

Appendix A: Existing Conditions Hydraulics and Hydrology Memorandum



MEMORANDUM - DRAFT

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CC:	Camille Bandy, PE, QSD Freyer and Laureta	Jeff Tarantino, PE Freyer and Laureta	
DATE:	December 19, 2024		
SUBJECT:	Pulgas Creek Watershed Study: Existing Conditions Hydraulics and Hydrology Memorandum Rev. 1		

BACKGROUND AND PURPOSE

The City of San Carlos, CA (City) is interested in developing a better understanding of the Pulgas Creek watershed and establishing a management plan with the aim of enabling creek restoration, increasing public access to sections of the creek, addressing existing flooding issues, and developing climate change mitigation strategies. A previous watershed study and hydraulic model was developed by GHD in 2017 as a part of the City's Storm Drain Master Plan (City of San Carlos, 2017). Traditionally, flood risk reduction efforts have focused on increasing channel capacity with large conduits which require substantial funding and have considerable impacts on traffic during implementation. More recently, guidance for managing watersheds also focus on reducing peak flow and sedimentation by re-naturalizing the watershed (Exhibit 1).

The objectives of this Existing Conditions Hydraulics and Hydrology (H&H) Memorandum are to:

- Describe the mechanisms impacting flood behavior in the Pulgas Creek watershed
- Identify and assess existing flood risks and behavior throughout the Pulgas Creek watershed
- Validate and calibrate the existing conditions model
- Provide a baseline assessment of flooding behavior

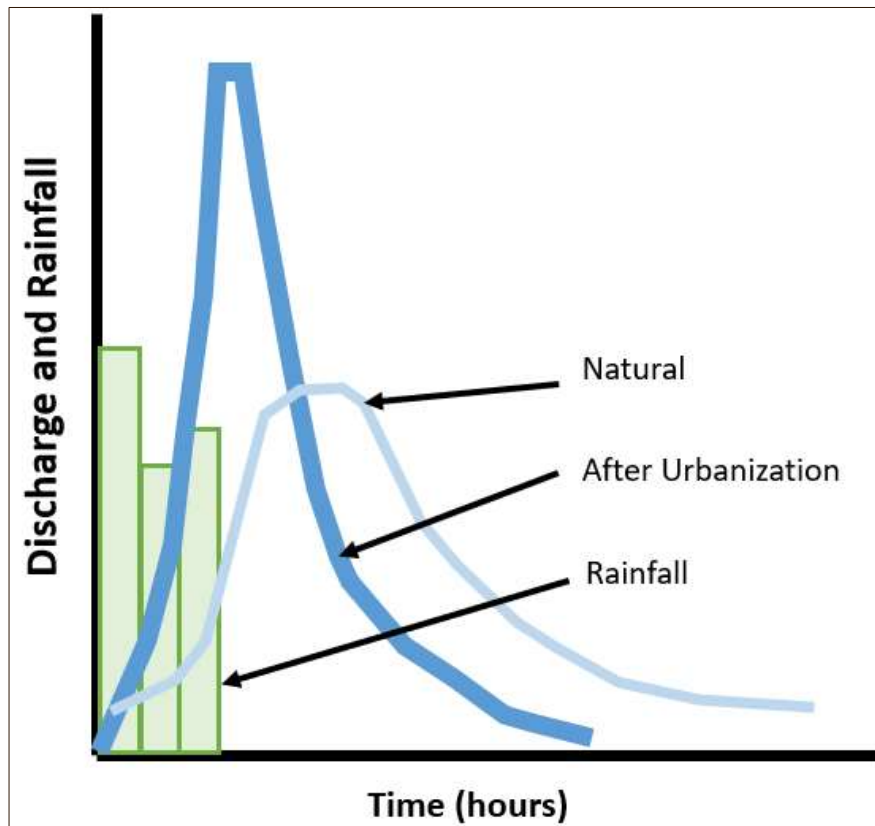


Exhibit 1. Impact of urbanization of previously undeveloped land on the flow hydrograph.

WATERSHED CHARACTERISTICS

Watershed Description

The Pulgas Creek watershed is primarily located within the City limits with portions of the watershed within unincorporated San Mateo County (Figure 1). The watershed begins in the hills around 0.5 miles east of Highway 280 and ends at Smith Slough before discharging into the San Francisco Bay. The watershed is comprised of two creeks—Pulgas Creek and Brittan Creek. Brittan Creek is tributary to Pulgas Creek, and the two converge through an underground storm drain along El Camino Real (Figure 2).

Stormwater generally flows from west to east from the City limit bordering the Santa Cruz Mountain ridgeline down to the San Francisco Bay. Local precipitation distribution within the Pulgas Creek watershed can be highly dynamic due to the variable temperature, wind, and humidity associated with the Santa Cruz Mountain range and the San Francisco Bay. Pulgas Creek and Brittan Creek are highly modified with approximately 64–87% of the creek containing bank hardening through concrete, gunnite, sackcrete, and stone. Erosion within the creek itself was low compared to other watersheds throughout San Mateo County (EOA, Inc., 2007). Hill slopes are steep in the City parks and some of the residential areas and can be highly susceptible to landslides which occur naturally due to geologic processes. Channel slopes vary depending on position in the watershed, with the upper watershed above the foothills containing slopes of 2–

15%, the mid watershed between Alameda de las Pulgas and El Camino Real around 1.5%, and the lower watershed east of El Camino Real around 0.5%. The flat slopes in the lower watershed substantially reduce stormwater capacity in Pulgas Creek and the storm drain network.

Flooding Mechanisms

Flooding in the Pulgas Creek watershed can be associated with a variety of risk factors including sedimentation, storm drain system clogging, insufficient storm-drain capacity, groundwater, and tides. Urbanization and development of the watershed also increase flood risk through replacement of previously permeable surfaces with impermeable developments. While municipal design standards require storm drain systems to accommodate the change in runoff, the analysis performed is typically under a clear water assumption where there is no significant presence of debris or sediment flowing with the water. Debris and sediment can drastically change the flow dynamics of a system, especially around constrictions and expansions, grade changes, and around erodible surfaces.

Sedimentation

Sedimentation is the result of suspended and bed-load sediment settling out of the water column where low energy conditions exist. Sediment is introduced to the waterway through erosion or landslides and can exist anywhere water flows, such as where precipitation impacts with the ground, on roads, inside storm water infrastructure, and within the creeks. Erosion can occur anywhere throughout the watershed where there is exposed soil experiencing sufficiently high local flow and can increase from small to large volumes of sediment. Sediment sources can include uncovered earth disruption activities, such as construction or landscaping, as well as creek bank erosion. Landslides typically involve large volumes of soil moving either immediately into the waterway if they occur along the creek banks, or over a longer period if they occur on upper hillslopes, farther from the waterway. They typically occur where topography is steep and geological, morphological, and hydrological conditions result in a weak region of the landscape (*Exhibit 2*). The majority of landslides within the City occur in the upper watershed, west of Alameda de las Pulgas (California Department of Conservation - California Geological Survey, 2015).



Exhibit 2. Temporarily stabilized landslide from the 2022-2023 storms along Dartmouth Ave above Arguello Park. Photo taken by WRA 4/12/24.

An in-depth analysis of erosion risk and sediment sources within the Pulgas Creek watershed has not been performed. Estimates of normal sediment load throughout the Bay Area, including the Pulgas Creek watershed have been made by the San Francisco Estuary Institute (SFEI) (SFEI, 2009). Approximately 2,186-2,791 metric tons per year (2,410-3077 tons per year) was estimated based on typical land use and flow for the watershed. It is assumed that the large grain sizes that typically cause issues with storm drain systems are delivered during the large flood events with intense flows typically occurring for a few hours. Pulses in sediment loading can constrain the existing storm drain systems, lowering capacity and resulting in flooding. Smaller storms can aid in flushing sediment out from the clogged storm drain systems such that little evidence of the underlying flooding issue remains after the wet season ends. Future City efforts to remove sediment from the storm drain network or creeks or sloughs should codify dates and estimated quantities and gradations of sediment removed. This information will aid in preparing appropriate and timely flood-risk reduction responses.

Storm Drain System Issues

Sediment and debris conveyed during a storm event can clog the intended stormwater conveyance route, resulting in flood water accumulation and potential for overtopping the channel, popping out of manholes and catch basins, or prevention of stormwater from entering

stormwater infrastructure. Man-made debris can include plastic items, metal objects, construction waste, and other synthetic materials, while natural debris can include branches, leaves, dead trees, and other plant materials. The dynamic nature of a storm can result in larger debris forming obstructions during high flows, with recessional flows causing flooding prior to the debris being removed. Sediment can also be conveyed into stormwater infrastructure and clog in lower slope conduits prior to reaching the San Francisco Bay, reducing conveyance and storage capacity for the next storm. The City of San Carlos and San Mateo County standards dictate a 100-year event minimum conveyance capacity for infrastructure within the Federal Emergency Management Agency (FEMA) mapped floodplain. Infrastructure outside the FEMA floodplain require a 10-year minimum conveyance capacity (San Mateo County, 2019). Sediment and debris can limit the actual conveyance and storage capacity resulting in a higher risk of flooding during smaller storm events. Anticipated flood volumes from a 10- and 100-year event can change over time as development continues. Increased areas of concrete, asphalt, and other impermeable surfaces can hasten the conveyance of stormwater into the drainage system and result in an increase in the peak flow for the watershed, resulting in flooding at the same 10- or 100-year precipitation event despite sizing the original infrastructure for the same event.

Groundwater and High Tides

Sources of inflow of water to the system includes precipitation runoff and potential groundwater springs, while outflow includes discharge into the San Francisco Bay, infiltration into the soil, evaporation, and transpiration. Groundwater levels during the winter can be as shallow as 3 feet below the ground surface east of El Camino Real, severely limiting infiltration potential and channel conveyance capacity (California Department of Water Resources, 2024). As storm flows reach the lower watershed, water surface elevations (WSEs) are altered by tidal and groundwater elevations, causing storm flows to overtop channel banks and pop out from manholes (*Exhibit 3*). This issue will be exacerbated by climate change through higher intensity storms and rising sea levels.



Exhibit 3. Tidal limitations on stormwater drainage and flooding. Graphic by (NOAA, 2024)

Flood Reports

Historically, flooding has occurred in the more heavily urbanized reaches of the Pulgas Creek watershed east of Alameda de las Pulgas, especially along El Camino Real. More recently, flooding effects have been observed in the less urbanized reaches of the watershed west of Alameda de las Pulgas, particularly at properties abutting existing parks and less developed regions. All available flood reports from those provided in the Storm Drain Master Plan and from the 2023 floods are shown in Figure 3. Based on a comparison of flood events to hourly precipitation intensity data from the CDEC station, the Pulgas watershed appears to be at risk of flooding beginning with rainfall intensity of 0.75 inch over one hour (*Exhibit 4*), equivalent to a 10-year precipitation event based on the National Oceanic and Atmospheric Administration's (NOAA) Atlas 14 (*Exhibit 5*). Flood timing data is based on the recorded time of reporting and not necessarily the exact time the flood occurred, limiting this analysis from assessing hour-scale precipitation to flooding relations.



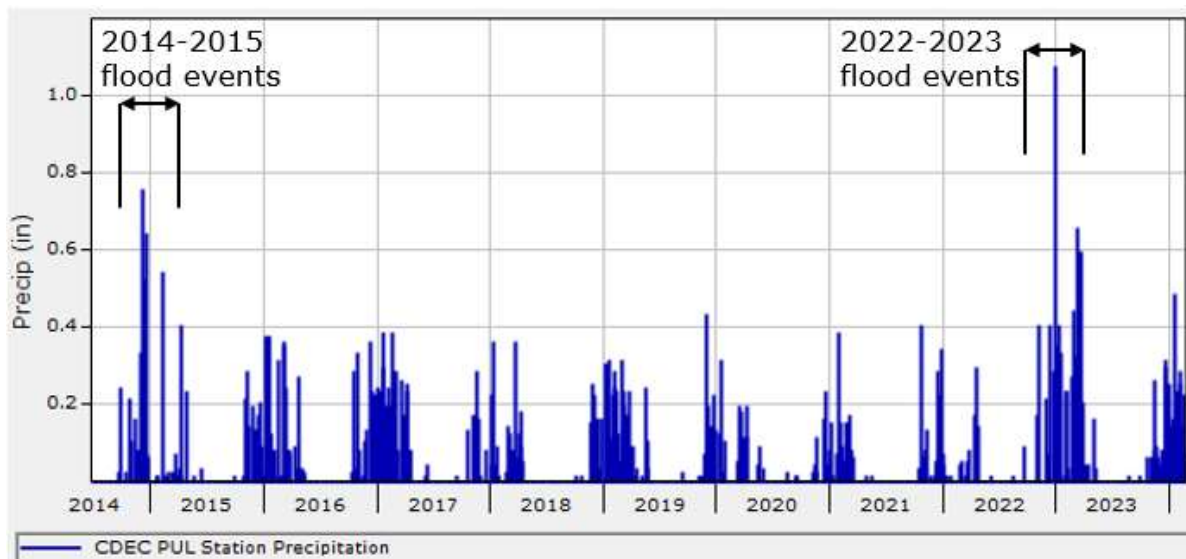


Exhibit 4. Flood impact years compared to hourly precipitation data from the CDEC PUL station

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches) ¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.123 (0.109-0.140)	0.149 (0.132-0.171)	0.186 (0.164-0.213)	0.216 (0.189-0.250)	0.259 (0.218-0.311)	0.294 (0.242-0.360)	0.330 (0.265-0.415)	0.368 (0.287-0.477)	0.422 (0.314-0.571)	0.465 (0.334-0.653)
10-min	0.176 (0.156-0.201)	0.214 (0.189-0.245)	0.266 (0.234-0.305)	0.310 (0.271-0.358)	0.372 (0.313-0.445)	0.421 (0.347-0.516)	0.473 (0.379-0.594)	0.527 (0.411-0.683)	0.604 (0.451-0.818)	0.666 (0.479-0.935)
15-min	0.213 (0.188-0.243)	0.259 (0.229-0.296)	0.322 (0.283-0.369)	0.375 (0.327-0.433)	0.449 (0.379-0.538)	0.509 (0.419-0.624)	0.571 (0.459-0.719)	0.638 (0.497-0.827)	0.731 (0.545-0.990)	0.805 (0.579-1.13)
30-min	0.295 (0.261-0.337)	0.359 (0.317-0.411)	0.446 (0.393-0.512)	0.520 (0.454-0.601)	0.624 (0.526-0.747)	0.706 (0.582-0.866)	0.793 (0.637-0.998)	0.885 (0.690-1.15)	1.01 (0.756-1.37)	1.12 (0.803-1.57)
60-min	0.417 (0.369-0.477)	0.508 (0.449-0.580)	0.631 (0.556-0.723)	0.735 (0.642-0.850)	0.881 (0.743-1.06)	0.998 (0.823-1.22)	1.12 (0.900-1.41)	1.25 (0.975-1.62)	1.43 (1.07-1.94)	1.58 (1.14-2.22)
2-hr	0.610 (0.540-0.696)	0.736 (0.651-0.842)	0.908 (0.800-1.04)	1.05 (0.918-1.22)	1.25 (1.06-1.50)	1.41 (1.16-1.73)	1.58 (1.27-1.98)	1.75 (1.37-2.27)	1.99 (1.49-2.70)	2.19 (1.57-3.07)
3-hr	0.766 (0.678-0.875)	0.926 (0.819-1.06)	1.14 (1.01-1.31)	1.32 (1.16-1.53)	1.57 (1.33-1.89)	1.77 (1.46-2.17)	1.98 (1.59-2.49)	2.20 (1.71-2.85)	2.50 (1.86-3.38)	2.74 (1.97-3.84)
6-hr	1.08 (0.959-1.24)	1.32 (1.17-1.51)	1.64 (1.44-1.88)	1.90 (1.66-2.20)	2.27 (1.91-2.72)	2.56 (2.11-3.14)	2.86 (2.30-3.60)	3.18 (2.48-4.12)	3.61 (2.70-4.89)	3.96 (2.85-5.56)
12-hr	1.41 (1.24-1.60)	1.76 (1.55-2.01)	2.22 (1.96-2.55)	2.61 (2.28-3.02)	3.16 (2.66-3.78)	3.58 (2.95-4.39)	4.02 (3.23-5.06)	4.48 (3.49-5.81)	5.12 (3.82-6.93)	5.62 (4.04-7.90)
24-hr	1.70 (1.56-1.90)	2.18 (2.00-2.44)	2.82 (2.57-3.16)	3.35 (3.04-3.78)	4.09 (3.60-4.74)	4.66 (4.03-5.50)	5.26 (4.45-6.34)	5.88 (4.85-7.26)	6.73 (5.36-8.62)	7.41 (5.73-9.78)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

Exhibit 5. NOAA Atlas 14 precipitation frequency estimates for San Carlos, CA (NOAA, 2014)

In general, the 2014–2015 flood events were located in the mid to lower watershed. Potential causes were mostly attributed to insufficient downstream capacity where excess runoff combined with the tidal condition limited drainage capacity and resulted in flows popping out of manholes and overwhelming catch basins. The 2022–2023 flood events were located in the upper watershed and potential causes were nearly all attributed to landslides and erosion overwhelming storm drains and diverting flood flows to homes and streets. In summary, the flood reports indicate that the watershed is at risk of flooding due to multiple mechanisms and only one mechanism is needed to cause flooding.

FLOW MONITORING

WRA installed a total of two barologgers and 11 water level loggers on December 20, 2023 to provide site-specific water level data around the Pulgas watershed for model calibration. Each barologger unit records barometric pressure for use in compensating for local atmospheric effects on the water level loggers' measurements. Each water level logger records water depth and temperature using a pressure sensor and temperature detector, respectively. The data loggers record pressure representing the height of water above the transducer sensor elevation. Water levels below the data logger sensors are not able to be measured. Loggers were placed along the low point of the selected feature (creek bottom, culvert invert, storm drain invert) and record levels in 6-minute intervals. The logger locations installed are shown in Figure 4. Loggers are labeled from number 1 to 13, with Loggers 5 and 6 omitted as the sites did not meet expectations for yielding usable data. Descriptions of the logger location, conditions, and purpose are provided in Table 1.

Table 1. Monitoring Locations and Intent

LOGGER #	ATTACHMENT FEATURE	LOCATION	PURPOSE
1	Storm drain manhole in Pulgas Creek watershed	In manhole adjacent to 400 Devonshire Blvd	Track urbanized catchment flow
2	Pulgas Creek on tree	Adjacent to hillside trail accessible from 400 Devonshire Blvd	Track non-urbanized catchment flow
3	On culvert for tributary to Pulgas Creek	At intersection between Cyn Vista Wy and Chesham Ave	Track non-urbanized catchment flow into urban storm drain system
4	Storm drain manhole in Pulgas Creek watershed	In manhole at San Carlos Ave and Wellington Dr	Track urbanized catchment flow
7	Pulgas Creek on tree	At Cedar St adjacent to Central Middle School	Track lower reach inundation along Pulgas Creek
8	Pulgas Creek on tree	Near Brittan Ave between Industrial Rd and Old County Rd	Track inundation near storm drain and tidal interface
9	Pulgas Creek in tidal slough	Just upstream of Pulgas Creek and Smith Slough confluence	Track tidal effects
10	Brittan Creek on concrete box culvert	On Elm St between Howard Ave and Greenwood Ave	Track urbanized flow
11	Brittan Creek on concrete box culvert	At Alameda de las Pulgas between Gaylord St and Howard Ave	Track urbanized flow

LOGGER #	ATTACHMENT FEATURE	LOCATION	PURPOSE
12	Storm drain manhole in Brittan Creek watershed	On Brittan Ave between Faribanks Ave and Sunset Dr	Track urbanized storm flow at the urban and non-urban interface
13	Tributary to Brittan Creek	In Eaton Park south of 3015 and 3017 Brittan Ave	Track non-urbanized catchment flow
Baro 1	On tree near logger 8	Near Brittan Ave between Industrial Rd and Old County Rd	Collect above ground atmospheric pressure data
Baro 2	In logger 12 storm drain manhole	On Brittan Ave between Faribanks Ave and Sunset Dr	Collect below ground atmospheric pressure data

EXISTING CONDITIONS MODEL

Baseline Model

A hydrologic and hydraulic model of all watersheds within the City's jurisdiction was developed by GHD in the PC SWMM software by Computational Hydraulics International (CHI) as a part of the City's Storm Drain Master Plan in 2017. WRA revised the existing condition models from GHD and performed validation of input data, model component additions and modifications, and model calibration. Details and descriptions of the components included in the existing conditions model built by GHD can be found in the Storm Drain Master Plan Section 4 (GHD, 2017). The baseline model includes the Cordilleras Creek and West Redwood Shores watersheds; however, no changes were made at these locations because the purpose of this study is to focus on the Pulgas Creek watershed (Figure 5). Model components are shown in Figure 2 including subbasin areas, conduit structures, and node junctions.

Model Calibration

A calibration model scenario was developed by utilizing precipitation and water level logger data from January 21, 2024 to January 22, 2024. The January 21/22, 2024 storm event yielded the greatest cumulative precipitation depth where logger data was available. The relation between precipitation and flow in the upper, mid, and lower sections of the Pulgas Creek watershed represented by loggers 2, 11, and 8, respectively, can be seen in Exhibit 6. No flooding was reported during the period of recorded logger data.

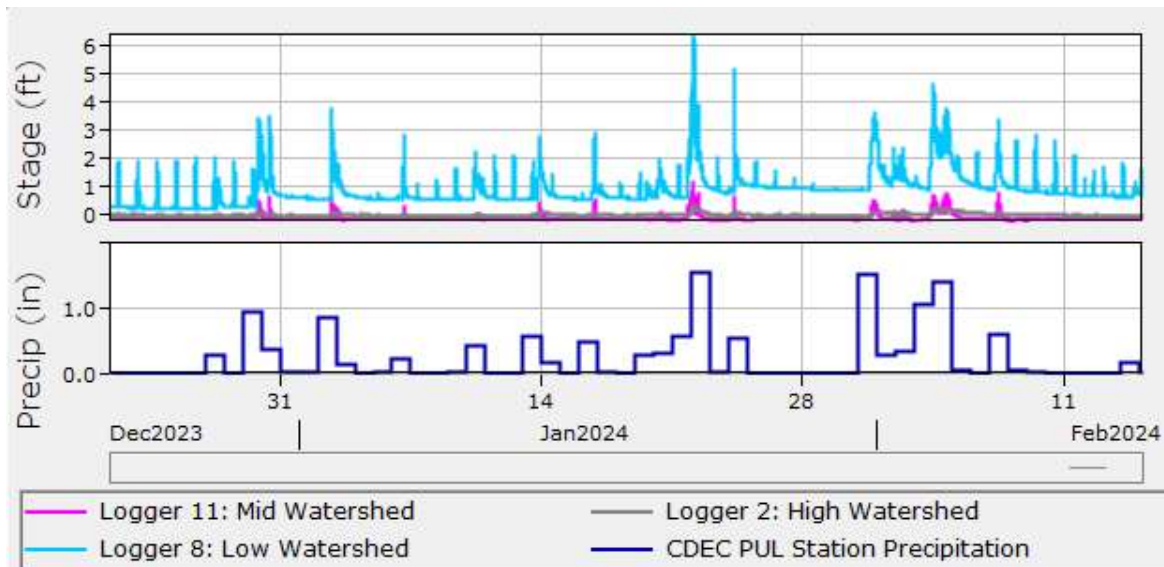


Exhibit 6. WRA Logger 2, 8, and 11 water level data and CDEC PUL station hourly precipitation

Calibration efforts involved manipulation of input parameters including slopes, curve number (CN) values, invert elevations, and impervious land percent. CN values are numbers applied based on land cover type associated with the Soil Conservation Service (SCS) method for estimating precipitation runoff. Higher CN values represent high potential for generating runoff, such as concrete and other impermeable surfaces, while low CN values represent low potential for generating runoff, such as highly porous, unsaturated, and well vegetated soils. Model calibration was expected to roughly match peak timings, peak values, and water accumulation trends. An exact match between modeled and measured values was not expected due to the inability of the model to accurately capture all physical factors that can have a significant impact in flow behavior such as sediment transport, complex storm drain geometries, debris effects, etc. Flood reports from the 2022–2023 storm events claim multiple locations of flooding at the edge of Eaton Park and Big Canyon Park. These locations require a qualitative assessment to account for sediment when comparing model outputs and observed data. It is anticipated the observed depth values will be higher than model outputs due to sediment in the system. Output from the calibration efforts can be found in the Model Output and Assessment section below.

Existing Conditions Hydraulic Model Adjustments

Model input parameters including storm drain inverts, CN values, rainfall, and land cover data such as impervious cover percent were updated based on field inspections and observed data. At loggers 2, 3, and 13, subbasin regions were split to account for existing conveyance channels not captured in the baseline model. Subbasin outlets were set upstream of the logger locations to be used for calibration purposes in comparing modeled vs. recorded water depths and timing. Transect geometries were assigned for creeks in newly split subbasins based on terrain elevations obtained from the San Mateo County 2017 1-Meter Digital Elevation Model (San Mateo County, 2017). Storm drain geometries were assumed based on existing data for nearby equivalent drainage area storm drains. Subbasin outfall locations were adjusted to better reflect real conditions.

Calibration Model Outputs

Modeled depths and timings roughly match logger data in the high watershed of Pulgas Creek based on Logger 2 observations (Exhibit 7). As expected, due to reports of landslides in Brittan Creek and substantial sediment mobilizing in the Brittan creek watershed, Logger 11 observations at the Alameda De Las Pulgas bridge demonstrate higher observed depth values than model outputs (Exhibit 8). This variance from model output to observations should be expected throughout Brittan Creek until high sediment loads are no longer expected to enter Brittan Creek or nearby storm drain conduits and sediment within the system is removed. Modeled depths downstream of Old County Road roughly match logger data in magnitude and timing. Observed values from Logger 8 show similar patterns as the model output with a slightly lower peak value and shorter time of concentration suggesting the watershed may have slightly more attenuation of the peak flow but also less detention than the model (Exhibit 9).

There are differences in the timing and higher deviations at the start and end of the model. The discrepancies at the start of the model may be described by irregularities during model warm-up such as insufficient pre-wetting, sediment mounds elevating water depths, and groundwater seepage into the system not accounted for in the modeling. The drift in timing near the end of the modeled time may be explained by the time interval of the precipitation data. Higher resolution precipitation data (1-minute) could provide model results more similar to observed data. Significant discrepancies between modeled and measured flow depths, such as that for Logger 11, can be explained by local factors such as debris/sediment pileup causing elevated water levels before being flushed through the system.

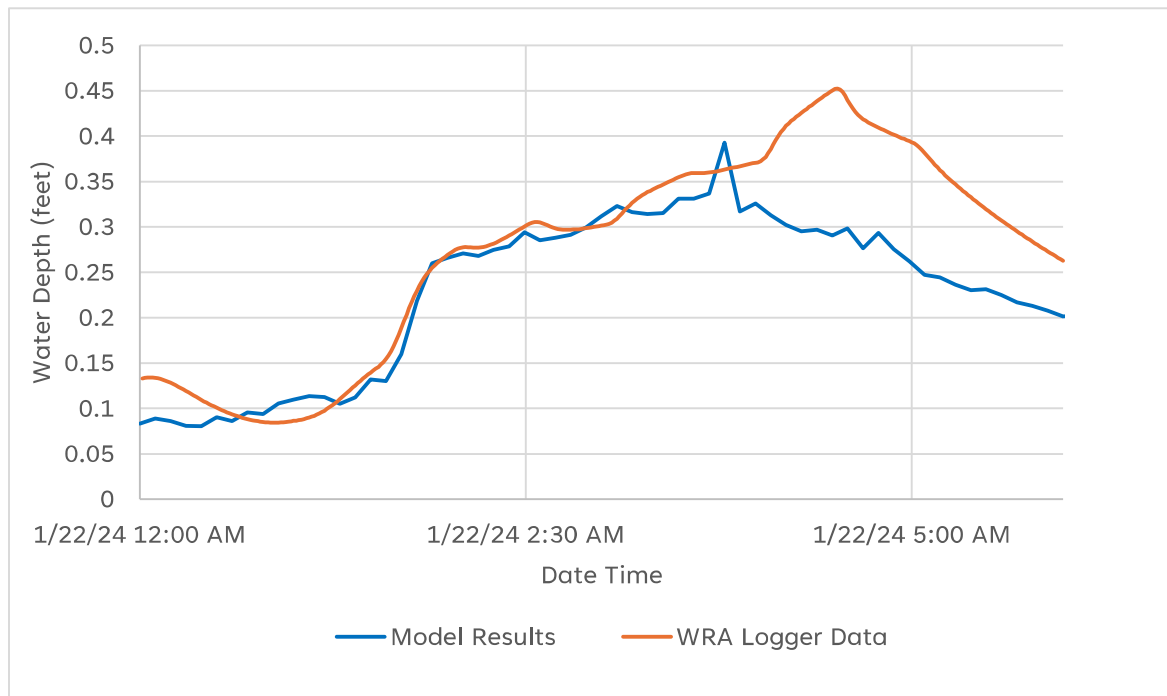


Exhibit 7. Logger 2 high watershed calibration model results and measured depth data

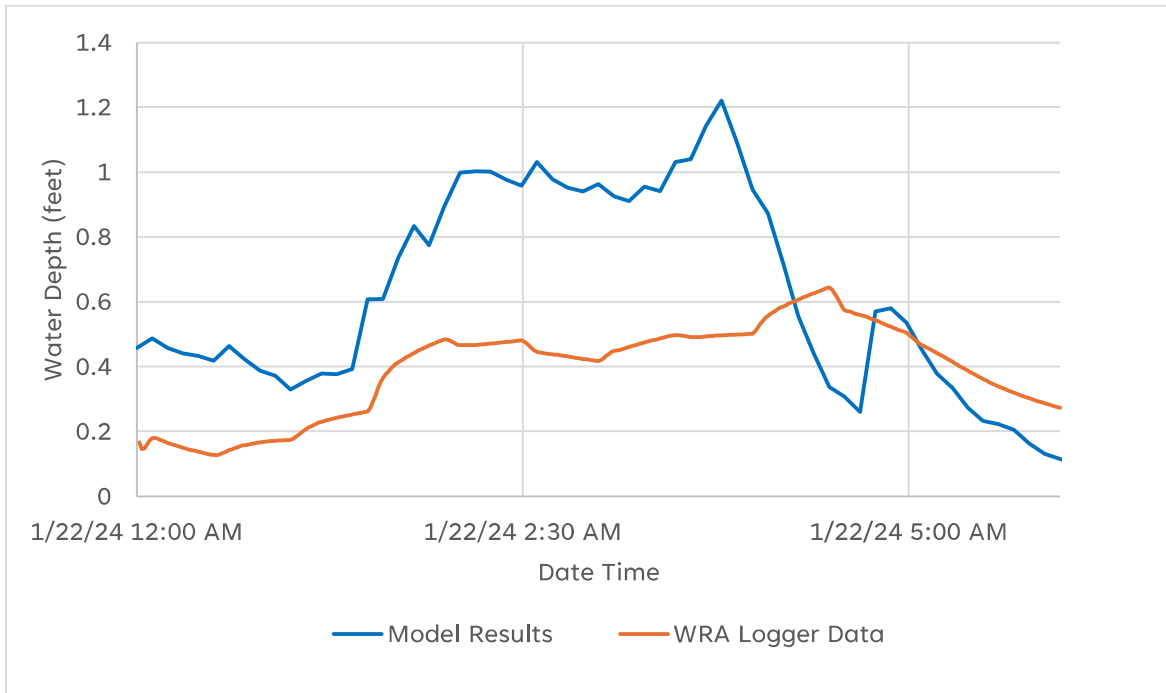


Exhibit 8. Logger 11 mid watershed calibration model results and measured depth data

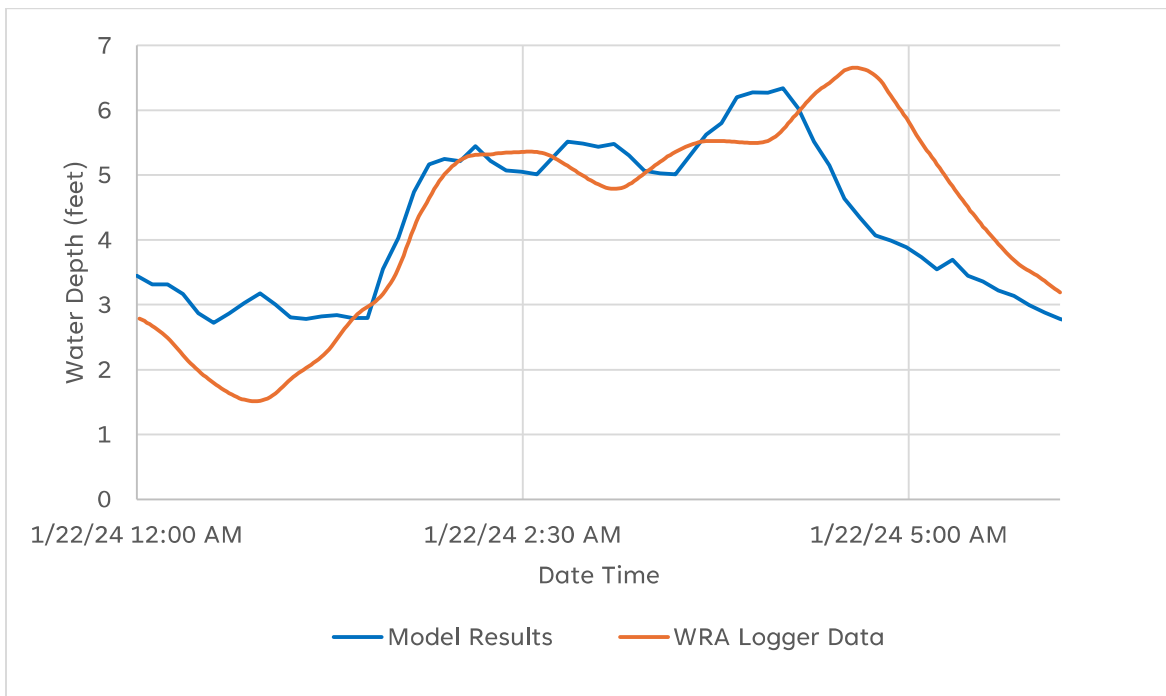


Exhibit 9. Logger 8 low watershed calibration model results and measured depth data

Findings during the model calibration suggest Pulgas watershed hydrographs are highly dependent on rainfall intensity patterns. The system is capable of quickly flushing through peak events throughout all but the lower watershed. Accurate modeling of the peaks and troughs of the hydrograph is contingent on having sufficiently high-resolution precipitation data. While previous recommendations to alleviate flooding in the downstream reaches involved increasing capacity of flood infrastructure, there may be opportunity to alleviate the downstream flood issues via detention of water from the upstream reaches.

MODEL OUTPUT AND ASSESSMENT

Model outputs provide quantitative context for assessing the watershed's flood risk. The model outputs can also be used to understand which bridges, storm drain conduits, or creek segments have insufficient capacity and also which features have unused capacity that could be used for detention. When using model outputs, it is important to acknowledge that the model assumes all storm drain features are working as designed and that proper maintenance was performed prior to any storm so that sediment does not enter the storm drain system. The model results discussed will be inaccurate for sediment-driven flooding areas in the watershed. These inaccuracies can be resolved with proper sediment treatment for runoff prior to entering the storm drain network and diligent inspection and maintenance of the watershed and storm drain system.

A map view of the 10-year storm event shows flooding in the lower watershed with depths in the surrounding parking lots and roads ranging from 0.5 to 1.5 feet (Figure 6). A map view of the 25-year storm event shows flooding in the lower watershed with depths in the surrounding parking lots and roads ranging from 0.5 to 2.5 feet (Figure 7). A map view of the 100-year storm event shows flooding in the lower watershed with depths in the surrounding parking lots and roads ranging from 0.5 to 2.5 feet (Figure 8).

Results from the modeling suggest most of the high watershed has sufficient storm drain capacity to prevent flooding. Profile view results of depths along the Pulgas Creek alignment from the headwaters to Smith Slough, and Brittan Creek alignment from the headwaters to the confluence with Brittan Creek at El Camino Real, are shown in Figure 9 to Figure 14 for each of the studied storm events. The profile views of Pulgas Creek show shallow depths in the upper and middle watershed in creek segments, with depths increasing in magnitude in the lower watershed. The profile views of Brittan Creek show a similar behavior to Pulgas Creek in the upper watershed, but an increase in depth in the middle watershed due to a change in channel slope from 2.5% to 1.5%. Pulgas Creek quickly conveys flows down to the lower watershed without an opportunity for water to pile up while Brittan Creek shows some attenuation behavior, retaining some flood waters in the middle watershed.

Most non-sediment-related flood effects are observed and predicted where the City topography flattens out around mid-watershed starting near Cedar Street and Grand Street. Flood risk of the low watershed near the Bay is tied to insufficient drainage capacity during extreme event peaks with higher tides. Improving slope stability in the high watershed is key to reducing flood risk in the region. The downstream reaches of the Pulgas Creek watershed where historic flooding occurs remains vulnerable to extreme events and rising tides.

An analysis of the flood inundation area indicates the primary location of flooding is from overbanking on Pulgas Creek downstream of Old County Road due to limitations in bridge and channel capacity. A comparison of the 100-year flood event hydrograph to the capacity of the bridges and channel downstream of Old County Road provide quantitative characteristics that need to be addressed to prevent flooding.

The recommended approach to prevent flooding is twofold:

1. Increase capacity of the bridges and channel as much as possible given the site constraints downstream of Old County Road and
2. Reduce the peak flow by adding detention features throughout the watershed.

An example of this approach would be:

Model results indicate the existing capacity downstream of Old County Road is approximately 360 cfs resulting in 97 acre-ft of stormwater floods the surrounding area (*Exhibit 10*). Two options which are likely infeasible are to:

1. increase capacity to approximately 650 cfs or
2. add detention basins to temporarily hold 97-acre feet of stormwater in the watershed for approximately four hours.

A more feasible solution would be to:

1. increase capacity to 500 cfs and
2. add detention basins to temporarily hold approximately 60 acre-feet of stormwater in the watershed for approximately four hours.

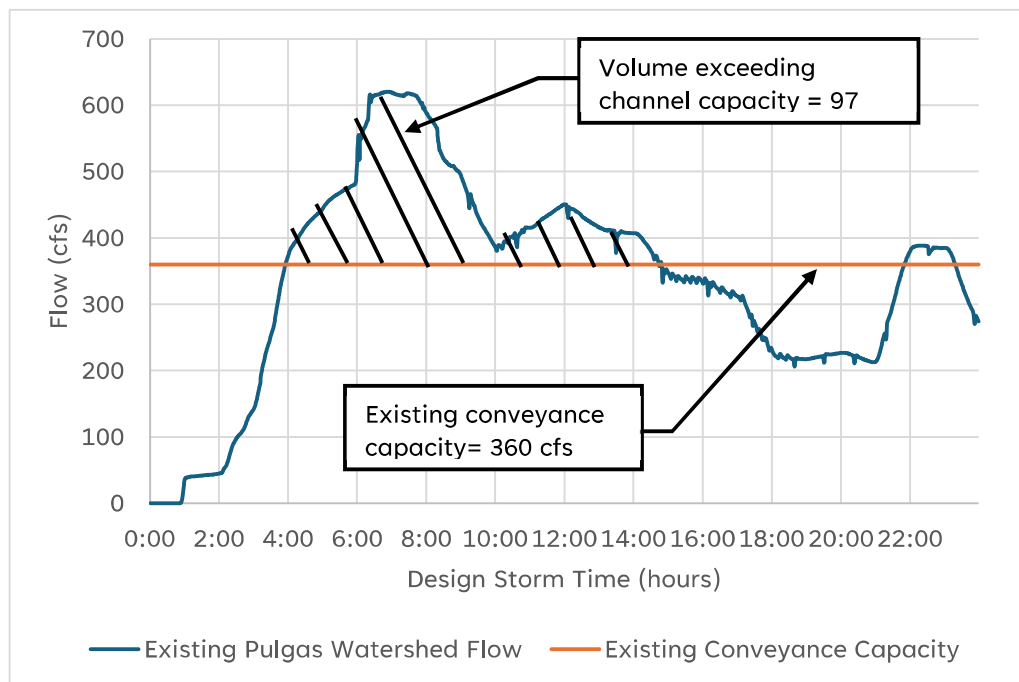


Exhibit 10. 100-year Hydrograph of Pulgas Creek downstream of Old County Road

SUMMARY

- The watershed is susceptible to landslides due to geologic processes which have a substantial impact on flood capacity.
- Due to sedimentation, inspections and maintenance to the storm drain network are critical functions in maintaining flood conveyance.
- Rising tide and ground water elevations increase risk of flooding in the lower watershed for both local storm drains and the main stem of the Pulgas Creek watershed.
- Opportunities exist for creek flow attenuation in the upper and middle watershed by adding detention basins in locations with sufficient capacity and feasible construction access.
- The lower watershed's flat hydraulic grade line is an indicator of reduced stormwater and sediment transport capacity.
- The strategy for improving the watershed and reducing flood risk is to focus on reducing the peak flow using detention basins in the upper and middle watershed while increasing capacity in the lower watershed.

LIMITATIONS

The model developed for this study is based on limited available data. Different climate characteristics, antecedent precipitation, groundwater intrusion, and more site-specific flow records would improve accuracy of the models. Adjustments to the existing conditions model were focused on areas of known discrepancy between modeled and real results. A whole model validation of all input parameters and results was not performed. The model was adjusted from data available at the time both recorded for this project's purposes and previously recorded data provided by the City of San Carlos. Figures presented in this memorandum are not intended to be used as reference material for determining construction locations or features.

Accounting for site-specific geomorphic conditions and topographic adjustments were not within the scope of this study. Flooding extents and depths shown in this study do not account for complications due to debris flow, nor other geotechnically related complicating factors such as landslides, earthquakes, bank failures, etc.

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ATTACHMENTS

Attachment A. Figures

- Figure 1. Regional Location Map*
- Figure 2. Pulgas Creek Watershed Drainage System*
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Attachment A.

Figures



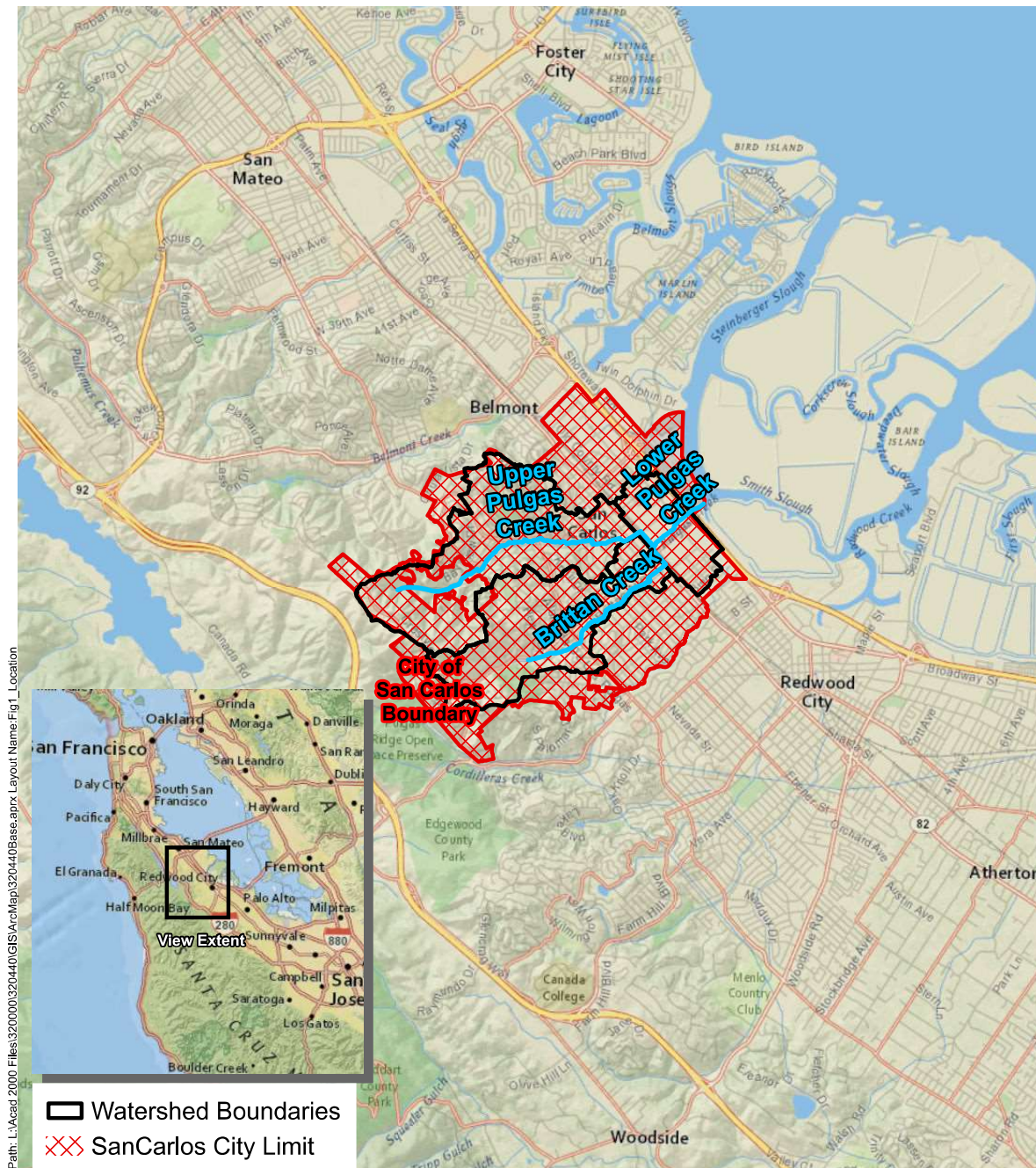
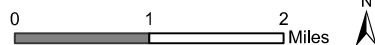


Figure 1. Regional Location Map

Pulgas Watershed Study
Existing Conditions H&H Memo
City of San Carlos, San Mateo, CA





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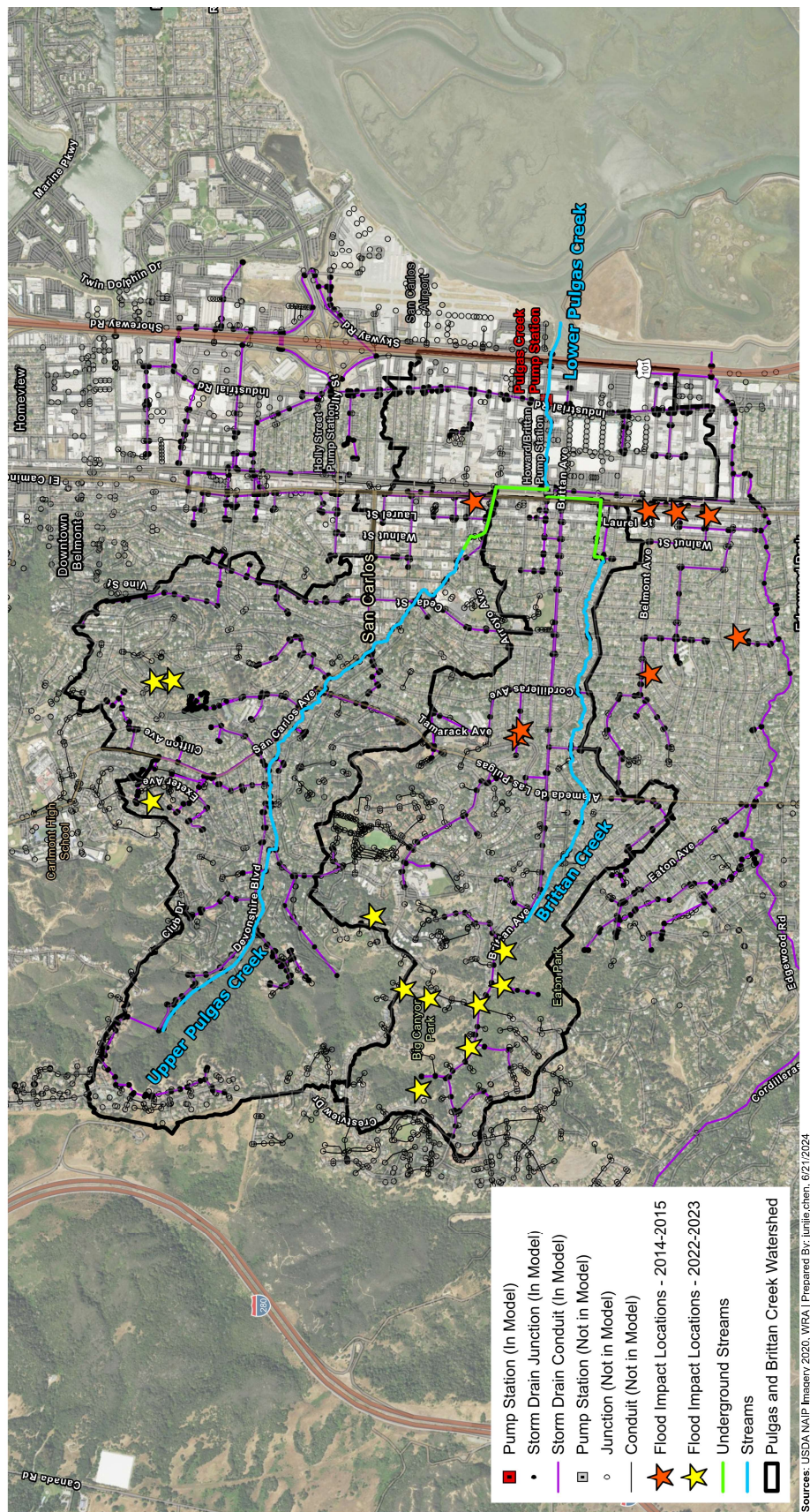


Figure 3. Pulgas Watershed Regions Impacted by Flooding

Pulgas Watershed Study
Existing Conditions H&H Memo
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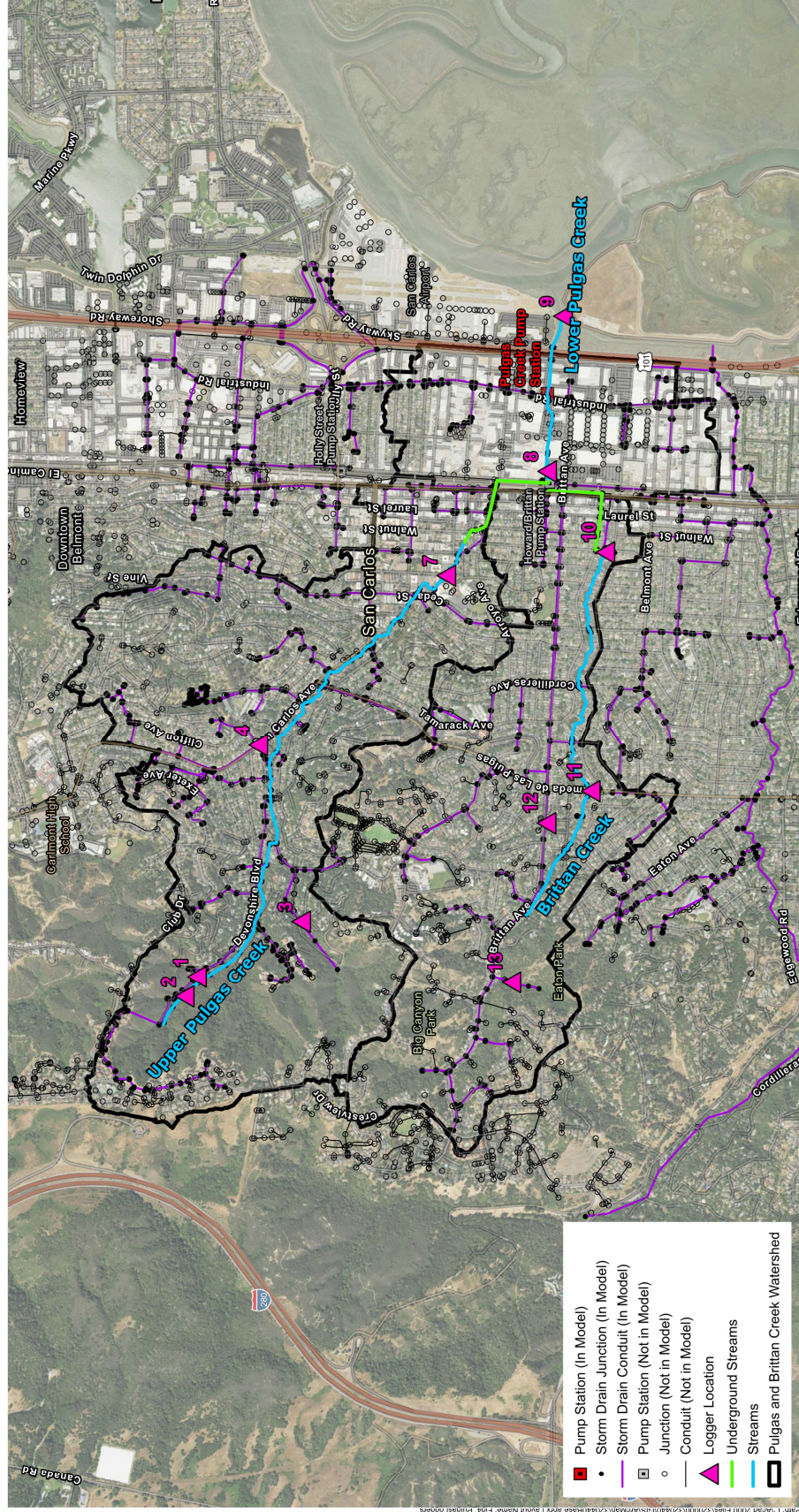
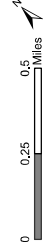
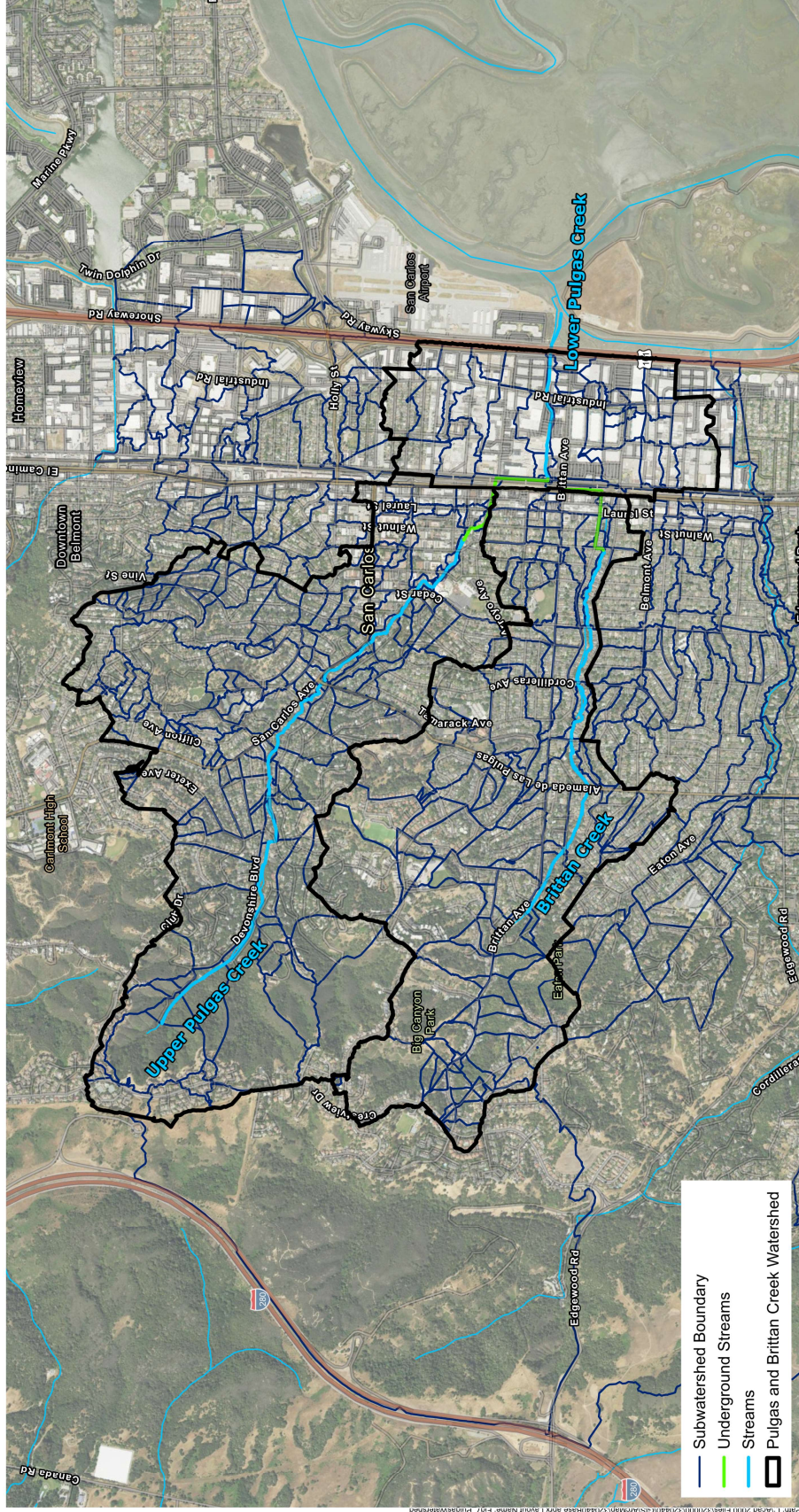


Figure 4. Storm Drain System Logger Locations

Pulgas Watershed Study
Existing Conditions H&H Memo
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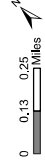




Sources: USDA NAIIP Imagery 2020, WRA | Prepared By: Julie Chen, 6/21/2024

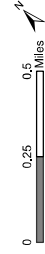
Figure 5. Sub-watersheds - Pulgas Creek Watershed

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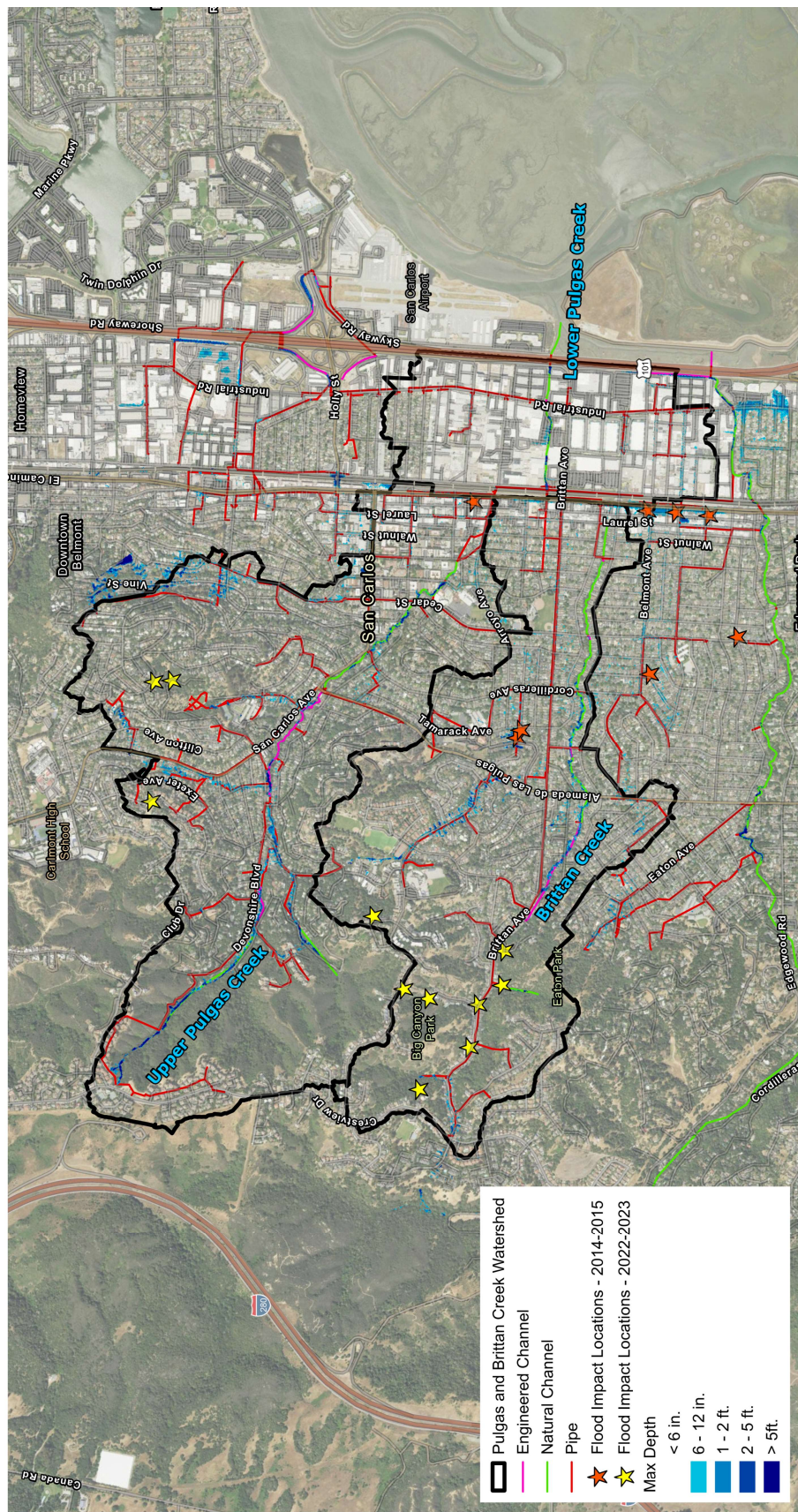
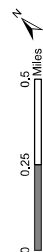
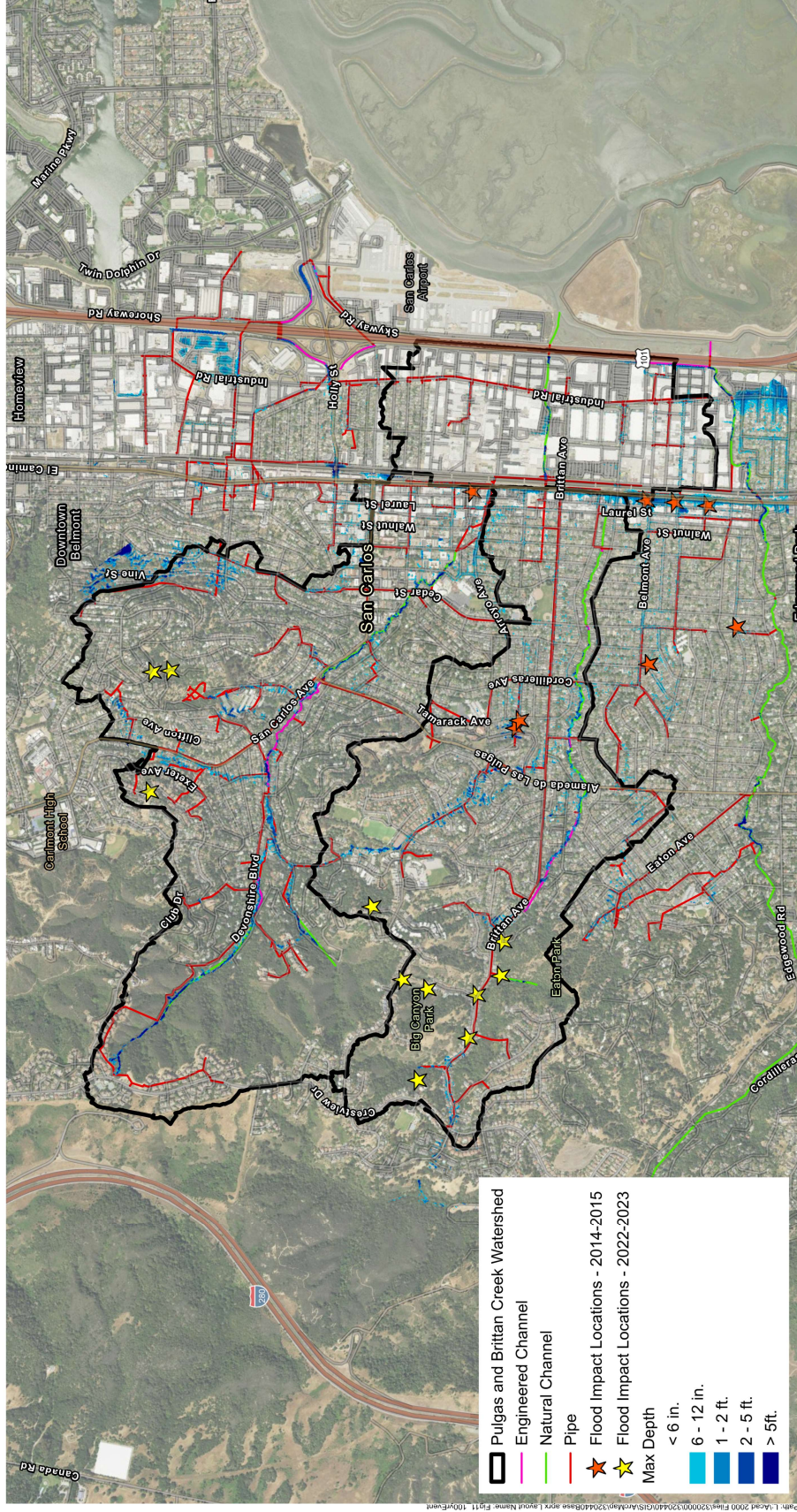


Figure 7. 25-year Flood Event (AMC II) Base Conditions

Pulgas Watershed Study
Existing Conditions H&H Memo
City of San Carlos, San Mateo, CA





Sources: USDA NAIIP Imagery 2020, WRA | Prepared By: Junjie Chen, 6/21/2024

Figure 8. 100-year Flood Event (AMC II) Base Conditions

Pulgas Watershed Study
Existing Conditions H&H Memo
City of San Carlos, San Mateo, CA

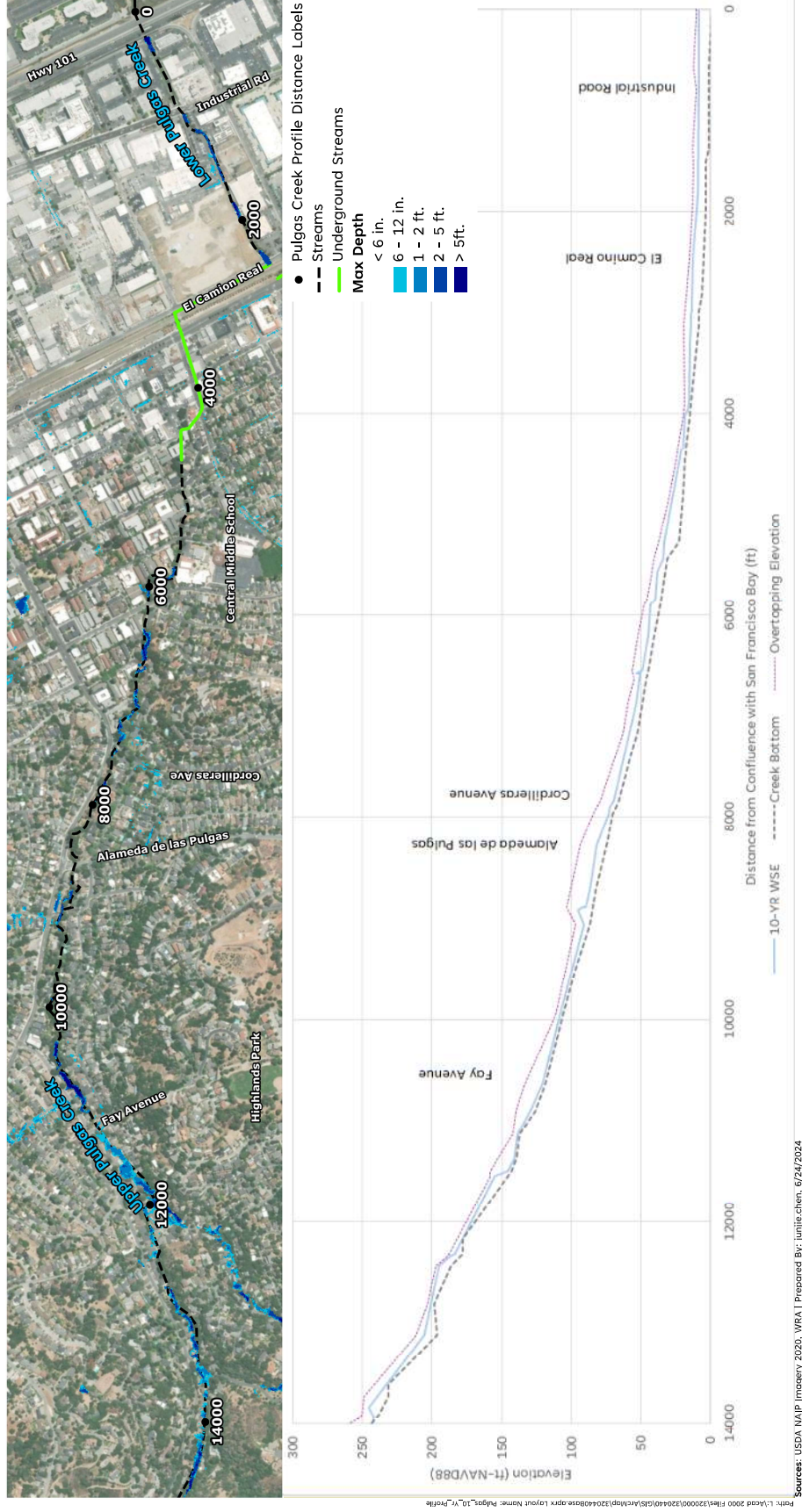


Figure 9. 10-Year Plan and Profile Views for Pulgas Creek

Pulgas Watershed Study
Existing Conditions H&H Memo
City of San Carlos, San Mateo, CA

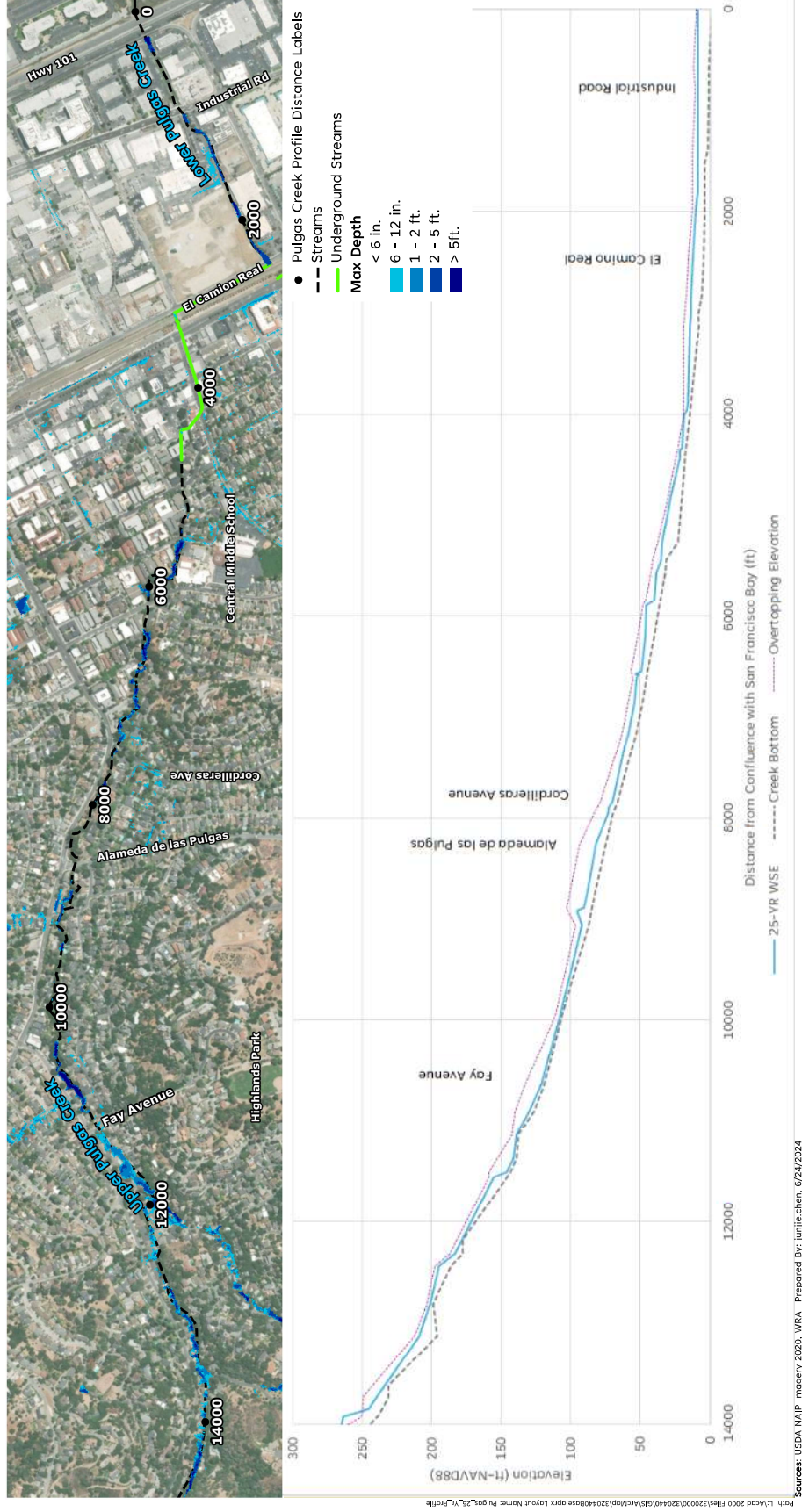


Figure 10. 25-Year Plan and Profile Views for Pulgas Creek

Pulgas Watershed Study
Existing Conditions H&H Memo
City of San Carlos, San Mateo, CA

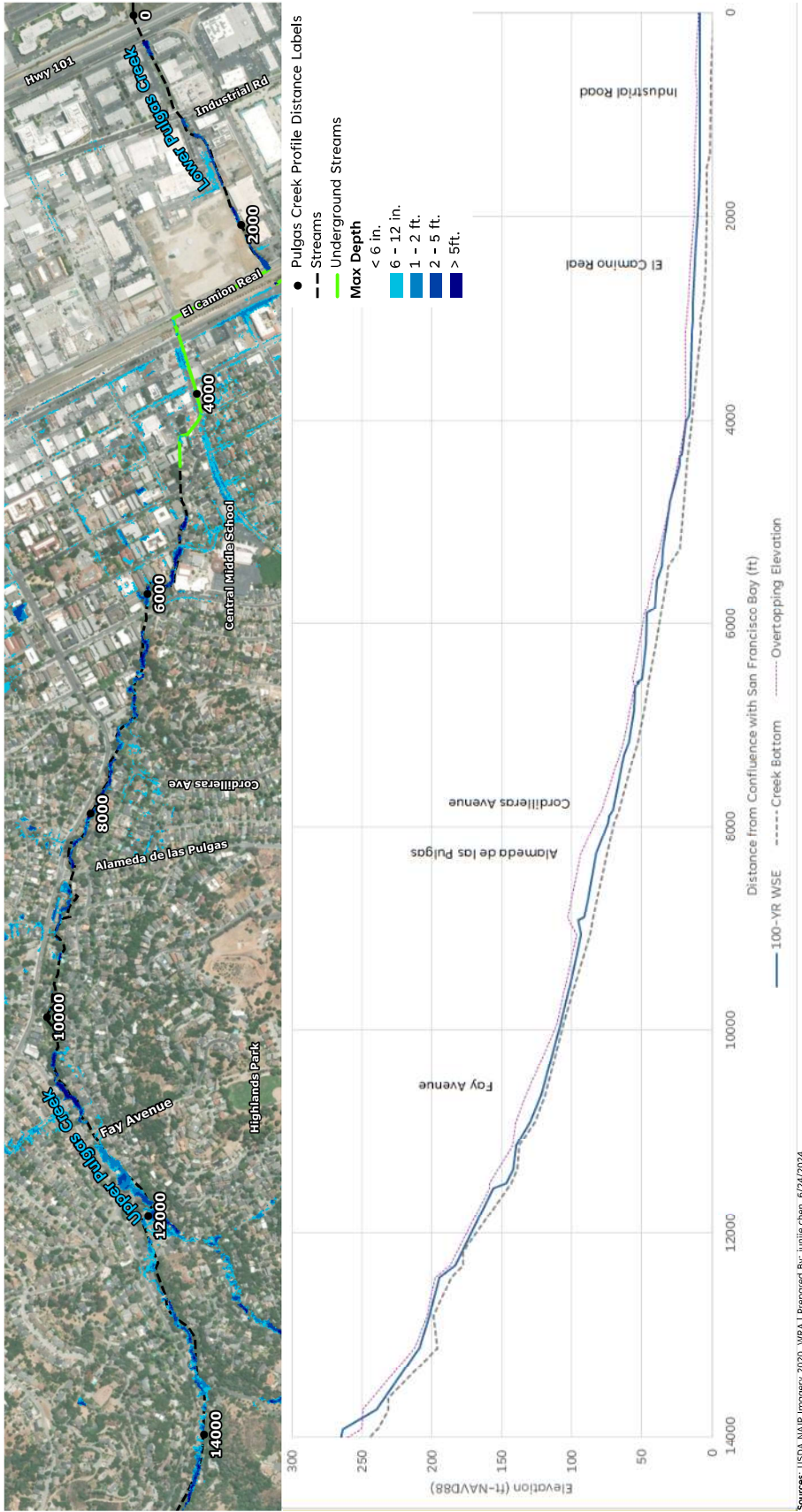
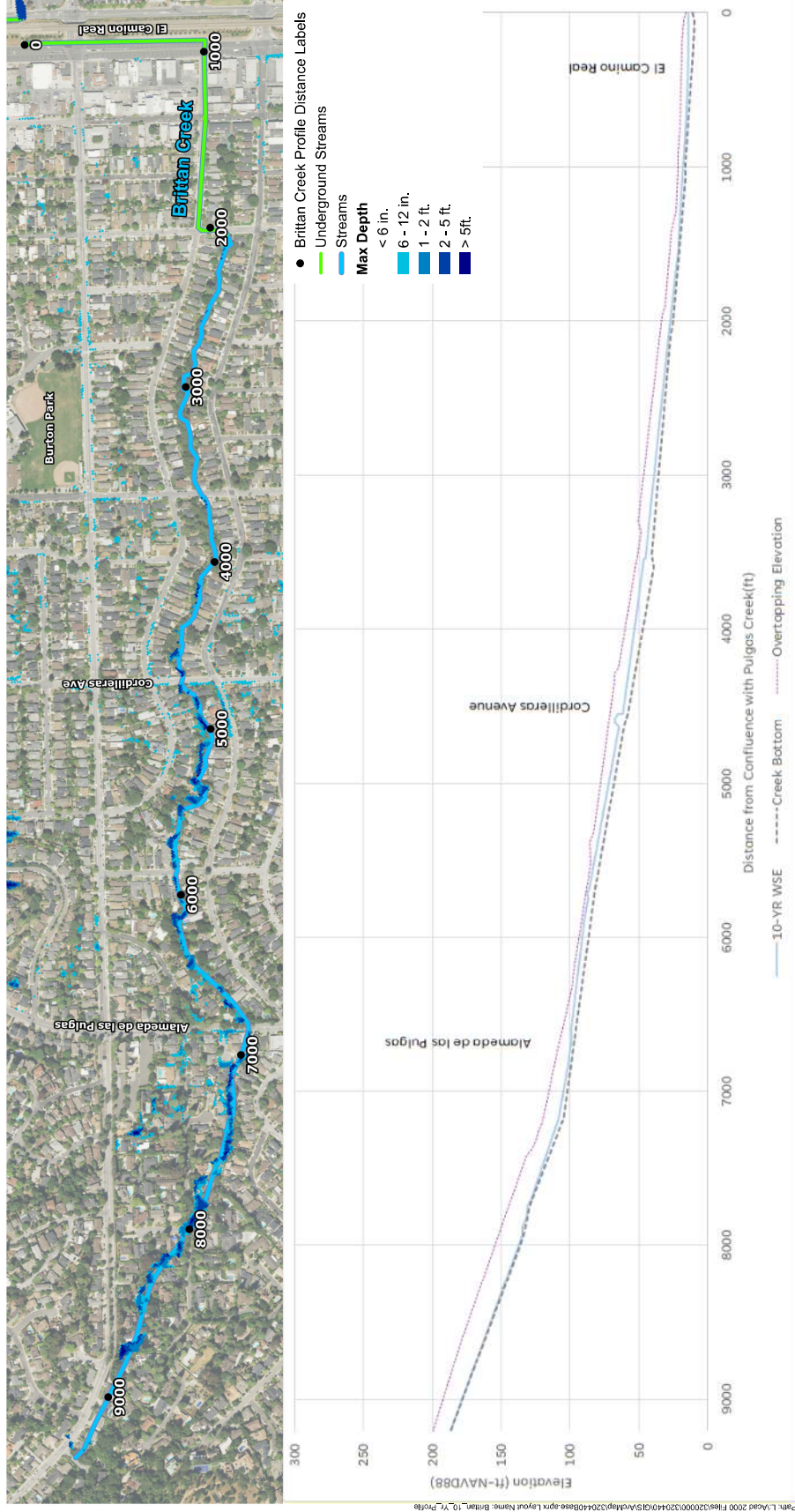


Figure 11. 100-Year Plan and Profile Views for Pulgas Creek



Pulgas Watershed Study
Existing Conditions H&H Memo
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Sources: USDA NAIIP Imagery 2020, WRA | Prepared By: Junjie Chen, 6/21/2024

Figure 12. 10-Year Plan and Profile Views for Brittan Creek

Pulgas Watershed Study
 Existing Conditions H&H Memo
 City of San Carlos, San Mateo, CA

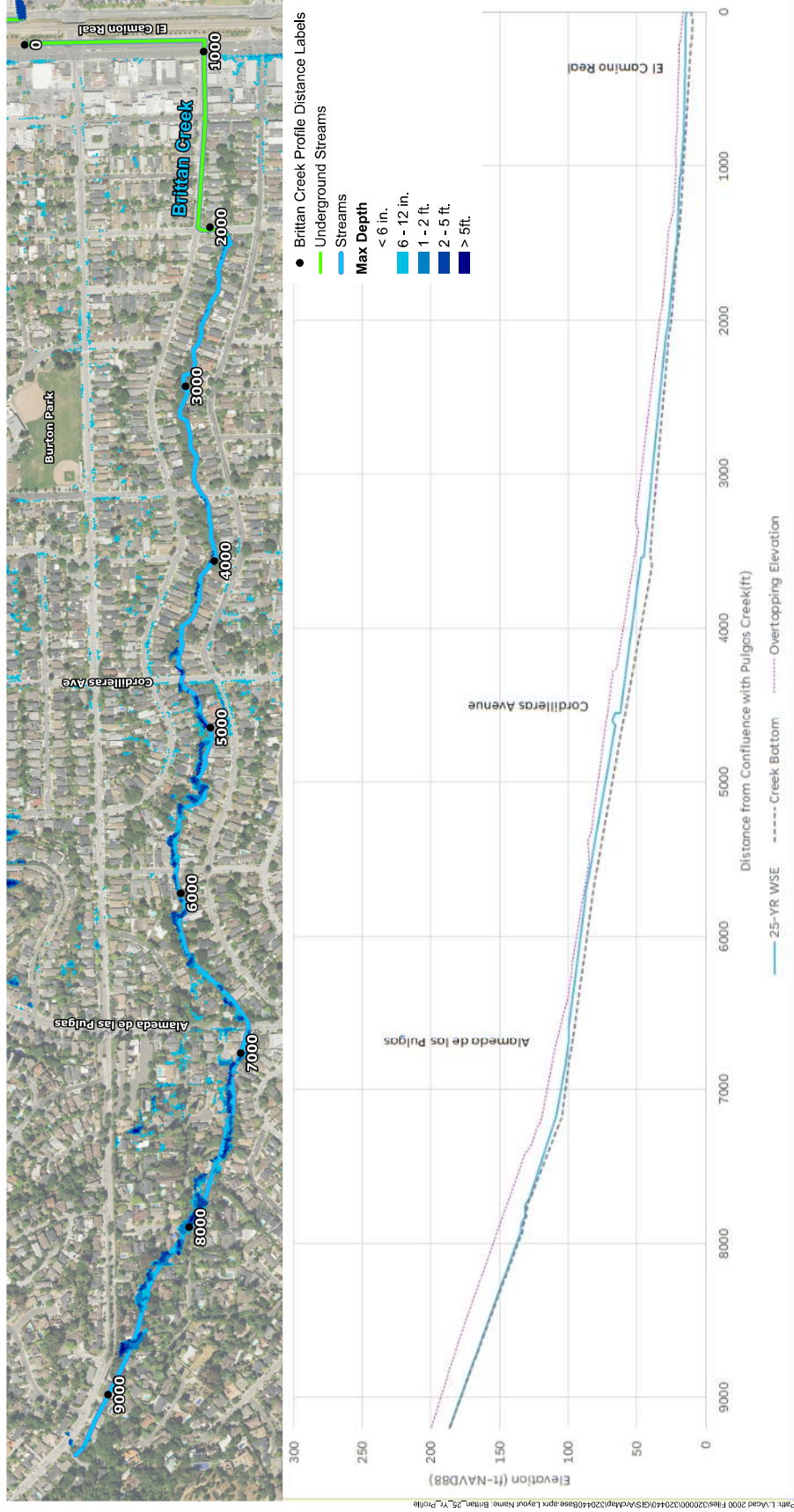
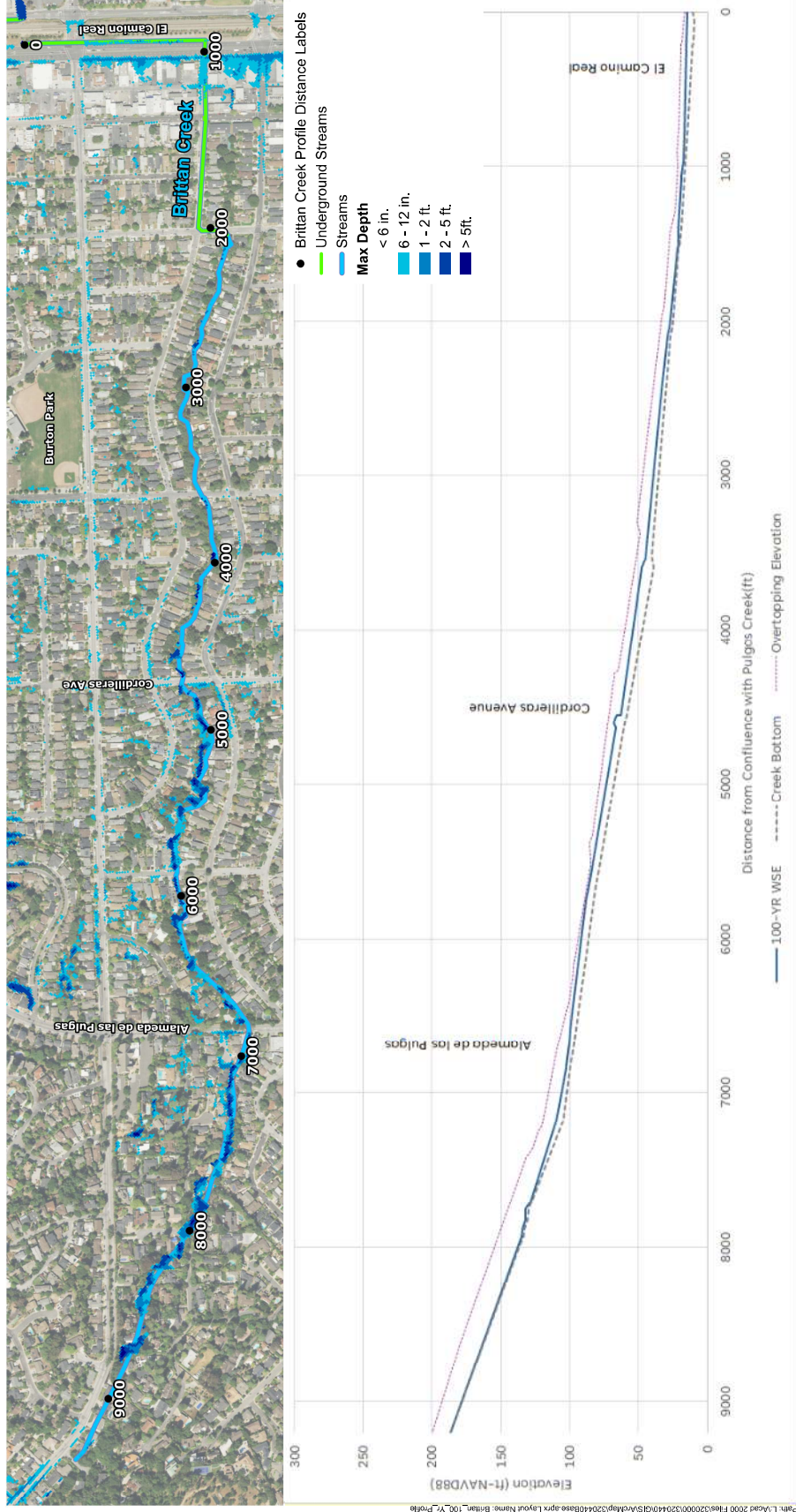


Figure 13. 25-Year Plan and Profile Views for Brittan Creek

Pulgas Watershed Study
Existing Conditions H&H Memo
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Sources: USDA NAIP Imagery 2020, WRA | Prepared By: Junjie Chen, 6/21/2024



Sources: USDA NAIIP Imagery 2020, WRA | Prepared By: Junjie Chen, 6/21/2024

Figure 14. 100-Year Plan and Profile Views for Brittan Creek

Pulgas Watershed Study
Existing Conditions H&H Memo
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