Appendix C: Flood Mitigation Evaluation Memorandum

MEMORANDUM – DRAFT

TO:	Grace Le, PE	**FROM:**	Andrew Smith, PE Chris Feng, PE Angela Hogan, PE
CC:	Camille, Bandy, PE, QSD Freyer & Laureta	Jeff Tarantino, PE Freyer & Laureta	
DATE:	December 19, 2024		
SUBJECT:	Pulgas Creek Watershed Study: Flood Mitigation Evaluation Memorandum Rev. 2		

BACKGROUND AND PURPOSE

The City of San Carlos, CA (City) is interested in developing a better understanding of the Pulgas Creek watershed (see *Figure **1*** and *Figure **2*** of Attachment A) 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 (GHD, 2017). An update to the existing conditions model and assessment of existing flood risks are presented in the Hydrology and Hydraulics (H&H) memorandum by WRA.

This memorandum aims to assess potential options to re-naturalize the hydrograph and reduce existing flood risk throughout the Pulgas Creek watershed by:

- Assessing potential alternatives to reduce peak flows and add detention to the system (i.e., increase the time of concentration)
- Identifying ideal locations throughout the City for implementing alternatives
- Quantifying potential flood risk benefits from the suite of proposed alternatives on an individual and collective basis

FLOOD MITIGATION ALTERNATIVES TARGETS

As described in the Existing Conditions Hydraulics and Hydrology Memorandum (H&H Memo) by WRA, flooding in the Pulgas Creek watershed can be attributed to high sediment flow for the upper watershed and peak flow volume for the lower watershed 0.75 inch of rain in one hour (WRA, 2024). The aim of each alternative presented is to reduce risk of flooding by addressing causes and reducing peak flows. Reduction of flood risk in the upper watershed can be achieved by prevention or mitigation of erosion and landslides as well as capture of sediment prior to entering storm drains. Reduction of flood risk in the lower watershed can be achieved by detaining peak flows in the upper and middle watershed regions and increasing capacity. The Pulgas Creek channel downstream of Old County Road has an approximate capacity of 360 cubic feet per second (cfs) prior to overtopping and is limited by an existing box culvert. A 100-year event can produce a peak flow of over 620 cfs and have a duration exceeding 360 cfs for 10.5 hours causing approximately 97 acre-feet of stormwater to overtop the channel and flood the community (*Exhibit 1*). This flood reduction target assessment is based on existing conditions downstream from Old County Road and does not consider other constrictions immediately upstream where capacity issues can only be alleviated through upsizing pipes or culverts. The memorandum provides alternatives that could reduce the peak flows, detain specific volumes of stormwater, and increase capacity.

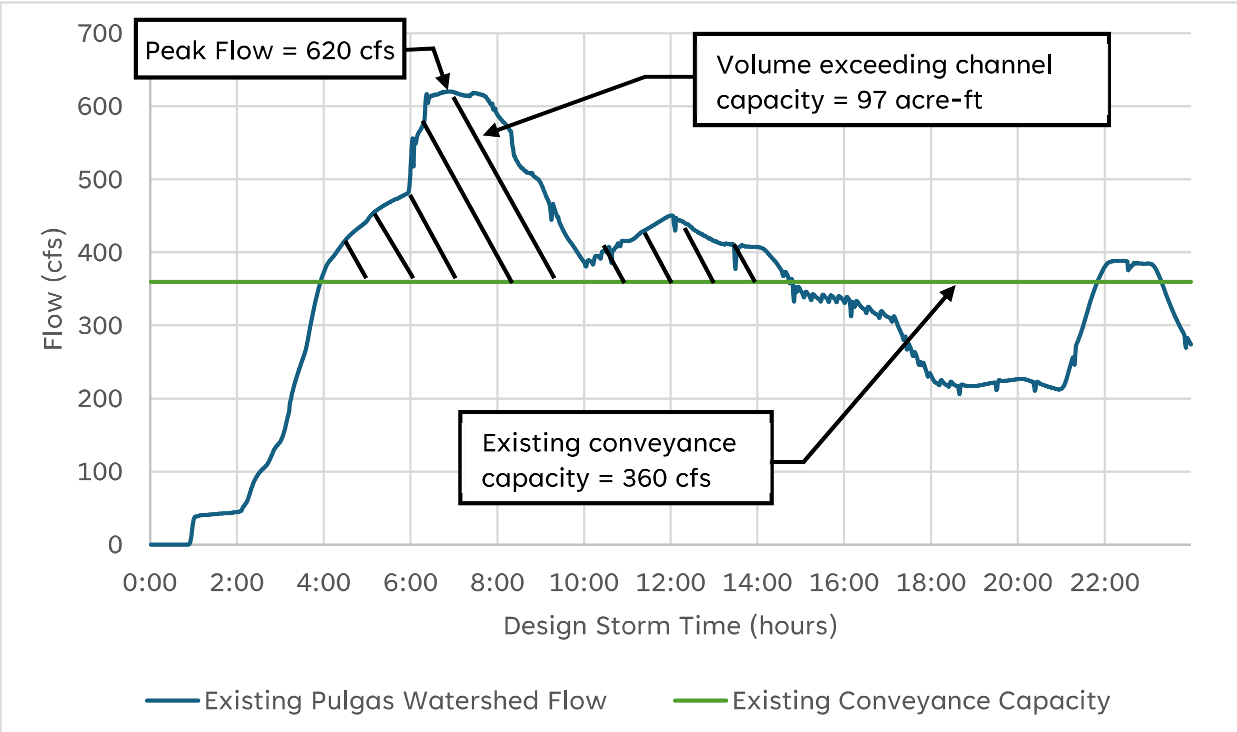

Exhibit 1. 100-year hydrograph of the Pulgas Creek watershed at Old County Road with capacity prior to flooding.

FLOOD MITIGATION ALTERNATIVES

WRA has identified seven flood mitigation alternatives focused on nature-based solutions and integration with existing City operations. The alternatives include:

A. Vegetation of existing exposed or sparsely vegetated slopes with strongly rooted native plants
B. Implementation of engineered flood plain detention basins where space is available, such as existing parks
C. Implementation of Low Impact Development (LID) and/or green infrastructure features throughout the City
D. Engineering analysis and site-specific plans for implementing nature-based solutions at specific creek crossings

E. Underground stormwater detention basins within public roadways, parks, right-of-way, etc.
F. Creekside public access through creek daylighting and establishment of small parks near public/private parcel intersections
G. Inspection and maintenance of historical problem sites

The alternatives differ in complexity, level of effort, and potential risks. Proposed locations for each alternative can be seen in *Figure **3*** of Attachment A. The ideal solution is likely a combination of the proposed alternatives. The objective for each alternative is to reduce flood risk throughout the Pulgas Creek watershed through attenuating flood flows by imitating the natural effect of floodplains and vegetation on water retention and detention. These alternatives are meant to represent a suite of options that vary in level of impact where one individual project may not resolve flooding issues for a region; however, once enough projects are undertaken, watershed scale flood benefits will be realized. Each alternative was roughly sized to accommodate a 10-year event or a 100-year event within the Federal Emergency Management Agency (FEMA) floodplain based on the City of San Carlos Design Guidelines (City of San Carlos, 2014).

Alternative A: Revegetation

Alternative A aims to address the dual impact of higher runoff and unstable slopes from low vegetative cover in regions of the Pulgas watershed, which can introduce sediment to the system and clog storm conveyance structures. Vegetation efforts are primarily concentrated on a landscape scale where land is available to be more densely vegetated, such as in the upland reaches of the Pulgas Creek watershed and around existing public parks, especially where landslide risk is prevalent. There are several locations primarily concentrated around existing parks where vegetation cover is dominated by non-native annual grasses that provide poor stability in the key wet months of October to December (*Exhibit **2***). The non-native annual grasses will yellow in the summer and only begin to re-establish in December when comprehensive vegetation coverage is needed to prevent landslides and capture precipitation. Establishment of native shrubbery and trees, which are persistent and deeply rooted, will likely decrease landslide risk, and provide precipitation absorption and abstraction throughout the year (Wilcox, et al., 2012). Attaining native establishment may involve a concerted annual effort to achieve success as establishment may be contingent upon a variety of factors such as soil suitability, existing soil microbial communities, nutrient availability, water availability, competition, and microclimate. An in-depth discussion of planting options and recommended planting palettes for the City are provided in Attachment B.

Impacts of land cover on precipitation can be quantified using a curve number (CN) with the Soil Conservation Service (SCS) method to calculate runoff rates for a given storm (USDA, 1999). Higher CN values indicate a more impermeable surface, such as concrete, with lower CN values indicating a more permeable surface. CN values are also dependent on the antecedent precipitation amounts where wet conditions or extreme storms can overwhelm the absorptive capacity of the soil and vegetation, resulting in an effectively increased value. Overly wet conditions can also continue to result in landslides and erosion, even with more deeply rooted native plants; thus, Alternative A aims to address landslide and runoff issues presented by a 10-year event.

Exhibit 2. Alternative A: opportunity for increased deeply rooted vegetative cover at Big Canyon Park. Photo credit: WRA

Alternative B: Floodplain Detention Basins

Alternative B aims to incorporate natural flood attenuation effects through construction of engineered flood plains. Flood plains naturally provide a variety of ecosystem benefits while calming high-flow energies to retain water within the floodplain, accrete sediment, and minimize erosion compared to a more typical engineered conveyance channel. While natural floodplains can have a large footprint, combining the morphology of a floodplain with a more typical detention basin design can provide increased ecological benefits with the intended sediment, peak flow, lowered footprint, and maintenance controls of a normal detention basin. These devices are intended to be placed in a tributary's natural flow path as it drains into the urban storm system and where there is sufficient lateral and longitudinal space, such as in San Carlos' existing parks.

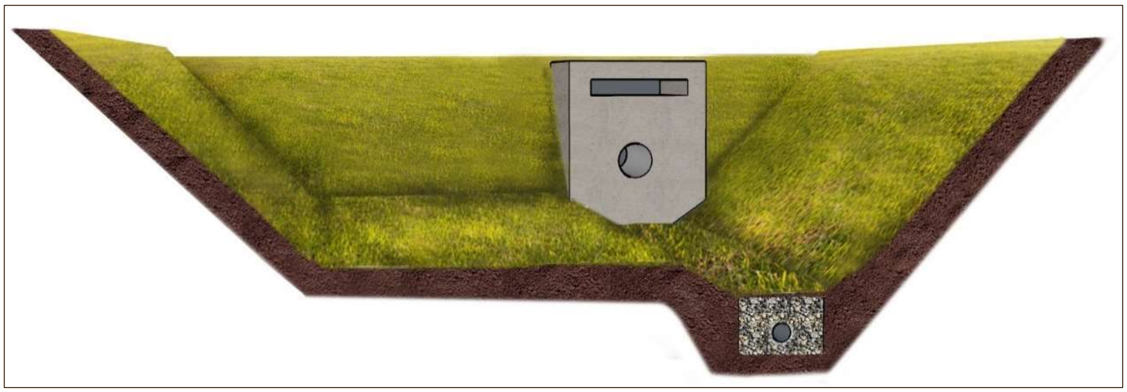

Exhibit 3. Alternative B: floodplain detention system concept for Arguello Park

Alternative C: LID Implementation

Alternative C aims to provide flood reduction benefits in the more urbanized environments of the City through implementation of LID. Currently, there are few well-implemented LID features within the public city limits. Existing LID features installed east of El Camino have limited effectiveness due to poor soil infiltration and a high groundwater table during flood events. Implementation of LID can represent a significant benefit to the City both in managing flood and water quality risks.

As LID project benefits are only expected to yield watershed scale benefits when reaching a critical mass, each road, park, or other public infrastructure project should be assessed for opportunities to implement LID features. Limitations and ideal scenarios for the LID options outlined in the C.3 Guidance are listed in the Green Infrastructure Plan (San Mateo Countywide Water Pollution Prevention Program, 2023) (City of San Carlos, 2019). It is recommended that City guidance for LID encourages targeting 1 inch of rain per hour for when detention in each LID feature activates, and the detention time be extended for four hours if possible.

Exhibit 4. Alternative C: incorporate LID into public projects. Photo credit: City of Burlingame

Alternative D: Creek Crossing Adjustments

Alternative D aims to consider opportunities to work directly in the creek by integrating multiple interests and project partners. Projects such as the bank stabilization project for privately owned streambanks should be thought of as opportunities for ecosystem restoration, flood risk mitigation, and parks planning. Currently, much of Pulgas and Brittan Creek exists underground in man-made storm conveyance features or within private parcels. Most creek crossings through public land involve tributary flow through parks or main channel flow through street crossings. In-channel work to alleviate flooding typically involves expansion of restrictive conveyance structures, or channel widening, which all require extensive funding and real estate. As a result, the opportunities for in-channel work capable of meeting flood reduction objectives for the City may be limited.

The primary lower watershed constraint of a series of bridges downstream of Old County Road was analyzed for a site-specific concept. The bridges consist of multiple box culverts spanning across private property lots and the Industrial Road and El Camino Real crossings. This analysis does not consider specific political, legal, and monetary viability widening, and is only intended to analyze the potential for flood reduction in the region.

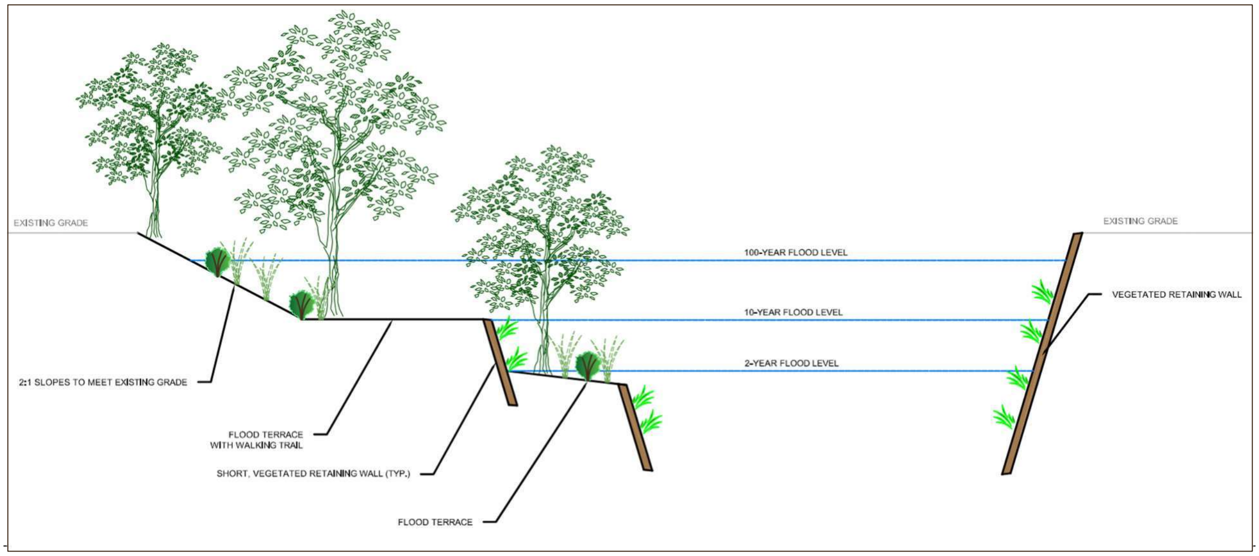

Exhibit 5. Alternative D: Specific Creek Alteration Concept (Widening)

Alternative E: Underground Detention Basins

Alternative E involves underground detention tanks which could be implemented by the City at Burton Park and a narrow space between the Caltrans railway and El Camino bounded by Arroyo Avenue and Brittan Avenue. The specific logistics of the detention tank design will not be discussed in this memo, including details of connections to existing storm drains and flow mechanics. It is assumed the detention tanks will have a rectangular configuration with a 10-ft depth and will operate in a way to fill during the peak flow of a storm event and drain beyond the peak flow.

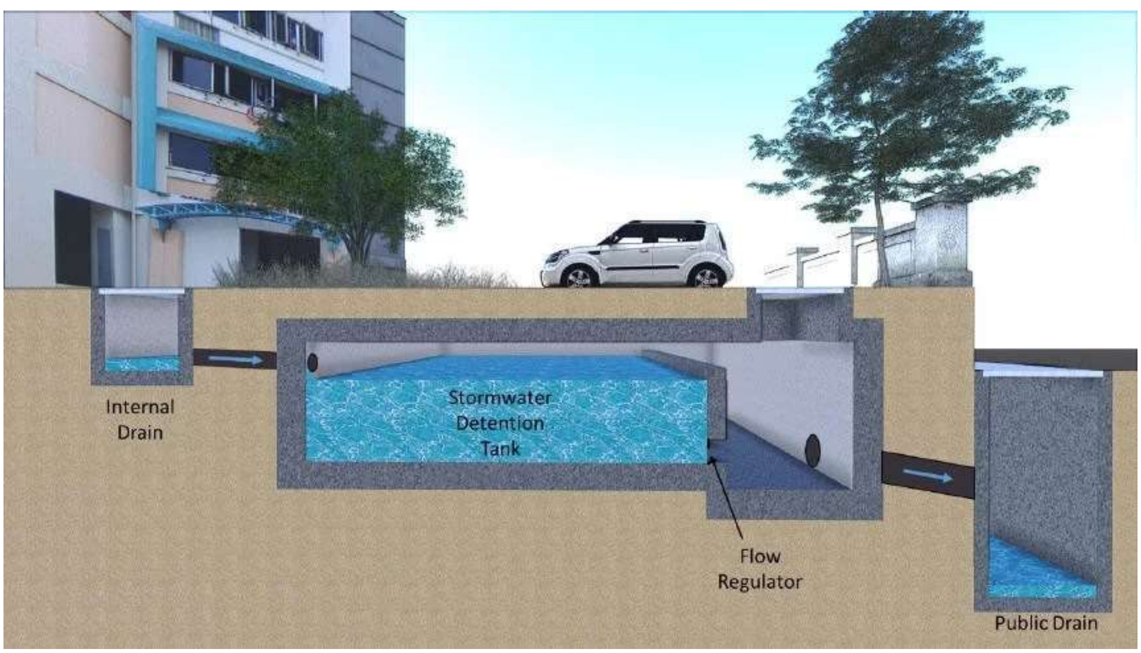

Exhibit 6. Alternative E: concept of underground storage tanks for detaining peak storm flows. Photo credit: (Stormwater Sydney, 2024)

Alternative F: Creekside Public Access

Alternative F is to establish Creekside public access and is focused more on increasing public park space and visibility of the City's creeks. There may be incorporation of flood mitigation benefits through the use of Alternatives A-D as a part of a parks project. Establishment of creekside parks can provide opportunity for resident engagement and foster a sense of shared responsibility for watershed management. There needs to be awareness of how the storm drain system is intended to work, potential failure points, and where to look for items to fix or report to better educate residents of the potential flood risks and actionable items on an individual level. Creekside parks present a unique opportunity to increase awareness, increase greenspace around the City, and increase resident education through placards.

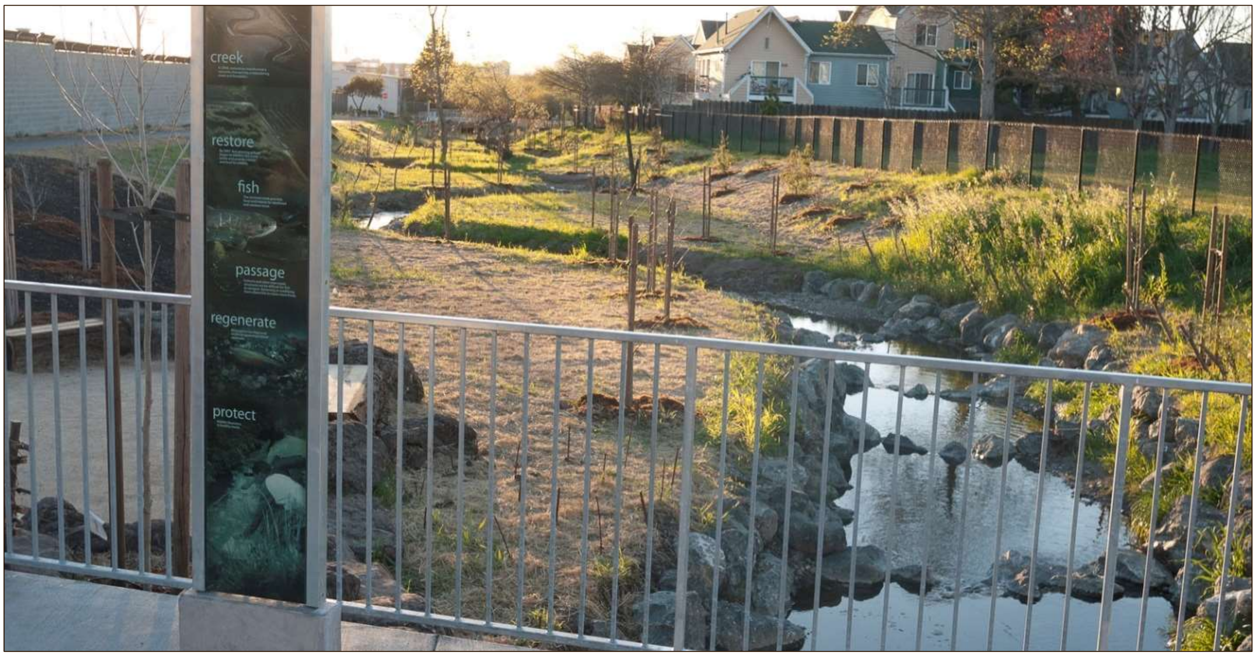

Exhibit 7. Alternative F: Creekside pocket park example at Cordonices Creek in Berkeley/Albany, California. Photo credit: (Restoration Design Group, 2024)

Alternative G: Targeted Inspection and Maintenance

Alternative G of targeted inspection and maintenance activities is intended to proactively investigate historic flood locations where opportunities for improvement is limited. These can include regions where the cause of the flooding is entirely within private property, is limited in utilizable space, or where flood mitigation options are likely to yield low to no benefit.

SITE SPECIFIC MODEL OUTPUT AND ASSESSMENT

Impacts of alternatives highlighting a per-project site-specific scale are described below. The flood detention impacts are quantified on a per-project scale to estimate an upper bound for total watershed detention capacity based on the total area of alternatives shown in *Figure **3***. The modeled cumulative effect of alternatives is provided in the Compounding Alternatives section.

Adjustments of the existing conditions PC SWMM model made to represent Alternatives A-E are described in Attachment C.

Alternative A: Revegetation

The studied subbasin and design condition for Alternative A is in increasing native vegetation cover in Big Canyon Park to affect a 10-year event. The subbasin chosen drains to 3184 Brittan Avenue. Approximately 50% of the subbasin could be revegetated with native cover (*Exhibit 8*). The studied subbasin represents approximately 2% of the total proposed area for revegetation. Impacts of the revegetation on runoff were modeled through a change in CN values from existing to proposed of 82 to 70. This resulted in a peak runoff reduction from 2.5 cfs to 1.5 cfs, or a 40% reduction with a volume reduction of 0.13 acre-feet (*Exhibit 9*). These results projected onto the entire proposed planting area represent an upper bound of 6.5 acre-feet for the potential runoff volume reduction.

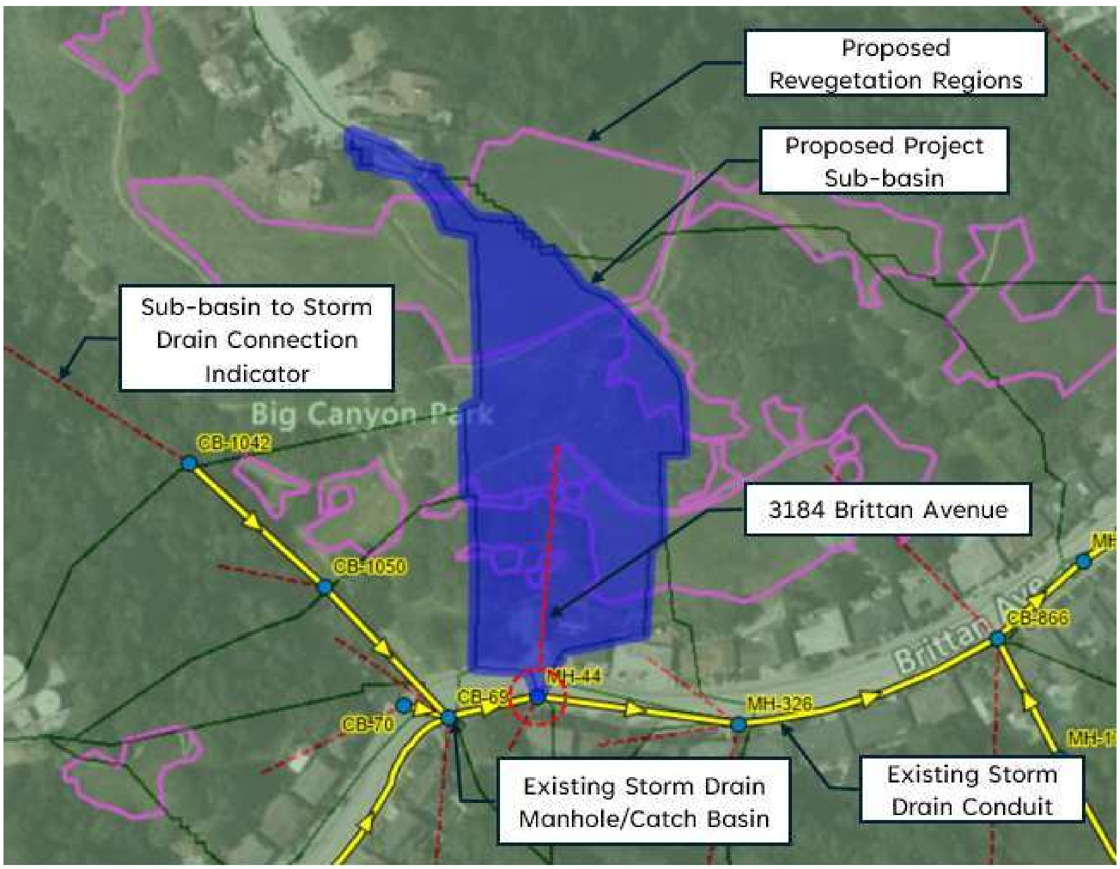

Exhibit 8. Location of studied subbasin for Alternative A – Revegetation

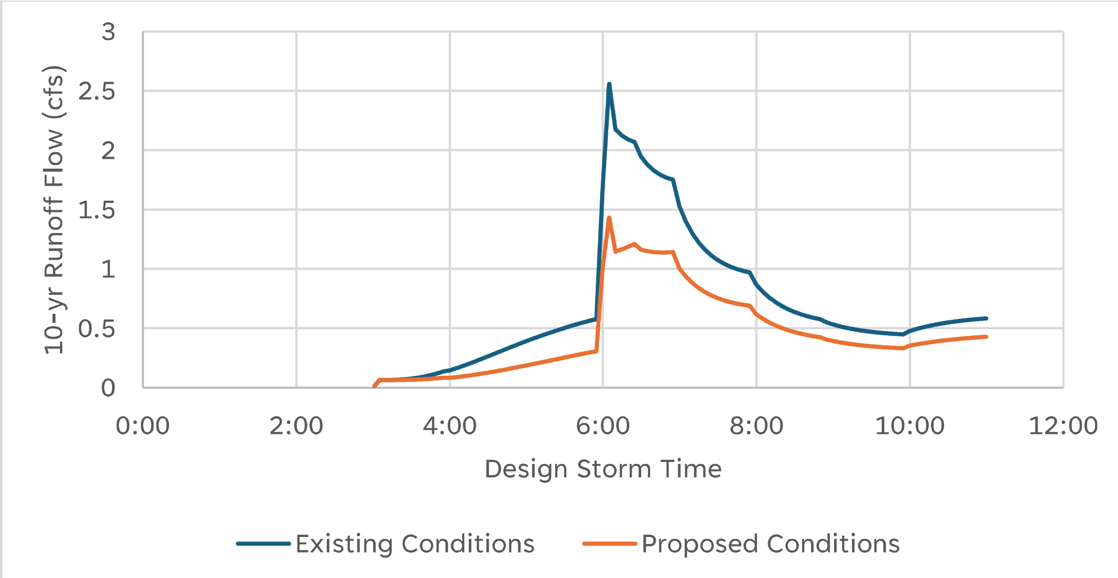

Exhibit 9. Change in peak flow rate from existing to proposed of the Alternative A studied subbasin

Alternative B: Floodplain Detention Basins

The studied subbasin and design condition for Alternative B is a series of three detention basins in Arguello Park that mimic floodplain behavior. The subbasin flows through Arguello Park with an approximate width-length-depth of 32'-115'-6' (*Exhibit **10***). The studied subbasin represents approximately three of 26 proposed locations where a floodplain detention basin may be viable. The actual available dimensions, and thus storage capacity, for each basin will vary. Possible designs may also differ from the concept shown in *Exhibit **3***. This resulted in a peak runoff reduction from 22 cfs to 13 cfs, or a 41% reduction with a volume reduction of 1.5 acre-feet (*Exhibit **11***). These results projected onto the entire proposed planting area represent an upper-bound of 13 acre-feet for the potential runoff volume reduction.

Exhibit 10. Proposed location for Alternative B – Floodplain Detention Basin in Arguello Park

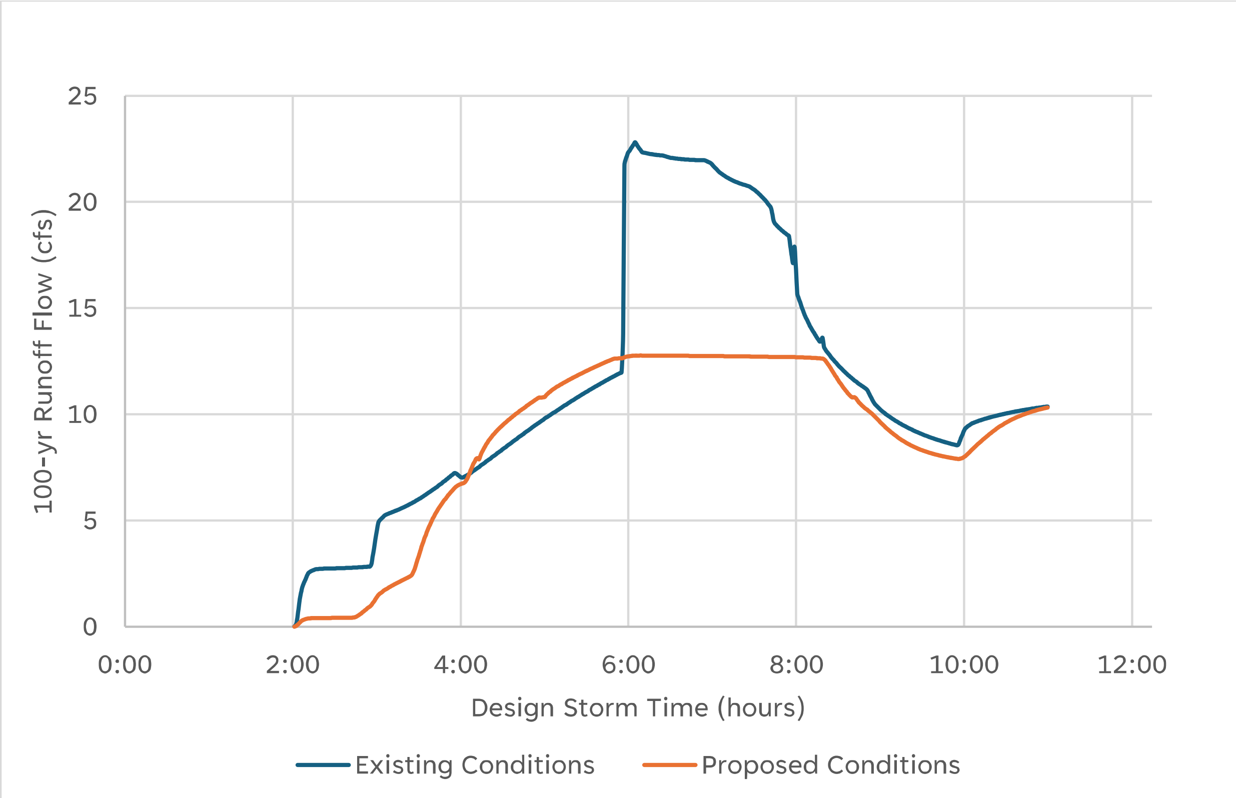

Exhibit 11. Change in peak flow rate from existing to proposed for the Alternative B studied subbasin

Alternative C: LID Implementation

The studied subbasin and design condition for Alternative C is bioretention LID designed for a 10-year event as described in the San Mateo County C3 Guidance and located at the intersection of Alameda de las Pulgas and Brittan Avenue (*Exhibit 12.*) (San Mateo Countywide Water Pollution Prevention Program, 2023) There is an existing roadway median approximately 1,780 square feet in area that has potential to be converted into a bio-retention cell to reduce the volume of runoff of lower storm events (i.e. 2-YR to 10-YR events). However, this area does not include prioritized parcels identified in the Green Infrastructure Plan and may involve privately owned parcels where direct City involvement is unnecessary (City of San Carlos, 2019). The modeled results after incorporating LID into the subbasin resulted in a peak runoff reduction from 6.4 cfs to 6.0 cfs and a volume reduction of 0.002 acre-feet (*Exhibit 13.*). Although the difference in peak values is minimal, the total volume of runoff is reduced by 45%, which can mediate flooding along Brittan Avenue. These results projected to the entire proposed LID implementation area represent an upper bound for the potential runoff volume reduction of 0.07 acre-feet. However, there may be a more pronounced individual effect in locations experiencing calmer flow patterns. LID designs and performance for the other proposed locations will differ from those modeled for the studied subbasin.

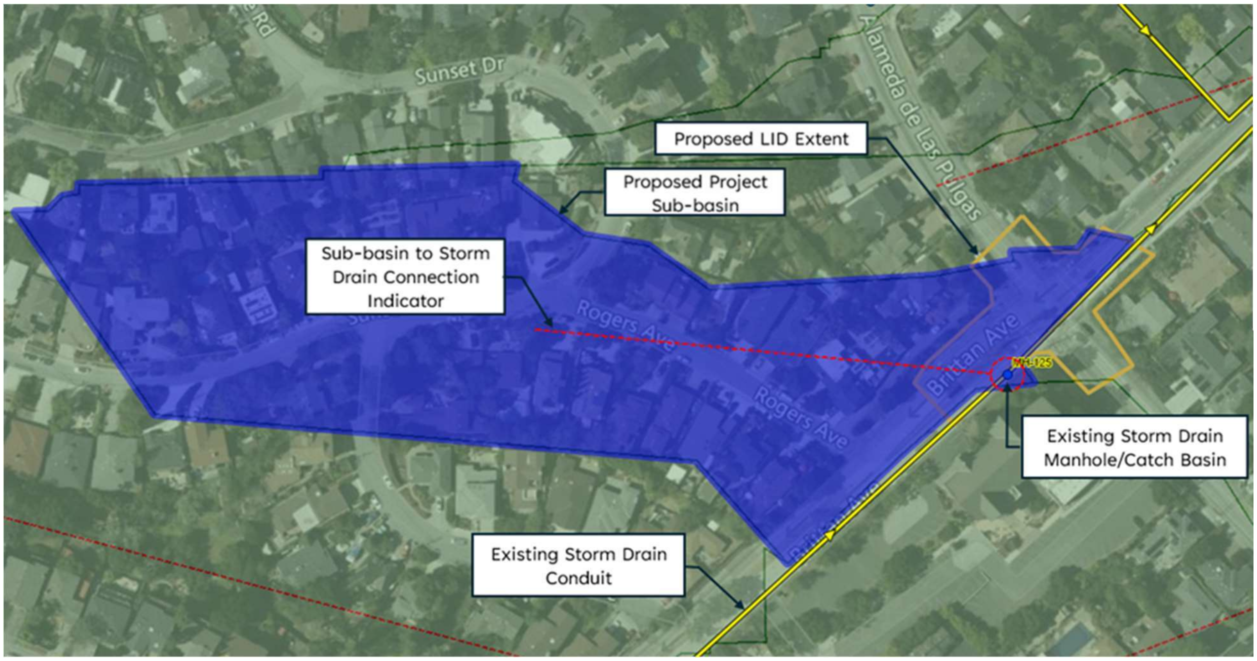

Exhibit 12. Proposed location for Alternative C – LID Implementation at San Carlos Avenue & Alameda de las Pulgas

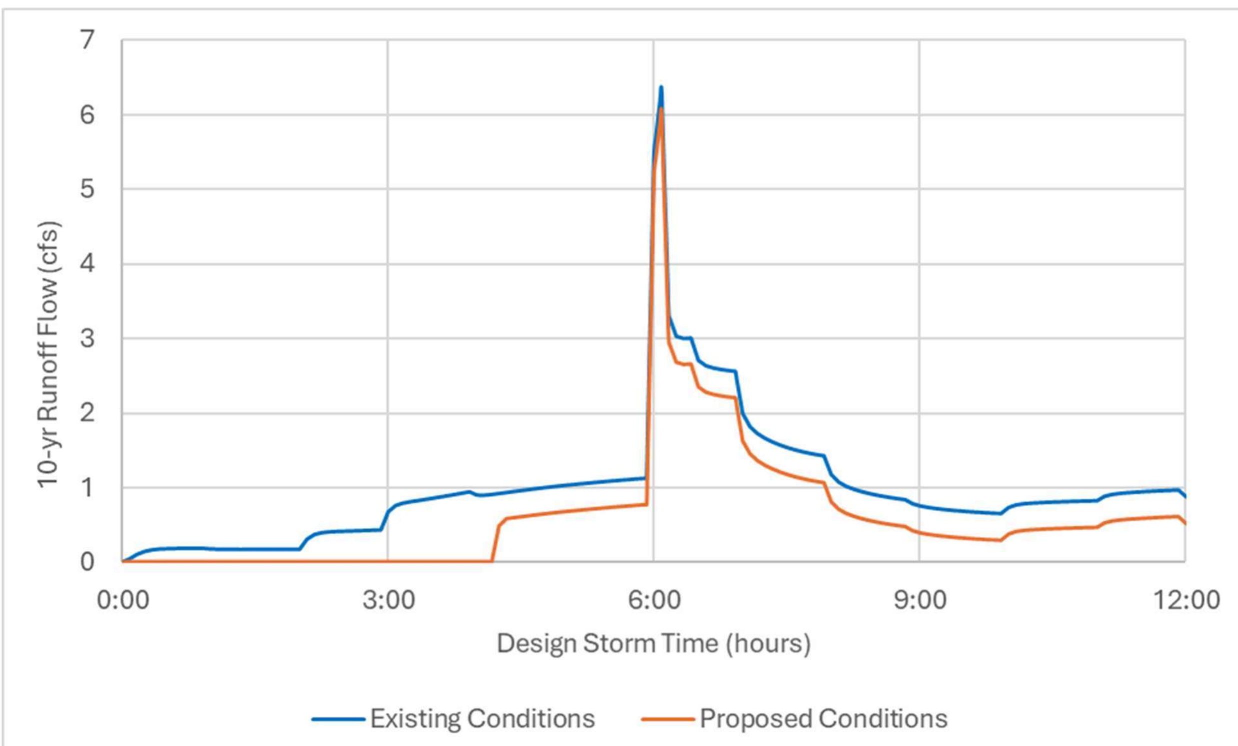

Exhibit 13. Change in peak flow rate from existing to proposed for the Alternative C studied subbasin

Alternative D: Creek Crossing Adjustments

The studied extent and design condition for Alternative D is improving capacity on a bridge crossing Pulgas Creek including some channel widening located between Old County Road and Industrial Road (*Exhibit* ***14***). The studied length includes alterations impacting approximately 1,500 linear feet of creek with the total proposed length of creek adjustments at 2,200 feet. The modeled results after widening portions of the Pulgas Creek channel indicate a flow capacity increase from 360 cfs to 1,300 cfs, or a 260% increase (*Exhibit* ***15***). Existing conditions are constrained by a double box culvert with a blocked opening, reducing its design capacity. The increase in capacity from widening could exceed the 100-year flow of 620 cfs, preventing flooding at the low watershed. Other creek-crossing adjustments can help alleviate local flooding due to capacity issues and can provide ecosystem and sediment transport benefits depending on design. Most adjustments are expected to have limited ability to attenuate flows due to limited space, but an increase in capacity can prevent local flooding while directing flows to alternative mechanisms for flow attenuation and peak flow reduction.

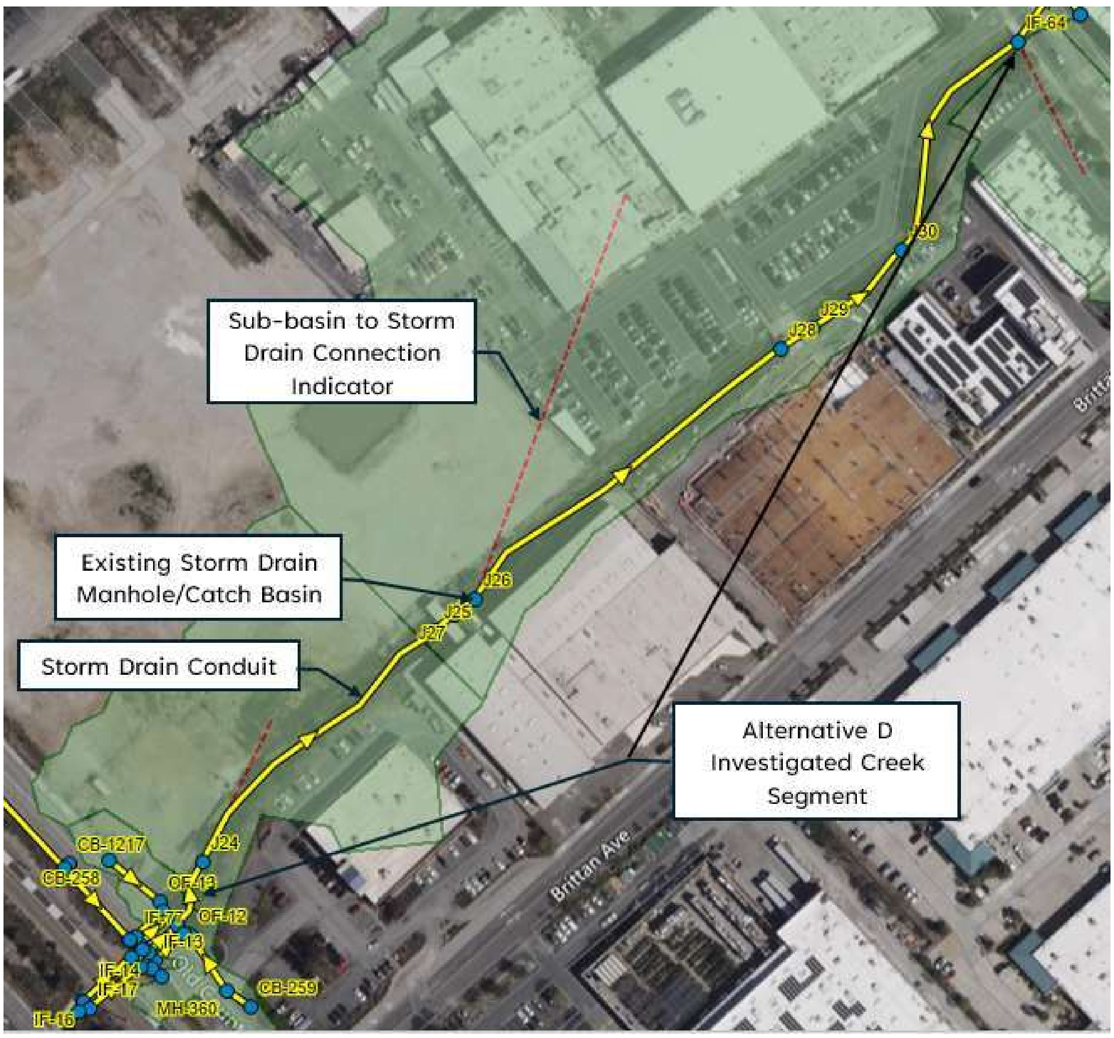

Exhibit 14. Proposed location for Alternative D:
Creek crossing adjustments between Old County Road and Industrial Road

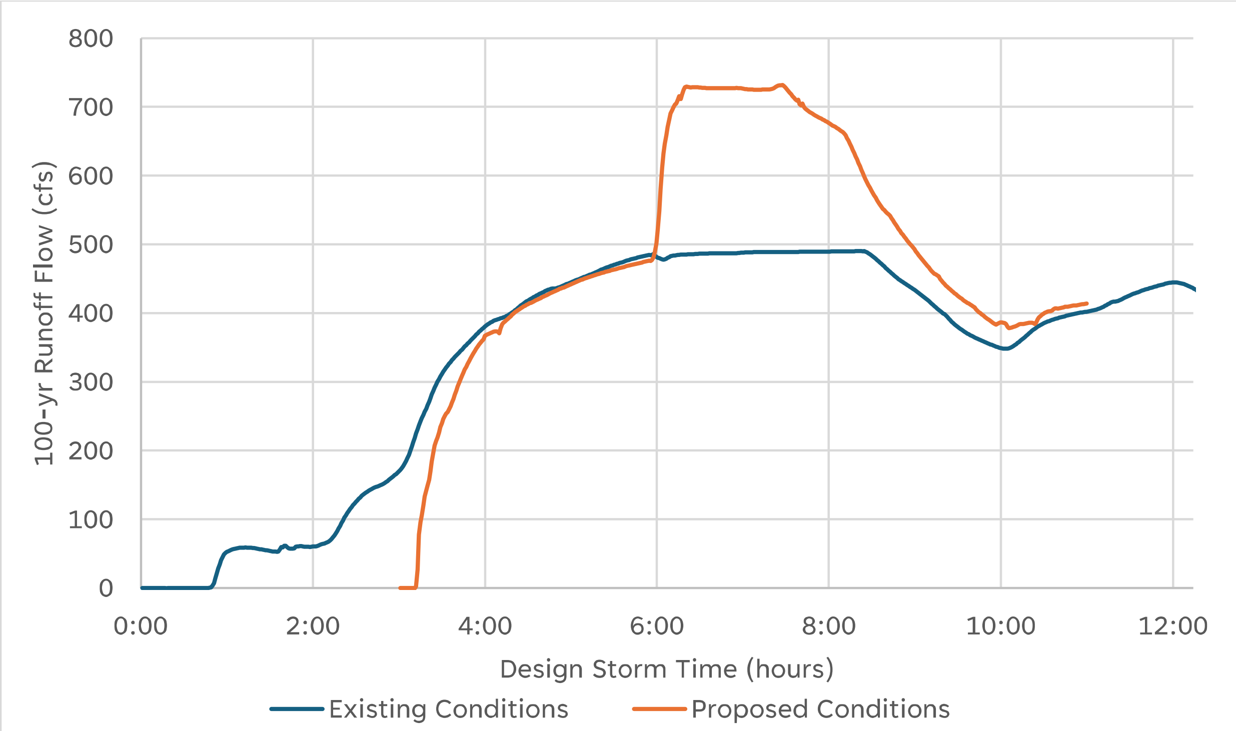

Exhibit 15. Change in peak flow rate capacity from existing to proposed for the Alternative D studied subbasin. Existing flow reaches gravity flow capacity at 360 cfs with flows higher indicating pressure flow or flooding.

Alternative E: Underground Detention Basins

Viability of Alternative E was assessed based on the calculated potential volume detention based on a target of lowering the 100-year peak flow over 4 hours. The calculation was based on the total available storage volume from the proposed basin footprint area with an assumed viable depth of 10 feet. The stored volume would be filled at a constant rate over 4 hours during a peak event, then allowed to discharge back to the storm drain system at a later time. The specific equipment and mechanisms needed for this process were not investigated. The reduction in peak flow was calculated from Equation 1 with results of the calculation provided in Table 1 below:

Equation 1. $$\textbf{Detained Flow}\ (cfs) = \frac{\textbf{Volume of Basin}\ (ft^3)}{\textbf{4 hours}}\ x\ \frac{\textbf{1 hour}}{\textbf{3600 seconds}}$$

Table 1. Summary of underground detention basin effectiveness

BASIN LOCATION	BASIN VOLUME (FT^3)	BASIN VOLUME (ACRE-FT)	DETAINABLE PEAK FLOW VOLUME (ACRE-FT)	PEAK FLOW REDUCTION (CFS)	PEAK FLOW REDUCTION (%)
Burton Park	4,000	0.09	9	0.3	1%
El Camino Real	300,000	6.9	84	20.8	5%

Effectiveness of underground detention basins are highly dependent on the available volume. The feasibility of basins will be dependent on site-specific conditions including the tie-in points of the storm drain network, available area, conflicting utilities, structural safety, groundwater depth, public opinion, and cost. Detention basins of less than 2 acre-feet are likely not viable cost-benefit wise compared to a normal above-ground detention basin or LID features.

COMPOUNDING ALTERNATIVES

Each alternative cannot independently address flood-risk issues in the watershed. Instead, a combination of these alternatives is assessed to demonstrate the plausibility of performance if the City invests in these alternatives. Extrapolating from the site-specific model outputs and applying to all potential site locations can provide context for watershed scale improvements. An estimate of the upper bound or best-case scenario for applying alternatives at all potential sites is presented in Table 2.

Table 2. Potential Upper Bound for Runoff Volume Reduction and Target Beneficiaries

ALTERNATIVE	RUNOFF VOLUME REDUCTION (ACRE-FT)	PRIMARY BENEFIT TARGET
A – Revegetation	6.5	Upper watershed entities
B – Floodplain Detention Basins	13	All entities in the Pulgas Watershed
C – LID Implementation	0.07*	All entities in the Pulgas Watershed
D – Creek Crossing Adjustments	0	Lower watershed entities
E – Underground Detention Basins	7	Middle and lower watershed entities
Total:	26.6	

*LID effectiveness highly depended on local conditions and design

It important to understand improvement to the watershed may vary spatially between the high, middle, and low watershed areas. Alternatives A-C are expected to have impacts on upper watershed sediment retention and alleviate flood risk in the region. The impacts on soil retention are not capable of being captured in the model; however, peak flows through the region are expected to decrease through the detention and abstraction mechanisms from the proposed alternatives. All proposed alternatives reduce peak flows to a total of 520 cfs from the existing 615 cfs crossing Alameda de las Pulgas from both Pulgas and Brittan Creeks.

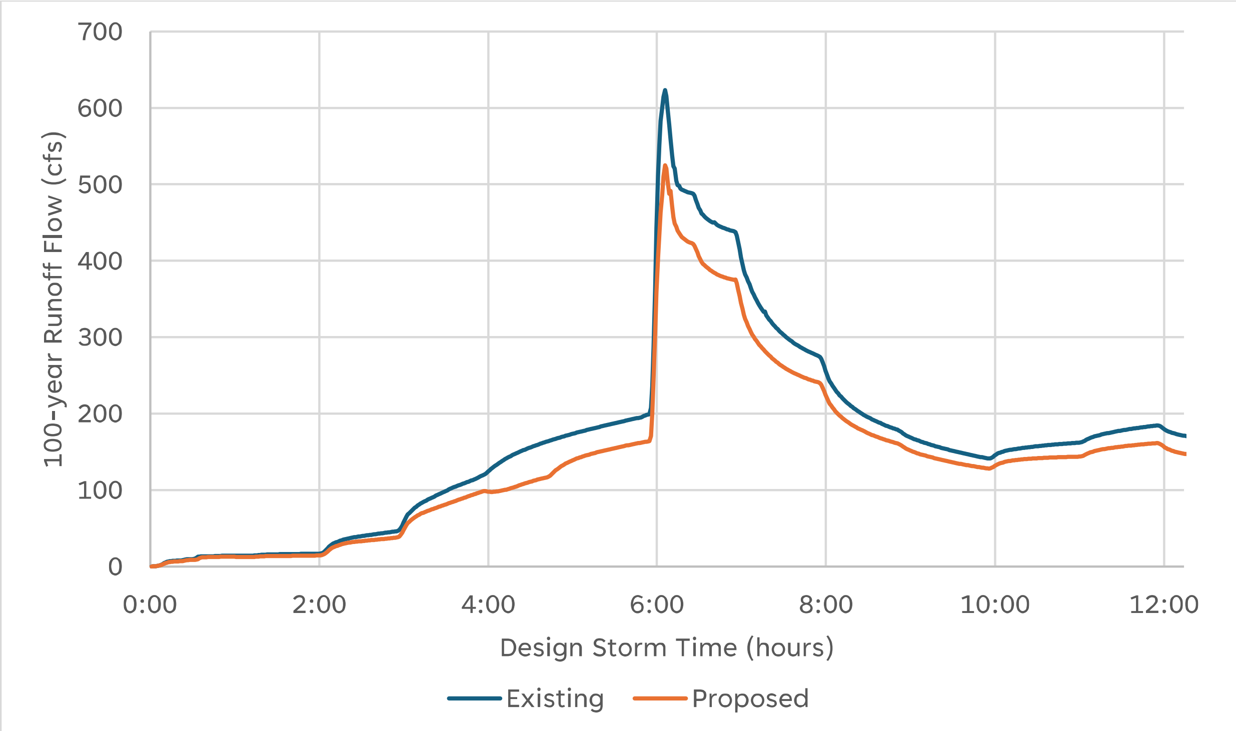

Exhibit 16. Upper watershed total flow hydrograph at Alameda de las Pulgas for Brittan and Pulgas Creeks with all alternatives compared to existing conditions hydrograph

The middle watershed is expected to primarily benefit from Alternatives C-E as the urbanization density increases. Benefits from the alternatives are expected to have a smaller impact per project than those in the upper watershed simply due to space constraints, which emphasizes the need for implementing alternatives wherever possible. All proposed alternatives reduce peak flows to a total of 765 cfs from the existing 875 cfs crossing El Camino Real from both Pulgas and Brittan Creeks.

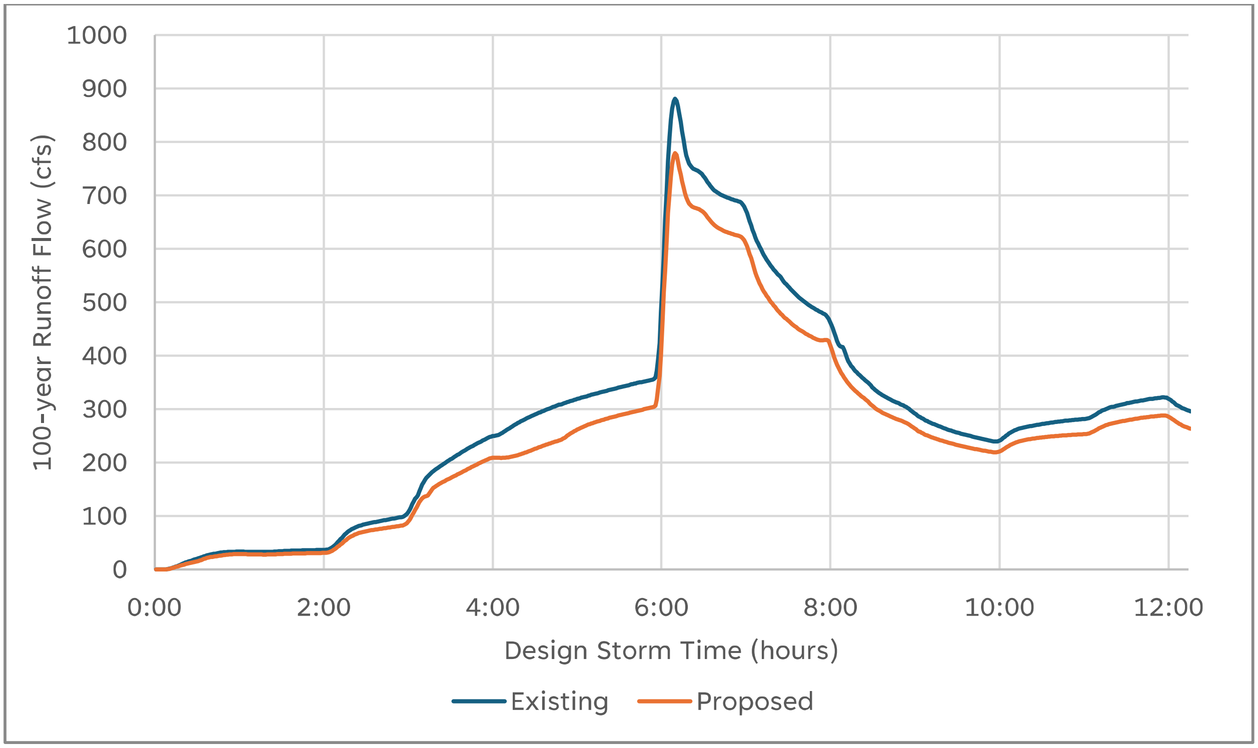

Exhibit 17. Middle watershed total flow hydrograph at El Camino Real for Brittan and Pulgas Creeks with all alternatives compared to existing conditions hydrograph

The lower watershed has limited viability for all alternatives due to the highest levels of urbanization, thereby space constraints, and groundwater factors limiting the effectiveness of Alternative C. The main improvement to be achieved in the lower watershed is a channel capacity increase. Combining the effects of a channel capacity increase with flow detention in the upper and middle watersheds will increase the flow threshold at which flooding occurs from the existing 360 cfs to 1,300 cfs. However, flow limiting and flood including factors upstream from Old County Road were not addressed. Due to the removal of the constriction in the lower watershed, the peak flow increases from 605 cfs to 655 cfs. Implementation of all proposed alternatives is expected to reduce flooding in the Pulgas Creek watershed.

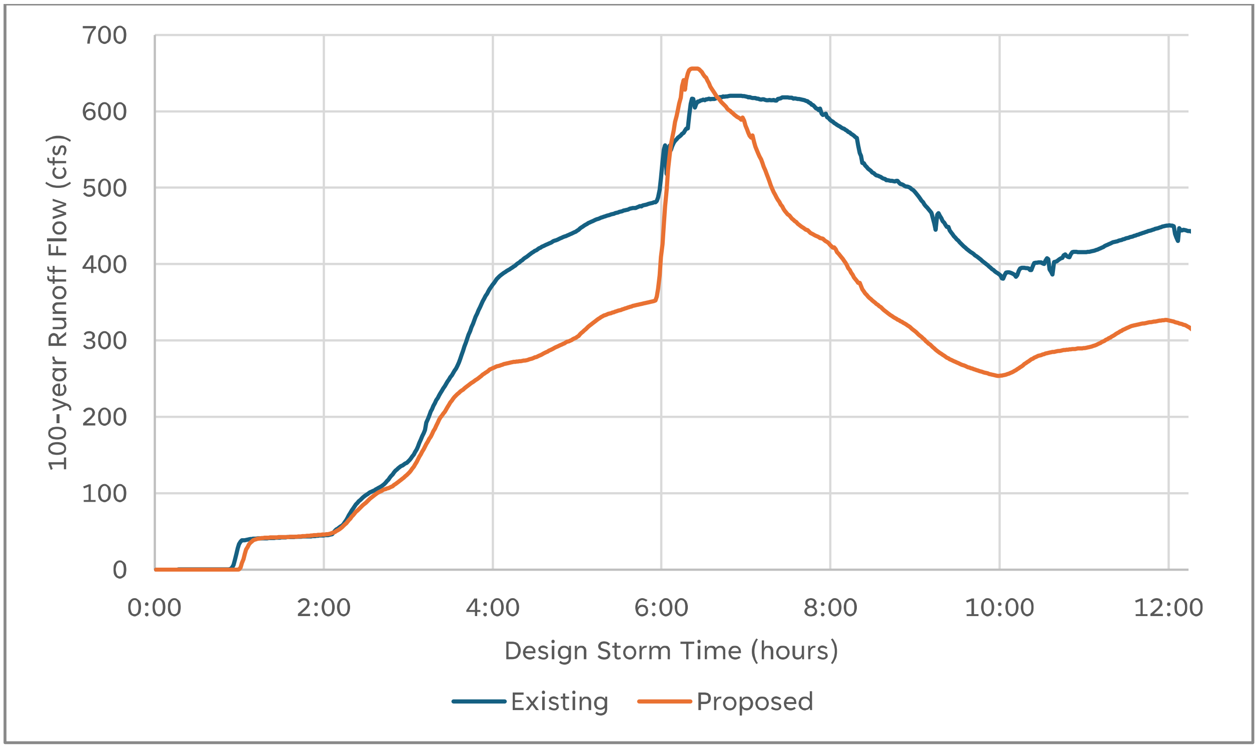

Exhibit 18. Lower watershed total flow hydrograph near Smith Slough for Brittan and Pulgas Creeks with all alternatives compared to existing conditions hydrograph

In analyzing the Pulgas Creek watershed, modeling suggests there are multiple flow constrictions in the lower watershed based on the decrease in peak flow from the middle to lower watershed. Flow through the channel is lost through flooding and flow constrictions that return to the main channel over time, resulting in the wider peak width under existing conditions. While the proposed alternatives lower the overall volume of flow encountered by the lower watershed, flooding issues are not resolved as demonstrated by the continued decrease in peak flow between the middle and lower watersheds under proposed conditions. It is unlikely that the Pulgas Creek watershed has sufficient opportunities for complete prevention of flooding impacts barring complete redevelopment of the City. However, there may be additional opportunities for flood mitigation not addressed in this analysis based on site specific flood control strategies, such as flood prevention measures for individual buildings while allowing street flooding up to an acceptable limit.

RISK ASSESSMENT

While viability of each alternative can depend on site-specific and time-dependent conditions not analyzed as a part of this evaluation, the generalized risks of each alternative can still be assessed. The ideal mix of solutions and alternatives to prevent flooding in the Pulgas Creek watershed may depend on a variety of factors including acceptable burden to City operations and maintenance, lifetime of project benefits in light of climate change, risk to life and safety of the City's residents, and potential available funding opportunities.

Risk Categories

Operations & Maintenance

The level of risk represents the expected potential problems or additional effort required throughout the lifetime of the alternative. For example, high risk to Operations & Maintenance (O&M) indicates an average increase in expected workload for O&M staff to address issues, even accounting for extreme events that occur during the project's lifetime. Alternative A is expected to require a medium level of risk as the first few years require annual attention to ensure planting success and manage invasives and maintain that level of risk as inevitable landslides require additional planting to restabilize slopes.

Resiliency

High resiliency risk represents an expectation of poor adaptation to changing climate conditions. Hard infrastructure built and designed for today is expected to perform poorly for sea-level rise, increases in extreme events, and require replacement prior to its projected end of life as priorities shift with changing local conditions.

Safety

High safety risk represents a high expectation of damaging flood events, landslides, wildfire, urban heat island, and sea-level rise impacts to occur contributed by undersized infrastructure and poorly managed vegetation cover.

Funding

High funding risk represents an expectation of difficulty in obtaining funding support or a high budget burden for the alternative. This can be due to expectation of local push back, lack of external funding opportunities for the project, or high expected design and construction costs. It does not consider the potential consequences or opportunity costs for alternatives.

Context for Risk

Vegetation may yield long-term benefits but will require significant effort to get a program started. Extended detention basins as proposed in currently easily accessible parks can provide significant benefits as a relatively small project. LID can have a small individual impact but will have a wider applicability throughout the urbanized regions of the City and requires additional expertise from City staff. Direct changes to the creek are expected to be the most difficult to implement under current conditions as the vast majority of the creek length is within private land, making comprehensive adjustments to the channel difficult to perform. While the City has opportunities to implement impactful solutions on its own, the current makeup of the City requires comprehensive planning, interagency cooperation, community engagement, and policy to meet the flooding challenges of now and the future. The general risks of each alternative plus a Without-Project condition based on these four categories are presented in Table 3.

Overall, it is expected that the Without-Project condition will yield an increased risk for resiliency and safety as designs will fail to adapt to changing conditions.

Table 3. Alternatives risk assessment. Higher risk indicates higher potential for problems, lower risk indicates low potential for problems.

ALTERNATIVE	OPERATIONS & MAINTENANCE	RESILIENCY	SAFETY	FUNDING
A – Revegetation	Medium	Low	Medium	Low
B – Floodplain Detention Basins	Medium	Low	Low	Low
C – LID Implementation	Medium	Medium	Medium	Medium
D – Creek Crossing Adjustments	Low	Medium	Medium	High
E – Underground Detention Basins	High	Medium	Low	Medium
F – Creekside Parks	Low	Low	Medium	Medium
G – Inspections and Maintenance	Low	Low	Low	Low
Without-Project	Medium	High	High	Medium

SUMMARY

- Flood risk mitigation alternatives focus on decreasing erosion and landslide risk, increasing detention of stormwater in the upper and middle watershed, and increasing capacity in the lower watershed
- Substantial flood risk reduction can be attained with proposed alternatives, but flood risk cannot be eliminated
- The available areas for alternative implementation differ from those proposed due to political, monetary, and physical factors that could be uncovered during a site-specific analysis
- Risk factors from implementing these alternatives are expected to be overall lower compared to the status quo

NEXT STEPS

Insights from this analysis can be used to strategize effective watershed-wide flood improvements in coordination with existing limitations throughout the City. Flooding throughout the City is due to a combination of factors, so a combination of solutions will be needed to address the issue. Prioritization of potential projects based on the alternatives will be incorporated into the greater Pulgas Creek Watershed Study. A cost-benefit analysis of the anticipated costs of alternatives versus the more hardscape-focused capital improvement projects presented by GHD in the City of San Carlos Storm Drain Master Plan (GHD, 2017). When funding opportunities arise, pilot projects should be pursued for the various alternatives to assess the construction viability, effectiveness, and compatibility with the City's goals and operations.

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, but were not considered as a part of this study. The model adjustments and location viability assessments were 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, minute changes in topography on a regional scale such as curbs, nor other geotechnical-related complicating factors such as landslides, earthquakes, bank failures, etc. Modeled results represent a snapshot of expected conditions and do not represent the full extent of real possibilities that could affect flooding behavior such as future construction, local ground disturbance, recent climate history, etc. Flooding behavior can be greatly impacted by policy decisions and local cooperation not studied by this memorandum.

REFERENCES

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ATTACHMENTS

Attachment A. Figures

Figure 1. Regional Location Map
Figure 2. Pulgas Creek Watershed Drainage System
Figure 3. Proposed Flood Mitigation Alternatives Locations

Attachment B. Revegetation Benefits and Palettes for San Carlos
Attachment C. Alternatives Hydraulic Model Adjustments

Attachment A.

Figures

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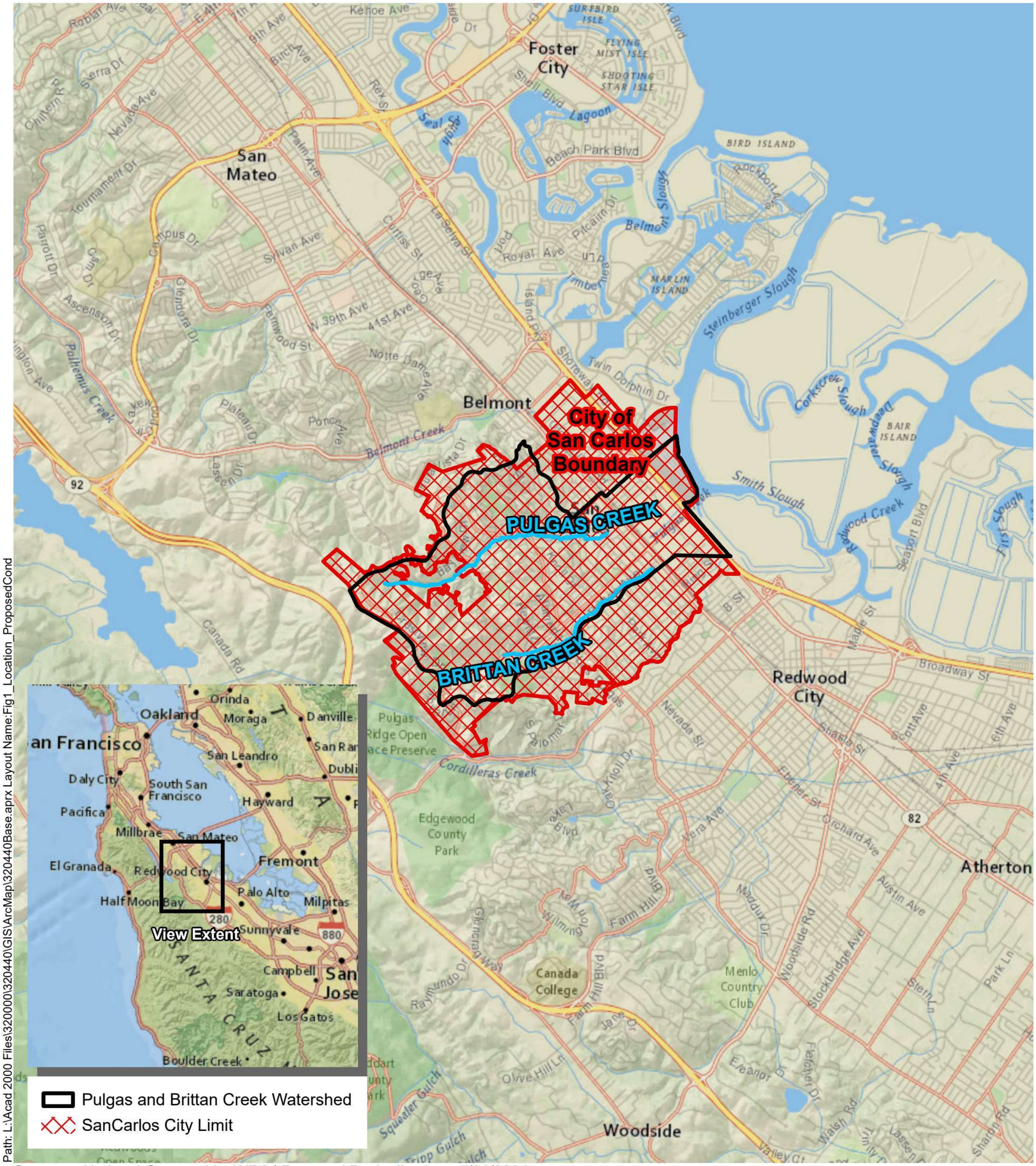

Sources: National Geographic, WRA | Prepared By: junjie.chen, 5/24/2024

Figure 1. Regional Location Map

Pulgas Watershed Study
Flood Mitigation Evaluation Memo
City of San Carlos, San Mateo, CA

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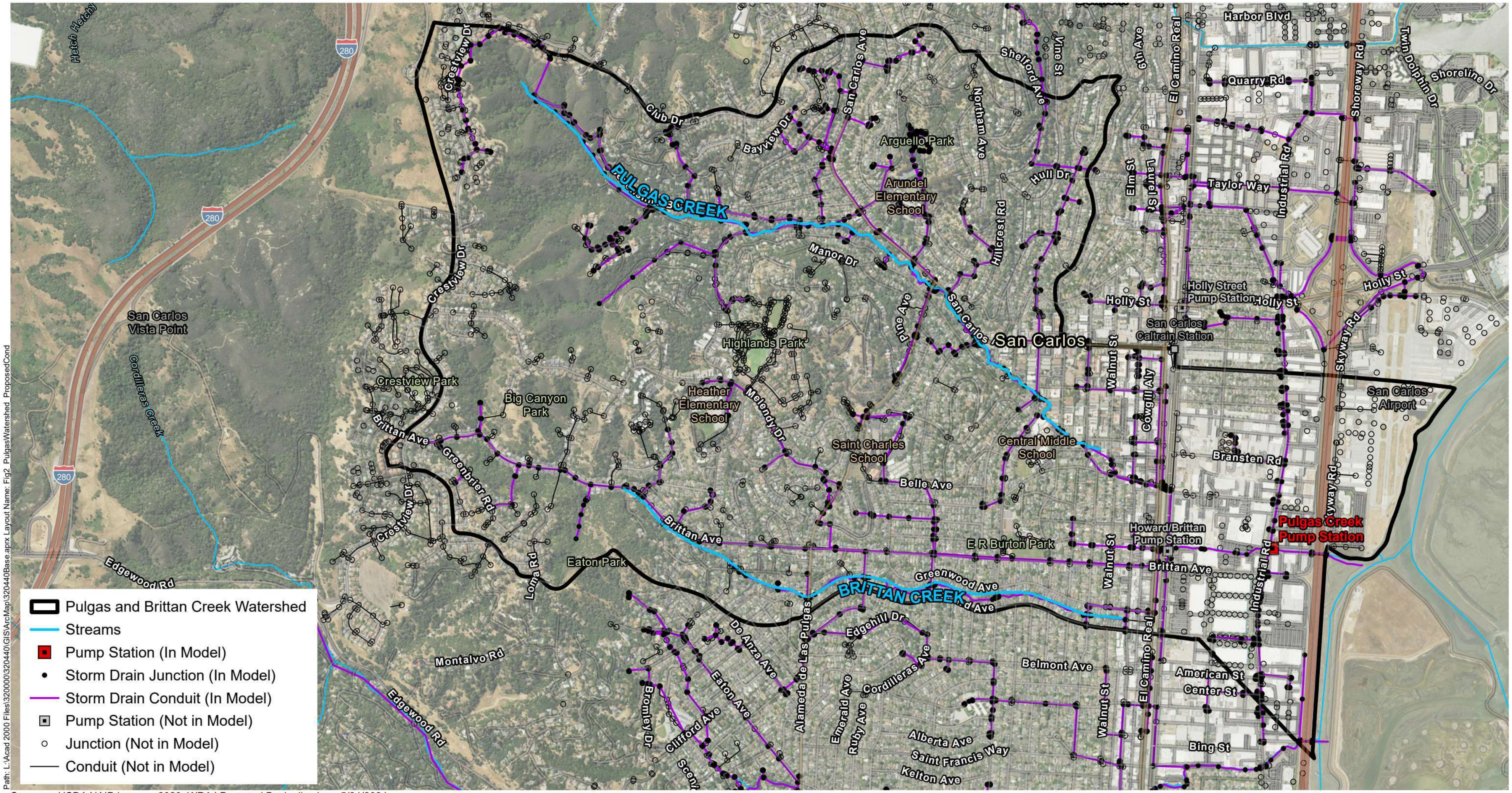

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Figure 2. Pulgas Watershed Drainage System

Pulgas Watershed Study
Flood Mitigation Evaluation Memo
City of San Carlos, San Mateo, CA

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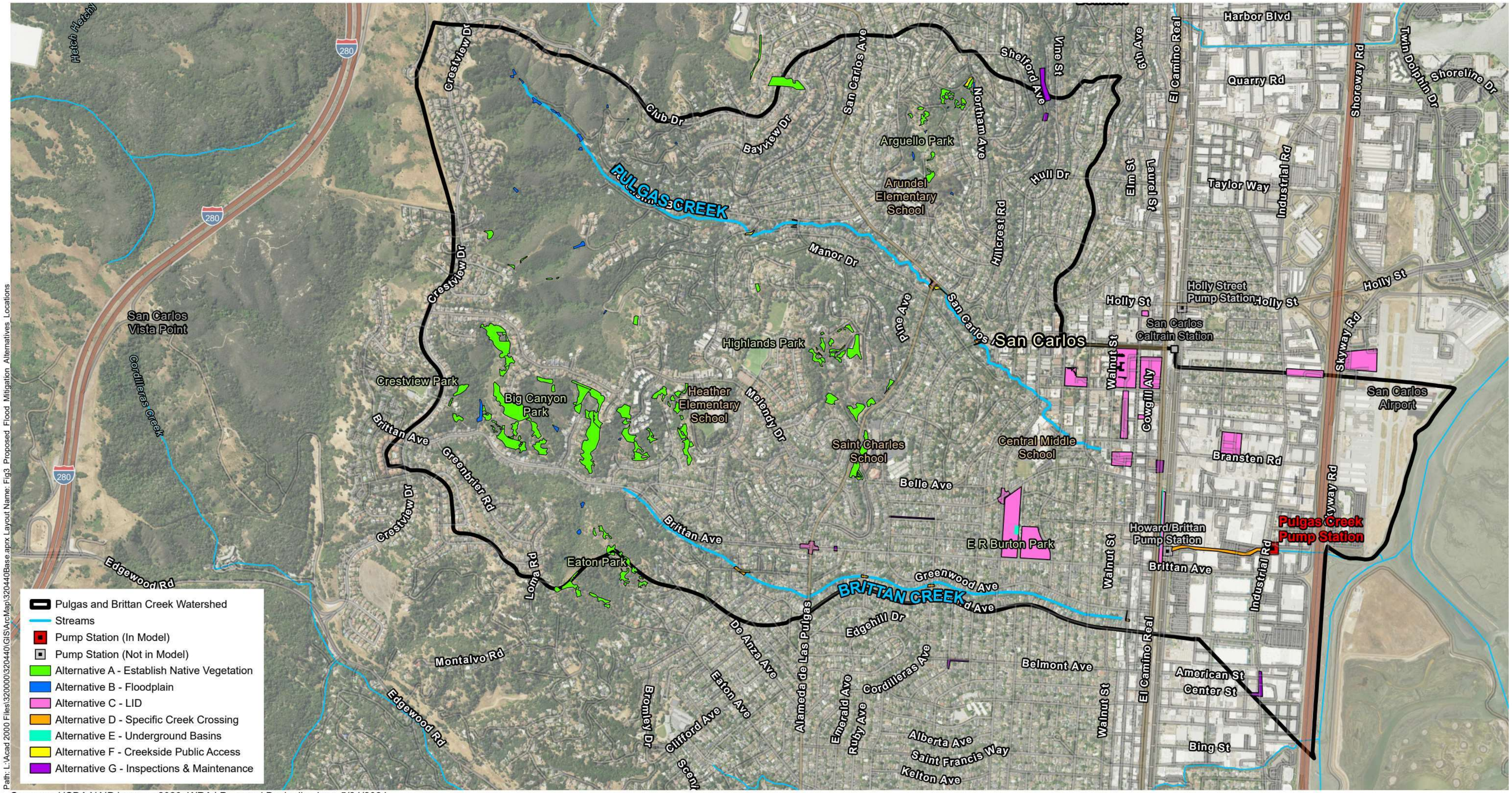

Sources: USDA NAIP Imagery 2020, WRA | Prepared By: junjie.chen, 5/24/2024

Figure 3. Proposed Flood Mitigation Alternatives Locations

Pulgas Watershed Study
Flood Mitigation Evaluation Memo
City of San Carlos, San Mateo, CA

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Attachment B.

Revegetation Benefits and Palettes for San Carlos

Attachment B.
Revegetation Benefits and Palettes for San Carlos

1.0 THE URBAN TREE CANOPY PROVIDES MULTIPLE BENEFITS

In recent decades, California communities have come to recognize the ecosystem services provided by the trees in local watersheds. Trees help reduce stormwater run-off, reduce urban temperatures, improve air quality, sequester carbon, enhance property values, provide wildlife habitat, and strengthen social connections in neighborhoods.

This report highlights a particular ecosystem service trees provide which contribute to watershed health—*trees reduce sediment transport and erosion by holding soils in place in the upper watershed.* Trees prevent soil erosion in several ways:

- Trees intercept rainfall which prevents splash erosion
- Trees reduce the amount of water in soil through transpiration
- Trees improve soil health and nurture seedlings
- Tree roots bind soil to sloping ground, preventing erosion and protecting topsoil
- Trees provide a wind break and prevent surface soil from blowing away

As the conservation nonprofit American Forests reminds us, "healthy forests are our most efficient, inexpensive, and natural systems to combat climate change." Both natural and urban forests play an essential role in reducing CO2, the main contributor to climate change. There are two direct ways that trees help (Canopy 2016):

Trees act as a CO2 sink:

- Trees sequester and store CO2, decreasing the concentration of CO2 in the atmosphere.
- Trees use CO2 during photosynthesis to produce sugars, which provide energy for trees as well as emitting oxygen as a by-product of the process.
- Planting more trees absorbs more CO2, reducing the overall concentration of CO2 in the atmosphere.
- An average-size tree can store hundreds of pounds of CO2 over its lifetime.

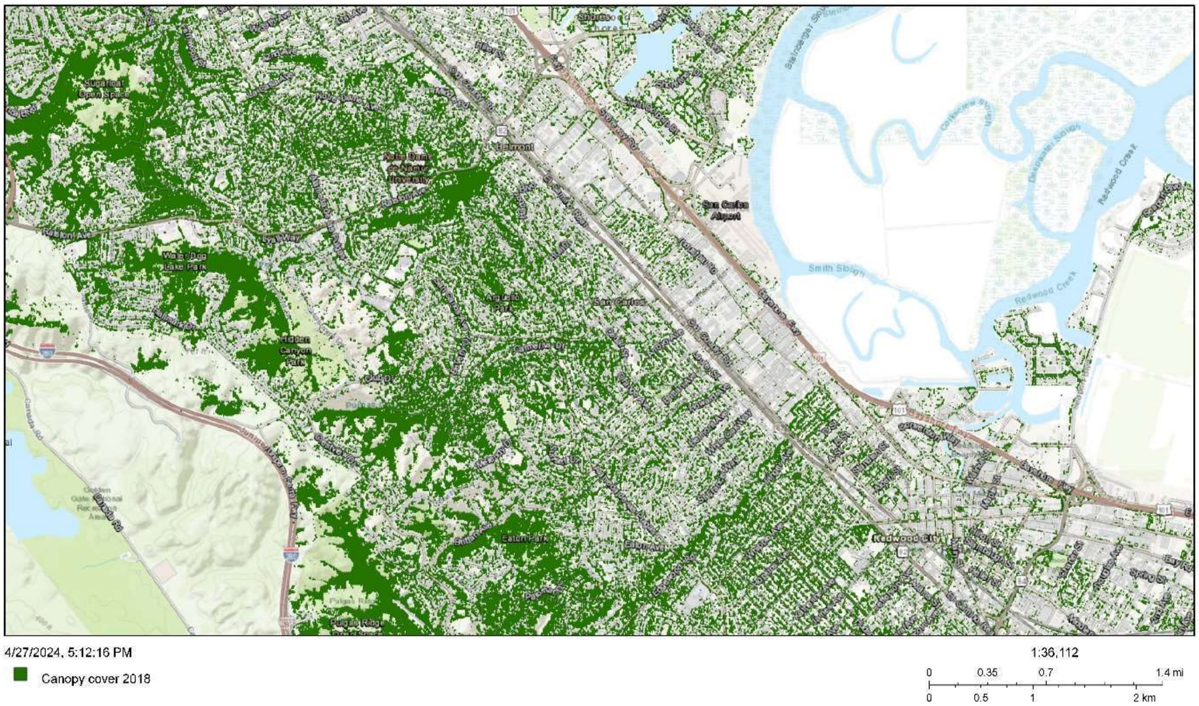
Trees reduce energy use:

- Neighborhoods well-shaded with street trees can be up to 6-10 degrees cooler than neighborhoods without, reducing overall energy needs.
- Three trees properly placed around a house can save up to 30% of energy use.

The ecosystem services trees provide also generate economic benefits. California's urban tree canopy covers 19% of the state's urban areas. It is estimated to contain 173 million trees; the annual value of ecosystem services from these trees has been estimated at $8.3 billion and the urban forest asset has been valued at $181 billion (McPherson et al. 2017).

According to the USFS and CAL FIRE, “understanding the extent and location of its existing tree canopy can help a community design and implement sound management practices to maximize those services: prioritizing locations for tree planting, establishing urban forestry master plans and sustainability plans, and managing threats to canopy loss.” The existing trees and tree canopy cover in the San Carlos are already mapped on the Urban Forest Ecosystems Institute (UFEI) California Urban Tree Map (CalPoly 2020) as well as the USFS and CAL FIRE Urban Tree Canopy in California (USFS & CAL FIRE 2018).

Urban Tree Canopy Map



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With a land area of about 16 km^2, zip code 94070 has 1,425 urban street trees according to the California Urban Forest Inventory, including 59 genera and 77 species. The pie chart below graphically indicates the distribution of tree species.

Analysis of the existing forest reveals that almost all of the trees are non-native, most lack drought resistance, and several are invasive species that increase fire risk. To maximize the ecosystem services that trees provide in the upper watershed, it is important to plant large, native trees and shrubs, uniquely adapted to local site conditions, to increase climate resilience. A healthy forest ecosystem is self-sustaining; with adaptive management it will require minimal maintenance, expense, and energy inputs from the city while providing multiple benefits.

2.0 PLANT PALETTES

WRA has assembled proposed plant palettes for the upper watershed to enhance and expand the tree canopy for a sustainable forest ecosystem that will help reduce sedimentation and erosion. Tables 1 and 2 include representative tree and shrub species, respectively, which are appropriate for planting on upland slopes of the upper watershed. The best practices defined by CAL FIRE for defensible space and other fire-smart landscape practices (CAL FIRE 2024) should be consistently employed.

2.1 Native Trees and Shrubs for Revegetation Areas

Table 1. Native Oak Woodland Community Trees for Upland Slopes

COMMON NAME	BOTANICAL NAME	CANOPY SPREAD (FEET)	DECIDUOUS / EVERGREEN	SUN	WATER USE
California Buckeye	*Aesculus californica*	40'	Deciduous	Pt Sh, F Sun	VL, L
Hollyleaf Cherry	*Prunus ilicifolia*	20'	Evergreen	F Sun, Pt Sh	VL
Coast Live Oak	*Quercus agrifolia*	15 - 35'	Evergreen	F Sun, Pt Sh	L
Blue Oak	*Quercus douglasii*	30'	Deciduous	F Sun, Pt Sh	L
Garry's Oak	*Quercus garryana*	30'	Deciduous	F Sun, Pt Sh	L
Valley Oak	*Quercus lobata*	50'	Deciduous	F Sun	L
Interior Live Oak	*Quercus wislizeni*	10 - 50'	Evergreen	F Sun, Pt Sh	VL,L

Table 2. Native Shrubs for Upland Slopes

COMMON NAME	BOTANICAL NAME	CANOPY	DECIDUOUS / EVERGREEN	SUN	WATER USE
Chamise	*Adenostoma fasciculatum*	1 - 8'	Evergreen	F Sun	EL, VL
California Sagebrush	*Artemisia californica*	4'	Summer Deciduous	F Sun	EL, VL
Coyote Bush	*Baccharis pilularis*	12'	Evergreen	F Sun, Pt Shade	VL, L
Ceanothus	*Ceanothus cuneatus*	5 - 12'	Evergreen	F Sun	VL
Blueblossom Ceanothus	Ceanothus thyrsiflorus	2 - 40'	Evergreen	Pt Shade	L
Bush Monkey Flower	*Diplacus aurantiacus*	5'	Evergreen	Pt Shade, F Sun	VL, L
Coffeeberry	*Frangula californica*	5 - 15'	Evergreen	F Sun, Pt Shade	L,VL

Table 2. Native Shrubs for Upland Slopes

COMMON NAME	BOTANICAL NAME	CANOPY	DECIDUOUS / EVERGREEN	SUN	WATER USE
Coast Silktassel	*Garrya elliptica*	6 - 10'	Evergreen	Pt Shade, F Sun	VL
Toyon	*Heteromeles arbutifolia*	10 - 15'	Evergreen	F Sun, Pt Shade	EL, VL
Silver Lupine	*Lupinus albifrons*	2 - 3'	Evergreen	F Sun	VL
Black Elderberry	*Sambucus nigra*	10 - 20'	Deciduous		L

2.2 Trees and Shrubs for Riparian Areas (Creekside Projects)

Riparian trees help control erosion and sedimentation, lower stream temperatures, conserve soil moisture, and improve water quality. Riparian plants are highly adapted to frequent disturbance seasonal flooding and have evolved to recover and grow rapidly as nature's way of healing itself. Representative riparian trees and shrubs appropriate for drainages within the watershed are included in Tables 3 and 4, respectively.

Table 3. Representative Native Trees for Riparian Areas

COMMON NAME	BOTANICAL NAME	CANOPY	DECIDUOUS / EVERGREEN	SUN	WATER USE
California Buckeye	*Aesculus californica*	40'	Deciduous	Pt Shade, F Sun	VL, L
Coast Live Oak	*Quercus agrifolia*	15 - 35'	Evergreen	F Sun, Pt Shade	L

Table 4. Representative Native Shrubs for Riparian Areas

COMMON NAME	BOTANICAL NAME	CANOPY	DECIDUOUS / EVERGREEN	SUN	WATER USE
Oregon Grape	*Berberis nervosa*	7'	Evergreen	Pt Shade	L
California Hazel	*Corylus cornuta* ssp. *californica*	10'	Deciduous	Pt Shade	L
Western Leatherwood	*Dirca occidentalis*	12'	Deciduous	Pt Shade	L
California Coffeeberry	*Frangula californica* ssp. *californica*	10 - 15'	Evergreen	F Sun, Pt Shade	L
Ocean Spray	*Holodiscus discolor*	10 - 15'	Deciduous	Shade, Pt Shade	L, M, H
Black Twinberry	*Lonicera involucrata*	3 - 4'	Deciduous	Pt Shade, F Sun	M, H
Pacific Ninebark	*Physocarpus capitatus*	8'	Deciduous	F/Pt Shade	M, H, L
Hillside Gooseberry	*Ribes californicum*	2 - 6'	Deciduous	Pt Shade	L
Canyon Gooseberry	*Ribes menziesii*		Deciduous	Shade	L
Red Flowering Currant	*Ribes sanguineum*	7'	Deciduous	Pt Shade	L

Table 4. Representative Native Shrubs for Riparian Areas

COMMON NAME	BOTANICAL NAME	CANOPY	DECIDUOUS / EVERGREEN	SUN	WATER USE
California Wildrose	*Rosa californica*	10'	Deciduous	F Sun, F/Pt Shade	L, M, H
California Blackberry	*Rubus ursinus*	6'	Deciduous	F Sun, F/Pt Shade	M, H
Blue Elderberry	*Sambucus mexicana*	20'	Deciduous	F/Pt Shade, F Sun	L
Common Snowberry	*Symphoricarpos albus*	6'	Deciduous	F/Pt Shade	L, M, H

2.3 Recommended Street Trees

Planting trees in the neighborhoods with inadequate tree canopy cover will also help to reduce urban heat, absorb stormwater, sequester carbon, and improve walkability. Both street trees and trees on private property provide environmental, economic, social and personal health benefits. The **Tree Equity Score map (Figure 2.2)** by American Forests illustrates the areas with the greatest need (the lowest tree canopy cover). The **heat map (Figure 2.3)** shows a corresponding disparity in urban temperatures due to this lack of tree canopy in the lower watershed. The tree canopy goal for the census blocks in San Carlos is 30% tree canopy coverage. Many residential neighborhoods already meet this goal, however some neighborhoods in the lower watershed only have 5% tree canopy cover today.

Table 5. The City of San Carlos Approved Street Tree List

COMMON NAME	BOTANICAL NAME	HEIGHT	CANOPY	DECIDUOUS / EVERGREEN	WATER USE
Chinese Pistache	*Pistacia chinensis*	40’	25-35’	Deciduous	L
Crape Myrtle	*Lagerstroemia indica*	25’	25’	Deciduous	L
Peppermint Tree	*Agonis flexuosa*	35’	15-30’	Evergreen	L

In addition, WRA recommends the following trees for sidewalk locations, based on input from professional arborists and tree planting organizations in the vicinity. Considerations include suitability to local climate conditions, soils, drought tolerance, longevity, available nursery stock, quality of nursery stock, and pest and disease resistance. The list also includes climate-ready species for warmer, drier urban conditions.

Selecting the right tree species and planting it in the right place is the first step toward expanding the tree canopy. To minimize maintenance and avoid infrastructure damage and utility conflicts above and below ground, select tree species based on available planting space, and only plant small trees below power lines. UFEI’s SelecTree (2024) Tree Selection Guide provides preselected lists of trees OK for under power lines, shade trees, drought tolerant trees, native tree species, and trees with low water requirements.

Small Trees

- *Callistemon viminalis* / Weeping Bottlebrush
- *x Chitalpa tashkentensis* ‘Pink Dawn’ / Pink Dawn Chitalpa

- Magnolia grandiflora 'Little Gem' / Dwarf Southern Magnolia
- *Prunus cerasifera* 'Krauter Vesuvius' / Krauter Vesuvius Plum

Medium Trees

- *Arbutus unedo* 'Marina' / Marina Strawberry Tree
- *Crataegus phaenopyrum* / Washington Hawthorn
- *Pistacia chinensis* 'Keith Davey' / Chinese Pistache

Large Trees

- *Fraxinus angustifolia* (syn. Oxycarpa) 'Raywood' / Raywood Ash
- *Ginkgo biloba* 'Autumn Gold' / Ginkgo
- *Platanus x hispanica* (syn. P x acerifolia) 'Bloodgood' 'Columbia' 'Yarwood' / Sycamore*
- *Quercus agrifolia* / Coast Live Oak
- *Quercus suber* / Cork Oak
- *Ulmus parvifolia* 'Frontier' or 'Drake' or 'Pioneer' / Chinese Elm

2.4 Native Tree Species for private property, parks, and gardens

The following are tree and arborescent shrub species that are appropriate for private property, public parks, schoolyards, and gardens. Local native trees and shrubs are optimum for providing wildlife habitat throughout the city.

- *Aesculus californica* / California Buckeye
- *Prunus ilicifolia* subsp. *lyonii* / Catalina Cherry
- *Quercus agrifolia* / Coast Live Oak
- *Umbellularia californica* / California Bay Laurel

2.5 Tree Planting Organizations and Local Resources

Local tree planting organizations are excellent resources for guidance on tree stewardship, planning and planting a sustainable urban forest including street trees, parks, schools and open space trees.

- **Canopy** is a nonprofit tree planting organization in Mountain View https://canopy.org/
- San Francisco **Friends of the Urban Forest** plants and cares for street trees in San Francisco https://www.friendsoftheurbanforest.org/
- **California ReLeaf** supports grassroots efforts and build strategic partnerships that protect, enhance, and grow California's urban and community forests https://californiareleaf.org/
- **California Urban Forests Council** https://caufc.org/
- Funding and other resources are available from the **USDA Forest Service Urban and Community Forestry Program** https://www.fs.usda.gov/managing-land/urban-forests
- **The Vibrant Cities Lab** and **USDA Forest Service** partnered to create the Urban Forestry Toolkit, which provides a step-by-step guide to planning and implementing an urban forestry project. https://www.vibrantcitieslab.com/toolkit/
- **Urban Forest Management Plan Toolkit** website provides a "how-to" approach to develop an Urban Forest Management Plan (UFMP). The toolkit will lead you through a planning process. https://ufmptoolkit.net/

3.0 GREEN STORMWATER INFRASTRUCTURE AND LID FEATURES

3.1 Plants Suitable for Bioretention Areas

Swales are shallow channels designed to catch rainwater and reduce or prevent its flow off the site. Swales planted with appropriate vegetation are known as bioswales. They promote infiltration of rainwater into the soil and help filter and breakdown pollutants in the stormwater runoff. Bioswales can also add beauty and value to the landscape. This plant list features mostly California native species that are suitable for many vegetated swales. Non-native species are marked with an asterisk (*).

The plants on this list are from the San Mateo County (SMCWPPP) *Plant List for Landscape-based Biotreatment Measures* available at FlowsToBay.org (https://www.flowstobay.org/wp-content/uploads/legacy_media/plant-list-all.pdf). For a more extensive list of plants appropriate for stormwater treatment features, see Appendix B of the Alameda County Clean Water Program's publication, "C.3 Stormwater Technical Guidance: A Handbook for Developers, Builders and Project Applicants," May 14, 2013, which can be downloaded from www.cleanwaterprogram.org/resources/resources-development.html.

Table 6. Plant List for Landscape-based Biotreatment Measures

COMMON NAME	BOTANICAL NAME	HEIGHT	SPREAD	SUN / SOIL	WATER USE
Emergent Plants (can grow in water with part of the plant above the surface)					
Santa Barbara sedge	*Carex barbarae*	1-3'	1-3'	Full sun or part shade	M/VL
Slough sedge	*Carex obnupta*	1-3'	1-3'	Full sun or part shade	M
Pacific rush	*Juncus effusus*	1-2'	1-2'	Sun to part shade	H
Blue rush	*Juncus patens*	1-2'	1-2'	Sun to part shade	H/Drought Tolerant
Plants that Tolerate Periodic Inundation					
Big leaf maple	*Acer macrophyllum*	30-100'	30-100'	Sun to part shade	Occasional-Regular
Box elder	*Acer negundo californicum*	30-50'	30-50'	Full sun or part shade	M
Buckeye	*Aesculus californica*	15-20'	30'	Full sun	Very Low
Red alder	*Alnus rubra*	45-50'	20-30'	Sun or shade	Regular/Ample
Mountain mahogany	*Cercocarpus betuloides*	5-12'	5-12'	Full sun/Tolerates clay and serpentine	Very Low
Berkeley sedge	*Carex divulsa (tumulicola)*	1-2'	1-2'	Part sun to part shade	M-Occasional
California meadow sedge	*Carex pansa*	1'	1'	Sun to shade	M/Drought Tolerant
Rusty sedge	*Carex subfusca*	1-1.5'	1-1.5'	Sun to shade	M/Drought Tolerant
Western dogwood	*Cornus sericea*	15'	15'	Sun to shade	Occasional-Regular
Redosier dogwood	*Cornus stolonifera*	7-9'	12'	Full sun or light shade	Regular

Table 6. Plant List for Landscape-based Biotreatment Measures

COMMON NAME	BOTANICAL NAME	HEIGHT	SPREAD	SUN / SOIL	WATER USE
Cape rush	*Chondropetalum tectorum**	4-6'	4-6'	Sun to part sun	M-Occasional
Crocosmia	*Crocosmia* 'Lucifer'*	4'	2'	Sun, some shade when hot	Regular
Tufted hairgrass	*Deschampsia cespitosa*	1-2'	2'	Part shade	Low
Fortnight lily	*Dietes bicolor, D. iridioides**	3'	3'	Sun or part shade	Occasional-None
Blue wild rye	*Elymus glaucus*	1-2'	2'	Full to part sun	Low
Horsetail	*Equisetum hyemale*	4'	2'	Full sun or partial shade	H
California fescue	*Festuca californica*	1-2'	2-3'	Sun to part shade	Low
Idaho fescue	*Festuca idahoensis*	1-2'	1-2'	Full sun to part sun	Very Low
Red fescue	*Festuca rubra*	3-12"	1'	Full sun to part sun	Low
Molate fescue	*Festuca rubra* 'molate'	3-12"	1'	Full sun to part sun	Low
Creeping wild rye	*Leymus triticoides*	1-3'	1-2'	Full sun to part sun	Occasional
Deerweed	*Lotus scoparius*	3'	3'	Full sun to part shade	Very Low
Deergrass	*Muhlenbergia rigens*	3'	3'	Full sun to part shade	Low
Wax myrtle	*Myrica californica*	10-30'	10-30'	Sun or part shade	Low
Foothill needlegrass	*Nassella lepida*	1'	1'	Full sun/Good drainage	Very Low
Purple needlegrass	*Nasella pulchra*	1-2'	1-2'	Full sun/Good drainage	Very Low
Pacific ninebark	*Physocarpus capitatus*	8'	8'	Sun or shade	M-Regular
Western sycamore	*Platanus racemosa*	30-80'	20-50'	Full sun	M
Fremont cottonwood	*Populus fremontii*	50-70'	50'	Sun/Moisture-retentive	Occasional-Regular
Valley oak	*Quercus lobata*	100'	100'	Sun/Adaptable	Low
California wild rose	*Rosa californica*	3'	6'	Part shade	Low
Arroyo willow	*Salix lasiolepis*	6-9'	9-12'	Sun	H
Red willow	*Salix laevigata*	9-30'	9-30'	Sun	H
Elderberry	*Sambucus mexicana*	8-25'	8-25'	Sun to partial shade	Low
Blue-eyed grass	*Sisyrinchium bellum*	6-12"	6-18"	Full sun to light shade	Very Low
Tall fescue	*Stipa arundinacea**	2'	2'	Full sun	M-Occasional
Upland Plants (for the swale's upland zone/top of slope)					
Common yarrow	*Achillea millefolium*	12-30"	2-4'	Full sun/Reasonable drainage	Low
Chamise	*Adenostema fasciculatum*	6-15'	6-15'	Sun/Adaptable except alkaline	Drought Tolerant
Manzanita	*Arctostaphylos* spp.	Varies	Varies	Full sun to part shade	Low

Table 6. Plant List for Landscape-based Biotreatment Measures

COMMON NAME	BOTANICAL NAME	HEIGHT	SPREAD	SUN / SOIL	WATER USE
Sea pink	*Armeria maritima*	4-8"	6-12"	Full sun/Good drainage	Little-Occasional
Prostrate Coyote brush	*Baccharis pilularis* 'Twin Peaks'	1'	10-15'	Full sun	Low
Mulefat	*Baccharis salicifolia*	8'	8'	Full sun	Low
Ceanothus	*Ceanothus* spp.	Varies	Varies	Full sun to part shade	Low
California fuchsia	*Epilobium canum*	1'	4'	Full sun to part shade/Good drainage	Low
Flattop buckwheat	*Eriogonum fasciculatum*	2-3'	4'	Full sun/Good drainage	Low
California poppy	*Eschscholzia californica*	6-12"	6"	Full sun/Good drainage	Very Low
Beach strawberry	*Fragaria chiloensis*	10"	Spreading	Sun to part shade/Well drained	Infrequent to Occasional
Toyon	*Heteromeles arbutifolia**	10-20'	10-15'	Full sun to part shade/Good drainage	VL
Tree mallow	*Lavatera* spp.	Varies	Varies	Full sun/Good drainage	Low
Pitcher sage	*Lepechina calycina*	3-5'	1-2'	Full sun with pm shade/Good drainage	VL
Bush lupine	*Lupinus albifrons**	3-5'	3-5'	Full sun/Excellent drainage	VL
Common monkeyflower	*Mimulus aurantiacus*	3-4'	3-4'	Full sun to part shade	Low
Scarlet monkeyflower	*Mimulus cardinalis*	2-3'	2-3'	Full sun to part shade/Adaptable	Low
Coast silk tassle	*Garrya elliptica*	10-20'	10-20'	Afternoon shade inland	Low
Coffeeberry	*Rhamnus californica*	3-15'	6-8'	Sun or part shade/Good drainage	Low
Chaparral currant	*Ribes malvaceum*	5'	5'	Sun to part shade	Very Low
Goldenrod	*Solidago californica*	1-4'	1-2'	Part shade	VL
Snowberry	*Symphoricarpos albus*	3-5'	3-5'	Part shade	Occasional-Little

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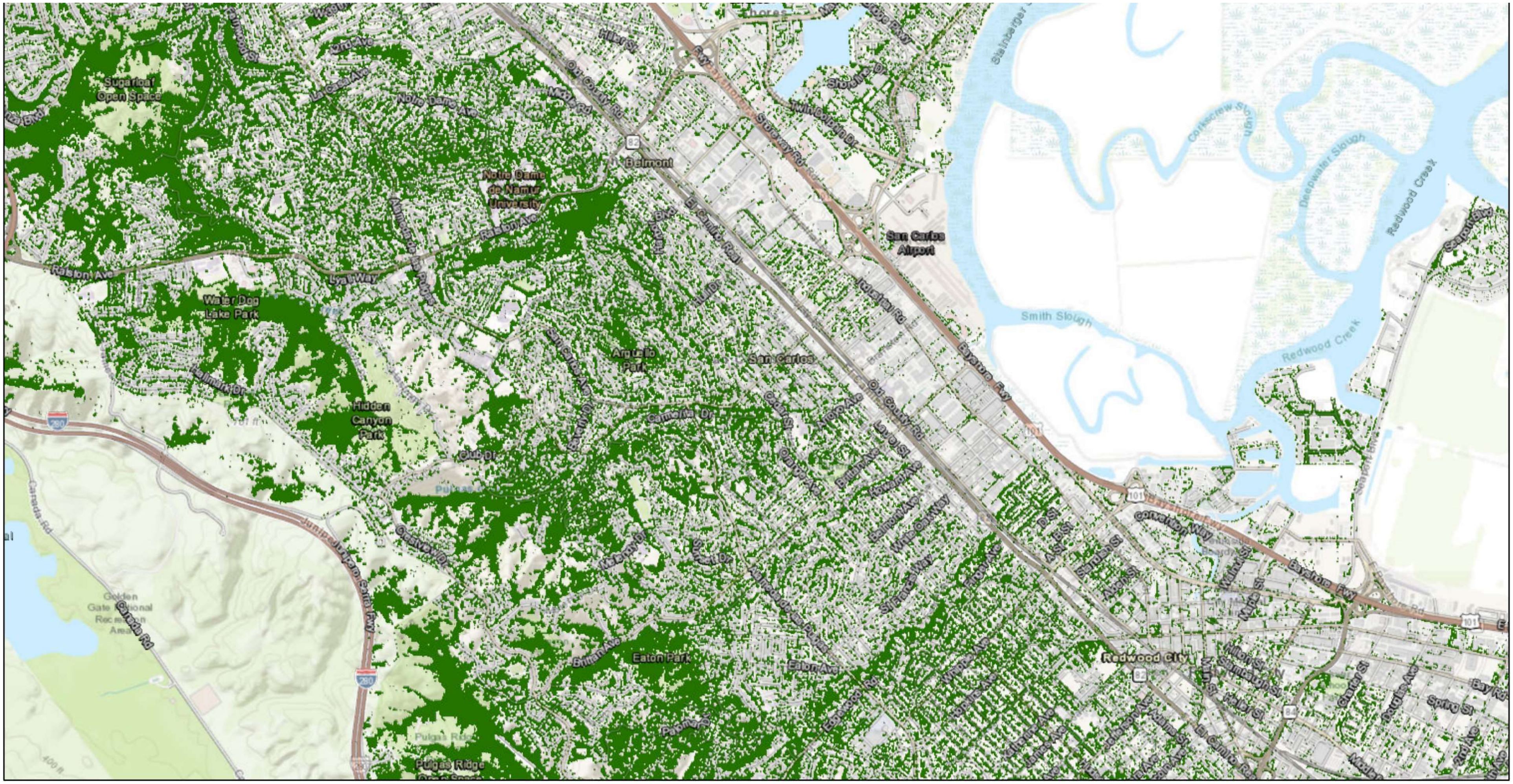
UFEI 2024	Urban Forest Ecosystems Institute (UFEI). 2024. A tree selection guide. SelecTree. Accessible online at: https://selectree.calpoly.edu/. Most recently accessed: May 2024.



4/27/2024, 5:12:16 PM

Canopy cover 2018

1:36,112

0 0.35 0.7 1.4 mi

0 0.5 1 2 km

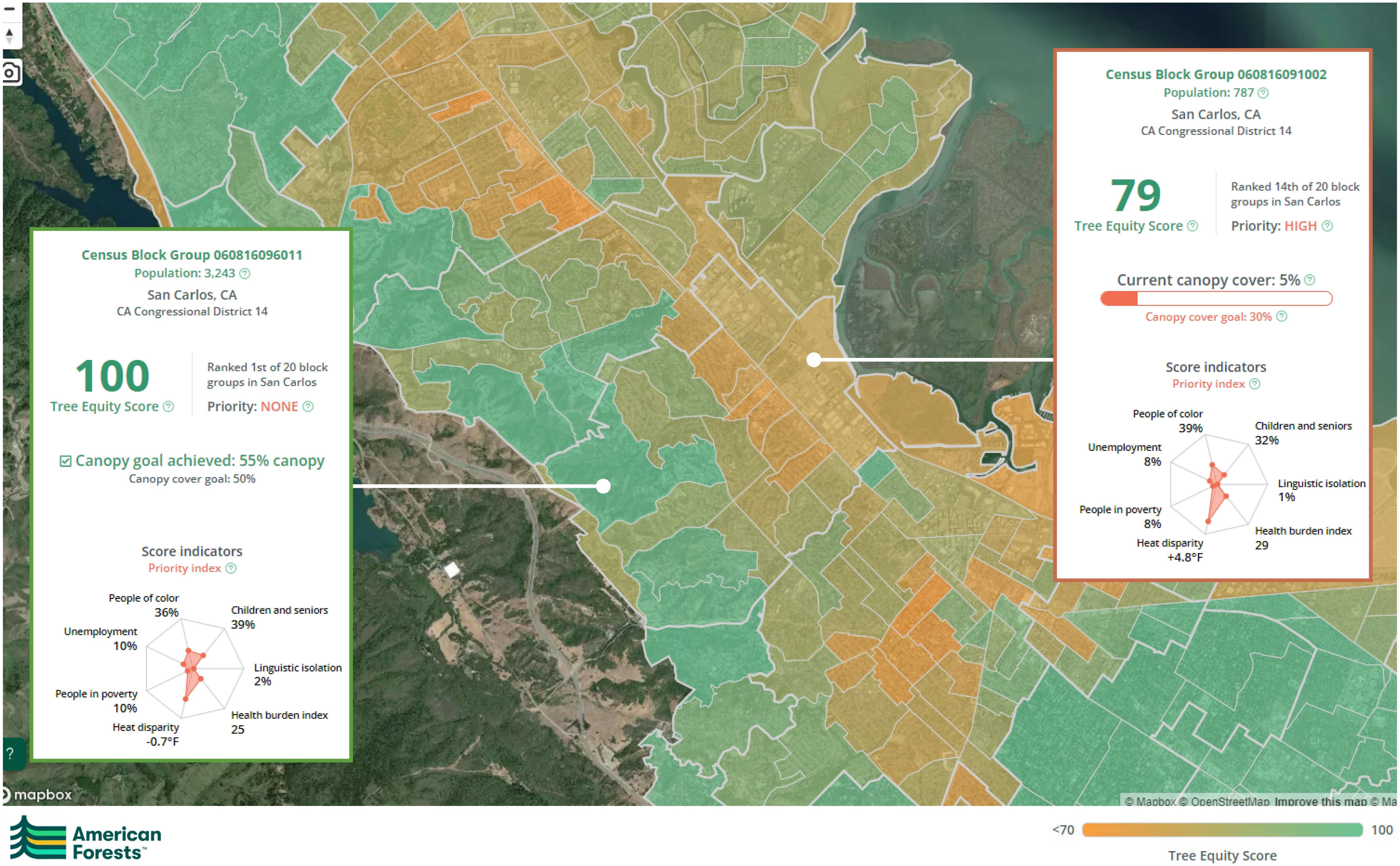
Redwood City, County of San Mateo, California, Bureau of Land Management, Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, EPA, USDA, Esri, HERE, Garmin, © OpenStreetMap contributors, and the GIS user community, EarthDefine, USDA Forest Service,

Figure 2.1 Urban Tree Canopy Map

wra Environmental Consultants

Pulgas Watershed Study
San Carlos, California

Date: 05/01/2024



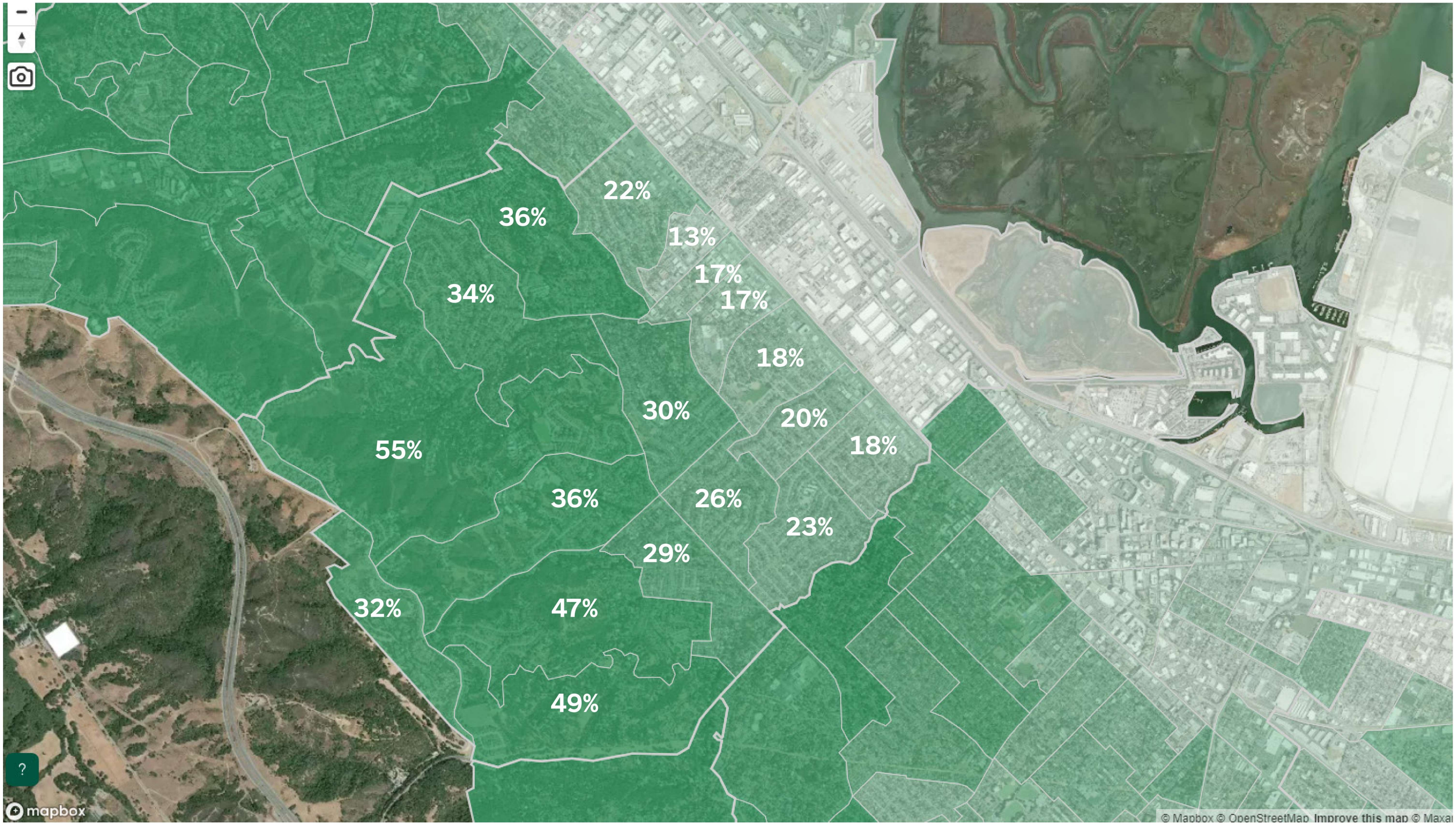
American Forests

Figure 2.2 American Forests Tree Equity Score Map

wra Environmental Consultants

Pulgas Watershed Study
San Carlos, California

Date: 05/01/2024



American Forests

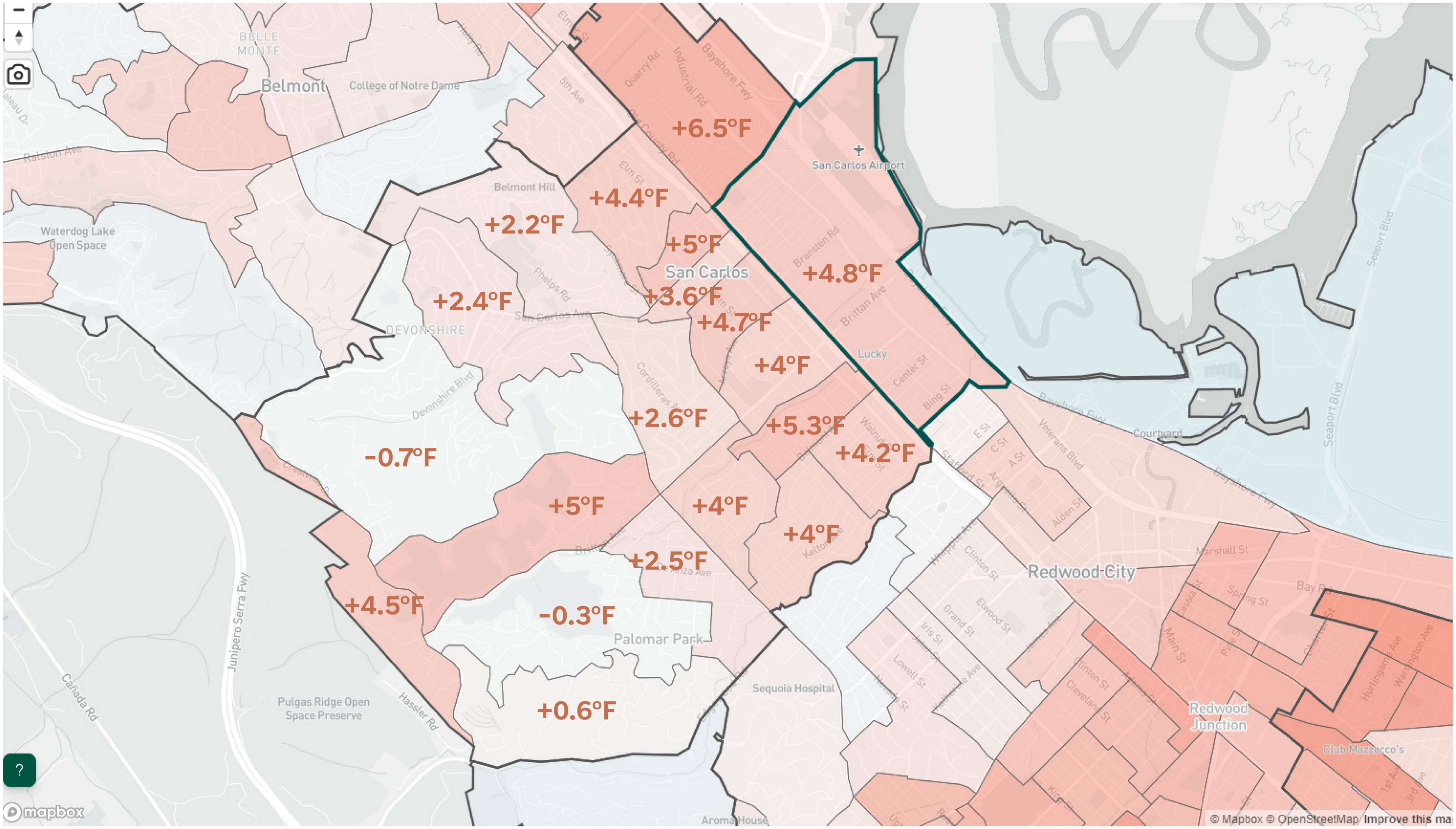
0% 50%
Tree canopy cover

Figure 2.3 Tree Canopy Cover

wra Environmental Consultants

Pulgas Watershed Study
San Carlos, California

Date: 05/01/2024



American Forests

-5°F +25°F
Heat disparity

Figure 2.4 Urban Temperatures

Pulgas Watershed Study
San Carlos, California

wra Environmental Consultants

Date: 05/01/2024

Attachment C.

Alternatives Hydraulic Model Adjustments

Attachment C.
Alternatives Hydraulic Model Adjustments

1.0 ALTERNATIVES HYDRAULIC MODEL

To assess potential flood reduction benefits, modifications were made to the existing conditions PC SWMM model discussed in the H&H Memo. The proposed conditions model for the 10, 25, and 100-year scenarios were re-run following incorporation of Alternatives A-E, with F and G not expected to yield quantifiable flood reduction impacts. Modifications made to subbasins, nodes, or junctions for each alternative is described below:

1.1 Alternative A: Revegetation

- Lowering of subbasin CN values by 2-12 points where revegetation is proposed

1.2 Alternative B: Floodplain Detention Basins

- Terrain modifications to incorporate a terraced floodplain, widened flow path, and outlet berm to prevent overflow flooding
- Adjustment of node connections at the outlet to incorporate a low flow and high flow outlet pipe to the existing downstream storm drain system
- Adjustment of conduit geometry to account for increase in storage volume

1.3 Alternative C: LID Implementation

- Addition of infiltration trench or bioretention cell LID parameters based on C3 guidance in PC SWMM to existing subbasin (San Mateo Countywide Water Pollution Prevention Program, 2023)

1.4 Alternative D: Creek Crossing Adjustments

- Terrain and roughness modifications to widen flow conduits of Pulgas Creek and Brittan Creek incorporating floodplain geometry to a conduit

1.5 Alternative E: Underground Detention Basins

- Modification of flow routing to the two proposed storage cells and connection back to the main flow path through pumping