Appendix C
Fluvial Flood Hazards

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Definitions, Acronyms, & Abbreviations

Definitions

100-Year/500-Year FEMA Flood Event: A fluvial flooding event based on extreme value analysis of historic storms with a 1% (100-Year)/0.2% (500-Year) chance of occurring in a given year; or a 1 in 100/1 in 500 chance of occurring in a given year.

Coastal Confluence: The combination of fluvial flooding and high tides elevated by sea level that expands river flooding extents.

Fluvial Flooding: Fluvial (or riverine) flooding occurs when rainfall over an extended period of time causes a river, stream, or creek to exceed its channel capacity. Fluvial floods are usually described by their volume of streamflow. Actual flood extents may also be influenced by sedimentation, material obstruction of a water corridor (e.g., debris blocking culverts), and extreme high tides, although these are not typically included in fluvial flood mapping.

Acronyms and Abbreviations

City	City of Carpinteria
ESI	Electronic Submittal of Information
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
NFIP	National Flood Insurance Program
WWTP	Wastewater Treatment Plant
TOT	Transient Occupancy Tax

Fluvial Flood Hazard Summary

While the vulnerability assessment focused on sea level rise and coastal hazards, the City of Carpinteria (City) felt it important to identify the potential magnitude of community impacts of creek flood hazards, particularly following the 2017 Thomas Fire and subsequent debris flows. Creek flood extents are assessed to compare the importance of existing flood hazards to climate change-influenced coastal hazards. The potential effects of fluvial hazards are estimated using a variety of possible future scenarios. However, the influence of existing development and/or future adaptation decisions are not considered within this analysis.

Fluvial flooding vulnerabilities identified outside of Carpinteria Creek are based on existing Federal Emergency Management Agency (FEMA) 100-year and 500-year flood maps. **All fluvial flooding impacts could occur under existing conditions.** Discussion of existing fluvial flooding threats given existing conditions (100-year FEMA flood event) and the 2100 time horizon (500-year FEMA flood event) is continued below.

Creek Flood Hazards Expansion

> Creek (fluvial) flood hazards associated with a 100-year or 500-year storm as mapped by FEMA could cause more damage to City resources and infrastructure than 5 feet of sea level rise and a 1% annual chance storm.

Fluvial flood hazards (e.g., creek flooding) associated with the existing 500-year FEMA flood event (0.2% annual chance) currently expose more properties, land uses, schools, and infrastructure to potential damages than future coastal hazards with ~5 feet of sea level rise by 2100. Climate change impacts to fluvial flooding along Carpinteria Creek show expanded potential for flooding near the commercial shopping center located at Carpinteria Avenue and Casitas Pass Road, and inland of the Union Pacific Railroad tracks toward Linden Avenue and 7th Street. However, data on climate change impacts to flood hazards on Franklin and Santa Monica Creeks is unavailable. In addition, this study does not access climate change impacts on catastrophic events such as floods and debris flows such those that occurred due to the 2017 Thomas Fire and 2018 Montecito Debris flows.

Existing Fluvial Flood Hazards

FEMA mapped a regulatory fluvial (creek) flood using a 100-year FEMA flood event (1% annual chance) and 500-year FEMA flood event (0.2% annual chance) to determine regulatory flood insurance rates. Both FEMA-mapped fluvial floods could have devastating impacts to residential and commercial land uses and infrastructure within the City. Under a 500-year FEMA flood event, transportation corridors including U.S. Highway 101, the Union Pacific Railroad, numerous surface streets, and bicycle and bus/transit routes could be affected. In addition, important community facilities including the Sansum Health Clinic, the Wastewater Treatment Plant (WWTP), Carpinteria State Beach Service Yard, Post Office, 3 churches, and 4 schools encompassing 34 school buildings could be vulnerable to flooding. Vulnerabilities to the community from existing fluvial flood risks are greater than those associated with future coastal hazards from high tides, wave run-up, ocean-related flooding, and coastal erosion, even with ~5 feet of sea level rise.

1. Existing Conditions & Physical Setting

1.1 Existing Fluvial Hazards

FEMA maps delineate creek (fluvial) flood hazards as part of the National Flood Insurance Program (NFIP). This program requires highly-specific technical analysis of watershed characteristics, topography, channel morphology, hydrology, and hydraulic modeling to map the extent of existing watershed-related flood hazards. These maps, representing the existing 100-year and 500-year FEMA flood events (1% and 0.2% annual chance of flooding), are known as FEMA Flood Insurance Rate Maps (FIRMs), and determine the flood extents and flood elevations across the landscape. Figure 1 illustrates the adopted FEMA flood event hazards across the City. Please note that FEMA flood maps are based only on existing conditions and do not account for coastal processes, climate change, or the interaction of fluvial and coastal processes in the analysis of fluvial flood hazards. It is noted, however, FEMA is currently in the process of updating all floodplain maps in the state of California.

Historic fluvial flooding has occurred in various parts of the City (Figure 2). FEMA flood maps and base flood elevations for the major watersheds at the downstream end are shown in Table 1 and Figure 1.

Figure 1 - Adopted FEMA Flood Insurance Rate Map

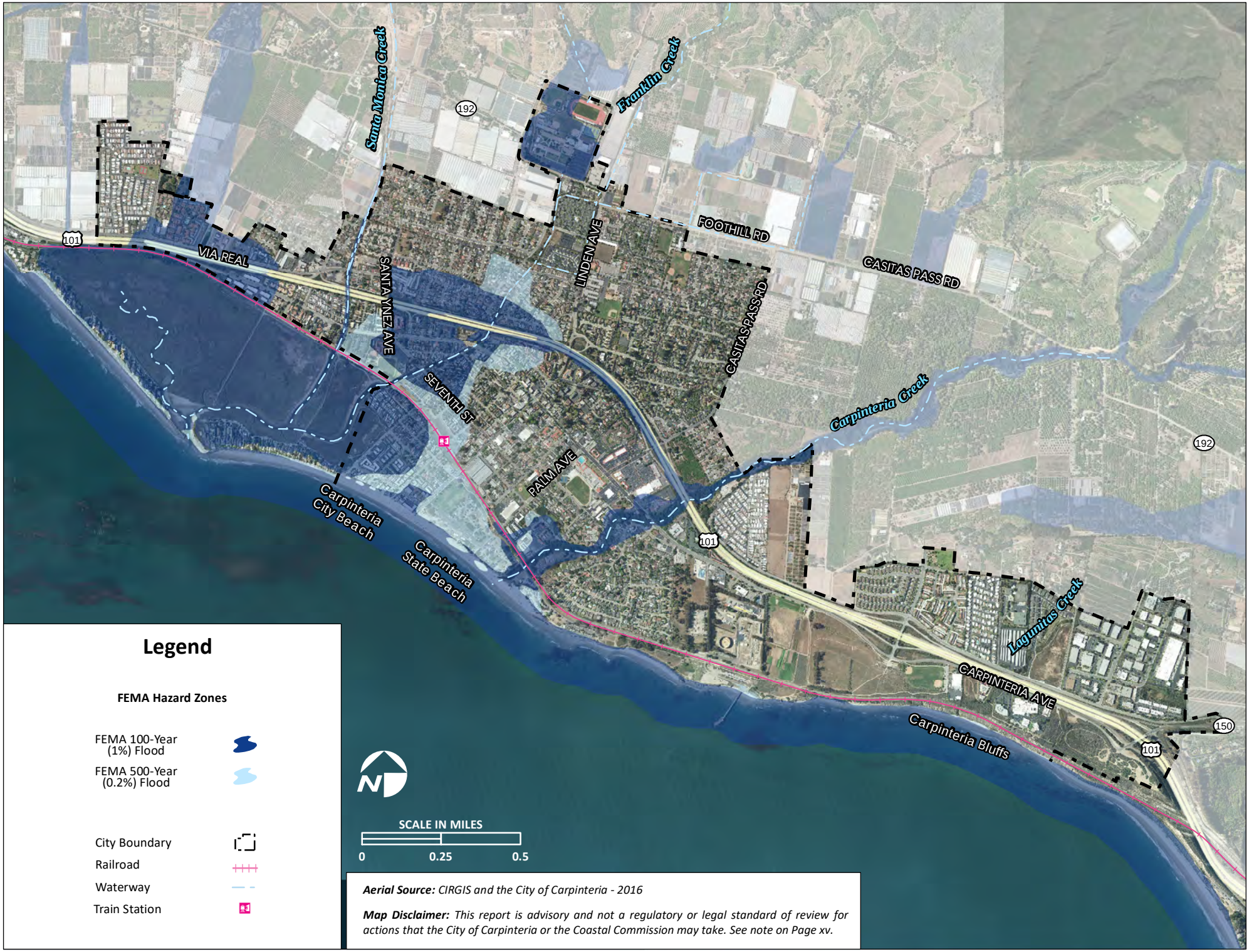

Figure 2. Fluvial Flooding along Via Real in Carpinteria in January 2018 (photo courtesy, W. Swing)

Table 1. FEMA Fluvial Flood Elevations for Major Watersheds in Carpinteria

Water Body	Base Flood Elevations (NAVD 88)
Carpinteria Creek	11 feet
Franklin Creek	13 feet
Santa Monica Creek	8 feet

2. Vulnerability Methodology

2.1 Coastal Hazards Projections

The modeling work for the 2016 *Santa Barbara County Coastal Resilience Project* (Coastal Resilience model) includes modeling of fluvial flooding and coastal confluence. Creek flood extents were initially assessed to provide estimates of the relative importance of existing flood hazards compared to climate change influenced coastal hazards.

Coastal Confluence and Fluvial Flooding

Coastal confluence modeling projects the influence of climate change on fluvial flood hazards. As sea levels rise, fluvial flooding is backwatered during high tides, which can cause additional flooding in previously unflooded areas upstream/upland beyond the riverine channel banks. An initial model used the downscaled climate modeling developed during the 2008-2009 Second California Climate Assessment to derive these precipitation and flood flow changes because the Fourth Climate Assessment data were not available at the time the Coastal Resilience model was run (2016).

This initial coastal confluence modeling was conducted only for Carpinteria Creek, using the existing FEMA flood model (Revell Coastal and Revell Coastal and ESA 2016). The locations that appear to be affected by this coastal confluence modeling occur with 1-2 feet of sea level rise, resulting in potential expansion of creek flooding along Carpinteria Creek over the tracks along Maple Avenue up to Linden Avenue and 7th Street. With ~5 feet of sea level rise, the influence of climate change expands fluvial flood hazards to Carpinteria Middle School, into the Downtown area from Palm Avenue to 8th Street and Linden Avenue to the Union Pacific Railroad tracks, and into the commercial shopping center as shown in Figure 3. Results of this initial modeling were not included in the vulnerability assessment, which focused on sea level rise and coastal hazards.

Figure 3 - Coastal Confluence Hazards

Modeling Assumptions

As with all modeling, assumptions had to be made to complete the work. Below are the modeling assumptions of the *Santa Barbara County Coastal Hazard Modeling and Vulnerability Assessment*, which were used for this analysis (Table 2; Revell Coastal and ESA 2016).

Table 2. Hazard Model Assumptions and Biases

Geospatial Data	Potential Bias	Type of Bias	Reason
Fluvial flooding combined with coastal confluence	Too Low	Spatial and Temporal	The influence of changes in precipitation and higher sea level rise, with the effects of expanding fluvial flood extents in all creeks and the Carpinteria Salt Marsh, has not been fully analyzed. FEMA maps indicate a 100-year and 500-year FEMA flood event could occur today; these have not been evaluated with sea level rise.

Fluvial flooding modeling for Santa Monica and Franklin Creeks does not consider future changes to precipitation and runoff from the watersheds with the joint occurrence of river and coastal flooding. Coastal confluence flood modeling has not been completed for the entire Santa Barbara County (aside from Carpinteria Creek). Therefore, the influence of changes in precipitation and higher sea levels on the overall extent of flooding in the various creek mouths and sloughs has not been fully analyzed.

To represent the remaining fluvial hazards on Santa Monica Creek and Franklin Creek, the existing 100-year FEMA flood event was used to characterize existing conditions. The 500-year FEMA flood event was used to characterize future fluvial flooding hazards. This likely underestimates the future potential flood extents along Franklin Creek and Santa Monica Creek which flow into the Carpinteria Salt Marsh. ***It is important to note that the mapped extents of the 500-year FEMA flood event could occur at any time between now and 2100.*** The assumption that climate change will have no impact on flooding likely results in under prediction of the combined costal and creek flood extents.

3. Sector Results

Overall, the existing fluvial flooding hazards appear to be a larger hazard threat to the City over coastal hazards, even with ~5 feet of sea level rise.

The sector profiles and analysis for this discussion are provided in Chapter 1.0, *Sector Profiles,* of the **2019 Sea Level Rise Vulnerability Assessment and Adaptation Project.**

3.1 Camping and Visitor Accommodations

Two hotels, the Best Western Plus Carpinteria Inn and the Sandyland Reef Hotel, are currently vulnerable to FEMA mapped creek fluvial flooding hazards. These hotels charge a Transient Occupancy Tax (TOT) which goes to the City. This Report does not estimate the loss in TOT due to fluvial flooding impacts; however, given the location of these two hotels within the fluvial flood hazard zone, the potential loss of TOT is considered to be a key vulnerability.

3.2 Hazardous Materials Sites and Oil and Gas Wells

Of the onshore oil wells, two are located within the existing fluvial flooding hazard zone near the mouth of Carpinteria Creek. Under existing conditions, fluvial flooding hazards pose a risk to two Electronic Submittal of Information (ESI) sites, one located at an industrial metalsmithing building on Carpinteria Avenue and Reynolds Avenue and the other is the WWTP. Fluvial hazards also pose a risk to two businesses storing hazardous materials, including one at a light industrial building on Carpinteria Avenue and exit 87B and a metal smith on Palm Avenue. Further, the shopping plaza is vulnerable to an existing 500-year flood event. One active cleanup site, a former (and now vacant) automobile repair shop off of Carpinteria Avenue, is also exposed to fluvial flooding.

3.3 Infrastructure

Stormwater Infrastructure

Currently, fluvial flooding from a FEMA 100-year flood event could substantially affect storm drains, inlets, and outfalls. Most of this infrastructure is located along the Highway 101 corridor and in the Franklin Creek and Santa Monica Creek floodplains. Compared to the 100-year flood event, fluvial flooding from a FEMA 500-year flood could affect an

additional 38 inlets (154 total), 22 outfalls (208 total), and 1.8 miles (9.5 miles total) of storm drains. Additional exposure would occur in the Downtown Beach Neighborhood, 6th Avenue east of Linden Avenue, and near the Albertsons Shopping Center. A 500-year FEMA flood event could be more damaging to stormwater infrastructure than coastal flooding under 5 feet of sea level rise.

Wastewater Infrastructure

Substantial fluvial flood hazards exist to the wastewater system today from a 100- or 500-year flood event, and potential damage from these events increases as climate change and sea level rise advances. Fluvial flooding from a FEMA 100-year flood event may affect wastewater infrastructure along all three creeks in Carpinteria, specifically in neighborhoods along Franklin Creek north of the Union Pacific Railroad, the west side of the Beach Neighborhood, and north of the Salt Marsh. As compared to a 100-year storm, fluvial flooding from a FEMA 500-year flood event may affect 7 buildings at the WWTP, as well as an additional 94 manholes (233 total), 2 lift stations (5 total), and 4.4 miles (11.1 miles total) of pipe inland of the Salt Marsh along Santa Monica Creek and 7th Avenue.

3.4 Community Facilities and Critical Services

The largest threat to this sector is existing fluvial flooding hazards as mapped by FEMA. Fluvial flooding under a FEMA 100-year flood event could inundate 24 buildings at Aliso Elementary School and Carpinteria High School, St. Joseph's Chapel and the Redeemer Community Church, 7 buildings at the WWTP, and the Carpinteria State Beach Service Yard. Fluvial flooding from a FEMA 500-year flood event could impact an additional 10 buildings at Main Elementary School, the Post Office, and the Sansum Health Care Clinic. In total, a FEMA 500-year flood event could impact 4 schools, 34 school buildings, 3 churches, the Sansum Health Care Clinic, and 4 community facilities, including the Post Office and WWTP.

4. Future Studies

Recommended Future Studies

Given the significant vulnerabilities identified in this Report, the City should consider a more detailed analysis of coastal confluence and fluvial hazards. Changes in the local climate could affect precipitation intensity, peak streamflows, and bottom of the watershed tailwater elevations, and could combine to impact the extents of future fluvial flooding hazards. Given the lack of modeling of coastal confluence flooding for Santa Monica Creek

and Franklin Creek, using the existing 100-year and 500-year FEMA floodplains as a substitute may under-predict the future risk of future fluvial flooding hazards. This may be particularly true for fluvial flood hazards associated with additional bridge upgrades along U.S. Highway 101 at Carpinteria Creek. Improved modeling of these coastal confluences particularly as they drain into the Carpinteria Salt Marsh is recommended in any future update to this type of vulnerability assessment or to the City's Local Hazard Mitigation Plan.