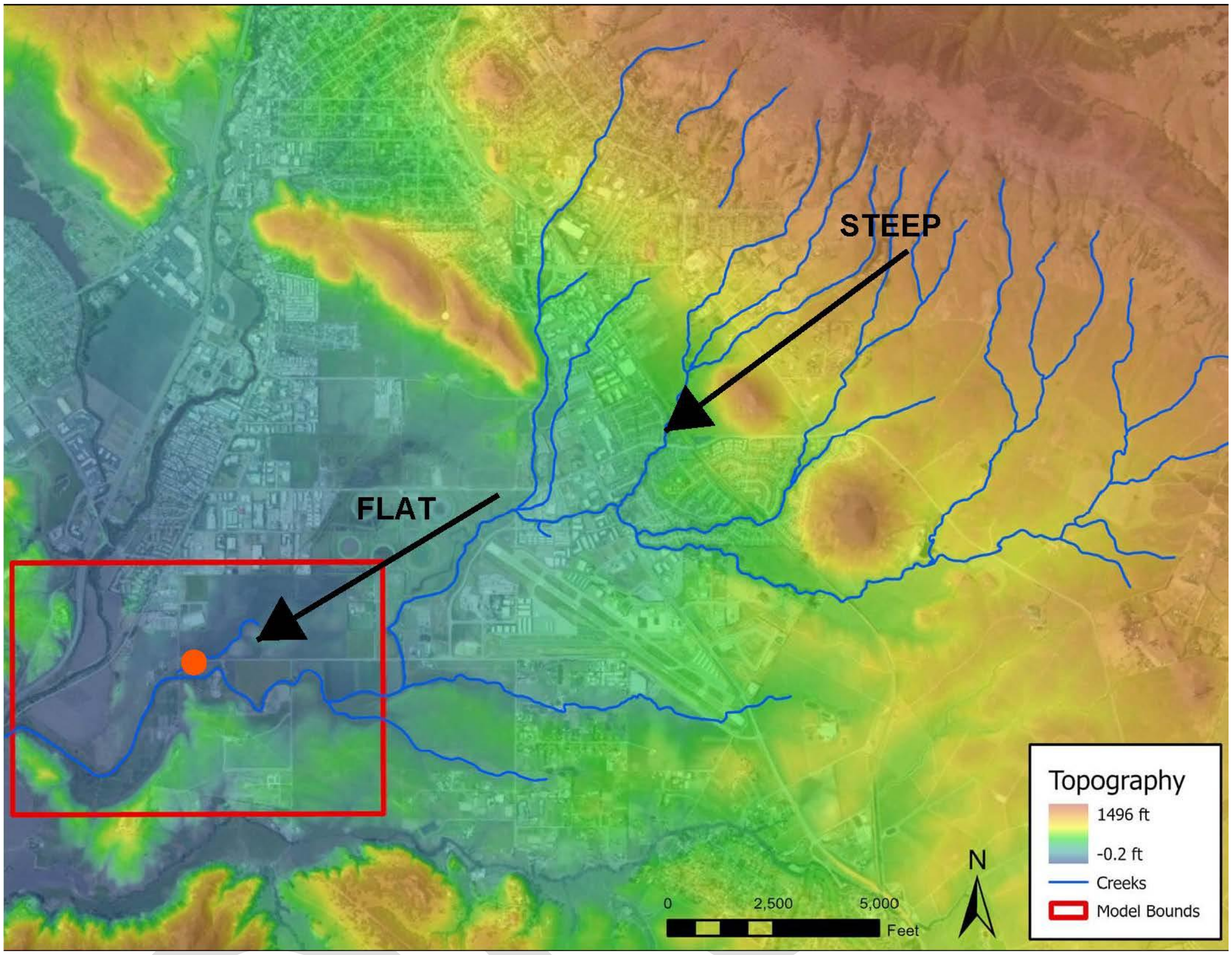

Figure 3 – Topographic Map

The upper watershed is mostly undeveloped with open space and range land. Runoff from the upper watershed is conveyed quickly through gullies and channels. Based on NRCS soils data mapping (Figure 4) the upper watershed has mostly and very slow (Type D) infiltrating soils. With steep slopes and higher rainfall intensities due to orographic effects, these hills can produce sharply peaked (rapid) runoff patterns. The approximate time of concentration from the upper-most peak to Buckley Road is 2.5 hours.

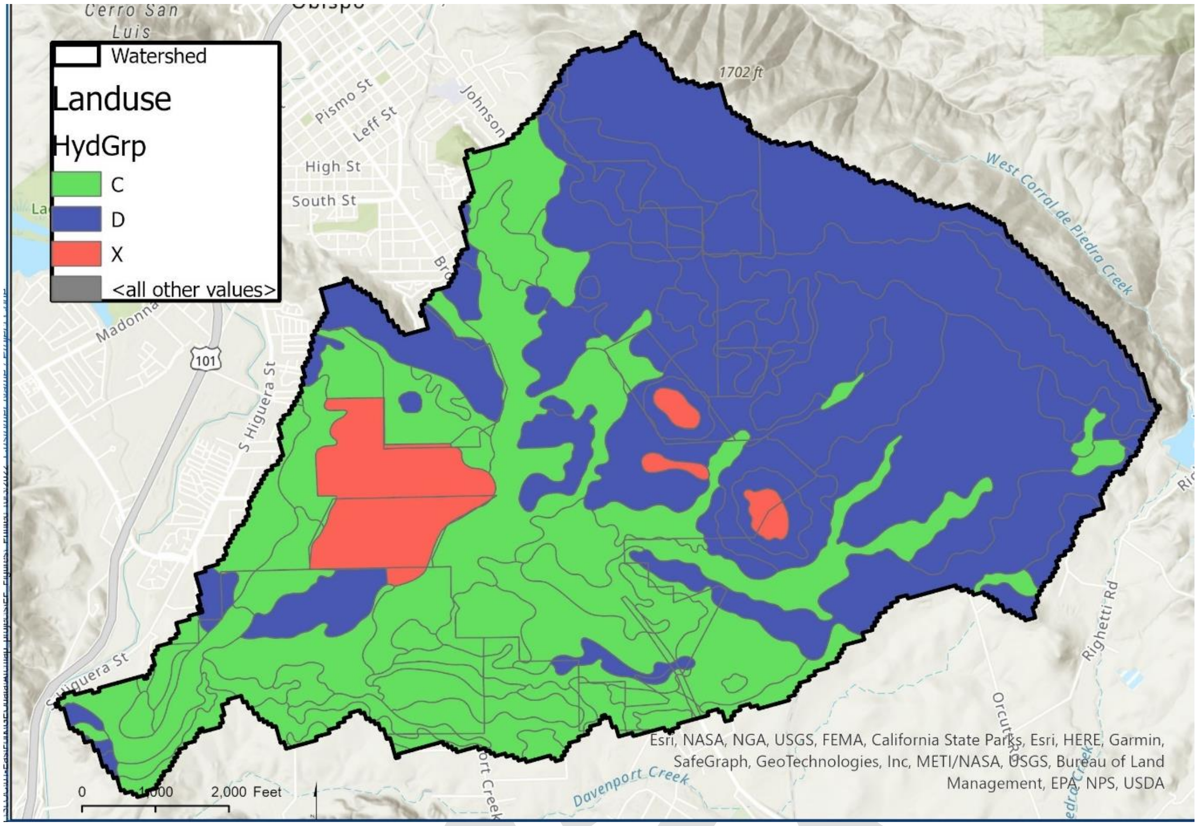

Figure 4 – NRCS Soils Map

The lower watershed is partially urbanized, mainly within the City of San Luis Obispo. The urban land uses are a combination of residential and commercial. The remainder of the lower watershed is agricultural and open space. The lower watershed is flat and has slow infiltrating (Type C) soils. Storm hydrographs tend to attenuate within the lower watershed as the floodplains store local and upstream runoff. As flows spill from the channel they pond along the floodplains and are slowly released back to the channels as the storm peak recedes. These floodplains are naturally occurring and can reduce downstream peak flows. The development pattern of the lower watershed has likely reduced the floodplain storage and increased peak flows over time.

The watershed’s proximity to the Pacific Ocean causes higher rainfall totals than nearby watersheds to the east. Most of the total annual rainfall in the East Fork watershed occurs between November and March. Storms capable of producing flooding can occur throughout this period, as demonstrated in the history of flooding above.

It has been noted that antecedent moisture conditions in the East Fork watershed are often wet immediately prior to flood-producing rain events. Antecedent moisture conditions refer to how dry or wet the soils of a watershed are at the time of a rain event. An increase in antecedent moisture conditions can result in higher runoff due to diminished initial abstraction (reduction of absorptive capacity) in otherwise reasonably pervious (infiltrative) soils. This concept can be explained by taking the March 1995 flood event as an example. The March 1995 storms produced an approximately 50-year flood event, the worst since the 1960s-70s. A report referenced in the Waterway Management Plan analyzed data from the Cal Poly rain gage to investigate the 1995 flood events. This analysis concluded that 24-hour rainfall totals from the

March 1995 storms were likely 5- to 10-year events. However, these relatively modest rainfall events still produced severe flooding. January 1995 had been an extremely wet month, so the watershed was still wetted on a seasonal timescale going into March 1995. Further, the storms of March 1995 came back-to-back. Although the first and second 24-hour storms produced similar amounts of rain, the worst flooding came with the second storm. Only one other year in the Cal Poly rain gage record of over 100 years had two months as wet as January and March 1995. These wet antecedent moisture conditions caused higher runoff than would otherwise be expected, producing approximately 50-year flooding from less than 10-year 24-hour rainfall.

Hydrologic Approach

The hydrology of San Luis Obispo Creek and its tributaries (including East Fork) was previously studied by Questa Engineering as part of the expansive Waterway Management Plan (WMP) published in 2003. The WMP included a HEC-HMS rainfall-runoff model of the entire San Luis Obispo Creek watershed, which was calibrated to the March 1995 flood events with County rain and stage gage data, historical radar, and high water marks. Following more moderate flood events from 2003-2005, it was observed that the WMP HMS model overpredicted flooding from recorded precipitation in these events. Questa Engineering attempted to recalibrate the model to these events but concluded the WMP HMS model still performed poorly in predicting runoff from storm events following relatively dry antecedent moisture conditions. Unfortunately, the period between the above efforts and preparation of this report has been dominated by drought conditions. Concerns remain that the WMP HMS model is not capable of accurately describing recent flood behavior due to the predominantly dry antecedent moisture conditions.

After reviewing the WMP HMS model and documentation, Schaaf & Wheeler concluded that it would be more efficient and technically defensible to create a new hydrologic model for the East Fork watershed rather than attempt to update the WMP model. Challenges identified with utilizing the WMP HMS model include:

- The WMP hydrologic model was developed in HEC-HMS version 2.1.3 (released 2001) and is not compatible with updated versions of the HMS software. The most recent HEC-HMS release that County staff and Schaaf & Wheeler were able to use to successfully run the WMP HMS model was version 3.2 (released 2008). As of the drafting of this report, the most recently released HMS version is 4.10 (released 2022).

- The WMP model utilized a pre-existing, now-obsolete study's delineation of sub-basins in the East Fork watershed. This resulted in the East Fork modeling being unnecessarily overcomplicated and difficult to adjust.

- GIS files of delineated sub-basins utilized in the WMP hydrologic analysis. were never provided to the County. Questa could not locate these files upon County inquiry in 2022.

Calibration of Rainfall-Runoff Factors

General watershed rainfall-runoff behavior was using calibrated utilizing long-term USGS gage records in the region. Calibration of antecedent moisture condition (AMC) using gage statistics provides a better estimate of uncertainty than the Questa approach. This does not imply that the Questa hydrology is less accurate than the new hydrology. Rather, the new approach is intended to better explore a range of storm events without biasing the results around a single event calibration.

Schaaf & Wheeler used two long-term gaged watersheds to calibrate the AMC for each storm frequency. Both the Lopez and Huasna (Figure 5) watersheds are undeveloped and have 55 and 63 years of records respectively. USGS StreamStats flow frequency statistics were utilized. USGS StreamStats also provided the estimated imperviousness of each watershed.

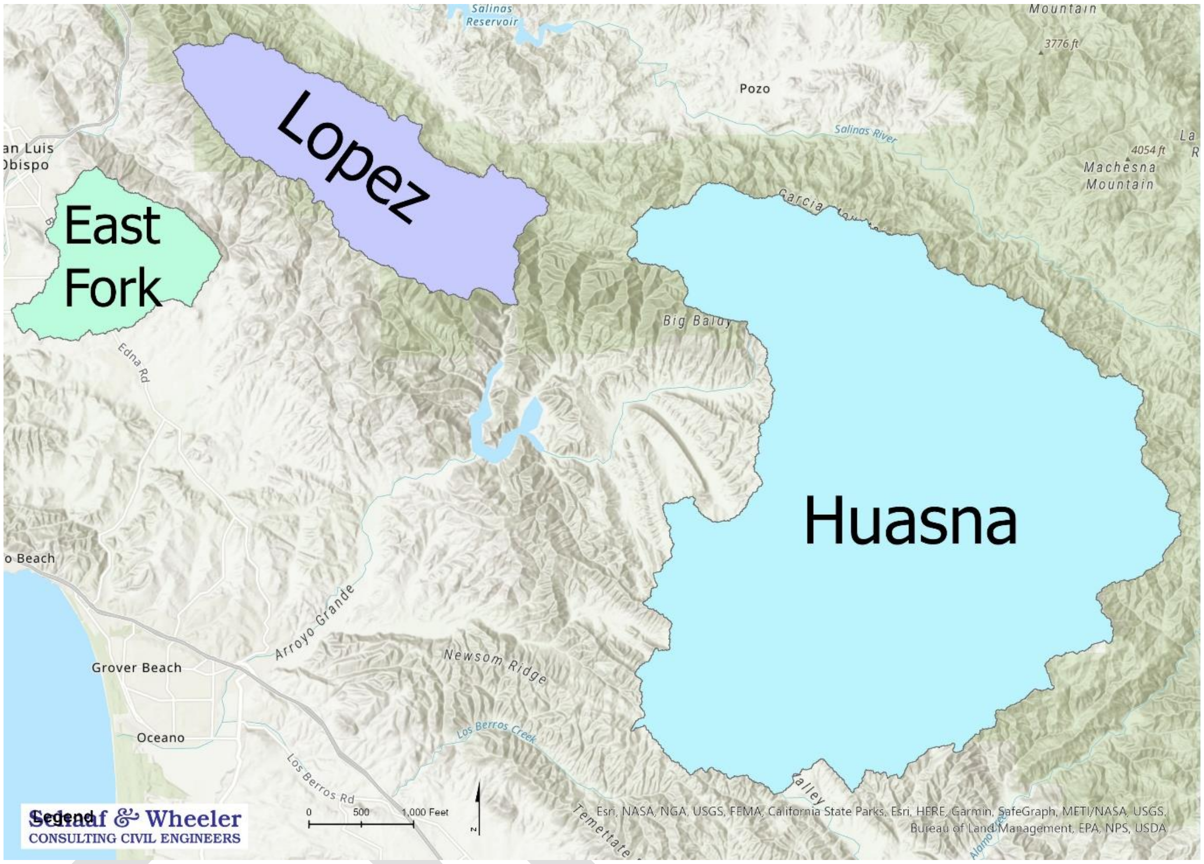

Figure 5 – Gaged Watersheds

A HEC-HMS model of each gaged watershed was developed. Hydrologic parameters were determined with readily available data and appropriate methods:

Topography was based on FEMA/USGS DEM (1 meter, 2017) and used for lag time calculations. The design rainfall patterns for each storm frequency match the WMP 24-hour calibration pattern (HYDRO-35, Fredrick, Myers, and Auciello, 1977) for East Fork. Precipitation depths were identified from NOAA Atlas 14 estimates.

Basin lag was estimated with the lag equation from the Santa Clara County Drainage Manual (2006):

$$t_{lag} = (0.862)\, 24\, N \left(\frac{L\, L_c}{\sqrt{S}} \right)^{0.38} - \frac{D}{2} \tag{4-1}$$

Where t_{lag} = SCS basin lag (hours)

N = watershed roughness value (dimensionless)

L = longest flow path from catchment divide to outlet (miles)

L_c = length along flow path from a point perpendicular with the basin centroid to its outlet (miles)

S = effective slope along main watercourse from Chapter 3 (feet/mile)

D = duration of unit hydrograph (hours)

The calculated lag values were compared to estimates using other lag equations, including TR55, Alameda County, Snyder, and the procedure utilized in the WMP, and deemed acceptable for use.

The HEC-HMS models of the gaged watersheds utilize the NRCS Unit Hydrograph loss and transform methods. This method requires determination of Curve Numbers (CNs).

The CN for a given basin is estimated as a function of hydrologic soil group, land use, and antecedent moisture condition (AMC), with AMC defined as the moisture content of a soil prior to any precipitation event. The AMC generally varies depending on the severity or recurrence interval of a given storm. AMC is characterized by the NRCS as:

AMC I	soils are dry
AMC II	average conditions
AMC III	heavy rainfall, or light rainfall with low temperatures; saturated soil

Curve Numbers vary from 0 to 100, with 0 equating to no runoff from a basin and 100 indicating that all precipitation will run off. USDA-NRCS Technical Release 55 (TR-55) Urban Hydrology for Small Watersheds was used to determine curve numbers for various land uses depending on soil type for a range of AMCs. Soil Hydrologic Groups for the watershed were obtained from the NRCS Web Soil Survey and land uses were based on County land use data.

Peak flows generated by each gaged watershed HEC-HMS models for various AMCs at the gage location were then compared to peak flows estimated by the flood-frequency analysis of that gage. The AMC corresponding to the closest match in runoff was identified for each storm event. It is critical to note that the resulting calibrated AMC only applies to the specific rainfall pattern, storm frequency, precipitation data, and loss and transform methods used in this analysis. In other words, if revisions to this analysis were to modify the rainfall pattern or lag equation, the AMC should be recalibrated.

Table 1 summarizes the results of this AMC calibration analysis.

Table 1: Results of AMC Calibration

Recurrence Interval	Lopez Creek		Huasna Creek	
	FFA Peak Flow (cfs)	Assigned AMC	FFA Peak Flow (cfs)	Assigned AMC
100-Year	3,880	I.5	12,700	I.75
25-Year	2,390	I.5	7,420	I.75
10-Year	1,520	I.5	4,500	I.75
5-Year	930	I.5	2,640	I.75
2-Year	335	I.5	869	I.5

The calibrated AMCs for Lopez Creek are similar to but slightly lower than Huasna Creek. The Lopez Creek watershed is closer in size and location to East Fork than the Huasna Creek watershed and is more likely to be an appropriate proxy for the East Fork watershed. This calibration indicates that utilizing an AMC of I.5 for analysis of the East Fork watershed is expected to produce the most accurate hydrologic modeling.

HEC-HMS Model

A hydrologic model of the East Fork watershed was developed using HEC-HMS version 4.8. This model was utilized to generate runoff hydrographs for subbasins within the overall East Fork watershed for later incorporation as inflows into a hydraulic model of the core study area.

Subbasin Delineation

The East Fork watershed was broken up into five catchments based on key hydrologic features. These areas are shown in Figure 7 and are designated as Upper Buckley, Airport, Tank Farm, Lower East Fork and Buckley to Tank Farm.

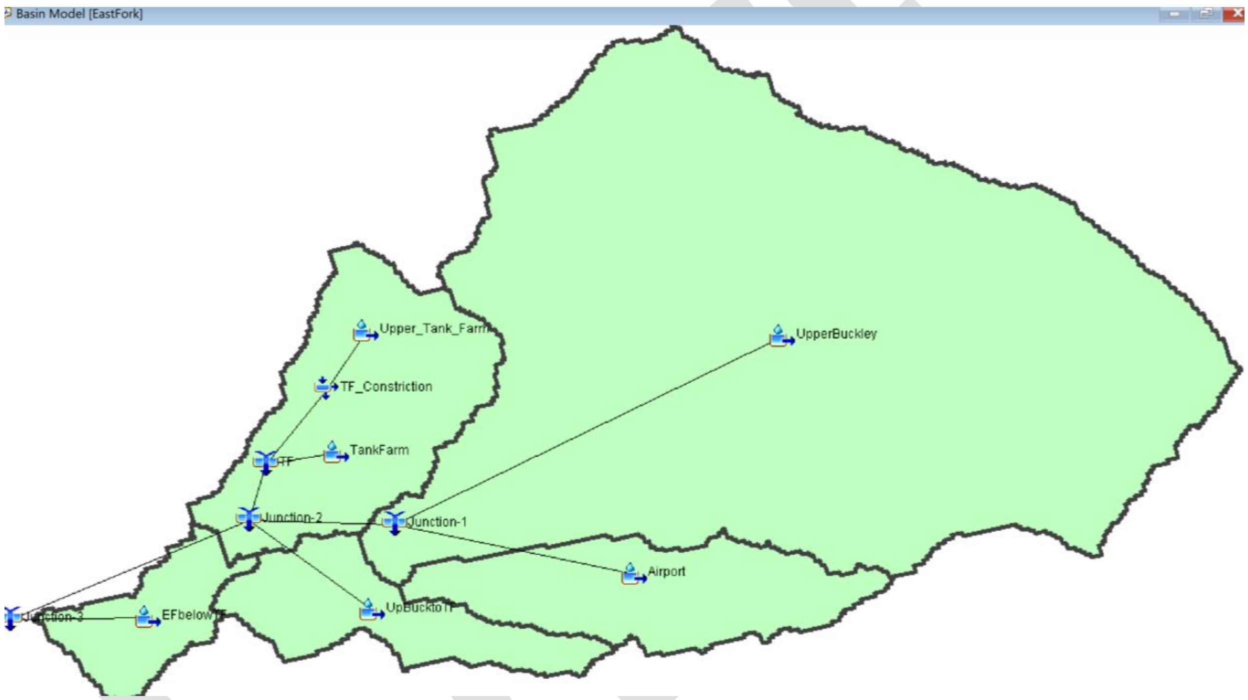

Figure 6 – HEC-HMS Basin Model Schematic

The Tank Farm catchment is the most complex and includes several structures that limit flows through culverts and storage areas. The Tank Farm watershed was studied by Avocet Environmental in "Revised Hydrology Study: Former San Luis Obispo Tank Farm" dated August 13, 2014. This study determined that the maximum flow from the upper reaches of the watershed was 81cfs with the lower system being unlimited. The HMS model includes an Upper Tank Farm catchment that passes through a diversion that limits downstream discharges to 81cfs. The resulting restructured hydrograph is combined with the lower Tank Farm area flows to form a single hydrograph for inflows into the hydraulic model area.

Model Methodology and Parameters

The East Fork HMS model was structured similarly to the calibration models detailed above.

The design rainfall patterns for each storm frequency match the WMP 24-hour storm pattern (HYDRO-35, Fredrick, Myers, and Auciello, 1977) for East Fork. Precipitation depths were identified from NOAA Atlas 14 estimates at centroids of the each catchment.

Subbasin lag times were estimated with the lag equation from the Santa Clara County Drainage Manual. Topography used for lag time calculations was based on FEMA/USGS DEM (1 meter, 2017).

The NRCS Unit Hydrograph method was used for subbasin loss and transform. To calculate Curve Numbers, Soil Hydrologic Groups for the watershed were obtained from the NRCS Web Soil Survey (Figure 4) and land uses were based on County and City land use data (Figure 6).

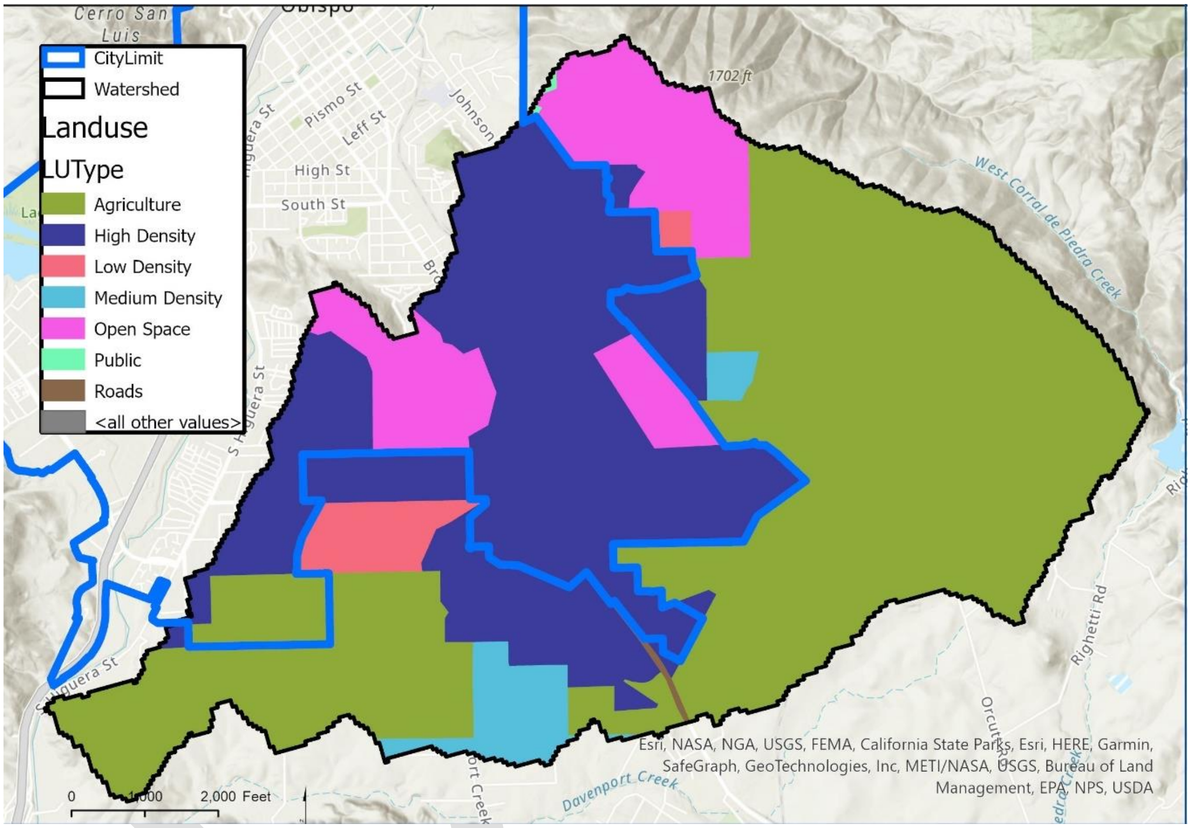

Figure 7 – Land Use Map

Per the calibration above, NRCS Curve Numbers were calculated for AMC 1.5. Curve Numbers were also calculated for AMC III to evaluate conditions more like those used to calibrate the WMP.

Areas without a defined Soil Group were assumed to be Type D. Table 3 lists the resulting Curve Numbers for each catchment under AMC I.5 and III conditions.

Table 2: Catchment Loss Parameters

Catchment	Impervious %	AMC I.5 CN	AMC III CN
Upper Buckley	26.7	61.4	86.1

Airport	23.4	58.4	84.4
Upper Tank Farm	30.3	68.6	88.6
Tank Farm	41.8	70.3	82.1
Buckley to Tank Farm	12.4	52.2	79.2
Lower East Fork	3.5	48.2	74.2

No hydrologic routing was performed in the HMS model as the unsteady two-dimensional hydraulic model will more accurately route the runoff from each basin through the study area.

Results

Peak flows generated by the East Fork HMS model are listed in Table 3. The 2-, 5-, 10-, 25- and 100-year events were modeled with the calibrated soil moisture condition of AMC I.5. The 10-year event with an AMCIII was also modeled to compare against WMP values from the East Fork watershed.

Table 3 Hydrology Results (cubic feet per second)

Catchment	2-year	5-year	10-year	25-year	100-year	10-year AMCIII
Upper Buckley	870	1,340	1,760	2,350	3,310	3,220
Airport	100	150	200	280	420	460
Tank Farm	190	230	270	320	400	310
Buckley to Tank Farm	20	30	40	70	110	160
Below Tank Farm	4	5	9	19	40	76

Hydraulic Analysis

Hydraulic Features

The core intent of this study is to better understand the floodplains and flood risks in the lower East Fork watershed. The existing system is comprised of a natural earthen channel with several bridge and culvert crossings (Figure 8). Below the confluence with Tank Farm Creek the natural channel and floodplain is artificially constrained by a private, non-engineered levee system.

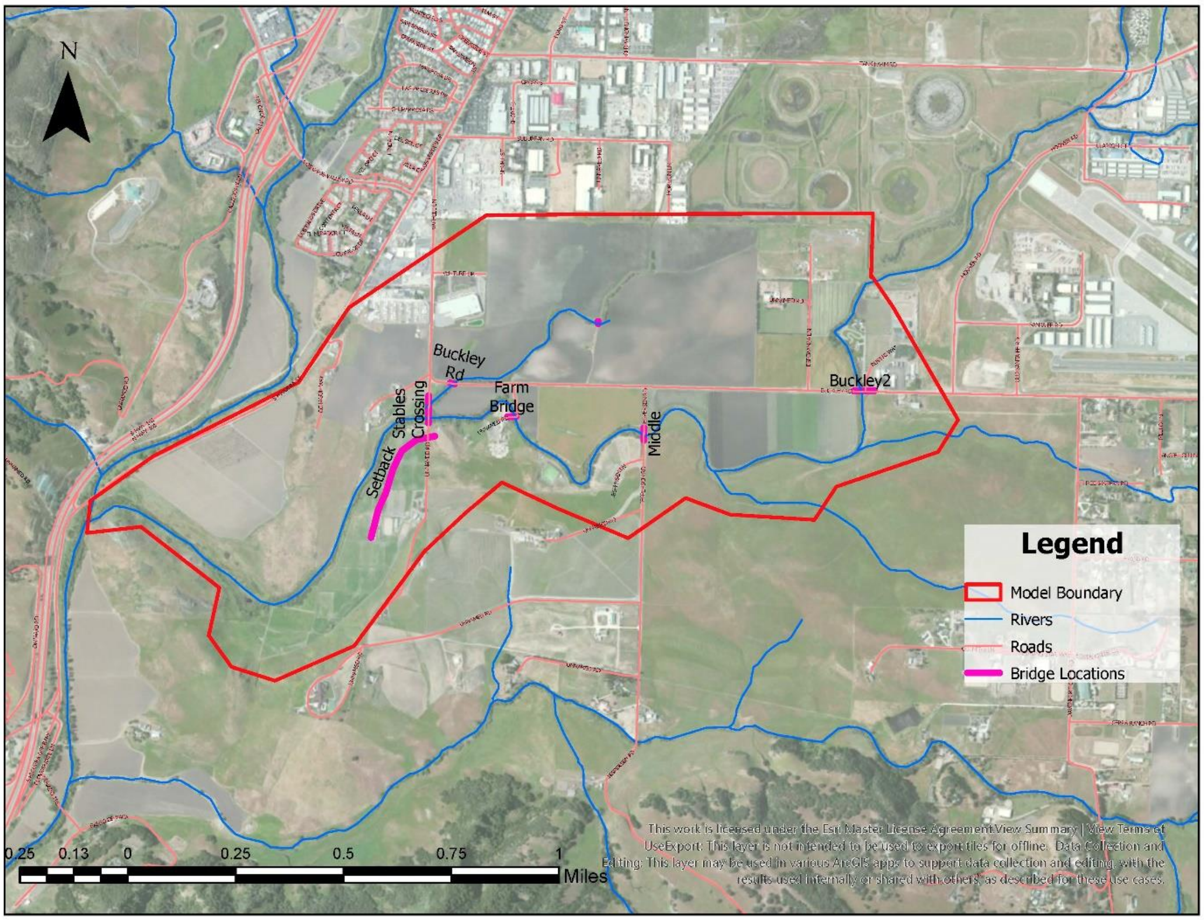

Figure 8 – Hydraulic Structure Locations

There are seven key channel crossings throughout the hydraulic study area. The East Fork crossings analyzed are Buckley Road, Jesperson Road, a private farm bridge and a private road leading to horse stables. On Tank Farm Creek they include Buckley Road, a private farm crossing, and a private road leading to horse stables. The private road leading to horse stables crosses both Tank Farm Creek and East Fork just upstream of their confluence. This study utilizes modern hydraulic modeling software to provide a better understanding than previous studies of how the channel, crossings and levees interact during storm events.

HEC-RAS Model

A two-dimensional hydraulic model of the project area was developed using HEC-RAS Version 6.2. HEC-RAS is hydraulic modeling software developed by the U.S. Army Corps of Engineers. Modeling parameters include boundaries, inflow hydrographs, the downstream boundary condition, geometry (bridges, culverts, levees, and ground surface terrain), and Manning's n values. Figure 9 provides an overall schematic view of the model with surrounding topography.

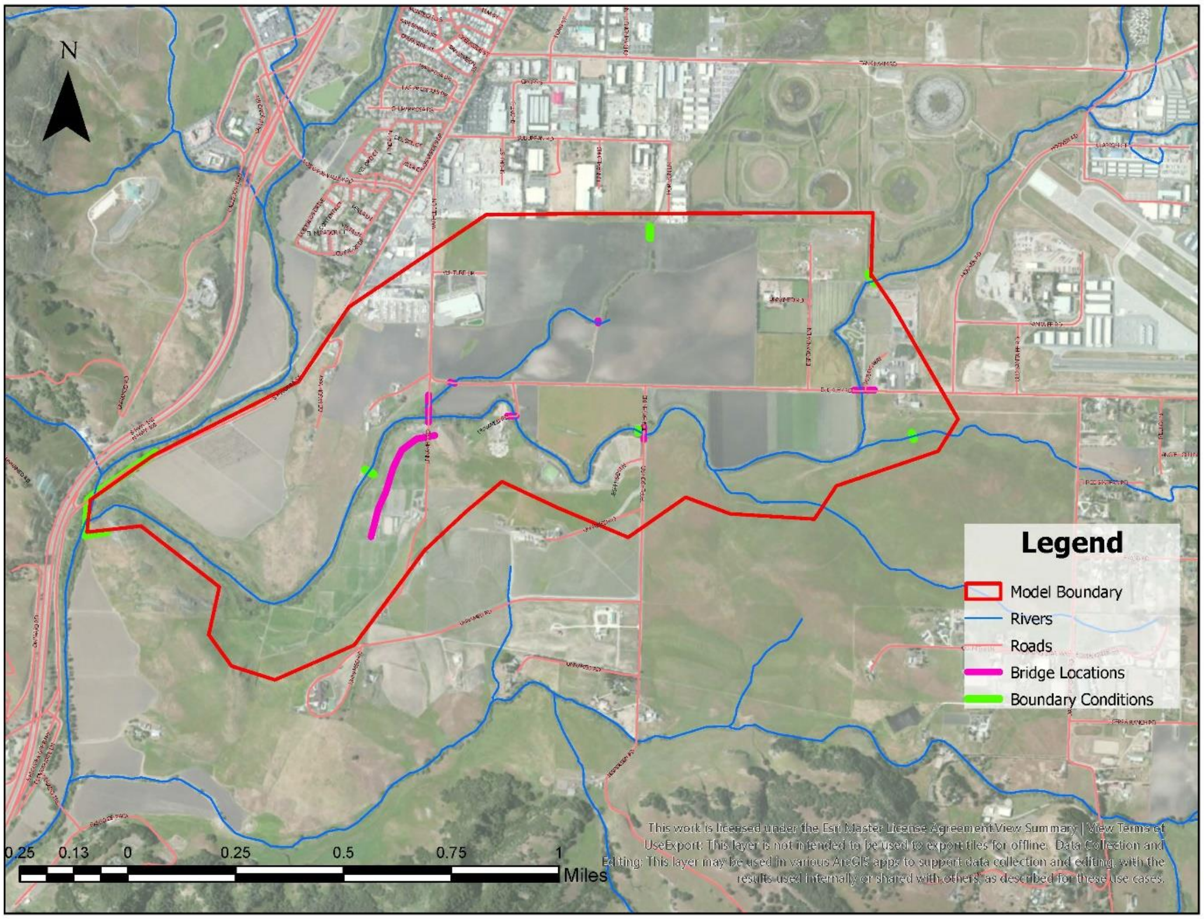

Figure 9 – Hydraulic Model Schematic

Model Bounds

The model boundary extends far enough upstream to capture floodplains and channel crossings that may impact flow at the key area of concern. The model's downstream boundary is near its confluence with San Luis Obispo Creek.

Boundary Conditions

Inflow hydrographs were added at locations corresponding to their representation in the HEC-HMS model. The downstream boundary condition was set to normal depth with a downstream channel slope of 0.01 feet/feet. A sensitivity analysis of potential boundary conditions at the confluence of SLO Creek was performed. The results, discussed later in this report, demonstrate that varying boundary conditions do not impact water levels at Buckley Road.

Existing Condition Geometry

The existing condition model terrain was developed with topographic data and field survey topographic data. 2017 USGS/FEMA 1-meter LiDAR data was used as the basis of the ground surface terrain, and the terrain was refined by "burning" in detailed field survey data. MBS Land Surveys, the project's surveying contractor, collected topographic survey data in September 2021 along Buckley Road at the Vachell Lane intersection, at the Tank Farm crossing at Buckley Road, the East Fork crossing at the private road, the next two upstream East Fork crossings, and along East Fork from Tank Farm to 2,500 feet downstream. Survey point locations are shown in Figure 10.

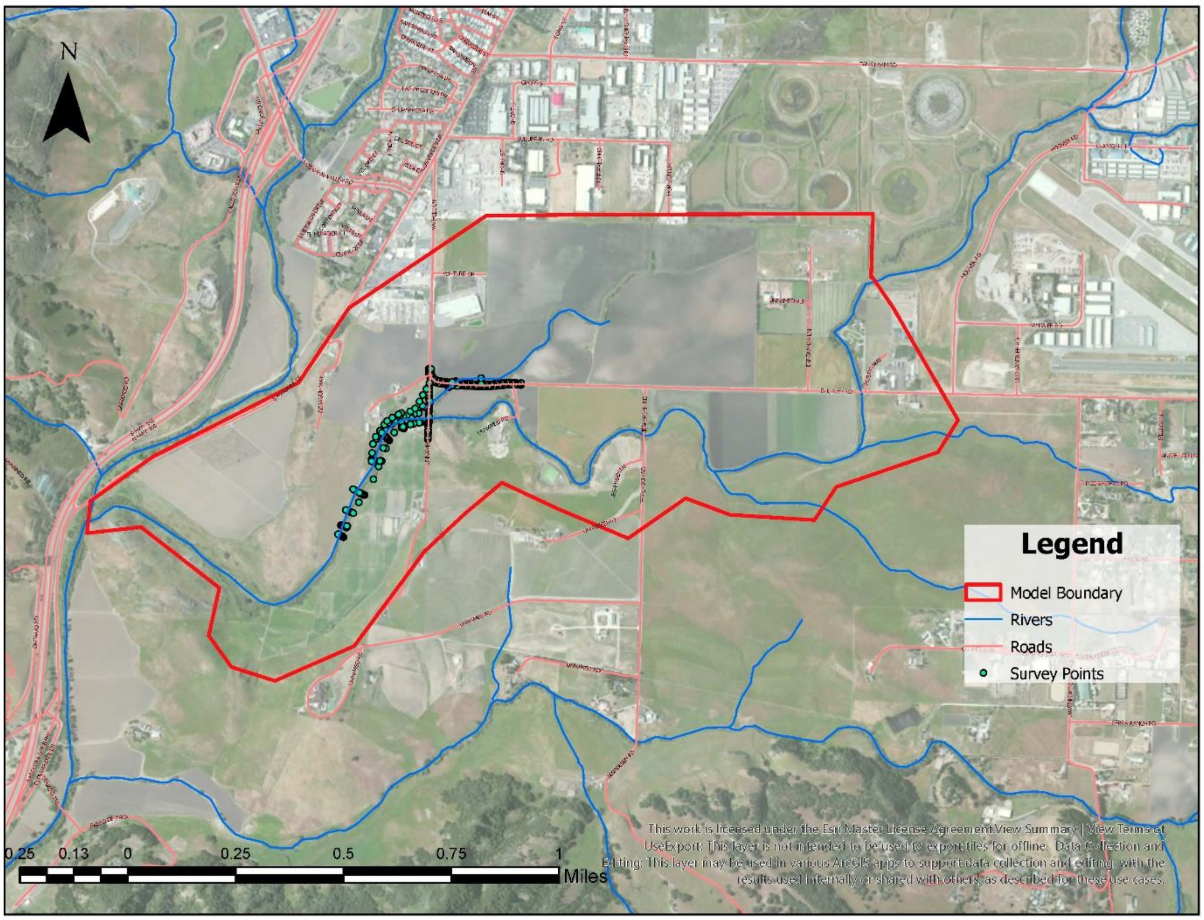

Figure 10 – Survey Locations

Recent Changes to Geometry

The hydraulic model terrain includes changes from the 2017 terrain topography reflecting two key projects that have the potential to affect flood behavior in the study area in the near future: the Avila Ranch development and the extension of Buckley Road to Highway 101.

The Avila Ranch project, currently under construction, encroaches on and grades the existing floodplain upstream of Buckley Road. These modifications affect the floodplain stage/storage relationship. This project will also remove the farm crossing of Tank Farm Creek.

The Buckley Road extension project, completed in 2022, raised the roadway profile of Buckley Road from the Tank Farm Creek culvert to west of the Vachell Lane intersection (Figure 10). This change should provide additional flood protection to the Buckley Road and Vachell Lane intersection.

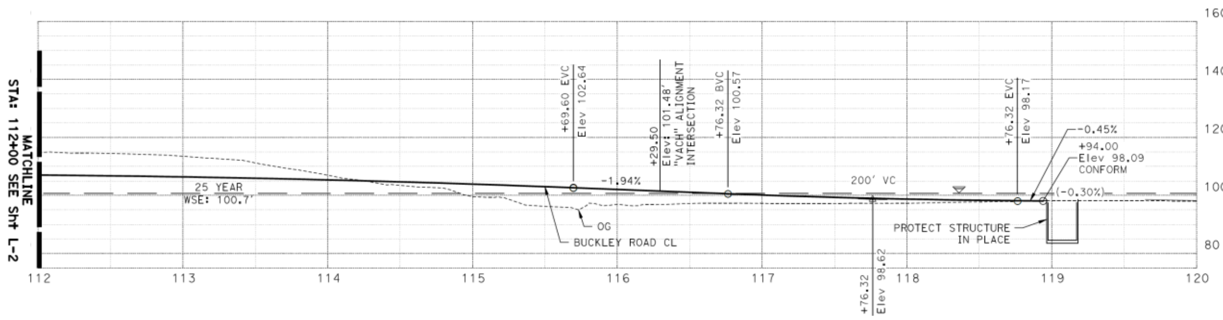

Figure 11 – Buckley Road Improvement Profile

The existing condition ground surface terrain was modified to represent these conditions. CAD improvement plan files were used to incorporate the Buckley Road extension. Because similar files were not available for the Avila Ranch project, Avila Ranch topography was approximated from development plans. The resulting terrain is shown in Figure 12.

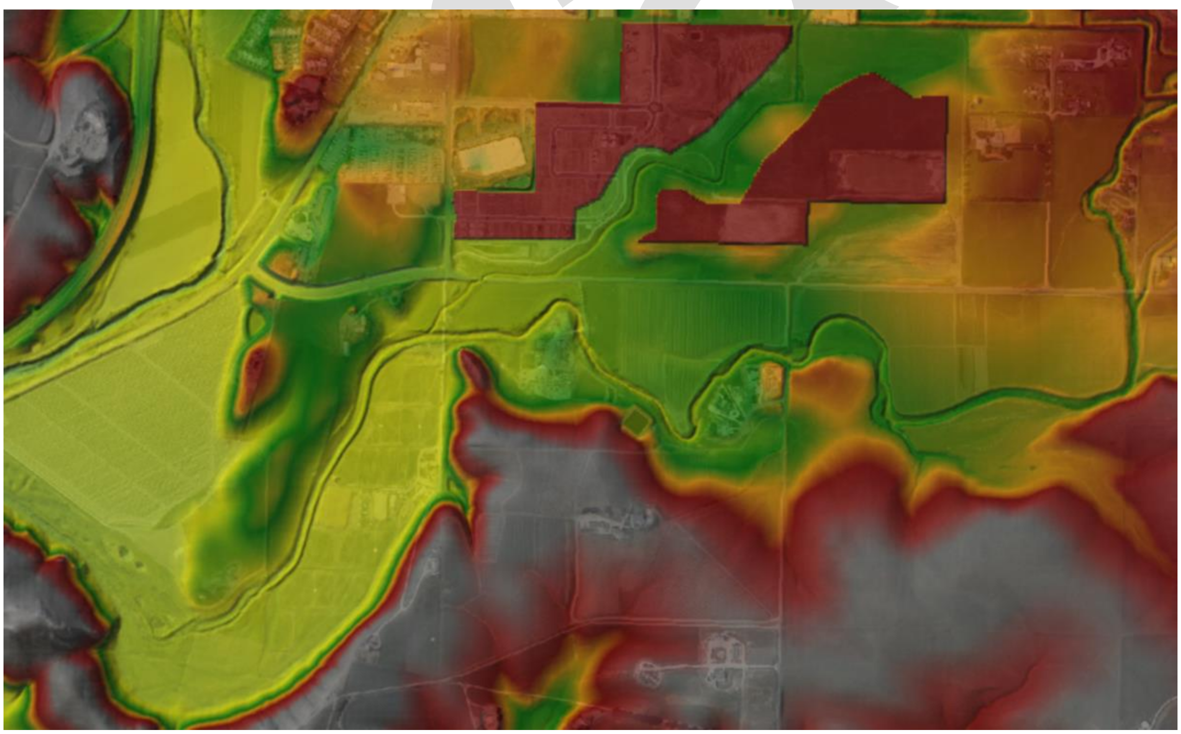

Figure 12 – Updated Terrain

Manning's 'n' Values

Manning's '*n'* values are assigned to the ground surface terrains based on land use and surface cover. The majority of the floodplain is characterized as agriculture and assigned a value of 0.04. Channel *n* values were estimated using field photographs, aerial images, and Fig. 5-5: "Typical channels showing different *n* values," from *Open-channel Hydraulics* (Chow, 1973). Manning's *n* values in the channels range from 0.035 for clean, straight channels to 0.07 for channels with bends and heavy vegetation. Land use and manning's *n* values are shown in Figure 14.

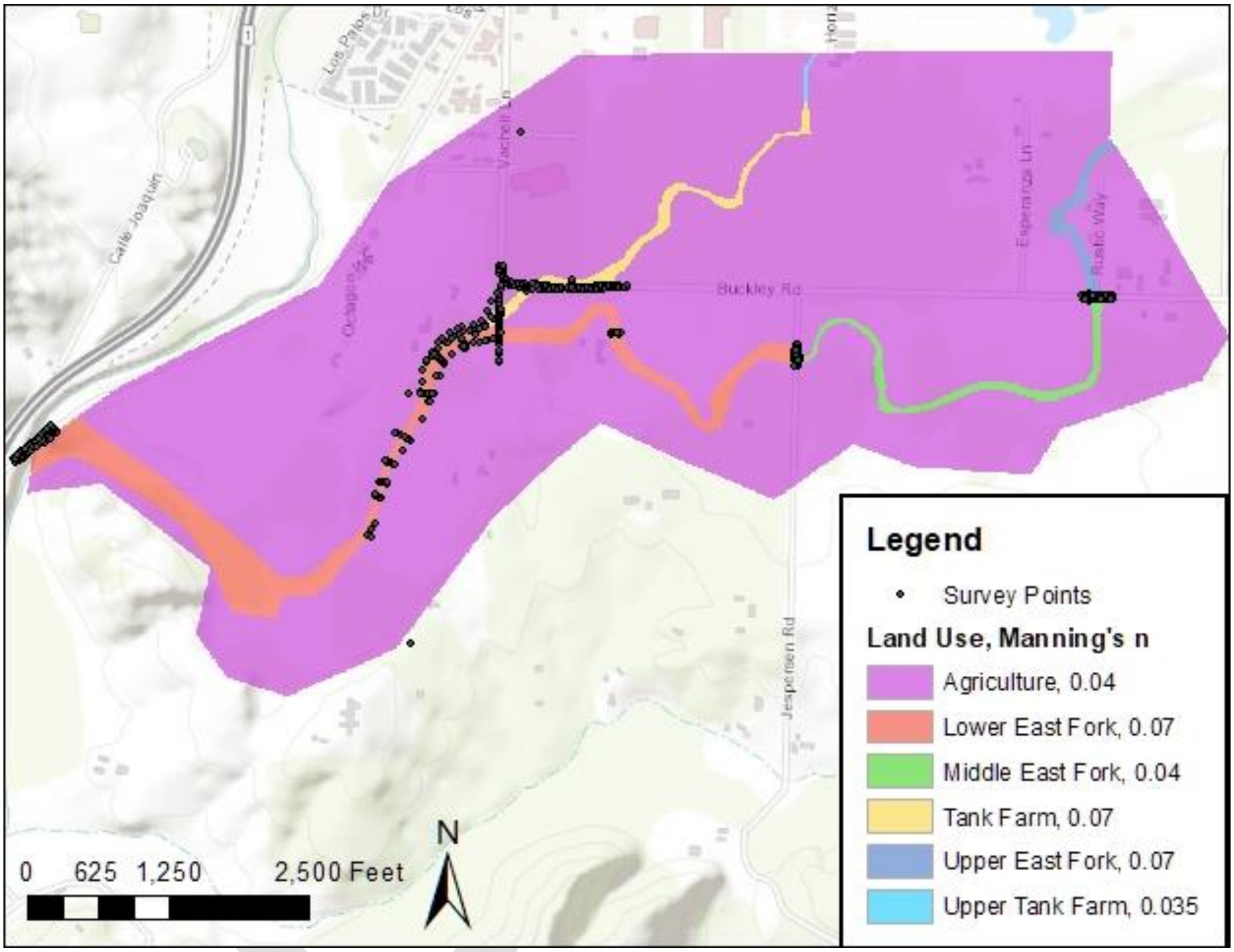

Figure 13 – Land Use, Manning's n Values, and Survey Locations for Existing Conditions

Results

All modeled scenarios and storm severities ran stable at a 5-second computational time step.

Downstream Boundary Sensitivity Analysis

The confluence with San Luis Obispo Creek (SLO Creek) creates a hydraulic boundary for East Fork with varying tailwater conditions dependent on the stage of SLO Creek. A sensitivity analysis was performed to determine how conditions at the confluence may impact flooding upstream on East Fork.

Figure 15 shows the extent where a static 100-year tailwater on SLO Creek would increase water surface elevations from 100-year flows on East Fork. These results demonstrate that increased water surface elevations on East Fork from any backwater effects from SLO Creek are isolated to the stream reach below the confluence of East Fork and Tank Farm Creeks. Flooding on SLO Creek does not impact the Buckley Road area. During the course of this study, FEMA informed the County in discussions of a separate modeling effort of SLO Creek that their analysis reached the same conclusion.

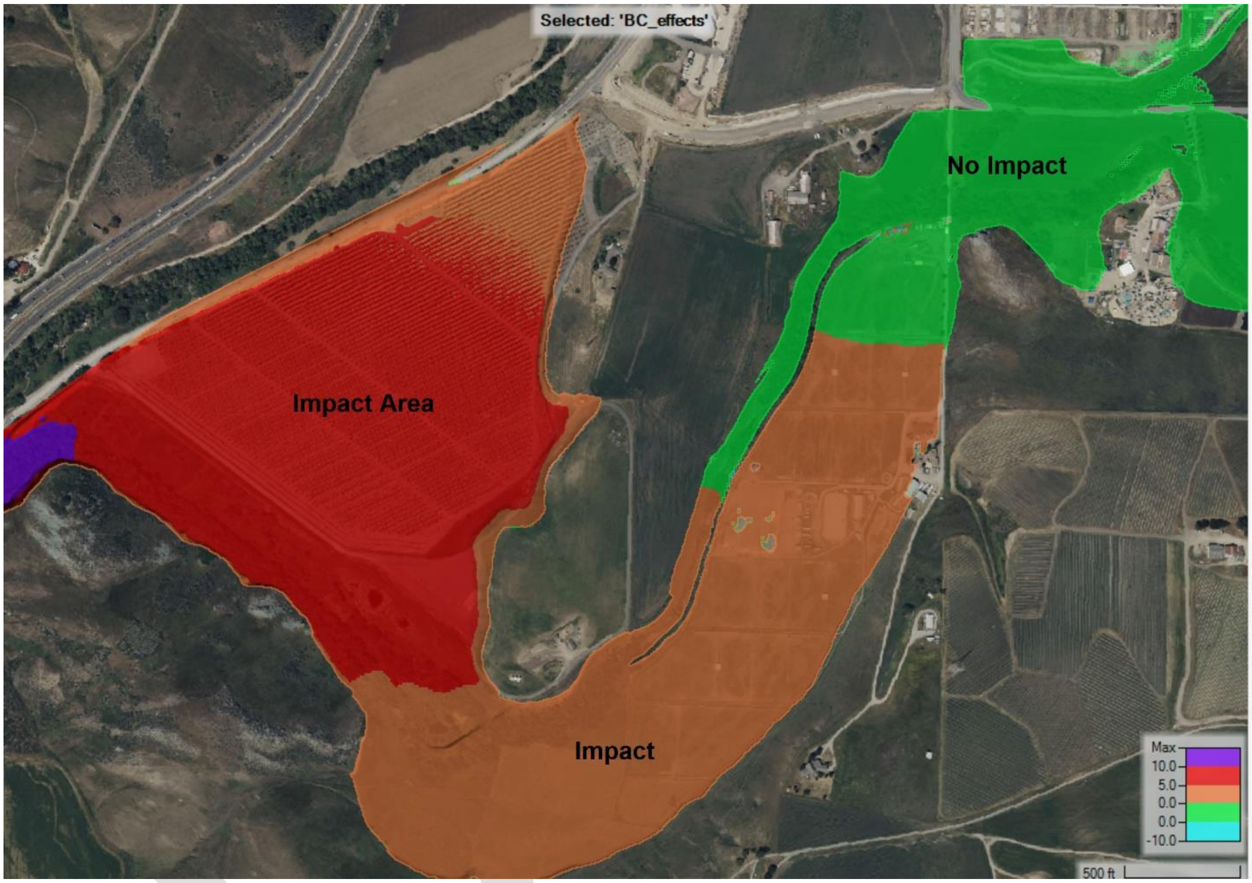

Figure 14 – SLO Creek Impact Area (100-year)

Flooding Depths and Extents

The HEC-RAS model was run for the 2-, 5-, 10-, 25-, and 100-year events. The 24-hour events ran stable at a 5-second computational time-step. The results are shown in Figures 16 to 20.

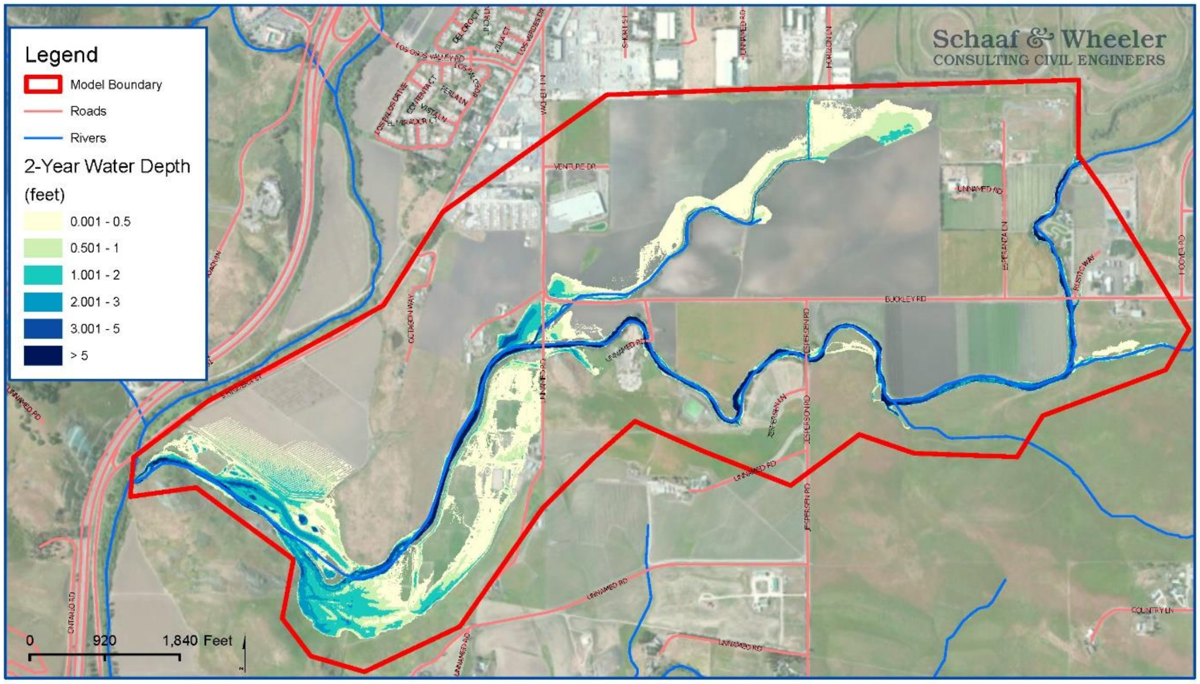

Figure 15 – 2-Year Floodplain

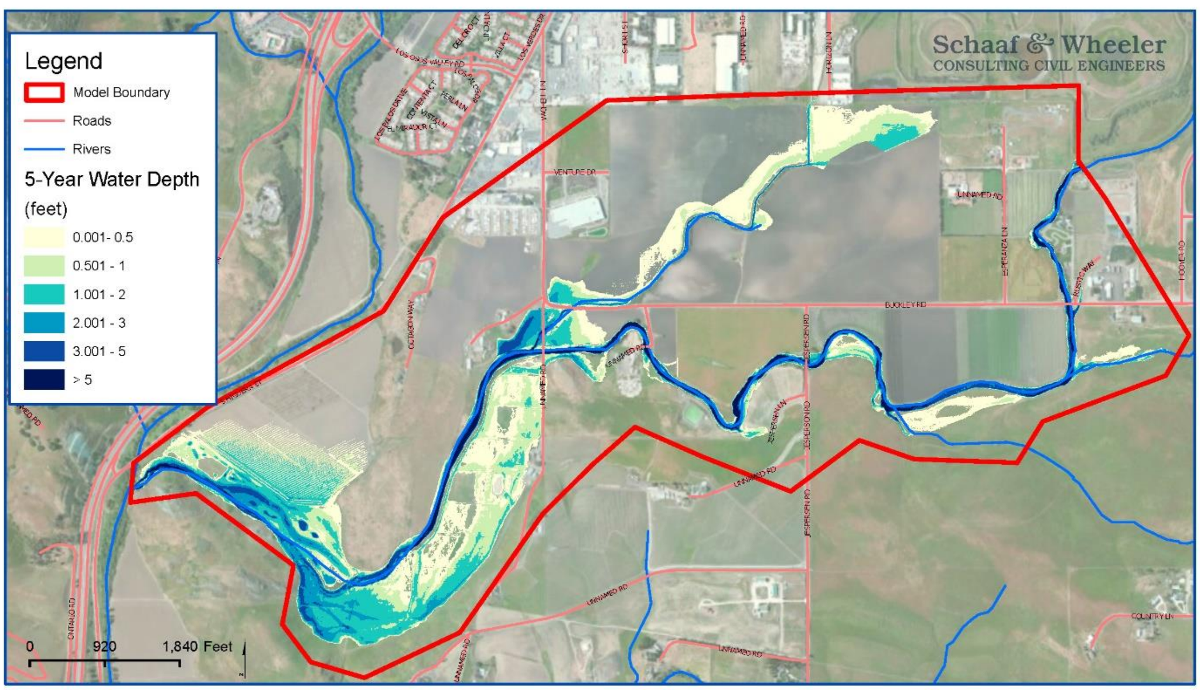

Figure 16 – 5-year Floodplain

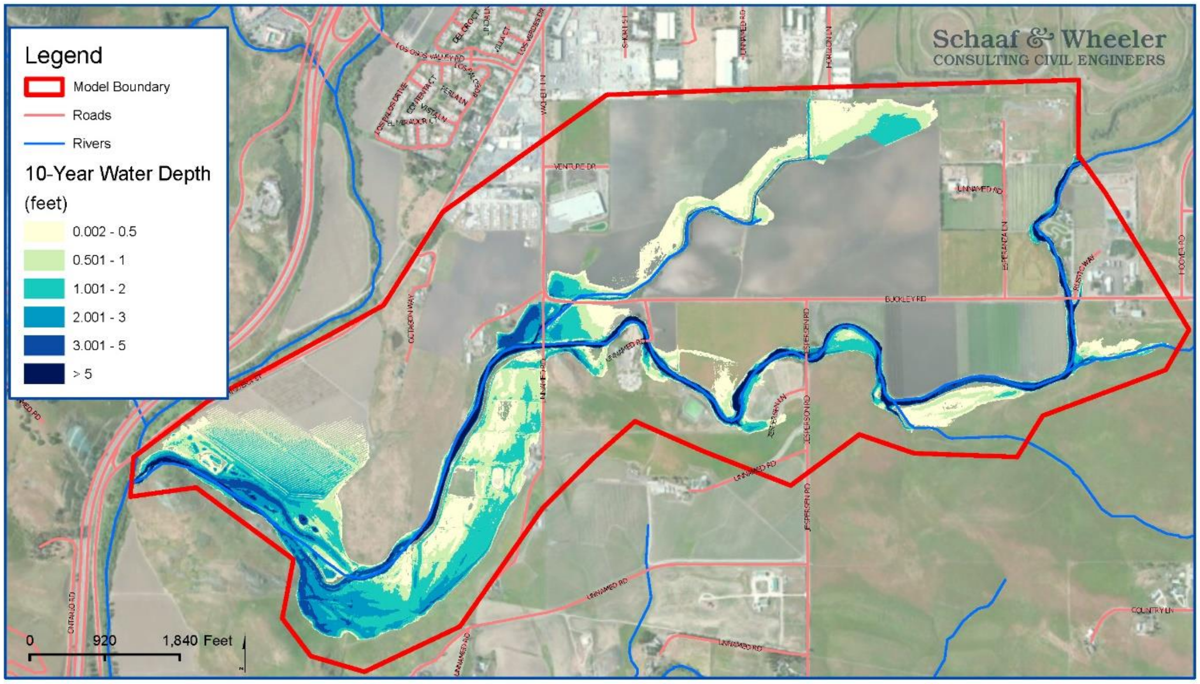

Figure 17 – 10-year Floodplain

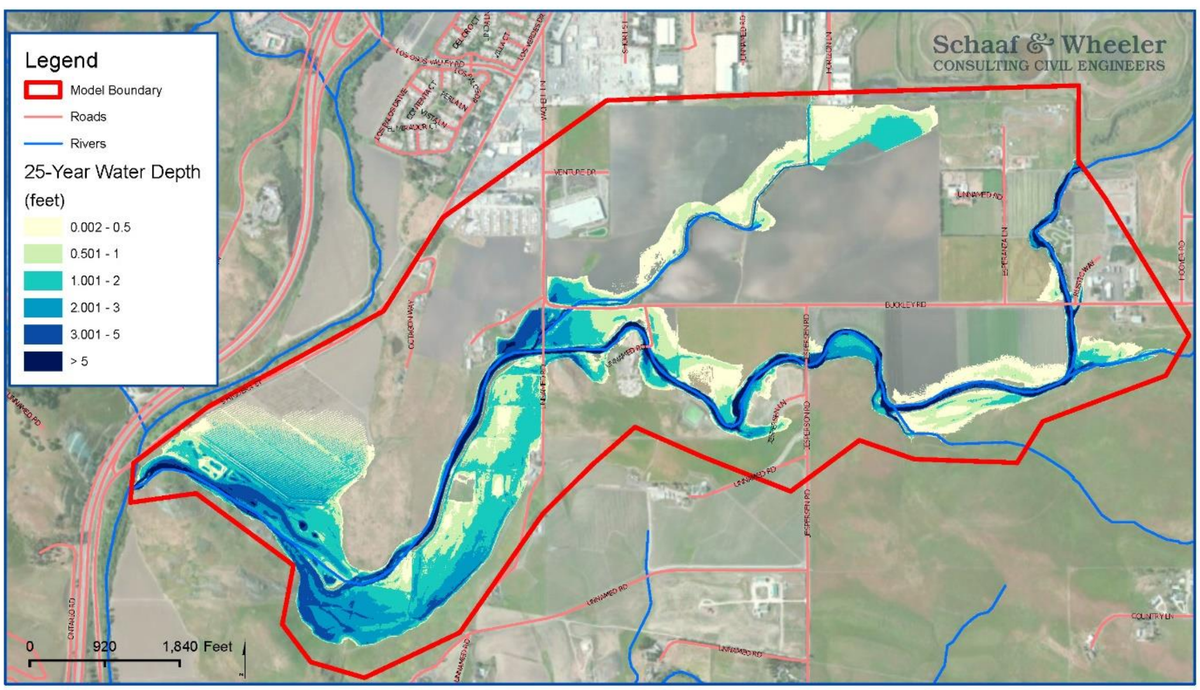

Figure 18 – 25-year Floodplain

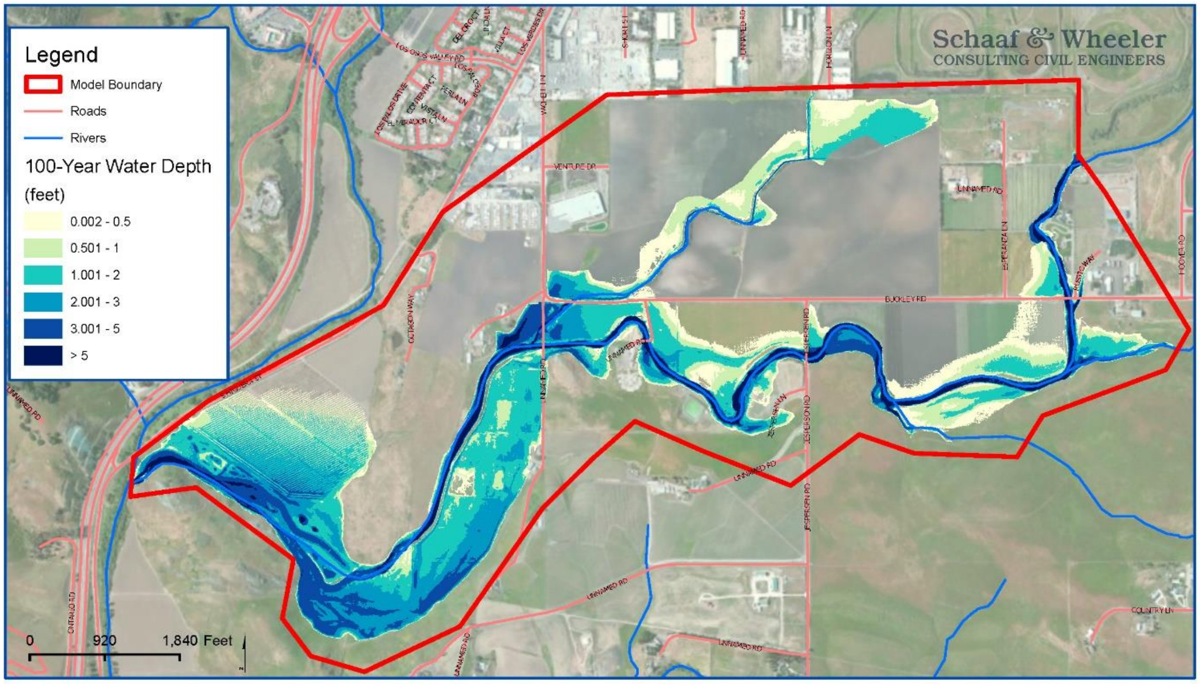

Figure 19 – 100-year Floodplain

Bridge Hydraulics

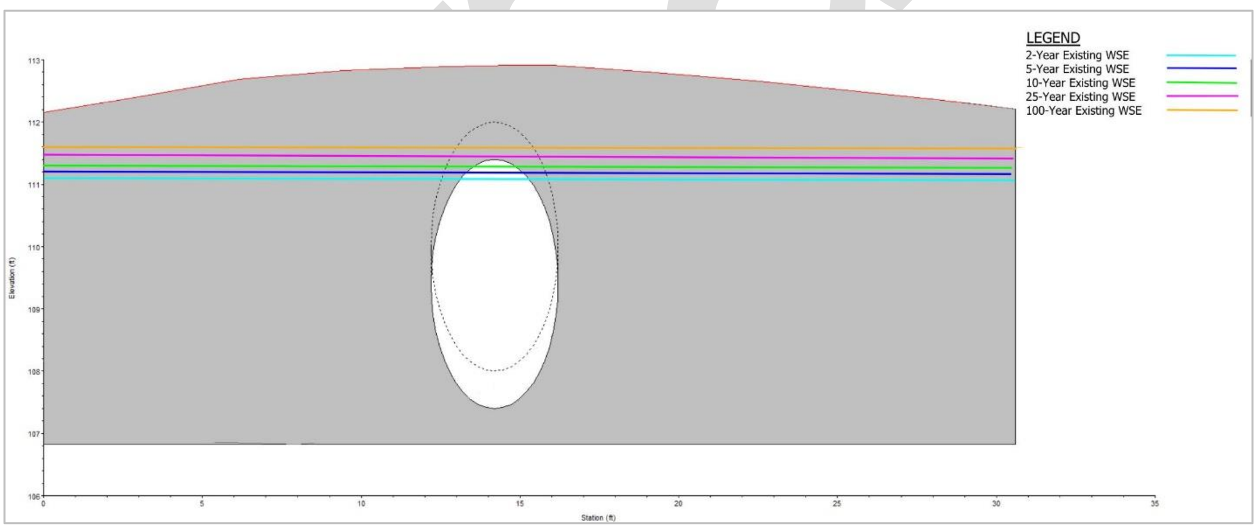

Figure 20 – East Fork at Buckley Road

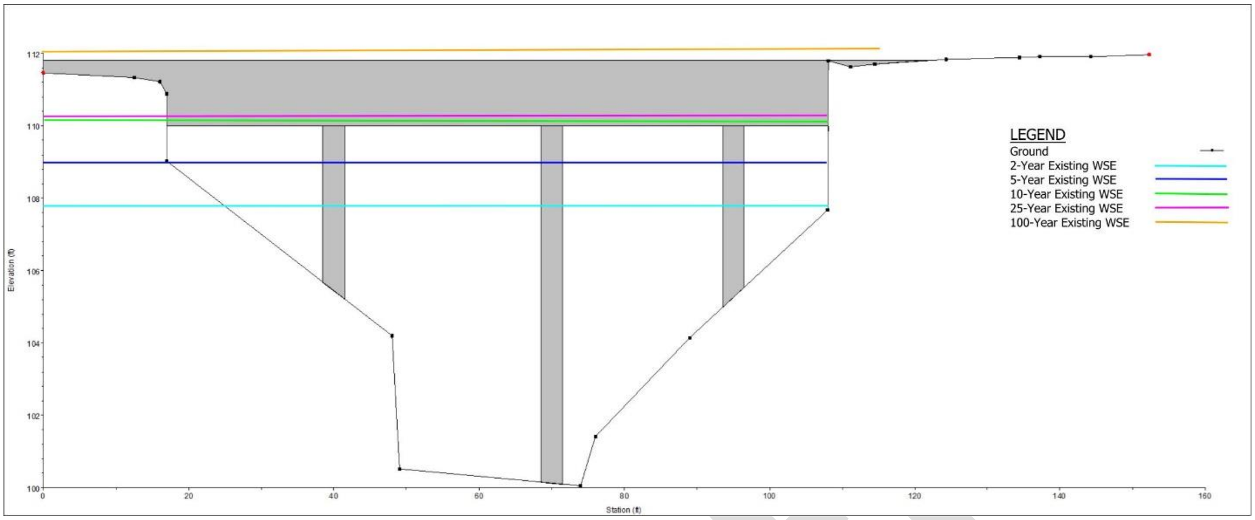

Figure 21 – East Fork at Jesperson Road

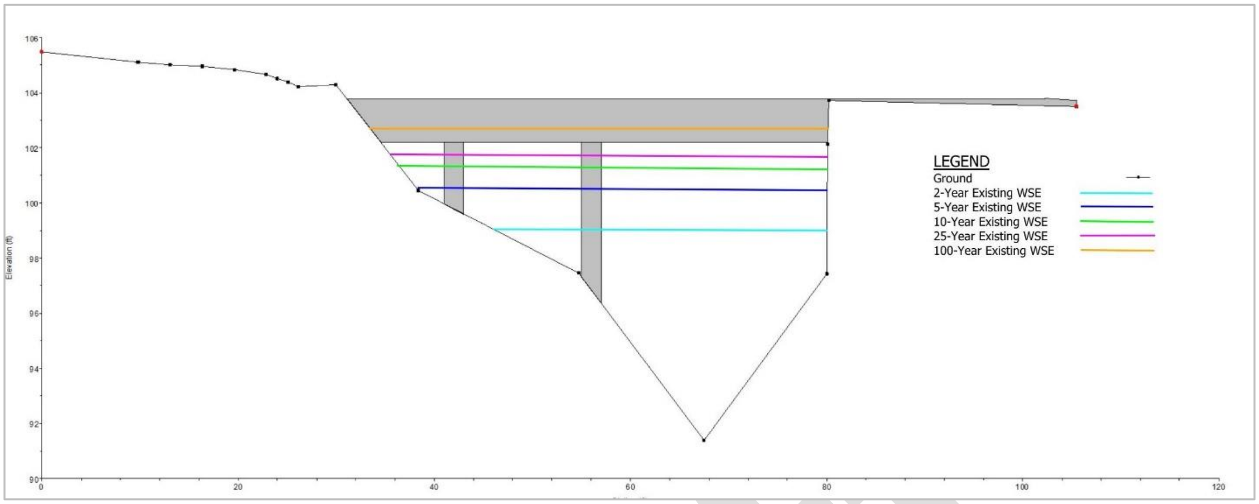

Figure 22 – East Fork at Farm Bridge

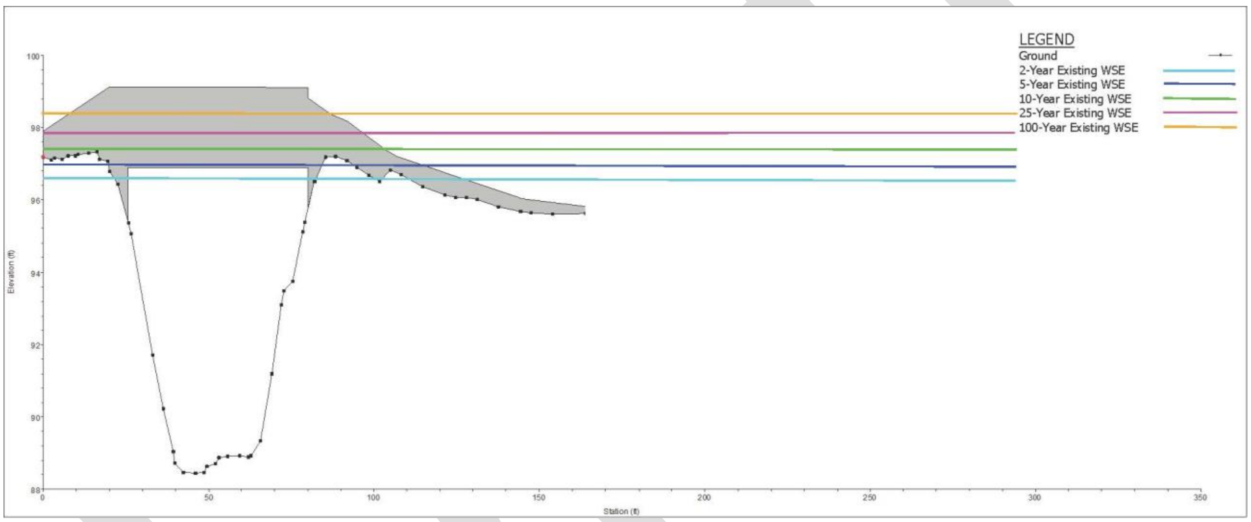

Figure 23 – East Fork at Private Road (Stables)

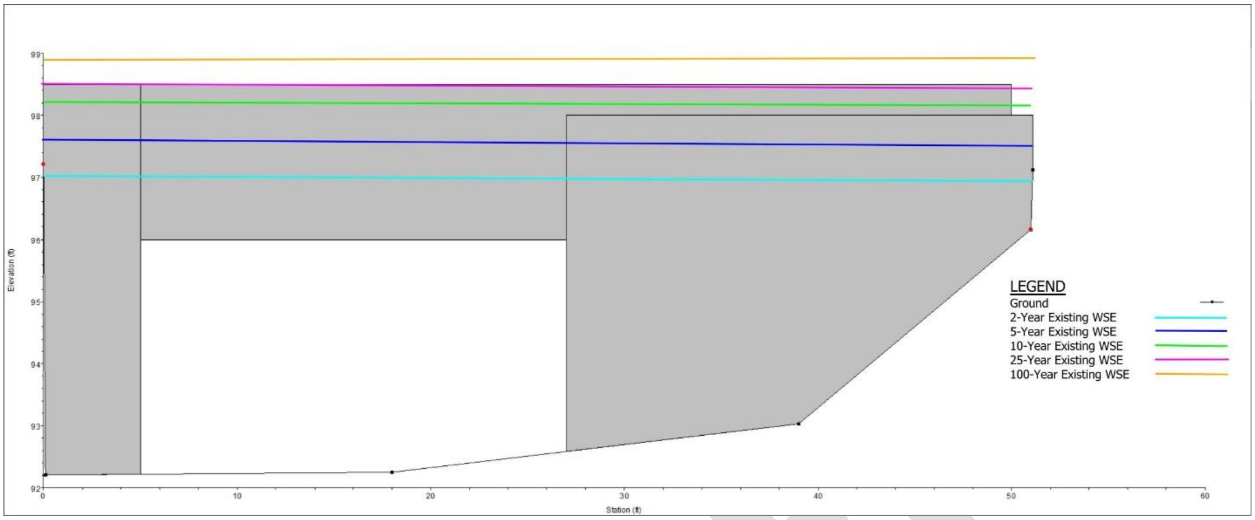

Figure 24 – Tank Farm at Buckley Road

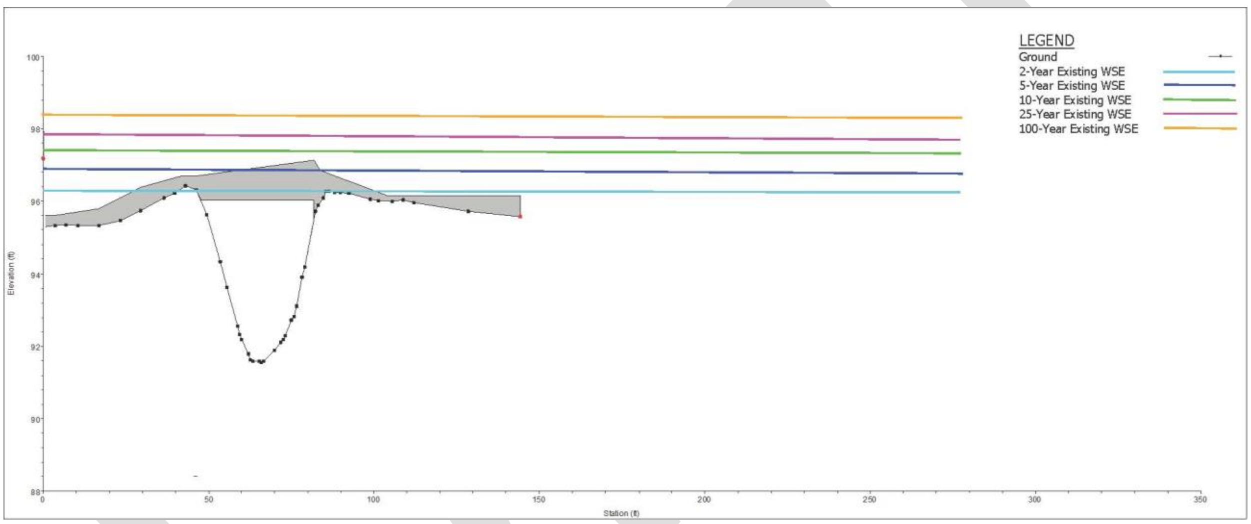

Figure 25 – Tank Farm at Private Road (Stables)

Table 4: Water Surface Elevations at Bridges (feet NAVD88)

Bridge	Creek	Top of Road	2-year	5-year	10-year	25-year	100-year
Buckley	**East Fork**	125.6	120.2	121.2	121.9	122.8	123.8
Jespersen	**East Fork**	112.0	107.8	109.1	110.1	110.2	112.5
Private Road (Stables)	**East Fork**	99.1	96.6	97.1	97.5	97.9	98.4
Buckley	**Tank Farm**	98.1	97.0	97.6	98.2	98.5	98.9
Private Road (Stables)	**Tank Farm**	97.1	96.2	97.1	97.5	97.9	98.4
Farm Bridge	**East Fork**	104.1	99.1	100.4	101.3	101.9	102.7

Discussion

Buckley Road does not overtop during the 2-, 5- or 10-year events, although the road shoulders and surrounding areas are inundated. Buckley Road is expected to be overtopped during the 25- and 100-year events. The maximum flood depth over the road is approximately 1-foot.

It is important to note that, per standard engineering practice, all bridges and culverts are assumed free of debris blockages. If crossings are not maintained, there is a higher potential for flows to backup and overtop the roadways. Using a 25% blockage on the Buckley Road crossing of Tank Farm Creek, the model shows that flows do overtop the roadway. This emphasizes the need for routine maintenance and provides a good example of the variability between model results and potential real-world conditions.

As hydraulic conditions on East Fork nearest the confluence with SLO Creek appear to have little effect on water surface elevations at Buckley Road, this study concludes the hydraulics in the vicinity of the confluence of Tank Farm Creek and East Fork are the key driver of flooding at Buckley Road. There are three primary causes of poor conveyance in this area. First, this portion of the watershed is notably flat. Prior to the construction of the levee in this area, it is likely that the area naturally experienced high sedimentation due to floodwaters slowing and spreading through what is now mostly the Buckley Stables and City properties. Second, the levee both significantly reduces available floodplain storage and hydraulically impairs the progression of flows from the confluence of Tank Farm Creek and East Fork to East Fork's curve back to the west. These conditions produce increased water surface elevations directly upstream of the levee, eventually causing East Fork to crest its southern bank and return to its historical floodplain behind the levee. Third, a lack of channel maintenance further hinders conveyance in this area in particular, where the channel is shallower and more constrained than much of the upstream reaches. To address the maintenance issue, the County and City have recently collaborated to address stream maintenance in the East Fork Area. 2022, the first year of this pilot program saw over 3000 linear feet of Tank Farm and East Fork creek channel cleared of dead and down debris, consistent with environmental permitting requirements and guidelines of Appendix II of the SLO Creek WMP.