**FINAL**

# SAUSAL CREEK WATERSHED ENHANCEMENT PLAN

# SUMMARY

Sausal Creek "Restoration Reach" in 2003

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For

Friends of Sausal Creek

March 2010

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# SAUSAL CREEK WATERSHED ENHANCEMENT PLAN
## Summary

In the middle of urban Oakland lies a series of parks which shelter Sausal Creek and create a green ribbon through the city. Unlike so many urban streams now flowing lifeless through pipes hidden beneath city streets, Sausal Creek has a natural channel over much of its length. Hikers can follow Sausal Creek and its tributaries from the top of the watershed on Skyline Boulevard down through Palo Seco and Dimond Canyons and past Interstate 580 before the natural creek channel is resigned to a culvert in the Oakland flatlands. Although the effects of its cemented urban drainage are everywhere, Sausal Creek is alive and inspiring. Native trees line the creek in many places and there is a small number of rainbow trout residing in its waters. These remnants of the natural world, gone from most of Oakland, make Sausal Creek a good candidate for enhancement actions, as well as community involvement and education.

The Friends of Sausal Creek (FOSC) formed in 1996 to focus community activities to learn about, protect, and enhance the creek and its watershed. FOSC has completed projects using volunteers to remove invasive non-native plants, install native plants, monitor water quality, control erosion, and complete a major creek habitat enhancement project. The Friends recognize that citizen participation is critical for building a long-term commitment to protecting Sausal Creek as a natural resource for the greater Oakland community. FOSC operates a native plant nursery at Joaquin Miller Park. FOSC worked with Laurel Marcus & Associates (LMA), a consulting firm specializing in watershed planning, to raise grant funds to complete a plan for the Sausal Creek watershed. Funding for this plan was provided by the State Water Resources Control Board and the San Francisco Foundation.

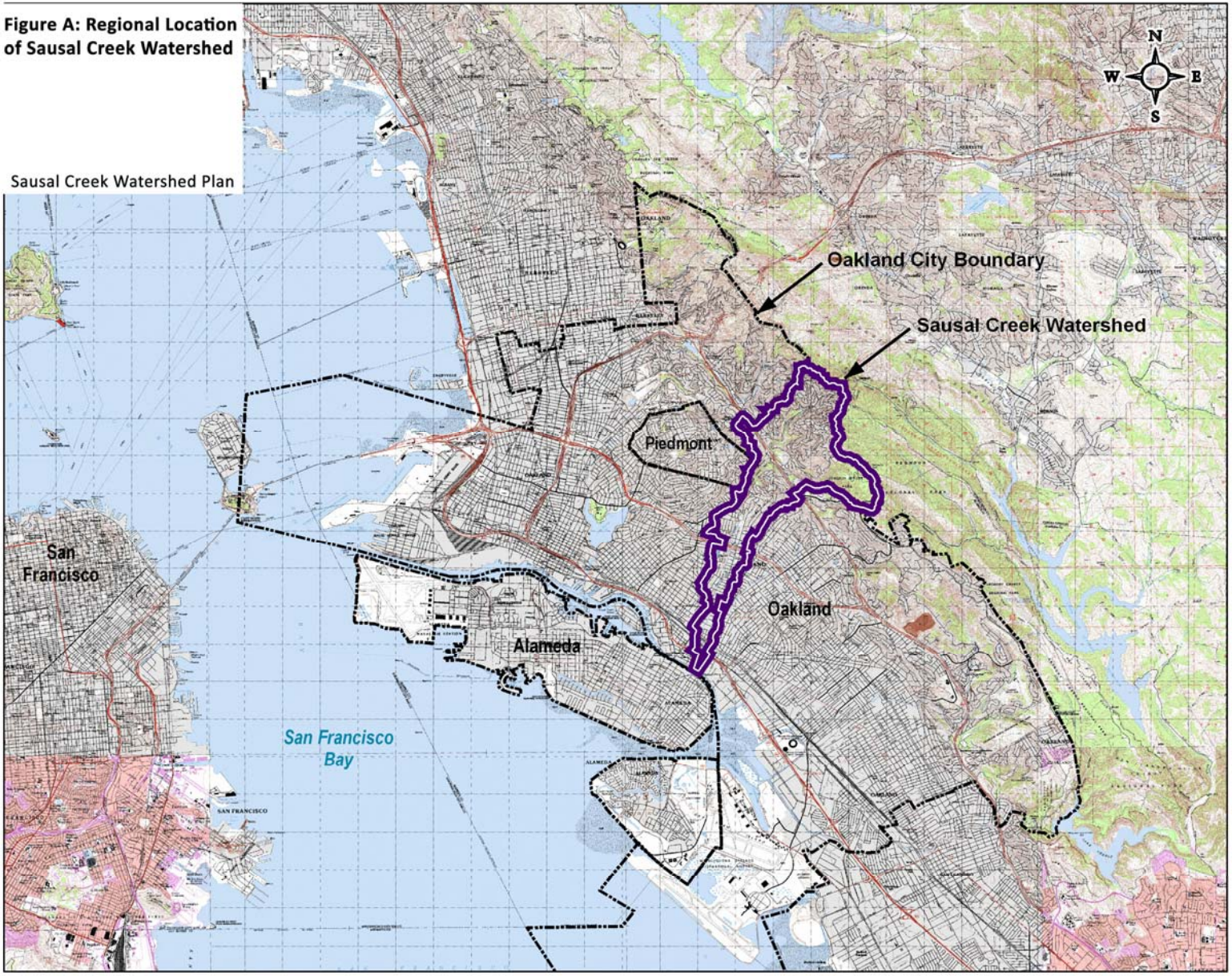
The Sausal Creek watershed covers 4.5 square miles (2,777 acres) in Oakland (Figure A). Most of the watershed has been developed for residential and commercial land uses. This development has changed the volume and rate of stormwater runoff. Impervious surface associated with development is the primary culprit, resulting in faster runoff and lower infiltration rates. The runoff is also collected in the pipes of a storm drain system and discharged into creeks. This urbanization process results in peak flood flows well in excess of the natural conditions that formed the creek. These effects of urbanization are further exacerbated by the steep slopes of the upper Sausal Creek watershed.

This plan characterizes the hydrology of the Sausal Creek watershed in order to document a baseline of flow, sediment loading, and channel conditions. From this baseline the impacted hydrological and ecological conditions of the channels, and the watershed processes that resulted in that degraded condition, can be identified. In highly urban watersheds, many factors that adversely impact the creek are intrinsic parts of the developed landscape. Successful restoration or revegetation of urban creeks depends upon evaluation of the larger watershed and implementation of projects that will most offset the effects of urbanization. This plan describes projects to address the conditions that are adversely impacting Sausal Creek and its tributaries, and their aquatic habitats and water quality. Enacting a long-term plan to repair and improve the watershed will sustain Sausal Creek for future generations.

This plan for the Sausal Creek watershed will:

- Document the hydrology of the Sausal Creek watershed and identify watershed-based projects that, to the greatest extent feasible, mitigate the effects of urban runoff on Sausal Creek, its habitats and water quality;

**Figure A: Regional Location of Sausal Creek Watershed**



- Collect and analyze existing water quality and aquatic insect monitoring data
- Document erosion problems in the urban storm drain system and recommend improvements to reduce this erosion;
- Discuss the location and extent of non-native invasive plants on parklands and evaluate measures to eradicate these plants and revegetate with appropriate native plant species;
- Identify locations where riparian habitat enhancement can be implemented;

The Sausal Creek watershed extends from the Oakland Hills to the San Francisco Bay. Three tributary creeks make up the upper watershed—Shephard Creek, Cobbledick, and Palo Seco Creeks (Figure B).

## HUMAN HISTORY

Prior to European arrival the Huichin Ohlone, a group of Native Americans, lived at very low densities in the East Bay including the Sausal Creek watershed and managed the landscape using fire, selective gathering of food plants, and hunting. In 1775-1776, the Spanish Anza expedition explored the Bay area and soon thereafter established missions in the area. The Spanish restricted the burning practices of the Ohlone and brought non-native European annual grasses to California. Americans were active in the watershed beginning in the 1840s when the San Antonio redwoods were logged. With statehood in 1850, American settlement of the East Bay expanded. Urbanization of the Sausal Creek watershed began in the flatlands and extended into the hills during the 1930s and 1940s. Sausal Creek watershed has been significantly altered with culverts, storm drain systems, and impervious surfaces in its drainage.

## NATURAL RESOURCES

### *Geology and Soils*

Sausal Creek is located along the eastern periphery of the San Francisco Bay. The steep hills on both sides of the bay were formed primarily through tectonic processes. The San Andreas Fault zone on the San Francisco side of the bay is one of a series of faults which dissect the Bay Area. The faults are areas of earth movement along the continental plates.

Sausal Creek watershed reflects this regional geology with very steep hills in its upper watershed. These hills are made up of a variety of rock types. The Hayward Fault is a major geological feature which created the valley where Highway 13 is located. Downstream of the Hayward Fault on the flatter lands, Sausal Creek spreads out depositing material eroded from the highly sheared rock in the fault zone and the steep upper drainage.

The soil types of the upper watershed have a high to very high erosion rating. Urbanization of these areas has created erosion problems by producing higher volumes of stormwater running off roofs, roads, and paved areas into steep ephemeral creek channels and onto highly erodible slopes. Ephemeral creeks only carry water immediately after a rainstorm. These steep channels, if not covered in dense vegetation or rock, will erode when urban development increases runoff volumes.

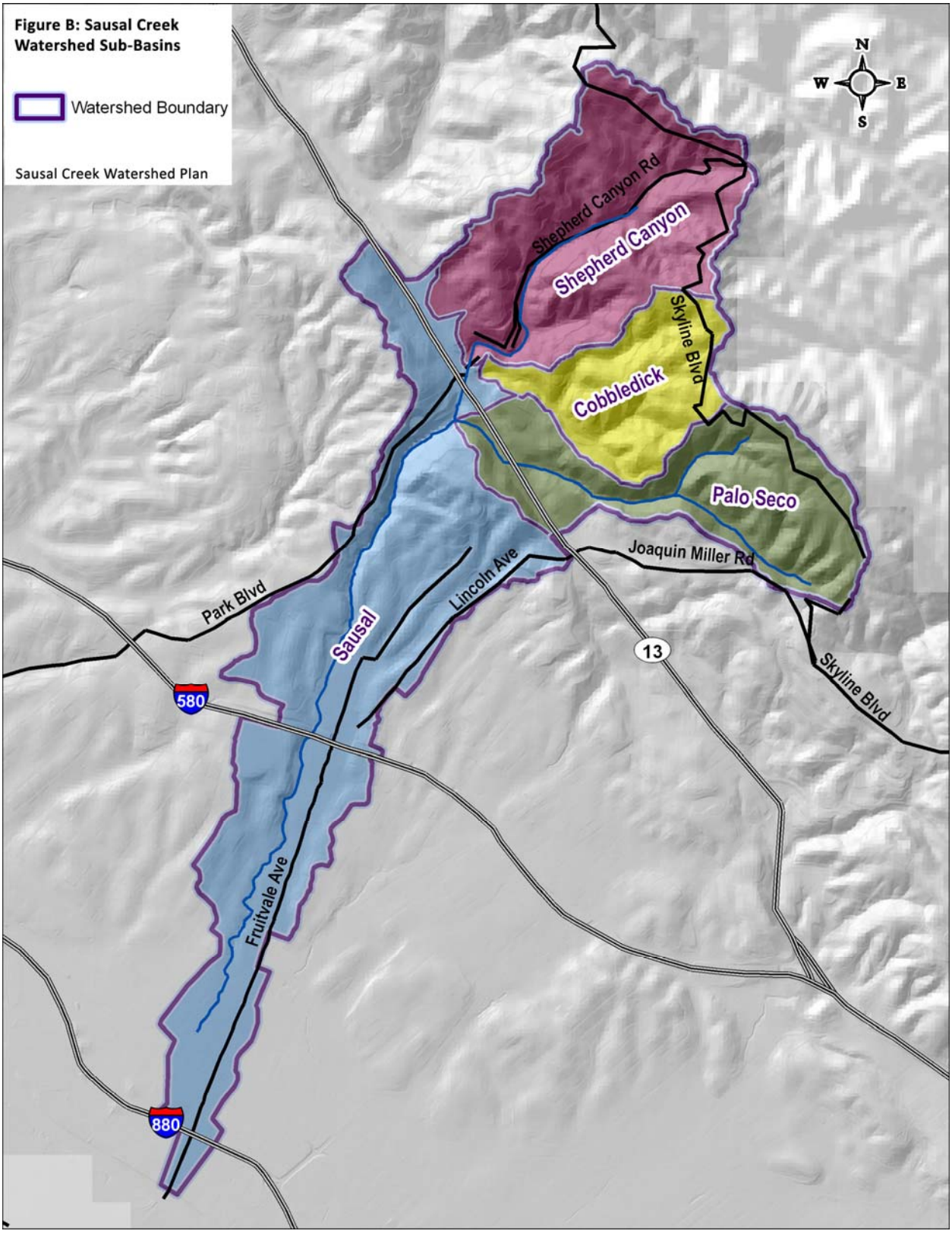


Figure B: Sausal Creek Watershed Sub-Basins
Watershed Boundary
Sausal Creek Watershed Plan
N
W
E
S
Shepherd Canyon Rd
Shepherd Canyon
Skyline Blvd
Cobbledick
Palo Seco
Joaquin Miller Rd
Lincoln Ave
Park Blvd
Sausal
13
Skyline Blvd
580
Fruitvale Ave
880

***Hydrology***

A hydrologic analysis was completed in order to develop a watershed model that would simulate the rainfall-runoff processes for 1-year through 100-year frequency storm events over the watershed. The model was developed at a level of detail that would allow for the evaluation of measures designed to reduce the peak discharge to Sausal Creek and its tributaries. A series of 33 hydrologic sub-basins were delineated for use in the model (Figure C). Six precipitation gages in the area were evaluated. The Environmental Protection Agency's Storm Water Management Model (SWMM) computer model was used which allows for the analysis of stormwater runoff from multiple linked basins with various runoff characteristics.

The Sausal Creek SWMM existing conditions model was run using dynamic wave analysis and time steps of 1 second or less for the 1 –year, 2-year, 5-year, 10-year, 25-year, and 100-year storm events. Existing conditions output for the Sausal Creek hydrology model was calibrated to streamflow measurements during significant storm events on October 19, 2009 and November 20, 2009. The SWMM existing conditions model was run with rainfall data of the Sausal Creek watershed from two Oakland gages for the same period as the two storms.

A hydraulic model was developed using surveyed cross-sections of Sausal and Palo Seco Creeks and the Hydrologic Engineering Center River Analysis System, commonly referred to as HEC-RAS. The hydraulic model was calibrated with measurements of high water marks and flow velocities at a known discharge. These calibration measurements were collected during significant storm event on October 19, 2009.

Channel bed and bank stability varies throughout the Sausal Creek watershed, however, in general, the channel bed and banks are likely stable for velocities up to approximately 7 ft/sec and shear stresses up to approximately 2 lbs/ft$^2$. These values are based on the US Army Corps of Engineers' Engineering Research and Development Center "Stability Thresholds for Stream Restoration Materials" to determine permissible shear strengths reference for selection of stream restoration materials, and a useful guide to assessing the stability of existing stream materials. While conditions vary throughout the watershed, we made the assumption that the system has geomorphic controls such as riffles and artificial grade control structures with cobble and coarser particle sizes and some woody vegetation on the banks. As shown in Table A, the reaches with these characteristics would be stable for velocities up to 7 feet per second and shear stresses up to 2 pounds per square foot. Therefore, portions of the Sausal channel network are at risk of erosion under existing hydrologic and hydraulic conditions, even during the 1-year discharge. Even moderate reductions in peak flows could reduce the frequency and duration of erosive flows and contribute to long-term improvements in creek habitat conditions ( Figures D and E)

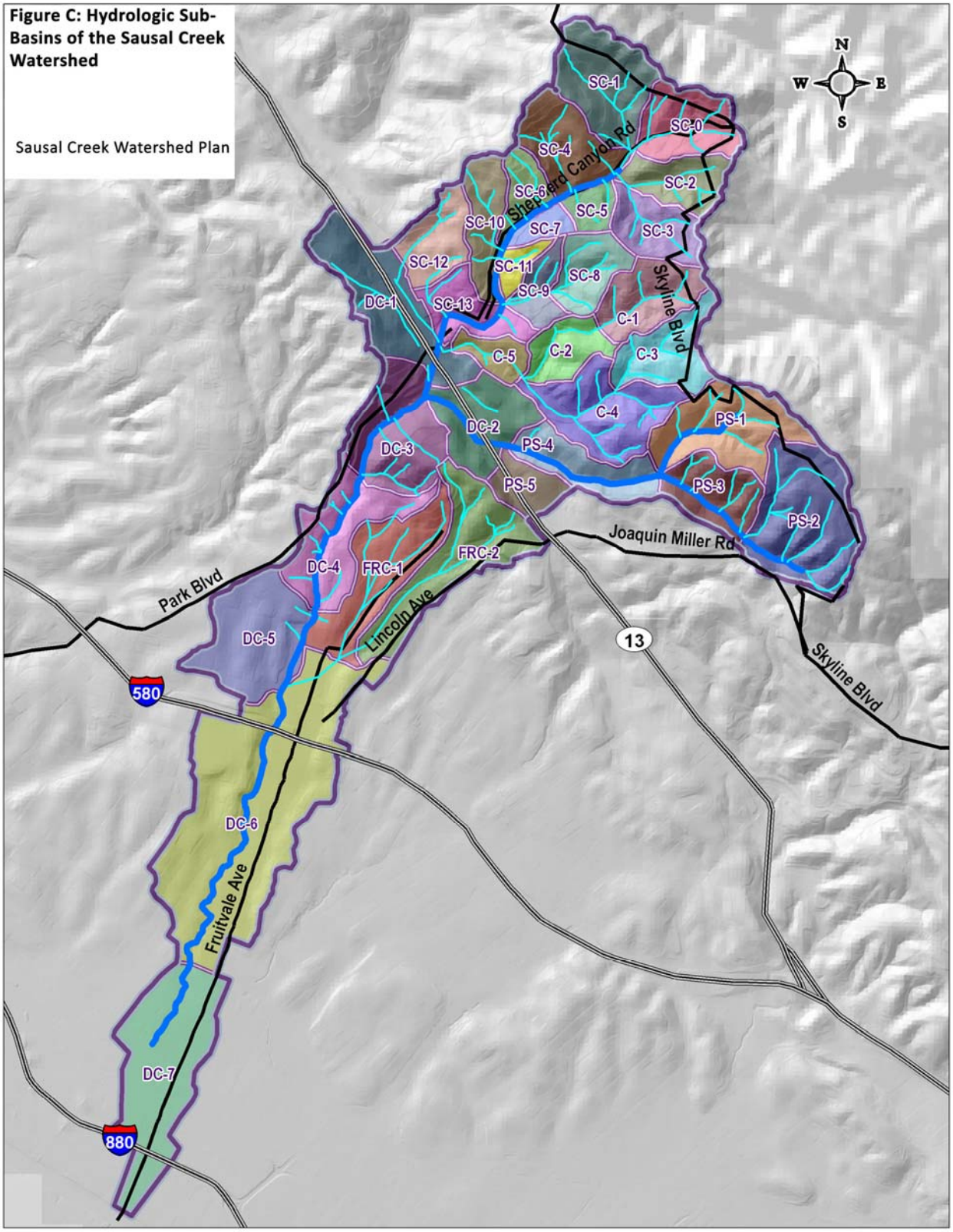


Figure C: Hydrologic Sub-Basins of the Sausal Creek Watershed
Sausal Creek Watershed Plan
N
W
E
S
SC-1
SC-0
SC-4
Shepherd Canyon Rd
SC-2
SC-6
SC-5
SC-10
SC-7
SC-3
SC-12
SC-11
SC-8
Skyline Blvd
SC-9
DC-1
SC-13
C-1
C-5
C-2
C-3
C-4
PS-1
DC-2
PS-4
DC-3
PS-5
PS-3
PS-2
Joaquin Miller Rd
FRC-2
DC-4
FRC-1
Park Blvd
Lincoln Ave
DC-5
13
Skyline Blvd
580
DC-6
Fruitvale Ave
DC-7
880

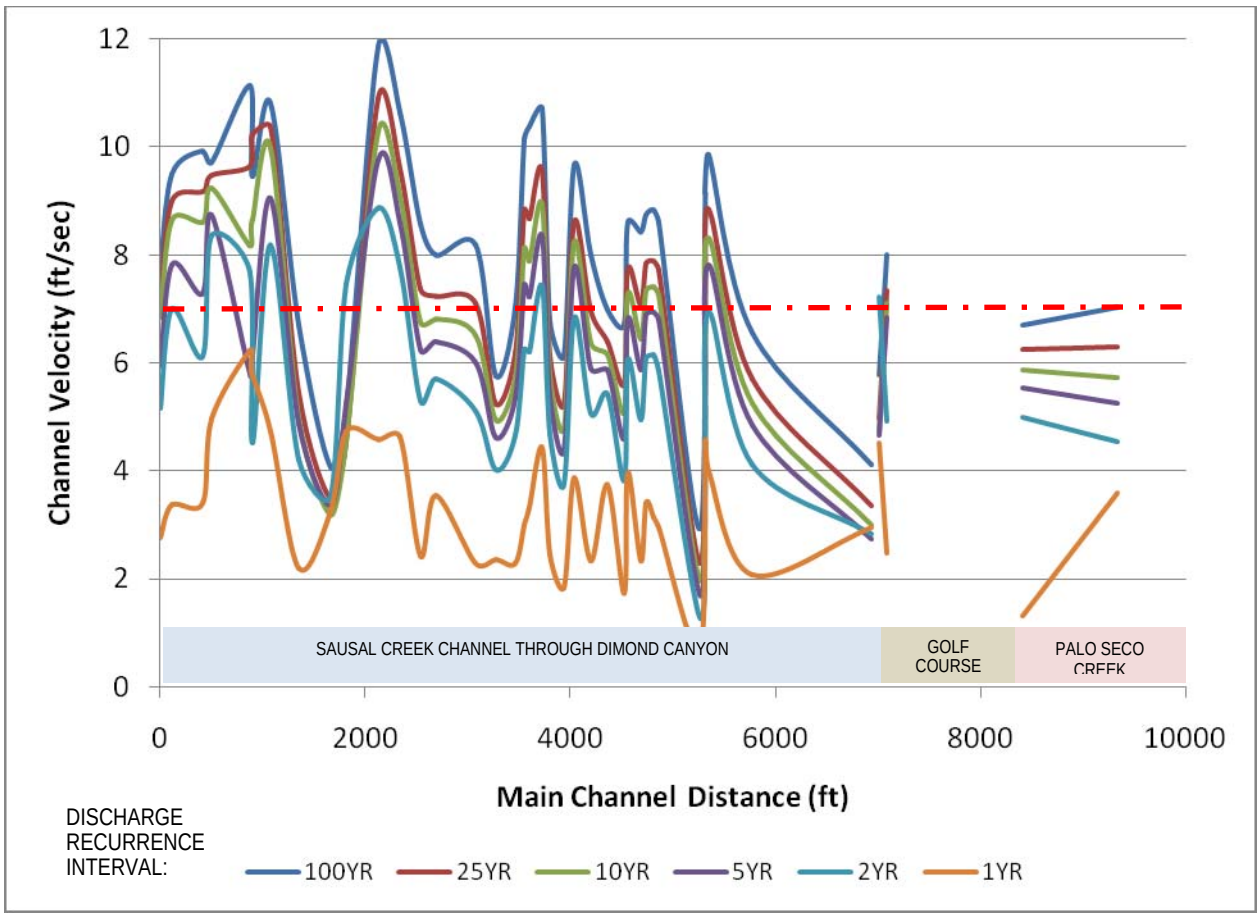



**Figure D: Existing conditions longitudinal velocity plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.**

**Table A: Permissible velocities and shear stresses for channel sediment and vegetation types similar to Sausal Creek (after Fischenich 2001)**

| Material | Permissible Velocity (ft/sec) | Permissible Shear Stress (lbs/ft$^2$) |
|---|---|---|
| Gravel (2 inch) | 3.0 – 6.0 | 0.67 |
| Cobble (6 inch) | 4.0 – 7.5 | 2.0 |
| Riprap (18 inch) | 12.0 – 16.0 | 7.6 |
| Emergents | n/a | 0.1 – 0.6 |
| Grasses | 3.0 – 6.0 | 0.7 – 1.7 |
| Woody Vegetation | 3.0 – 10.0 | 2.1 – 3.1 |

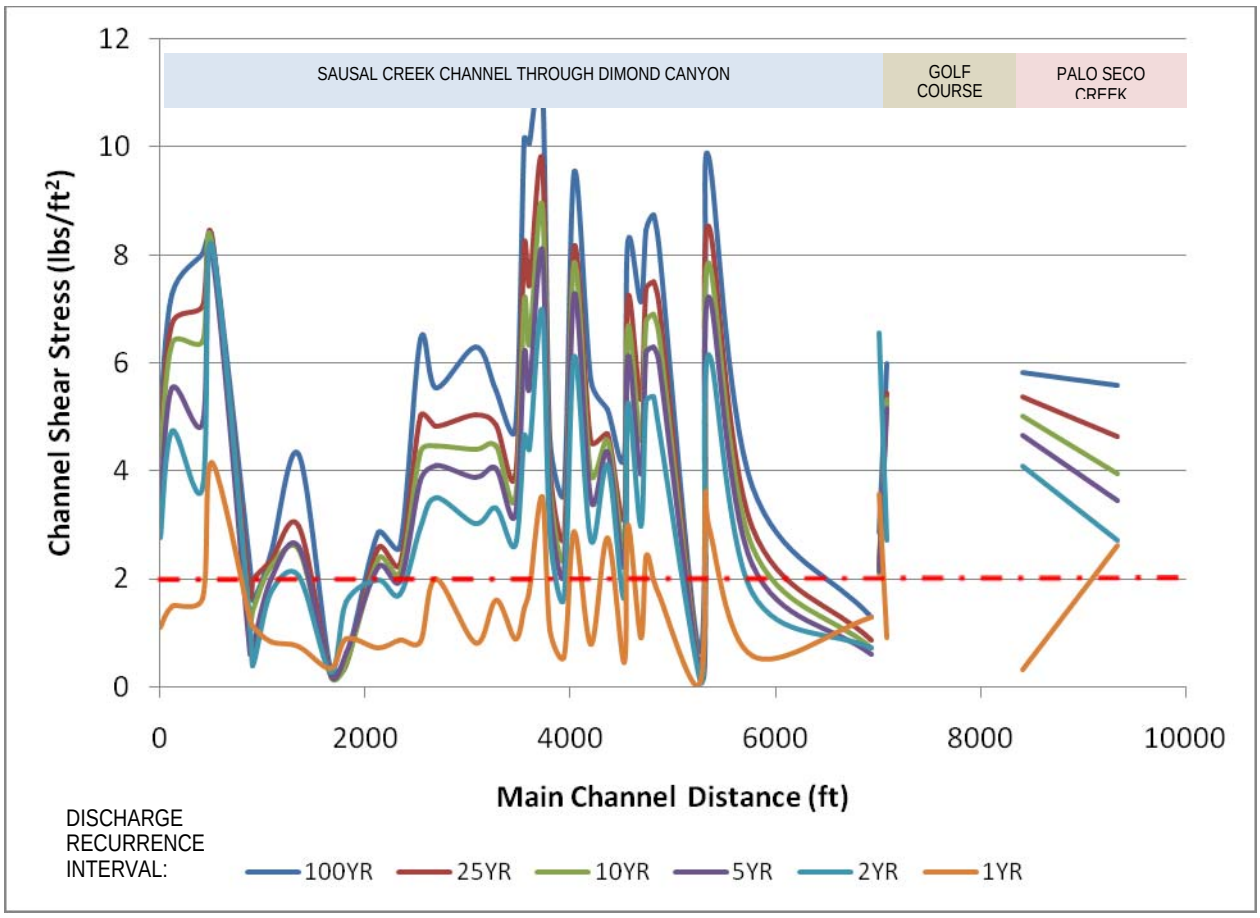


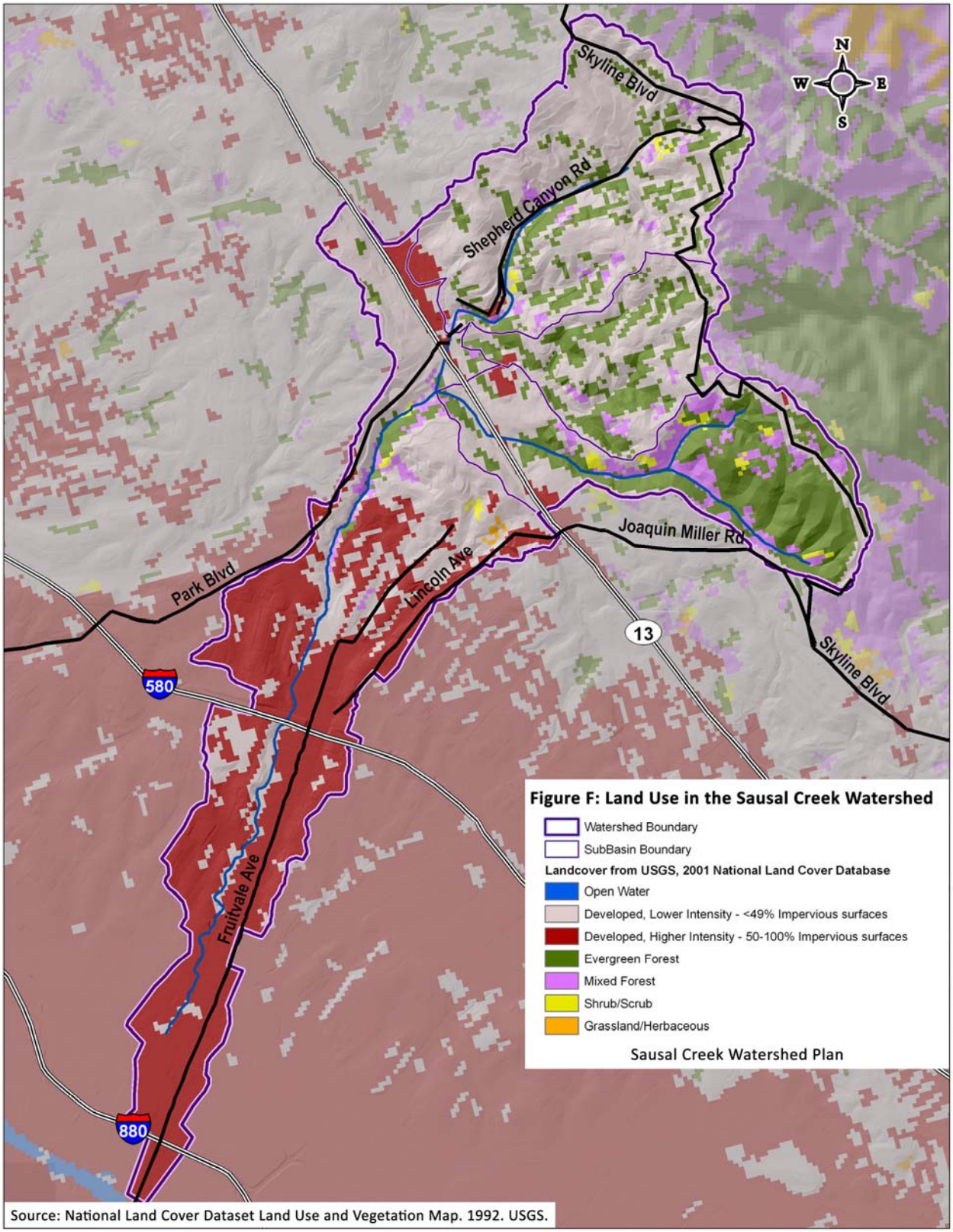

**Figure E: Existing conditions longitudinal shear stress plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.**

***Vegetation***

The vegetation growing in Sausal Creek watershed is a combination of native plant species primarily found in parks and ornamental species (including planted natives) surrounding residential and commercial areas. In the upper watershed, evergreen forest dominates the parkland and vegetated areas next to houses, including creek areas.

The upslope area of Joaquin Miller Park in the Palo Seco sub-basin is part of a five square-mile area in the Oakland hills once dominated by redwood forest called the San Antonio Redwoods. Logging of the redwoods started in the late 1840s and all of the trees were cut by 1860. The redwoods in this area are now second-growth. Besides the redwood forest, most early accounts and photographs of the upper Sausal Creek watershed describe large areas of grassland with trees along the ephemeral and seasonal water courses. Following the logging of the redwoods, numerous trees were planted in Joaquin Miller Park and surrounding hill areas, like Piedmont Pines and Oakmore. Planted species included trees native to other areas of California—Monterey pine and Monterey cypress—as well as non-native invasive tree species: Eucalyptus and Acacia. Palo Seco Creek sub-basin holds over 250 acres of this mix of native and non-native trees termed "evergreen forest," mostly focused in Joaquin Miller Park. Cobbledick Creek sub-basin has 110 acres of evergreen forest dispersed between houses. Similarly, Shephard Creek sub-basin has 110 acres of evergreen forest spread out in residential and park areas (Figure F).

The native vegetation areas that remain in the Sausal Creek watershed are under constant threat of invasion and replacement by invasive, non-native plant species. These plants were typically brought to California as garden plants or by the government to provide erosion control along streams or on agricultural lands. Some, such as Eucalyptus, were widely planted in the East Bay hills under the mistaken assumption that Eucalyptus would produce good lumber in California. The spread of invasive non-native plants is a primary cause of the degradation and loss of native habitat in California. Most invasive plants are adapted to rapid germination and growth following ground disturbance. Some produce chemicals which suppress the growth of other native plants, resulting in complete dominance by the invasive species. Most invasive plants do not provide habitat values for wildlife, nor do they have natural predators outside their native land to reduce their rapid spread.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Skyline Blvd
Shepherd Canyon Rd
Joaquin Miller Rd
Park Blvd
Lincoln Ave
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580
880
Fruitvale Ave
Skyline Blvd
Figure F: Land Use in the Sausal Creek Watershed
Watershed Boundary
SubBasin Boundary
Landcover from USGS, 2001 National Land Cover Database
Open Water
Developed, Lower Intensity - <49% Impervious surfaces
Developed, Higher Intensity - 50-100% Impervious surfaces
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Sausal Creek Watershed Plan
Source: National Land Cover Dataset Land Use and Vegetation Map. 1992. USGS.

**Figure G: Top: Invasive non-native cape ivy adjacent to a residential area in the Shepherd Canyon sub-basin. Bottom: French broom, a highly flammable invasive plant, is widespread in the Sausal Creek watershed and is seen here as an understory plant in both native vegetation**

Replacement of native species by invasives can exacerbate the effects of fires and floods. Most of the invasive plants that cover the understory areas along streams provide little to no erosion control, allowing streambanks to fail in floods. Some invasives are extremely fire-prone; the 1991 Oakland firestorm was spread as Eucalyptus stands exploded, sending burning embers across major freeways to start additional fires.

Typically the approach to invasive species control is to: 1) document the species present and their areal extent; 2) determine the primary dissemination pattern (from upstream to downstream along watercourses, along trails, from parking lots into parkland, etc.); and 3) complete a multi-year strategy for eradication. When the processes of invasive plant dissemination are contained entirely within public lands, this type of approach can be successful if funding is available.

In the Sausal Creek watershed, however, public and private landscapes are intertwined, making eradication of invasives on public lands and along creeks very difficult. Unfortunately, private land in Sausal Creek watershed contains numerous non-native invasive species and serves as a permanent source for dissemination of these plants ( Figure G). For the most part, homeowners are largely unaware of invasive plants and can still purchase many of the worst species for their gardens. Although state and local governments fund invasive plant removal, and park and fire districts carry out management to remove these species, the plants have not been banned for sale in the state. This situation creates a never-ending supply of invasive plants to open space areas, while there are limited resources to remove them. Unless the ongoing cultivation of invasive plants by homeowners in the watershed is reduced, invasive non-native plants can never be eradicated on public land and along creeks in the Sausal Creek watershed.

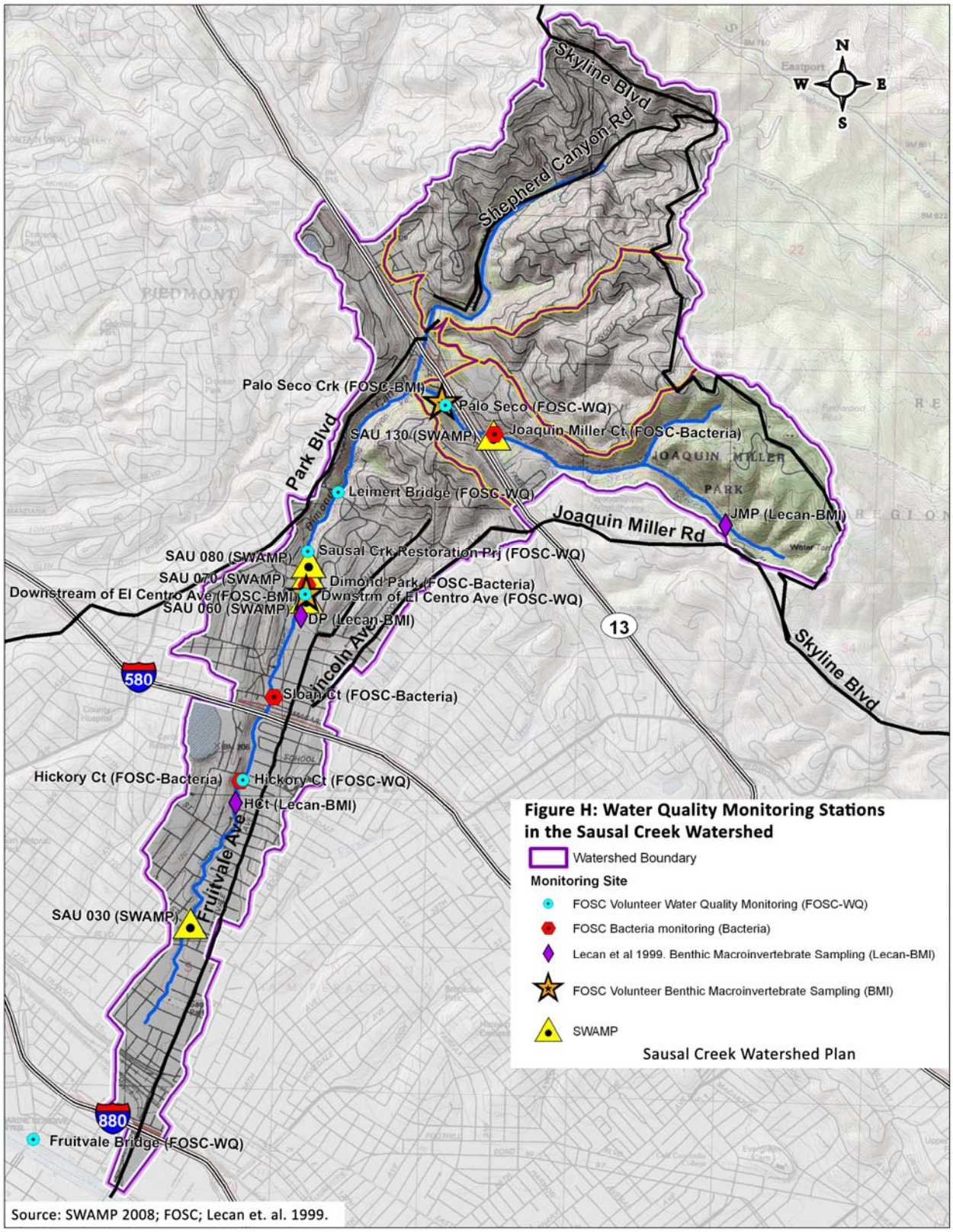
***Water Quality***

In urban watersheds, rainfall flushes numerous contaminants off of roofs, driveways, gardens, parks, and streets into storm drains and creeks. Rainfall also moves pollutants from the air into storm runoff. Due to the large volumes of runoff in winter, most of these contaminants are transported to San Francisco Bay. During the dry season, however, there are also many sources of pollutants in urban watersheds which may reach storm drains and creeks. Due to the low flows in the creeks in summer there is little dilution and pollutants can have a large effect on aquatic life.

In the Sausal Creek watershed the primary land use is residential with limited commercial areas and some parkland. These land uses produce pollutants including oil and gas residues, trash, pesticides, fertilizers, sediment, dog feces, heavy metals, and other materials. These pollutants are generated by numerous sources in the watershed. One of the only effective methods for reducing pollutants is changing the habits and materials used by urban residents.

Several different programs have measured water quality parameters in Sausal Creek. Friends of Sausal Creek (FOSC) has carried out a volunteer monitoring program for a number of years for basic water quality parameters in several locations.

The San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) completed comprehensive water quality, sediment quality, and aquatic insect monitoring in Sausal Creek in 2004-2005 at five stations (Figure H).


Skyline Blvd
Shepherd Canyon Rd
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W
E
S
Palo Seco Crk (FOSC-BMI)
Palo Seco (FOSC-WQ)
SAU 130 (SWAMP)
Joaquin Miller Ct (FOSC-Bacteria)
Park Blvd
Leimert Bridge (FOSC-WQ)
JMP (Lecan-BMI)
Joaquin Miller Rd
SAU 080 (SWAMP)
Sausal Crk Restoration Prj (FOSC-WQ)
SAU 070 (SWAMP)
Dimond Park (FOSC-Bacteria)
Downstream of El Centro Ave (FOSC-BMI)
Dwnstrm of El Centro Ave (FOSC-WQ)
SAU 060 (SWAMP)
DP (Lecan-BMI)
13
Skyline Blvd
580
Lincoln Ave
Sloan Ct (FOSC-Bacteria)
Hickory Ct (FOSC-Bacteria)
Hickory Ct (FOSC-WQ)
HCt (Lecan-BMI)
Fruitvale Ave
SAU 030 (SWAMP)
880
Fruitvale Bridge (FOSC-WQ)
Figure H: Water Quality Monitoring Stations in the Sausal Creek Watershed
Watershed Boundary
Monitoring Site
FOSC Volunteer Water Quality Monitoring (FOSC-WQ)
FOSC Bacteria monitoring (Bacteria)
Lecan et al 1999. Benthic Macroinvertebrate Sampling (Lecan-BMI)
FOSC Volunteer Benthic Macroinvertebrate Sampling (BMI)
SWAMP
Sausal Creek Watershed Plan
Source: SWAMP 2008; FOSC; Lecan et. al. 1999.

**Table B: SWAMP Program Comparison of Nutrient Concentrations in Years 4 and 5 Samples to Water Quality Benchmarks (WQB) for Sausal Creek**

| Station | Season | Ammonia as N (mg/L) | qual | pH | Temperature (°C) | Unionized Ammonia as N (mg/L) (WQB=0.025) | Unionized Ammonia Exceedance Factor | Nitrate as N (mg/L) (WQB=0.16) | Nitrate Exceedance Factor | Phosphorus as P, Total (mg/L) (WQB=0.03) | Total P Exceedance Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 1/10/05 | 0.097 | J | 7.84 | 11.5 | 0.001 | 0.04 | 2.27 | 14.2 | 0.07 | 2.3 |
| SAU030 | 4/12/05 | | ND | 7.56 | 12.8 | | | 1.41 | 8.8 | 0.06 | 2.1 |
| SAU030 | 6/14/05 | 0.05 | J | 7.68 | 15.5 | | | 1.25 | 7.8 | 0.08 | 2.7 |

* ND=not detected. "J" is defined as 'estimated'; the analyte was detected but the value is below the Reporting Limit

**Table C: SWAMP Metal Concentrations in Comparison to Quality Benchmarks for Sausal Creek**

| Station | Aluminum (mg/Kg) | Arsenic (mg/Kg) | Cadmium (mg/Kg) | Chromium (mg/Kg) | Copper (mg/Kg) | Lead (mg/Kg) | Manganese (mg/Kg) | Mercury (mg/Kg) | Nickel (mg/Kg) | Silver (mg/Kg) | Zinc (mg/Kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 15552 | 4.2 | 0.16 | 66.5 | 12.4 | 12.7 | 250 | 0.243 | 44.3 | 0.11 | 50 |
| Threshold Effect Concentration Values: | | 9.79 | 0.99 | 43.4 | 31.6 | 35.8 | | 0.18 | 22.7 | | 121 |

**Table D: FOSC/EPA E. coli Monitoring in Sausal Creek (in MPN/100ml)**

| Date | Palo Seco Creek | Sausal Creek | | |
|---|---|---|---|---|
| | Joaquin Miller Ct. | Dimond Park | Sloan Ct. | Hickory Ct. |
| 3/10/1999-4/7/1999 | 400 | 7800 | 7800 | 1900 |
| 9/8/1999-10/6/1999 | 150 | 1500 | 12000 | 1900 |

* MPN=Most Probable Number

**Table E: SWAMP Total Coliform Counts and *E. coli* Counts (MPN/100ml) in Sausal Creek in Years 4 and 5**

| Station: SAU060 | 7/20/04 | 7/27/04 | 8/3/04 | 8/10/04 | 8/17/04 | Median |
|---|---|---|---|---|---|---|
| Total Coliform | 7300 | 5500 | 1800 | 17000 | 1200 | 5500 |
| *E. coli* | 260 | 120 | 160 | 150 | 160 | 164 |

* Counts are Most Probable Number per 100 milliliters (MPN/100ml). Values in red exceed the limit for freshwater recreation (126 MPN for the geomean).
Tables from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

These stations include:

- Sausal Creek at E. 22nd Street (SAU030)
- Sausal Creek near Lions Pool in Dimond Park (SAU 060)
- Sausal Creek at El Centro Ave. (SAU070)
- Sausal Creek in Dimond Park (SAU080)
- Palo Seco Creek (SAU130)

The SWAMP program monitored for a range of persistent pollutants typical of urban contaminants. The results of the SWAMP monitoring found excessive levels of nutrients (nitrate and total phosphorus), slightly high water temperatures, and a few low dissolved oxygen measurements. Water and sediment samples were tested for a number of persistent pollutants including metals, pesticides, PCBs, and PAHs. Sediment samples from the downstream area of Sausal Creek had concentrations of chromium, mercury, and nickel that exceed threshold effect concentrations (TEC). Water samples did not show any high contaminant levels. Bioassays on water and sediment found no acute toxicities, but sediment sample tests found hindered growth in the test organism (Tables B and C).

Bacterial data was collected by FOSC in 1999 and analyzed by the EPA, and shows high *E. coli* levels in all locations sampled. SWAMP bacterial monitoring in 2004 found lower *E. coli* levels, but levels still exceeded water contact recreation standards (Table D and E).

**AQUATIC AND RIPARIAN HABITATS**

The Sausal Creek watershed, unlike most urban areas, has many open, unculverted creek channels. In the Sausal Creek watershed, aquatic habitat consists of the stream channel bottom and banks in the creeks with perennial and intermittent, or seasonal, flow. Riparian habitat consists of the vegetation bordering the low flow channel and covering the adjacent floodplain. Riparian vegetation is dependent on a source of summer water. Willows and alders are the most abundant riparian plants along Sausal Creek and are considered “pioneer” species. Both species are able to rapidly colonize deposited sediment, stream banks, and channel edges. Other common plants found along streams in the watershed include trees: coast redwoods, California bay laurel, and big-leaf maple, and understory plants: Pacific dogwood, nine bark, and native blackberry. Uncommon riparian species in the Sausal Creek watershed include elk clover, red alder, box elder, rushes and sedges, California wild rose, and red elderberry.

An important concept in the ecology of riparian systems is ecological succession. The diversity of riparian vegetation species varies over a continuum of the conditions created by flood events and associated changes in stream channel morphology. Willows and alders, as pioneer species, occur near the active channel in alluvial streams or along the edges and among rocks in confined channels. Their reproductive and adaptive strategy is tuned to a highly variable physical environment. Farther away from the channel, other species occur on the floodplain that are still riparian in nature but are adapted to less physical variation. These include big-leaf maple, California bay laurel, and coastal redwood.

**<u>Effects of Urbanization of the Watershed on Riparian and Aquatic Habitats</u>**

The urbanization of Sausal Creek began along the lower creek where the land is flat, and eventually extended up into the headwaters and onto steep slopes. Only one tributary—Palo Seco Creek—retains a largely undeveloped drainage basin. Shephard and Cobbledick Creeks have less intensive urban development than Sausal Creek, but are still highly impacted by runoff from impervious surfaces.

Creeks in a natural state are formed and changed by flood events. Each watershed has a unique set of features, including size and shape of the basin and stream network, topography, geology, vegetative cover, land use, and rainfall patterns. Over time, the creek's size, shape, and condition reflect watershed conditions. For example, large-scale grading, road building, and land disturbance for residential development in upper Sausal Creek watershed likely increased soil erosion, including landslides in wet years, resulting in large volumes of sediment being delivered to Sausal Creek. The creek channel might have had increased over-bank flooding and reduced aquatic habitat due to the sedimentation. Once large areas of the watershed were paved and many creek channels replaced with storm drains, Sausal Creek experienced larger volumes of runoff over a shorter time and a decreased sediment supply. Erosion of the sediment stored in the creek bed and banks occurred, resulting in incision or entrenchment. Once the channel is incised, storm flows are confined to the channel and increase erosion. In addition, urbanization typically involves channelization of creeks to reduce the area the creek occupies in order to maximize buildable land.

During the urbanization process, the riparian habitat is eroded out as the creek channel incises. As the channel bottom erodes, the former floodplain is isolated from frequent inundation. The entrenched channel has high flow velocities precluding much sediment deposition and the germination of riparian trees. The habitat in the new incised channel is limited in area and diversity. As the channel deepens, the banks fail, eroding habitat remaining on the original floodplain.

Aquatic habitats are affected by the high flow velocities. Channel scour and frequent gravel movement decrease the abundance and diversity of aquatic insects. Sand transport can shred the insects. High water temperatures caused by the loss of riparian shading, persistent urban pollutants, and fine sediments also limit aquatic insects.

To revegetate the riparian corridor and achieve conditions which support natural ecosystem processes of succession and diversity, the effects of urbanization on flow volumes, velocities, and channel form have to be mitigated. Willow, the species most adapted to high velocity flows, can withstand a flow velocity of up to 7 ft./sec. and shear stresses of 2 lbs./$ft^2$. Sausal Creek typically exceeds these conditions during the 1-year frequency event (Figures D and E).

**Benefits and Limitations of Creek Restoration**

Urban creek restoration typically means changing the stream channel by grading and possibly adding rock or removing a culvert and recreating a channel. A narrow band of vegetation, usually willows, is installed on the newly graded channel banks. The creek usually remains in the same area. Due to space limitations of urban areas it is uncommon for a floodplain to be created where storm flows can spread out and slow down. The footprint of the riparian corridor is rarely wide enough to support ecological processes, or a diversity of plant species. The restored urban stream may continue to have physical conditions such as frequent high velocity flows, which scour the channel and reduce the abundance and diversity of aquatic insects and riffles and pools for spawning and rearing fish. By restoring only one reach of an urban creek, the habitat benefits that can be achieved are limited to what can be changed in this very limited area. A broader approach, integrating improvements in the watershed with creek projects to mitigate the effects of urbanization, offers the possibility for changing both the creek and the processes which have caused the degradation of the creek. A focus on watershed restoration instead of just creek restoration requires a greater level of analysis but has the potential to produce higher quality, more sustainable environmental conditions in habitat areas.

A number of studies have looked at the long-term changes in aquatic habitat conditions in restored urban creeks. One of these studies focused on changes in aquatic insect assemblages in a creek in the East Bay. A restored section of Baxter Creek in Poinsett Park was evaluated in 1999 and in 2004 (Purcell et. al. 2002; Purcell 2004). The creek was removed from a culvert, a new channel was graded and stabilized with rock, and willows were planted. The size of the new creek channel was restricted by adjacent urban development and no floodplain was created as part of the project.

Aquatic insects were monitored in 1999 and again in 2004. Samples were taken after the project was completed and were evaluated for taxa richness, number of taxa of EPT (pollutant intolerant taxa), and family richness. Habitat areas were also evaluated.

The restored reach was compared with an unrestored reach of Baxter Creek and a high quality habitat area of Strawberry Creek deemed "best attainable conditions." The same sampling design was applied to all three creek reaches. The study found that the "restored" reach of Baxter Creek had slightly improved aquatic habitat conditions over the unrestored reach of Baxter Creek but showed no significant improvements in aquatic habitat between 1999 and 2004, and had lower quality habitat than the Strawberry Creek site. The study attributed the lack of improvement in aquatic habitat in the restored reach to the continued urban runoff and high velocity flows in the channel.

Studies of stream restoration in Australia (Walsh et. al. 2005) concluded:

> "Restoration of streams degraded by urbanization has usually been attempted by enhancement of instream habitat or riparian zones. Such restoration approaches are unlikely to substantially improve instream ecological conditions because they do not match the scale of the degrading process. Recent studies of urban impacts on streams in Melbourne, Australia, on water chemistry, algal biomass and assemblage composition of diatoms and invertebrates, suggested that the primary degrading process to streams in many urban areas is effective imperviousness (EI), the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater drainage pipes. The direct connection of impervious surfaces to streams means that even small rainfall events can produce sufficient surface runoff to cause frequent disturbance through regular delivery of water and pollutants; where impervious surfaces are not directly connected to streams, small rainfall events are intercepted and infiltrated…Alternative drainage methods, which maintain a near-natural frequency of surface runoff from the catchment were identified as the best approach to stream restoration in urban catchments…"

Studies of urban stream restoration in the Seattle area (Booth 2005) found:

> "Undoing harm by catchment urbanization on stream channels and their resident biota is challenging because of the range of stressors in this environment. One primary way in which urbanization degrades biological conditions is by changing flow patterns; thus, re-establishing natural flow regimes in urban streams demands particular attention if restoration is to have a chance for success. Enhancement efforts in urban streams typically are limited to rehabilitating channel morphology and riparian habitat, but such physical improvements alone do not address all factors affecting biotic health. Some habitat-forming processes such as the delivery of woody debris or sediment may be amenable to partial restoration, even in highly disturbed streams, and they constitute obvious high-priority actions. There is no evidence to suggest, however, that improving

non-hydrologic factors can fully mitigate hydrologic consequences of urban development."

This plan focuses on changing the watershed processes which have the largest effects on streams and are the result of the high level of urbanization in the Sausal Creek watershed.

## Description of Stream Conditions

### Cobbledick Creek

Most of Cobbledick Creek and its tributaries have open channels with seasonal flow. With the exception of two areas, however, this sub-basin is private residential land. In addition, in many areas of this sub-basin homes border the creek or have foundations or deck piers next to or in the creek. In these private creeks, control and eradication of invasive plants such as broom, Himalayan blackberry, cape ivy, Algerian ivy, and blue periwinkle will reduce the spread of these problem plants into downstream habitat areas. Erosion control and bank stabilization may also be needed. Native shrubs and trees such as toyon, manzanita, oaks, and madrone occur as natural vegetation.

*Cobbledick Creek 1 (CC1)*
This reach along Larry Lane is bordered with houses. The channel is semi-confined between hillslopes and much of the former floodplain is filled with houses. Mixed conifers line the creek and Eucalyptus, Algerian ivy, and broom are common. A sediment/detention basin blocks the channel near the Ascot Road crossing. The dam creating this basin was overtopped and eroded portions of the dam and Larry Lane road fill. Downstream from this basin the creek channel consists of fill with a culvert and has a house on the fill. There is erosion at the outlet. Downstream of the Ascot Rd. crossing the creek channel is filled and the creek goes through a culvert under Joaquin Miller Elementary/Montara Middle schools.

*Cobbledick Creek 2 (CC2)*
This reach is Cottonwood Creek, which flows through Beaconsfield Canyon. The channel is semi-confined between hillslopes and the channel bed is mostly fine sediment with some gravel. Black cottonwoods line the creek and broom and Himalayan blackberry make up the understory. The downstream end of this reach has a rapidly eroding inlet where the creek drops into a storm drain.

*Cobbledick Creek 3 (CC3)*
This reach is made up of ephemeral creeks in an undeveloped but private 15-acre area. There are willows, elk clover, and dogwoods growing along one of the creeks.

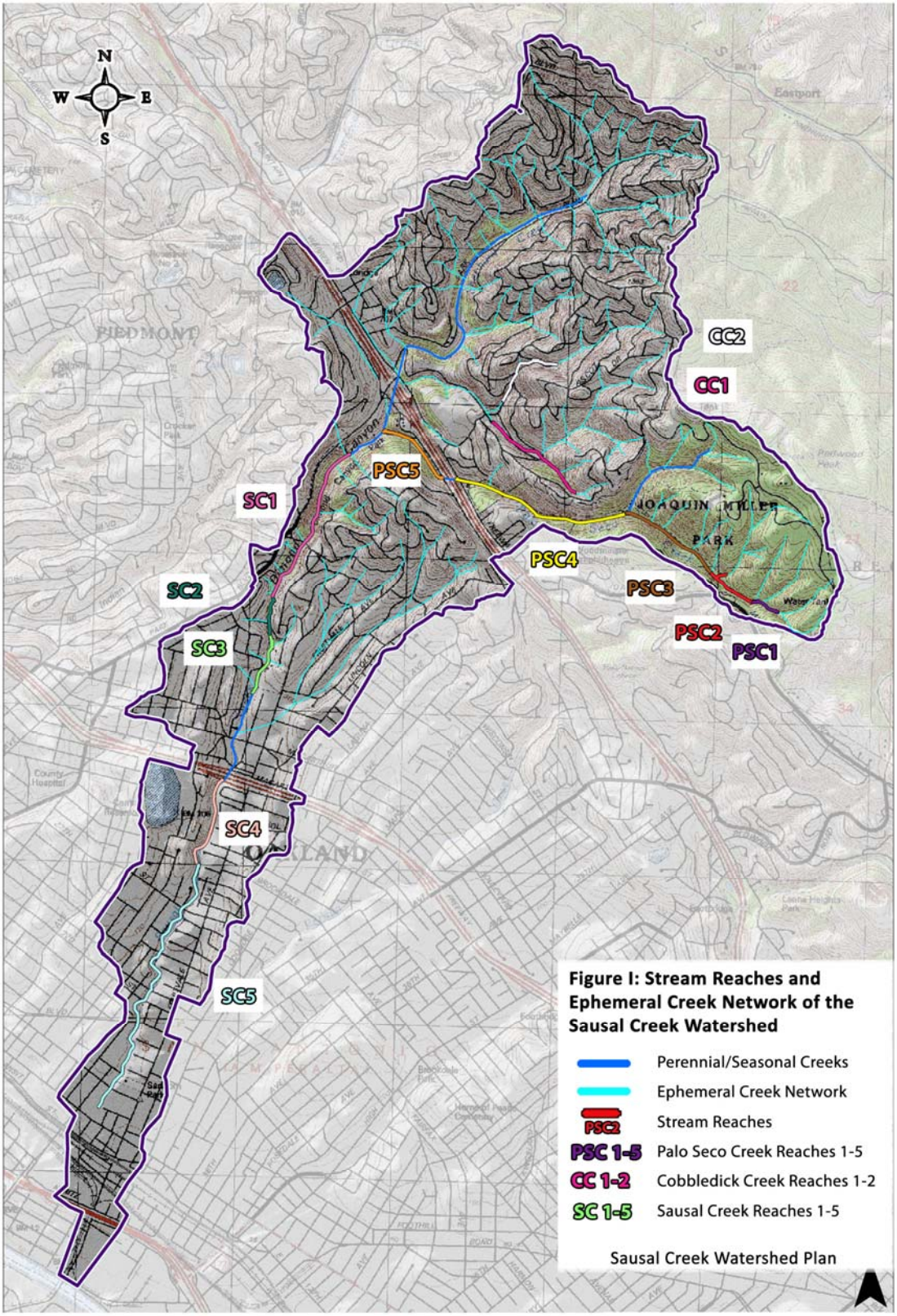

N
W
E
S
CC2
CC1
PSC5
SC1
PSC4
PSC3
SC2
PSC2
SC3
PSC1
SC4
SC5
Figure I: Stream Reaches and Ephemeral Creek Network of the Sausal Creek Watershed
Perennial/Seasonal Creeks
Ephemeral Creek Network
PSC2
Stream Reaches
PSC 1-5
Palo Seco Creek Reaches 1-5
CC 1-2
Cobbledick Creek Reaches 1-2
SC 1-5
Sausal Creek Reaches 1-5
Sausal Creek Watershed Plan

**Figure J: Houses line the tributary channels in the Cobbledick Creek sub-basin. House and deck foundations are located within the area of the channel that is subject to bank erosion and failure.**

*Cobbledick Creek 4 (CC4)*
This reach extends from the outlet of the culvert underneath the Joaquin Miller Elementary/Montara Middle schools to the confluence with Shephard Creek. The channel is lined by live oaks and Eucalyptus and has erosion in many locations with undercut trees.

**Palo Seco Creek**

The Palo Seco Creek sub-basin is the least developed area of the Sausal Creek watershed.

*Palo Seco Creek 1 (PSC1)*
This reach is the upper meadow area of Joaquin Miller Park. Dominant trees are coast redwoods and willows with an understory of Himalayan blackberry. The channel appears to have been relocated to one edge of the meadow area. Currently the meadow serves as a floodplain (Figure K). A drop inlet into the culverted section of creek (PSC2) occurs at the downstream end of this reach.

*Palo Seco Creek 2 (PSC2)*
This reach of creek was culverted to create a meadow. This reach was likely lined by redwoods prior to clearcutting in the 1860s and park development projects in the 1930s and 1940s. This reach includes the confluence with Fern Ravine Creek, which is culverted from a picnic area to its confluence with culverted Palo Seco Creek. The drop inlet for Fern Ravine Creek frequently fills with bedload, and water creates an overland course to meet the open channel of Palo Seco Creek.

*Palo Seco Creek 3 (PSC3)*
This reach of Palo Seco Creek stretches from the culvert outlets at the downstream end of the meadow to the confluence with Cinderella Creek. The slope of the creek bed increases over this reach and contains several knickpoints. The creek channel is incised below these knickpoints and several trees have been undercut on the banks. Aquatic insect monitoring showed good aquatic conditions (Figure L).

*Palo Seco Creek 4 (PSC4)*
This steep rockbound channel is lined by redwood and California bay laurel trees. Many trees, however, are covered with parasitic Algerian ivy and numerous invasive non-native holly trees are growing in the redwood forest.

*Palo Seco Creek 5 (PSC5)*
This reach stretches from the Highway 13 culvert outlet to the confluence with Sausal Creek. The channel is confined with hillslopes, and the channel bed is mostly fine sediment with gravel. The density of vegetation is high, dominated by coast redwoods with Algerian ivy, Himalayan blackberry, and American elm. Since 2003, FOSC has been working to re-create the understory vegetation under the redwoods along the switchback trail. An erosion control project consisting of a swale was installed to divert flow from a storm drain outlet.

**Figure K: Palo Seco Creek (PSC1) overflows onto a grassed floodplain and trail during larger flow events This reach could be easily restored.**

**Figure L: Top: Palo Seco Creek (PSC3) in the Jan. 1, 2006 flood event. Bottom: Small trail bridge with culverts serves as a grade control structure for Palo Seco Creek. Small trash rack visible upstream is also a grade control structure. Note sediment runoff from adjacent trails.**

**Shephard Creek**

Shephard Creek has very little riparian or aquatic habitat and few feasible opportunities for native revegetation exist on the main creek. Controlling invasive non-native plants (Eucalyptus, broom, Acacia, pampas grass) in tributaries and on hillslopes will benefit downstream creek areas. This sub-basin has a large number of storm drains and most of the main creek channel has been culverted. Shepherd Canyon Park was once an open creek channel. A large amount of fill and a pipe was placed in the creek to create a flat area for the park. Escher Creek is an ephemeral tributary to Shephard Creek which was relocated to flow along the edge of Shepherd Canyon Park, and has been cleared of invasive plants and planted with native plants by the Shepherd Canyon Homeowners Association. Downstream of this park, the creek has an open channel up to Highway 13 and the confluence with Cobbledick Creek.

**Sausal Creek**

Sausal Creek extends from the confluence of Palo Seco Creek and Shephard Creek to San Francisco Bay.

*Sausal Creek 1 (SC1)*
SC1 extends from the confluence of Shephard and Palo Seco Creeks to the restoration project. The creek is confined in a relatively deep canyon lined by California bay laurels and white alders covered by parasitic Algerian ivy. Grade control structures, culverts, and cement lining cover most of the creek channel. Cobble dominated substrate has built up behind the stair steps of grade control structures. A major sewer line borders the creek and runs down the channel. There are numerous erosion sites from storm drains which outlet on the slopes of the canyon (Figure M)

*Sausal Creek 2 (SC2)*
This is the 600-foot reach where a restoration project was completed in 2001. It begins one-quarter mile upstream from the El Centro culvert. Several grade control structures were removed and the sanitary sewer pipe in the middle of the creek was replaced. A series of rock weirs were installed along with some riprap at the base of the banks. Overstory California bay laurel trees were cut and willows and other native species were planted along the channel banks. Thousands of native plants were installed in the narrow riparian corridor and adjacent slopes (Figure N).

*Sausal Creek 3 (SC3)*
This reach stretches from just upstream of the El Centro culvert through Dimond Park. The Sausal Creek channel would be unconfined with a floodplain if it were not channelized and culverted. The area downstream of the El Centro culvert is lined by white alders. There are few alder seedlings and no regeneration of the riparian corridor. Along the downstream section, the right bank is residential with various types of revetments to protect against erosion. The left bank is parkland with native and ornamental trees. The channel is entrenched and eroding in this downstream area. The City of Oakland is planning to change this reach by daylighting part of the creek out of the culvert west of Wellington Street, protecting the private property downstream on the right bank and installing native vegetation on the left bank.

*Sausal Creek 4 (SC4)*
This reach extends from the Highway 580 culvert to 27$^{th}$ St. The creek channel would be naturally unconfined but due to urban development is highly entrenched and culverted. The creek borders an intensively urbanized area and has been affected by the McKillop slide. This slide filled in Sausal Creek in 2006 and undercut several houses. A similar incident occurred in the 1970s and a culvert was installed to

**Figure M: These photos are examples of the drop structures in Sausal Creek (SC1) in Dimond Canyon.**

**Figure N: Top: California bay laurel trees were trimmed to open up the creek corridor to more light and allow for willow growth as part of the restoration project in SC2. Bottom: The project in 2003 shows the riparian corridor and trail.**

**Figure O: Top: Sausal Creek at Logan Road. Bottom: Sausal Creek at E. 22nd St (SC5).**

direct the creek away from the slide through William D. Wood Park. At the downstream end of the culvert a pump operated by Alameda County Flood Control lifts water up to the creek channel downstream.

*Sausal Creek 5 (SC5)*
This reach extends from 27th St. to the culvert at the most downstream end of Sausal Creek. The creek channel would be naturally unconfined but due to urban development is highly entrenched and culverted. Houses line the creek. The streambed holds little gravel and has eroded down to clay hardpan. Banks are vertical and tall in many locations. Riparian vegetation is limited and primarily consists of non-native species, and shade canopy is sparse. One SWAMP station is located in this reach (Figure O).

**Aquatic Insects**

An indicator of both the health of the aquatic ecosystem and water quality is the diversity and abundance of aquatic insects in a creek. Typically aquatic insects are monitored in creeks with perennial flows. Some families of aquatic insects are more tolerant of pollution than others. The term EPT refers to *Ephemeroptera*, *Plecoptera*, and *Trichoptera*, three orders of aquatic insects. Within the EPT are particular taxa that are highly sensitive to pollutants. If the number of taxa of EPT sensitive to pollution is high in a creek, then the pollutant levels may be low. If pollution-sensitive taxa are missing, then it is likely that water pollution, poor habitat conditions, or excessive channel scour is occurring.

In 1999 a benthic macroinvertebrate (BMI) study in Sausal Creek was completed (Lacan et.al. 1999) Three stations were sampled: Palo Seco Creek upstream of the creek canyon, Sausal Creek in Dimond Park, and Sausal Creek at Hickory Court. Pebble counts, streamflow measurements, channel cross-sections, and evaluation of riparian canopy were done at each sampling site. Basic water quality parameters—pH, water temperature, dissolved oxygen, and specific conductivity—were also measured during the sampling as instantaneous measurements. This study found a significant difference between the Palo Seco Creek station and the two stations on Sausal Creek in terms of taxa richness, percent of dominant taxon, and indices of functional feeding groups. These results show that the Palo Seco Creek station has a healthy aquatic habitat, while the two Sausal Creek stations have low quality habitat. The authors state that the Sausal stations are highly affected by urbanization. Riparian forest canopy is inadequate to shade the creek at the Sausal Creek stations and the gravel substrate is frequently scoured, turning rocks and moving smaller gravel. The study cites channel incision, which increases flow velocities, steepens stream banks and often erodes riparian trees, along with the higher velocities of urban runoff, as major causes of the lack of healthy aquatic habitat at the Sausal Creek stations.

The San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) completed BMI sampling at three stations in April 2005. These included SAU030 (Sausal Creek at E. 22nd Street), SAU080 (Sausal Creek in Dimond Park), and SAU130 (Palo Seco Creek) (Figure H). For stations SAU030 and SAU080, the BMI assemblages were in poor condition. Taxonomic richness was low and sensitive EPT taxa were largely absent. These conditions were found for the majority of urban creeks in Oakland and Berkeley and are considered indicators of poor water quality and the high scour conditions in urban creeks. The sampling site on Palo Seco Creek (SAU130) demonstrated far better conditions. Taxonomic richness and percent sensitive EPT were much higher, with many pollution-intolerant taxa present.

BMI results from the 2005 SWAMP study and the 1999 Lacan study found similar results: low taxonomic richness and a near absence of sensitive EPT taxa at all the Sausal Creek stations. Stations on Palo Seco Creek showed significantly better conditions with higher taxonomic richness and a moderate percentage of sensitive EPT taxa. These results demonstrate the poor water quality conditions in the urban areas of Sausal Creek and the relatively good conditions on Palo Seco Creek, the only non-urban tributary.

A small number of rainbow trout have been observed in Sausal and Palo Seco Creeks. These fish are at risk from scouring flows and pollutants. The current levels of information don't identify whether the fish successfully reproduce and where they find refuge during floods. The broken areas of the grade control structures in Sausal Creek may serve as areas of lower velocity during floods.

**EVALUATION OF WATERSHED EROSION SITES**

A focused evaluation of several types of erosion sites was carried out in the Sausal Creek watershed. Outlets of the stormdrain system were assessed for erosion. The City of Oakland GIS layer of storm drain pipes was used to assign letter/number identities to all of the storm drain outlets in the watershed. These outlets were then evaluated to create a list of priority outlets for field inspection. Priorities included outlets along major open channels, large pipe outlets, outlets in extremely steep areas, and outlets of storm drains which drain a large land area. The primary purpose of the field inspection was to identify major erosion problems associated with concentrated flow at outlets of storm drains. A number of features of each outlet was recorded—size and shape of pipe, pipe material, conditions of outlet, whether the culvert was plugged and, if so, by what percentage; whether the outlet was undercut and the number of feet of undercut, the material in the impact zone of outlet, the drop height from the outlet to the impact zone, the condition of the impact zone, the condition of the channel, whether a gully was present at the outlet and, if so, the length and depth of the gully; comments on the site, and a photograph.

The results were mapped with categories for the amount of erosion at the outlet: extreme, significant, or little to no erosion. Not surprisingly, most of the erosion at the storm drain outlets occurs in the upper watershed and along Dimond Canyon. Many of the storm drains in the watershed have been in place since the development of the area; however, one of the newest developments in the watershed, the Chabot Space and Science Center, has caused significant erosion to surrounding lands from its storm water outlets. This facility has large parking lots, roofs, and other paved areas which drain to a few outlets. There is significant erosion at these storm drain outlets and further downstream in the creek channels. The affected creeks are all on public property. The Castle Drive erosion site in Joaquin Miller Park appears to have been caused by a storm drain outlet at the ridge top which releases storm water into the park.

Parks in the Sausal Creek watershed have several primary areas of erosion: recreational facilities such as trails and roads, outlets of concentrated flows from adjoining urban lands, and changes to creeks from watershed changes and management actions. Major erosions sites are summarized in Table F. Many of the trails in Joaquin Miller Park date from prior logging activities and were not built for long-term use. There is a general lack of stream crossing culverts, waterbars, and proper drainage on trails.

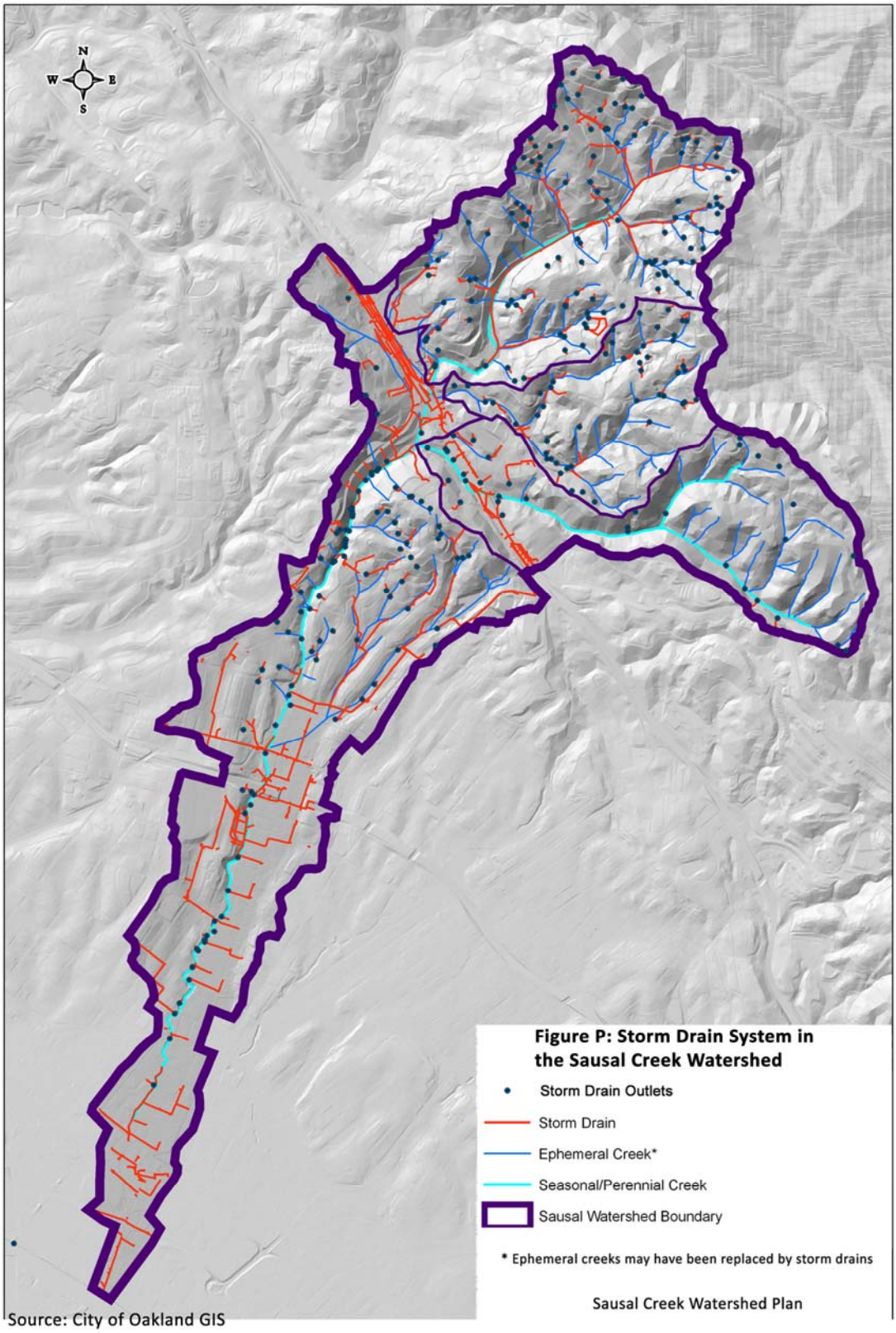

N
W
E
S
Figure P: Storm Drain System in the Sausal Creek Watershed
Storm Drain Outlets
Storm Drain
Ephemeral Creek*
Seasonal/Perennial Creek
Sausal Watershed Boundary
* Ephemeral creeks may have been replaced by storm drains
Sausal Creek Watershed Plan
Source: City of Oakland GIS

**Figure Q: Erosion site #2. Lack of a culverted stream crossing causes water to flow down Sunset Loop Trail, eroding the trail and creating a pile of mud on Sunset Trail (bottom)and in Palo Seco Creek.**

**Figure R: Top: Cinderella Trail is a major erosion site and needs to be re-designed or re-located. Bottom: Casual trails cause soil erosion directly into Palo Seco Creek.**

**Table F: High Priority Erosion Sites**

| Priority for Repair | Comments and Recommendations |
|---|---|
| **Joaquin Miller Park** | |
| High – direct delivery to creek; damage to vegetation and trail | The Sunset Loop Trail crosses an ephemeral creek with no culvert and captures the creek flow. Consequently, creek flow courses down the trail, eroding 3-4 inch deep rills and delivering fine sediment to the base of the oak tree on Sunset Trail and into Palo Seco Creek. A culvert needs to be installed to route the stream flow under the trail and back into the creek. |
| High – direct delivery to the creek | This is the most upstream grade control on Palo Seco Creek and consists of a trail bridge with three 20-inch culverts and an upstream trash rack. Trails at this junction are rilling, particularly Sinawik Loop Trail. In addition, the ephemeral creek on the north side of Sunset Trail is actively eroding from storm drain runoff along Skyline Blvd. directed into this small creek. A major repair will be needed here as major runoff events deepen Palo Seco Creek at the downstream side of the bridge. Trail and ephemeral creek runoff flows down the creek banks, eroding and widening the channel. The channel bed is up to seven feet deeper below the bridge than in the areas upstream of the trash rack. The bridge and trash rack cannot simply be removed, as removal will cause the channel to adjust and undercut numerous redwoods along the creek banks. Any replacement structure should be designed as a grade control structure. Stream banks should be revegetated and the culvert under Sunset Trail between the northern ephemeral creek and Palo Seco Creek replaced with a much larger culvert which will not clog with rocks but will allow for the transport of rock into Palo Seco Creek. |
| High – direct delivery to creek | This is another major knickpoint in Palo Seco Creek at a casual creek crossing. The knickpoint is over five vertical feet and has eroded approximately five feet upstream in the past ten years. Several tree roots are temporarily preventing the site from further erosion moving upstream. This site should have a rock grade control structure to avoid further upstream migration of this knickpoint. Downstream banks need to be set back to reduce erosive velocities and allow willow sprigging. Large wood debris in the channel should also be retained at this location. |
| Moderate | Sunset Trail crosses Cinderella Trail and a very large erosion site occurs in the channel of Cinderella Creek downstream of this crossing. The addition of urban runoff from Chabot Space & Science Center greatly increased the level of erosion at this site. The channel downstream of this crossing is over 20 ft. lower in elevation from the upstream side. Unfortunately, a culvert replacement completed in 2007 was installed incorrectly. Stream crossing culverts need to be installed at the same slope as the stream channel. The repair set the culvert at no slope, resulting in a large drop for the water at the outlet. The culvert also appears undersized, with flow overwhelming the culvert during the 2006 flood and flowing over the trail. This site should have a critical dip installed to avoid flow coursing down the trail and causing additional erosion. |

**Table F: High Priority Erosion Sites**

| Priority for Repair | Comments and Recommendations |
|---|---|
| High – direct delivery to creek; trail damage | Cinderella Trail borders Cinderella Creek and probably was originally constructed as a skid trail for logs. This trail is very steep and highly eroded. It currently functions as a bucket road: the convex road surface concentrates flow in the low point at the center of the trail and erodes fine sediment in storms. These fines are deposited on Sunset Trail and in Cinderella Creek. This trail needs to be re-graded to an outsloped condition with rolling dips to intercept sheet flow from the road. Several ephemeral tributaries and one spring to Cinderella Creek also course over the trail, adding to the runoff on the trail. These tributaries need culverts to move the water to Cinderella Creek. This trail should be considered for closure due to the high cost to repair and stop the environmental damage it causes. |
| Moderate | Chaparral Trail has numerous rills and gullies and needs to be rebuilt in sections using new grade control steps to stabilize the trail and reduce erosion. |
| Moderate – monitor repairs for downstream effects | A storm drain at the top of the ridge on Castle Drive combined with clearcutting of Eucalyptus caused a major erosion site in an ephemeral creek channel. An expensive repair was installed following over 10 years of erosion, ineffective repairs, direct delivery to Palo Seco Creek, and environmental damage. Several temporary repairs, installed prior to current project, failed. Current repair includes a pipe to move runoff through the gully and beneath the trail. The pipe outlets in the ephemeral creek channel just downslope from the trail crossing. This creek has significantly eroded and needs to be carefully monitored to avoid continued erosion. Pipe should be extended to culvert at Palos Colorados Trail to avoid eroding the creek. |
| Moderate | Palos Colorado Trail is eroding in numerous locations with direct delivery to Palo Seco Creek. Repairs should avoid filling or narrowing the creek to support the trail. |
| High – direct delivery to creek; trail damage | Stormwater runoff from Chabot Space & Science Center parking lots is eroding the Castle Park Trail. Directly delivers sediment to Cinderella Creek. |
| Moderate | Gully on Sinawik Trail |
| Moderate | Rill erosion on short steep trail near Horse Arena |
| Moderate | Rill erosion on steep section of Fern Ravine Trail |
| **Dimond Canyon** | |
| High | There is extreme erosion at two culvert outlets in Dimond Canyon; the first is the gigantic hole created by the shotgun culvert at Estates Drive on Park Blvd. and the second is near Park Blvd., just south of the Leimert Bridge: water runs down the trail for a considerable distance and has created numerous gullies. |
| High | The storm drain outlet near San Luis Avenue creates a huge gully in the restoration area. |
| High | The storm drain outlet at the end of Benevides Ave. has created a small landslide into the creek. |
| Moderate | There is a significant amount of erosion due to off-trail dogs; they've done a tremendous amount of damage to the native plantings in the El Centro restoration area and there are denuded swaths between Sam's Trail and the creek, and also along the Bridgeview switchbacks. |

**Table F: High Priority Erosion Sites**

| Priority for Repair | Comments and Recommendations |
|---|---|
| Moderate | Montclair Golf Course uses a golf ball vacuum on the lower area of the driving range, creating a sediment source just above the culvert outlet. |
| **Shepherd Canyon and Montclair Railroad Trail Park** | |
| High | The Zinn Drive/trail area is the source of a lot of sediment along the Montclair Railroad Trail. There are two or three shotgun culverts with large gullies below the trail; the deteriorating edge of the fire road has many small landslides; and the very large landslide below Cortez Court has blocked the creek channel, creating rills and gullies for about 150 feet along the fire road. The 500 feet of ephemeral creek channel above is basically an eroding gully, up to 3 feet deep and 5 feet wide. |
| Moderate | Escher Creek is eroding very quickly: former eroding ephemeral creek channels upstream were culverted a few years ago. Karen Paulsell estimates that the creek has downcut at least 1 foot in about 5 years at one creek crossing. |
| Moderate | A lot of the steep hillsides above and below Escher Drive are regularly denuded, with a lot of bare soil exposure, partially due to the WPD vegetation management. Erosion continues all the way down the Escher Creek channel, and is high between the restroom and the standpipe at Shepherd Canyon Road. |
| High | Storm drain outlets SC-4-04 and SC-4-05 join to form a large gully, 6 feet wide by 8 feet deep and at least 100 feet in length. |
| Moderate | Many homeowners clear like the WPD does: down to bare soil, adding to the silt load. |
| **Cobbledick Creek** | |
| High | A landslide at Haverhill Dr. is affecting Beaconsfield Canyon, with the landslide deposition blocking the creek channel and flow diverted onto the fire road. |
| Moderate | Upstream from Haverhill Dr., the creek is eroding soil from under the edge of the road. |
| Moderate | A new and significant gully has appeared in Castle Canyon; a possible cause is a new storm drain installed on private property at the top of the canyon. It is very likely that this gully is responsible for the large amounts of deposition in the channel along Larry Lane. |
| High | One of the extreme creek channels is located on Holyrood Dr. in the upper part of the watershed; the homes next to this creek channel have soil eroded from underneath their foundations. |

## LAND USE AND MANAGEMENT

### *Relevant Plans, Policies, and Permitting*

Sausal Creek watershed is home to about 80,000 residents and includes 2127.6 acres of urban land covering 76.5% of the drainage. The density of housing varies between the steep hills of the upper watershed and flatter lands of the lower watershed. Above and just below Highway 13, residential density has less than 49% cover of impervious surfaces. From Dimond Park downstream, high intensity urban areas have 50-100% impervious coverage. Parkland and open space covers approximately 650 acres in the watershed or 23.5% of the drainage.

The City of Oakland has a Creek Protection, Storm Water Management and Discharge Control Ordinance. The purpose of the ordinance is to:

- Eliminate non-storm water discharges to the municipal storm drain system;
- Control the discharge to municipal storm drains from spills, dumping or disposal of materials other than storm water;
- Reduce pollutants in storm water discharges to the maximum extent practicable;
- Safeguard and preserve creeks and riparian corridors in a natural state;
- Preserve and enhance creekside vegetation and wildlife;
- Prevent activities that would contribute significantly to flooding, erosion or sedimentation, or that would destroy riparian areas or would inhibit their restoration;
- Enhance recreational and beneficial uses of creeks;
- Control erosion and sedimentation;
- Protect the public health and safety, and public and private property.

Portions of the Sausal Creek watershed are in the City of Oakland Wildfire Prevention District. The priorities of the Wildfire Prevention District for 2004-2014 are to:

- Establish and implement a strategic, cost-effective, sustainable, environmentally sensitive fuel management plan
- Encourage the involvement of and increase the knowledge of property owners, developers and the public-at-large in fire safe practices

### *Infrastructure*

The sanitary sewer system carries raw sewage from residential and commercial areas to the East Bay Municipal Utilities District (EBMUD) wastewater treatment facility in west Oakland. The maze of sewer lines in the hilly residential areas of Shephard Creek and Cobbledick Creek sub-basins appear to feed into main lines along the major creek courses. This system of sewer pipes from the upper watershed feeds into the main sewer, which follows Sausal Creek through Dimond Canyon. Several major lateral pipes feed into the main sewer in Dimond Canyon. Sewer pipes also cross Sausal Creek at several points in the lower watershed. The route of the main sewer line leaves the Sausal Creek bed at the end of Dimond Park and follows Dimond Avenue and then Fruitvale Avenue. There are several locations where the sanitary sewer system is known to overflow during large rainstorms. Where the main sewer extends down Sausal Creek from Highway 13 to Dimond Avenue, the manhole covers pop off the sewer in large storms and raw sewage flows into Sausal Creek. Sewage also flows out of the sewer manhole into Palo Seco Creek just upstream of the Highway 13 crossing on Joaquin Miller Court. There are likely additional locations where similar problems occur (Figure S).

**Figure S: Sanitary sewer overflow following the January 1, 2006 flood**

**Table G: Summary of Watershed Conditions**

| Feature | Opportunities | Constraints |
|---|---|---|
| Physical Features | Many of the creek channels in the upper watershed are open and unculverted.<br><br>Most of the Palo Seco Creek sub-basin is undeveloped.<br><br>Sausal Creek is largely unculverted from the Montclair Golf Course to just below Foothill Boulevard.<br><br>Palo Seco Creek and a large portion of Sausal Creek are in public parks.<br><br>Many of the ephemeral creeks in the upper watershed are natural channels. | The Sausal Creek watershed is "built out" as a residential area with some commercial areas. In a built out area it is more difficult to implement creek setbacks, low impact development (LID), stormwater detention, and other facilities to mitigate the pollutant and peak flow effects caused by urbanization than if an area is in the process of being developed.<br><br>The upper watershed is prone to landslides and erosion due to the steep slopes and highly fractured rock along the Hayward fault.<br><br>Most of the creeks downstream of I-580 are culverted.<br><br>Rainstorms of 1 inch precipitation or less cause a 1-year frequency flow event. This frequency flow disturbs aquatic habitats.<br><br>Trails in Joaquin Miller Park have numerous erosion sites.<br><br>Storm drains direct additional runoff into hillside ephemeral creeks, increasing erosion at the outlet of the culvert and in the creek channel. |
| Biological Features | Palo Seco Creek retains high quality aquatic habitat as demonstrated by the diversity, abundance, and pollution-sensitive taxa of aquatic insects sampled in the creek.<br><br>Although infested with invasive non-native plants in some locations, the parkland of the Sausal Creek watershed supports a diversity of native and rare plant species. | Sausal Creek watershed is 78% urban land uses with intensive development from the El Centro crossing downstream and less intensive development upstream.<br><br>Residential areas harbor numerous ornamental plants, some of which are invasive and can spread into natural creeks and out-compete native plants. These invasive non-native plants are widespread in the natural lands of Sausal Creek watershed. Urban areas are a never-ending source of infestation. Many invasive plants are fire hazards. |

**Table G: Summary of Watershed Conditions**

| Feature | Opportunities | Constraints |
|---|---|---|
| | A small population of rainbow trout lives in Sausal Creek and lower Palo Seco Creek.<br><br>There are a number of city parks in the watershed where projects to improve creeks and habitats can be implemented. | Water quality sampling at the five stations in the Sausal Creek watershed found excessive levels of nutrients, no persistent pollutants, and some negative effects from bioassay tests on sediment samples.<br><br>Aquatic insect sampling at all the Sausal stations found poor aquatic habitat conditions and limited aquatic insect abundance and diversity, with almost no pollution-sensitive taxa.<br><br>Bacteria sampling in Sausal Creek and Palo Seco Creek found levels of *E. coli* in excess of standards for water contact recreation in all but one sample. |
| Planning and Infrastructure | The City of Oakland has a creek protection ordinance.<br><br>Oakland has a Wildfire Prevention District works with residents to control invasive non-native plants that are also fire hazards.<br><br>FOSC has implemented a program of invasive non-native plant control and native plant installation involving and educating many residents. | The main sanitary sewer is located adjacent to and in Sausal Creek from below Highway 13 to Dimond Avenue. Raw sewage overflows occur during flood events and *E. coli* sampling indicates leaks may also be occurring.<br><br>Storm drain outlets in the Sausal Creek watershed create erosion in a number of locations.<br><br>The control methods used by the Wildfire Prevention District often cut the same vegetation numerous times and is believed to spread invasive plants through inappropriate management actions (FOSC 2010). |

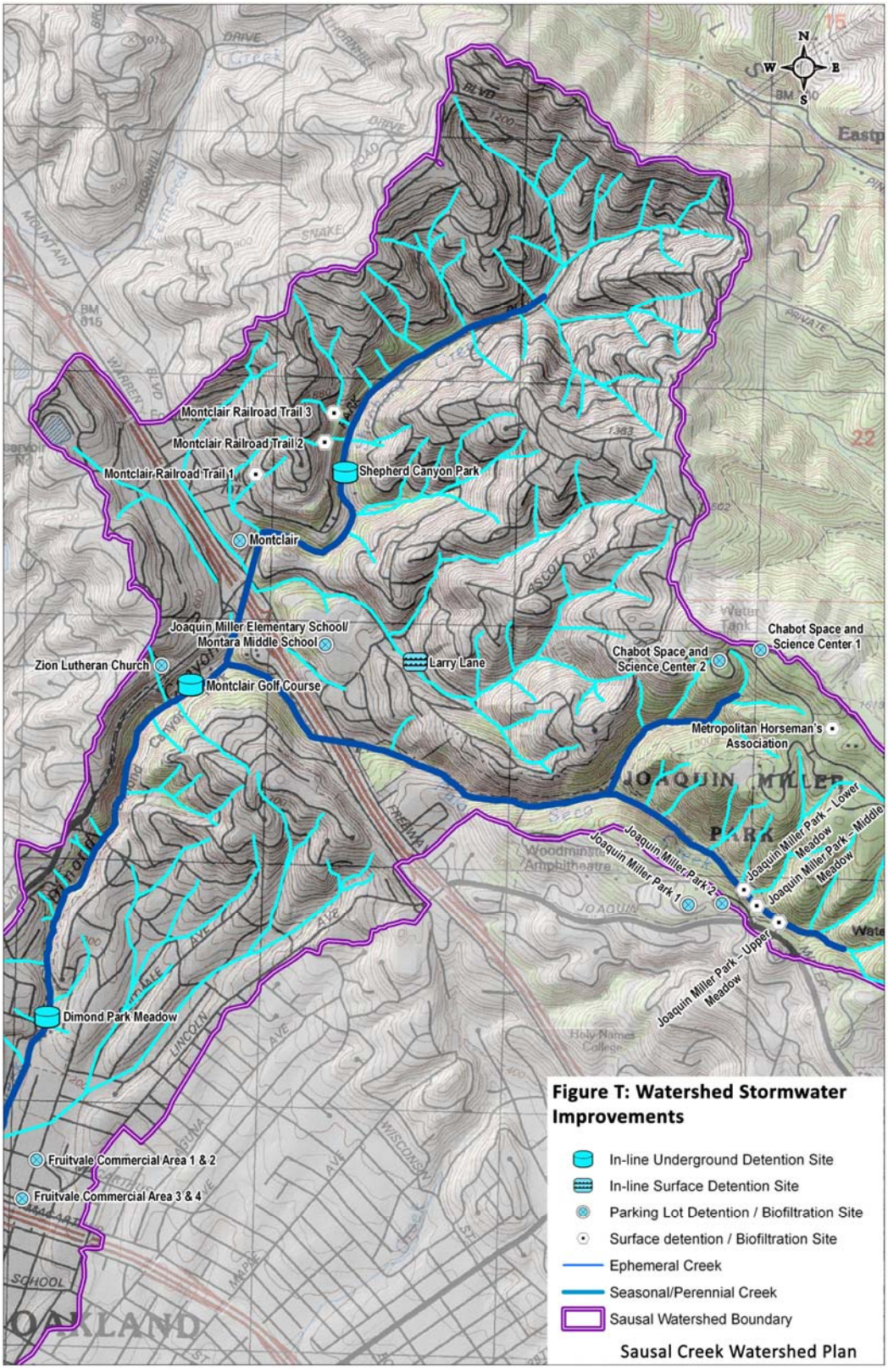
## EVALUATING WATERSHED STORMWATER IMPROVEMENTS

The assessment of existing conditions in the Sausal Creek watershed demonstrated that changing the volume and timing of stormwater entering the creek system could reduce the negative effects of urbanization on the aquatic and riparian system.

These conditions include:

- High levels of impervious surfaces (asphalt, cement, buildings) resulting in reduced infiltration of rainfall and increased runoff volumes over a shorter period of time.
- Small increments of rainfall produce larger runoff volumes. For example, a storm event with 0.5 inches of rainfall in a 24-hour period can generate a significant level of runoff.
- Poor habitat conditions for aquatic insects in Sausal Creek but good conditions in Palo Seco Creek, a largely undeveloped tributary basin.
- Frequent runoff events (1-year frequency) are capable of scouring the creek, moving gravel and reducing the ability of the creek to support aquatic insects and aquatic habitats.
- Channel entrenchment and the lack of functional floodplain limits riparian corridors to a narrow width and removes natural regeneration and ecological successional processes.
- Numerous erosion sites from storm drain outlets and erosion in many small creeks in the upper watershed.

The watershed was reviewed for locations where stormwater could be detained or temporarily held and released slowly to reduce the volume of peak flows in Sausal Creek. Figures T and U and Table F depict the locations of a series of watershed improvements.


Montclair Railroad Trail 3
Montclair Railroad Trail 2
Montclair Railroad Trail 1
Shepherd Canyon Park
Montclair
Joaquin Miller Elementary School/ Montara Middle School
Zion Lutheran Church
Montclair Golf Course
Larry Lane
Chabot Space and Science Center 1
Chabot Space and Science Center 2
Metropolitan Horseman's Association
Joaquin Miller Park – Lower Meadow
Joaquin Miller Park – Middle Meadow
Joaquin Miller Park 2
Joaquin Miller Park 1
Joaquin Miller Park – Upper Meadow
Dimond Park Meadow
Fruitvale Commercial Area 1 & 2
Fruitvale Commercial Area 3 & 4
Figure T: Watershed Stormwater Improvements
In-line Underground Detention Site
In-line Surface Detention Site
Parking Lot Detention / Biofiltration Site
Surface detention / Biofiltration Site
Ephemeral Creek
Seasonal/Perennial Creek
Sausal Watershed Boundary
Sausal Creek Watershed Plan

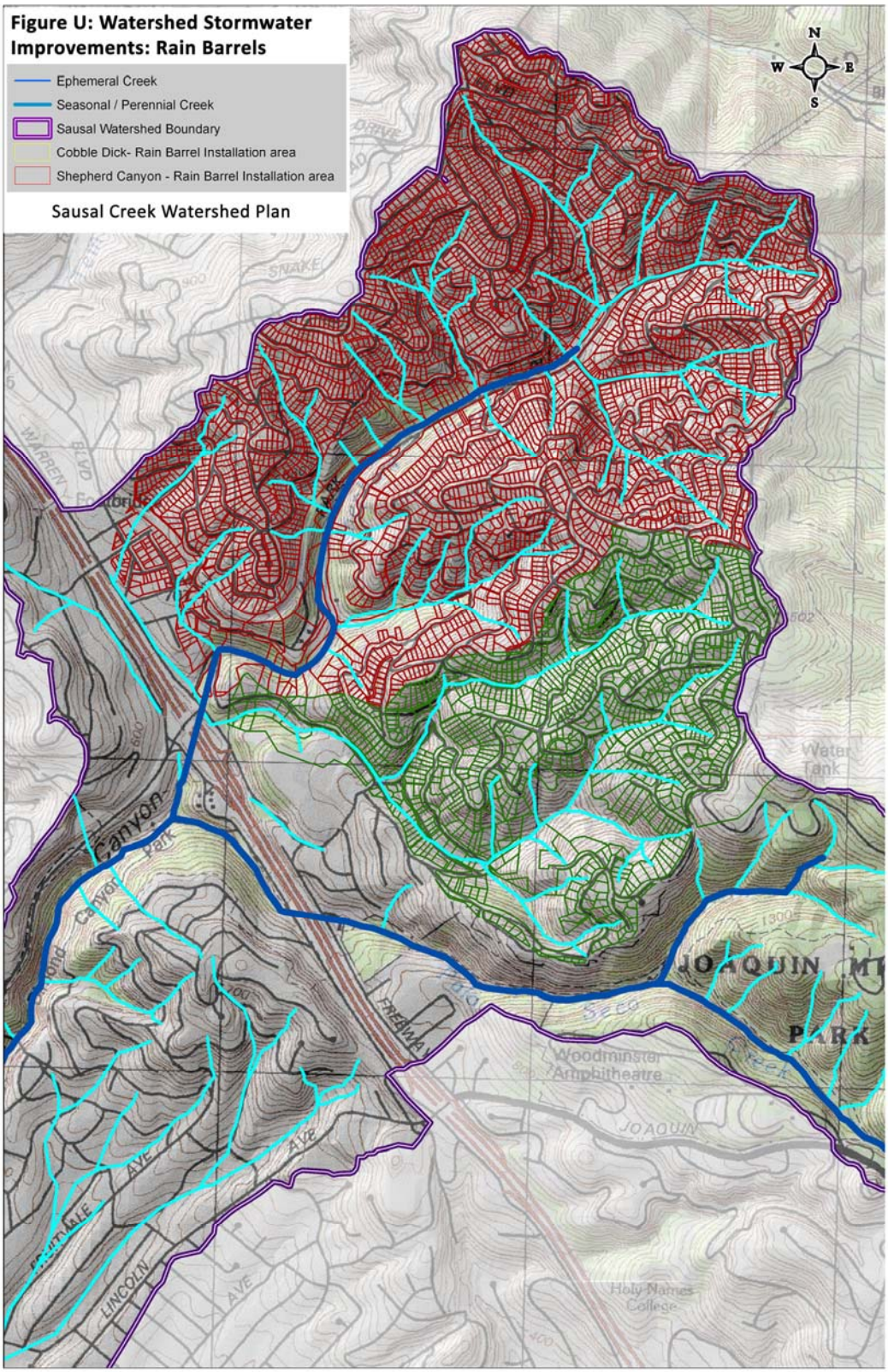


Figure U: Watershed Stormwater Improvements: Rain Barrels
Ephemeral Creek
Seasonal / Perennial Creek
Sausal Watershed Boundary
Cobble Dick- Rain Barrel Installation area
Shepherd Canyon - Rain Barrel Installation area
Sausal Creek Watershed Plan
N
W
E
S
Canyon
Park
FREEWAY
Woodminster Amphitheatre
JOAQUIN
Holy Names College
LINCOLN
AVE

**Table H: Sausal Creek Watershed Stormwater Improvement Sites**

| Improvement | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Rain barrel at each house in the Shephard and Cobbledick Creek sub-basins | ✓ | ✓ | ✓ |
| Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Joaquin Miller Elementary School/Montara Middle School Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Montclair Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Joaquin Miller Park Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Zion Lutheran Church Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 1 | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 2 | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 3 | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Upper Meadow Detention Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Middle Meadow Detention Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Lower Meadow Detention Site | ✓ | ✓ | ✓ |

**Table H: Sausal Creek Watershed Stormwater Improvement Sites**

| Improvement | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Metropolitan Horseman's Association Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 3 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 4 | ✓ | ✓ | ✓ |
| Shepherd Canyon Park – Underground Cistern | | ✓ | ✓ |
| Larry Lane On-stream Detention Pond | | ✓ | ✓ |
| Montclair Golf Course – Underground Cistern | | | ✓ |
| Dimond Park Meadow – Underground Cistern | | | ✓ |

The watershed improvements under Scenarios 1, 2, and 3 for Sausal Creek watershed would result in localized reductions to flow rates and flow volumes in Sausal Creek and tributaries. The hydrology results indicate that while all three scenarios would reduce runoff rates and volumes in the Sausal Creek watershed, the specific types of stormwater facilities and their locations in the watershed have a great bearing on localized hydrologic patterns. Comparing the three scenarios to existing conditions reveals the following trends:

- Stormwater source control practices such as the rain barrels, parking lot detention, and small detention basins simulated in Scenario 1 have a significant effect on reducing flow rates and volumes for the 1-year event. Larger storm events produce larger quantities of runoff, which quickly overflow these facilities; thus reductions in flow rates and volumes are minor for the 2 to 100 year events.

- Cisterns and detention basins significantly reduce flow rates in the reaches below the facilities for the 1-year event, and less so for the larger events. However, as other, uncontrolled

tributaries join the channel downstream of the detention facility, the flow dampening effect becomes less pronounced. Flow volumes are less affected by the detention facilities.

- The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

- In relation to the other sub-basins, Palo Seco Creek is relatively undeveloped. The proposed improvements in that sub-basins included in Scenario 1 reduce flow rates by 14% to 17%, and flow volumes by 15% to 24% compared to existing conditions for the range of storm events. Because the majority of the improvements occur on publicly-owned lands, implementation of these measures may be simpler and less expensive. For these reasons, it is recommended that the Palo Seco Creek sub-basins be considered for a demonstration project.

In an urbanized watershed like Sausal Creek, reductions in peak water depths, velocities, and shear stresses can lead to habitat improvements in the creeks. However, it can be extremely difficult to identify and acquire adequate space to implement measures that can have meaningful impacts on watershed hydrology in an urbanized watershed. The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

As a first step in implementing the watershed stormwater improvements of Scenario 3 the proposed improvements in Palo Seco Creek sub-basin should be completed as a demonstration projects

**Biofiltration**

An additional water quality benefit can be gained through the installation of biofiltration facilities in the parking lots. Parking lots concentrate oil and grease residues, a persistent pollutant in urban stormwater. With the use of biofiltration facilities, stormwater runs off the parking lot and into biofiltration units before entering the storm drain. Each biofiltration facility has a surface mulch layer which catches particles. Shredded hardwood, pine bark, tree chips, or coarse peat moss are typical mulch materials. Leaf or grass compost is not recommended. Stormwater is directed into the biofiltration facility through a curb cut in the parking lot. Floatable trash is caught on the surface of the device. As the stormwater filters through the mulch layer, trash and particulates are caught. Beneath the mulch are rapid infiltration layers of coarse sand and gravel. It is important to limit clay and silt in

this layer to less than five percent of the total volume. At the base is an underdrain which takes the filtered water to the storm drain system. It is also possible to infiltrate the filtered water if soil types and groundwater levels are appropriate. Each facility has plants, trees, shrubs, and low-growing herbs or rushes which are part of the filtration system. As nutrients such as nitrate fertilizers are filtered out, the plant roots uptake these materials. There needs to be a large number of these small facilities distributed over the drainage in order to have an impact on pollutant levels.

## RECOMMENDED ACTIONS

### MAJOR EROSION SITES

- The watershed assessment identified a number of storm drain outlets with erosion problems. Many of these erosion sites are in public parks. Each one of the erosion sites requires a site-specific repair and the involvement of the City of Oakland Public Works Department. The storm drain system is owned and maintained by the City and repair is their responsibility.
- Homeowners could benefit from workshops on storm water management to reduce erosion and increase slope stability. This workshop could be combined with workshops on rain barrel installation and maintenance.
- The erosion sites documented for Joaquin Miller Park point to a need for re-design and maintenance of many of the park trails. In addition, several of these erosion sites were caused by urban stormwater runoff released into public lands from residential areas (Castle Drive) and new developments (Chabot Space & Science Center). The City's approval of a large development like the Chabot Space & Science Center with no provision to reduce the effects of storm water runoff from large parking lots built on top of a slope indicates the need for the City of Oakland to specifically evaluate this impact when permitting new development in the Oakland hills.

### WATERSHED STORMWATER IMPROVEMENTS

- Urban development causes a permanent change in the watershed processes of infiltration of rainfall and runoff of stormwater. These system-wide changes in the drainage basin produce larger volumes of stormwater delivered into creek channels over a short time frame. In response, ephemeral creeks in the steep hills of the watershed erode and can initiate a slide on the hillslope.
- All of the aquatic insect studies in Sausal Creek show poor aquatic habitat conditions. While urban creeks can be daylighted and enhanced with vegetation, studies of urban creek restoration projects in numerous locations show only small improvements in aquatic habitat conditions. This lack of habitat improvement occurs because the urban watershed still produces high velocity flows which scour creeks and greatly reduce aquatic habitat values. Mitigating the effects of urbanization through watershed stormwater improvements can improve aquatic conditions, reduce bank erosion and sustain riparian habitat to a much greater extent than creek restoration projects alone will ever accomplish.

- Stormwater source control practices such as the rain barrels, parking lot detention, and small detention basins simulated in Scenario 1 have a significant effect on reducing flow rates and volumes for the 1-year runoff event. Larger storm events produce larger quantities of runoff,

which quickly overflow these facilities producing only minor reductions in flow rates and volumes for the 2- to 100-year events.

- Cisterns and detention basins significantly reduce flow rates in the reaches below the facilities for the 1-year event, and less so for the larger events. However, as additional tributaries join the channel downstream of the detention facility, the flow dampening effect becomes less pronounced. Flow volumes are less affected by the detention facilities.

- The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

- In relation to the other sub-basins, Palo Seco Creek is relatively undeveloped. The proposed improvements included in Scenario 1 within the sub-basin reduce flow rates by 14% to 17%, and flow volumes by 15% to 24% compared to existing conditions for the range of storm events. Because the majority of the improvements occur on publicly-owned lands, implementation of these measures may be simpler and less expensive. For these reasons, it is recommended that implementation of watershed stormwater improvements in the Palo Seco Creek sub-basin be considered as a demonstration project.

- The larger program of watershed stormwater improvements in the other sub-basins can be phased over a 10-year period as grant funds become available.

- Installation of biofiltration facilities along roads and in parking lots should be implemented in as many locations as possible as part of the pilot green street projects required by the Regional Board NPDES permit.

**INVASIVE NON-NATIVE PLANTS**

The abundance and broad distribution of invasive non-native plants in the Sausal Creek watershed is a major threat to native habitat in public parkland and creeks. This problem is further exacerbated by the purchase and planting of many of these invasive species by uninformed homeowners, creating an infinite source of infestation in the watershed.

The main actions recommended to address the invasive plant problem are:

- Eradication of invasives in the Palo Seco Creek sub-basin would implement the best opportunity for improvements of both upland and creek habitats.

This effort, while involving FOSC and the Friends of Joaquin Miller Park, will require grant funding and contracts with companies who specialize in invasive plant mapping and eradication projects. This is a major ecological restoration project and requires a larger-scale, more difficult work effort than community volunteers can provide. The watershed lands outside the park need to be included to evaluate all infested locations on ridge tops and upstream locations. The ridge tops and headwaters are sources of infestation to downhill and downstream areas and should be treated first. Using GPS/GIS, map invasive plants listed in Table 77 and devise an eradication strategy, taking into account the rate of spread, population size, and proximity to at-risk stands of rare plants or intact stands of native vegetation. Using GPS/GIS, also map and identify any rare, unusual or significant plants at risk from invasive plant populations and identify native plant "hotspots" at risk from invasive plant populations. Determine creek and hillside locations most susceptible to bank failure or erosion due to invasive plant infestations.

Areas along trails and roads are priority control areas due to the spread of seed and stem materials by hikers, dogs, and bicyclists.

The use of herbicide as a cut-and-paint method will be needed to make eradication efforts effective. The use of controlled burns may also be evaluated, especially for Algerian ivy infestations. Work should be done by paid contractors.

The eradication effort needs to be well-publicized to neighboring homeowners and park users. Both fire hazards and ecological issues need to be explained thoroughly. Neighboring homeowners with these species on their property should be encouraged to participate in the eradication effort. For the other invasive species—Cape ivy, Algerian ivy, yellow star thistle, Himalayan blackberry, holly, and various grasses—a broad-based community outreach effort is needed.

By focusing on invasive plant eradication in Joaquin Miller Park, public funding may be available, particularly if the program can describe this effort in terms of acres of each habitat type improved and number of private landowners involved. The eradication of non-natives in the Palo Seco Creek watershed will need to extend over at least a 5- to 10-year period.

- Homeowner education throughout the watershed on invasive garden plants could reduce the re-infestation problem. Homeowners provide the primary infestation mechanism of invasive non-native plants in the Sausal Creek watershed through their planting, cultivation, and disposal of garden waste in creeks and empty lots. It is likely that most homeowners do not realize the long-term negative effects of their actions.

- The sale of known invasive non-native plants in the state needs to be restricted.

- Maintenance of revegetation sites free of invasive non-native plants is needed.

- Focused eradication of fire hazard invasive plants is needed in the entire watershed.

**WATER QUALITY**

- The most serious water quality problem identified from the monitoring data is high *E. coli* levels in Sausal Creek and raw sewage spills and overflows from the sanitary sewer system. In the short-term when sewage spills occur in open creek areas where children have access to the water, the City of Oakland must post closure signs. *E. coli* measured at high levels by the water quality monitoring indicates a potential health hazard for water contact recreation. A watershed-wide program of bacterial monitoring and monitoring of the location of sewage spills and overflows need to be implemented by the City in conjunction with the San Francisco Bay Regional Water Quality Control Board and the Environmental Protection Agency. Identifying the locations of sewage spills will assist in implementing a control program. In the long-term, the sewer system needs to be upgraded so that stormwater infiltration into the sewer pipes, a major cause of overflows, is eliminated. Dry season leaks indicated by the monitoring results also need to be identified and repaired.

- In addition to bacteria monitoring, monitoring of aquatic insects in creeks in the watershed can provide a long-term basis for comparison of conditions and improvements. As discussed on page 105, aquatic insects are an excellent indicator of the condition of aquatic habitats. Sausal and Palo Seco Creeks have had aquatic insect monitoring from 1999-2004/2005 to set a baseline for current watershed conditions. As watershed stormwater improvements are implemented, continued aquatic insect monitoring can document the change in aquatic habitat conditions resulting from reduced scour and lower flow velocities. Aquatic insect monitoring should be done using the SWAMP protocols and a professional lab. A spring and fall sampling at all the SWAMP stations with an additional station in the upstream area of Palo Seco Creek would provide adequate review of changes and improvements.

- The implementation of biofiltration improvements, if completed in enough locations, can effectively remove nutrients and persistent pollutants typical of urban runoff. These facilities also collect floatable trash. Biofiltration facilities, however, require maintenance annually or they are not effective.

- Trash as a pollutant also can be reduced through the work of volunteers, neighborhood groups, and businesses. It can also be controlled through enforcement of littering and dumping laws. The City of Oakland has tried using citations to reduce littering.

**AQUATIC AND RIPARIAN HABITATS**

- Except for Palo Seco Creek, the aquatic and riparian habitats of the Sausal Creek watershed have been significantly degraded by urbanization of the watershed and the increase in storm flow volumes and velocities, and the resulting scour of the channel. The first and most important step in restoring aquatic habitats in the Sausal Creek watershed is implementation of watershed stormwater improvements to reduce the scouring high velocity flows caused by urbanization of the watershed.

- By focusing on creek restoration, invasive plant removal, and watershed stormwater improvements in Palo Seco Creek, the greatest degree of habitat enhancement can be achieved.

This approach could create high quality aquatic habitat in Palo Seco Creek and provide a genuine refuge for a resident population of rainbow trout. This same goal cannot be met on Sausal Creek. With implementation of all of the watershed stormwater improvements in Scenario 3, flow velocities and channel scour in Sausal Creek still exceed thresholds needed to support high quality aquatic habitat conditions under most flood levels. Implementation of Scenario 3, however, does represent a major improvement in creek conditions under the most frequent 1-year flow event.

- Table I outlines recommended actions in the creek reaches available for revegetation and improvement. Most of the restoration recommendations will require designs by qualified professionals: civil engineers, geomorphologists, hydrologists, and riparian ecologists. They will also require implementation by contractors with experience in stream restoration. Community groups like FOSC and Friends of Joaquin Miller Park can supply assistance to grant efforts, grow native plants in the Joaquin Miller nursery, coordinate volunteer assistance with planting native plants, and maintain creek areas after restoration.

**Table I: Restoration Recommendations for Stream Reaches***

| Reach | Priority | Recommendations |
|---|---|---|
| PSC1 | High | • Repair Erosion Site 1 by installing culvert where the trail crosses an ephemeral creek. Culvert must be set in the channel at the slope of the stream to minimize erosion at the culvert outlet and have a minimum of 18 inches of trail fill on top to avoid damage to culvert. Fine sediment from this erosion site is filling the creek.<br>• Relocate trail out of meadow and direct traffic onto Sunset Trail. Restrict bikers and hikers to allow stream restoration.<br>• Install berm at downstream end of Upper Meadow with standpipe connected to culvert under trail. Eradicate Himalayan blackberry and revegetate the floodplain with native trees.<br>• This reach offers one of the only locations for a floodplain riparian restoration with a detention and sediment basin. This site is part of the overall watershed improvements to reduce velocity and volume of stormwater and improve Palo Seco Creek aquatic habitat. |
| PSC2 | High | • The creek is culverted through a meadow likely created during the WPA era when recreational areas were created at the expense of environmental protection.<br>• This reach is a major candidate for daylighting and restoration, especially as the culverts are old and will require replacement in the near future.<br>• Install berm at downstream end to detain stormwater during peak runoff events.<br>• The downstream portion of Fern Ravine Creek now runs overland during nearly every rainfall event as the culvert outlet clogs. The creek should be daylighted and directed into the proposed stormwater detention area and eventually integrated with a daylighted and restored Palo Seco Creek. |
| PSC3 | High | • Improved grade control structures need to be installed at the two knickpoints (Erosion Sites 3 and 4) to avoid the migration of the knickpoints upstream and the undercutting of large trees. Downstream of the bridge a number of trees along the banks have been eroded. The banks should be set back and revegetated once the Himalayan blackberry is removed. |
| PSC4 | High | • Invasive non-native plants are degrading the redwood/California bay laurel forest riparian habitat and weakening the trees. Holly trees are the only species regenerating in the corridor. The holly and ivy need to be eradicated to restore the health of the forest. Ivy should be cut around the base of each tree, and the stumps immediately painted with herbicide to kill the ivy quickly and effectively. If the trees along the steep-sided gorge become weakened by the parasitic ivy and fall, the slopes may fail due to the ground disturbance. The holly needs to be cut and the stumps painted with herbicide to quickly remove this invader before it becomes established and dominates the corridor. |
| PSC5 | Moderate | • FOSC has completed an erosion control project and an invasive plant removal/native plant revegetation project here. Continued maintenance will be needed.<br>• Replace bridge at stream level or re-route trail. |

**Table I: Restoration Recommendations for Stream Reaches***

| Reach | Priority | Recommendations |
|---|---|---|
| CC1 | Low | • Houses line the upstream portion of this reach, leaving few opportunities for restoration. The sediment/stormwater detention basin on this reach needs to be cleaned out and retrofitted in order to function better. A large gully in this sub-basin requires repair. |
| CC2 | Moderate | • The Beaconsfield Canyon reach needs to have the rusted culvert removed and a geomorphic /revegetation restoration plan that includes a riparian floodplain area completed.<br>• Downstream drop inlet to storm drain needs to be repaired/replaced. |
| SC1 | Low | • This reach presents a real challenge for restoration. There are two major culverts and numerous concrete structures including a cement wall protecting the sanitary sewer pipe.<br>• California bay laurel trees have eroded off the canyon wall and into the creek. Replanting these trees will maintain shade cover for the creek.<br>• Eradicate ivy and other invasives to retain health of native trees.<br>• Work with the City of Oakland to repair erosion from storm drains, especially the major erosion sites along Park Blvd.<br>• Sanitary sewer overflows into Sausal Creek occur during major storms and need to be alleviated to avoid both contamination of the creek and a public health problem. |
| SC2 | Low | • This reach is a restoration project completed in 2001. Control of invasive plants and revegetation are necessary both along the channel and alongside channels. The channel does not provide adequate room for regeneration of riparian species, and replanting will be required. Installing white alder along the channel could diversify the vegetation and provide some stability to the undercut bank areas, which provide refuge to wildlife in floods. |
| SC3 | Moderate | • Replanting of white alder and removal of waste cement and asphalt is needed along this reach. Riparian shade cover over the El Centro pool is also needed to maintain cool water temperatures.<br>• Recreation uses preclude the option of daylighting the creek through Dimond Canyon Park.<br>• Future City of Oakland project to stabilize private property and revegetate stream banks. |
| SC4 | Low | • Creek is entrenched with steep banks and fill from the McKillop slide. With this slide affecting the creek it is difficult to implement revegetation. Houses are very close to the channel, further restricting restoration options. Community-based invasive plant removal and native plant installations would provide local educational opportunities. |
| SC5 | Low | • Creek is entrenched with steep banks and numerous houses. Channel is hardpan clay and revegetation will be difficult in most locations. Community-based invasive plant removal and native plant installations would provide local educational opportunities. |

* Stream restoration should be implemented once watershed stormwater improvements are also implemented.

**IMPLEMENTATION OF THE WATERSHED PLAN**

There are recommended actions in this plan that are suitable for community groups such as Friends of Sausal Creek (FOSC), Friends of Joaquin Miller Park, Shepherd Canyon Homeowners' Association, and others. Many of the actions needed to restore productive aquatic habitat to Sausal Creek and its tributaries, however, require a significant change to storm drain and sanitary sewer infrastructure, including construction of both stormwater detention facilities and creek restoration. This change requires the involvement of the owner of the infrastructure: the City of Oakland. Many areas of Oakland have old and deteriorating infrastructure such as storm drain and sewer systems. The construction of stormwater detention and biofiltration facilities may be able to attract grant funds and allow for the upgrade of storm pipes as part of water quality and creek improvements. The recent municipal stormwater permit from the San Francisco Bay Regional Water Quality Control Board to Alameda County requires implementation of LID (low impact development) practices. This permit also requires the construction of two pilot green street projects. The recommended focus on Palo Seco Creek sub-basin as a demonstration project includes a number of stormwater detention facilities on City property. Table J outlines lead and supporting agencies and organizations for each of the recommended actions in the watershed plan.

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| **Major Erosion Sites** | | | |
| Repair extreme and eroded sites at outlets of City storm drain system | City of Oakland | San Francisco Bay Regional Water Quality Control Board<br><br>FOSC and neighborhood groups | Adopt-a-Stormdrain program could be used to maintain repaired outlets and repaired erosion sites. |
| Homeowner workshops on stormwater management | Alameda Countywide Clean Water Program | FOSC and neighborhood groups | |
| Repair erosion sites in City parks, including relocation and re-grading of trail | City of Oakland | FOSC, Friends of Joaquin Miller Park, Friends of Beaconsfield Canyon, Piedmont Pines Neighborhood Association, and other neighborhood groups | Volunteer groups can play a major role in implementing improvements in parks but designs need to be done by professionals. |
| **Watershed Stormwater Improvements** | | | |
| *High Priority* | | | |
| Implement Scenario 1 improvements in Palo Seco Creek sub-basin including:<br>• Retrofit Chabot Space & Science Center parking lots 1 and 2 to detain stormwater and install biofiltration units<br>• Retrofit Joaquin Miller Park parking lots to detain stormwater and install biofiltration units | Chabot Space and Science Center Joint Powers Agency<br><br>City of Oakland | FOSC<br><br>San Francisco Bay Regional Water Quality Control Board<br><br>Alameda Countywide Clean Water Program<br><br>Friends of Joaquin Miller Park | Due to the low level of development in this sub-basin, the greatest level of creek habitat improvement can be achieved by installing stormwater facilities. Detention facilities can also reduce the need for replacement of undersized storm drains.<br>The ridgetop parking lots near the Joaquin Miller Community Center drain toward Joaquin Miller Park. The stormwater runoff from the Chabot Space and Science Center is actively eroding areas of the park. |
| Joaquin Miller Park – Upper, Middle, and Lower Meadow detention sites | City of Oakland<br><br>FOSC | Friends of Joaquin Miller Park<br><br>Alameda Countywide Clean Water Program | These facilities include daylighting lower Fern Ravine Creek. Daylighting Palo Seco Creek through the meadow can also be included in the detention design. |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Metropolitan Horsemen's Association parking lot detention and biofiltration site | City of Oakland | Friends of Joaquin Miller Park<br><br>Alameda Countywide Clean Water Program<br><br>FOSC | |
| Implementation of biofiltration facilities along streets and in parking lots | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | Alameda Countywide Clean Water Program<br><br>FOSC and other community organizations | |
| *Long-Term Priority* | | | |
| Implementation of watershed stormwater improvements for Sausal Creek | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | Alameda Countywide Clean Water Program<br><br>FOSC and other community organizations | The only long-term option for sustainable improvement in Sausal Creek requires the implementation of Scenario 3 of watershed stormwater improvements. |
| **Invasive Non-Native Plants** | | | |
| Implement a comprehensive mapping, invasive plant eradication/native planting program in the Palo Seco Creek sub-basin | FOSC<br><br>City of Oakland | Wildfire Prevention District | This program should be implemented with grants and contractors skilled in invasive plant eradication (i.e., Shelterbelt Builders, California Conservation Corps). Relying on community volunteers limits the extent and location of invasives removed and cannot accomplish a comprehensive program. Palo Seco Creek sub-basin offers the best opportunity for large-scale restoration of upland and wetland/riparian habitats. |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Homeowner education | Wildfire Prevention District<br><br>FOSC<br><br>City of Oakland | Homeowner and community groups | Urban gardens are the primary infestation mechanism for invasive non-native plants. Most homeowners are not aware of the problem and could be convinced to avoid planting them. |
| Ban the sale of invasive plants for gardens | City of Oakland<br><br>FOSC and Friends of Joaquin Miller Park<br><br>Wildfire Prevention District | Homeowner and community groups<br><br>California Native Plant Society<br><br>California Invasive Plant Council | The continued sale of invasive plants in California is a state-wide issue. |
| Maintain FOSC revegetation projects | FOSC | Community volunteers | Invasives have affected FOSC revegetation projects in several locations. |
| Control fire hazard plants | Wildfire Prevention District | FOSC, Friends of Joaquin Miller Park, Friends of Beaconsfield Canyon, Piedmont Pines Neighborhood Association, and other neighborhood groups | Eradicating fire hazards and not planting these species are important actions in fire reduction. |
| **Water Quality** | | | |
| Monitor creeks for *E. coli* | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | EPA, FOSC, and community groups | |
| Monitor location and frequency of sewage spills | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | EPA, FOSC, and community groups | |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Post creek areas in parks when sewage overflows occur | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | EPA, FOSC, and community groups | |
| Twice annual monitoring of aquatic insects at a number of stations in the watershed | San Francisco Bay Regional Water Quality Control Board<br><br>FOSC | City of Oakland | A long-term study of changes in aquatic insect communities as watershed improvements are implemented may attract academic interest. |
| Implement biofiltration projects to reduce nutrients, trash, and other pollutants | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | Alameda Countywide Clean Water Program<br><br>FOSC and other community groups | |
| **Aquatic and Riparian Habitats** | | | |
| *High Priority* | | | |
| Implement Watershed Stormwater Improvements, Scenario 1 | | | |
| Creek Reach PSC1<br>• Repair Erosion Site 1 by installing culvert where the trail crosses an ephemeral creek. Culvert must be set in the channel at the slope of the stream to minimize erosion at the culvert outlet and have a minimum of 18 inches of trail fill on top to avoid damage to culvert. Fine sediment from this erosion site is filling the creek.<br>• Relocate trail out of meadow and direct traffic onto Sunset Trail. Restrict bikers and hikers to allow | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Community groups | Palo Seco Creek has the greatest potential for major improvement in aquatic habitat conditions through a combined program of watershed stormwater improvements, creek restoration, and invasive plant eradication. This focus would create a sustainable habitat area to provide refuge for resident rainbow trout. |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| stream restoration.<br>• Install berm at downstream end of Upper Meadow with standpipe connected to culvert under trail. Eradicate Himalayan blackberry and revegetate the floodplain with native trees.<br>• This reach offers one of the only locations for a floodplain riparian restoration with a detention and sediment basin. This site is part of the overall watershed improvements to reduce velocity and volume of stormwater and improve Palo Seco Creek aquatic habitat. | | | |
| Creek Reach PSC2<br>• The creek is culverted through a meadow likely created during the WPA era when recreational areas were created at the expense of environmental protection.<br>• This reach is a major candidate for daylighting and restoration, especially as the culverts are old and will require replacement in the near future.<br>• Install berm at downstream end to detain stormwater during peak runoff events.<br>• The downstream portion of Fern Ravine Creek now runs overland during nearly every rainfall event as | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Urban Creeks Council and other community groups | Daylighting Palo Seco and Fern Ravine Creeks would be one of the largest habitat improvements in the watershed; however, it would require a major re-design of recreational uses of a part of Joaquin Miller Park |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| the culvert outlet clogs. The creek should be daylighted and directed into the proposed stormwater detention area and eventually integrated with a daylighted and restored Palo Seco Creek. | | | |
| Creek Reach PSC3<br>• Improved grade control structures need to be installed at the two knickpoints (Erosion Sites 3 and 4) to avoid the migration of the knickpoints upstream and the undercutting of large trees. Downstream of the bridge a number of trees along the banks have been eroded. The banks should be set back and revegetated once the Himalayan blackberry is removed. | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Community groups | |
| Creek Reach PSC4<br>• Invasive non-native plants are degrading the redwood/California bay laurel forest riparian habitat and weakening the trees. Holly trees are the only species regenerating in the corridor. The holly and ivy need to be eradicated to restore the health of the forest. Ivy should be cut around the base of each tree, and the stumps immediately painted with herbicide to kill the ivy quickly and effectively. If the trees along the steep-sided gorge become weakened by the | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Community groups | |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| parasitic ivy and fall, the slopes may fail due to the ground disturbance. The holly needs to be cut and the stumps painted with herbicide to quickly remove this invader before it becomes established and dominates the corridor. | | | |
| *Moderate Priority* | | | |
| Creek ReachPSC5<br>• FOSC has completed an erosion control project and an invasive plant removal/native plant revegetation project here. Continued maintenance will be needed.<br>• Replace bridge at stream level or re-route trail. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach CC2<br>• The Beaconsfield Canyon reach needs to have the rusted culvert removed and a geomorphic /revegetation restoration plan that includes a riparian floodplain area completed.<br>• Downstream drop inlet to storm drain needs to be repaired/ replaced. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach SC3<br>• Replanting of white alder and removal of waste cement and asphalt is needed along this reach. Riparian shade cover over the El Centro pool is also needed to maintain cool water temperatures.<br>• Recreation uses preclude the option | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| of daylighting the creek through Dimond Canyon Park.<br>• Future City of Oakland project to stabilize private property and revegetate stream banks. | | | |
| *Low Priority* | | | |
| Creek Reach CC1<br>• Houses line the upstream portion of this reach, leaving few opportunities for restoration. The sediment/ stormwater detention basin on this reach needs to be cleaned out and retrofitted in order to function better. A large gully in this sub-basin requires repair. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach SC1<br>• This reach presents a real challenge for restoration. There are two major culverts and numerous concrete structures including a cement wall protecting the sanitary sewer pipe.<br>• California bay laurel trees have eroded off the canyon wall and into the creek. Replanting these trees will maintain shade cover for the creek.<br>• Eradicate ivy and other invasives to retain health of native trees.<br>• Work with the City of Oakland to repair erosion from storm drains, especially the major erosion sites along Park Blvd.<br>• Sanitary sewer overflows into Sausal | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Creek occur during major storms and need to be alleviated to avoid both contamination of the creek and a public health problem. | | | |
| Creek Reach SC2<br>• This reach is a restoration project completed in 2001. Control of invasive plants and revegetation are necessary both along the channel and alongside channels. The channel does not provide adequate room for regeneration of riparian species, and replanting will be required. Installing white alder along the channel could diversify the vegetation and provide some stability to the undercut bank areas, which provide refuge to wildlife in floods. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach SC4<br>• Creek is entrenched with steep banks and fill from the McKillop slide. With this slide affecting the creek it is difficult to implement revegetation. Houses are very close to the channel, further restricting restoration options. Community-based invasive plant removal and native plant installations would provide local educational opportunities. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach SC5<br>Creek is entrenched with steep banks and numerous houses. Channel is hardpan | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats |

**Table J: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| clay and revegetation will be difficult in most locations. Community-based invasive plant removal and native plant installations would provide local educational opportunities. | | Other community groups | unless Scenario 3 watershed stormwater improvements are implemented. |

**FINAL**

# SAUSAL CREEK WATERSHED ENHANCEMENT PLAN

Sausal Creek "Restoration Reach" in 2003

Prepared by Laurel Marcus and Associates, NewFields River Basin Services, Hydrologic Systems Inc.

For

Friends of Sausal Creek

March 2010

Funding provided by the State Water Resources Control Board and the San Francisco Foundation Bay Fund

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# SAUSAL CREEK WATERSHED ENHANCEMENT PLAN

## I. INTRODUCTION

In the middle of urban Oakland lies a series of parks which shelter Sausal Creek and create a green ribbon through the city. Unlike so many urban streams now flowing lifeless through pipes hidden beneath city streets, Sausal Creek has a natural channel over much of its length. Hikers can follow Sausal Creek and its tributaries from the top of the watershed on Skyline Boulevard down through Palo Seco and Dimond Canyons and past Interstate 580 before the natural creek channel is resigned to a culvert in the Oakland flatlands. Although the effects of its cemented urban drainage are everywhere, Sausal Creek is alive and inspiring. Native trees line the creek in many places and there is a small number of rainbow trout residing in its waters. These remnants of the natural world, gone from most of Oakland, make Sausal Creek a good candidate for enhancement actions, as well as community involvement and education.

The Friends of Sausal Creek (FOSC) formed in 1996 to focus community activities to learn about, protect, and enhance the creek and its watershed. FOSC has completed projects using volunteers to remove invasive non-native plants, install native plants, monitor water quality, control erosion, and complete a major creek habitat enhancement project. FOSC worked with Laurel Marcus & Associates (LMA), a consulting firm specializing in watershed planning, to raise grant funds to complete a plan for the Sausal Creek watershed.

The Sausal Creek watershed covers 4.5 square miles (2,777 acres) in Oakland (Figure 1). Most of the watershed has been developed for residential and commercial land uses. This development has changed the volume and rate of stormwater runoff. Impervious surfaces associated with development are the primary culprits, resulting in faster runoff and lower infiltration rates. The runoff is also collected in the pipes of a storm drain system and discharged into the creek at a few locations. This urbanization process results in peak flood flows well in excess of the natural conditions that formed the creek. These effects of urbanization are further exacerbated by the steep slopes of the upper Sausal Creek watershed.

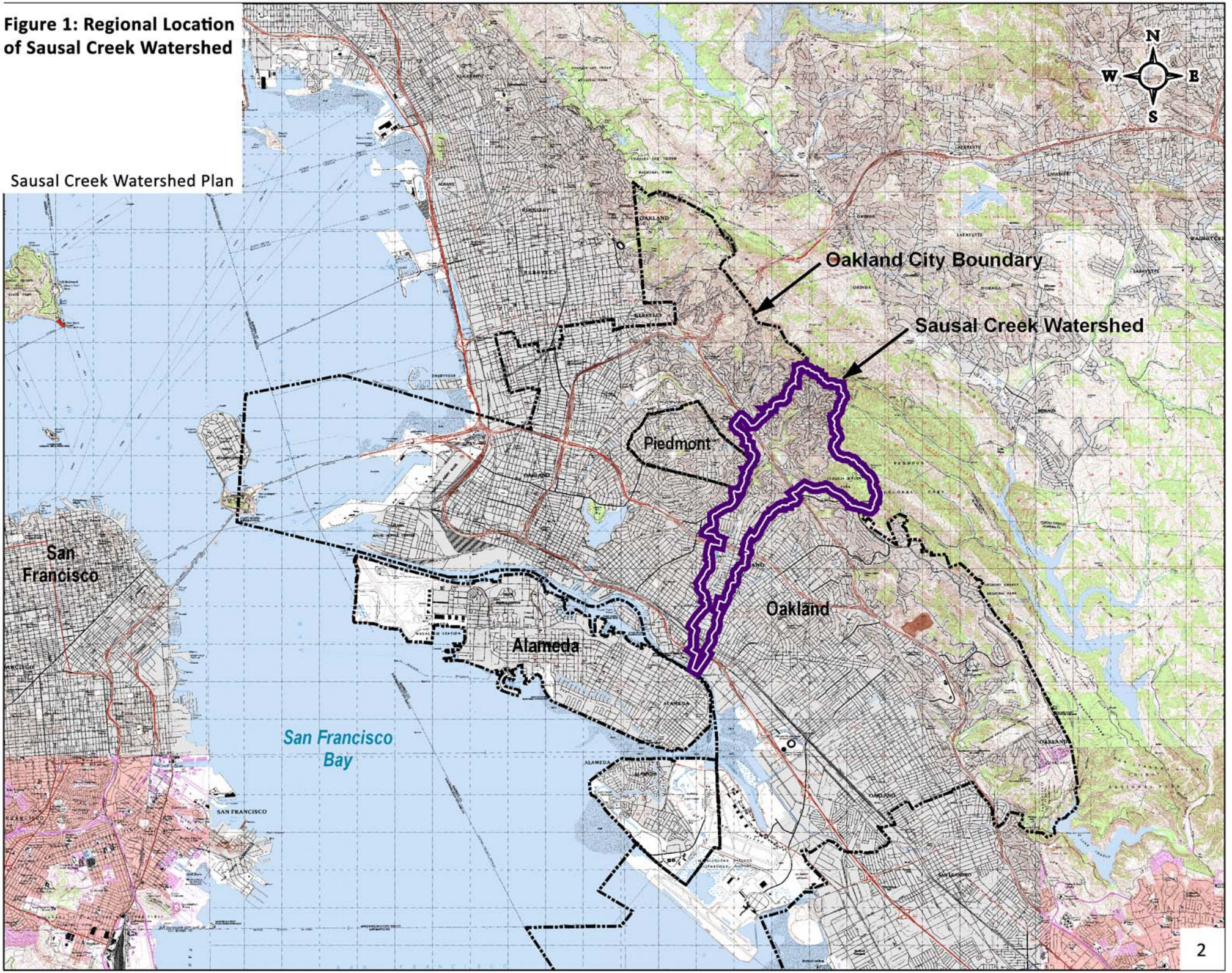
This plan characterizes the hydrology of the Sausal Creek watershed in order to document a baseline of flow, sediment loading, and channel conditions. From this baseline the degraded hydrological and ecological conditions of the channels, and the watershed processes that resulted in that degraded condition, can be identified. In highly urban watersheds, many factors that adversely impact the creek are intrinsic parts of the developed landscape. Successful restoration or revegetation of urban creeks depends upon evaluation of the larger watershed and implementation of projects that will most offset the effects of urbanization. This plan describes projects to address the conditions that are adversely impacting Sausal Creek and its tributaries, aquatic habitats, and water quality. Enacting a long-term plan to repair and improve the watershed will sustain Sausal Creek for future generations.

This plan for the Sausal Creek watershed will:

- Document the hydrology of the Sausal Creek watershed and identify watershed-based projects that, to the greatest extent feasible, mitigate the effects of urban runoff on Sausal Creek, its habitats and water quality;
- Collect and analyze existing water quality and aquatic insect monitoring data;

**Figure 1: Regional Location of Sausal Creek Watershed**





- Document erosion problems in the urban storm drain system and recommend improvements to reduce this erosion;
- Discuss the location and extent of non-native invasive plants on parklands and evaluate measures to eradicate these plants and revegetate with appropriate native plant species;
- Identify locations where riparian habitat enhancement can be implemented;

**FRIENDS OF SAUSAL CREEK (FOSC)**

The Friends of Sausal Creek (FOSC) are a group of residents, teachers, students, merchants, and elected officials working together with the City of Oakland and County of Alameda to improve the Sausal Creek watershed. The Friends Vision Statement expresses the group's hope of creating an intact riparian corridor from the hills to the bay that's accessible to all. The Friends' mission is: "to promote awareness and appreciation of the Sausal Creek watershed, and to inspire action to preserve and protect the creek and its watershed as both a natural and a community resource." Formed in 1996, the Friends recognize that citizen participation is critical for building a long-term commitment to protecting Sausal Creek as a natural resource for the greater Oakland community. FOSC operates a native plant nursery at Joaquin Miller Park

## II. BACKGROUND

In 2005 the State Water Resources Control Board (SWRCB) approved an $180,000 grant to the Friends of Sausal Creek (FOSC) to produce a watershed plan for the Sausal Creek watershed. Additional grant funds of $46,000 were provided by the San Francisco Foundation to FOSC. FOSC subcontracted with Laurel Marcus & Associates (LMA) for completion of the watershed plan. LMA also provided matching in-kind services for the state grant.

The grant included the following tasks:

- Collect existing information
- Create Geographic Information System (GIS)
- Collect field data
- Hydrologic and geomorphic analysis evaluation
- Creation of hydraulic model
- Preparation of Draft Watershed Plan
- Urban pollution prevention workshop
- Completion of Final Watershed Plan

Due to State budget problems, work on the grant was stopped December 18, 2008. The grant was restarted in October 2009. During this period, LMA changed the hydrology contractor to NewFields River Basin Services, LLC. to complete the hydrologic and hydraulic modeling for the watershed plan.

Karen Paulsell of FOSC provided extensive information on native and non-native plant species recorded for the public lands in the Sausal Creek watershed. Karen also provided information on the goat grazing management plan for Joaquin Miller Park and completed field assessments of storm drain outlets in the basin. Sara Marcellino served as the project director for FOSC until March 2009, when Kimra McAfee took over the responsibilities of project director.

## III. DESCRIPTION AND HUMAN HISTORY OF THE SAUSAL CREEK WATERSHED

The Sausal Creek watershed extends from the Oakland Hills to the San Francisco Bay (Figure 1). The total watershed area is approximately 4.5 square miles. The highest elevation in the watershed is approximately 1,525 ft. NGVD. The lowest elevation of the watershed is approximately sea level or 0 ft. NGVD. Figure 2 depicts the elevations in the watershed showing the mean elevation of the upper, middle, and lower portions of the watershed. Figure 3 depicts the areas of the watershed which have greater than 30% slopes.

Three tributary creeks make up the upper watershed—Shephard or Shepherd Canyon Creek, which drains Shepherd Canyon (spelling difference is an historical anomaly), Palo Seco Creek, which drains Joaquin Miller Park and adjacent lands, and Cobbledick Creek which drains the lands between Chelton Drive and Ascot Drive (Figure 4). Table 1 lists the acreage of each major sub-basin. These three tributaries come together near Highway 13 and form Sausal Creek. Another major tributary which drains the Whittle and Fruitvale Avenues neighborhood joins Sausal Creek near Diamond Avenue. The entire watershed is in the City of Oakland.

**Table 1: Tributary Sub-Basins of Sausal Creek Watershed**

| Sub-Basin | Total Acres | Acres over 30% Slope |
|---|---|---|
| Cobbledick Creek | 308.74 | 188.0 |
| Shephard Creek | 704.97 | 441.9 |
| Palo Seco Creek | 505.54 | 266.9 |
| Sausal Creek | 1258.4 | 213.2 |
| **TOTAL** | **2,777.88** | **1,110.0** |

### HUMAN HISTORY

Sausal Creek and its tributaries reflect the geology, flood events, land uses, and land conditions of their watershed. The Sausal Creek drainage has changed a great deal over the past 200 years, and its creeks reflect these changes.

### The Ohlone

Native Americans, the Huichin Ohlone, lived in the East Bay including the Sausal Creek watershed at a population density of 2 people/square mile in tribelets of approximately 250 people (Lowe 2000). As hunter-gatherers, the Ohlone managed the landscape extensively to produce food and other resources (Anderson 2006). A primary tool was fire. The Ohlone used fire to change the type of vegetation that dominated the landscape and to modify the species composition in other vegetation types. The broad extent of grasslands in the East Bay in the 1700-1800s was likely the result of Ohlone groups setting fires at certain times of the year to reduce bunchgrass thatch, release nutrients, and increase growing area for their food plants (Lowe 2000, Margolin 1978). The Ohlone harvested and replanted numerous plants with fleshy bulbs such as *Brodiaea*. Tule elk, black-tailed deer, rabbits, and many birds favored the perennial grassland created by Ohlone management. Chaparral and forest areas would also have been burned to increase biodiversity, reduce over-growth and create better habitat for game species. Smoke from the fires cleared pest insects out of oak trees, fostering improved acorn production, another major food source for the Ohlone. Management practices also encouraged plants which produced fleshy sweet

**Figure 2: Elevations in the Sausal Creek Watershed**

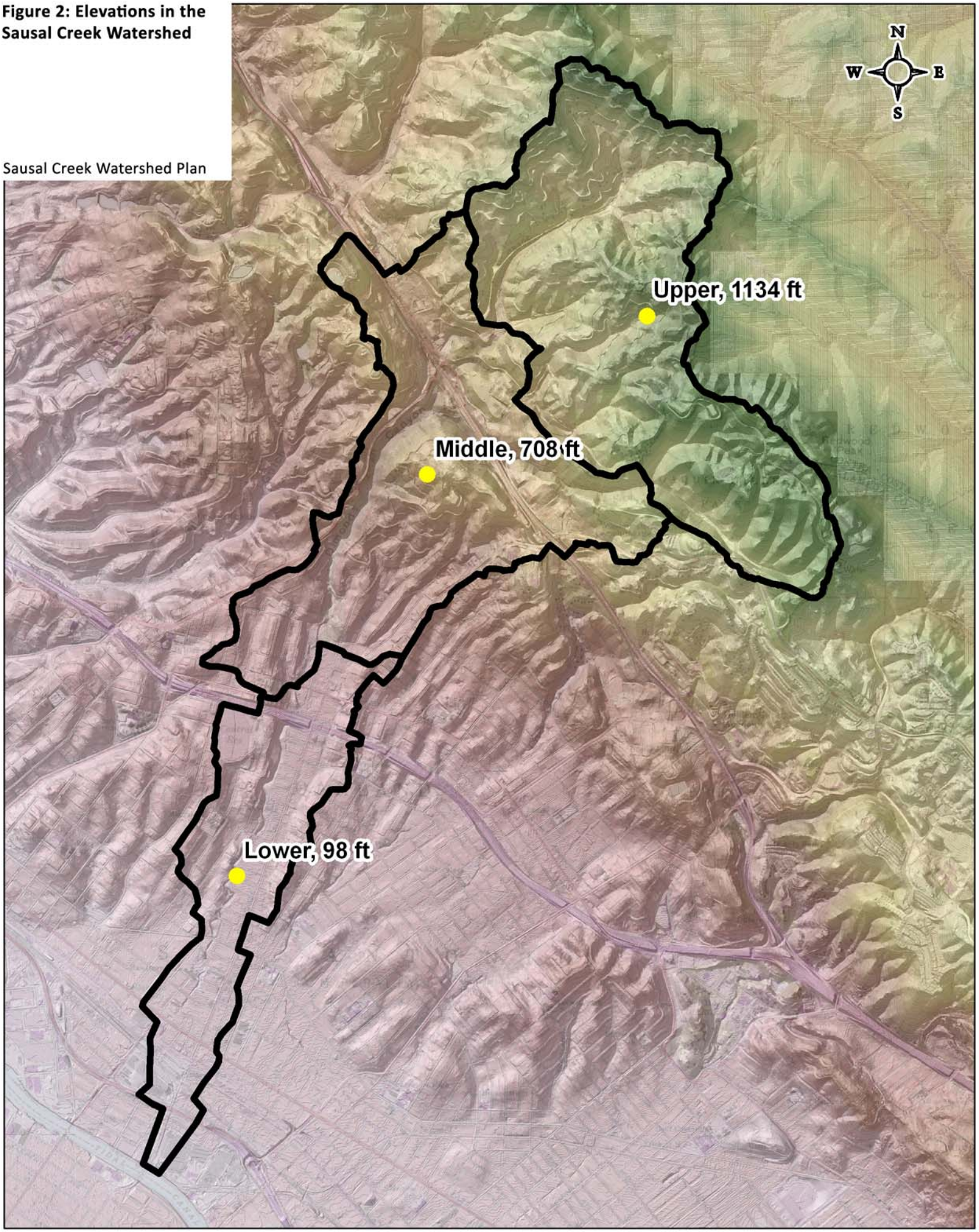


**Figure 3: Areas of Sausal Creek Watershed with Greater than 30% Slopes**

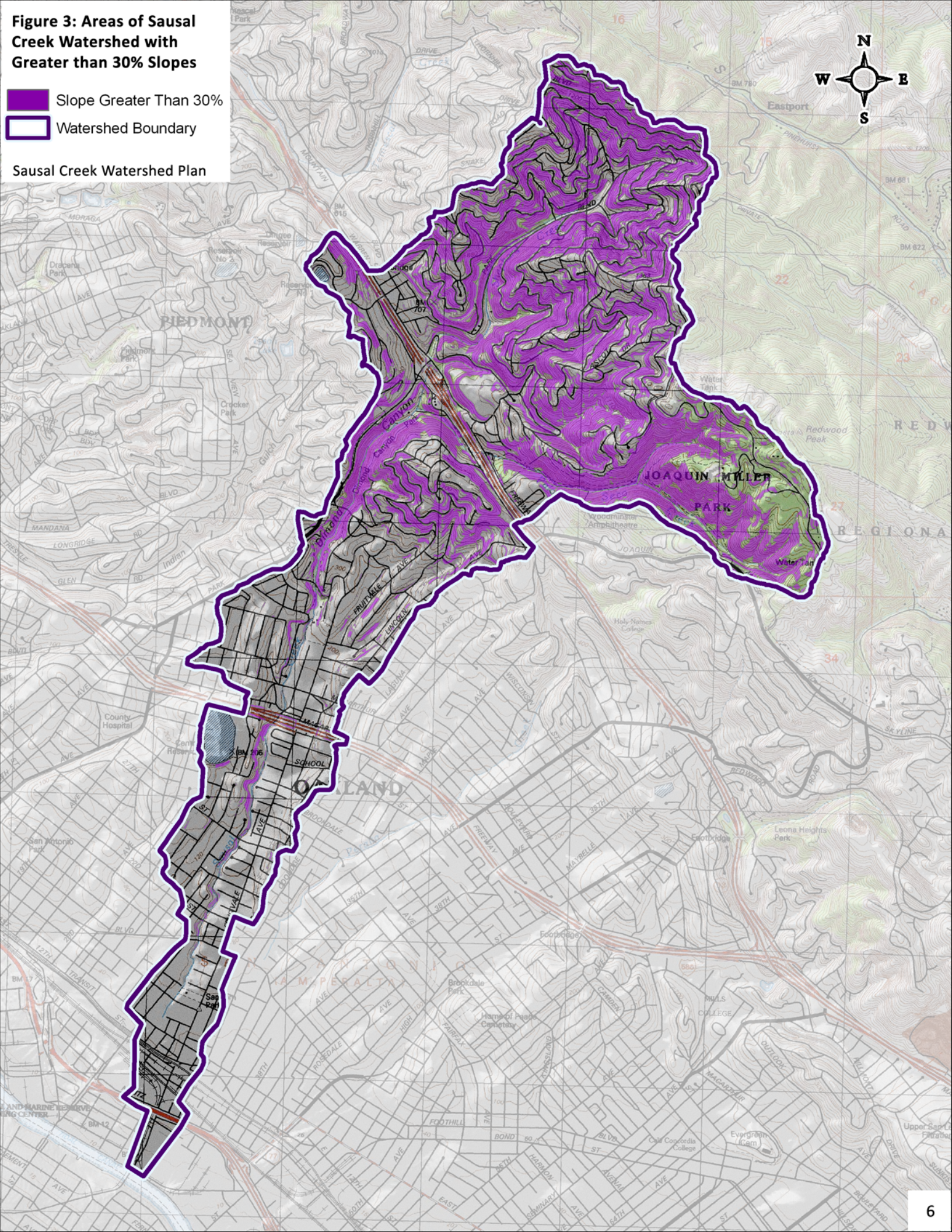
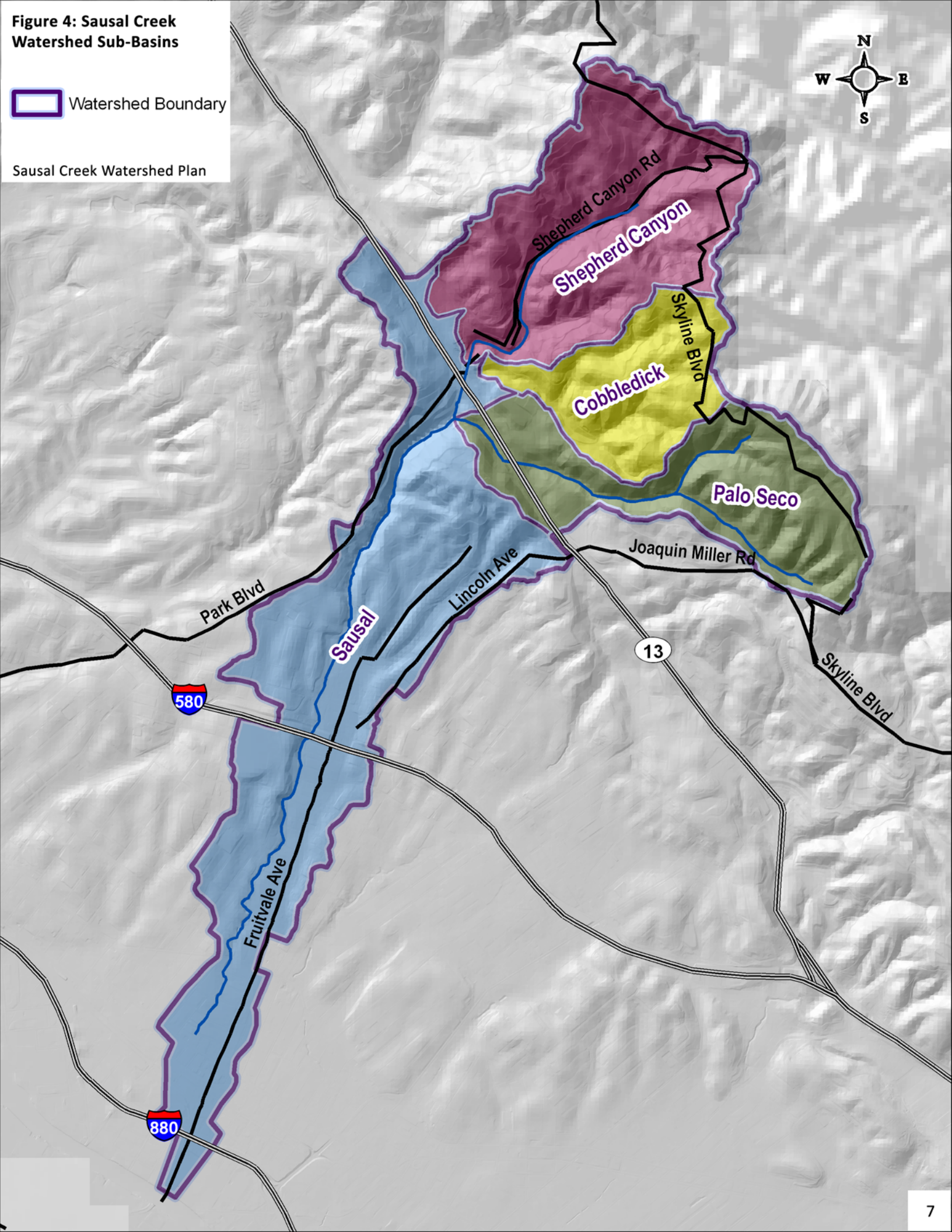


**Figure 4: Sausal Creek Watershed Sub-Basins**

Watershed Boundary

Sausal Creek Watershed Plan



fruits. The Ohlone managed plants to produce straight roots and rhizomes and straight branches for use in basket-making. The riparian zones of creek and freshwater marshes were managed for particular plants and to create habitat for waterfowl, another food source.

The Ohlone management of the landscape created particular types of vegetative cover, creek conditions, and habitats based on their need for food and fiber.

**The Spanish/Mexican Era**

The Anza Expedition explored the Bay Area in 1775-1776. They described the East Bay as a broad, grassy plain with steep hills dissected by creek corridors filled with live oak, bay laurel, cottonwood, sycamore, and alder. This open landscape was likely produced by the land and fire management of the Ohlone. The Spanish originally named Sausal Creek the Arroyo del Bosque, or "stream of the woods," due to the redwoods in the upper watershed.

The Spanish built a series of 21 missions in California including three in the Bay area: San Francisco, Santa Clara, and San Jose. The missions enlisted local native people to provide labor for farming and building. The Spanish also brought European diseases to California, including smallpox, which decimated Native American populations in a very short time. The Spanish banned all Ohlone burning practices and brought cattle and sheep to graze the native perennial grasslands. Combined with the introduction of annual European grasses, these changes resulted in a complete transformation of the grasslands. The Spanish allowed their livestock to range over large areas in low numbers and harvested them for hides, tallow, and meat.

The Sausal Creek watershed was part of the San Antonio Rancho, which stretched from Cerrito Creek to San Leandro Creek and was owned by the Peralta family. The Peraltas had more than 200,000 head of cattle on San Antonio Rancho. The family patriarch, Luis Maria Peralta, split the Rancho between his four sons. Antonio Peralta received the portion of the Rancho containing the Sausal drainage. Antonio built an adobe home near the current intersection of 34$^{th}$ Ave. and Paxton Ave.

**The American Era**

In 1846 the Americans living in northern California staged the Bear Flag Revolt and in 1850 California became a state. The ownership of Mexican ranchos was settled by American courts and the Peraltas received title to their land but then had to sell much of it to cover legal costs.

In the 1840s, prior to statehood, Americans George Patterson, John Parker, and others started logging the San Antonio redwoods in the headwaters of the Sausal Creek watershed. Some of these redwoods were 300 ft. tall and used as a navigational landmark by ships on San Francisco Bay. Redwoods covered a 5-square mile area encompassing the headwaters of Sausal, Redwood, and San Leandro creeks. This was one of the only locations of redwood forest in the East Bay hills; most other redwoods were in creek canyons (Evanosky 2006).

Over a 20-year period the redwood forest was completely clear cut. There were a number of lumber mills in the area, including one on Palo Seco Creek near the present location of Highway 13 (Figure 5). Over 98% of the redwood forest in the Sausal Creek watershed was clear cut. Between 1870s-1880s, the stumps of the redwoods were taken for shingles and firewood, providing more than half of the firewood

**Figure 5: Lumber Mill along Palo Seco Creek in the 1850's. There were 8 mills operating in the area at the time. First growth redwood was the primary tree harvested.**

for East Bay households. The redwood forest was burned after logging and then grazed. Many of the original logging roads and skid trails are now used as hiking trails or major roads.

By 1878 there were 10 major landowners in the upper watershed. In 1886 the poet Joaquin Miller built "The Hights" in what later became Joaquin Miller Park, near the lower end of Sanborn Rd. The steep hills of this site are shown in Figure 6 and are largely treeless. Joaquin Miller planted over 75,000 trees, many of which were non-native species such as Eucalyptus and Acacia as well as Monterey pine and Monterey cypress. Most of the lands in the watershed were used for cattle and sheep pasture, dairy, orchards, and row crops. Americans fenced their lands and had many more animals grazing per acre than their Mexican and Spanish predecessors.

**Urbanization**

Residential development in the watershed started near the Bay where goods were shipped to San Francisco and beyond. In 1871 a stone dam was built across Sausal Creek in Dimond Canyon, located about 0.3 miles downstream of the current location of Highway 13. This reservoir was the water supply for the Fruitvale and East Oakland area until 1920.

Gravel was extracted from the creek at the current location of Fruitvale Ave. and E. 14$^{th}$ Street. A 25-foot deep pit was dug out of the creek and winter floods re-filled it with gravel. An 1878 description portrays lower Sausal Creek with banks of 15-20 feet and a straightened channel. Figure 7 shows the Fruitvale neighborhood near the turn of the century. Figure 8 shows historic photographs of the Montclair area.

In the earliest descriptions of Sausal Creek, the channel ends in a willow grove upstream of the Bay shoreline. Sausal Creek includes an alluvial fan reach below the current location of Highway 13. Alluvial fans are very common in the Bay area due to the tectonic uplift of mountain ranges. Creeks deposit sand, gravel, and cobble in a conical fan as they exit steep rockbound gorges, and spread out on flatter open land. Streamflows percolate into the coarse alluvium of the fan and exit at the base of the fan on the flatlands, often forming wetlands or willow groves. Sausal Creek, like many streams in the Bay area, did not have a creek channel perennially connected to the Bay. Anadromous steelhead would only have had access into Sausal Creek on years when rainfall was high and maintained flows adequate for fish migration through the alluvial fan.

With urbanization the location and condition of Sausal Creek was significantly changed. In 1900 a tidal canal was dredged near the Sausal Creek mouth to make Alameda an island. The downstream reach of Sausal Creek was re-located in 1902 to avoid silting in the new canal; however, the creek was relocated back to its original position a few years later. Over time, the lower portion of Sausal Creek was straightened to maximize development area. Figure 9 shows the topographic map of Sausal Creek watershed in 1897. Streets and buildings are concentrated in the downstream, flatter lands of the drainage. Roads in the upper watershed remain from the logging operations. Roads are indicated where Fruitvale Ave., Park Blvd., Lincoln Ave., Skyline Blvd., and Highway 13 are now located. The original Central Reservoir is also visible with a creek going in and out of the pond. Figure 10 and 11 show Dimond Canyon, Park Boulevard, and Montclair in 1910.

Figures 12-14 show the progression of urbanization of the Sausal watershed. The 1915 map shows more urban development and the Oakland and Antioch railroad extending up Shepherd Canyon and through a tunnel to "Eastport" (Figure 15). The railroad bed is currently a public trail from the Montclair

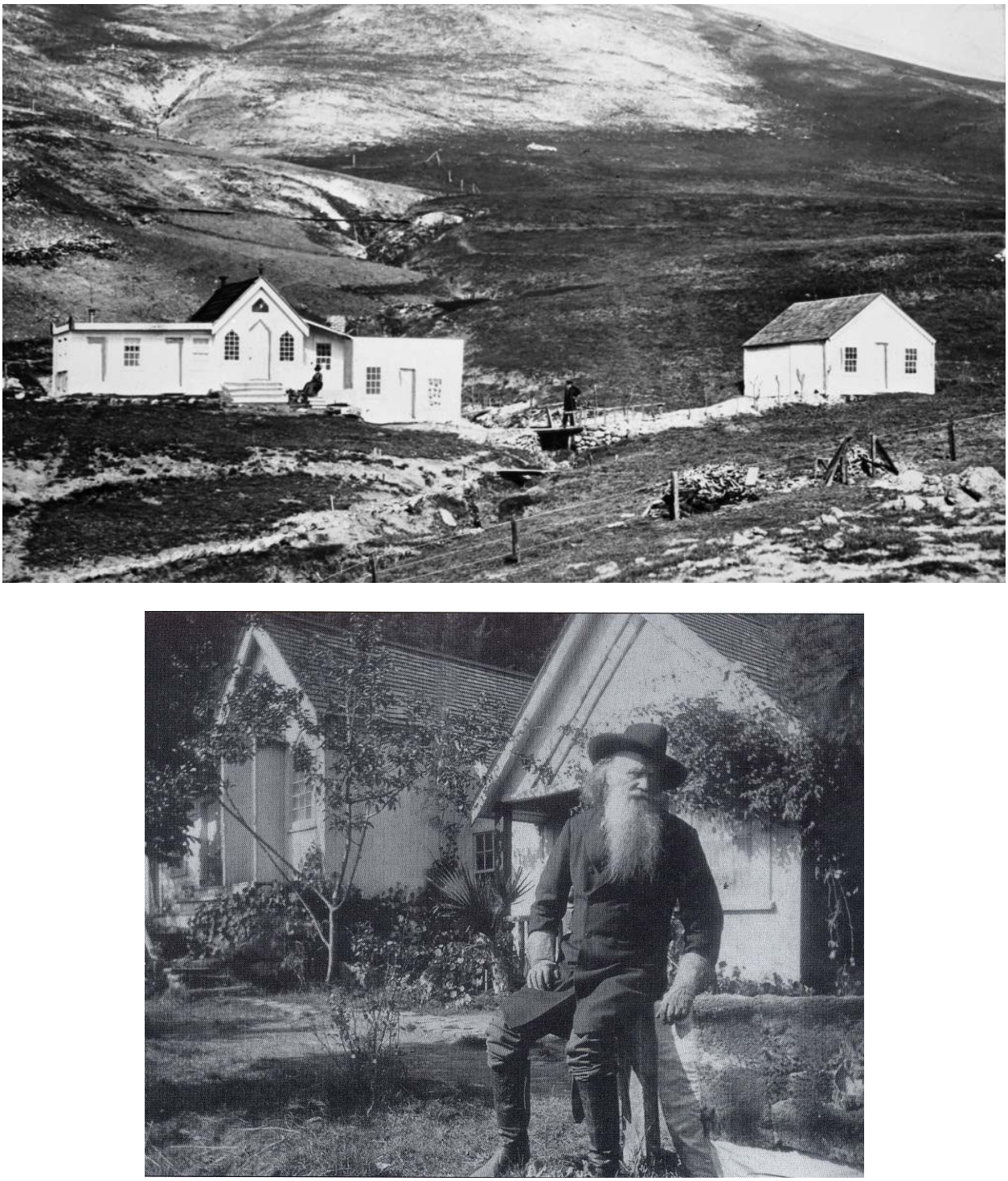


**Figure 6: Top: The Hights was built on a treeless hill by Joaquin Miller in 1886. Bottom: Joaquin Miller a few years later after thousands of trees were planted, primarily non-native species like Eucalyptus.**

**Figure 7: Top: Children swimming in Sausal Creek in the early 1900's. Bottom: The intersection of MacArthur Blvd. (formerly Hopkins St.) and Fruitvale Ave. in 1890.**

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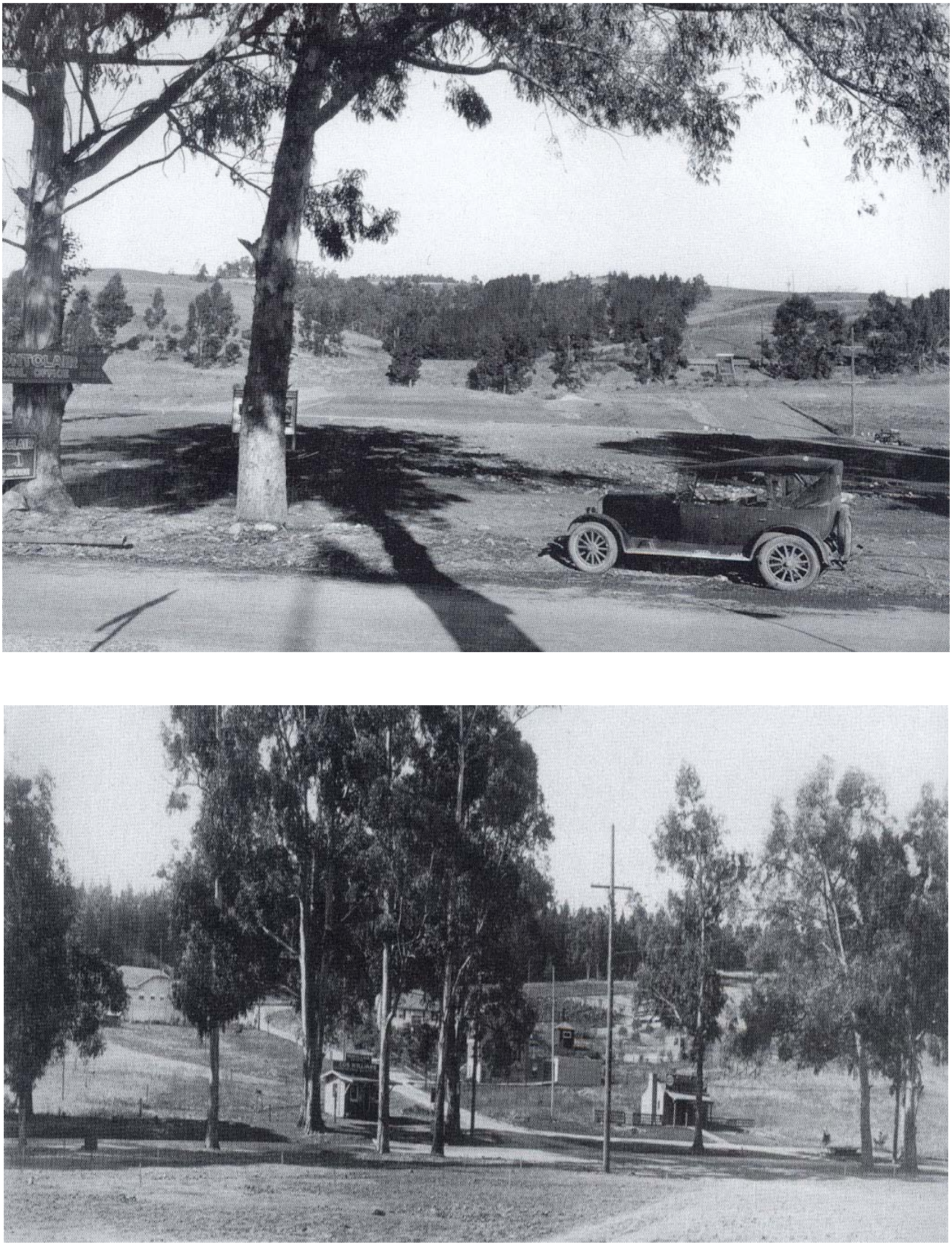

**Figure 8: Two views of the Montclair area in the late 1800's to early 1900's.**

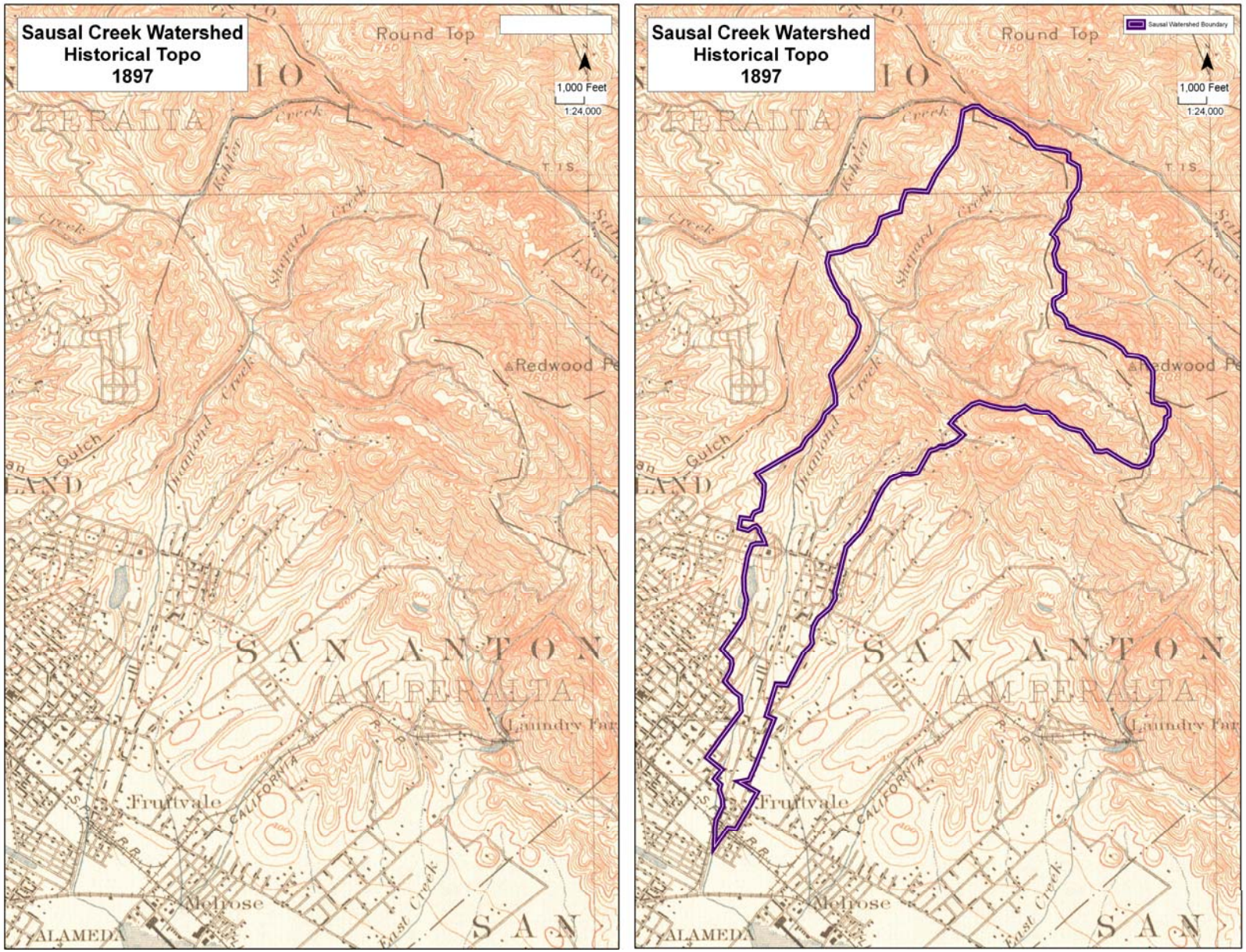


**Figure 9: Topographic map of the Sausal Creek watershed in 1897 with and without the watershed boundary.**

**Figure 10: Dimond Canyon in the early 1900's**

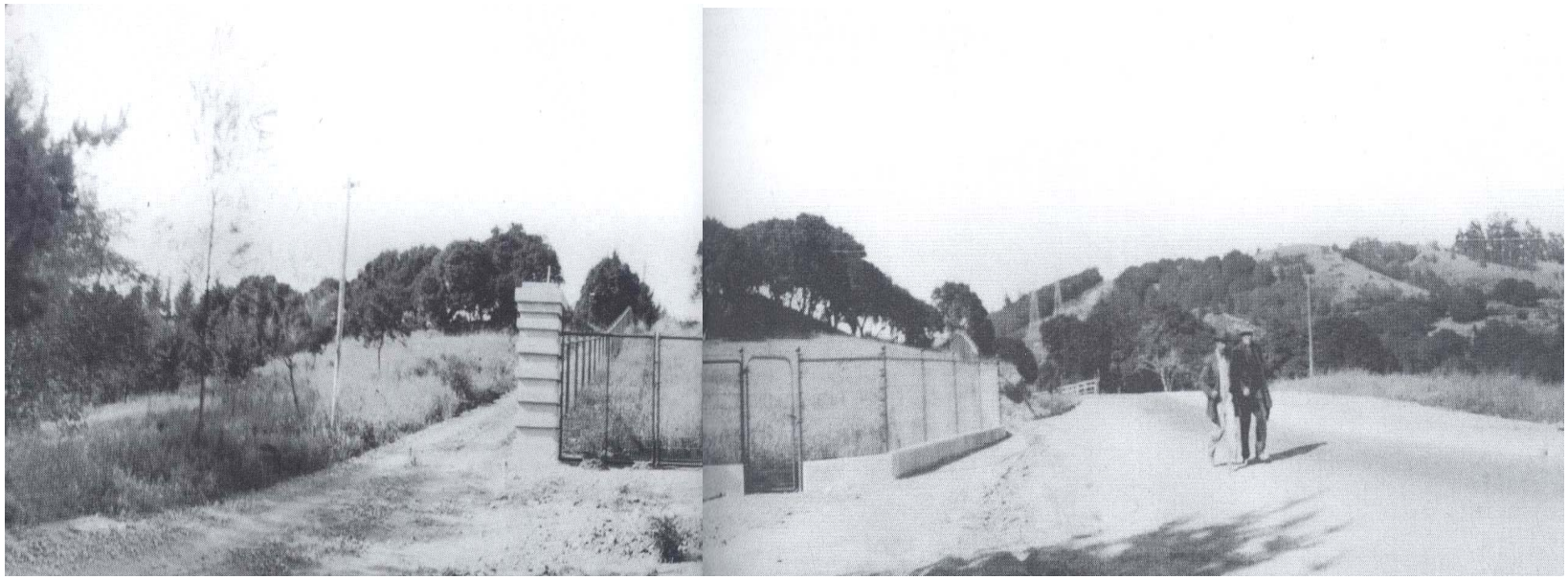

**Figure 11: Looking up Park Blvd. into the upper Sausal Creek watershed in the early 1900's.**

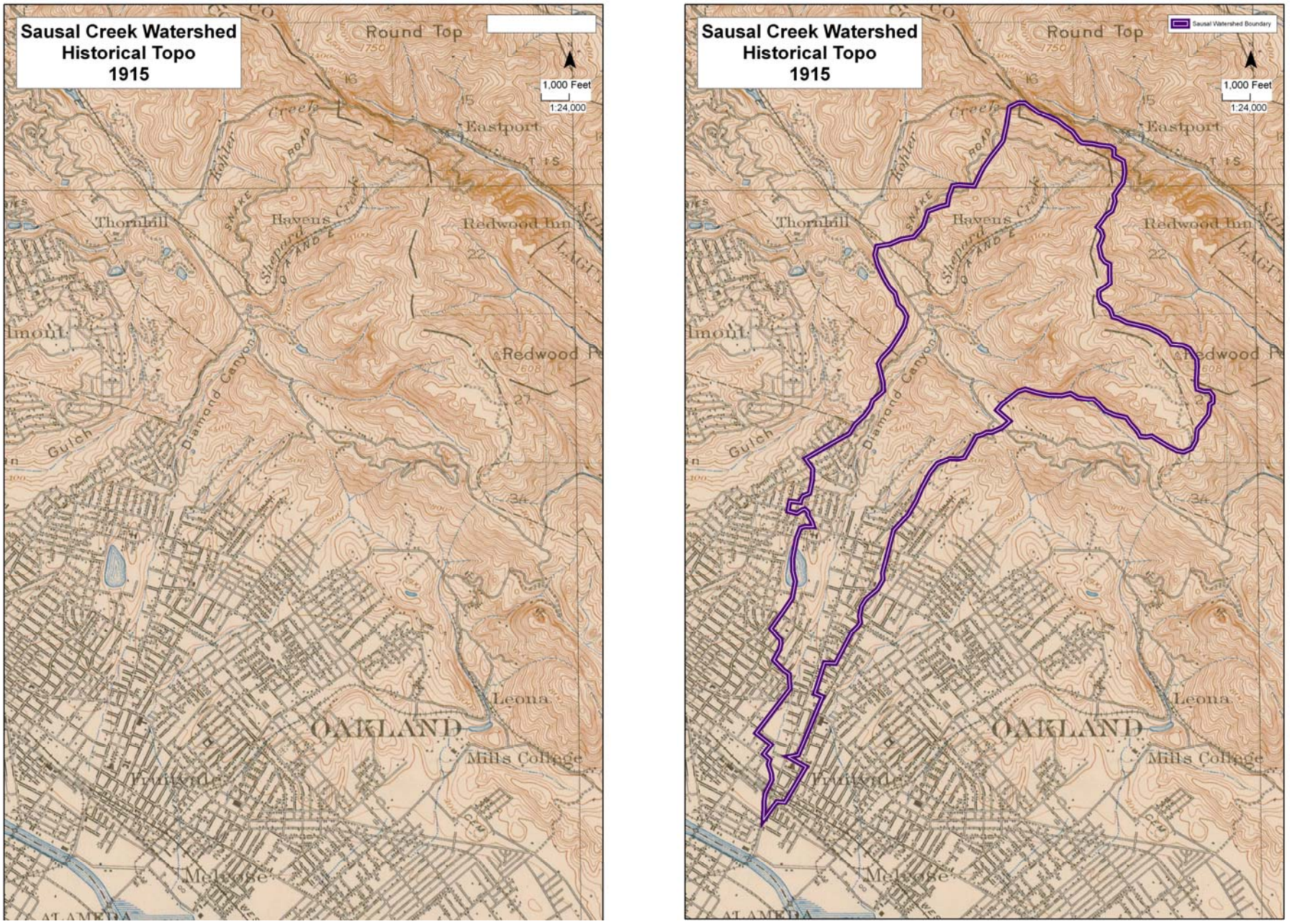


**Figure 12: Topographic map of the Sausal Creek watershed in 1915 with and without the watershed boundary**

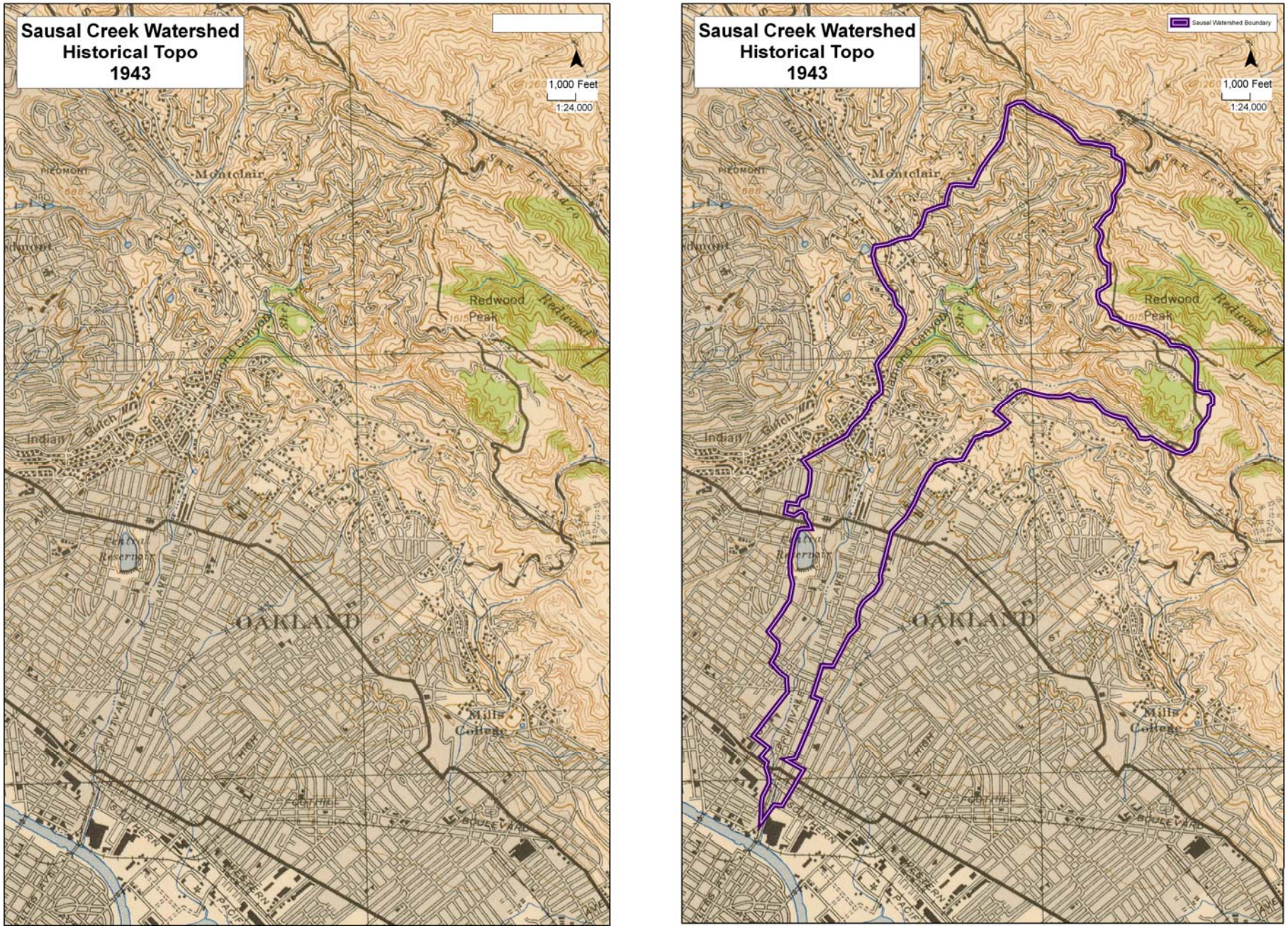


**Figure 13: Topographic map of the Sausal Creek watershed in 1943 with and without the watershed boundary**

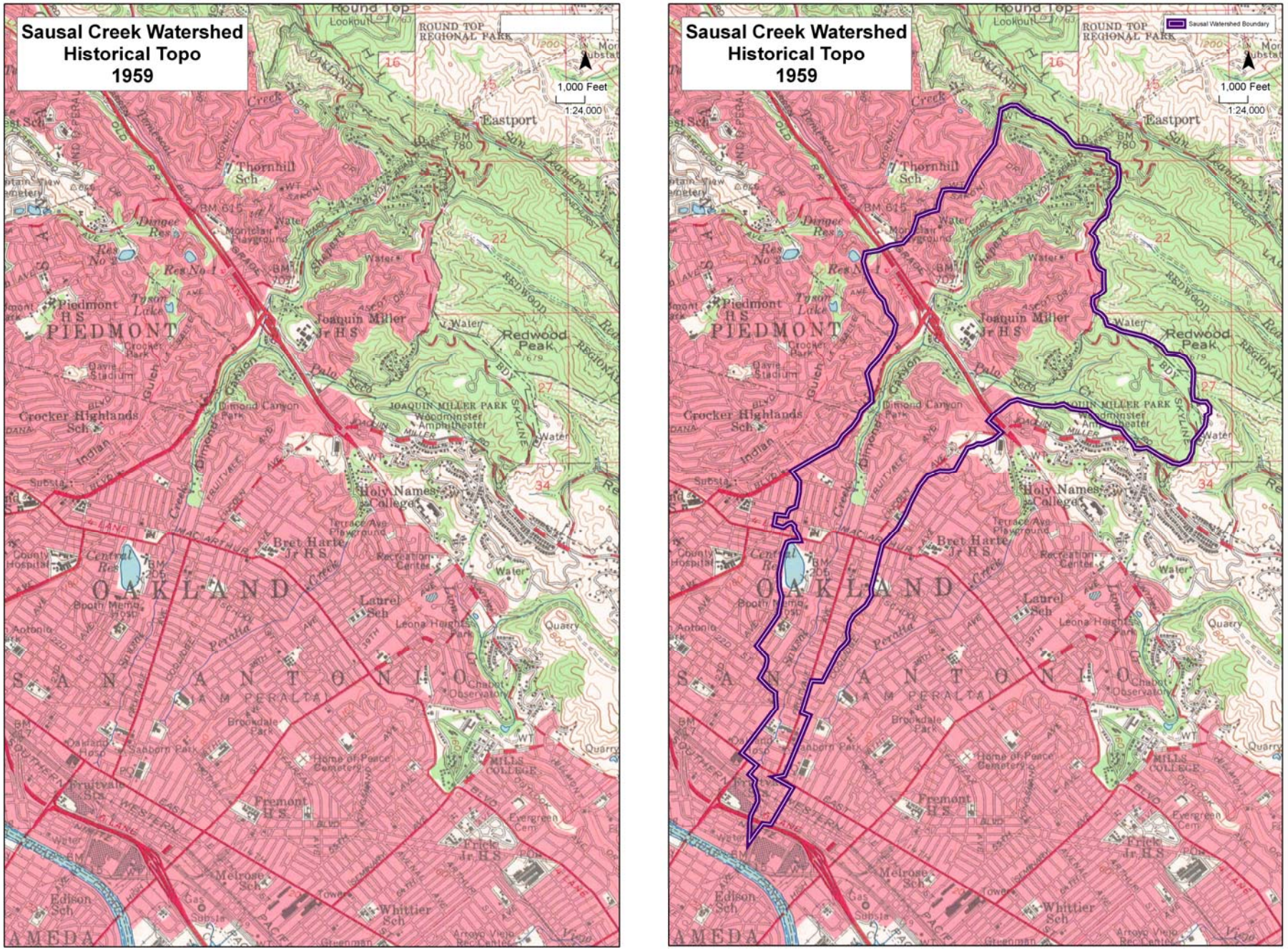


**Figure 14: Topographic map of the Sausal Creek watershed in 1959 with and without the watershed boundary**

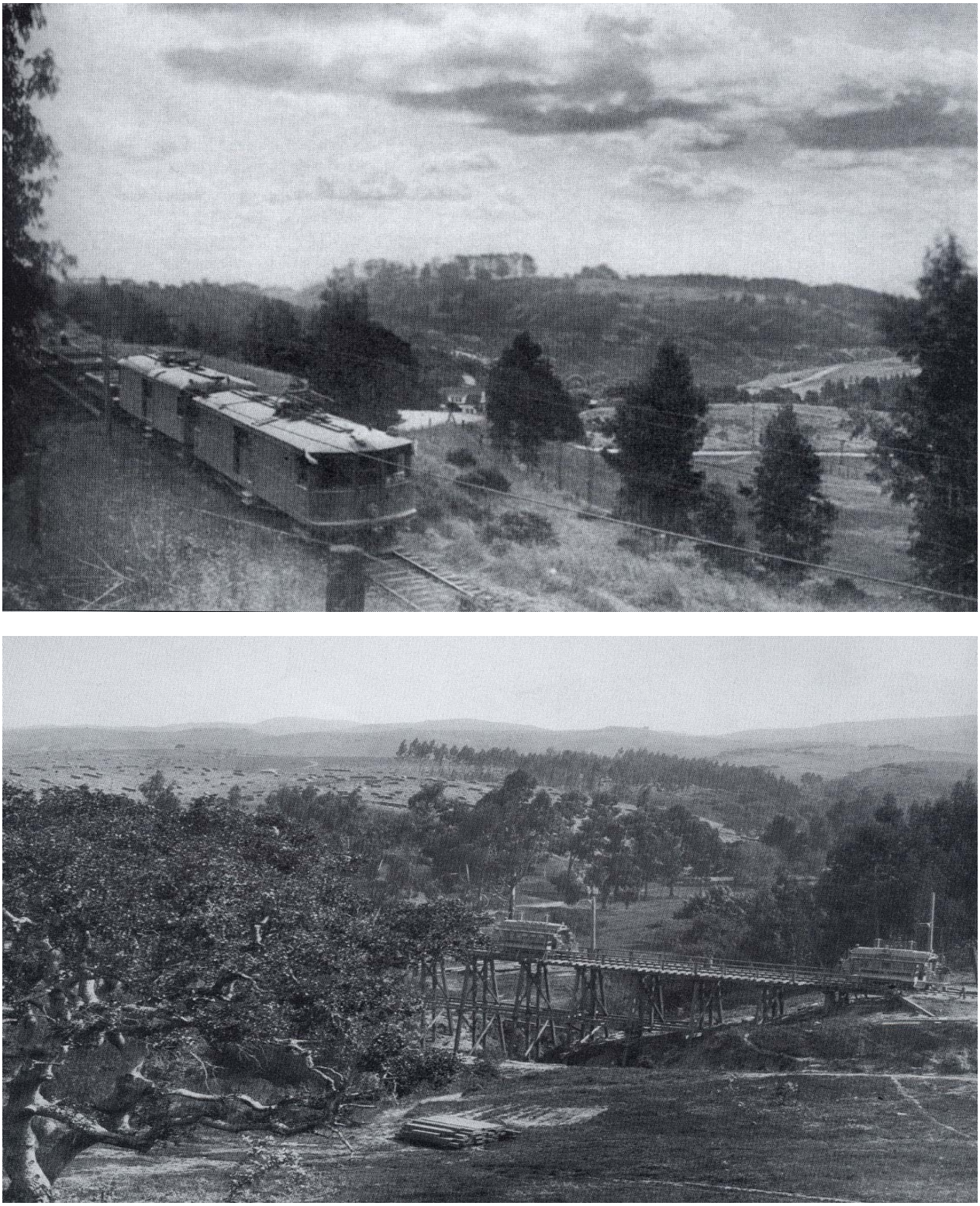

**Figure 15: Top: The Oakland and Antioch Railroad (later the Sacramento Northern RR) began in 1909 and went through Montclair and up Shepherd Canyon to a tunnel through the hills. Bottom: Trestle Glen in the late 1800's with the upper Sausal Creek watershed in the background showing the general lack of tree cover.**

neighborhood into Shepherd Canyon. Shephard Creek was put into a culvert as part of the railroad development in 1909. The train stopped operating in March 1957. The 1943 topographic map shows extensive road construction in the upper watershed. This development followed the construction of the Leimert Bridge across Dimond Canyon in 1926. Figures 16 and 17 depict the bridge construction and accompanying road and housing development in the Oakmore area.

Figure 14 is the 1959 topo map of the Sausal watershed. Highway 13 and Interstates 580 and 880 are built and most of the watershed is urban. Most of the areas depicted in green in the upper watershed have since been developed. Large sections of Sausal Creek and its tributaries have been culverted and their watersheds covered with urban development (Figure 18). However, land was set aside for parks in a number of locations.

## IV. NATURAL RESOURCES

### GEOLOGY

Sausal Creek is located along the eastern periphery of the San Francisco Bay (Figure 19). The steep hills on both sides of the bay were formed primarily through tectonic processes. The Pacific Plate is diving beneath and pushing up the North American Plate, crumpling the edge of the continent into the Coastal Range. The San Andreas Fault zone on the San Francisco side of the bay is one of a series of faults which dissect the Bay Area. The faults are areas of earth movement along the continental plates.

Sausal Creek watershed reflects this regional geology with very steep hills in its upper watershed. These hills are made up of a variety of rock types. The Hayward Fault is a major geologic feature which created a valley where Highway 13 is located. Downstream of the Hayward Fault on the flatter lands, Sausal Creek spreads out, creating an alluvial fan and depositing material eroded from the highly sheared rock in the fault zone and the steep upper drainage.

Figure 20 depicts the geologic features of the watershed. Table 2 describes the characteristics of each rock type. Great Valley Complex and Franciscan Complex are the primary geologic formations in the watershed. Franciscan Complex is an ancient sea floor dating from 150-200 million years ago, that has been uplifted through the movement of continental plates. Great Valley Complex is also composed of sedimentary rock and was deposited in a shallow inland sea 70-100 million years ago. Franciscan Complex is the basement rock for much of the San Francisco Bay area. As the Pacific Plate subducted or moved beneath the North American Plate, the Franciscan Complex was crumpled and uplifted into the coastal mountains. Although deposited on top of the Franciscan Complex, the Great Valley Complex rock layers often shifted from their original positions through the process of faulting and uplift.

Surface deposits are also found, including mudstones in the uppermost end of the watershed, and extensive alluvial fan deposits in the lower half of the watershed. These alluvial deposits are formed as the steep hilly area of the drainage erodes, and cobble, sand, and gravel deposit over the flatlands of the lower drainage.

Schumm, Mosley and Weaver (1987) note that
“An alluvial fan is an accumulation of sediment that has been deposited where a debris-laden stream emerges from the confined valley of an upland area onto the piedmont, where it is free to spread laterally and deposit its load. The ideal form of an alluvial fan is semicircular in plan. Because of their

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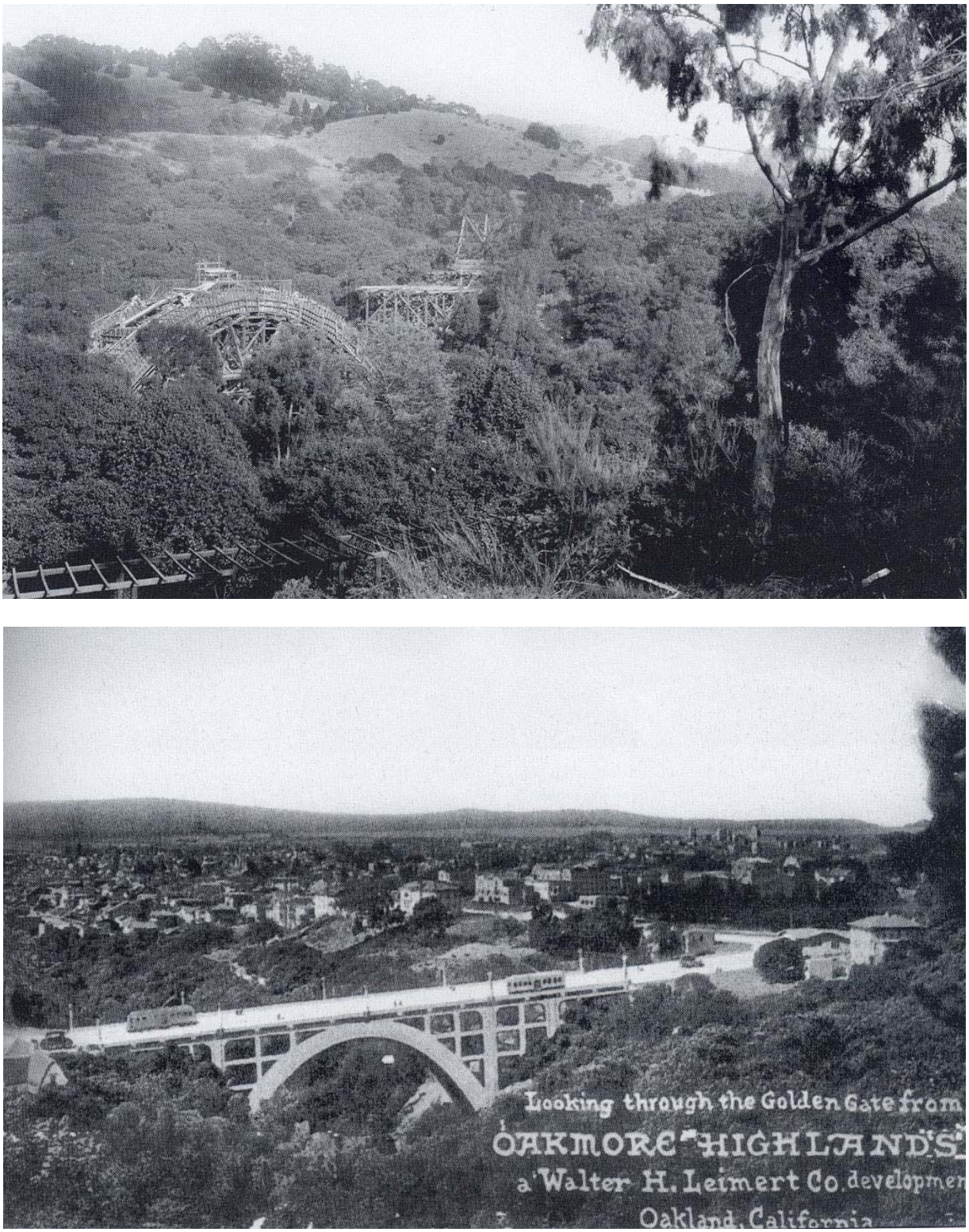



**Figure 16: Construction of the Leimert Bridge in 1926 opened up large areas of the upper Sausal Creek watershed to residential development**

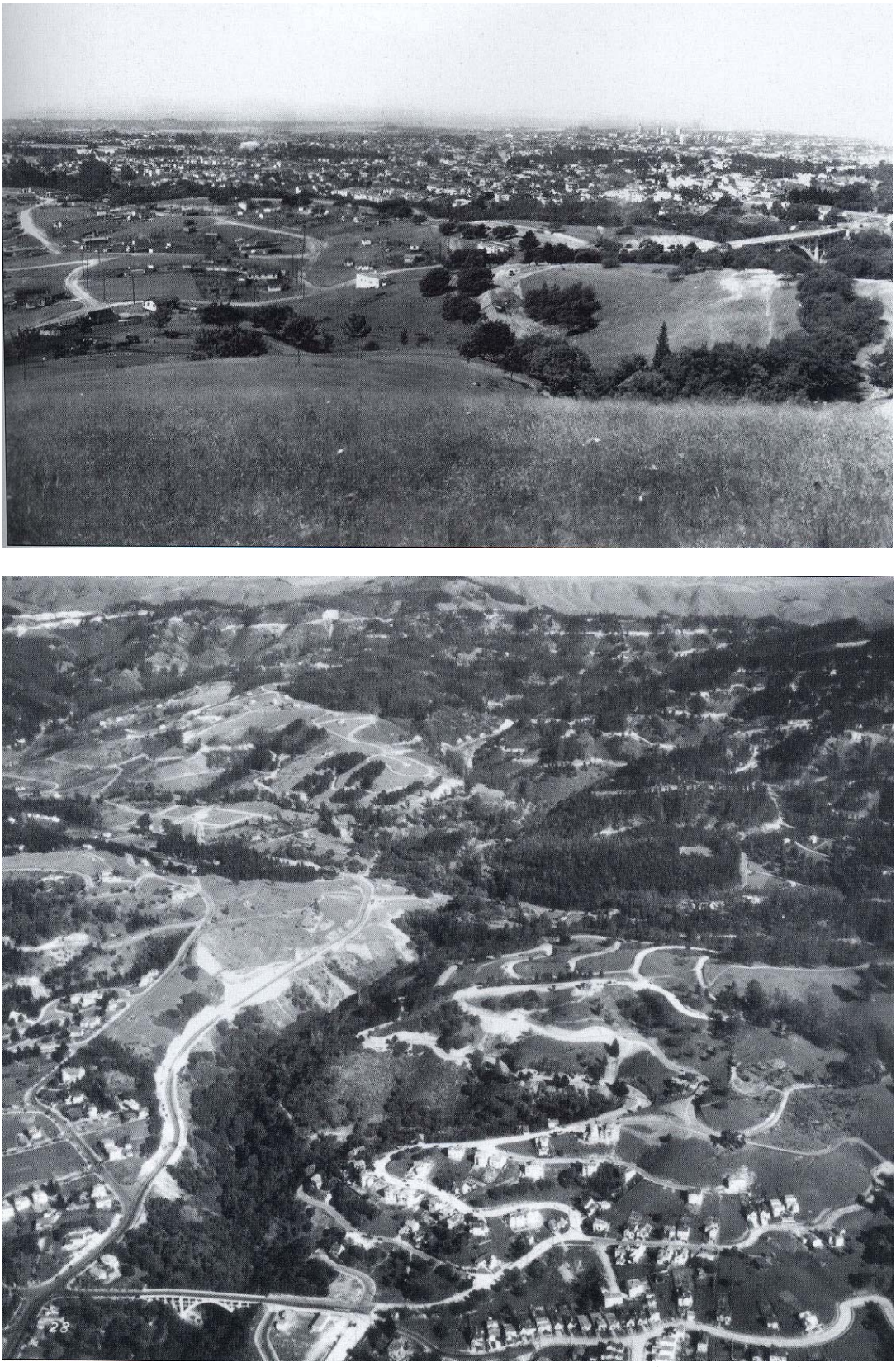


**Figure 17: Top: Oakmore area in 1926 prior to the construction of large areas of housing. Bottom: Aerial photograph showing the construction of housing in the Oakmore area in 1935.**

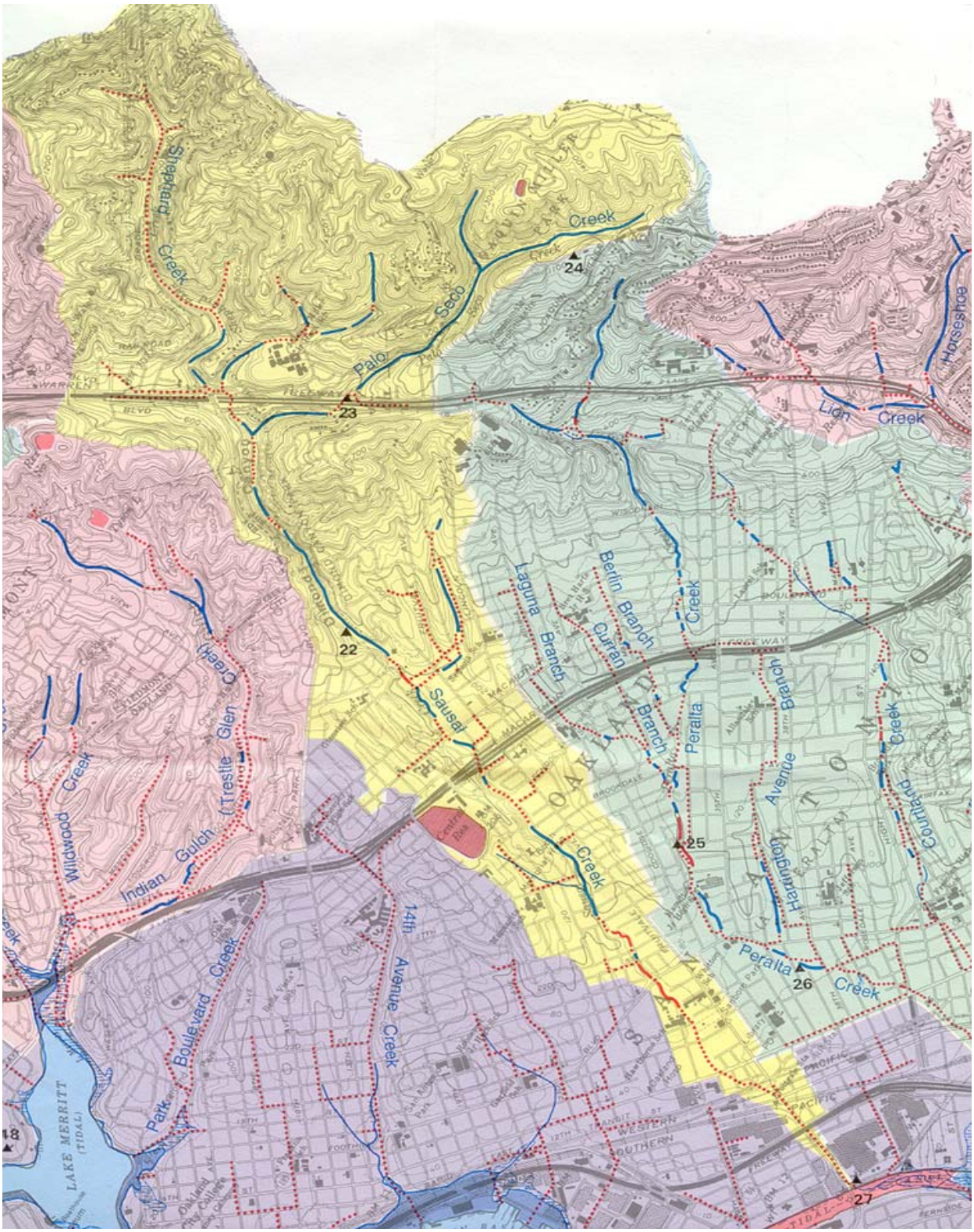
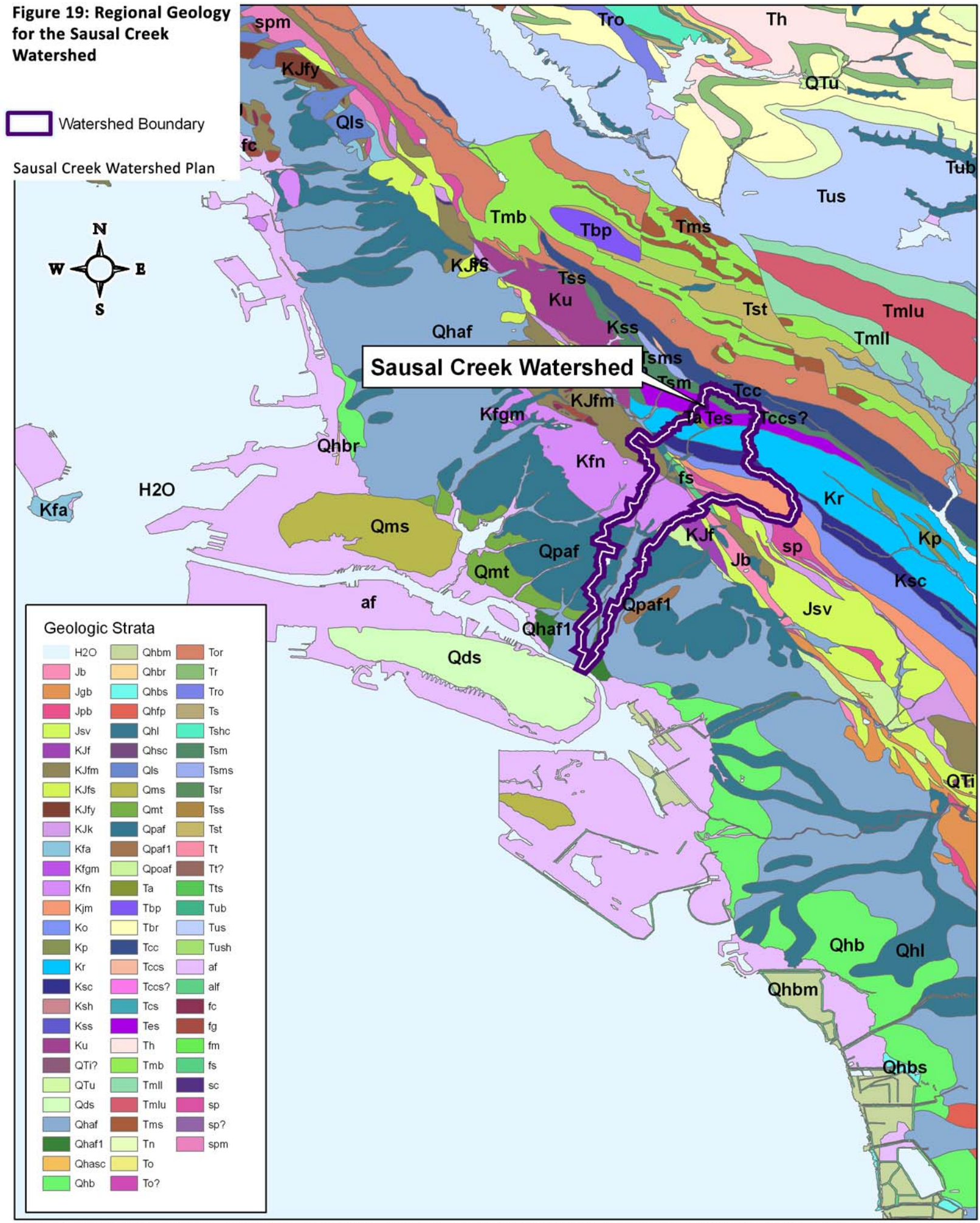


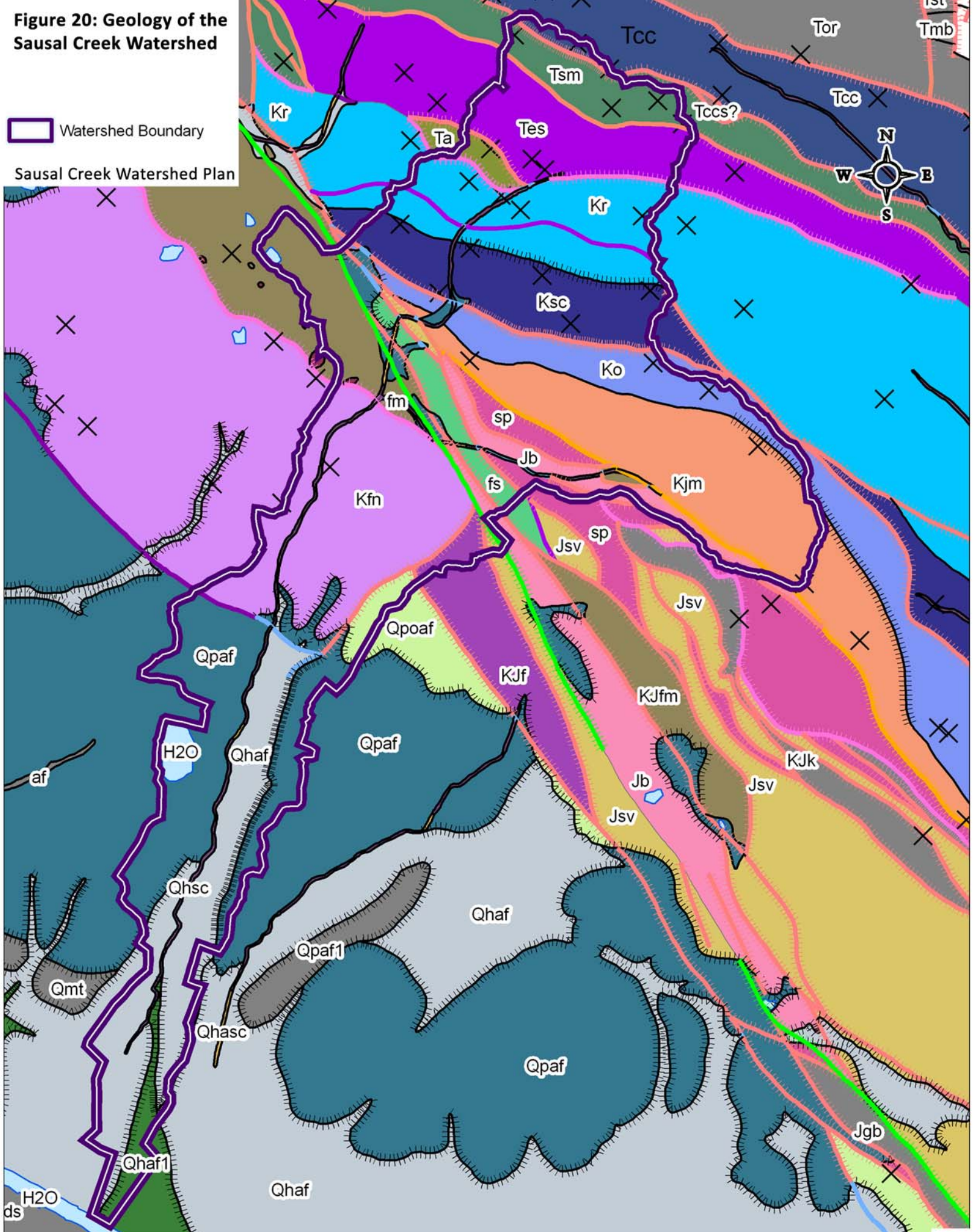

**Figure 18: Oakland Museum map of creek channels in the Sausal Creek watershed, Blue indicates natural and the historic location of the channel. Red dots indicate culverted reaches and red lines indicate channelized reaches.**

**Figure 19: Regional Geology for the Sausal Creek Watershed**




Source: Graymer, R.W. 2000. Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California. Pamphlet to accompany MISCELLANEOUS FIELD STUDIES MF-2342 Version 1.0. USGS.

**Figure 20: Geology of the Sausal Creek Watershed**




Source: Graymer, R.W. 2000. Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, California. Pamphlet to accompany MISCELLANEOUS FIELD STUDIES MF-2342 Version 1.0. USGS.

excellent exposure and ease of investigation, alluvial fans in arid and semiarid areas have received the greatest attention in recent scientific literature. However, fans are also common features of more humid regions ...."

As Figure 20 shows, there are numerous faults crossing through the Sausal Creek watershed. The Hayward Fault is located approximately where Highway 13 is located. The Hayward Fault is a strike-slip fault like the San Andreas Fault. The land on the west of this type of fault moves north, while the land on the east side moves south. Figure 20 shows that there are many different rock types within the Hayward Fault indicative of the shearing of rock and north/south movement along this fault. Other faults are also indicated along a northwest/southeast axis in the upper watershed, a common pattern in California's coastal ranges. Palo Seco Creek and the upstream reaches of Shephard Creek and flow in a southeast to northwest direction due to the effects of earth movements from faulting

The rock types in the Sausal Creek watershed affect plant species distribution, groundwater movement, and erosion potential. For example, along the contact between Oakland Conglomerate (Ko) and Joaquin Miller Formation (Kjm) there are numerous springs and wetlands. "This contact is very near Skyline Boulevard through Joaquin Miller Park, and is the source of the wetland near Sequoia Arena, and also the source for the small tributaries to Cinderella and Palo Seco Creeks. Similarly, a contact between the Oakland Conglomerate and Shephard Creek Formation (Ksc) in Beaconsfield Canyon produces riparian plants 100 feet above the creek. At the contact line, a stand of mesic coastal scrub immediately gives way to coyote brush (FOSC 2009)." Immediately following the 1989 Loma Prieta earthquake, surface water began flowing in several creeks in the Palo Seco tributary drainage. These creeks had been dry before the earthquake. Figure 21 shows the landslide hazard rating for lands in the Sausal Creek watershed and nearby region.

**Table 2: Geology of Sausal Creek Watershed**

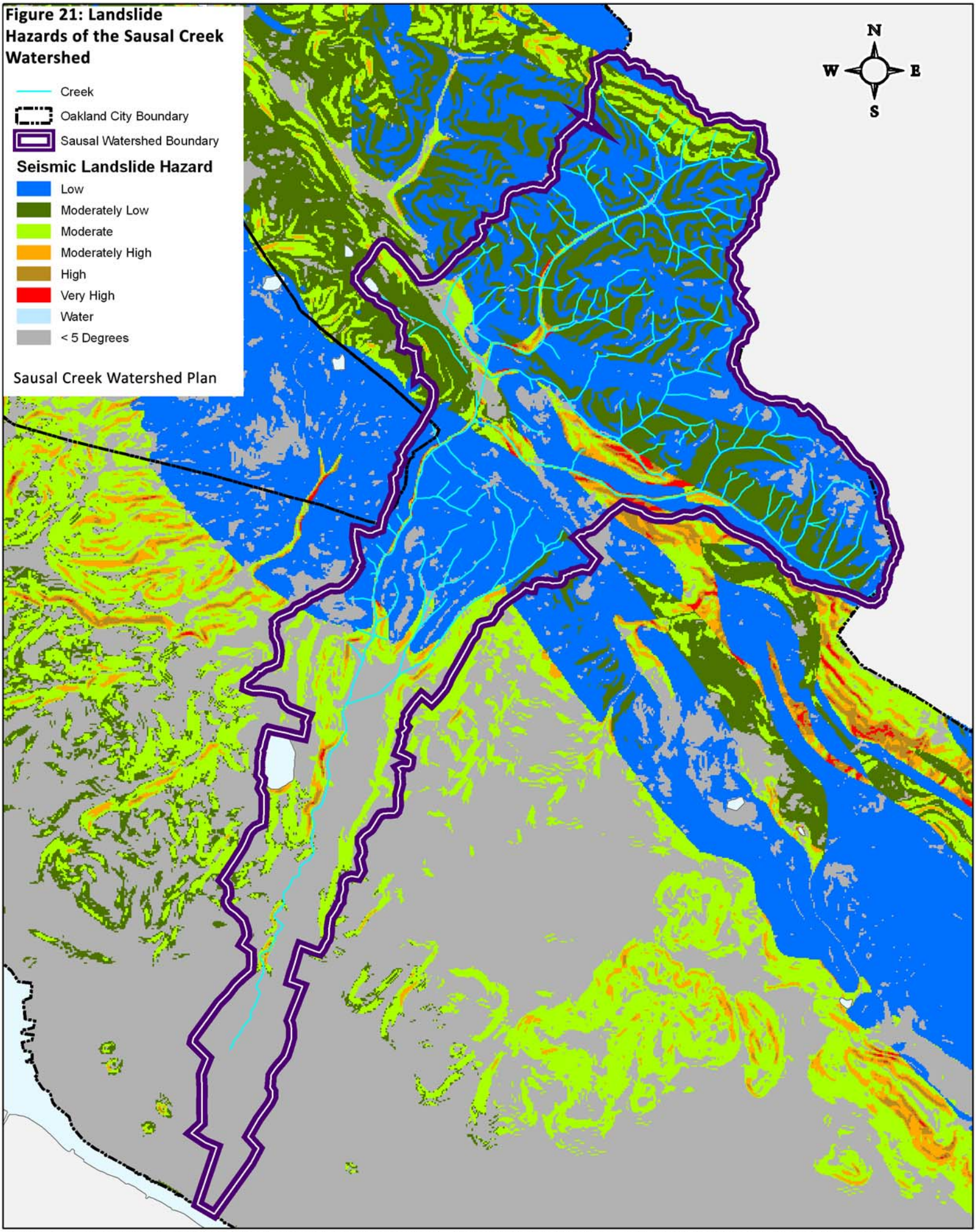
| Abbreviation | Name | Geologic Era | Description |
|---|---|---|---|
| *Surficial Deposits* | | | |
| Qhaf1 | Younger alluvial fan deposits | Holocene (10,000 years before present) | Brown, poorly-sorted, dense, sandy or gravelly clay. Small fans at mountain fronts have a probable debris flow origin. |
| Qhaf | Alluvial fan and fluvial deposits | Holocene (10,000 years before present) | Alluvial fan deposits are brown or tan, medium dense to dense, gravelly sand or sandy gravel that generally grades upward to sandy or silty clay. Near the distal fan edges, the fluvial deposits are typically brown, never reddish, medium dense sand that fines upward to sandy or silty clay. The best developed Holocene alluvial fans are on the San Francisco Bay plain. All other alluvial fans and fluvial deposits are confined to narrow valley floors. |
| Qpaf | Alluvial fan and fluvial deposits | Pleistocene (2.5 million to 12,000 years before present) | Brown, dense, gravely and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display various sorting and are located along most stream channels in the county. All Qpaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger soil profile development. They are less permeable than Holocene deposits and locally contain fresh water mollusks and extinct late Pleistocene vertebrate fossils. They are overlain by Holocene deposits on lower parts of the alluvial plain and incised by channels that are partly filled with Holocene alluvium on higher parts of the alluvial plain. Maximum thickness is |

| Abbreviation | Name | Geologic Era | Description |
|---|---|---|---|
| | | | unknown but at least 50m. |
| Qpoaf | Older alluvial fan deposits | Pleistocene (2.5 million to 12,000 years before present) | Brown dense gravely and clayey sand or clayey gravel that fines upward to sandy clay. These deposits display various sorting qualities. All Qpoaf deposits can be related to modern stream courses. They are distinguished from younger alluvial fans and fluvial deposits by higher topographic position, greater degree of dissection, and stronger profile development. They are less permeable than younger deposits, and locally contain freshwater mollusks and extinct Pleistocene vertebrate fossils. |
| Tsm | Un-named glauconitic mudstone | Miocene/ Oligocene (35-5 million years before present) | Brown mudstone is interbedded with sandy mudstone containing prominent glauconite grains. Both rock types locally contain phosphate nodules up to one centimeter in diameter. The unit is bounded below and above by faults. It includes interbedded sandstone. |
| Ta | Un-named glauconitic sandstone | Paleocene (65-55 million years before present | Coarse-grained, green, glauconite-rich, lithic sandstone with well-preserved coral fossils. Locally interbedded with gray mudstone and hard, fine-grained, mica-bearing quartz sandstone. Outcrop of this unit is restricted to a small, fault-bounded area in the Oakland hills. |
| Tes | Un-named mudstone | Eocene (55-30 million years before present) | Green and maroon, foraminifer-rich mudstone, locally interbedded with hard, distinctly bedded, mica-bearing, quartz sandstone. This unit is bounded above and below by faults. |
| *Great Valley Complex* | | | |
| Kr | Redwood Canyon Formation | Late Cretaceous (100-70 million years before present) | Siliceous shale with interbedded sandstone and siltstone. This unit also includes maroon, concretionary shale at base. This formation was originally considered to be Paleocene, but it contains foraminifers and radiolarians of Campanian age in its type area and throughout its outcrop extent. |
| Kjm | Joaquin Miller Formation | Late Cretaceous (100-70 million years before present) | Thinly bedded shale with minor sandstone. The shale grades into thinly bedded, fine-grained sandstone near the top of the formation. The contact with the overlying Oakland Sandstone is gradational. |
| Jsv | Keratophyre and quartz keratophyre | Late Jurassic (150 million years before present) | Highly altered intermediate and silicic volcanic and hypabyssal rocks. Feldspars are almost all replaced by albite. In some places, closely associated with or possibly intruded into basalt. These rocks are probably the altered remnants of a volcanic arc deposited on ophiolite during the Jurassic Period. |
| Ksc | Shephard Creek Formation | Late Cretaceous (100-70 million years before present) | Distinctly bedded mudstone and shale, mica-rich siltstone, and thin beds of fine-grained, mica-rich wacke. This formation is conformably overlain by the Redwood Canyon Formation. |
| Jb | Coast Range ophiolite-massive basalt and diabase | Jurassic (200 million years before present) | |
| sp | Coast Range | Jurassic | Mainly sheared serpentinite, but also includes massive serpentinized |

| Abbreviation | Name | Geologic Era | Description |
|---|---|---|---|
| | ophiolite-Serpentinite | (200 million years before present) | harzburgite. In places, pervasively altered to silica carbonate rock. |
| Ko | Oakland Conglomerate | Late Cretaceous (100-70 million years before present) | Massive, medium- to coarse-grained, biotite and quartz-rich wacke and prominent interbedded lenses of pebble to cobble conglomerate. Conglomerate clasts are distinguished by a large amount of silicic volcanic detritus, including quartz porphyry rhyolite. Conglomerate composes as much as fifty percent of the unit in the Oakland hills, but it becomes a progressively smaller portion of the unit to the south. In areas of little conglomerate, this unit is distinguished from other Great Valley complex sandstones by its stratigraphic position, the presence of minor conglomerate, and its massive character. Includes, mapped locally: conglomerate and siltstone. |
| *Franciscan Complex* | | | |
| KJfm | Franciscan complex mélange | Cretaceous/Late Jurassic (150-100 million years before present) | Sheared black argillite, graywacke, and minor green tuff, containing blocks and lenses of graywacke and meta-graywacke (fs ), chert (fc), shale, metachert, serpentinite (sp), greenstone (fg), amphibolite, tuff, eclogite, quartz schist, greenschist, basalt, marble, conglomerate, and glaucophane schist (fm). Blocks range in size from pebbles to several hundred meters in length. |
| KJfs | Franciscan complex sandstone, undivided | Late Cretaceous to Late Jurassic (150-100 million years before present) | Graywacke and meta-graywacke not assigned to any terrane. |
| Kfn | Sandstone of the Novato Quarry terrane | Late Cretaceous (100-70 million years before present) | Distinctly bedded to massive, fine- to coarse-grained, mica-bearing, lithic wacke. Where distinctly bedded, sandstone beds are about 1 m thick, and siltstone interbeds are a few centimeters thick. Sedimentary structures are well preserved. At the type area in Marin County, fossils of Campanian age have been discovered, but none have yet been collected in Alameda County. In north Oakland, the sandstone is associated with a 1-km-diameter body of fine-grained quartz diorite. |
| KJf | Undivided Franciscan complex | Cretaceous and Jurassic (200-70 million years before present) | More or less sheared and metamorphosed graywacke, shale, mafic volcanic rock, chert, ultramafic rock, limestone, and conglomerate. Highly sheared sandstone and shale forms the matrix of a mélange containing blocks of many rock types, including sandstone, chert, greenstone, blueschist, serpentinite, eclogite, and limestone. |

Compiled from Geologic Map and Map Database of the Oakland Metropolitan Area, Alameda, Contra Costa, and San Francisco Counties, CA. by R.W. Grayner. 2000. Miscellaneous Field Studies MF-2342, USGS

**Figure 21: Landslide Hazards of the Sausal Creek Watershed**




Source: Richard Pike, Russell Graymer, Sebastian Roberts 2001. Map and map database of susceptibility to slope failure by sliding and earthflow in the Oakland Area, MF-2385, California, US Geological Survey, 2001.

**SOILS**

Soil types in the Sausal Creek watershed are depicted in Figure 22. Table 3 lists the characteristics of each soil type. The slope class of each soil type is also listed.

Soil types vary by the composition of clay, loam, sand, gravel, or rock; as well as their depth, slope, permeability, and erosion potential. These features of each soil type affect the rate of infiltration of rainwater, the amount of groundwater stored, and the type of vegetation (forest, shrub, grassland) associated with the soil type and able to protect the soil from erosion.

The soil types of the upper watershed have a high to very high erosion rating. Urbanization of these areas has created erosion problems by producing higher volumes of stormwater running off roofs, roads, and paved areas into steep natural ephemeral creek channels and onto highly erodible slopes. Ephemeral creeks only carry water immediately after a rainstorm. These steep channels, if not covered in dense vegetation, can rapidly erode when urban development increases runoff volumes. In both Shepherd Canyon and Cobbledick Creek sub-basins, housing and roads are built next to and over numerous ephemeral creeks.

**Table 3: Soil Types of Sausal Creek Watershed**

| Soil Type Number | Name | Characteristics | | |
|---|---|---|---|---|
| | | Permeability | Erosion Hazard Rating | Description |
| 126 | Maymen loam, 30-75% slopes | High to very high runoff; moderate to moderately rapid permeability | High to very high | The Maymen series consists of shallow, somewhat excessively drained soils that formed in material weathered from sandstone, shale, and conglomerate. Maymen soils are on mountains and have slopes of 5 to 100 percent. |
| 127 | Maymen-Los Gatos complex, 30-75% slopes | Rapid to very rapid runoff; moderate permeability | High to very high | The Los Gatos series is a member of the fine-loamy, mixed, mesic family of Typic Argixerolls. Typically, Los Gatos soils have brown, light clay loam, granular, slightly acid A1 horizons, brown and yellowish red, slightly and medium acid clay loam and gravelly clay loam Bt horizons over sandstone bedrock at a depth of 36 inches. |
| 129 | Millsholm silt loam, 50-75% slopes | Low to very High runoff; moderate permeability | Very high | The Millsholm series consists of shallow, well drained soils that formed in material weathered from sandstone, mudstone and shale. Millsholm soils are on hills and mountains and have slopes of 50 to 75 percent. |
| 130 | Montara-Rock outcrop complex, 30-75% slopes | Medium and high runoff; moderately | High to very high | The Montara series consists of shallow well drained soils that formed in material weathered from |

**Table 3: Soil Types of Sausal Creek Watershed**

| Soil Type Number | Name | Characteristics | | |
|---|---|---|---|---|
| | | Permeability | Erosion Hazard Rating | Description |
| | | slow permeability | | serpentinitic rocks. Montara soils are on uplands and ridge tops and have slopes of 5 to 75 percent. Seep areas adjacent to rock outcrops may persist for several months after the end of the rainy season. |
| 146 | Urban land | | | |
| 148 | Urban land-Clear Lake complex | Negligible to high runoff and low to very low permeability | None to slight | The Clear Lake series consists of very deep, poorly drained soils that formed in fine textured alluvium derived from sandstone and shale. Clear Lake soils are in basins and in swales of drainageways. Slopes are 0 to 2 percent. The water table is at depths of 4 to 10 feet in the late summer and in some areas is very near the surface during wet months of winter. |
| 150 | Urban land-Tierra complex, 2-5% slopes | Slow to rapid runoff; very low permeability | Slight | The Tierra series consists of deep, moderately well drained soils that formed in alluvial materials from sedimentary rocks. Tierra soils are on dissected terraces and low hills and have slopes of 2 to 50 percent. |
| 151 | Urban land-Tierra complex, 5-15% slopes | | Moderate | |
| 152 | Urban land-Tierra complex, 15-30% slopes | | Moderate to high | |
| 158 | Xerorthents-Los Osos complex, 30-50% slopes | Moderate permeability; rapid to very rapid runoff | High | Xerorthents consist of soil material resulting from cutting or filling for urban development.<br>The Los Osos series consists of moderately deep, well drained soils that formed in material weathered from sandstone and shale. Los Osos soils are on uplands and have slopes of 5 to 75 percent. |
| 159 | Xerorthents-Millsholm complex, 30-50% slopes | Moderate permeability; rapid to very rapid runoff | High to very high | Xerorthents consist of soil material resulting from cutting or filling for urban development.<br>The Millsholm series consists of shallow, well drained soils that formed in material weathered from sandstone, mudstone and shale. Millsholm soils are on hills and mountains and have slopes of 5 to 75 percent. |
| 162 | Water | | | |

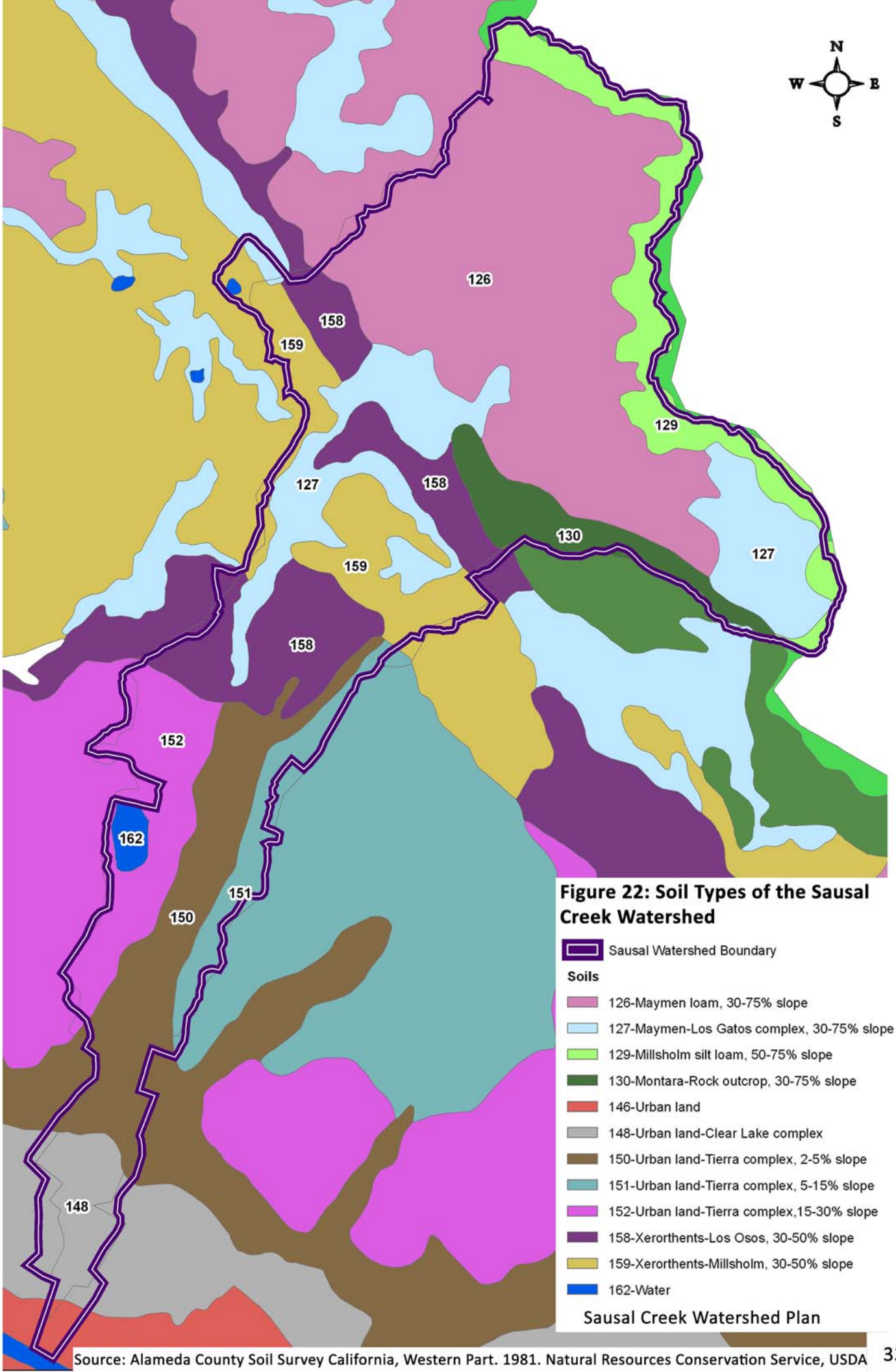



**Figure 22: Soil Types of the Sausal Creek Watershed**

Sausal Watershed Boundary

**Soils**

- 126-Maymen loam, 30-75% slope
- 127-Maymen-Los Gatos complex, 30-75% slope
- 129-Millsholm silt loam, 50-75% slope
- 130-Montara-Rock outcrop, 30-75% slope
- 146-Urban land
- 148-Urban land-Clear Lake complex
- 150-Urban land-Tierra complex, 2-5% slope
- 151-Urban land-Tierra complex, 5-15% slope
- 152-Urban land-Tierra complex,15-30% slope
- 158-Xerorthents-Los Osos, 30-50% slope
- 159-Xerorthents-Millsholm, 30-50% slope
- 162-Water

Sausal Creek Watershed Plan

Source: Alameda County Soil Survey California, Western Part. 1981. Natural Resources Conservation Service, USDA

## HYDROLOGY

This section presents a discussion of the hydrologic analysis completed for the Sausal Creek Watershed. The goal of the analysis was to develop a watershed model that would simulate the rainfall-runoff processes for the 1-year through 100-year storm events over the watershed. The model was developed at a level of detail that would allow for the evaluation of measures designed to reduce the peak discharge to Sausal Creek and its tributaries.

The results of the hydrologic analysis provide flow rates and flow duration data for Sausal Creek and each of its major tributaries. This flow from the watershed model was used as input to a hydraulic model to determine the flow characteristics along the creek system. This section contains the results of the hydrologic analysis completed by Hydrologic Systems, Inc. (HSI) and revised and completed by NewFields River Basin Services, LLC (NRBS).

### Watershed Delineation

The Sausal Creek watershed drains from the Oakland Hills to the San Francisco Bay. The total watershed area is approximately 4.5 square miles. The upper elevation of the watershed is approximately 1,525 ft. NGVD and the lower elevation is approximately sea level or 0 ft. NGVD (Figure 2).

To accurately define the runoff characteristics of the Sausal Creek Watershed, the watershed was divided into 33 separate sub-basins. The sub-basins were defined through common runoff characteristics that were distinct from adjacent basins. Figure 23 is a plan view of the watershed showing the location and extent of the different sub-basins. The acreage of each sub-basin is provided in Table 4. Storm drains can redirect flow from the boundary of one watershed into a different one. This effect occurs along the Sanborn Road area of Sausal Creek drainage where some areas are now draining into the adjacent Peralta Creek watershed.

### Precipitation

#### Methodology

There are a variety of precipitation gages in the vicinity of the Sausal drainage. To develop precipitation data sets for the 2-, 5-, 10-, 25-, and 100-year, 24-hour storm events, a long-term hourly precipitation gage is required. There was no single gage that accurately reflected the precipitation across the watershed. Therefore, a precipitation dataset needed to be created from data collected at gages near the watershed. Figure 24 is a map showing the location of precipitation gages that were identified in the vicinity of the project.

**Figure 23: Hydrologic Sub-Basins of the Sausal Creek Watershed**

Sausal Creek Watershed Plan

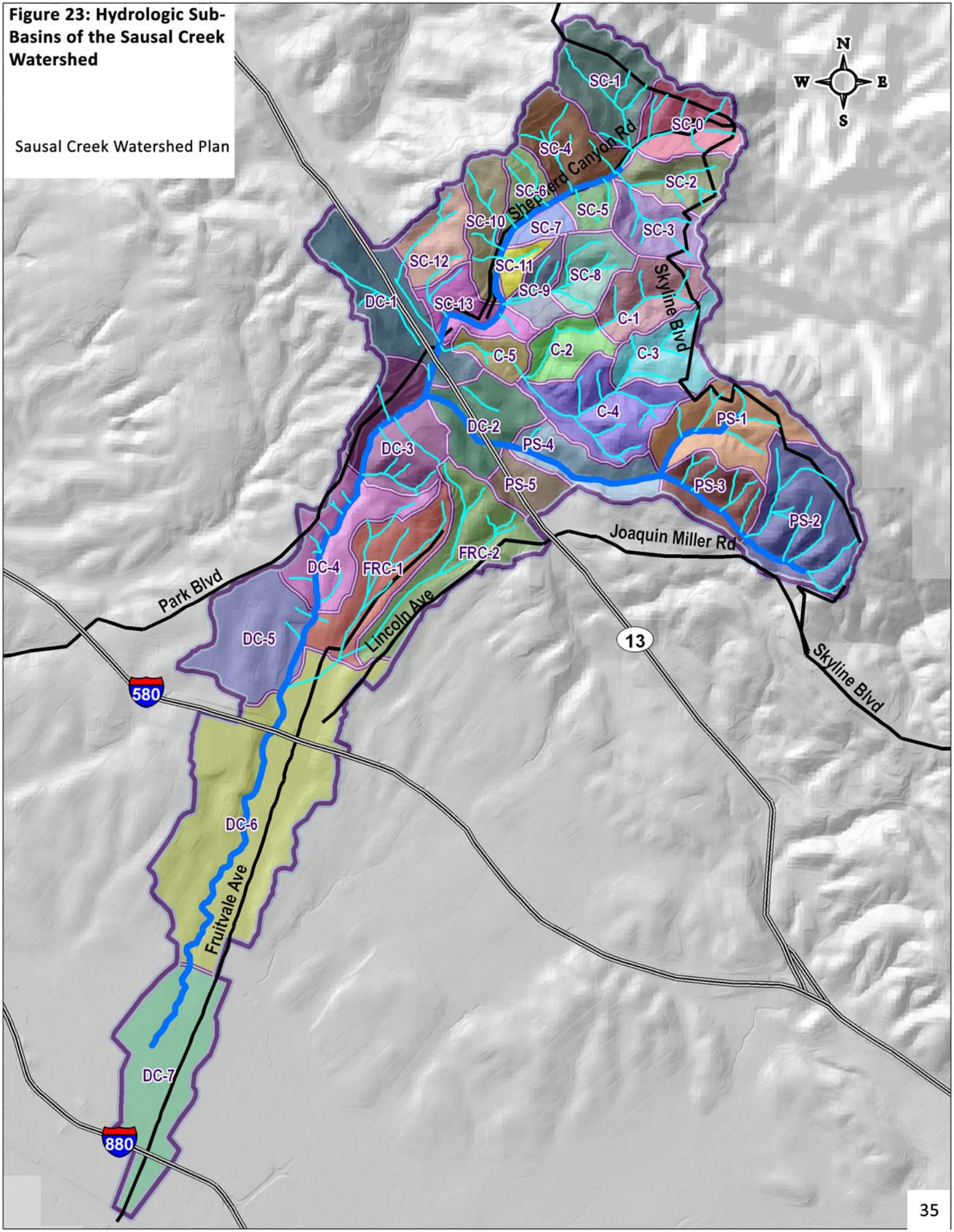
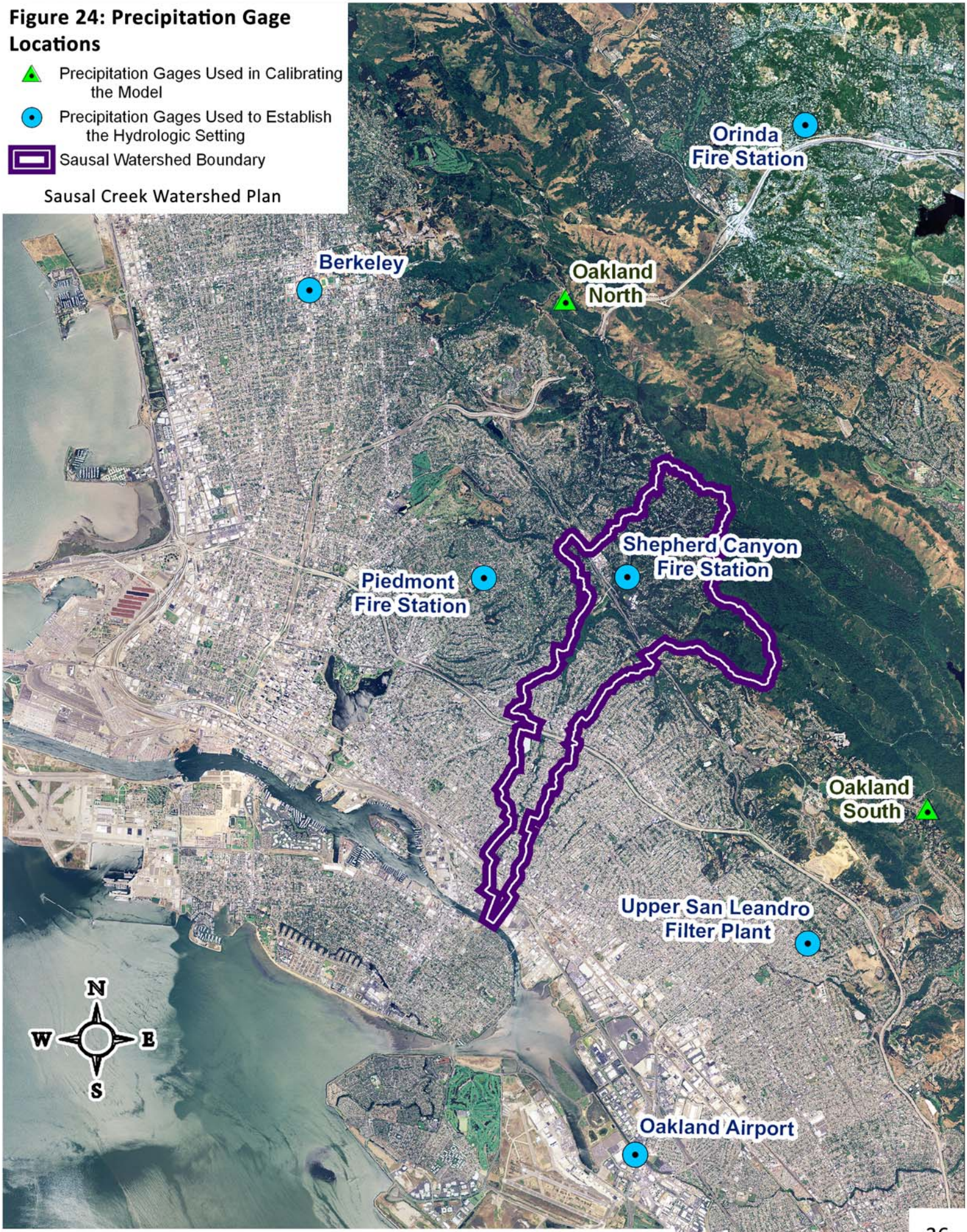


**Figure 24: Precipitation Gage Locations**

- Precipitation Gages Used in Calibrating the Model
- Precipitation Gages Used to Establish the Hydrologic Setting
- Sausal Watershed Boundary

Sausal Creek Watershed Plan




Sources: Hydrologic Systems, Inc. 2008. and NewFields River Basin Services. 2009

**Table 4: Sausal Creek Watershed Sub-Basins Used in Hydrologic Model**

| Sub-Basin | Sub-Basin Name | Total Area (ac) | Total Area (sq mi) |
|---|---|---|---|
| Shephard Creek | SC-0 | 72.9 | 0.114 |
| | SC-1 | 100.3 | 0.157 |
| | SC-2 | 54.5 | 0.085 |
| | SC-3 | 56.6 | 0.088 |
| | SC-4 | 77.9 | 0.122 |
| | SC-5 | 23.0 | 0.036 |
| | SC-6 | 34.0 | 0.053 |
| | SC-7 | 19.2 | 0.030 |
| | SC-8 | 51.9 | 0.081 |
| | SC-9 | 31.9 | 0.050 |
| | SC-10 | 56.1 | 0.088 |
| | SC-11 | 18.8 | 0.029 |
| | SC-12 | 55.7 | 0.087 |
| | SC-13 | 53.5 | 0.084 |
| Cobbledick Creek | C-1 | 68.3 | 0.107 |
| | C-2 | 45.6 | 0.071 |
| | C-3 | 67.5 | 0.105 |
| | C-4 | 105.3 | 0.164 |
| | C-5 | 27.7 | 0.043 |
| Palo Seco Creek | PS-1 | 109.2 | 0.171 |
| | PS-2 | 147.5 | 0.230 |
| | PS-3 | 64.4 | 0.101 |
| | PS-4 | 65.9 | 0.103 |
| | PS-5 | 35.9 | 0.056 |
| Dimond Canyon | DC-1 | 124.0 | 0.194 |
| | DC-2 | 80.4 | 0.126 |
| | DC-3 | 108.3 | 0.169 |
| | DC-4 | 103.6 | 0.162 |
| | DC-5 | 119.9 | 0.187 |
| | DC-6 | 387.1 | 0.605 |
| | DC-7 | 173.7 | 0.271 |
| Whittle Creek | FRC-1 | 107.8 | 0.168 |
| | FRC-2 | 129.3 | 0.202 |
| | **Total** | **2,777** | **4.34** |

Precipitation varies across the San Francisco Bay Area, both in the east to west direction as well as north to south. Precipitation also typically varies with elevation, with precipitation increasing as the elevation increases. The winter season storms that produce the greatest amount of precipitation typically come out of the northwest. As storms move to the southeast, the orographic effect of the Oakland Hills increases the precipitation intensity. To account for this effect, the precipitation gage must be representative of the location, elevation, and orientation of the Oakland Hills. The precipitation data from an adjacent gage has to be adjusted to reflect the conditions specific to the Sausal Creek watershed.

Precipitation gages in the vicinity of the watershed include: Oakland Airport, Upper San Leandro Filter Plant, Piedmont Fire Station, and Orinda Fire Station, and Berkeley (Table 5, Figure 24). Another gage is located at the Shepherd Canyon Fire department, but it only collects daily precipitation data. This gage is useful because it is located in the center of the Sausal Creek Watershed, and provides a good estimate of annual precipitation. The remaining gages were either too far away from the project site, or were located at elevations that were not representative of the watershed.

Of the 6 available gages, the most appropriate gage was the Upper San Leandro Filter Plant Gage (USLFP), which is located approximately 2.6 miles south of the watershed. For hourly precipitation, this gage has a period of record from 1945 through 1989, providing a total of 45 years of record. From 1989 to present, only daily precipitation totals have been recorded.

The Mean Annual Precipitation (MAP) for the period of record at the Upper San Leandro Filter Plant is 24.37 inches. Figure 25 is a time-series plot of the annual precipitation for the Upper San Leandro Filter Plant gage. Figure 26 is a plot of the Mean Annual Precipitation at each gage as a function of the gage elevation. The data for the USLFP gage was adjusted to reflect the elevation of the Sausal Creek Watershed. Three separate modifications to the precipitation data were preformed. The first modification adjusted the precipitation data to reflect the elevation of the upper basin. Two additional adjustments were developed for the middle and lower basin elevations. For the final model, three separate precipitation datasets were used for the watershed.

A tabulation of the annual data from the USLFP gage has been provided in Appendix A. Table 6 shows the precipitation intensity-duration data for the upper, middle, and lower basins. Figure 27 is a plot of the frequency distribution for the 1-hour, 2-hour, 3-hour, and 6-hour continuous precipitation volumes. The return frequencies were computed using a Log Pearson Type III analysis of the peak annual precipitation values from the USLFP gage. The details of the Log Pearson Analysis are provided in Appendix A.

**Table 5: Precipitation Gages Used in the Hydrology Analysis**

| Name | Gage No. | Operator | Latitude | Longitude | Elevation (ft.) | Type | From | To | Source |
|---|---|---|---|---|---|---|---|---|---|
| Orinda | E40 766100 | Contra Costa Fire | 37.895 | -122.170 | 700 | Hourly Precipitation | 1973 | Present | DWR |
| Upper San Leandro Filter Plant | E40 918500 | EBMUD | 37.767 | -122.167 | 390 | Hourly Precipitation | 1948 | Present | DWR |
| Piedmont Fire Station | E40 685670 | Alameda County | 37.823 | -122.232 | 330 | Hourly Precipitation | 1972 | 1989 | DWR |
| Oakland Airport | E40 633500 | HPD | 37.733 | -122.200 | 3 | Hourly Precipitation | 1940 | 1985 | DWR |
| Berkeley | n/a | UC | 37.868 | -122.268 | 205 | 15 Minute Precipitation | 2001 | Present | UC |
| Shepherd Canyon Fire Station | n/a | Oakland Fire Department | 37.824 | -122.204 | 630 | Daily Precipitation | Unknown | Present | OFD |
| Oakland North | ONO | Oakland Fire Services Agency | 37.867 | -122.217 | 1,300 | Hourly Precipitation | 11/1/1992 | Present | CDEC |
| Oakland South | OSO | Oakland Fire Services Agency | 37.7881 | -122.1436 | 1,180 | Hourly Precipitation | 11/1/1992 | Present | CDEC |

**Figure 25: Upper San Leandro Filter Plant Annual Precipitation Totals**

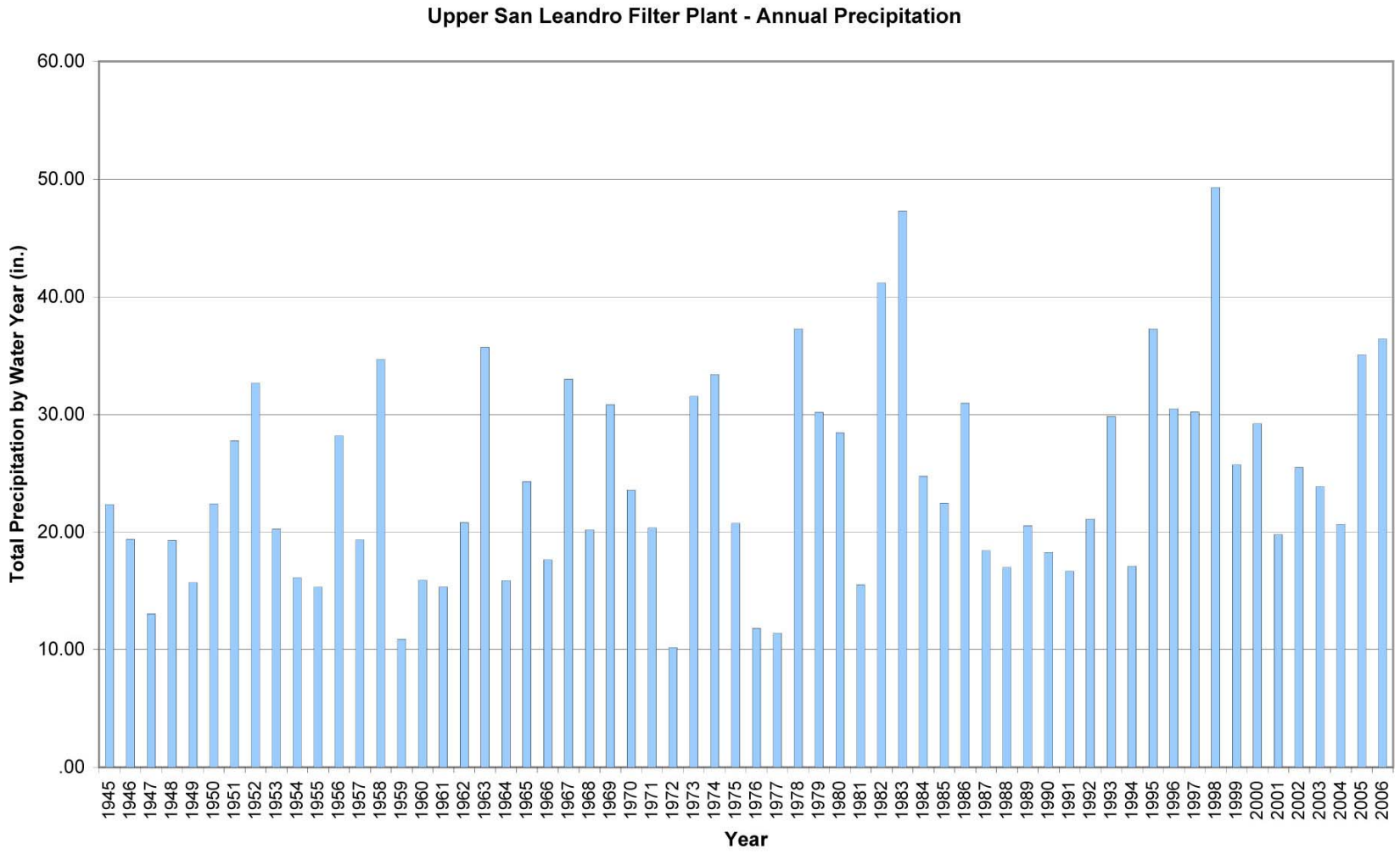


**Figure 26: Comparison of Annual Precipitation by Elevation**

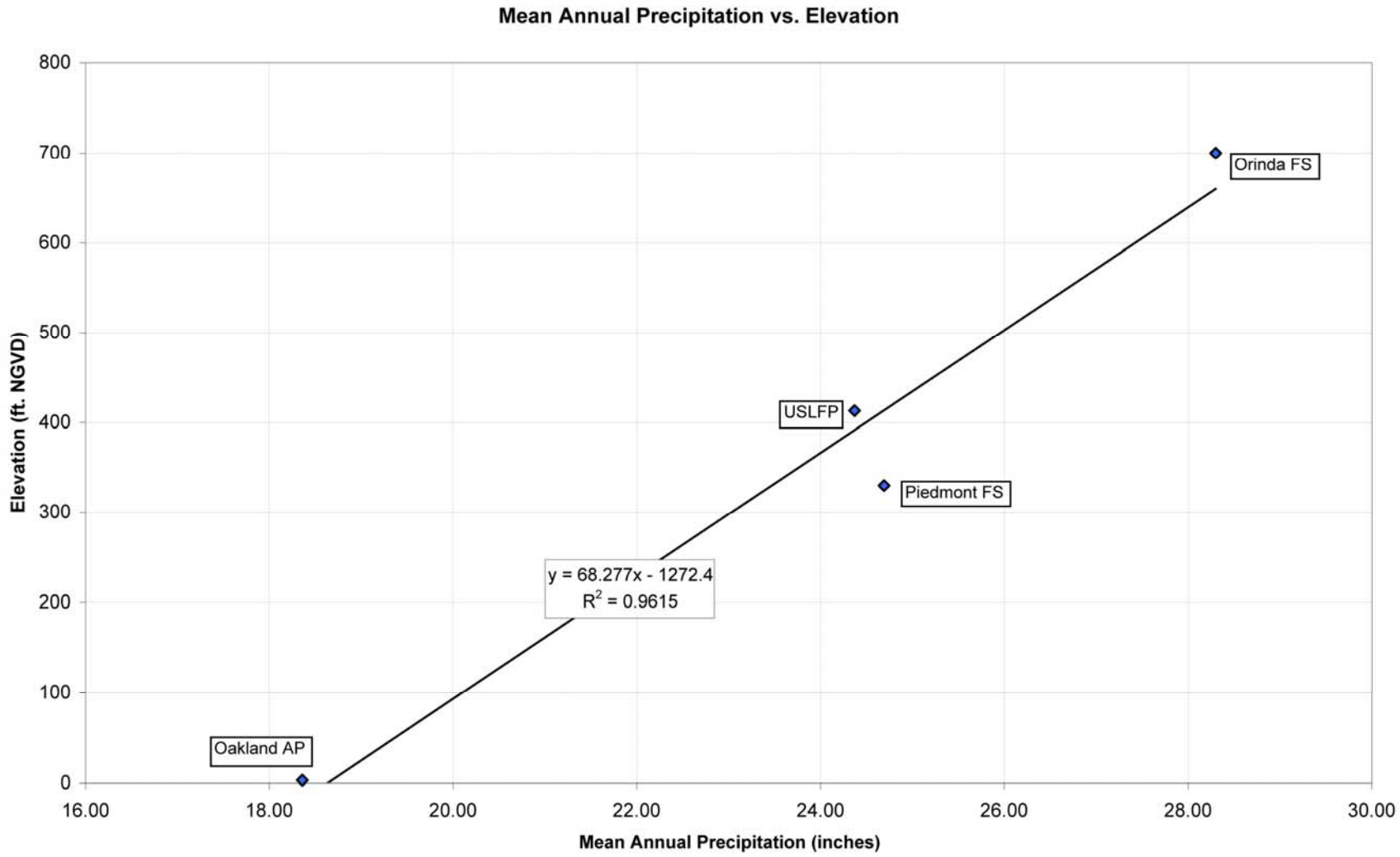
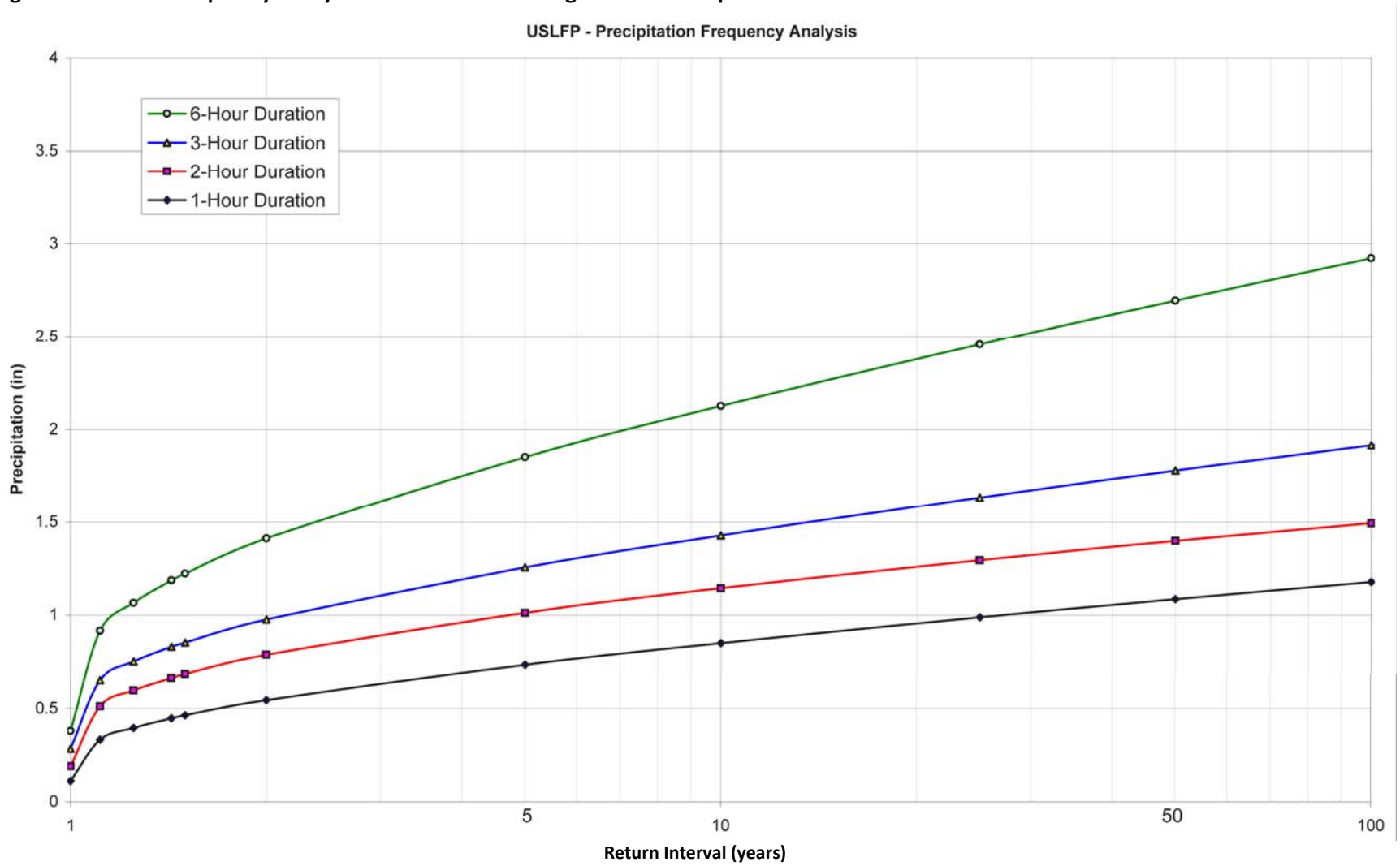


**Table 6: Peak Precipitation Volumes for the 1-Hour through 24-Hour Storm Events**

| **Upper Basin** | | | | | | | |
|---|---|---|---|---|---|---|---|
| Elevation | Return Interval | 1 HR | 2HR | 3HR | 6HR | 12HR | 24 HR |
| 1134 | 2-yr | 0.61 | 0.95 | 1.22 | 1.86 | 2.65 | 3.33 |
| 1134 | 5-yr | 0.83 | 1.25 | 1.60 | 2.49 | 3.62 | 4.69 |
| 1134 | 10-yr | 0.96 | 1.42 | 1.84 | 2.88 | 4.26 | 5.65 |
| 1134 | 25-yr | 1.12 | 1.63 | 2.13 | 3.37 | 5.07 | 6.92 |
| 1134 | 100-yr | 1.35 | 1.91 | 2.54 | 4.06 | 6.24 | 8.94 |
| **Middle Basin** | | | | | | | |
| Elevation | Return Interval | 1 HR | 2HR | 3HR | 6HR | 12HR | 24 HR |
| 708 | 2-yr | 0.57 | 0.86 | 1.08 | 1.60 | 2.16 | 2.75 |
| 708 | 5-yr | 0.77 | 1.11 | 1.40 | 2.11 | 2.94 | 3.87 |
| 708 | 10-yr | 0.90 | 1.26 | 1.60 | 2.44 | 3.45 | 4.67 |
| 708 | 25-yr | 1.04 | 1.43 | 1.84 | 2.83 | 4.08 | 5.74 |
| 708 | 100-yr | 1.25 | 1.66 | 2.17 | 3.39 | 5.02 | 7.47 |
| **Lower Basin** | | | | | | | |
| Elevation | Return Interval | 1 HR | 2HR | 3HR | 6HR | 12HR | 24 HR |
| 98 | 2-yr | 0.52 | 0.71 | 0.87 | 1.21 | 1.47 | 1.91 |
| 98 | 5-yr | 0.69 | 0.91 | 1.10 | 1.57 | 1.96 | 2.69 |
| 98 | 10-yr | 0.80 | 1.02 | 1.25 | 1.79 | 2.28 | 3.26 |
| 98 | 25-yr | 0.93 | 1.15 | 1.41 | 2.06 | 2.68 | 4.05 |
| 98 | 100-yr | 1.10 | 1.31 | 1.64 | 2.43 | 3.27 | 5.37 |

**Figure 27: Return Frequency Analysis for the 1-Hour through 6-Hour Precipitation Duration**



**Balanced Hyetograph Development**

A hyetograph is a time series of precipitation over the duration of a storm event. The hourly precipitation data from the precipitation analysis were evaluated for frequency and occurrence to develop a balanced hyetograph for the 2-, 5-, 10-, 25-, and 100-year storm events. The duration for each of the design storms was 24-hours. A balanced hyetograph is constructed in a way to ensure that the 24-hour hyetograph contains the 1-hour peak rainfall as well as the 2-hour and 3-hour through the 24-hour duration event for the specified return frequency. This allows the 24-hour storm event to be applied to basins that peak within different duration periods. Table 7 lists the hourly precipitation data for the different storm events as calculated from the three synthetic Sausal Creek precipitation gages. These hyetographs were applied to the sub-basins in the upper, middle, and lower sections of the watershed. Figures 28 through 31 are time series plots of each of the storm hydrographs.

**Table 7: Sausal Creek Lower Watershed 24-Hour Storm Hyetographs (inches)**

| Hour | 1-Year Event | 2-Year Event | 5-Year Event | 10-Year Event | 25-Year Event | 100-Year Event |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.02 | 0.05 | 0.06 | 0.09 | 0.13 |
| 2 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.14 |
| 3 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.17 |
| 4 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 5 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 6 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 7 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 8 | 0.01 | 0.04 | 0.07 | 0.09 | 0.11 | 0.18 |
| 9 | 0.02 | 0.08 | 0.09 | 0.10 | 0.13 | 0.18 |
| 10 | 0.02 | 0.11 | 0.15 | 0.17 | 0.20 | 0.24 |
| 11 | 0.03 | 0.15 | 0.19 | 0.22 | 0.25 | 0.29 |
| 12 | 0.10 | 0.52 | 0.69 | 0.80 | 0.93 | 1.10 |
| 13 | 0.04 | 0.20 | 0.22 | 0.22 | 0.27 | 0.33 |
| 14 | 0.03 | 0.14 | 0.19 | 0.21 | 0.22 | 0.26 |
| 15 | 0.02 | 0.09 | 0.14 | 0.16 | 0.20 | 0.21 |
| 16 | 0.01 | 0.06 | 0.09 | 0.10 | 0.12 | 0.18 |
| 17 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 18 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 19 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 20 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 21 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 22 | 0.01 | 0.04 | 0.06 | 0.08 | 0.11 | 0.18 |
| 23 | 0.01 | 0.03 | 0.06 | 0.07 | 0.10 | 0.14 |
| 24 | 0.00 | 0.02 | 0.04 | 0.05 | 0.07 | 0.11 |
| **Peak Hour Intensity** | **0.103** | **0.52** | **0.69** | **0.80** | **0.93** | **1.10** |
| **24-Hour Total** | **0.39** | **1.91** | **2.69** | **3.26** | **4.05** | **5.37** |

**Table 8: Sausal Creek Middle Watershed 24-Hour Storm Hyetographs (inches)**

| Hour | 1-Year Event | 2-Year Event | 5-Year Event | 10-Year Event | 25-Year Event | 100-Year Event |
|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 2 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 3 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 4 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 5 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 6 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 7 | 0.01 | 0.07 | 0.11 | 0.14 | 0.18 | 0.24 |
| 8 | 0.02 | 0.10 | 0.14 | 0.18 | 0.22 | 0.28 |
| 9 | 0.03 | 0.14 | 0.19 | 0.22 | 0.25 | 0.31 |
| 10 | 0.04 | 0.18 | 0.24 | 0.28 | 0.32 | 0.39 |
| 11 | 0.04 | 0.22 | 0.29 | 0.34 | 0.39 | 0.43 |
| 12 | 0.11 | 0.57 | 0.77 | 0.90 | 1.04 | 1.25 |
| 13 | 0.06 | 0.28 | 0.33 | 0.36 | 0.41 | 0.51 |
| 14 | 0.04 | 0.20 | 0.27 | 0.31 | 0.36 | 0.42 |
| 15 | 0.03 | 0.15 | 0.21 | 0.25 | 0.31 | 0.39 |
| 16 | 0.02 | 0.11 | 0.16 | 0.20 | 0.24 | 0.31 |
| 17 | 0.02 | 0.08 | 0.13 | 0.16 | 0.20 | 0.26 |
| 18 | 0.01 | 0.06 | 0.10 | 0.12 | 0.16 | 0.22 |
| 19 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 20 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 21 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 22 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 23 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| 24 | 0.01 | 0.05 | 0.08 | 0.10 | 0.14 | 0.20 |
| **Peak Hour Intensity** | **0.113** | **0.57** | **0.77** | **0.90** | **1.04** | **1.25** |
| **24-Hour Total** | **0.55** | **2.75** | **3.87** | **4.67** | **5.74** | **7.47** |

**Table 9: Sausal Creek Upper Watershed 24-Hour Storm Hyetographs (inches)**

| Hour | 1-Year Event | 2-Year Event | 5-Year Event | 10-Year Event | 25-Year Event | 100-Year Event |
|---|---|---|---|---|---|---|
| 1 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 2 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 3 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 4 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 5 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 6 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 7 | 0.02 | 0.10 | 0.16 | 0.19 | 0.25 | 0.32 |
| 8 | 0.03 | 0.13 | 0.20 | 0.24 | 0.29 | 0.38 |
| 9 | 0.04 | 0.18 | 0.25 | 0.29 | 0.35 | 0.43 |
| 10 | 0.04 | 0.22 | 0.30 | 0.35 | 0.41 | 0.50 |
| 11 | 0.05 | 0.27 | 0.36 | 0.42 | 0.50 | 0.56 |
| 12 | 0.12 | 0.61 | 0.83 | 0.96 | 1.12 | 1.35 |
| 13 | 0.07 | 0.34 | 0.42 | 0.46 | 0.51 | 0.63 |
| 14 | 0.05 | 0.24 | 0.32 | 0.38 | 0.44 | 0.53 |
| 15 | 0.04 | 0.19 | 0.26 | 0.31 | 0.38 | 0.48 |
| 16 | 0.03 | 0.15 | 0.22 | 0.26 | 0.32 | 0.48 |
| 17 | 0.02 | 0.12 | 0.17 | 0.21 | 0.27 | 0.35 |
| 18 | 0.02 | 0.09 | 0.14 | 0.18 | 0.22 | 0.30 |
| 19 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 20 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 21 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 22 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 23 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| 24 | 0.01 | 0.06 | 0.09 | 0.12 | 0.15 | 0.23 |
| **Peak Hour Intensity** | **0.121** | **0.61** | **0.83** | **0.96** | **1.12** | **1.35** |
| **24-Hour Total** | **0.67** | **3.33** | **4.69** | **5.65** | **6.92** | **8.94** |

**Figure 28: 24-Hour Storm Hyetographs, Upper Sausal Creek Watershed**

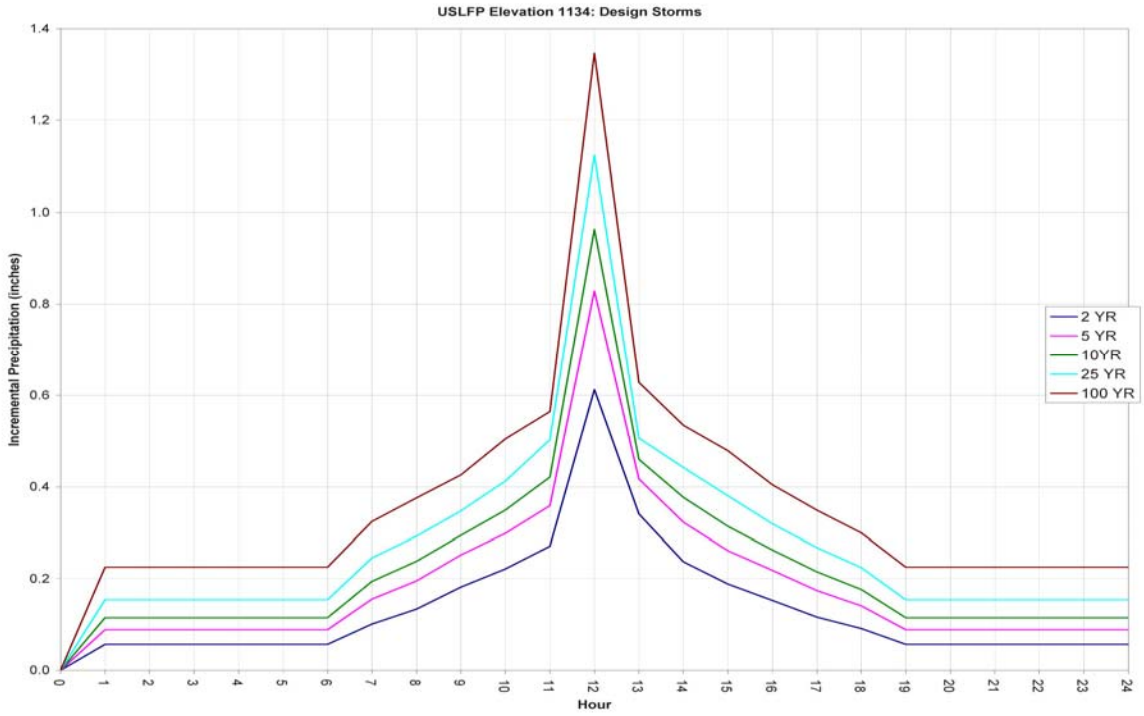



**Figure 29: 24-Hour Storm Hyetographs, Middle Sausal Creek Watershed**

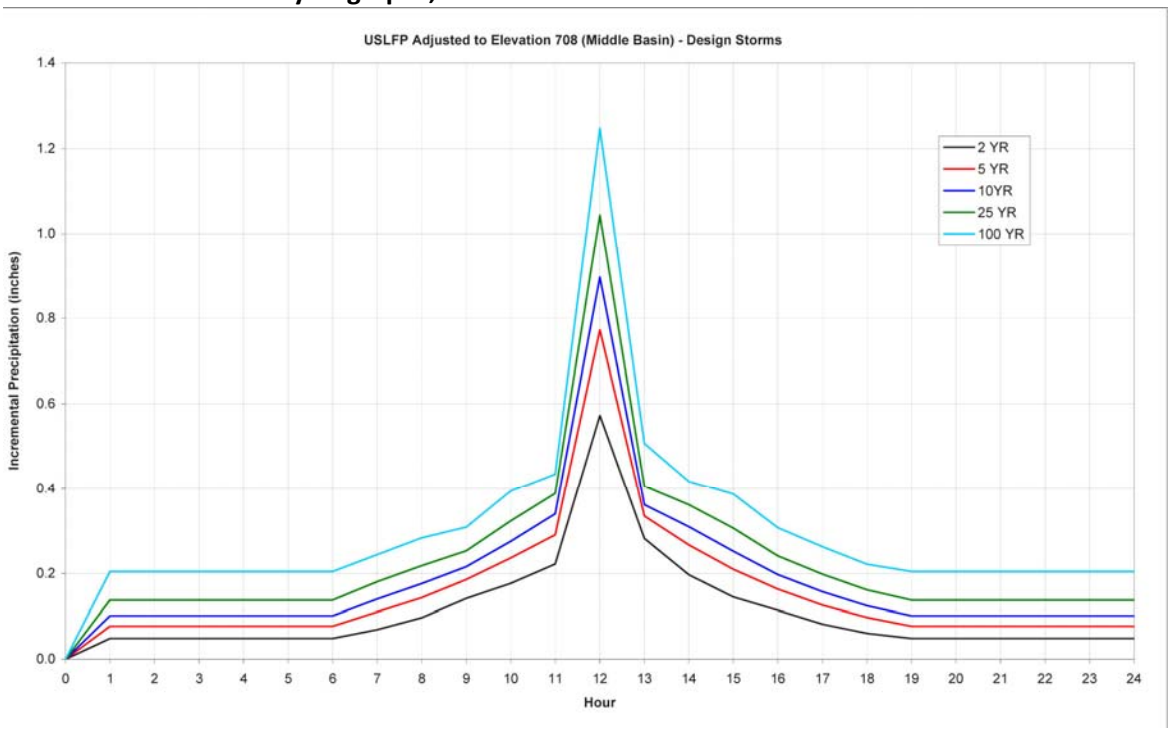
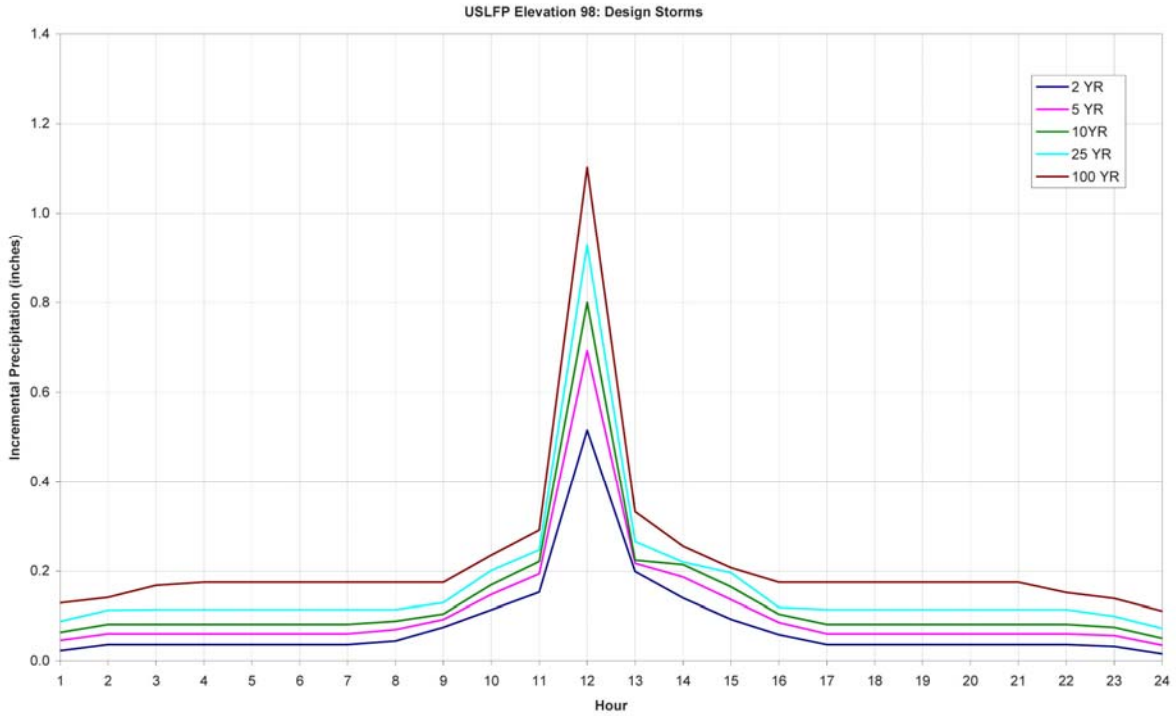


**Figure 30: 24-Hour Storm Hyetographs, Lower Sausal Creek Watershed**




**Soils Analysis**

One of the key components in evaluating runoff in the watershed is the soil type and texture. The data developed in the Soil Conservation Service Soil Survey for Alameda County (SCS 1978) were used to characterize the soils within the watershed. Soil characteristics can have a strong impact on the volume and timing of runoff. The two factors that have the greatest influence on runoff are soil permeability and hydrologic soil group. These factors have been determined by the Natural Resource Conservation Service (NRCS) in their analysis of Alameda County soils.

*Hydrologic Soil Group*

Soils are classified by the NRCS into four Hydrologic Soil Groups based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D. Soils classified as an A generally has the smallest runoff potential, whereas D's have the greatest potential. Details of this classification can be found in 'Urban Hydrology for Small Watersheds' published by the Engineering Division of the Natural Resource Conservation Service, United States Department of Agriculture, Technical Release–55. The four different soil groups are shown below.

> Group A soils consist of sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well- to excessively-drained sands or gravels and have a high rate of water transmission.
>
> Group B soils consist of silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly or moderately deep to deep, moderately well- to well-drained soils with moderately fine to moderately coarse textures.

Group C soils consist of sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.

Group D soils consist of clay loam, silty clay loam, sandy clay, silty clay or clay. This soil group has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

Figure 22 shows soil types in the Sausal Creek watershed. A description of the soil type, infiltration rate, and the hydrologic soil group is provided in Table 10.

**Table 10: Soils Characteristics**

| MUSYM Number | Name | Permeability (inches/hour) | Soil Class (A-D) |
|---|---|---|---|
| 126 | Maymen loam, 30-75% slopes | 0.6-2.0 | D |
| 127 | Maymen-Los Gatos complex, 30-75% slopes | 0.6-2.0 | C |
| 129 | Millsholm silt loam, 50-75% slopes | 0.6-2.0 | D |
| 130 | Montara-Rock outcrop complex, 30-75% slopes | 0.2-0.6 | D |
| 146 | Urban land | | |
| 148 | Urban land-Clear Lake complex | | |
| 150 | Urban land-Tierra complex, 2-5% slopes | 0.6-2.0 | D |
| 151 | Urban land-Tierra complex, 5-15% slopes | 0.6-2.0 | D |
| 152 | Urban land-Tierra complex, 15-30% slopes | 0.2-0.6 | C |
| 158 | Xerorthents-Los Osos complex, 30-50% slopes | 0.2-0.6 | C |
| 159 | Xerorthents-Millsholm complex, 30-50% slopes | 0.6-2.0 | D |
| 162 | Water | | W |

*Curve Number Determination*

The runoff curve number (CN) is a land cover/use index that represents the effect of soils, land use, and antecedent moisture conditions on rainfall runoff. Curve numbers for this project were taken from the textbook Hydrologic Analysis and Design by Richard McCuen (McCuen, 1989). For any particular land use, the CN can change depending on the hydrologic soil group underlying the basin.

The area of each soil type within each of the sub-basins was calculated to come up with a composite hydrologic soil group for each of the sub-basins. This information together with the land use within each of the sub-basins was used to compute a composite runoff curve number for each sub-basin. Table 12 is a listing of each of the sub-basins in the analysis along with the distribution of soil groups, and composite curve numbers. The composite curve number was computed for each sub-basin based on the land use and soil types represented in the basin.

*Flow Path and Lag Time*

The runoff, as computed by the model, is a function of precipitation, basin topography, land use and soil types. The basin topography dictates the slope and path that runoff will follow through the basin. The

topography of the watershed was obtained from a 5-foot DEM of the City of Oakland conducted in 2004. The topographic information was entered into the project GIS to determine the slope and path lengths that overland flow will follow. Through an analysis of the flow path, the timing of the runoff from each watershed was determined. The runoff timing is converted into a lag time parameter which represents the difference in timing between the peak of the precipitation and the peak of the runoff. Table 11 is a summary of the runoff flow path analysis. The area and percent impermeable in the table were developed from the watershed GIS.

This hydrologic and hydraulic analysis is expressed in terms of recurrence intervals, which are used to estimate the probability of the occurrence of a given precipitation or streamflow event. For example, assume there is a 1 in 50 chance that 4.20 inches of rain will fall in a certain area in a 24-hour period during any given year. Thus, a rainfall total of 4.20 inches in a consecutive 24-hour period is said to have a 50-year recurrence interval. The recurrence interval is based on the probability that the given event will be equaled or exceeded in any given year. Rainfall recurrence intervals are based on both the magnitude and the duration of a rainfall event, whereas streamflow recurrence intervals are based solely on the magnitude of the annual peak flow.

Recurrence intervals for the annual peak streamflow at a given location change if there are significant changes in the flow patterns at that location, possibly caused by an impoundment or diversion of flow. The effects of development (conversion of land from forested or agricultural uses to commercial, residential, or industrial uses) on peak flows is generally much greater for low-recurrence interval floods than for high-recurrence interval floods, such as 25- 50- or 100-year floods. During these larger floods, the soil is saturated and does not have the capacity to absorb additional rainfall. Under these conditions, essentially all of the rain that falls, whether on paved surfaces or on saturated soil, runs off and becomes streamflow.

**Stormwater Runoff Analysis**

A watershed runoff model was developed to determine the runoff characteristics that result from precipitation over the Sausal Creek Watershed. For this analysis, the Environmental Protection Agency's Storm Water Management Model (SWMM) was used. This computer model allows for the analysis of stormwater runoff from multiple linked basins with various runoff characteristics. It is commonly used in urban watershed studies due to its ability to accurately analyze multiple linked storm drain pipe networks. The basins can be connected by common channels, overland flow or storm drain pipes.

A preliminary effort at characterizing and modeling the hydrologic and hydraulic properties of the Sausal Creek watershed was performed by Hydrologic Systems, Inc (HSI), and documented in the August, 2008 report entitled *Draft Technical Memo: Sausal Creek Watershed Analysis Hydrologic and Hydraulic Assessment* (HSI 2008). HSI developed a SWMM-XP hydrologic model, a propriety software platform that expands the capabilities of EPA SWMM 5.0, a free, publicly-available hydrologic modeling application developed by the USEPA. Because the HSI SWMM-XP license only allowed a limited number of nodes and conduits in the model (100), this computational model actually consisted of two separate models, one a more detailed model of the upper watershed, and one a more simplified model of the entire system. HSI also developed a HEC-RAS model of the Dimond Canyon section of the Sausal Creek channel, up to and including the lower sections of the Palo Seco Creek tributary.

**Table 11: Sub-Basin Runoff Characteristics**

| Basin | Area | Percent Impermeable | Pervious Area Curve Number | Total Lag Time |
|---|---|---|---|---|
| | (acres) | | CN | (minutes) |
| SC-0 | 72.9 | 35.09 | 80 | 8.94 |
| SC-1 | 100.3 | 34.23 | 84 | 10.56 |
| SC-2 | 54.5 | 38.86 | 84 | 13.40 |
| SC-3 | 56.6 | 38.38 | 84 | 17.44 |
| SC-4 | 77.9 | 33.44 | 84 | 10.89 |
| SC-5 | 23.0 | 32.22 | 84 | 11.56 |
| SC-6 | 34.0 | 28.79 | 84 | 18.03 |
| SC-7 | 19.2 | 33.83 | 84 | 11.47 |
| SC-8 | 51.9 | 34.22 | 84 | 12.55 |
| SC-9 | 31.9 | 31.72 | 84 | 16.55 |
| SC-10 | 56.1 | 30.97 | 84 | 17.80 |
| SC-11 | 18.8 | 28.82 | 80 | 16.74 |
| SC-12 | 55.7 | 34.79 | 79 | 12.26 |
| SC-13 | 53.5 | 23.68 | 77 | 14.18 |
| C-1 | 68.3 | 33.55 | 80 | 25.64 |
| C-2 | 45.6 | 33.47 | 78 | 15.74 |
| C-3 | 67.5 | 30.46 | 80 | 17.14 |
| C-4 | 105.3 | 23.62 | 82 | 24.35 |
| C-5 | 27.7 | 22.95 | 75 | 17.08 |
| PS-1 | 109.2 | 4.95 | 81 | 21.39 |
| PS-2 | 147.5 | 4.84 | 78 | 25.72 |
| PS-3 | 64.4 | 0.00 | 81 | 13.86 |
| PS-4 | 65.9 | 3.35 | 81 | 20.26 |
| PS-5 | 35.9 | 32.13 | 79 | 15.45 |
| DC-1 | 124.0 | 48.57 | 77 | 16.40 |
| DC-2 | 80.4 | 35.37 | 75 | 17.27 |
| DC-3 | 108.3 | 25.96 | 75 | 20.63 |
| DC-4 | 103.6 | 32.96 | 75 | 21.04 |
| DC-5 | 119.9 | 78.67 | 79 | |
| DC-6 | 387.1 | 79.03 | 83 | |
| DC-7 | 173.7 | 79.61 | 84 | |
| FRC-1 | 107.8 | 76.67 | 76 | |
| FRC-2 | 129.3 | 69.94 | 78 | |

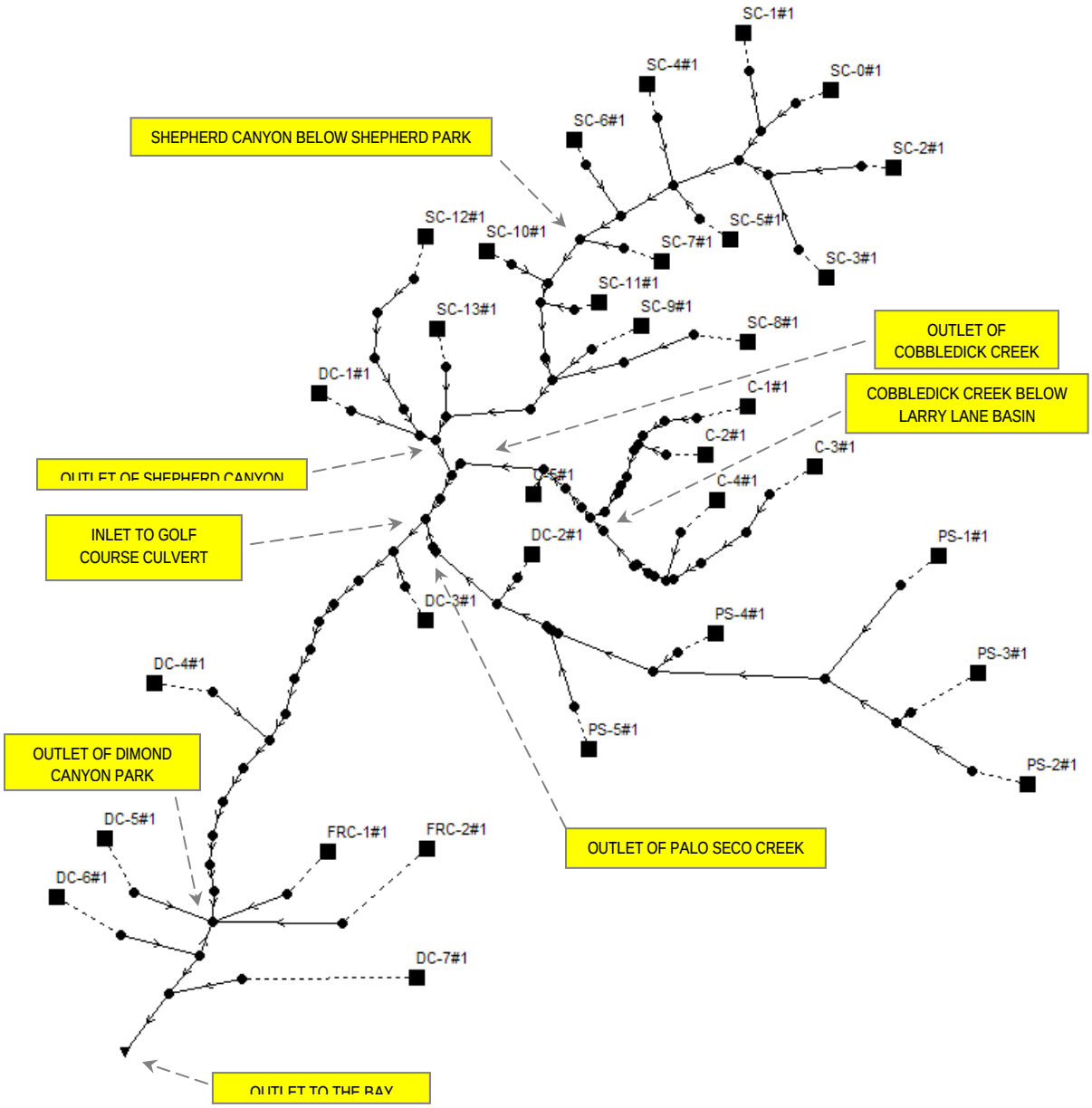
NewFields River Basin Services, LLC (NRBS) was retained in October 2009 to complete the existing conditions hydrology and hydraulic models, calibrate the models to verify accuracy, and model the hydrologic and hydraulic effects of proposed stormwater detention facilities in the watershed.

Watershed delineation, precipitation data and hyetograph development, soils analyses, and sub-basin runoff characteristics were developed by HSI. The two Sausal Creek SWMM-XP models previously developed by HSI were converted to the EPA SWMM 5.0 platform. When this conversion was made, some data did not export correctly and was re-tabulated and re-entered into the Sausal Creek EPA

SWMM 5.0 model. This included sub-catchment slope values and some of the conduit transects. This data was obtained from HSI and re-entered into the model. In addition, the two Sausal Creek XP-SWMM models were combined into one Sausal Creek hydrologic model in EPA SWMM 5.0 to enable consistency and ease of use (Figure 31).

In addition, NRBS developed a 1-year rainfall hyetograph that was not included in the original HSI hydrology analysis (Table 12). The Sausal Creek EPA SWMM 5.0 existing conditions model was run using dynamic wave analysis and time steps of 1 second or less for the 1 –year, 2-year, 5-year, 10-year, 25-year, and 100-year storm events.

**Figure 31: Schematic of the Sausal Creek EPA SWMM 5.0 existing conditions model. Sub-basins are labeled and represented by the black squares, nodes by the black circles, the watershed outfall by a black triangle and conduits by the lines. Arrows show the direction of flow; yellow boxes indicate locations of interest.**



The SCS Unit Hyetograph procedure is used within the SWMM Model to calculate the runoff that would result from the design storm precipitation. This procedure involves calculating the direct runoff from a basin after fulfilling the requirements of initial abstraction and basin storage. The basic methodology was developed by the Soil Conservation Service (SCS 1972). Numerically the process is shown in Equations 1 through 3 below:

Equation 1:

$$Q = \frac{(P-I_a)^2}{(P-I_a) + S}$$

Equation 2:

$$S = \frac{25400 - (254\text{-}CN)}{CN}$$

Equation 3:

$$I_a = 0.2\ S$$

Where:

Q = direct runoff
P = precipitation
$I_a$ = initial abstraction
S = maximum storage
CN = NRCS curve number

Two additional key parameters in the SCS Unit Hyetograph procedure are the runoff lag time and the runoff curve number. The lag time is the time (in hours) between the center of mass of the excess rainfall to the time to the peak discharge. This lag time can be estimated by Equation 4:

Equation 4:

$$T_{lag} = 0.6\ T_c$$

Where:

$T_{lag}$ = the lag time in hours
$T_c$ = the time of concentration of runoff to the point of discharge

*Model Calibration*

Existing conditions output for the Sausal Creek hydrology model was calibrated to streamflow measurements during significant storm events on October 19, 2009 and November 20, 2009. However, because the October 19 storm was larger and NRBS was able to conduct measurements during the runoff peak on this date, we relied primarily on these measurements for model calibration.

Because of access limitations, calibration measurements were collected in an approximately 2000-foot long reach upstream of El Centro Avenue. NRBS measured the high water mark elevation at the

upstream end of the culvert at El Centro Avenue (Figure 32) for the peak discharge on October 19, 2009. NRBS also surveyed the longitudinal profile slope through the culvert and assessed the roughness of the concrete culvert. Then, using a standard calculation for flow through a partially filled culvert, the discharge in Sausal Creek that corresponded to the high water mark elevations for the October 19 event was calculated as 167 cfs. Discharge was calculated as the product of velocity and cross-sectional area ($Q=VA$). A high water mark was measured in the culvert and the area of the pipe filled with water was calculated to provide $A$. Velocity ($V$) was measured in the reach just upstream of the culvert and the two numbers are multiplied to get the $Q$ or discharge value.

**Figure 32: The photo on the left shows the October 19, 2009 peak discharge water surface elevation at the upstream end of the culvert at El Centro Avenue. For comparison, the photo on the right shows conditions during low or base flow.**

Hourly precipitation data for the October 19 storm event was obtained from the California Data Exchange Center (CDEC) website for two stations, the Oakland North station which lies 11,000 feet to the north of the Sausal Creek watershed at an elevation of 1,300', and the Oakland South station which lies 11,500 feet to the south of the Sausal Creek watershed at an elevation of 1,180' (Figure 24).

Hourly precipitation data for the October 19 event at these two stations is presented in Figure 33 below. The October 19, 2009 flow event was slightly larger than a 1-year recurrence event.

**Figure 33: Hourly Precipitation Data at Oakland North and Oakland South Stations for October 19, 2009 Storm Event**

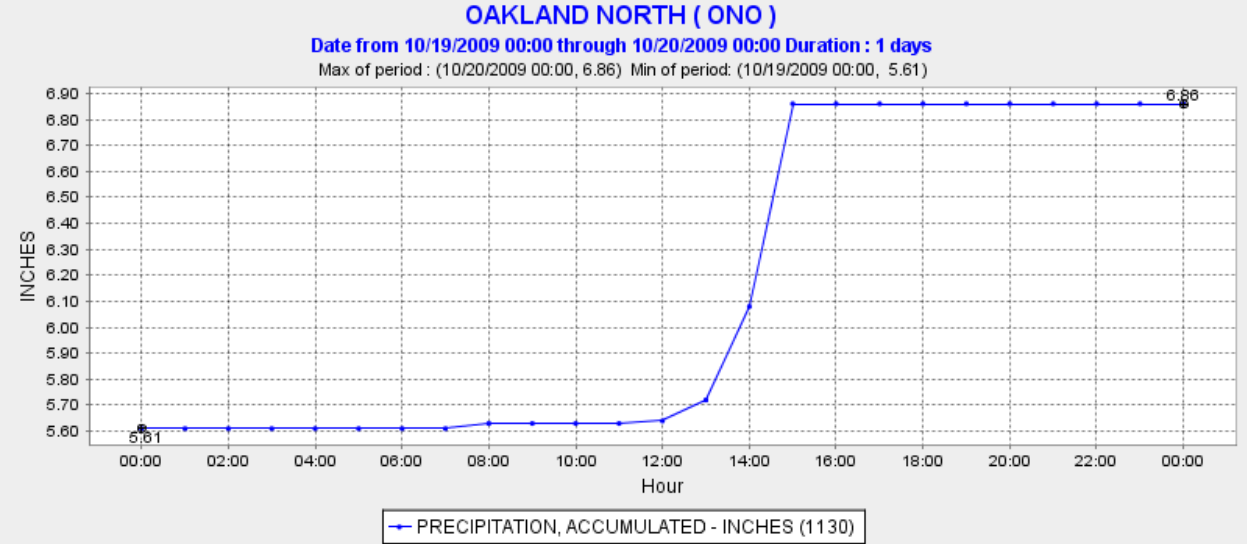
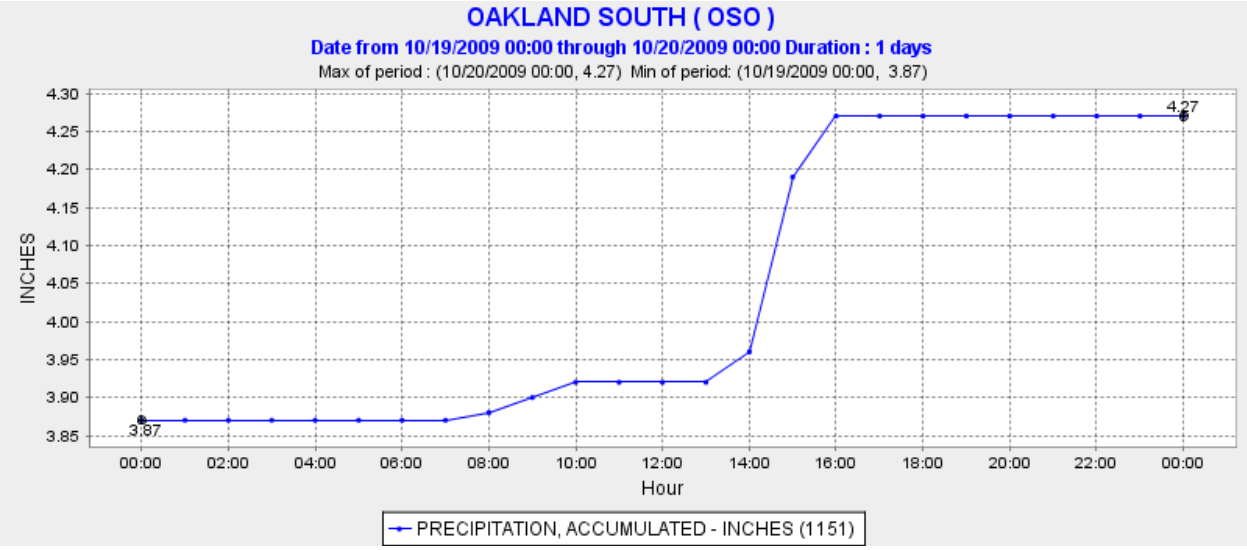



**Figure 33: Hourly Precipitation Data at Oakland North and Oakland South Stations for October 19, 2009 Storm Event (continued)**




Source: DWR, CDEC website, 2009

The highest elevation in the Sausal Creek watershed is approximately 1,300' at the crest of the Oakland Hills. This is similar to the Oakland North and Oakland South stations, which lie at 1,300' and 1,180' feet elevation, respectively. Because the midpoint of the Sausal Creek watershed lies halfway in between these stations, the calibration rainfall values were averaged between the two stations for the specific events. A 24-hour hyetograph for each station was developed (Table 12), and the averaged values were input into SWMM to mimic the rainfall during the calibration storm event.

**Table 12: Hyetograph for the October 19, 2009 Storm Event**

| Date / Time | Oakland South Station | | Oakland North Station | | Average |
|---|---|---|---|---|---|
| | Elevation of Rain in Gage (Inches) | Hourly Rainfall (Inches) | Elevation of Rain in Gage (Inches) | Hourly Rainfall (Inches) | Hourly Rainfall (Inches) |
| 10/19/09 0:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 1:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 2:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 3:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 4:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 5:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 6:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 7:00 | 3.87 | 0.00 | 5.61 | 0.00 | 0.00 |
| 10/19/09 8:00 | 3.88 | 0.01 | 5.63 | 0.02 | 0.01 |
| 10/19/09 9:00 | 3.9 | 0.02 | 5.63 | 0.00 | 0.01 |
| 10/19/09 10:00 | 3.92 | 0.02 | 5.63 | 0.00 | 0.01 |
| 10/19/09 11:00 | 3.92 | 0.00 | 5.63 | 0.00 | 0.00 |
| 10/19/09 12:00 | 3.92 | 0.00 | 5.64 | 0.01 | 0.00 |
| 10/19/09 13:00 | 3.92 | 0.00 | 5.72 | 0.08 | 0.04 |
| 10/19/09 14:00 | 3.96 | 0.04 | 6.08 | 0.36 | 0.20 |
| 10/19/09 15:00 | 4.19 | 0.23 | 6.86 | 0.78 | 0.51 |
| 10/19/09 16:00 | 4.27 | 0.08 | 6.86 | 0.00 | 0.04 |
| 10/19/09 17:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| 10/19/09 18:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| 10/19/09 19:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| 10/19/09 20:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| 10/19/09 21:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| 10/19/09 22:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| 10/19/09 23:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| 10/20/09 0:00 | 4.27 | 0.00 | 6.86 | 0.00 | 0.00 |
| **24-Hour Total** | | **0.40** | | **1.25** | **0.83** |

The SWMM existing conditions model was run with the calibration rainfall data. Comparison of modeled flow versus observed flow is provided in Table 13.

**Table 13: Comparison of Measured Versus Modeled Flow at the El Centro Culvert in Dimond Canyon**

| | Location | Maximum Flow (cfs) | Maximum Depth (ft) | Time of Measurement / Max Occurrence |
|---|---|---|---|---|
| **Measured Discharge** | El Centro culvert | 167 | 1.8 | 15:45 |
| **SWMM Model Output** | Node 153 (approximate location of El Centro culvert) | 211 | 2.25 | 16:06 |

The final modeled flow rate of 211 cfs is 26% larger than the measured rate of 167 cfs at the El Centro culvert. However, because of the scale and complexity involved in modeling the Sausal Creek watershed in SWMM, and limitations in the resolution of model input parameters describing watershed conditions, this calibration was determined to be acceptable as validation of the order of magnitude of predictions from the model. This exercise also provided information on the magnitude of potential error associated

with model output that could be reduced with additional characterization of the watershed and associated development of the model. Potential sources of error between the measured and modeled flows include the abstraction of available hourly precipitation data from stations outside of the watershed, errors involved in measuring flow through the culvert during the calibration measurements, and errors in the architecture of the hydrology model.

*Hydraulic Model*

Hydrologic Systems, Inc. initiated development of a hydraulic model for portions of the Sausal Creek watershed using the Hydrologic Engineering Center River Analysis System, commonly referred to as HEC-RAS (USACE 2008). The model focuses on the reach of Sausal Creek through Dimond Canyon. NRBS analysis included completion of the Sausal Creek hydraulic model (including model calibration) and evaluation of hydraulic characteristics under existing hydrologic conditions and "proposed" hydrologic conditions with implementation of watershed improvements to reduce peak magnitudes of runoff from rainfall in the watershed. The completed HEC-RAS model consists of two (2) cross sections in Palo Seco Creek and thirty-seven (37) cross sections in the mainstem of Sausal Creek between Highway 13 at the upstream end and the northern end of Dimond Avenue at the downstream end (Figure 34). The hydraulic model also includes four culverts in the modeled reach. NRBS evaluated the preliminary model cross sections and culvert parameters against measured field conditions to validate the model prior to calibration.

Details of the culverts within the watershed were obtained from storm drain design maps that are maintained by the City of Oakland. This information was augmented with a detailed channel invert survey of Dimond Canyon between Highway 13 and Dimond Park. Figure 34 shows the profile of Sausal Creek between the outlet at the bay and Highway 13 at the upper end of Dimond Canyon.

*Model Calibration*

The objective of hydraulic model calibration is to make model predictions of hydraulic parameters such as water surface elevation and velocity consistent with actual conditions in the modeled system. Model calibration is especially important for this analysis of Sausal Creek because the changes in hydrology from watershed projects are relatively small.

The preliminary hydraulic model completed by HSI utilized uniform Manning's *n* (roughness) values of 0.035 throughout the entire model domain for both the in-channel and overbank areas. While 0.035 is generally accepted as a reasonable starting roughness value for natural creeks, NRBS determined based on a reconnaissance evaluation of the modeled reaches that 0.035 was not an appropriate roughness value for all of the modeled reaches in Sausal Creek, especially for hydraulic analysis of more frequent peak discharges (i.e. discharges with recurrence intervals of less than 2-years) that appeared likely to be influenced by significant channel bed complexity and dense riparian vegetation in many areas.

Therefore, the hydraulic model was calibrated with measurements of high water marks and flow velocities at a known discharge. NRBS collected these calibration measurements during significant storm events on October 19, 2009 and November 20, 2009. However, because the October 19 storm was larger and measurements were collected during the runoff peak on this date, NRBS relied primarily on these measurements for model calibration.

**Figure 34: Schematic Diagram of the Sausal Creek Hydraulic Model as Implemented in HEC-RAS. Numbers indicate locations of channel cross section included in the model. Yellow polygons represent culverts and bridges included in the model as hydraulic structures. Flow is from top to bottom as indicated by the orange arrow.**

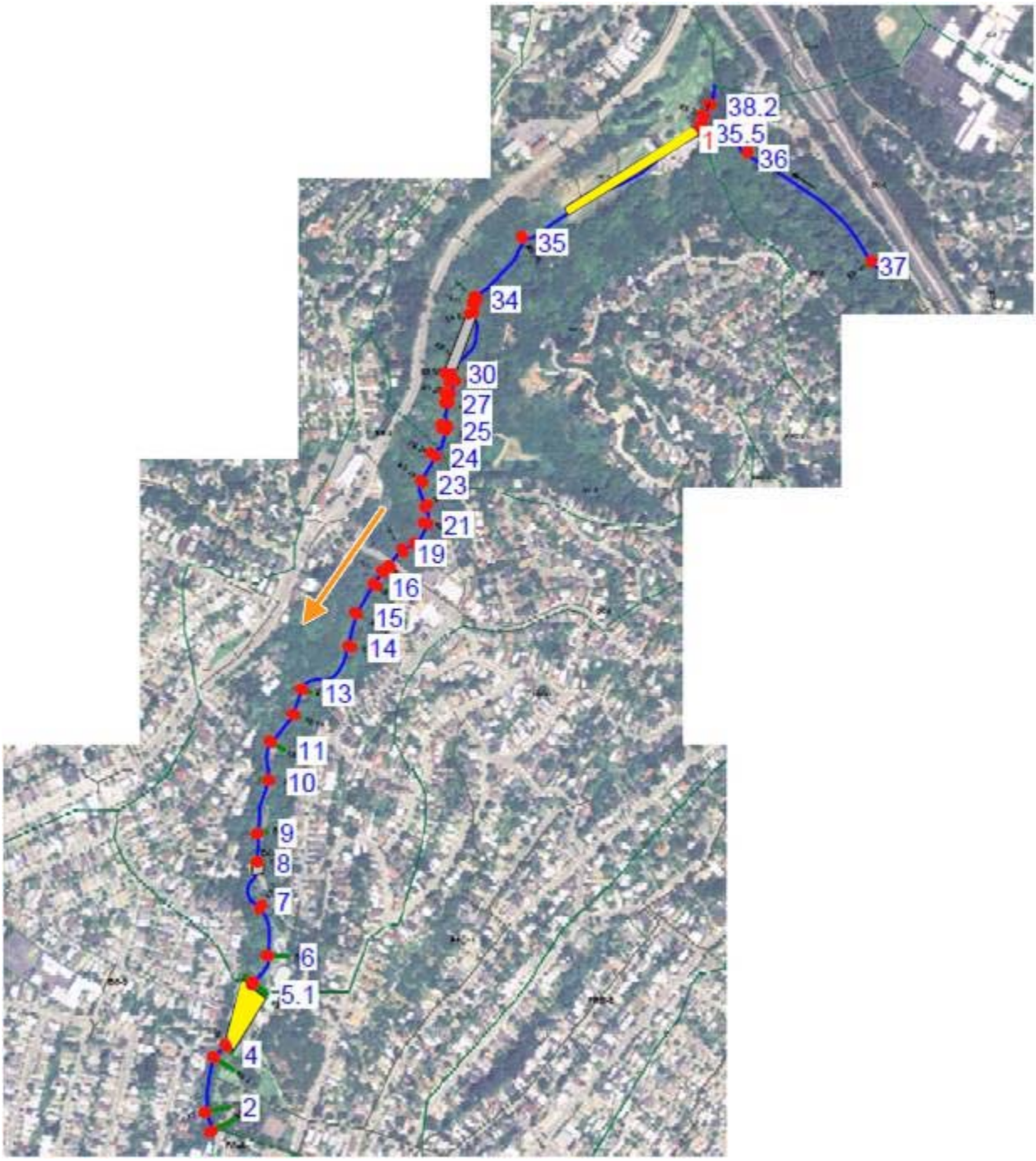


**Figure 35: Sausal Creek Channel Profile, Station 0 to 8000**

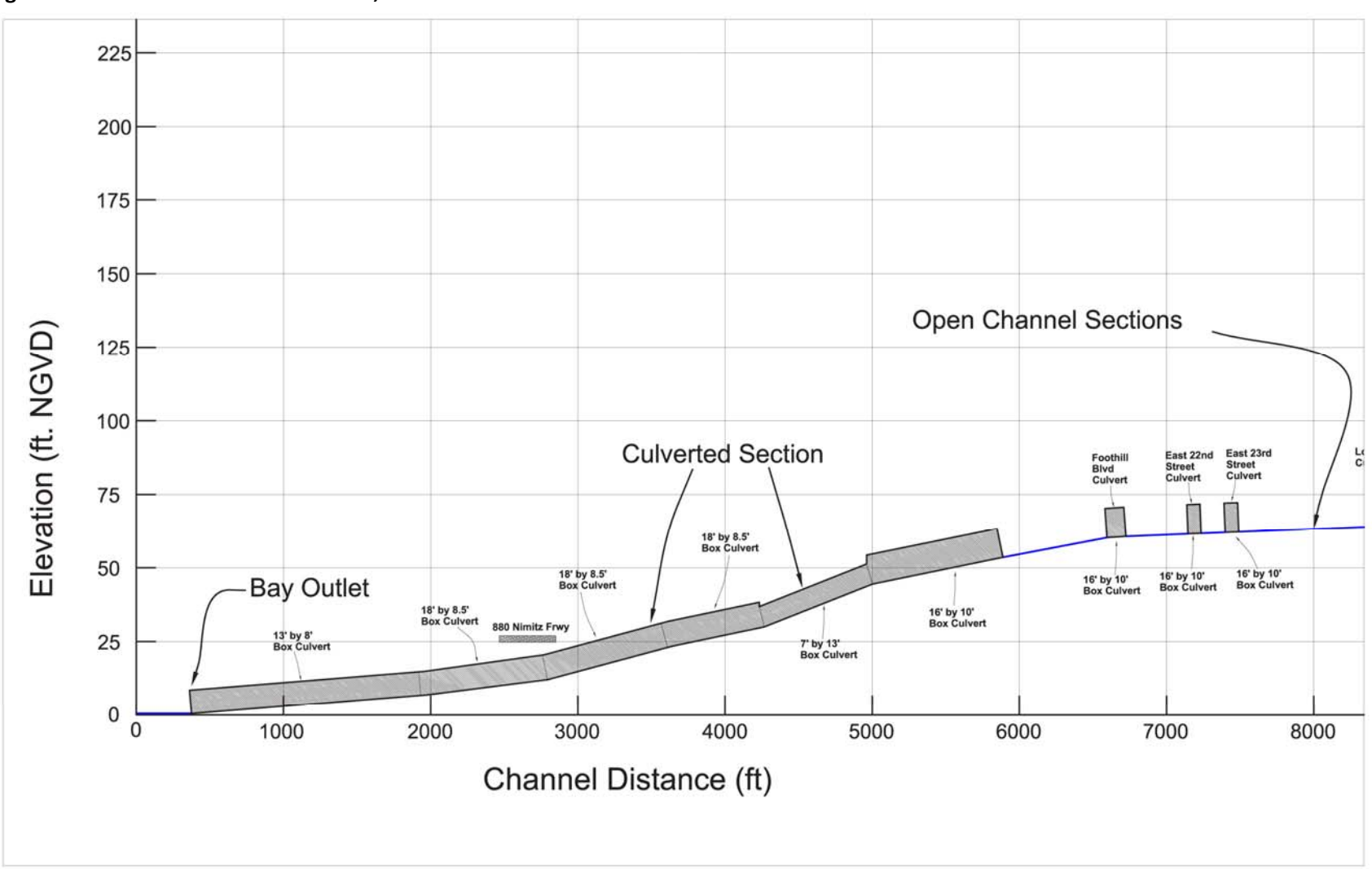


**Figure 35 (continued): Sausal Creek Channel Profile, Station 8000 to 16000**

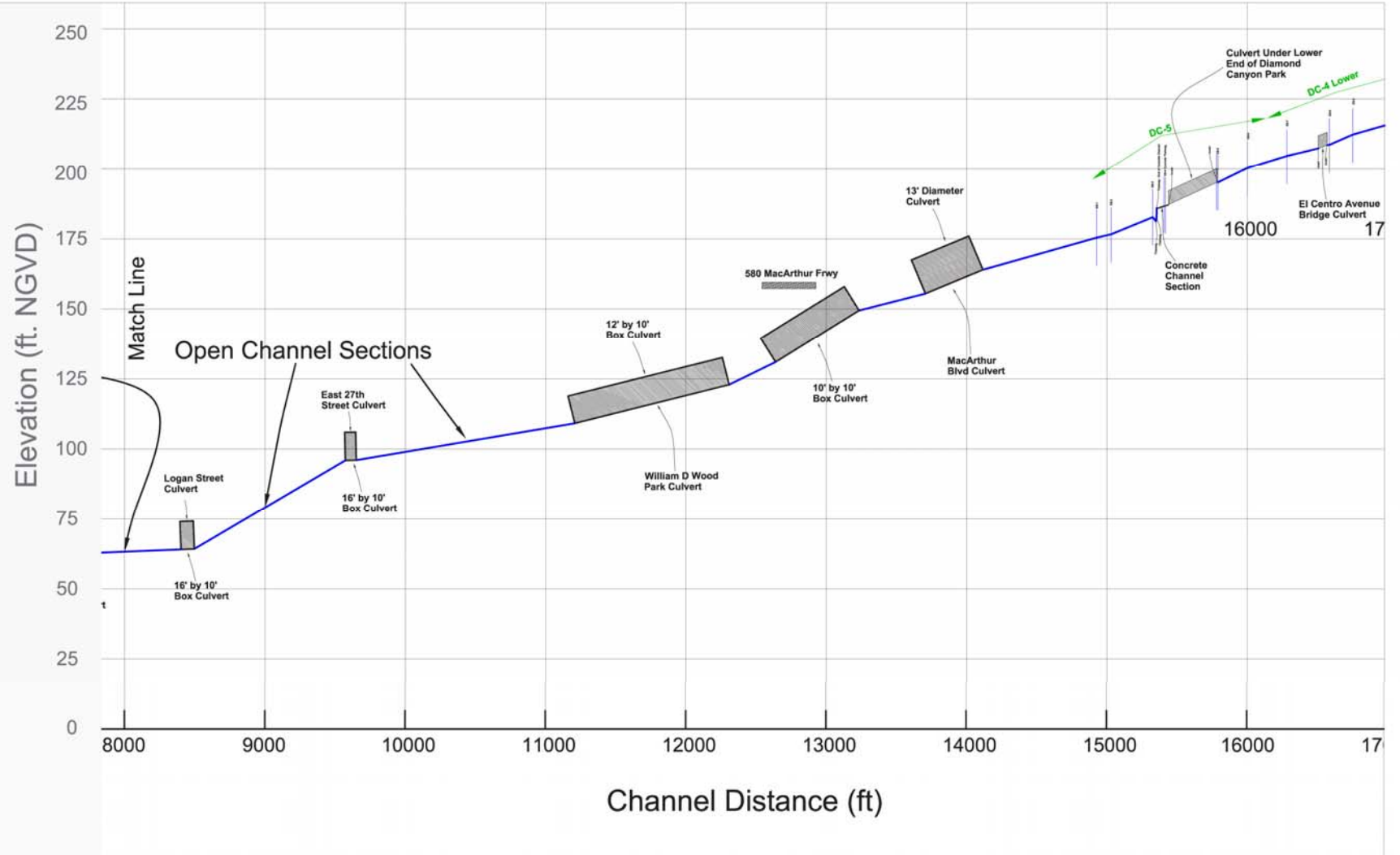
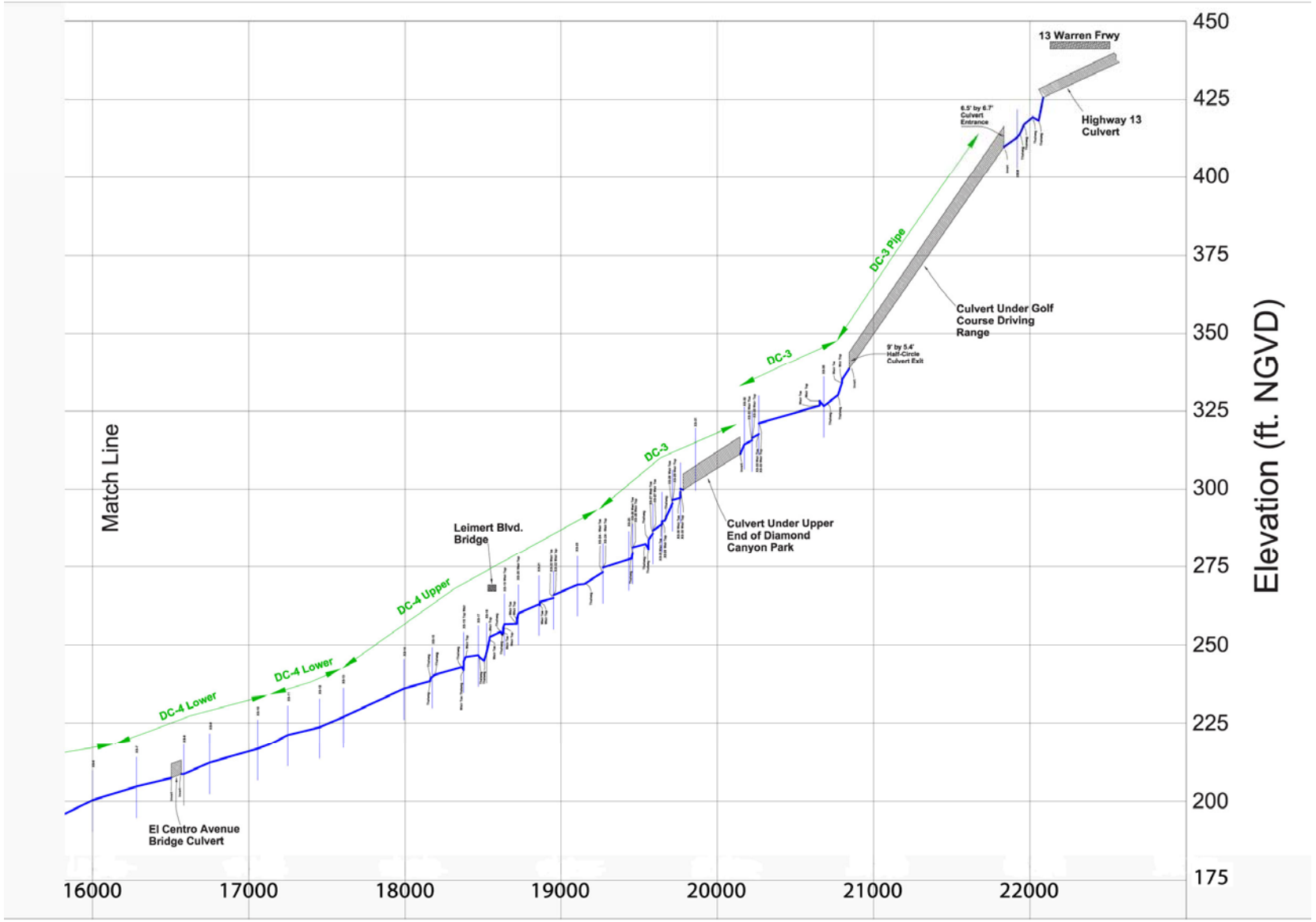


**Figure 35 (continued): Sausal Creek Profile, Station 16000 to 230000**



Because of access limitations, calibration measurements were collected in an approximately 2000-foot long reach upstream of El Centro Avenue. NRBS applied calibrated roughness values from this reach to the remaining reaches of the model. The calibration exercise consisted of field measurements of discharge, high water mark elevations, and flow velocities, and iterative adjustment of roughness values in the HEC-RAS model until modeled water surface elevations matched measured water surface elevations at the calibration flow.

**Figure 36: Typical high water marks measured in Sausal Creek including flattened riparian vegetation, debris lines, and sediment deposition.**

*High Water Mark Elevations*

Because discharge in Sausal Creek changes rapidly during and after rainfall events in the watershed, NRBS measured both flow depth and high water mark elevations. Figure 36 illustrates a typical high water mark used in this set of calibration measurements.

*Flow Velocity*

NRBS used a neutrally buoyant float to estimate flow velocity in several areas of the Dimond Canyon reach of Sausal Creek. The travel time of the float over a 100 foot distance was recorded and velocity was calculated as distance divided by time. Estimated velocities ranged from 4 ft/sec to 5.3 ft/sec.

NRBS ran the uncalibrated HEC-RAS model for the 167 cfs discharge and compared the resulting modeled water surface elevation profile with the measured water surface elevation profile for the 2000-foot long reach upstream of El Centro Avenue. Figure 37 is a plot of this comparison and shows that the

model predictions using a uniform roughness of 0.035 for the channel and overbank areas are reasonable between Station 1600 and Station 1800. NRBS determined that this was consistent with the relationship between the relatively homogeneous channel conditions in this area and the uniform roughness of 0.035 in the uncalibrated model. Therefore, roughness values were not adjusted for this portion of the model. The first two hundred feet upstream of the culvert (Stations 0 through 200) were not used in this calibration because backwater effects from the culvert made identification of reliable high water marks impossible.

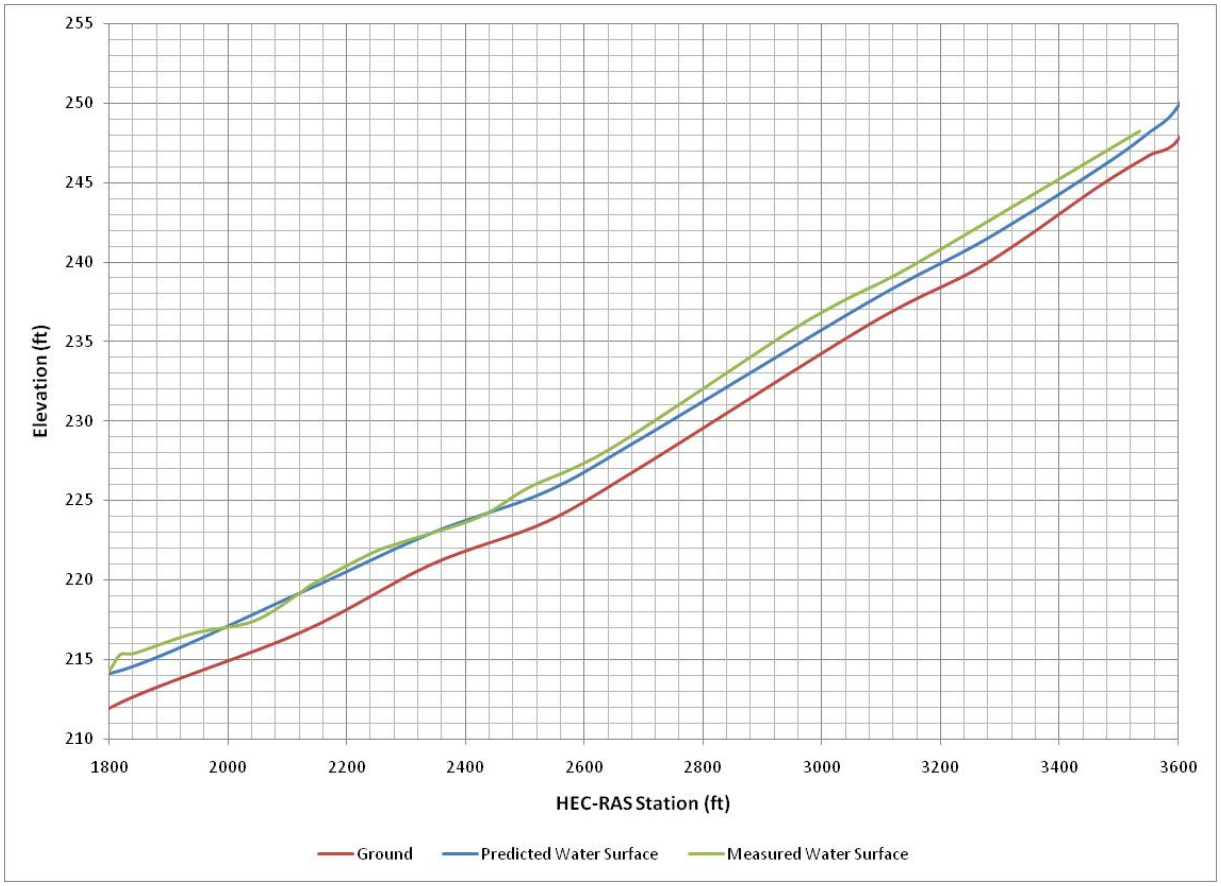



**Figure 37: Comparison of model predicted and measured water surface elevations upstream of El Centro Avenue for the 167 cfs discharge on October 19, 2009 using the uncalibrated HEC-RAS model. Note the consistently high predicted water surface elevations upstream of Station 1800.**

Figure 37 also shows that the modeled water surface elevations were consistently lower (by approximately one foot) than the measured water surface elevations upstream of Station 800. NRBS determined that this was consistent with the discrepancy between the more complex channel conditions in these reaches and the uniform roughness of 0.035 in the uncalibrated model. Therefore, roughness values were adjusted in the model to achieve a better fit between predicted and measured water surface elevations. Initially, NRBS tested the sensitivity of water surface elevation to changes in the overbank roughness values. There was no sensitivity to overbank roughness because flow is confined to the main channel during the calibration discharge of 167 cfs. Next, more appropriate roughness values for the calibration cross sections were estimated using guidance from the United States Geological Survey (USGS 1990). Final roughness values varied from 0.075 in typical reaches of the channel to 0.1 for reaches with large sheet-pile flow obstructions in the channel. Figure 38 shows the improved fit between modeled and measured water surface elevations in the final calibrated HEC-RAS model. The typical channel roughness of 0.075 was also applied in model reaches outside of the calibration reach where no additional site specific information was available. It is important to note that roughness likely changes with changes in discharge. However, because the primary focus of this analysis was on the relatively frequent peak discharges that are the most important with respect to habitat and sediment transport, roughness values were not varied with flow in the final model runs. Future efforts could extend the range of calibration flow measurements and improve model performance for higher flows.

As a final check on the performance of the calibrated model, flow velocities measured during the October 19, 2009 peak discharge were compared with predicted velocities from the calibrated model run at 167 cfs. Figure 39 is a plot of this comparison. Most of the modeled velocities are within the range of measured velocities. While two velocity predictions are significantly greater than the range of measured velocities, NRBS did not feel this indicated a significant problem in the model construction, as the measured velocities were averaged over long distances and the modeled velocities are calculated as specific cross sections where local geometry and slope conditions could produce locally elevated velocities.

**Existing Hydrologic Conditions**

Aggregated peak discharge at the outlets of Shephard Creek, Cobbledick Creek, Palo Seco Creek, Sausal Creek, and other specific locations along the main channel are provided in Table 14. Water surface profiles through the Dimond Canyon reach are provided in Figure 40.

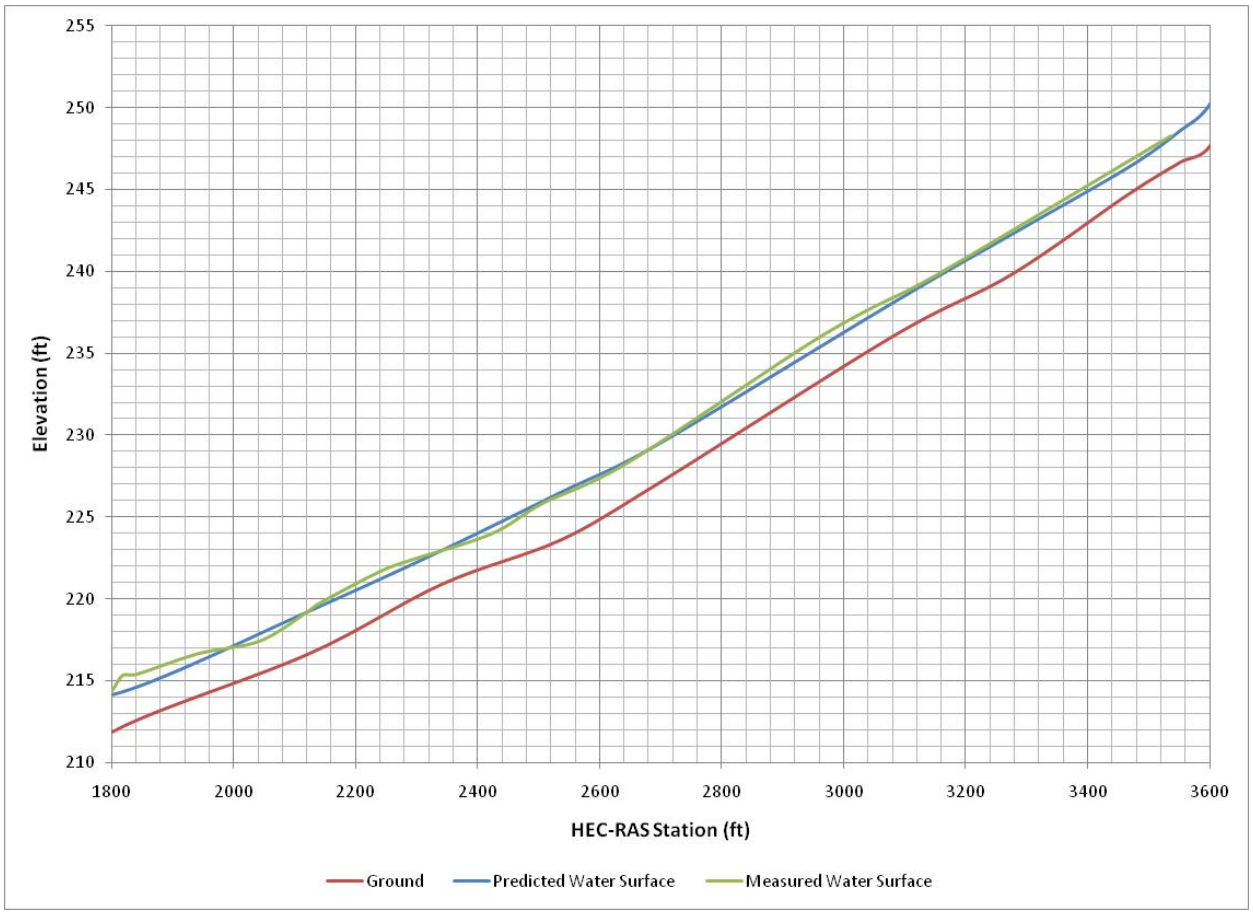



**Figure 38: Comparison of model predicted and measured water surface elevations upstream of El Centro Avenue for the 167 cfs discharge on October 19, 2009 using the calibrated HEC-RAS model. Note the improved fit between measured and predicted water surface elevations upstream of Station 1800.**

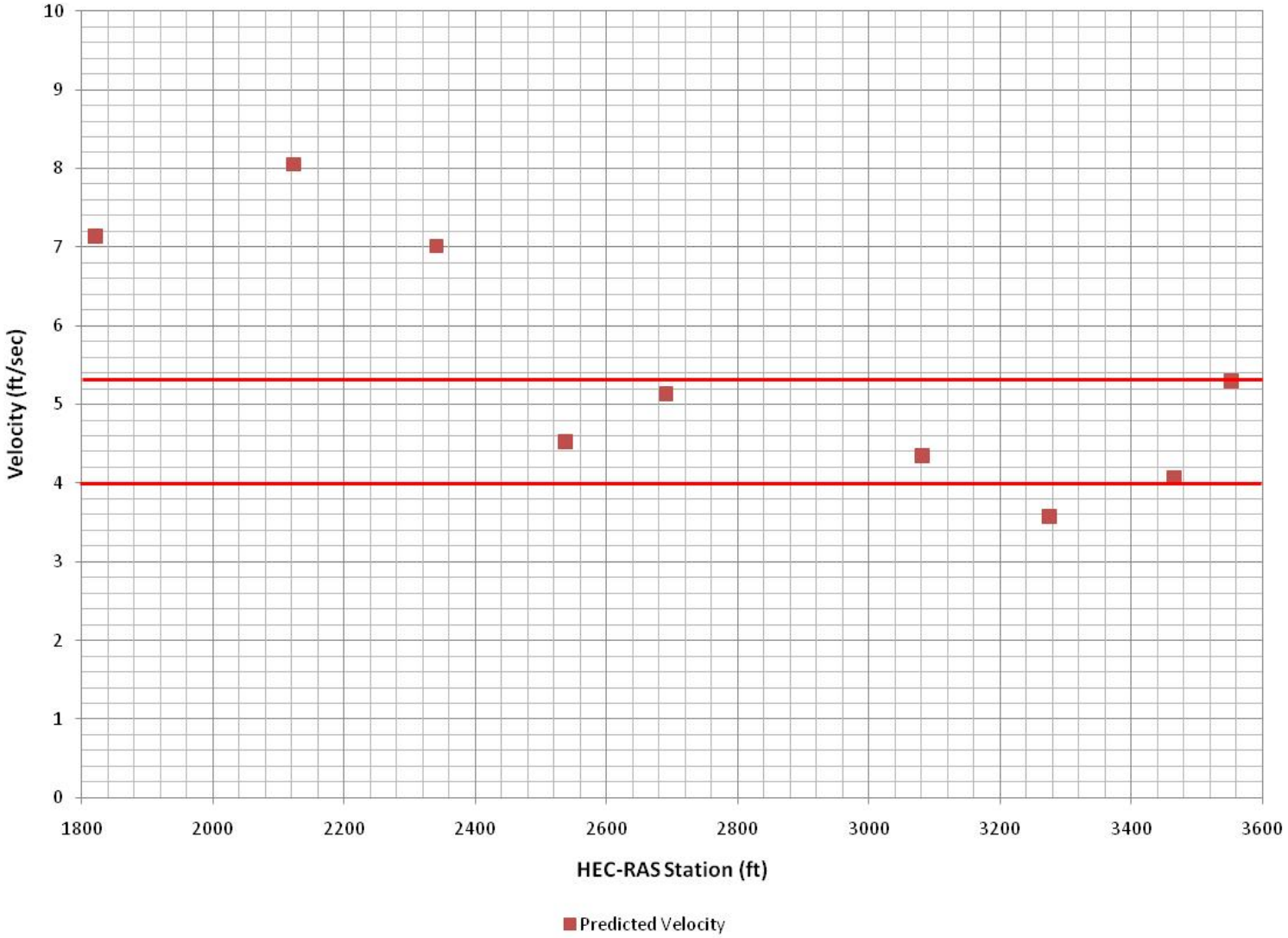
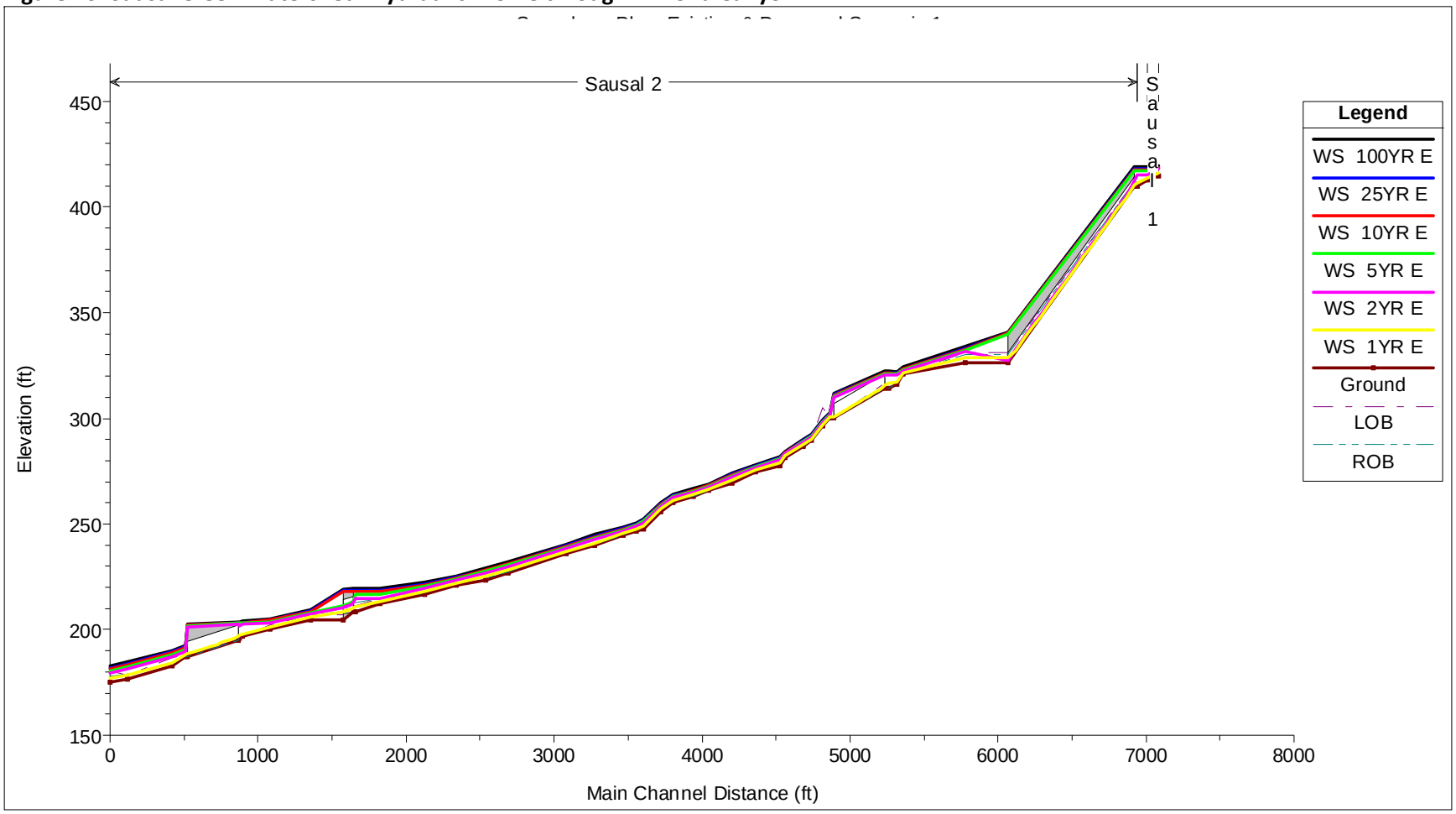



**Figure 39: Comparison of model predicted and measured velocities for a discharge of 167 cfs. Red squares are model predicted velocities at specific model cross sections. Red lines represent the upper and lower bounds of the average velocity measurements. The average velocity measurements were conducted in a 100-foot reach upstream of El Centro Ave. that was determined to be representative of flow conditions throughout the modeled reach.**

**Table 14: Existing Conditions Computed Peak Discharge at Selected Locations along Sausal Creek and Tributary Channels**

| PEAK RUNOFF (CFS) | | | | | | |
|---|---|---|---|---|---|---|
| Storm Return Frequency | | | | | | |
| **Reach** | **100 Year** | **25 Year** | **10 Year** | **5 Year** | **2 Year** | **1 Year** |
| Shephard Creek Culvert Outlet downstream of Shepherd Park (Node SC-F / ShepParkOutlet) | 277.92 | 214.17 | 176.64 | 142.91 | 97.07 | 17.08 |
| Cobbledick Creek below Larry Lane Basin at Culvert Outlet at Scout Rd. and Ascot Dr. (Node 47) | 74.43 | 57.58 | 47.19 | 39.09 | 27.12 | 4.90 |
| Outlet of Cobbledick Creek (in pipe) at Confluence with Shephard Creek (in pipe) under Hwy. 13 (Node 30) | 138.9 | 108.4 | 91.9 | 76.3 | 53.9 | 9.35 |
| Outlet of Shepherd Canyon upstream of Confluence with Sausal Creek (Node SC-R) | 472.3 | 312.5 | 254.5 | 208.7 | 142.0 | 26.46 |
| Outlet of Palo Seco Creek just upstream of Confluence with Sausal Creek (Node 121) | 133.2 | 100.8 | 80.2 | 64.9 | 44.8 | 6.72 |
| Shephard Creek Upstream of Palo Seco Creek Confluence (Node 32) | 610.9 | 420.7 | 346.3 | 284.9 | 195.7 | 35.6 |
| Inlet to the Golf Course Culvert (Node 52) | 744.0 | 521.3 | 426.3 | 349.8 | 240.4 | 42.26 |
| Outlet of Dimond Park (Node 163) | 1106.1 | 913.1 | 789.7 | 538.3 | 363.2 | 58.85 |
| Outlet to the Bay (Node 179) | 1122.5 | 881.7 | 735.2 | 592.4 | 408.6 | 60.12 |

**Figure 40: Sausal Creek Watershed: Hydraulic Profile through Dimond Canyon**



**Existing Conditions Hydraulic Analysis**

Figures 41 and 42 are longitudinal plots of existing velocity and shear stress, respectively, in the modeled reaches of Palo Seco Creek and Sausal Creek for the 1, 2, 5, 10, 25, and 100-year discharges. All of the tabular data in these plots is summarized in the HEC-RAS output tables in Appendix H. Both plots illustrate that existing hydraulic conditions in Sausal Creek could lead to geomorphic instability, especially for 2-year discharges and above.

Table 15 summarizes permissible velocities and shear stresses for bed and bank sediment and vegetation similar to conditions in Sausal Creek. Channel bed and bank stability varies throughout the Sausal Creek watershed, however, in general, the channel bed and banks are likely stable for velocities up to approximately 7 ft/sec and shear stresses up to approximately 2 lbs/ft$^2$ (Fischenich 2001). NewFields used the US Army Corps of Engineers' Engineering Research and Development Center "Stability Thresholds for Stream Restoration Materials" to determine permissible shear strengths reference for selection of stream restoration materials, and a useful guide to assessing the stability of existing stream materials. While conditions vary throughout the watershed, we made the assumption that the system has geomorphic controls such as riffles and artificial grade control structures with cobble and coarser particle sizes and some woody vegetation on the banks. As shown in Table 15, the reaches with these characteristics would be stable for velocities up to 7 feet per second and shear stresses up to 2 pounds per square foot. Therefore, portions of the Sausal channel network are at risk of erosion under existing hydrologic and hydraulic conditions, even during the 1-year discharge. Even moderate reductions in peak flows could reduce the frequency and duration of erosive flows and contribute to long-term improvements in creek habitat condition.

**Table 15: Permissible velocities and shear stresses for channel sediment and vegetation types similar to Sausal Creek (after Fischenich 2001)**

| Material | Permissible Velocity (ft/sec) | Permissible Shear Stress (lbs/ft$^2$) |
|---|---|---|
| Gravel (2 inch) | 3.0 – 6.0 | 0.67 |
| Cobble (6 inch) | 4.0 – 7.5 | 2.0 |
| Riprap (18 inch) | 12.0 – 16.0 | 7.6 |
| Emergents | n/a | 0.1 – 0.6 |
| Grasses | 3.0 – 6.0 | 0.7 – 1.7 |
| Woody Vegetation | 3.0 – 10.0 | 2.1 – 3.1 |

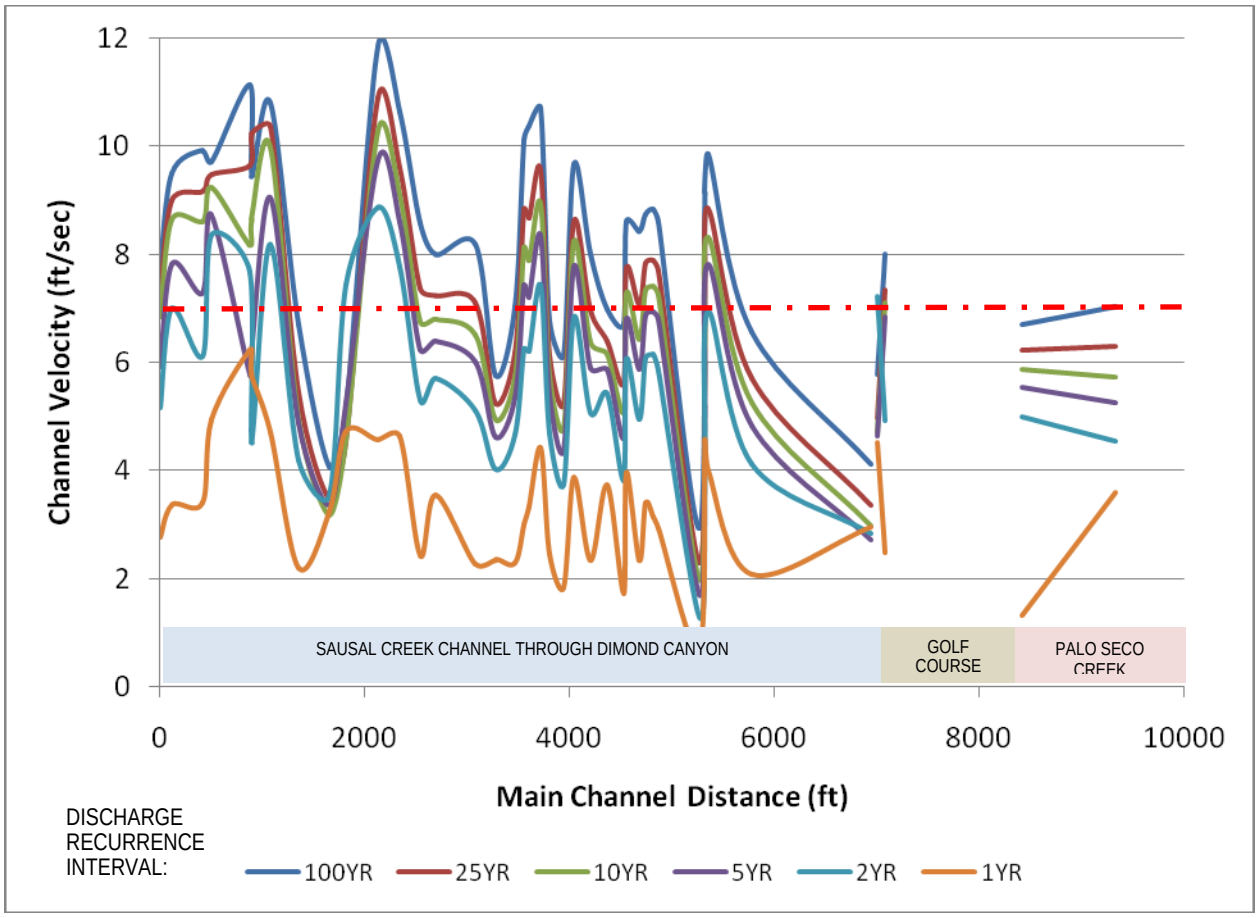



**Figure 41: Existing conditions longitudinal velocity plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.**

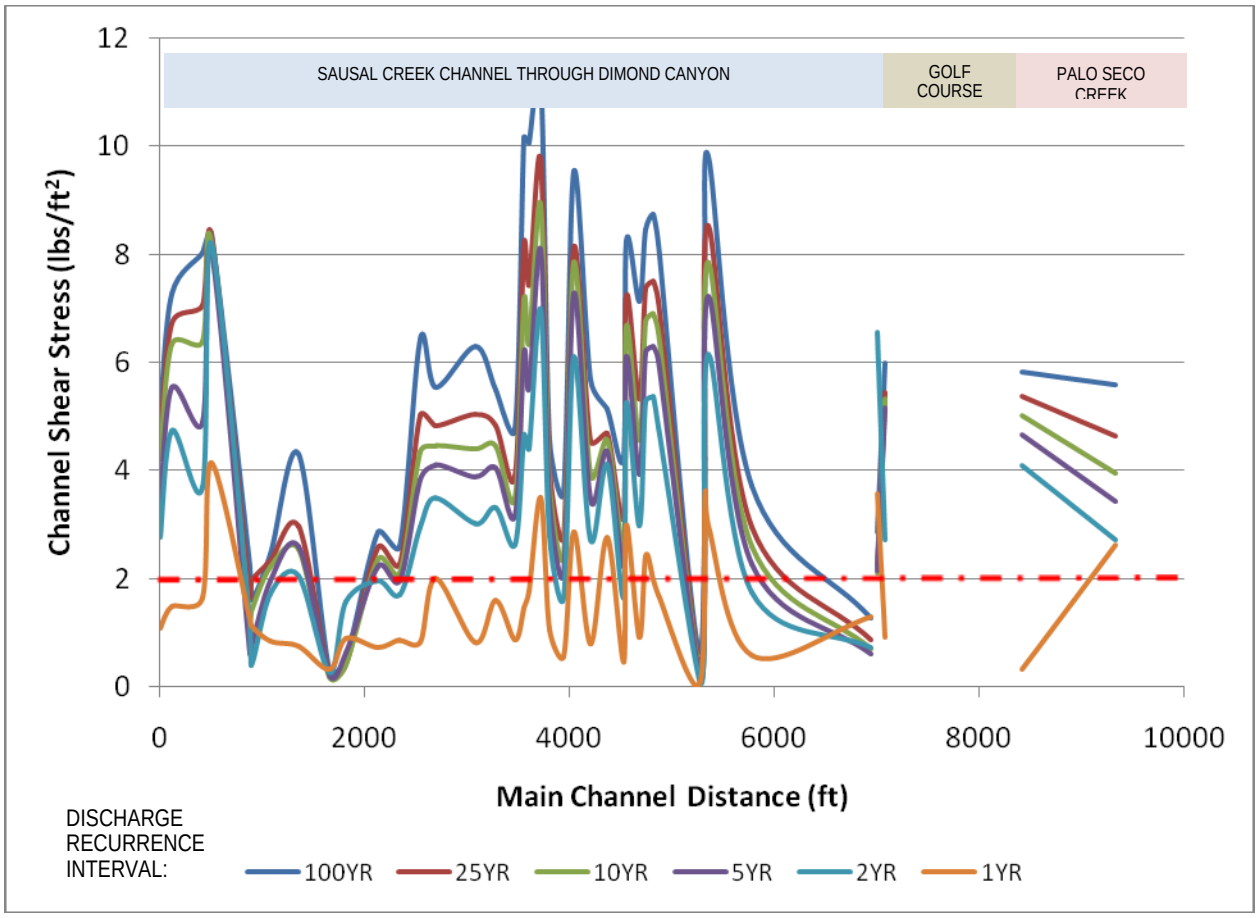



**Figure 42: Existing conditions longitudinal shear stress plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.**

**VEGETATION**

The vegetation growing in Sausal Creek watershed is a combination of native plant species primarily found in parks and ornamental species (including planted natives) surrounding residential and commercial areas. Figure 43 shows a general depiction of vegetation types and land uses in the watershed (USGS 2001). Tables 16 and 17 describe the features of each vegetation type on the map and the acres of each by sub-basin. The USGS GIS layer is based on satellite imagery in which each pixel covers 30 meters (90 ft.); therefore, any patch of vegetation of less than 30 meters is not delineated. Small areas of riparian vegetation along creeks and small wetland areas are not delineated under this coverage. Appendix B has a comprehensive list of native plant species and locations where they were recorded in the Sausal Creek watershed. FOSC has an ongoing effort to track and map native plants that are rare in the watershed.

**Table 16: Description of Vegetation Types for Figure 43**

| Area | Description |
|---|---|
| Open Water | All areas of open water, generally with less than 25% cover or vegetation or soil |
| Developed, High Intensity | Includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80 to100 percent of the total cover. |
| Developed, Low Intensity | Includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20-49% of total cover. These areas most commonly include single-family housing units. |
| Evergreen Forest | Areas dominated by trees generally greater than 15 ft. tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage. |
| Mixed Forest | Areas dominated by trees generally greater than 15 ft. tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover. |
| Shrub/Scrub | Areas dominated by shrubs; less than 15 ft. tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions. |
| Grassland/Herbaceous | Areas dominated by grammanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing. |

From: US Geologic Survey Land Cover Dataset

**<u>Evergreen Forest</u>**

In the upper watershed, evergreen forest dominates the parkland and vegetated areas next to houses, including creek areas. Palo Seco Creek sub-basin holds over 250 acres of evergreen forest, mostly focused in Joaquin Miller Park. Cobbledick Creek sub-basin has 110 acres of evergreen forest dispersed between houses. Similarly, Shephard Creek sub-basin has 110 acres of evergreen forest spread out in residential and park areas.

The upslope area of Joaquin Miller Park in the Palo Seco sub-basin is part of a five square-mile area in the Oakland hills once dominated by redwood forest. The area of the forest in the Sausal Creek watershed was called the San Antonio Redwoods. Logging of the redwoods started in the late 1840s and all of the trees in the Sausal Creek watershed were cut by 1860. The redwoods in this area are now second-growth. Besides the redwood forest, most early accounts and photographs of the upper Sausal

Creek watershed describe grassland and shrub/scrub cover with trees along the ephemeral and seasonal water courses (Figures 6 and 11).

Lowe (1998) evaluated the pre-European/American settlement vegetative cover in the Sausal Creek watershed. This study estimated that in 1700 watershed cover was 66% grassland and shrub/scrub vegetation, 25% riparian/mixed forest and 9% redwood forest.

**Table 17: Vegetation Types and Land Uses in Sausal Creek Watershed**

| Land Use/Vegetation Type | Sub-Basin | | | | Total |
|---|---|---|---|---|---|
| | Cobbledick | Palo Seco | Shepherd Canyon | Sausal | |
| **Developed, Higher Intensity - 50-100% Impervious surfaces** | 185.98 | 155.22 | 547.21 | 439.89 | 1328.3 |
| **Developed, Lower Intensity - <49% Impervious surfaces** | 1.97 | 17.74 | 13.22 | 766.4 | 799.33 |
| **Evergreen Forest** | 109.62 | 250.3 | 119.27 | 24.1 | 503.29 |
| **Mixed Forest** | 10.81 | 71.48 | 22.15 | 21.75 | 126.19 |
| **Shrub/Scrub** | 0.35 | 10.79 | 3.12 | 3.89 | 18.15 |
| **Grassland/Herbaceous** | <0.01 | <0.01 | <0.01 | 2.59 | 2.59 |
| **Total Acres** | **308.73** | **505.53** | **704.97** | **1258.62** | **2,777.85** |
| | | | | | |
| **Percent Urban (High and Low Intensity)** | **61%** | **41%** | **80%** | **96%** | **76%** |
| **Percent Vegetation (all types)** | **39%** | **59%** | **20%** | **4%** | **24%** |

Following the logging of the redwoods, thousands of trees were planted in Joaquin Miller Park and surrounding hill areas, like Piedmont Pines and Oakmore. Planted species included trees native to other areas of California—Monterey pine and Monterey cypress—as well as non-native invasive tree species: Eucalyptus and Acacia. Presently, the areas marked on Figure 43 as evergreen forest are likely to be Monterey pine forest or second-growth redwood/Douglas fir forest. Live oak, California bay laurel, and Pacific madrone may also be part of the forest along with areas of non-native Eucalyptus, Acacia, and ornamental tree species. Monterey pine and Monterey cypress cover about 25.3 acres of Joaquin Miller Park. Eucalyptus covers about 15 acres of the park and Acacia covers about 7.4 acres (Table 20).

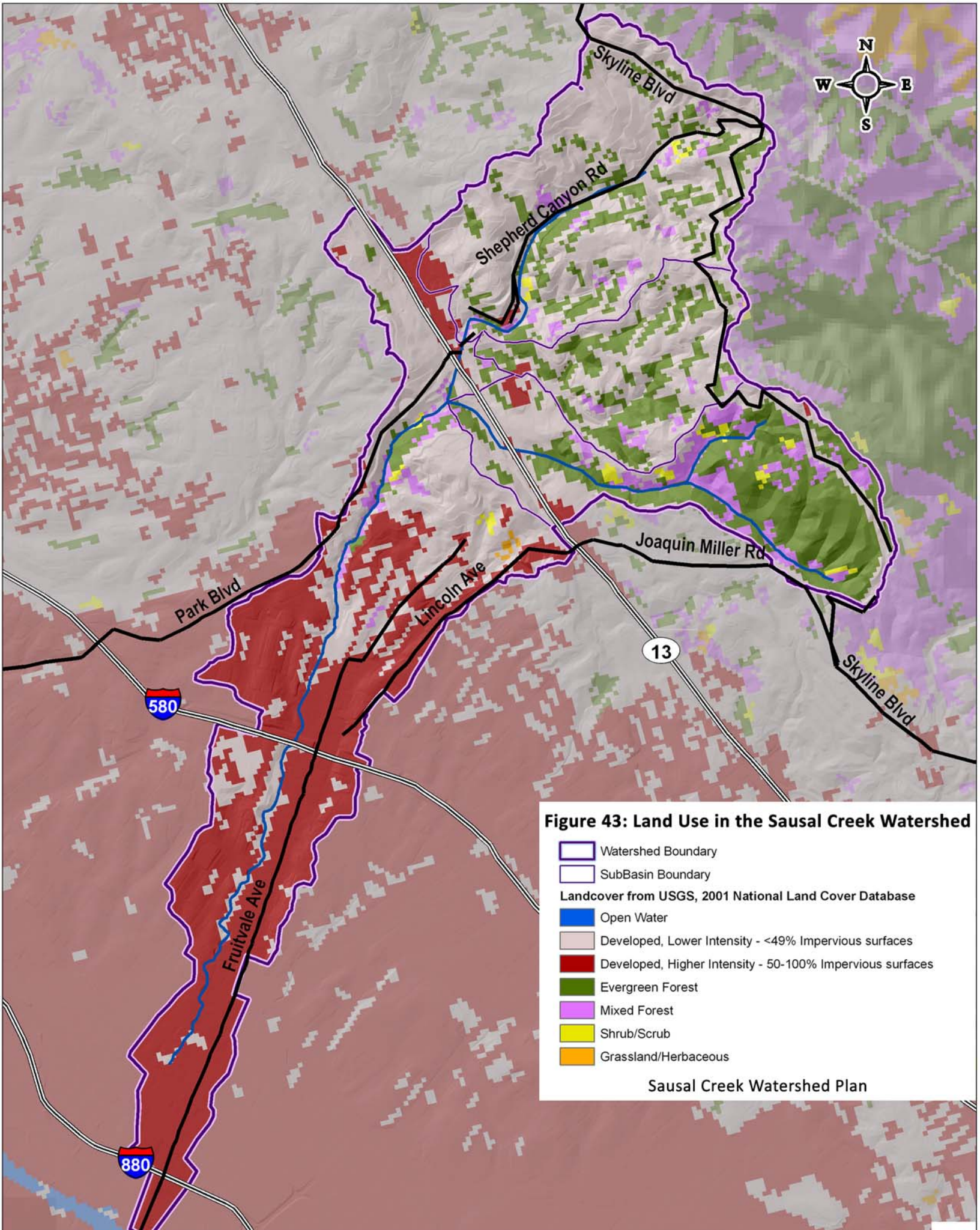



**Figure 43: Land Use in the Sausal Creek Watershed**

- Watershed Boundary
- SubBasin Boundary

**Landcover from USGS, 2001 National Land Cover Database**

- Open Water
- Developed, Lower Intensity - <49% Impervious surfaces
- Developed, Higher Intensity - 50-100% Impervious surfaces
- Evergreen Forest
- Mixed Forest
- Shrub/Scrub
- Grassland/Herbaceous

Sausal Creek Watershed Plan

Source: National Land Cover Dataset Land Use and Vegetation Map. 1992. USGS.

**Mixed Forest**

Mixed forest is mapped in a number of locations and, unlike the evergreen forest, contains deciduous species. Plant species include big-leaf maple, California buckeye, coast and interior live oak, canyon oak, box elder, California bay laurel, and Pacific madrone. Redwoods, Monterey pine, Monterey cypress, Eucalyptus, Acacia, and ornamental tree species may also be mixed in with the deciduous trees.

**Shrub/Scrub**

Shrub/scrub vegetation includes chaparral with two species of manzanita, ceanothus, coffeeberry, buckthorn, ocean spray, toyon, and monkeyflower. Coastal sage scrub, with sagebrush, monkeyflower, and lupine, is also mapped in this category.

**Grassland**

Grassland/herbaceous cover is largely free of trees and shrubs. Although the Sausal Creek watershed was once largely native grassland, this vegetation type is now rare. Grassland consisting of non-native European grasses is relatively rare in the watershed. Native grasses including needlegrass, junegrass, and California melic occur in areas with serpentine soils.

**Invasive Non-Native Plants**

The native vegetation areas that remain in the Sausal Creek watershed are under constant threat of invasion and replacement by invasive, non-native plant species. These plants were typically brought to California as garden plants or by the government to provide erosion control along streams or on agricultural lands. Some, such as Eucalyptus, were widely planted in the East Bay hills under the mistaken assumption that Eucalyptus would produce good lumber in California.

The spread of invasive non-native plants is a primary cause of the degradation and loss of native habitat in California. Most invasive plants are adapted to rapid germination and growth following ground disturbance. Some produce chemicals which suppress the growth of other native plants, resulting in complete dominance by the invasive species. Most invasive plants do not provide habitat values for wildlife, nor do they have natural predators outside their native land to reduce their rapid spread.

Invasive plants can exacerbate the effects of fires and floods. Most of the invasive plants that cover the understory areas along streams provide little to no erosion control, allowing streambanks to fail in floods. Some invasives are extremely fire-prone; the 1991 Oakland firestorm was spread as Eucalyptus stands exploded, sending burning embers across major freeways to start additional fires.

Monterey pine and cypress are native to other locations in California but were planted in the Sausal Creek watershed. The needle litter of these trees increases soil acidity and this change in soil characteristics appears to favor the growth of invasive non-native plants over native species (K. Paulsell, pers. comm.).

Appendix C has a long list of the invasive species recorded for the parklands of the Sausal Creek watershed. Forty-three species are described and their known occurrences listed for public park areas. Typically the approach to invasive species control is to: 1) document the species present and their areal extent; 2) determine the primary dissemination pattern (from upstream to downstream along watercourses, along trails, from parking lots into parkland, etc.); and 3) complete a multi-year strategy for eradication. When the processes of invasive plant dissemination are contained entirely within public lands, this type of approach can be successful if funding is available.

In the Sausal Creek watershed, however, public and private landscapes are intertwined, making eradication of invasives on public lands and along creeks very difficult. Unfortunately, private land in Sausal Creek watershed contains numerous non-native invasive species and serves as a major source for dissemination of these plants. For the most part, homeowners are largely unaware of invasive plants and can still purchase many of the worst species for their gardens. Although state and local governments fund invasive plant removal, and park and fire districts carry out management to remove these species, the plants have not been banned for sale in the state. This situation creates a never-ending supply of invasive plants to open space areas, while there are limited resources to remove them. Unless the ongoing cultivation of invasive plants by homeowners in the watershed is reduced, invasive non-native plants can never be eradicated on public land and along creeks in the Sausal Creek watershed. Figures 44-47 illustrate invasive non-native plants in the urban areas of the Sausal Creek watershed.

**Joaquin Miller Park**

Of all the public parks, Joaquin Miller Park is the least affected by private gardens due to its position in the headwaters of Palo Seco Creek. Redwood Regional Park borders the east side of the park. Developed lands border the park along Joaquin Miller Blvd. Along this border goats are used to graze and reduce invasive plants moving into the park. There are sites along Skyline Boulevard and the Castle Road neighborhood, however, which affect park biota, although these areas are also grazed. The riparian corridor adjoining Joaquin Miller Court is also badly infested with non-native plants (K. Paulsell, pers. comm.). Construction and landscaping projects have also brought invasive non-native plants into the watershed. Karen Pausell has observed yellow starthistle and perennial pepperweed germinating from construction fill and mulch. A mulch and soil storage area at Park Blvd. near Leimert Blvd. with numerous invasive plants is on the adjacent downslope area of Dimond Canyon.

Non-native invasive plants that infest the park include: cape ivy, Acacia, broom, American elm, and Eucalyptus. Tables 18 and 19 list the approximate acreage of each species and Figures 48 and 49 depict known locations. Coverage for each species was mapped by Karen Paulsell. In addition to these mapped invasive species, a number of others have been recorded in the park but have not yet been mapped. These plants include: Algerian ivy, Himalayan blackberry, poison hemlock, spiderwort, and veldt grass. Mapped invasives and Monterey pine and Monterey cypress cover 14% of the land area of the park. Figure 50 shows the mixture of trees on a slope in the park. Several of the invasive plants are well-known fire hazards and include Acacia, Eucalyptus, and broom.

**Figure 44: Top: Sausal Creek in Dimond Canyon has a very urbanized watershed. Bottom: Cape ivy, a highly invasive non-native plant, covers over native trees and shrubs and kills them, leaving a monoculture of the ivy. Urban areas are a never ending supply of invasive plants to infest downstream natural areas.**

**Figure 45: Top: Cape ivy adjacent to a residential area in the Shepherd Canyon sub-basin. Bottom: Algerian ivy covering native plants in an ephemeral creek.**

**Figure 46: Invasive non-native species French broom and Eucalyptus are fire hazards.**

**Figure 47: French broom, a highly flammable invasive plant, is widespread in the Sausal Creek watershed and is seen here as an understory plant in both native vegetation and Eucalyptus forest.**

**Table 18: Mapped Invasive Non-Native Species in Parks[1, 2]**

| Park | Total Park Area (acres) | Acres of Invasive Non-Native Plants | | | | |
|---|---|---|---|---|---|---|
| | | Acacia | Cape Ivy | American Elm | Eucalyptus | Broom[3] |
| Joaquin Miller Park | 355.1 | 7.45 | 0.54 | 0.32 | 15.05 | 1.67 |
| Sequoia Lodge | 5.7 | - | 0.02 | - | - | - |
| Dimond Canyon Park | 69.2 | 1.75 | 1.12 | 0.77 | - | 0.51 |
| Shepherd Canyon Park and Bike Path | 5.1 | - | 0.77 | 0.02 | 3.68 | 0.97 |
| Beaconsfield Canyon Park | 4.2 | - | 0.05 | - | - | 0.04 |
| Castle Canyon Park | 9.4 | - | - | - | 0.45 | 0.25 |

[1] Table only includes invasive species that have reliable mapping coverage. Each park has additional invasive species; see text.
[2] Vegetation mapping completed by Karen Paulsell
[3] All species of broom are included here.

**Table 19: Acres of Monterey Pine and Monterey Cypress**

| Park | Acres |
|---|---|
| Joaquin Miller Park | 25.38 |
| Dimond Canyon Park | 0.01 |
| Shepherd Canyon Park and Bike Path | 2.28 |

Vegetation mapping completed by Karen Paulsell

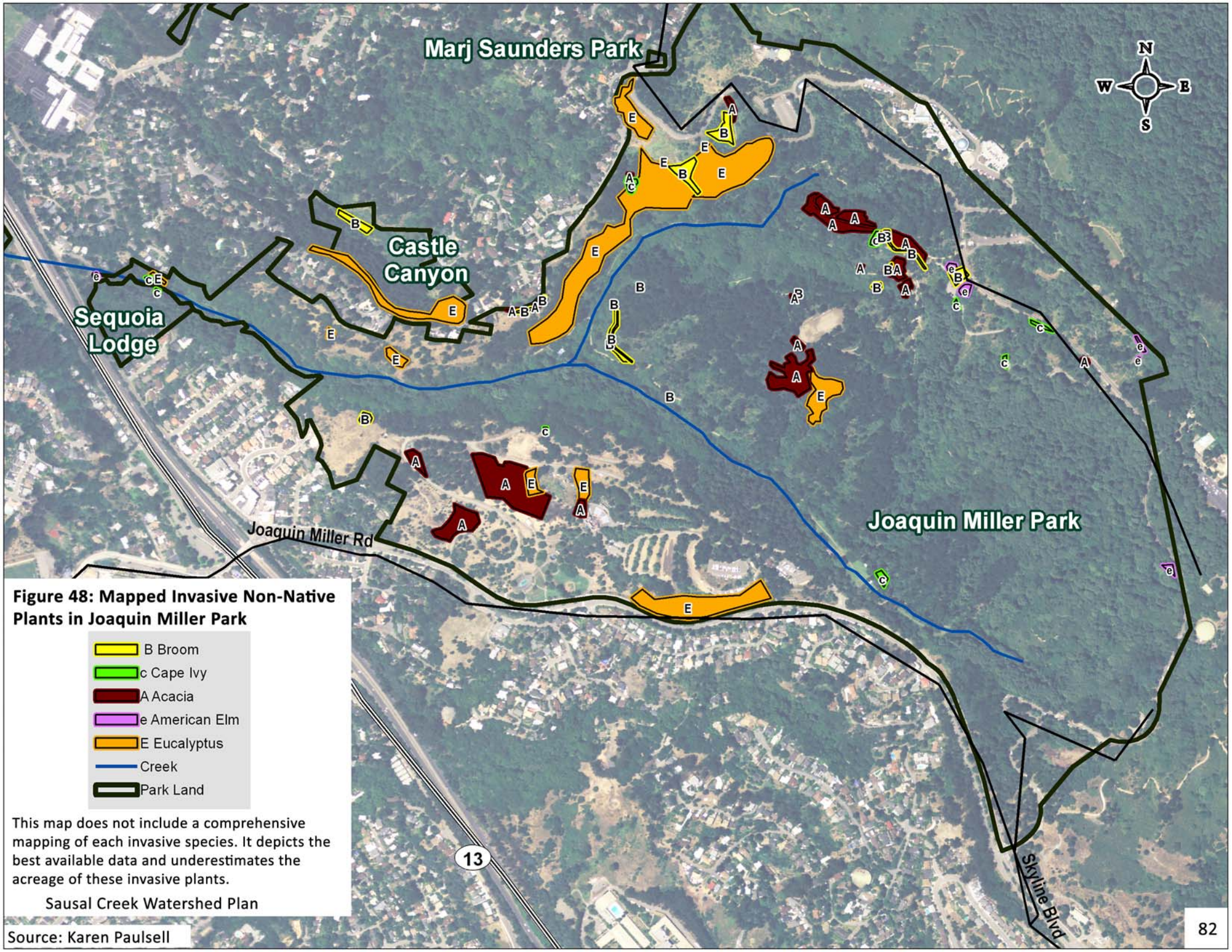



**Figure 48: Mapped Invasive Non-Native Plants in Joaquin Miller Park**

This map does not include a comprehensive mapping of each invasive species. It depicts the best available data and underestimates the acreage of these invasive plants.

Sausal Creek Watershed Plan

Source: Karen Paulsell

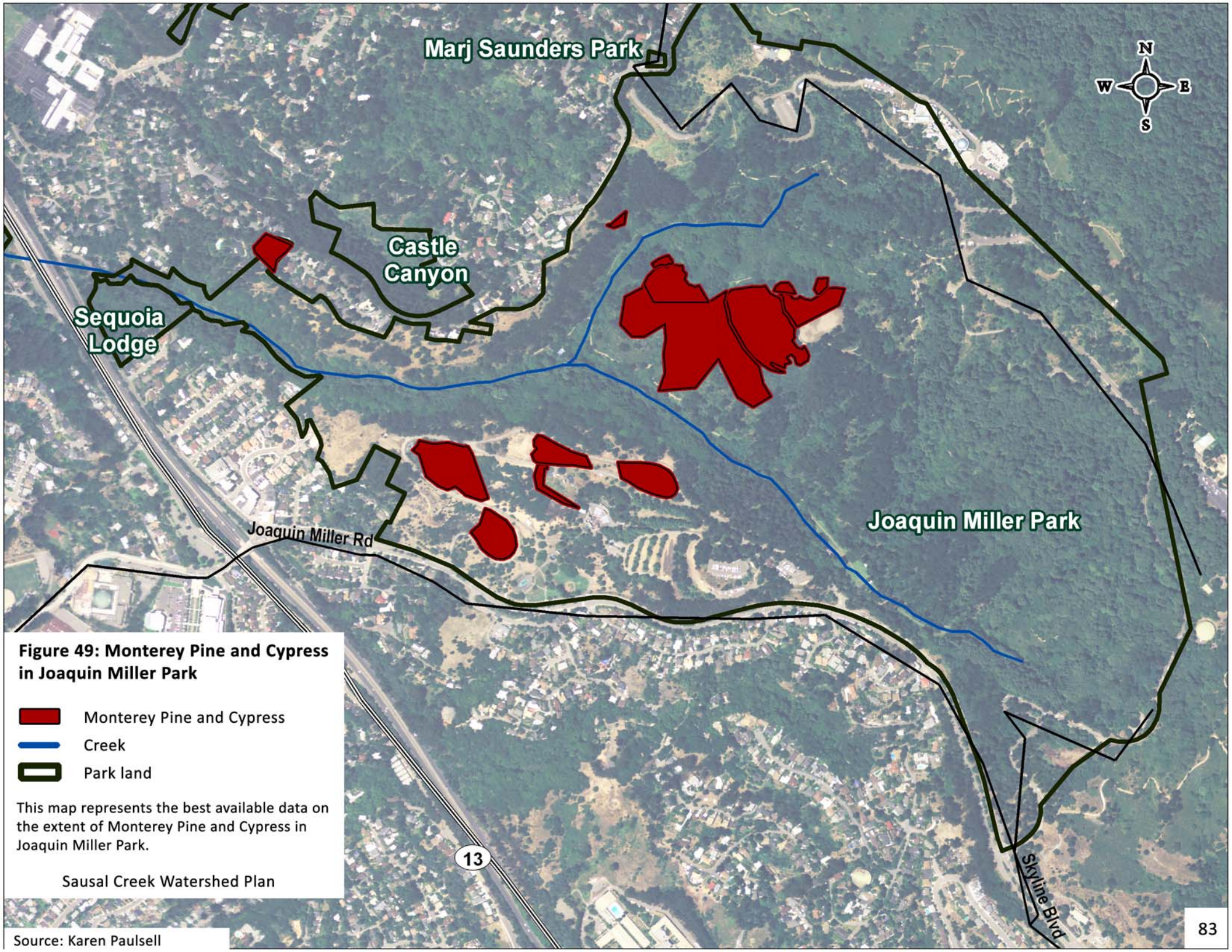



**Figure 49: Monterey Pine and Cypress in Joaquin Miller Park**

Monterey Pine and Cypress

Creek

Park land

This map represents the best available data on the extent of Monterey Pine and Cypress in Joaquin Miller Park.

Sausal Creek Watershed Plan

Source: Karen Paulsell

**Figure 50: Mixture of vegetation in Joaquin Miller Park includes planted natives such as Monterey Pine, which does not naturally occur in the Oakland area, and non-native Acacia.**

**Sequoia Lodge**

This small park adjacent to Joaquin Miller Park has mapped coverage of cape ivy (Figure 49) but also has Algerian ivy and Himalayan blackberry.

**Shepherd Canyon Park and Montclair Railroad Trail**

Shepherd Canyon Park and the Montclair Railroad trail have a large concentration of Eucalyptus and broom (Figures 47 and 51), creating a high fire hazard. In addition, Acacia, American elm, and blue periwinkle have been mapped in the park. Other invasive species in the park include Algerian ivy, Harding grass, poison hemlock, Himalayan blackberry, pampas grass, and spurge. Figure 52 depicts the extent of planted Monterey pine and cypress in Shepherd Canyon Park.

**Dimond Canyon Park**

Figure 53 depicts the mapped extent of several invasive species in Dimond Canyon Park. Several patches of Cape ivy have been eradicated and are "Adopt-a-Spot" maintenance sites. This species is invading Dimond Canyon Park along the Park Blvd. border from the adjoining residential area (K. Paulsell pers. comm.). In addition to these mapped species, a number of other invasive plants have been found in the park, including: Bermuda buttercup, fennel, gorse, Himalayan blackberry, Algerian ivy, pampas grass, and spiderwort. Algerian ivy is particularly widespread as a parasitic understory species. Algerian ivy climbs trees and sends adventitious roots through bark and into the cambial layer, where the tree moves sugar from leaves to roots. Over time, the ivy will weaken the tree and potentially kill it. Algerian ivy is also abundant along Palo Seco Creek canyon where this species can easily disperse into Dimond Canyon. Mapped invasive plants and Monterey pine and cypress cover 6% of the park area.

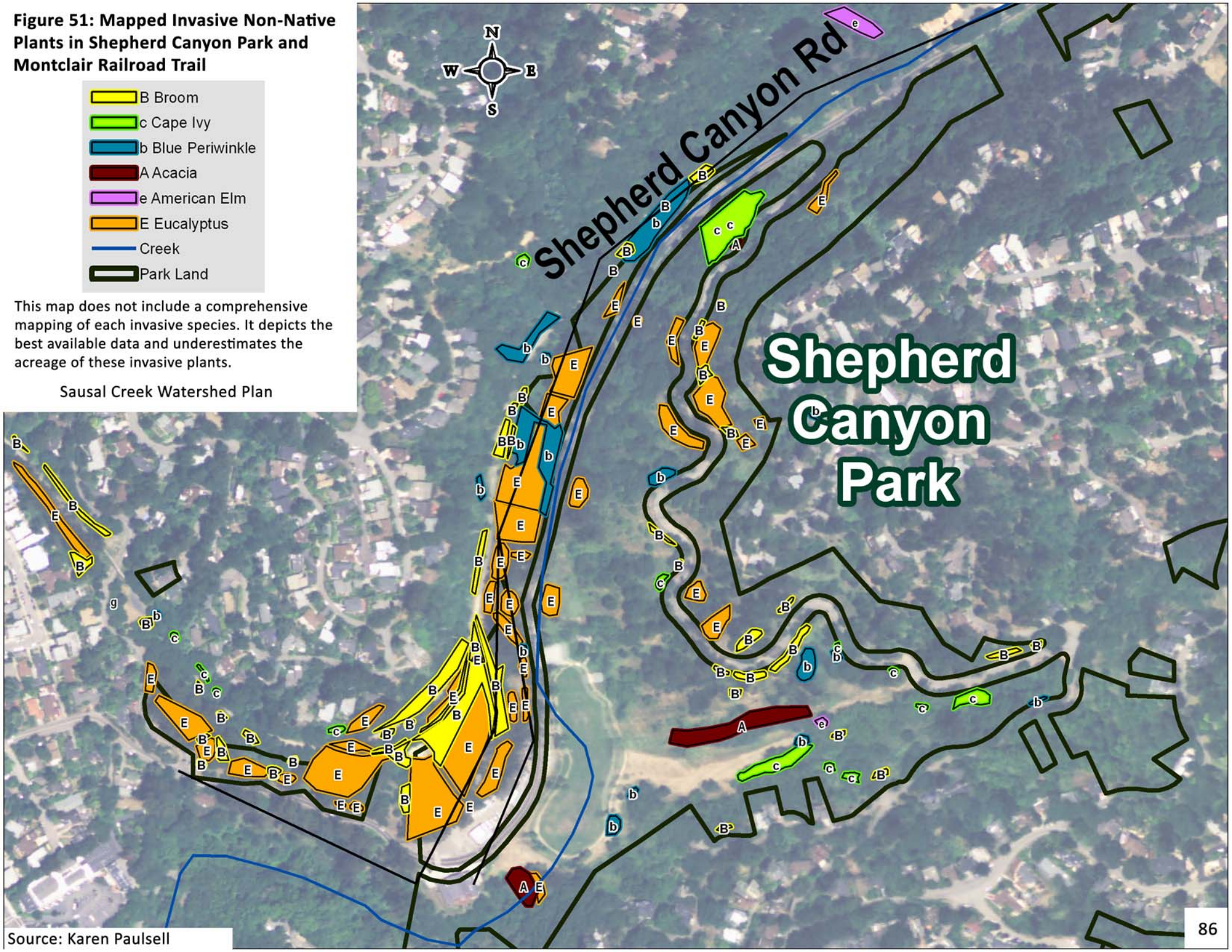
**Beaconsfield Canyon Park**

This small park has mapped coverage of tree of heaven, broom, cape ivy (Table 18). Other invasive species include Himalayan blackberry, veldt grass, Italian and other thistles, annual grasses, and poison hemlock.

**Castle Canyon Park**

This park has a large concentration of Eucalyptus and broom, both fire hazard species. Mapped invasive species cover 7% of the park area.

**Figure 51: Mapped Invasive Non-Native Plants in Shepherd Canyon Park and Montclair Railroad Trail**




This map does not include a comprehensive mapping of each invasive species. It depicts the best available data and underestimates the acreage of these invasive plants.

Sausal Creek Watershed Plan

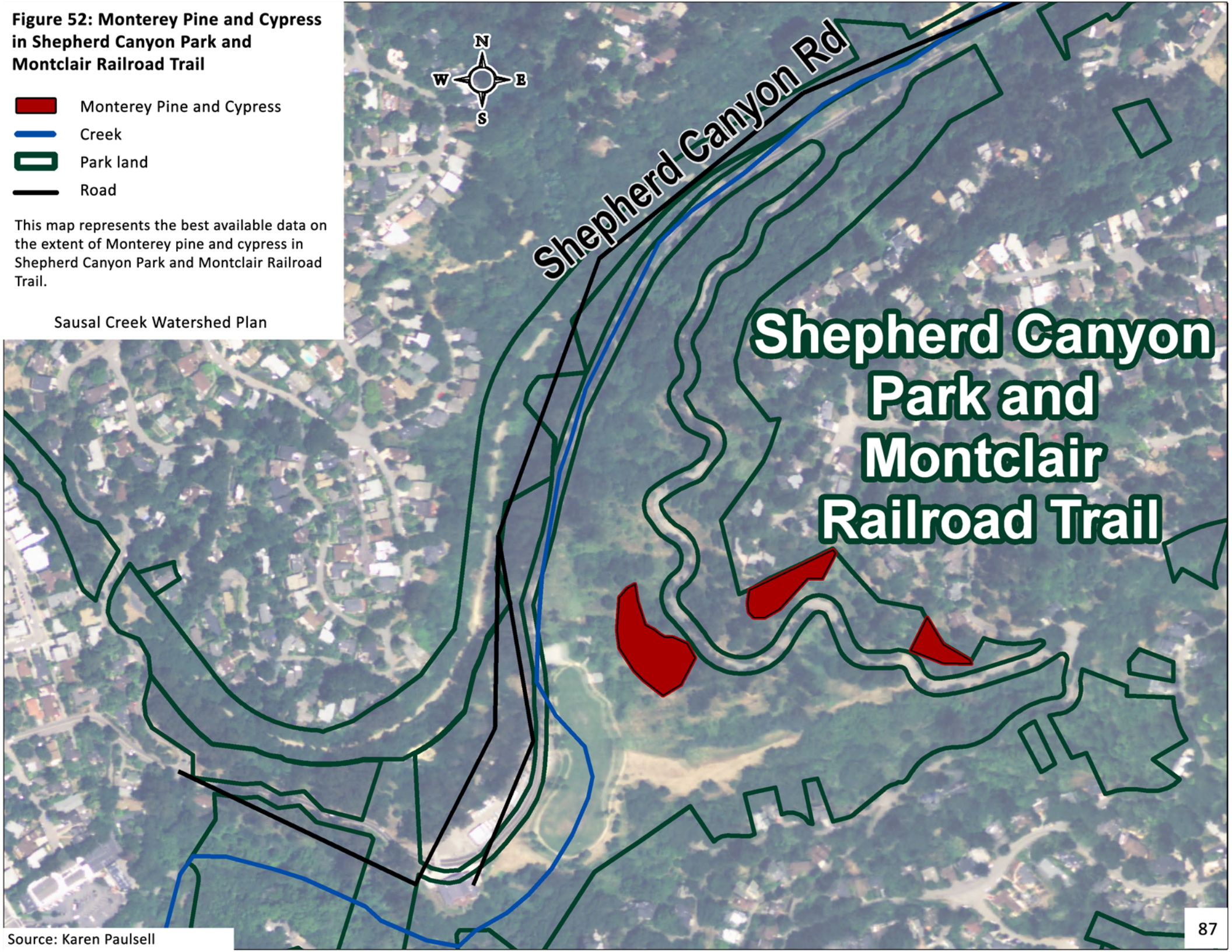
Source: Karen Paulsell

**Figure 52: Monterey Pine and Cypress in Shepherd Canyon Park and Montclair Railroad Trail**

Monterey Pine and Cypress
Creek
Park land
Road

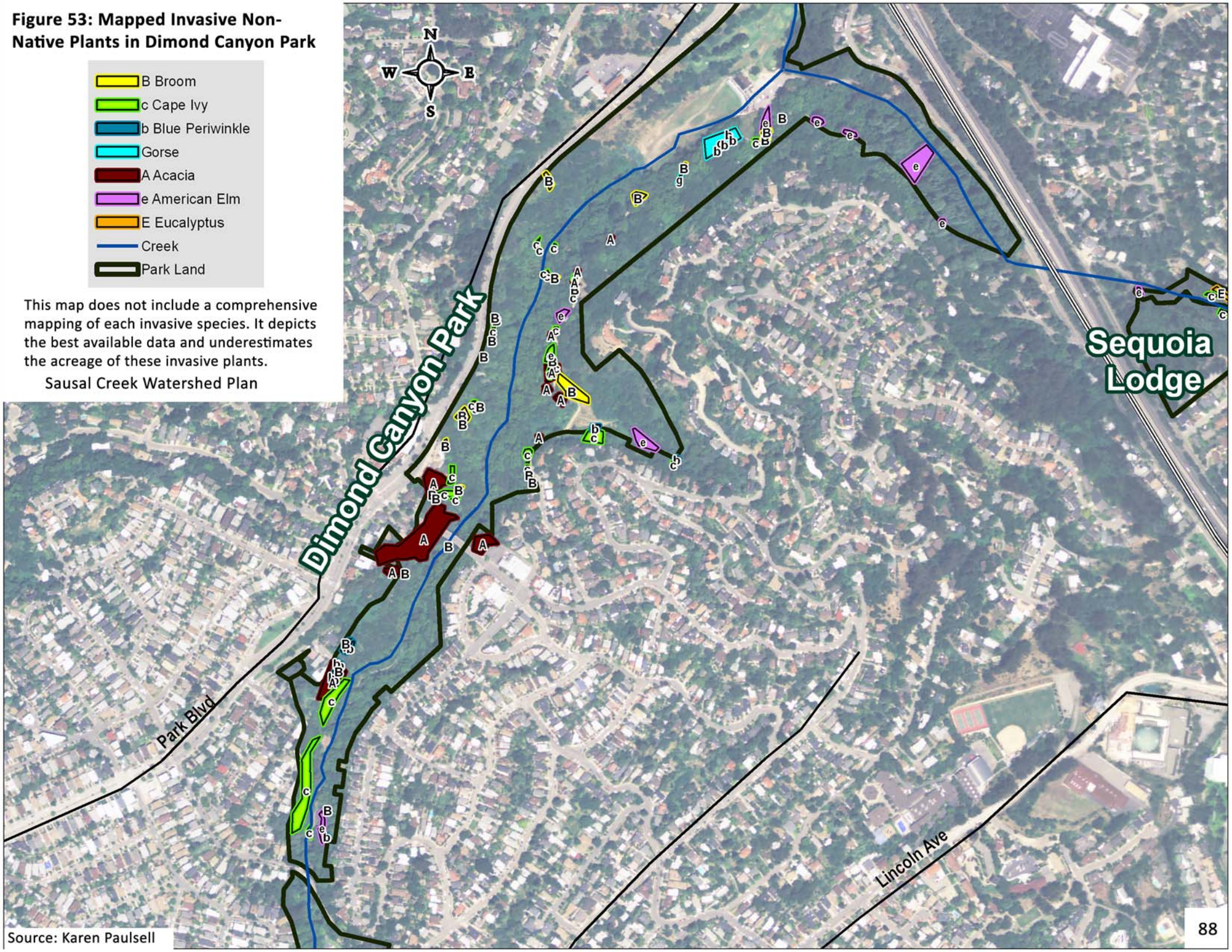
This map represents the best available data on the extent of Monterey pine and cypress in Shepherd Canyon Park and Montclair Railroad Trail.

Sausal Creek Watershed Plan




Source: Karen Paulsell

**Figure 53: Mapped Invasive Non-Native Plants in Dimond Canyon Park**




This map does not include a comprehensive mapping of each invasive species. It depicts the best available data and underestimates the acreage of these invasive plants.

Sausal Creek Watershed Plan

Source: Karen Paulsell

## WATER QUALITY

In urban watersheds, rainfall flushes numerous contaminants off of roofs, driveways, gardens, parks, and streets into storm drains and creeks. Rainfall also moves pollutants from the air into storm runoff. Due to the large volumes of runoff in winter, most of these contaminants are transported to San Francisco Bay and are diluted. During the dry season, however, there are also many sources of pollutants in urban watersheds which may reach storm drains and creeks. Due to the low flows in the creeks in summer there is little dilution and pollutants can have a greater effect on aquatic life.

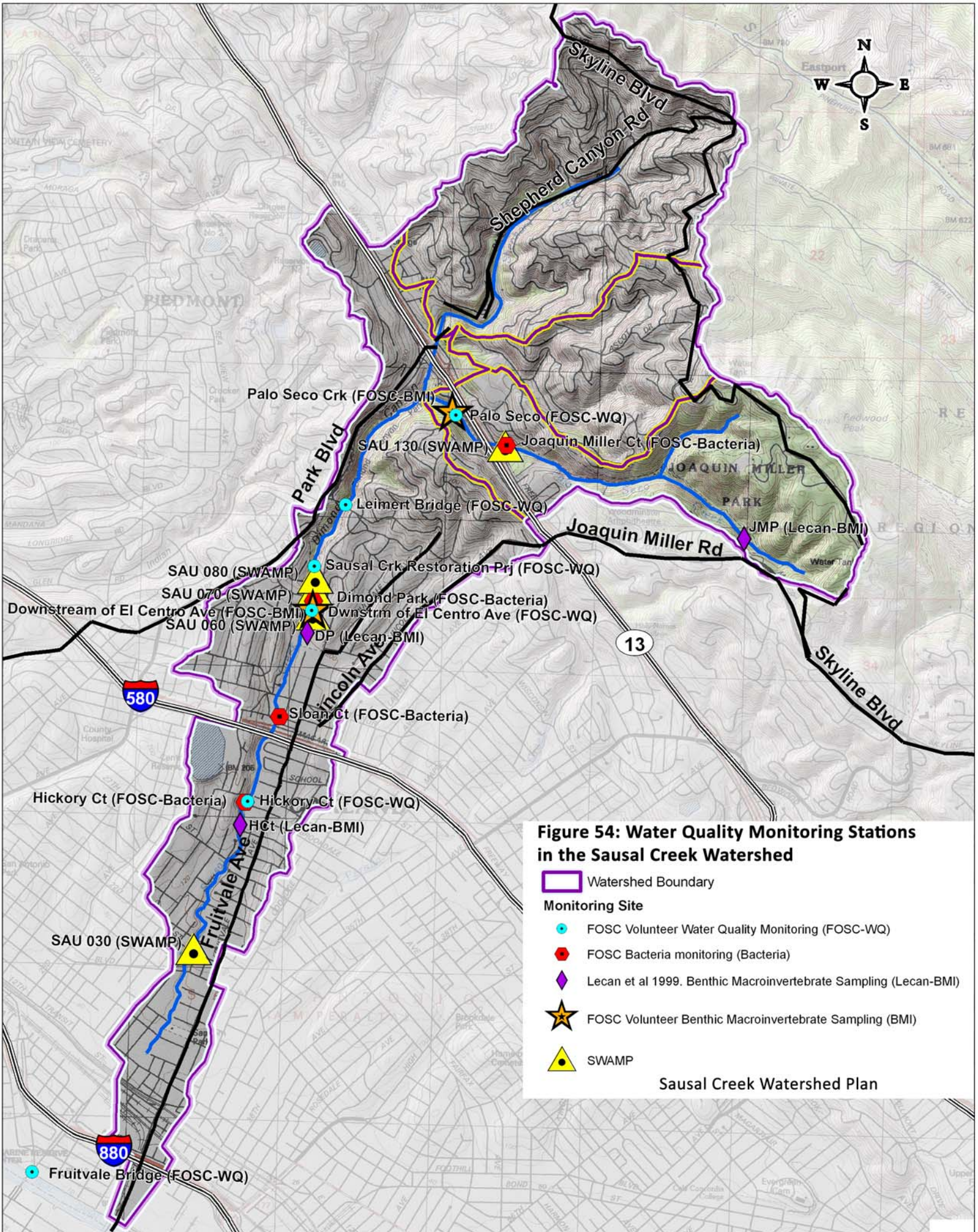
In the Sausal Creek watershed the primary land use is residential with limited commercial areas and some parkland. These land uses produce pollutants including oil and gas residues, trash, pesticides, fertilizers, sediment, dog feces, heavy metals, and other materials. These pollutants are generated by numerous sources in the watershed. One of the only effective methods for reducing pollutants is changing the habits and materials used by urban residents.

Several different programs have measured various water quality parameters in Sausal Creek (Figure 54). Friends of Sausal Creek (FOSC) has carried out a volunteer monitoring program for a number of years for basic water quality parameters in several locations. The FOSC program conducted sampling starting in March 1998. The parameters sampled were air temperature, water temperature, dissolved oxygen, pH, and conductivity and turbidity on an occasional basis. FOSC, in conjunction with the Environmental Protection Agency (EPA), also completed coliform testing in several locations in the watershed.

The San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) completed comprehensive water quality, sediment quality, and aquatic insect monitoring in Sausal Creek in 2004-2005.

### Water Quality – Volunteer Monitoring

The FOSC volunteer monitoring program used a variety of different stations. In 1998, the first year of the monitoring program, three stations were used: Palo Seco Creek just upstream of the Montclair Golf Course, Sausal Creek just downstream of the El Centro Avenue culvert, and Hickory Court near the Central Reservoir. In 2001-2002 another station at the Fruitvale Bridge was monitored, and in 2003 a station located in Sausal Creek near Leimert Bridge was sampled twice. Starting in 2002 the reach of Sausal Creek upstream of El Centro Avenue, where a major restoration project was implemented, was added as a station. In 2004 the program was revised and only three stations were used: Palo Seco Creek just upstream of the junction with Shephard Creek; Sausal Creek just downstream of the El Centro Avenue culvert; Sausal Creek in the channel area upstream of El Centro Avenue where the restoration project was completed. The monitoring was conducted by volunteers, on an approximately monthly basis. No written protocol was used to indicate the Quality Assurance/Quality Control (QA/QC) procedures used. The sampling program used meters supplied by the EPA, but it is not clear if the meters were calibrated before and after the sampling was done. LaMotte kits and pH strips were also used. These are instantaneous measurements rather than continuous measurements and give a snapshot view of water quality conditions. If this program continues, it is important that a QA/QC program be used and that methods be revised to assure the accuracy and reliability of the water quality data. Without a QA/QC program, the FOSC water quality data is useful only in a general way.




Source: SWAMP 2008; FOSC; Lecan et. al. 1999.

| Table 20: FOSC Water Quality Volunteer Monitoring Results 1998-2006<br>Instantaneous Water Temperatures (°C) | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sausal Creek at El Centro Avenue | | | | | | | | Palo Seco Creek | | | | | | | | Sausal Creek Restoration Reach | | | | |
| Month | 1998 | 1999 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 1998 | 1999 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2002 | 2003 | 2004 | 2005 | 2006 |
| 1 | | 9 | | 11.4 | 12 | 10 | 8.1 | 10.5 | | 10.0/9.0 | | 10.5 | 11.2 | 9.4 | 7.8 | 19.5 | | 12.1 | 10.2 | 8.3 | 10.5 |
| 2 | 14 | 10 | | 6.6 | 11.8 | | | | | 9.5 | | 6.5 | 11.2 | | | | | 11.9 | | | |
| 3 | 14 | 11.5 | | 9.8 | 8.9 | 12.8 | | | 10.0/14.0 | 10.5 | | 8.5 | 8.7 | 11.9 | | | | 9.1 | 12.9 | | |
| 4 | 12/11.5 | 10 | | 11.9 | 8.9 | 10.1 | | 12.7 | 10.5 | 9.5 | | 10.6 | 8.8 | 9.8 | | 11.9 | | 9.3 | 10.3 | | 12.6 |
| 5 | 20/14/13.5 | | | 12 | 12.9 | | 13.3 | | 14/11.5 | | | 11 | 11.4 | | | | | 12.8 | | 13.5 | |
| 6 | 15 | | | 15 | 14.9 | 17.3 | | | 14 | | | 13.5 | 13.5 | 14.8 | 15.3 | | 15.5 | 14.7 | 18.9 | | |
| 7 | 17 | | | 15.5 | 15.1 | 18.4 | | | 14 | | | 14.4 | 14.1 | 15.4 | | | 16.7 | 15.4 | 19.2 | | |
| 8 | 16 | | | 17.4 | 18.3 | 17.2 | 16.1 | | 15 | | 15.3 | 15 | 15.6 | 14.9 | 15.6 | | 17.3 | 17.8 | 17.2 | 15.9 | |
| 9 | 17.5 | | 15 | 14.3 | 17.9 | | | | 15 | | 13.5 | 12.7 | 15.7 | | | | 13.6 | 17.1 | | | |
| 10 | 13 | | 15 | 13.5 | 15.6 | | 13 | | 12 | | | 12.4 | 13.7 | | 12 | | 13 | 15.2 | | 12.5 | |
| 11 | 11 | | | 9 | 10.7 | | | | 10.5 | | | 9.1 | 10.3 | | | | 8.9 | 9.7 | | | |
| 12 | 9 | | 10.7 | 10 | 13.3 | | | | 8.5 | | 9.6 | 10.1 | 11.9 | | | | 10.5 | 13.3 | | | |

In reviewing the FOSC water quality data there are occasional measurements of low dissolved oxygen (<7.0 mg/l) associated with increases in water temperature. Table 20 shows instantaneous water temperatures by month for the three stations with the most data: Sausal Creek at El Centro, Palo Seco Creek, and Sausal Creek at the Restoration Reach. In general, the rainy season (December-March) has the lowest water temperatures, although the data shows a wide range of water temperatures for the same month at the same station. The water temperatures at the Palo Seco Creek station are consistently colder than in Sausal Creek at the El Centro and Restoration locations, indicating that lack of shade canopy along the creek may allow warming or that the stream flows from Cobbledick and Shephard Creeks may be warmer. Unfortunately there is no water temperature data for these two tributary creeks.

**Water Quality – SWAMP Monitoring**

The San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) monitored water quality in Sausal Creek in 2004-2005 at five stations (Figure 54). These stations include:

- Sausal Creek at E. 22nd Street (SAU030)
- Sausal Creek near Lions Pool in Dimond Park (SAU060)
- Sausal Creek at El Centro Ave. (SAU070)
- Sausal Creek in Dimond Park (SAU080)
- Palo Seco Creek (SAU130)

This monitoring was done using a continuous monitoring instrument and with strict QA/QC protocols at a larger number of stations on Sausal Creek. This data shows similar water temperatures as the FOSC monitoring. The station at Dimond Park has low dissolved oxygen levels in May and September 2004 (Table 21).

The SWAMP program also monitored for a range of persistent pollutants more typical of urban contaminants. On Sausal Creek, samples were collected at SAU030 (Sausal Creek at E. 22nd Street), the most downstream station. Both water samples and sediment samples were collected and analyzed for a large number of pollutants and results compared to standards for beneficial uses (Tables 22 through 24). Samples were collected at SAU030 on 1/10/05, 4/12/05, and 6/14/05 for water chemistry and toxicity analysis and on 4/12/05 for sediment chemistry and toxicity analyses. Tables 25 through 29 list the results of the water chemistry and toxicity analysis. All three samples exceeded the guidelines for nitrate and total phosphorous. Metals, pesticides, and other contaminants did not exceed the recommended levels (Table 27).

The water samples were also used in a bioassay test where freshwater test organisms are subject to the water and their survival is determined (Table 30). The organisms did not show any significant effects. Sediment samples from SAU030 were evaluated (Table 31). There were high enough levels of chromium, mercury, and nickel to exceed the threshold effect concentration (TEC). At the TEC level the contaminant is in just high enough concentration to affect aquatic life. When a bioassay was performed with the sediment samples the test organisms did not grow but also did not die in significant numbers. The water and sediment chemistry and toxicity tests indicate some sediment contamination by metals but no acutely toxic effects from water or sediment (Table 32 and 33).

**Table 21: SWAMP Program Summary Statistics of Continuous Monitoring Conducted in Sausal Creek**

| | | Spring | | Summer | | | Fall | | | Winter | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Start Date** | 5/14/04 | | 8/2/04 | | | 9/10/04 | | | 2/4/05 | | | |
| | **End Date** | 5/21/04 | | 8/9/04 | | | 9/20/04 | | | 2/10/05 | | | |
| | | **SAU030** | **SAU080** | **SAU030** | **SAU070** | **SAU130** | **SAU030** | **SAU080** | **SAU130** | **SAU030** | **SAU080** | **SAU130** | Evaluation thresholds |
| **Temp °C** | ***Min*** | 14 | 13.5 | 15.8 | 16 | 13.9 | 15.1 | 16.1 | 12.5 | 10.1 | 8.9 | 8.5 | |
| | ***Median*** | 14.7 | 14.8 | 16.8 | 17.1 | 14.8 | 17.3 | 16.7 | 14.8 | 11.2 | 10.3 | 9.3 | |
| | ***Max*** | 16.3 | 18.4 | 19 | 17.9 | 15.9 | 18.9 | 17.4 | 15.5 | 12.1 | 11.8 | 10 | >24 |
| | ***7-day Mean*** | 15.1 | 15.4 | 17.5 | 17.1 | 15.3 | 17.4 | 16.8 | 14.9 | 11.3 | 10.3 | 9.3 | >14.8, >17 |
| | *Accuracy* | NR [1] | NR [1] | NR [1] | NR [1] | NR [1] | NR [1] | NR [1] | NR [1] | NR [1] | NR [1] | NR [1] | |
| **DO mg/L** | ***Min*** | 8.5 | 4.0 | *7.2* | *7.9* | 8.1 | 7.1 | *0.3* | 7.6 | *10.8* | 10.3 | 11.1 | |
| | ***Median*** | 9.5 | 6.6 | *8.6* | *10.2* | 8.6 | 8.3 | *1.9* | 8.1 | *11.4* | 11.0 | 11.7 | |
| | ***Max*** | 11.1 | 10.7 | *11.2* | *15.0* | 9.0 | 11.3 | *6.8* | 9.8 | *12.0* | 12.0 | 12.2 | |
| | ***7-day Avg. Min*** | 8.8 | 4.9 | *7.7* | *8.5* | 8.3 | 7.5 | 0.9 | 7.8 | *11.2* | 10.5 | 11.5 | <7, < 5 |
| | *Accuracy (MQO: ± 0.5 mg/L)* | *0.2* | *0.1* | ***5%*** [2] | ***6.6%*** [2] | *1.2%* [2] | *0.2* | ***0.6*** | *0.1* | ***0.7*** | *0.3* | *0.4* | |
| **pH** | ***Min*** | 7.6 | 7.4 | 7.6 | 7.7 | 7.8 | 7.7 | 6.7 | 7.7 | 7.8 | *6.7* | 7.9 | < 6.5 |
| | ***Median*** | 7.7 | 7.8 | 7.7 | 7.8 | 7.9 | 7.8 | 6.9 | 7.9 | 8.0 | *7.2* | 8.0 | |
| | ***Max*** | 7.9 | 8.3 | 8.1 | 8.1 | 8.0 | 8.2 | 7.1 | 8.0 | 8.2 | *7.4* | 8.1 | > 8.5 |
| | *Accuracy (MQO: ± 0.5)* | *0.1* | *0.1* | *0.1* | *0.04* | *0.02* | *0.04* | *0.03* | *0.1* | *0.1* | ***2*** | *0.02* | |
| **SC µS/cm** | ***Min*** | *330* | 634 | 210 | 960 | 726 | 249 | 1007 | 675 | 202 | 202 | 408 | |
| | ***Median*** | *464* | 759 | 419 | 969 | 739 | 407 | 1066 | 735 | 612 | 713 | 540 | |
| | ***Max*** | *490* | 781 | 438 | 975 | 749 | 459 | 1104 | 747 | 645 | 754 | 586 | >1000, >2000 |
| | *Accuracy (MQO: ± 5.0%)* | ***7.3%*** | *3.1%* | *0.9%* | *0.7%* | *0.7%* | *1.4%* | *0.7%* | *0.8%* | *0.4%* | *0.4%* | *0.8%* | |
| | ***n*** | *669* | *667* | *654* | *469* | *655* | *828* | *831* | *958* | *573* | *570* | *567* | |

Notes:
*Red italicized* font indicates that data did not meet SWAMP MQO's. **NR:** Value not recorded.
1 = Post-deployment accuracy checks performed during annual lab calibration - Temp. probe met SWAMP MQO's.
2 = Accuracy value gleaned from percent saturation check; substituted 5% for 0.5 mg/L SWAMP MQO.
3 = Data met SWAMP MQO's but field operator noted that probe was dewatered during deployment. Data has been clipped but may be unreliable.

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 22: SWAMP Laboratory Analyses, Tests, or Counts Performed with Water Samples**

| Group | Analyte | Laboratory | Method | Unit | MDLs Min | MDLs Max | RLs Min | RLs Max |
|---|---|---|---|---|---|---|---|---|
| **Conventional** | | | | | | | | |
| | Alkalinity as CaCO3 | DFG-WPCL | QC 10303311A | mg/L | 3 | 3 | 8 | 10 |
| | Ammonia as N | DFG-WPCL | EPA 350.3 | mg/L | 0.04 | 0.04 | 0.1 | 0.1 |
| | Boron,Total | MLML-TM | EPA 1638M | mg/L | 0.0001 | 0.0001 | 0.0003 | 0.0003 |
| | Boron,Total | SFL | EPA 200.7 | mg/L | 0.0044 | 0.0097 | 0.05 | 0.05 |
| | Chloride | DFG-WPCL | EPA 300.0 | mg/L | 0.2 | 4 | 0.35 | 7 |
| | Chlorophyll a | MPSL-DFG | EPA 445.0M | µg/L | 0.045 | 0.045 | 0.045 | 0.045 |
| | Dissolved Organic Carbon | AMS | EPA 415.1 | mg/L | 0.1 | 0.1 | 0.1 | 0.1 |
| | Dissolved Solids,Total | DFG-WPCL | SM 2540 C | mg/L | 10 | 10 | 10 | 10 |
| | Hardness as CaCO3 | DFG-WPCL | QC 10301311B | mg/L | 5 | 5 | 10 | 10 |
| | Hardness as CaCO3 | DFG-WPCL | SM 2340 C | mg/L | 1 | 1 | 1 | 1 |
| | Manganese,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.01 | 0.01 | 0.03 | 0.03 |
| | Nickel,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.01 | 0.01 | 0.05 | 0.05 |
| | Nitrate as N | DFG-WPCL | QC 10107041B | mg/L | 0.01 | 0.2 | 0.02 | 0.4 |
| | Nitrite as N | DFG-WPCL | QC 10107041B | mg/L | 0.002 | 0.005 | 0.005 | 0.01 |
| | Nitrogen, Total Kjeldahl | DFG-WPCL | QC 10107062E | mg/L | 0.12 | 0.12 | 0.25 | 0.25 |
| | OrthoPhosphate as P,Dissolved | DFG-WPCL | QC 10115011M | mg/L | 0.005 | 0.005 | 0.01 | 0.01 |
| | Phosphorus as P,Total | DFG-WPCL | QC 10115011D | mg/L | 0.03 | 0.03 | 0.05 | 0.05 |
| | Sulfate | DFG-WPCL | EPA 300.0 | mg/L | 0.5 | 10 | 0.7 | 14 |
| | Suspended Sediment Concentration | MPSL-DFG | ASTM D3977M or SM 2540 B | mg/L | 5 | 5 | 5 | 5 |
| | Total Organic Carbon | AMS | EPA 415.1 | mg/L | 0.1 | 0.1 | 0.1 | 0.1 |
| | Total Organic Carbon | DFG-WPCL | EPA 415.1M | mg/L | 0.2 | 0.2 | 1 | 1 |
| **Metals** | | | | | | | | |
| | Aluminum,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.1 | 0.1 | 0.5 | 0.5 |
| | Arsenic,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.1 | 0.1 | 0.5 | 0.5 |
| | Cadmium,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.01 | 0.01 | 0.03 | 0.03 |
| | Chromium,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.03 | 0.03 | 0.1 | 0.1 |
| | Copper,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.01 | 0.01 | 0.03 | 0.03 |
| | Lead,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.01 | 0.01 | 0.03 | 0.03 |
| | Mercury,Total | MPSL-DFG | EPA 1631EM | **ng/L** | 0.16 | 0.2 | 0.16 | 0.2 |
| | Selenium,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.1 | 0.1 | 0.5 | 0.5 |
| | Silver,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.01 | 0.01 | 0.05 | 0.05 |
| | Zinc,Dissolved | MPSL-DFG | EPA 1638M | µg/L | 0.1 | 0.1 | 0.3 | 0.3 |
| **Organics** | | | | | | | | |
| | Chlorpyrifos | UCD-GC or ToxScan | ELISA | µg/L | 0.05 | 0.05 | 0.1 | 0.1 |
| | Diazinon | UCD-GC or ToxScan | ELISA | µg/L | 0.03 | 0.03 | 0.06 | 0.06 |
| | Herbicides Suite | DFG-WPCL | EPA 619M | µg/L | 0.02 | 0.02 | 0.05 | 0.05 |
| | Carbaryl Suite | DFG-WPCL | EPA 632M | µg/L | var | var | var | var |
| | Organochlorine Pesticides | DFG-WPCL | EPA 8081AM/BM | µg/L | var | var | var | var |
| | OrganophosphatePesticides | DFG-WPCL | EPA 8141AM | µg/L | var | var | var | var |
| | PAHs Suite | DFG-WPCL | EPA 8270M | µg/L | 0.005 | 0.005 | 0.005 | 0.005 |
| | PCBs Suite | DFG-WPCL | EPA 8082M | µg/L | 0.001 | 0.001 | 0.002 | 0.002 |
| **Toxicity testing** | | | | | | | | |
| | Ceriodaphnia dubia | MPSL-DFG or ToxScan | EPA 600/4-91-002 mod | NA | NA | NA | NA | NA |
| | Pimephales promelas | MPSL-DFG or ToxScan | EPA 600/4-91-002 mod | NA | NA | NA | NA | NA |
| | Selenastrum capricornutum | MPSL-DFG or ToxScan | EPA 600/4-91-002 mod | NA | NA | NA | NA | NA |
| **Coliform counts** | | | | | | | | |
| | total coliform | EPA R-IX | SM 9223 IDEXX | MPN /100mL | 10 | 10 | 10 | 10 |
| | E, coli | EPA R-IX | SM 9223 IDEXX | MPN /100mL | 10 | 10 | 10 | 10 |

MDL - minimum detection limit; RL - reporting limit; NA - not applicable
Complete analytical suites for OCs, OPs, PAHs, and PCBs are presented in appendix Table D-2

AMS: Applied Marine Sciences
DFG-WPCL: Department of Fish and Game Water Pollution Control Laboratory
EPA R-IX: EPA Region IX laroatroy, Richmond CA
MLML-TM
MPSL-DFG: Marine Pollution Studies Laboratory, Department of Fish and Game
SAL: Sequoia Analytical Laboratories, Inc.
SFL: Sierra Foothill Laboratory
ToxScan - ToxScan Inc. Watsonville
UCD-GC: University of California at Davis, Granite Canyon Laboratory

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 23: SWAMP Water Quality Benchmarks for Protection of Aquatic Life**

| Characteristic | Description of Benchmark | Numeric Limit | Units | Reference |
|---|---|---|---|---|
| Temperature | Max, salmonids | 24 | ° C | USEPA, 1977 |
| | MWAT for Coho | 19.7 | ° C | Sullivan *et al*, 2000 |
| | 7-day Mean for Coho | 14.8 | ° C | Sullivan *et al*, 2000 |
| | MWAT for steelhead | 19.6 | ° C | Sullivan *et al*, 2000 |
| | 7-day Mean for steelhead | 17 | ° C | Sullivan *et al*, 2000 |
| Oxygen, dissolved | 7-day Avg. Min, WARM | 5 | mg/L | Basin Plan, 2005 |
| | 7-day Avg. Min, COLD | 7 | mg/L | Basin Plan, 2005 |
| pH | Range | 6.5 to 8.5 | S.U. | Basin Plan, 2005 |
| Ammonia, unionized | Annual median | 0.025 | mg/L | Basin Plan, 2005 |
| Nitrate as N | Maximum | 0.16 | mg/L | USEPA, 2000b |
| Phosphorus, total as P | Maximum | 30 | µg/L | USEPA, 2000b |
| Arsenic, dissolved | 1-hour average WQO | 340 | µg/L | Basin Plan, 2005 |
| | 4-day average WQO | 150 | µg/L | Basin Plan, 2005 |
| Arsenic, total | Maximum | 10 µg/L | | (Dept. of Public Health) |
| Cadmium, total[a] | 1-hour average WQO | 3.9 | µg/L | Basin Plan, 2005 |
| | 4-day average WQO | 1.1 | µg/L | Basin Plan, 2005 |
| Chromium VI, dissolved | 1-hour average WQO | 16 | µg/L | Basin Plan, 2005 |
| | 4-day average WQO | 11 | µg/L | Basin Plan, 2005 |
| Copper, dissolved[a] | 1-hour average WQO | 13 | µg/L | Basin Plan, 2005 |
| Copper, dissolved | 4-day average WQO | 9 | µg/L | Basin Plan, 2005 |
| Lead, dissolved[a] | 1-hour average WQO | 65 | µg/L | Basin Plan, 2005 |
| | 4-day average WQO | 2.5 | µg/L | Basin Plan, 2005 |
| Mercury, total | 1-hour average WQO | 2.4 | µg/L | Basin Plan, 2005 |
| Nickel, dissolved[a] | 1-hour average WQO | 470 | µg/L | Basin Plan, 2005 |
| | 4-day average WQO | 52 | µg/L | Basin Plan, 2005 |
| Selenium, total | 1-hour average WQO | 20 | µg/L | Basin Plan, 2005 |
| | 4-day average WQO | 5 | µg/L | Basin Plan, 2005 |
| Silver, dissolved[a] | 1-hour average WQO | 3.4 | µg/L | Basin Plan, 2005 |
| Zinc, dissolved[a] | 1-hour average WQO | 120 | µg/L | Basin Plan, 2005 |
| | 4-day average WQO | 120 | µg/L | Basin Plan, 2005 |
| PCBs | Continuous 4-day average | 0.014 | µg/L | CTR |
| Chlorpyrifos | Continuous 4-day average | 0.015 | µg/L | CVRWQCB, 2006 |
| Dacthal (DCPA) | Instantaneous max. AWQC | 14,300 | µg/L | USEPA, 1987 |
| Diazinon | 1-hour average | 0.1 | µg/L | SFBRWQCB, 2005 |
| Disulfoton (Disyston) | Instantaneous max. AWQC | 0.05 | µg/L | USEPA, 1973 |
| Endosulfan | Instantaneous maximum | 0.22 | µg/L | CTR |
| | Continuous 4-day average | 0.056 | µg/L | CTR |
| HCH, gamma- (gamma-BHC, Lindane) | Maximum 1-hour average | 0.95 | µg/L | CTR |
| Parathion, methyl | Instantaneous max. AWQC | 0.08 | µg/L | CDFG |
| Thiobencarb | Instantaneous max. AWQC | 3.1 | µg/L | CDFG |
| E. coli | log mean | 126 | MPN/100 mL | Basin Plan, 2005 |
| Total Coliforms | median | 240 | MPN/100 mL | Basin Plan, 2005 |
| | maximum | 10000 | MPN/100 mL | Basin Plan, 2005 |

Note [a]: Table values for total cadmium and for dissolved copper, lead, nickel, silver, and zinc assume a hardness of 100 mg/L CaCO3. Samples at other hardness levels must be calculated using formulas in the Basin Plan.

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 24: SWAMP Sediment Quality Benchmarks**

| Characteristic | Description of Benchmark [1] | Numeric Limit | Units |
|---|---|---|---|
| Arsenic | PEC | 33 | mg/kg |
| | TEC | 9.79 | mg/kg |
| Cadmium | PEC | 4.98 | mg/kg |
| | TEC | 0.99 | mg/kg |
| Chromium | PEC | 111 | mg/kg |
| | TEC | 43.4 | mg/kg |
| Copper | PEC | 149 | mg/kg |
| | TEC | 31.6 | mg/kg |
| Lead | PEC | 128 | mg/kg |
| | TEC | 35.8 | mg/kg |
| Mercury | PEC | 1.06 | mg/kg |
| | TEC | 0.18 | mg/kg |
| Nickel | PEC | 48.6 | mg/kg |
| | TEC | 22.7 | mg/kg |
| Zinc | PEC | 459 | mg/kg |
| | TEC | 121 | mg/kg |
| Anthracene | PEC | 845 | µg/kg |
| | TEC | 57.2 | µg/kg |
| Benz(a)anthracene | PEC | 1050 | µg/kg |
| | TEC | 108 | µg/kg |
| Benzo(a)pyrene | PEC | 1450 | µg/kg |
| | TEC | 150 | µg/kg |
| Chlordane | PEC | 17.6 | µg/kg |
| | TEC | 3.24 | µg/kg |
| Chrysene | PEC | 1290 | µg/kg |
| | TEC | 166 | µg/kg |
| DDD (sum op + pp) | PEC | 28 | µg/kg |
| | TEC | 4.88 | µg/kg |
| DDE (sum op + pp) | PEC | 31.3 | µg/kg |
| | TEC | 3.16 | µg/kg |
| DDT (sum op + pp) | PEC | 62.9 | µg/kg |
| | TEC | 4.16 | µg/kg |
| DDT (total) | PEC | 572 | µg/kg |
| | TEC | 5.28 | µg/kg |
| Dibenz(a,h)anthracene | **TEC** | 33 | µg/kg |
| Dieldrin | PEC | 61.8 | µg/kg |
| | TEC | 1.9 | µg/kg |
| Endrin | PEC | 207 | µg/kg |
| | TEC | 2.22 | µg/kg |
| Fluoranthene | PEC | 2230 | µg/kg |
| | TEC | 423 | µg/kg |
| Fluorene | PEC | 536 | µg/kg |
| | TEC | 77.4 | µg/kg |
| HCH, gamma | PEC | 4.99 | µg/kg |
| | TEC | 2.37 | µg/kg |
| Heptachlor epoxide | PEC | 16 | µg/kg |
| | TEC | 2.47 | µg/kg |
| Naphthalene | PEC | 561 | µg/kg |
| | TEC | 176 | µg/kg |
| PAH (total) | PEC | 22800 | µg/kg |
| | TEC | 1610 | µg/kg |
| PCB (total) | PEC | 676 | µg/kg |
| | TEC | 59.8 | µg/kg |
| Phenanthrene | PEC | 1170 | µg/kg |
| | TEC | 204 | µg/kg |
| Pyrene | PEC | 1520 | µg/kg |
| | TEC | 195 | µg/kg |

Source: MacDonald et al 2000a

[1] *PEC=Probable Effect Concentration; TEC=Threshold Effect Concentration*

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 25: SWAMP Program Comparison of Nutrient Concentrations in Years 4 and 5 Samples to Water Quality Benchmarks (WQB) for Sausal Creek**

| Station | Season | Ammonia as N (mg/L) | qual | pH | Temperature (°C) | Unionized Ammonia as N (mg/L) (WQB=0.025) | Unionized Ammonia Exceedance Factor | Nitrate as N (mg/L) (WQB=0.16) | Nitrate Exceedance Factor | Phosphorus as P, Total (mg/L) (WQB=0.03) | Total P Exceedance Factor |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 1/10/05 | 0.097 | J | 7.84 | 11.5 | 0.001 | 0.04 | 2.27 | 14.2 | 0.07 | 2.3 |
| SAU030 | 4/12/05 | | ND | 7.56 | 12.8 | | | 1.41 | 8.8 | 0.06 | 2.1 |
| SAU030 | 6/14/05 | 0.05 | J | 7.68 | 15.5 | | | 1.25 | 7.8 | 0.08 | 2.7 |

* ND=not detected. "J" is defined as 'estimated'; the analyte was detected but the value is below the Reporting Limit

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 26: SWAMP Program Concentrations of Selected Nutrients, Chlorophyll a, TOC, and SSC in Years 4 and 5 Water Samples for Sausal Creek**

| Station | Season | Nitriteas N (mg/L) | qual | Nitrogen, Total Kjeldahl (mg/L) | qual | Ortho-Phosphate as P (mg/L) | Chlorophyll a (µg/L) | Total Organic Carbon (mg/L) | Suspended Sediment Concentration (mg/L) | qual |
|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 1/10/05 | 0.02 | | 0.50 | | 0.07 | 0.17 | 2.9 | 7 | |
| SAU030 | 4/12/05 | 0.01 | J | 0.25 | | 0.07 | 0.19 | 4.1 | | ND |
| SAU030 | 6/14/05 | 0.01 | J | 0.19 | J | 0.09 | 0.28 | 3.5 | 6 | |

* ND=not detected. "J" is defined as 'estimated'; the analyte was detected but the value is below the Reporting Limit

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 27: SWAMP Program Comparison of Metal Concentrations in Years 4 and 5 Samples to Water Quality Objectives (WQOs) for Sausal Creek**

| Station | Season | Hardness (mg/L) | Metal Name | Metal, Total (ug/L) | Metal, Dissolved (ug/L) | qual | Acute WQ Objective (ug/L) | Acute Exceedance Factor | Chronic WQ Objective (ug/L) | Chronic Exceedance Factor | WQ Objective Fraction |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 1/10/05 | 209 | Cadmium | | 0.03 | | | | | | |
| SAU030 | 4/12/05 | 276 | Cadmium | | 0.02 | J | | | | | |
| SAU030 | 6/14/05 | 254 | Cadmium | | 0.01 | J | | | | | |
| SAU030 | 1/10/05 | 209 | Copper | | 2.86 | | 28.0 | 0.10 | 17.5 | 0.16 | Dissolved |
| SAU030 | 4/12/05 | 276 | Copper | | 1.73 | | 36.4 | 0.05 | 22.2 | 0.08 | Dissolved |
| SAU030 | 6/14/05 | 254 | Copper | | 2.2 | | 33.7 | 0.07 | 20.7 | 0.11 | Dissolved |
| SAU030 | 1/10/05 | 209 | Lead | | 0.05 | | 208.7 | 0.000 | 8.13 | 0.006 | Dissolved |
| SAU030 | 4/12/05 | 276 | Lead | | 0.06 | | 297.3 | 0.000 | 11.59 | 0.005 | Dissolved |
| SAU030 | 6/14/05 | 254 | Lead | | 0.05 | | 267.5 | 0.000 | 10.42 | 0.005 | Dissolved |
| SAU030 | 1/10/05 | 209 | Nickel | | 3.66 | | 875 | 0.00 | 97 | 0.04 | Dissolved |
| SAU030 | 4/12/05 | 276 | Nickel | | 2.38 | | 1107 | 0.00 | 123 | 0.02 | Dissolved |
| SAU030 | 6/14/05 | 254 | Nickel | | 1.59 | | 1032 | 0.00 | 115 | 0.01 | Dissolved |
| SAU030 | 1/10/05 | 209 | Silver | | | ND | 14.4 | | | | |
| SAU030 | 4/12/05 | 276 | Silver | | | ND | 23.3 | | | | |
| SAU030 | 6/14/05 | 254 | Silver | | | ND | 20.2 | | | | |
| SAU030 | 1/10/05 | 209 | Zinc | | 5.34 | | 223.8 | 0.02 | 223.8 | 0.02 | Dissolved |
| SAU030 | 4/12/05 | 276 | Zinc | | 5.07 | | 283.2 | 0.02 | 283.2 | 0.02 | Dissolved |
| SAU030 | 6/14/05 | 254 | Zinc | | 2.46 | | 264.0 | 0.01 | 264.0 | 0.01 | Dissolved |
| SAU030 | 1/10/05 | 209 | Arsenic | | 1.27 | | 340.0 | 0.00 | 150.0 | 0.01 | Dissolved |
| SAU030 | 4/12/05 | 276 | Arsenic | | 0.64 | | 340.0 | 0.00 | 150.0 | 0.00 | Dissolved |
| SAU030 | 6/14/05 | 254 | Arsenic | | 0.94 | | 340.0 | 0.00 | 150.0 | 0.01 | Dissolved |
| SAU030 | 1/10/05 | 209 | Chromium | | 0.77 | | 16 | 0.05 | 11 | 0.07 | Dissolved |
| SAU030 | 4/12/05 | 276 | Chromium | | 0.99 | | 16 | 0.06 | 11 | 0.09 | Dissolved |
| SAU030 | 6/14/05 | 254 | Chromium | | 0.55 | | 16 | 0.03 | 11 | 0.05 | Dissolved |
| SAU030 | 1/10/05 | 209 | Mercury | 0.0630 | | | 2.4 | 0.026 | | | Total |
| SAU030 | 4/12/05 | 276 | Mercury | 0.0023 | | | 2.4 | 0.001 | | | Total |
| SAU030 | 6/14/05 | 254 | Mercury | 0.0022 | | | 2.4 | 0.001 | | | Total |
| SAU030 | 1/10/05 | 209 | Selenium | | 2.62 | | | | | | |
| SAU030 | 4/12/05 | 276 | Selenium | | 1.12 | | | | | | |
| SAU030 | 6/14/05 | 254 | Selenium | | 2.51 | | | | | | |
| SAU030 | 1/10/05 | 209 | Aluminum | | 9.18 | | | | | | |

**Table 27: SWAMP Program Comparison of Metal Concentrations in Years 4 and 5 Samples to Water Quality Objectives (WQOs) for Sausal Creek (continued)**

| Station | Season | Hardness (mg/L) | Metal Name | Metal, Total (ug/L) | Metal, Dissolved (ug/L) | qual | Acute WQ Objective (ug/L) | Acute Exceedance Factor | Chronic WQ Objective (ug/L) | Chronic Exceedance Factor | WQ Objective Fraction |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 4/12/05 | 276 | Aluminum | | 3.35 | | | | | | |
| SAU030 | 6/14/05 | 254 | Aluminum | | 6.09 | | | | | | |
| SAU030 | 1/10/05 | 209 | Manganese | | 27.2 | | | | | | |
| SAU030 | 4/12/05 | 276 | Manganese | | 13 | | | | | | |
| SAU030 | 6/14/05 | 254 | Manganese | | 8.16 | | | | | | |

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 28: SWAMP Program Comparison of Concentrations to Water Quality Benchmarks (WQBs) for Sausal Creek**

| Station | Season | Diazinon (µg/L) (WQB=0.1) |
|---|---|---|
| SAU030 | 1/10/05 | ND |
| SAU030 | 4/12/05 | ND |
| SAU030 | 6/14/05 | ND |

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 29: SWAMP Program Concentrations of All Organic Compounds Detected in Years 4 and 5 Water Samples (µg/L) for Sausal Creek**

| Station | Season | Total Organic Carbon | Acenaphthene | Benz(a)anthracene | Benzo(a)pyrene | Benzo(b)fluoranthene | Benzo(e)pyrene | Benzo(g,h,i)perylene | Benzo(k)fluoranthene | Biphenyl | Carbofuran | Chrysene | Chrysenes, C1- | Chrysenes, C2- | Chrysenes, C3- | Diazinon | Dibenzothiophenes, C1- | Dibenzothiophenes, C2- | Dibenzothiophenes, C3- | Dimethylnaphthalene, 2, 6- | Disulfoton | Diuron | Fluoranthene | Fluoranthene/Pyrenes, C1- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 1/10/05 | 2.9 | ND | ND | ND | ND | ND | ND | ND | ND | 0.110 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| SAU030 | 4/12/05 | 4.1 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| SAU030 | 6/14/05 | 3.5 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |

**Table 29: SWAMP Program Concentrations of All Organic Compounds Detected in Years 4 and 5 Water Samples (µg/L) for Sausal Creek - continued**

| Station | Season | Fluorene | Fluorenes, C1- | Fluorenes, C3- | Indeno(1,2,3-c,d)pyrene | Methyldibenzothiophene, 4- | Methylfluorene, 1- | Methylnaphthalene, 1- | Methylnaphthalene, 2- | Methylphenanthrene, 1- | Naphthalene | Naphthalenes, C1- | Naphthalenes, C3- | Naphthalenes, C4- | Oxadiazon | Parathion, Methyl | Phenanthrene | Phenanthrene/Anthracene, C1- | Phenanthrene/Anthracene, C2- | Phenanthrene/Anthracene, C3- | Phenanthrene/Anthracene, C4- | Pyrene | Simazine | Timethylnaphthalene, 2, 3, 5- |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 1/10/05 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.007 | ND | ND | ND | ND | ND | ND | ND | 0.008 | ND | ND | ND | 0.026 | ND |
| SAU030 | 4/12/05 | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| SAU030 | 6/14/05 | ND | ND | ND | ND | ND | ND | ND | ND | ND | 0.006 | ND | ND | ND | ND | ND | 0.005 | ND | ND | ND | ND | ND | n/me | ND |

* ND=not detected; n/me=not measured

**Table 30: SWAMP Program Bioassay Test—Toxicity of Years 4 and 5 Water Samples to Three Freshwater Test Organisms for Sausal Creek**

| Station | Season | *Ceriodaphnia dubia* | | | | | | *Pimephales promelas* | | | | | | *Selenastrum capricornutum* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean Survival (%) | % of Control | Code | Avg. # of Young/ Female | % of Control | Code | Survival (%) | % of Control | Code | Growth (Avg. weight, mg/ind) | % of Control | Code | Cell Count (million cells/ml) | % of Control | Code |
| SAU030 | 1/10/05 | 100 | 100 | NSG | 30.1 | 97.41 | NSG | 87.5 | 89.7 | SG | 0.667 | 98.4 | NSG | 10067500 | 134 | NSG |
| SAU030 | 4/12/05 | 100 | 100 | NSG | 25.4 | 120.9 | NSG | 95 | 97.4 | NSG | 1.036 | 125 | NSG | 6670000 | 112.3 | NSG |
| SAU030 | 6/14/05 | 90 | 100 | NSG | 30.4 | 92.4 | NSG | 95 | 95 | NSG | 0.945 | 103.5 | NSG | 5657820 | 100.95 | NSG |

* Codes:
NSG=Not significantly different from negative control (alpha=0.05), and sample value was above 80% of control (No 'toxicity criteria' met)
SG=Significantly different from negative control (alpha=0.05), BUT sample value is above 80% of control (Only first 'toxicity criteria' met)

**Table 31: SWAMP Metal Concentrations in Comparison to Quality Benchmarks for Sausal Creek**

| Station | Aluminum (mg/Kg) | Arsenic (mg/Kg) | Cadmium (mg/Kg) | Chromium (mg/Kg) | Copper (mg/Kg) | Lead (mg/Kg) | Manganese (mg/Kg) | Mercury (mg/Kg) | Nickel (mg/Kg) | Silver (mg/Kg) | Zinc (mg/Kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 15552 | 4.2 | 0.16 | 66.5 | 12.4 | 12.7 | 250 | 0.243 | 44.3 | 0.11 | 50 |
| Threshold Effect Concentration Values: | | 9.79 | 0.99 | 43.4 | 31.6 | 35.8 | | 0.18 | 22.7 | | 121 |

**Table 32: SWAMP Sediment Properties and Concentrations of Detected Pesticides in Comparison to Quality Objectives for Sausal Creek**

| Station | Total Organic Carbon (%) | Percent Moisture | % Clay & Silt (<0.075mm) | % Fine & Medium Sand (0.075-2mm) | % Coarse (>2mm) | Aldrin | Bifenthrin | Biphenyl | Chlordane, cis- | Chlordane, trans- | Chlordane, Total | Cypermethrin-1 | Cypermethrin-2 | Cypermethrin-3 | Cypermethrin-4 | Dieldrin | Endrin | HCH, gamma | Heptachlorepoxide | Hexachlorobenzene | Nonachlor, cis- | Nonachlor, trans- | Oxadiazon | Oxychlordane | Permethrin-1 | Permethrin-total | Tedion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SAU030 | 0.23 | 20.5 | 1.5 | 83.3 | 15.1 | | | 4.68 | 1.64 | 1.54 | 3.18 | | | | | 1.74 | | | | | | 1.32 | | | | | 1.52 |

Tables from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 33: SWAMP Sediment Observed Toxicity and Probable (Toxic) Effect Concentration Quotients for Selected Substances for Sausal Creek**

| Station | Metals Mean PEC[1] Quotient | PCB PEC Quotient | PAH PEC Quotient | Sample Mean PEC Quotient | *Hyalella azteca* Survival | | | H. azteca Growth (weight, mg/ind) | | | % Fines (<0.075 mm) | Total Organic Carbon (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean | % of Control | Code | Mean | % of Control | Code | | |
| SAU030 | 0.280 | 0.020 | 0.002 | 0.10 | 81 | 125 | NSG | 0.40 | 63 | SL | 2 | 0.23 |

[1] PEC=Probably (Toxic) Effect Concentration

Codes:

NSG=Not significantly different from negative control (alpha=0.05), and sample value was above 80% of control (No 'toxicity criteria' met)

SL=Significantly different from negative control (alpha=0.05), and sample value is below 80% of control (Both 'toxicity criteria' met)

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 34: SWAMP Continuous Field Monitoring Summaries for Sausal Creek in 2004-2005**

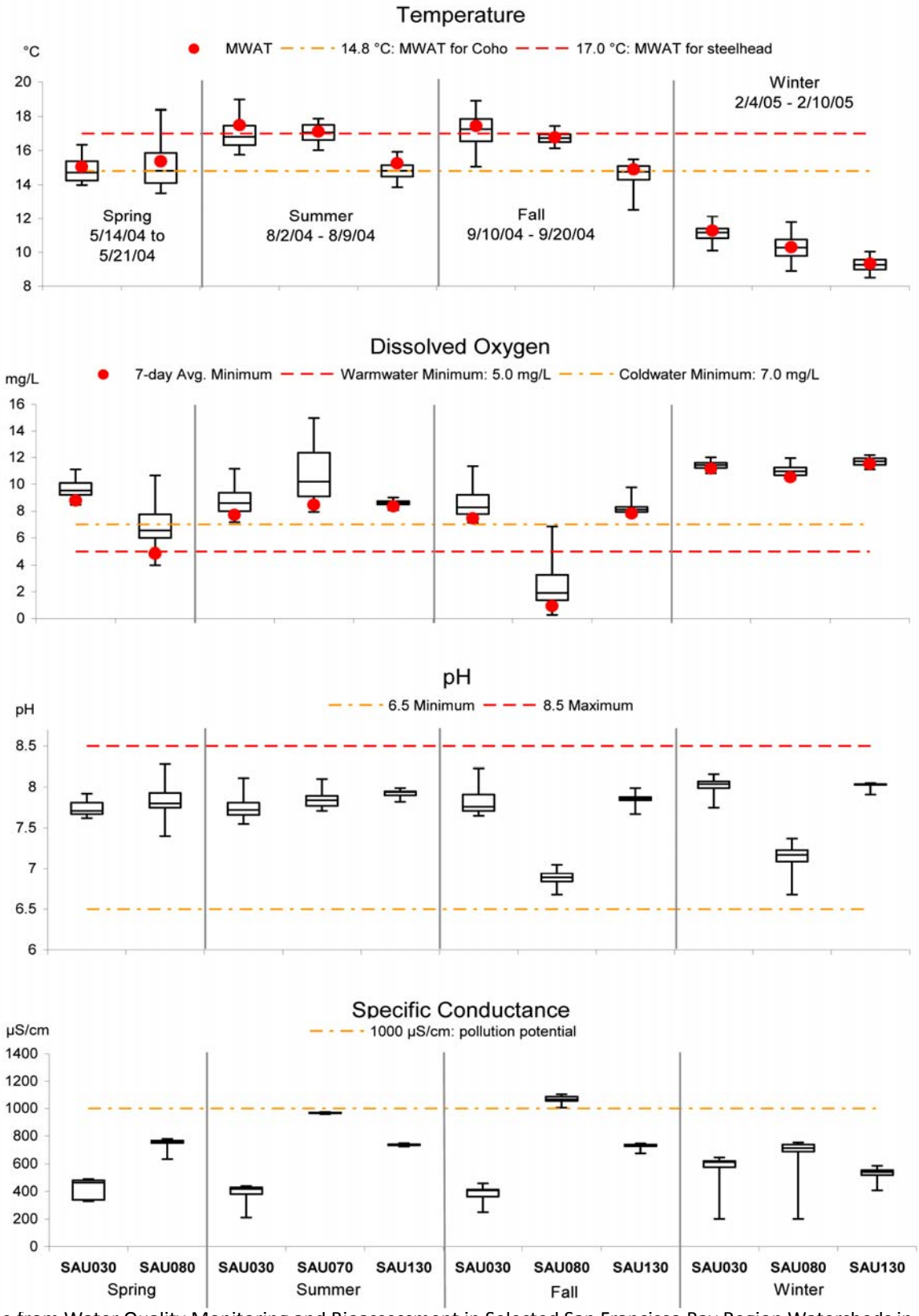



Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Bacteria Monitoring**

In 1999 FOSC worked with the EPA to test four sites along the creek for *E. coli* bacteria (Table 35). *E. coli* levels were over the acceptable level of 126 MPN/100ml at all sites. Significant levels (7800 MPN/100ml) of *E. coli* were found at Dimond Park and Sloan Ct. in the spring. High levels of *E. coli* (12,000 MPN/100ml) were also found at Sloan Ct. in the fall. The presence of high levels of *E. coli* indicates likely fecal contamination from leaking sanitary sewer pipes and sewage overflows. High *E. coli* levels represent a health hazard for anyone wading or coming into contact with the creek water.

SWAMP also completed bacterial monitoring. Samples were taken on 7/20/04, 7/27/04, 8/3/04, 8/10/04, and 8/17/04 at SAU060 (Sausal Creek at Lions Pool). Table 36 lists the results for total coliform counts. Total coliform measures coliform bacterial from all sources. *E. coli* tests are for fecal bacteria. The EPA standard for water contact recreation for *E. coli* is 240 for the median value. The SAU060 median for the test period for total coliform was 5500. A separate test for *E. coli* bacteria found a median of 164 MPN/100ml. The EPA standard for water contact recreation is a mean of 126.

The SWAMP numbers for *E. coli* are much lower than the 1999 FOSC numbers. It should be noted that the large sanitary sewer line which runs down the middle of Sausal Creek in Dimond Canyon was partially replaced as part of the creek restoration project between the 1999 and 2004 samples. The new pipe would be expected to have less leakage; however, the sewer pipe upstream of the restoration reach has not been replaced and is known to overflow in storm events (Figure 107).

**Table 35: FOSC/EPA E. coli Monitoring in Sausal Creek (in MPN/100ml)**

| Date | Palo Seco Creek | Sausal Creek | | |
|---|---|---|---|---|
| | Joaquin Miller Ct. | Dimond Park | Sloan Ct. | Hickory Ct. |
| 3/10/1999-4/7/1999 | 400 | 7800 | 7800 | 1900 |
| 9/8/1999-10/6/1999 | 150 | 1500 | 12000 | 1900 |

* MPN=Most Probable Number

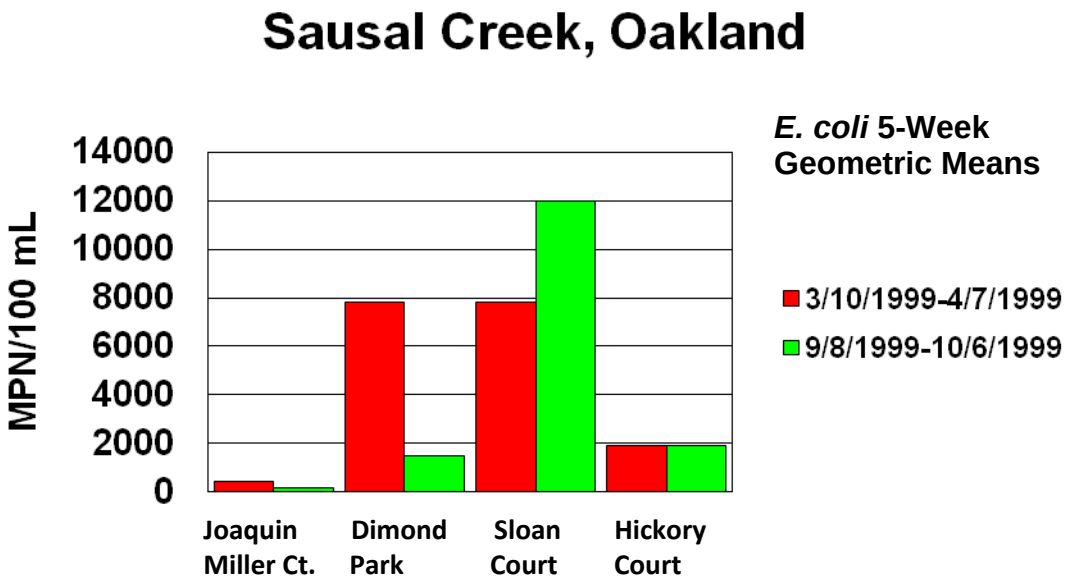


**Table 36: SWAMP Total Coliform Counts and *E. coli* Counts (MPN/100ml) in Sausal Creek in Years 4 and 5 as Determined by the Colilert Method**

| Station: SAU060 | 7/20/04 | 7/27/04 | 8/3/04 | 8/10/04 | 8/17/04 | Median |
|---|---|---|---|---|---|---|
| Total Coliform | 7300 | 5500 | 1800 | 17000 | 1200 | 5500 |
| *E. coli* | 260 | 120 | 160 | 150 | 160 | 164 |

* Counts are Most Probable Number per 100 milliliters (MPN/100ml). Values in red exceed the limit for freshwater recreation (126 MPN for the geomean).
Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Summary: Water Quality**

Several different sets of water quality and bacteria monitoring data have been collected in the Sausal Creek watershed. The Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) provides high-quality monitoring data subjected to strict Quality Assessment/Quality Control (QA/QC) measures. In 2004-2005 SWAMP measured a comprehensive number of parameters at five stations on Sausal Creek. The results of the SWAMP monitoring found excessive levels of nutrients (nitrate and total phosphorus), slightly high water temperatures, and a few low dissolved oxygen measurements. Water and sediment samples were tested for a number of persistent pollutants including metals, pesticides, PCBs, and PAHs. Sediment samples from the downstream area of Sausal Creek had concentrations of chromium, mercury, and nickel that exceed the threshold effect concentrations (TEC). Water samples did not show any high contaminant levels. Bioassays on water and sediment found no acute toxicities, but sediment sample tests found hindered growth in the test organism.

FOSC water quality data lacks any description of methods or QA/QC measures and as such its accuracy and reliability cannot be established.

Bacterial data was collected by FOSC in 1999 and analyzed by the EPA, and shows high *E. coli* levels in all locations sampled. SWAMP bacterial monitoring in 2004 found lower *E. coli* levels, but levels still exceeded water contact recreation standards.

## AQUATIC AND RIPARIAN HABITATS

### Introduction

The Sausal Creek watershed, unlike most urban areas, has many open, unculverted creek channels. Compared to culverted reaches, these creeks have the ability to support aquatic and riparian habitats for fish and wildlife. One of the goals of this plan is to determine what watershed improvements are needed to reduce the negative effects of urbanization on these habitats. This section will review how urban development affects creeks and their habitats and will inventory open channel reaches and their enhancement potential.

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|---|---|---|---|---|---|---|
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| *E. coli* | 260 | 120 | 160 | 150 | 160 | 164 |

* Counts are Most Probable Number per 100 milliliters (MPN/100ml). Values in red exceed the limit for freshwater recreation (126 MPN for the geomean).
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In the Sausal Creek watershed, aquatic habitats consist of the stream channel bottom and banks in the creeks with perennial and intermittent, or seasonal, flow. Ephemeral creeks carry water only during and immediately after rainfall and are delineated using the topographic contours but are not indicated as creeks on the topo map. Most ephemeral creeks in this watershed are steep and short. Cobbledick Creek is not indicated as a blue line (perennial/seasonal) creek. Perennial and seasonal open channel creeks include: Palo Seco Creek and its tributary; Cinderella Creek, Shephard Creek downstream of Shepherd Canyon Park, and Sausal Creek (Figure 55).

Riparian habitat consists of the vegetation bordering the low flow channel and covering the adjacent floodplain. Riparian vegetation is dependent on a source of summer water. Willows and alders are the most abundant riparian plants along Sausal Creek and are considered "pioneer" species. Both species are able to rapidly colonize deposited sediment, stream banks, and channel edges. Alder has the ability to grow roots both above and below ground, creating an anchor along rocky, eroding channel edges. Willow can spread by seed or root runners as well as re-root and grow from broken stems and roots.

Other common plants found along streams in the watershed include trees—coast redwoods, California bay laurel, and big-leaf maple—and understory—Pacific dogwood, nine bark, and native blackberry. Uncommon riparian species include elk clover, red alder, box elder, rushes and sedges, California wild rose, red elderberry, and others (Appendix B). The distribution of plant species varies according to the type of stream channel, whether it is confined in a gorge or unconfined as occurs on an alluvial plain.

An important concept in the ecology of riparian systems is ecological succession. The diversity of riparian vegetation species varies over a continuum of the conditions created by flood events and associated changes in stream channel morphology. Willows and alders, as pioneer species, occur near the active channel in alluvial streams or along the edges and among rocks in confined channels, and are eroded out frequently. Their reproductive and adaptive strategy is tuned to a highly variable physical environment. Farther away from the channel, other species occur on the floodplain that are still riparian in nature but are adapted to less physical variation. These include big-leaf maple, California bay laurel, and coastal redwood. Among conifers, coastal redwood is unique in its ability to grow along streams and withstand the buildup of alluvium around its trunk. Redwoods can grow adventitious roots along its trunk as sediment accumulates. Redwood seeds are also known to germinate after the deposition of fresh alluvium.

Alluvial fans typically have oak savannah rather than riparian corridors due to the high infiltration rates and lack of perennial flow. As stream channels fill, erode, or meander, the composition of vegetation changes, creating a diverse habitat structure which serves the needs of numerous insects and animals.

In many areas of the channels in the Sausal Creek watershed, gravel deposits and stream morphology create pools, riffles, and glides. Riffles are typically areas of high aquatic insect production. Aquatic insects live attached to rocks and within the spaces between rocks. Some are the aquatic nymph stage of flying adult insects such as dragonflies, damselflies, and mayflies. Others spend their entire life cycle in the water. All must be able to hold on to the creek substrate in the current, or hide within or beneath the gravel.

## Effects of Urbanization on Riparian and Aquatic Habitats

The urbanization of Sausal Creek began along the lower creek where the land is flat, and eventually extended up into the headwaters and onto steep slopes. Only one tributary—Palo Seco Creek—retains a largely undeveloped drainage basin. Shephard and Cobbledick Creeks have less intensive urban development than Sausal Creek, but are still highly impacted by impervious surfaces.
Creeks in a natural state are formed and changed by flood events. Each watershed has a unique set of features, including size and shape of the basin and stream network, topography, geology, vegetative cover, land use, and rainfall patterns. Over time, the creek's size, shape, and condition reflect watershed conditions. For example, large-scale grading, road building, and land disturbance for residential development in upper Sausal Creek watershed (Figure 17) likely increased soil erosion, including landslides in wet years, resulting in large volumes of sediment being delivered to Sausal Creek. The creek channel might have had increased over-bank flooding and reduced aquatic habitat due to the sedimentation. Once large areas of the watershed were paved and many creek channels replaced with storm drains, Sausal Creek experienced larger volumes of runoff over a shorter time and a decreased sediment supply. Erosion of the sediment stored in the creek bed and banks occurred, resulting in incision or entrenchment. Once the channel is incised, stormflows are confined to the channel and increase erosion. In addition, urbanization typically involves channelization of creeks to reduce the area the creek occupies in order to maximize buildable land.

During the urbanization process, the riparian habitat is eroded out as the creek channel incises. As the channel bottom erodes, the former floodplain is isolated from frequent inundation. The entrenched channel has high flow velocities precluding much sediment deposition and the germination of riparian trees. The habitat in the new incised channel is limited in area and diversity. As the channel deepens, the banks fail, eroding habitat remaining on the original floodplain.

Aquatic habitats are highly affected by the high flow velocities. Channel scour and frequent gravel movement decrease the abundance and diversity of aquatic insects. Sand transport can shred the insects. High water temperatures caused by the loss of riparian shading, persistent urban pollutants, and fine sediments also limit aquatic insects.

To revegetate the riparian corridor and achieve conditions which support natural ecosystem processes of succession and diversity, the effects of urbanization on flow volumes, velocities, and channel form have to be mitigated. Willow, the species most adapted to high velocity flows, can withstand a flow velocity of up to 7 ft./sec. and shear stresses of 2 lbs./$ft^2$. Sausal Creek typically exceeds these conditions during the 1-year frequency event. As is discussed in the watershed section (p. 213), changing these physical flow conditions requires a watershed approach.

## Benefits and Limitations of Creek Restoration

Urban creek restoration typically means changing the stream channel by grading and possibly adding rock or removing a culvert and recreating a channel. A narrow band of vegetation, usually willows, is installed on the newly graded channel banks. The creek usually remains in the same area. It is uncommon for a floodplain to be created where storm flows can spread out and slow down due to space limitations of urban areas. The footprint of the riparian corridor is rarely wide enough to support ecological processes, or a diversity of plant species. The restored urban stream may continue to have physical conditions such as frequent high velocity flows, which scour the channel and reduce the abundance and diversity of aquatic insects and riffles and pools for spawning and rearing fish. By

restoring only one reach of an urban creek, the habitat benefits that can be achieved are limited to what can be changed in this very limited area. A broader approach, integrating improvements in the watershed with creek projects to mitigate the effects of urbanization, offers the possibility for changing both the creek and the processes which have caused the degradation of the creek. A focus on watershed restoration instead of just creek restoration requires a greater level of analysis but has the potential to produce higher quality, more sustainable environmental conditions in habitat areas.

A number of studies have looked at the long-term changes in aquatic habitat conditions in restored urban creeks. One of these studies focused on changes in aquatic insect assemblages in a creek in the East Bay. A restored section of Baxter Creek in Poinsett Park was evaluated in 1999 and in 2004 (Purcell et. al. 2002; Purcell 2004). The creek was removed from a culvert, a new channel was graded and stabilized with rock, and willows were planted. The size of the new creek channel was restricted by adjacent urban development and no floodplain was created as part of the project.

Aquatic insects were monitored in 1999 and again in 2004. Samples were taken after the project was completed and were evaluated for taxa richness, number of taxa of EPT (pollutant intolerant taxa), and family richness. Habitat areas were also evaluated.

The restored reach was compared with an unrestored reach of Baxter Creek and a high quality habitat area of Strawberry Creek deemed "best attainable conditions." The same sampling design was applied to all three creek reaches. The study found that the "restored" reach of Baxter Creek had slightly improved aquatic habitat conditions over the unrestored reach of Baxter Creek but showed no significant improvements in aquatic habitat between 1999 and 2004, and had lower quality habitat than the Strawberry Creek site. The study attributed the lack of improvement in aquatic habitat in the restored reach to the continued urban runoff and high velocity flows in the channel.

Studies of stream restoration in Australia (Walsh et. al. 2005) concluded:

> "Restoration of streams degraded by urbanization has usually been attempted by enhancement of instream habitat or riparian zones. Such restoration approaches are unlikely to substantially improve instream ecological conditions because they do not match the scale of the degrading process. Recent studies of urban impacts on streams in Melbourne, Australia, on water chemistry, algal biomass and assemblage composition of diatoms and invertebrates, suggested that the primary degrading process to streams in many urban areas is effective imperviousness (EI), the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater drainage pipes. The direct connection of impervious surfaces to streams means that even small rainfall events can produce sufficient surface runoff to cause frequent disturbance through regular delivery of water and pollutants; where impervious surfaces are not directly connected to streams, small rainfall events are intercepted and infiltrated…Alternative drainage methods, which maintain a near-natural frequency of surface runoff from the catchment were identified as the best approach to stream restoration in urban catchments…"

Studies of urban stream restoration in the Seattle area (Booth 2005) found:

> "Undoing harm by catchment urbanization on stream channels and their resident biota is challenging because of the range of stressors in this environment. One primary way in which urbanization degrades biological conditions is by changing flow patterns; thus, re-establishing natural flow regimes in urban streams demands particular attention if

> restoration is to have a chance for success. Enhancement efforts in urban streams typically are limited to rehabilitating channel morphology and riparian habitat, but such physical improvements alone do not address all factors affecting biotic health. Some habitat-forming processes such as the delivery of woody debris or sediment may be amenable to partial restoration, even in highly disturbed streams, and they constitute obvious high-priority actions. There is no evidence to suggest, however, that improving non-hydrologic factors can fully mitigate hydrologic consequences of urban development."

This plan focuses on changing the watershed processes which have the largest effects on streams and are the result of the high level of urbanization in the Sausal Creek watershed.

**Stream Reach Description**

Palo Seco and Sausal Creek are largely open, unculverted channels with perennial water flow. Shephard Creek is largely culverted. Cobbledick Creek is mostly an open channel but is very steep and mostly bordered with houses. Figure 55 depicts those reaches of creek in the Sausal Creek watershed which have an open channel and moderate slope.

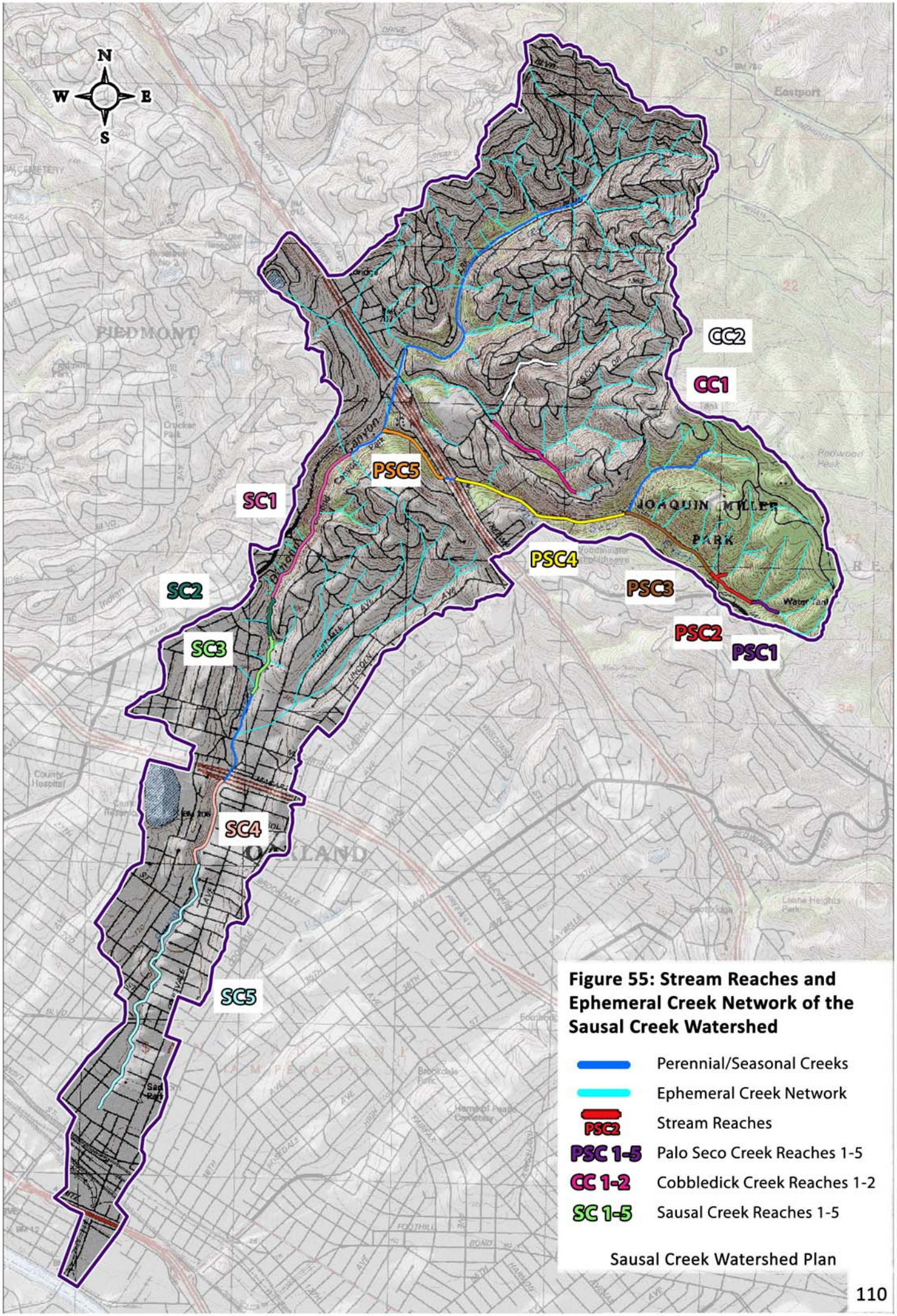


**Figure 55: Stream Reaches and Ephemeral Creek Network of the Sausal Creek Watershed**

**Cobbledick Creek**

Most of Cobbledick Creek and its tributaries have open channels with seasonal flow. With the exception of two areas, however, this sub-basin is private residential land. In addition, in many areas of this sub-basin homes border the creek or have foundations or deck piers next to or in the creek (Figure 56). In these private creeks, control and eradication of invasive plants such as broom, Himalayan blackberry, cape ivy, Algerian ivy, and blue periwinkle will reduce the spread of these problem plants into downstream habitat areas. Erosion control and bank stabilization may also be needed. Native shrubs and trees such as toyon, manzanita, oaks, and madrone occur as natural vegetation.

*Cobbledick Creek 1 (CC1)*
This reach along Larry Lane is bordered with houses. The channel is semi-confined between hillslopes and much of the former floodplain is filled with houses. The channel bed is fine sediment and gravel. Mixed conifers line the creek and Eucalyptus, Algerian ivy, and broom are common. A sediment/detention basin blocks the channel near the Ascot Road crossing (Figure 57). The dam creating this basin was overtopped and eroded portions of the dam and Larry Lane road fill. Downstream from this basin the creek channel consists of fill with a culvert and has a house on the fill. There is erosion at the outlet (C-2-01; Figure 79) Downstream of the Ascot Rd. crossing the creek channel is filled and the creek goes through a culvert under Joaquin Miller Elementary/Montara Middle schools.

*Cobbledick Creek 2 (CC2)*
This reach is Cottonwood Creek, which flows through Beaconsfield Canyon. The channel is semi-confined between hillslopes and the channel bed is mostly fine sediment with some gravel. Black cottonwoods line the creek and broom and Himalayan blackberry make up the understory. An old culvert in the creek bed has been filled by the creek and the creek has carved a new channel around the culvert. Neighborhood residents have removed numerous invasive plants and, with FOSC, have installed native plants. The downstream end of this reach has a rapidly eroding inlet where the creek drops into a storm drain.

*Cobbledick Creek 3 (CC3)*
This reach is made up of ephemeral creeks in an undeveloped but private 15-acre area. There are willows, elk clover, and dogwoods growing along one of the creeks.

*Cobbledick Creek 4 (CC4)*
This reach extends from the outlet of the culvert underneath the Joaquin Miller Elementary/Montara Middle schools to the confluence with Shephard Creek. The channel is lined by live oaks and Eucalyptus and has erosion in many locations with undercut trees.

**Figure 56: Houses line the tributary channels in the Cobbledick Creek sub-basin. House and deck foundations are located within the area of the channel that is subject to bank erosion and failure.**

**Figure 57: Top: Tributary to Cobbledick Creek along Larry Lane (CC1) flows into a sediment basin. Bottom: Lack of maintenance of basin shows in this buried and largely nonfunctional standpipe.**

**Palo Seco Creek**

The Palo Seco Creek sub-basin is the least developed area of the Sausal Creek watershed. Five different reaches of the creek were delineated based on physical features.

*Palo Seco Creek 1 (PSC1)*
This reach is the upper meadow area of Joaquin Miller Park. This channel is unconfined and low in slope with a low density of riparian vegetation. Dominant trees are coast redwoods and willows with an understory of Himalayan blackberry. The channel appears to have been relocated to one edge of the meadow area (Figure 58). Palo Seco Creek channel filled with fine sediment in 2006. Currently the meadow serves as a floodplain. A drop inlet into the culverted section of creek (PSC2) occurs at the downstream end of this reach.

*Palo Seco Creek 2 (PSC2)*
This reach of creek was culverted to create a meadow. This reach was likely lined by redwoods prior to clearcutting in the 1860s and park development projects in the 1930s and 1940s. This reach includes the confluence with Fern Ravine Creek, which is culverted from a picnic area to its confluence with culverted Palo Seco Creek. The drop inlet for Fern Ravine Creek frequently fills with bedload, and water creates an overland course to meet the open channel of Palo Seco Creek (Figures 59 and 60).

*Palo Seco Creek 3 (PSC3)*
This reach of Palo Seco Creek stretches from the culvert outlets at the downstream end of the meadow to the confluence with Cinderella Creek (Figures 61 and 62). The slope of the creek bed increases over this reach and the channel is semi-confined by adjacent hillslopes. The channel bed is fine sediment with some gravel and the channel contains several knickpoints (Erosion Sites 3 and 4, Figure 90). The creek channel is incised below these knickpoints and several trees have been undercut on the banks. Vegetation density along the creek is moderate with coast redwoods, California bay laurel, and live oak and an understory of Himalayan blackberry. The Lacan BMI station is located in this reach which showed good aquatic habitat conditions.

*Palo Seco Creek 4 (PSC4)*
This steep rockbound channel is lined by redwood and California bay laurel trees. Many trees, however, are covered with parasitic Algerian ivy and numerous invasive non-native holly trees are growing in the redwood forest (Figure 63). A SWAMP station and FOSC bacteria sampling station are located at the downstream end of this reach.

*Palo Seco Creek 5 (PSC5)*
This reach stretches from the Highway 13 culvert outlet to the confluence with Sausal Creek. The channel is confined with hillslopes, and the channel bed is mostly fine sediment with gravel. The density of vegetation is high, dominated by coast redwoods with Algerian ivy, Himalayan blackberry, and American elm. A small cement footbridge crosses the channel and there are several causes of erosion on the slopes including trail erosion and storm drain outlets. FOSC water quality/BMI sampling occurs in this reach. Rainbow trout have been observed in this reach.

**Figure 58: Palo Seco Creek (PSC1) overflows onto a grassed floodplain and trail during larger flow events.**

**Figure 59: Top: Fern Ravine Creek, part of PSC2, in Joaquin Miller Park after the Jan 1, 2006 flood where the creek flowed out of its concrete channel and overland. Bottom: Filled-in culvert drop inlet.**

**Figure 60: Top: Fern Ravine Creek overland flow crosses the trail and spreads out into the middle and lower meadow area in PSC2. Bottom: Fern Ravine Creek joins Palo Seco Creek where it comes out of the culvert into a natural channel just downstream of the meadow.**

**Figure 61: Top: Palo Seco Creek at beginning of reach PSC3.**
**Bottom: Knickpoint in Palo Seco Creek where tree roots are serving as a grade control structure.**

**Figure 62: Top: Palo Seco Creek (PSC3) in the Jan. 1, 2006 flood event. Bottom: Small trail bridge with culverts serves as a grade control structure for Palo Seco Creek. Small trash rack visible upstream is also a grade control structure. Note sediment runoff from adjacent trails.**

**Figure 63: Palo Seco Creek (PSC4) during the Jan. 1, 2006 flood in its rock canyon and at its terminus at Joaquin Miller Court. Note Algerian ivy covering trees and slopes.**

Since 2003, FOSC has been working to re-create the understory vegetation under the redwoods along the switchback trail. An erosion control project consisting of a swale was installed to divert flow from a storm drain outlet.

**Shephard Creek**

Shephard Creek has very little riparian or aquatic habitat and few feasible opportunities for native revegetation exist on the main creek. Controlling invasive non-native plants (Eucalyptus, broom, Acacia, pampas grass) in tributaries and on hillslopes will benefit downstream creek areas (Figures 45-47). This sub-basin has a large number of storm drains and most of the main creek channel has been culverted. Shepherd Canyon Park was once an open creek channel. A large amount of fill and a pipe was placed in the creek to create a flat area for the park. Escher Creek is an ephemeral tributary to Shephard Creek which was relocated to flow along the edges of Shepherd Canyon Park, and has been cleared of invasive plants and planted with native plants by the Shepherd Canyon Homeowners Association. Downstream of this park, the creek has an open channel up to Highway 13 and the confluence with Cobbledick Creek.

**Sausal Creek**

Sausal Creek extends from the confluence of Palo Seco Creek and Shephard Creek to San Francisco Bay.

*Sausal Creek 1 (SC1)*
SC1 extends from the confluence of Shephard and Palo Seco Creeks to the restoration project. The creek is confined in a relatively deep canyon lined by California bay laurels and white alders covered by parasitic Algerian ivy. Grade control structures, culverts, and cement lining cover most of the creek channel (Figures 64-66). Cobble dominated substrate has built up behind the stair steps of grade control structures. A major sewer line borders the creek and runs down the channel. There are numerous erosion sites from storm drains which outlet on the slopes of the canyon. Water quality, aquatic insect, and bacteria monitoring stations are located in this reach. Rainbow trout have been observed in this reach.

*Sausal Creek 2 (SC2)*
This is the 600 foot reach where a restoration project was completed in 2001. It begins one-quarter mile upstream from the El Centro culvert. Several grade control structures were removed and the sanitary sewer pipe in the middle of the creek was replaced. A series of rock weirs were installed along with some riprap at the base of the banks. Overstory California bay laurel trees were cut and willows and other native species were planted along the channel banks. The riparian corridor is narrow and no floodplain restoration was included in the project (Figures 67-69). FOSC and SWAMP water quality stations are located in this reach. Rainbow trout have been observed in this reach.

In 2001 the City of Oakland and FOSC completed a creek restoration project on Sausal Creek one-quarter mile upstream of the El Centro crossing. The project included removal of the old grade control structures (check dams), replacement of the sanitary sewer pipe in the creek, and cutting of the California bay laurel overstory. The creek channel was graded with rock weirs installed across the channel. Thousands of native plants were also installed both along the creek and on adjacent slopes.

**Figure 64: These photos are examples of the drop structures in Sausal Creek (SC1) in Dimond Canyon.**

**Figure 65: Grade control structures in SC1 during the Jan.1 2006 flood.**

**Figure 66: Top: Erosion of bay trees along Sausal Creek (SC1) in Dimond Canyon. Bottom: Roots of white alder (SC3) protect banks during floods.**

**Figure 67: Top: California bay laurel trees were trimmed to open up the creek corridor to more light and allow for willow growth as part of the restoration project in SC2. Bottom: The project in 2003 shows the narrow riparian corridor and wide trail.**

**Figure 68: Top: Vortex weir in a small flood in 2003. The weirs were installed as part of the restoration project. Bottom: Invasive non-native plants invade the new willows in the restoration project (SC2).**

**Figure 69: Top: Upstream end of El Centro culvert in SC3.
Bottom: Downstream pool at outlet of El Centro culvert.**

Monitoring of the project in 2003 by FOSC compared percent cover and species diversity in the restoration reach and an upland area and another section of the creek. The results are shown in Table 37.

**Table 37: FOSC Comparison of Percent Cover and Species Diversity in Sausal Creek Project**

| Vegetation Type | Riparian | Upland | Control |
|---|---|---|---|
| Bare Ground | 44% | 43% | 9% |
| Native | 41% | 24% | 11% |
| Non-native | 14% | 33% | 80% |
| Unknown | 1% | .2% | |

*Sausal Creek 3 (SC3)*
This reach stretches from just upstream of the El Centro culvert through Dimond Park. The Sausal Creek channel would be unconfined with a floodplain if it were not channelized and culverted. The area downstream of the El Centro culvert is lined by white alders. The white alders are relatively old and do not appear to be regenerating. California bay laurel, live oak, California buckeye, and coast redwood also occur. The creek has been channelized and culverted through much of the Dimond Park (Figures 70-72). Along the downstream section, the right bank is residential with various types of revetments to protect against erosion. The left bank is parkland with native and ornamental trees. The channel is entrenched and eroding in this downstream area. The Whittle Road tributary flows into this reach. The City of Oakland is planning to change this reach by daylighting part of the creek out of the culvert west of Wellington Street, protecting the private property downstream on the right bank and installing native vegetation on the left bank. Water quality, aquatic insect, and bacteria monitoring stations are in this reach. Rainbow trout have been observed in this reach.

*Sausal Creek 4 (SC4)*
This reach extends from the Highway 580 culvert to 27$^{th}$ St. The creek channel would be naturally unconfined but due to urban development is highly entrenched and culverted. The stream bed is made of hard pan clay in many locations. The creek borders an intensively urbanized area and has been affected by the McKillop slide (Figures 73-74). This slide filled in Sausal Creek in 2006 and undercut several houses. A similar incident occurred in the 1970s and a culvert was installed to direct the creek away from the slide through William D. Wood Park. At the downstream end of the culvert a pump operated by Alameda County Flood Control lifts water up to the creek channel downstream. Water quality, aquatic insect, and bacteria monitoring stations are in this reach. Rainbow trout have been observed in this reach.

*Sausal Creek 5 (SC5)*
This reach extends from 27$^{th}$ St. to the culvert at the most downstream end of Sausal Creek. The creek channel would be naturally unconfined but due to urban development is highly entrenched and culverted. Houses line the creek (Figures 75-76). The streambed holds little gravel and has eroded down to clay hardpan. Banks are vertical and tall in many locations. Riparian vegetation is limited and primarily consists of non-native species, and shade canopy is sparse. One SWAMP station is located in this reach.

**Figure 70: Left: White alder along Sausal Creek (SC3) with dead vines of Algerian ivy, a parasitic species. Right: Erosion of alders from the creek bank in the Jan 1, 2006 flood.**

**Figure 71: Top: Sausal Creek in Dimond Park (SC3). Bottom: Whittle Road tributary enters from its culvert into Sausal Creek.**

**Figure 72: Top: Sausal Creek in downstream area of Dimond Park where private residences border the creek (SC3). Failed gabions (rock-filled baskets) remain from prior bank stabilization project. Bottom: Large culvert carries Sausal Creek under meadow.**

**Figure 73: Top: Sausal Creek downstream of Hwy 580. The channel is entrenched and has little gravel in its bed or native trees on its banks. Bottom: Algerian ivy covers trees along many of the small ephemeral streams in the watershed and is a source of re-infestation to downstream restoration areas.**

**Figure 74: Sausal Creek at Barry Place and E. 27th St (SC4).**

**Figure 75: Top: Sausal Creek at Logan Road. Bottom: Sausal Creek at E. 22nd St (SC5).**

**Figure 76: Top: Sausal Creek at Foothill Blvd in SC5. Bottom: Grassy area on top of culverted section of Sausal Creek.**

*Aquatic Insects*

An indicator of both the health of the aquatic ecosystem and water quality is the diversity and abundance of aquatic insects in a creek. Typically aquatic insects are monitored in creeks with perennial flows. Some families of aquatic insects are more tolerant of pollution than others. The term EPT refers to *Ephemeroptera*, *Plecoptera*, and *Trichoptera*, three orders of aquatic insects. Within the EPT are particular taxa that are highly sensitive to pollutants. If the number of taxa of EPT sensitive to pollution is high, then the pollutant levels may be low. If pollution-sensitive taxa are missing, then it is likely that water pollution, poor habitat conditions, or excessive channel scour is occurring. FOSC has carried out monitoring of aquatic insects in several locations, from 1998 to 2006 (Figure 54). Unfortunately, no QA/QC protocol for the sampling or insect identification methods or other information is available on this monitoring program. No station-specific features such as water temperatures, channel features, or riparian canopy levels were recorded when insect sampling was done. These deficiencies in the data sets limit their usefulness.

In 1999 a benthic macroinvertebrate (BMI) study in Sausal Creek was completed (Lacan et.al. 1999) Three stations were sampled: Palo Seco Creek upstream of the creek canyon, Sausal Creek in Dimond Park, and Sausal Creek at Hickory Court. Pebble counts, streamflow measurements, channel cross-sections, and evaluation of riparian canopy were done at each sampling site (Figure 54). Basic water quality parameters—pH, water temperature, dissolved oxygen, and specific conductivity—were also measured during the sampling as instantaneous measurements.

This study found a significant difference between the Palo Seco Creek station and the two stations on Sausal Creek in terms of taxa richness, percent of dominant taxon, and indices of functional feeding groups (FFGs). There are five functional feeding groups including scrapers, shredders, predators, filtering collectors, and gathering collectors. Table 38 lists the results of the sampling. These results show that Palo Seco Creek station has a healthy aquatic habitat. Lacan attributes the results to the undeveloped watershed and intact shade canopy of Palo Seco Creek. By comparison, the two Sausal Creek stations have low quality habitat. The authors state that the Sausal stations are highly affected by urbanization. Riparian forest canopy is inadequate to shade the creek at the Sausal Creek stations and the gravel substrate is frequently scoured, turning rocks and moving smaller gravel. The study cites channel incision, which increases flow velocities, steepens stream banks and often erodes riparian trees, along with the higher velocities of urban runoff, as major causes of the lack of healthy aquatic habitat at the Sausal Creek stations.

**Table 38: Benthic Macroinvertebrate (BMI) Study in 1999**

| Site | Metric | | | | |
|---|---|---|---|---|---|
| | **Taxa Richness** | **Shannon Diversity[1]** | **% Dominant Taxon** | **Hilsenhoff Biotic Index (HBI)[2]** | **Jaccard Coefficient[3]** |
| **Palo Seco Creek** | 14 | 7.66 | 31.7 | 3.49 | 1 (ref.) |
| **Dimond Park – Sausal Creek** | 7 | 3.38 | 46.4 | 2.52 | 0.3125 |
| **Hickory Court – Sausal Creek** | 8 | 2.61 | 72.1 | 3.18 | 0.2222 |

[1] Shannon Diversity: a diversity index that treats species as symbols and relative population sizes as probabilities

[2] Hilsenhoff Biotic Index (HBI): an index to assess low dissolved oxygen caused by organic loading in streams

[3] Jaccard Coefficient: A measure of the similarity between two individuals in a population

Source: Lacan, Eisenstein, and Soules. 1999. Hydrological and Ecological Assessment of Sausal Creek.

The San Francisco Bay Regional Water Quality Control Board's Surface Water Ambient Monitoring Program (SWAMP) completed BMI sampling at three stations in April 2005. These included SAU030 (Sausal Creek at E. 22nd Street), SAU080 (Sausal Creek in Dimond Park), and SAU130 (Palo Seco Creek) (Figure 55). The SWAMP program used the California Department of Fish and Game aquatic biology lab to complete the sampling and insect identification. The methodology used was an interim protocol based on the California Stream Bioassessment Procedure. Samples were collected and analyzed by scientific professionals.

The BMI results are listed in Table 39. For stations SAU030 and SAU080, the BMI assemblages were in poor condition. Taxonomic richness was low and sensitive EPT taxa were largely absent. These conditions were found for the majority of urban creeks in Oakland and Berkeley and are considered indicators of poor water quality and the high scour conditions in urban creeks. The sampling site on Palo Seco Creek (SAU130) largely drains parkland rather than urban land and demonstrated far better conditions. Taxonomic richness and percent sensitive EPT were much higher, with many pollution-intolerant taxa present. Tables 40-46 list the features of each sampling site.

The FOSC aquatic insect sampling (Table 47) lacks the level of detail completed by the SWAMP program and cannot be compared. This program could revise its methods to sample twice a year, use the SWAMP sampling protocol and send its samples to a professional lab in order to produce high quality results. In addition, as part of taking samples, an analysis of the sampled reach should be done to evaluate if site-specific conditions, water pollution, or some other feature is influencing the benthic macroinvertebrates.

*Summary*

BMI results from the 2005 SWAMP study and the 1999 Lacan study found similar results: low taxonomic richness and a near absence of sensitive EPT taxa at all the Sausal Creek stations. Stations on Palo Seco Creek showed significantly better conditions with higher taxonomic richness and a moderate percentage of sensitive EPT taxa. These results demonstrate the poor water quality conditions in the urban areas of Sausal Creek and the relatively good conditions on Palo Seco Creek, the only non-urban tributary.

The results of the BMI sampling clearly demonstrate the differences between creeks in the Sausal Creek watershed based on the level of impervious surfaces. Palo Seco Creek with a largely non-urbanized drainage basin has aquatic insect taxa richness indicative of very high quality habitat. Aquatic insect sampling in Sausal Creek in Dimond Canyon and downstream reaches demonstrates poor quality habitat conditions. These are likely the result of channel scouring flow velocities, loss of riparian habitat, urban stormwater pollutants, and high bacterial (*E. coli*) levels from leaking sanitary sewers as discussed in the water quality section.

**Table 39: SWAMP BMI Sampling Results for Sausal Creek**

| Metric | SAU030 (Sausal Creek at E. 22nd Street) | SAU080 (Sausal Creek in Dimond Park) | SAU130 (Palo Seco Creek) | Metric Definitions |
|---|---|---|---|---|
| *Coleoptera* Taxa | 3 | 1 | 5 | Number of *Coleoptera* (beetle) taxa |
| *Diptera* Taxa | 2 | 3 | 6 | Number of *Diptera* (true fly) taxa |
| *Ephemeroptera* Taxa | 1 | 1 | 3 | Number of *Ephemeroptera* (mayfly) taxa |
| *Hemiptera* Taxa | 0 | 0 | 0 | Number of *Hemiptera* (true bug) taxa |
| *Lepidoptera* Taxa | 0 | 0 | 0 | Number of *Lepidoptera* (moth) taxa |
| *Megaloptera* Taxa | 0 | 0 | 0 | Number of *Megaloptera* (heligrammite) taxa |
| *Odonata* Taxa | 1 | 0 | 0 | Number of *Odonata* (dragonfly and damselfly) taxa |
| *Plecoptera* Taxa | 0 | 1 | 3 | Number of *Plecoptera* (stonefly) taxa |
| *Trichoptera* Taxa | 0 | 0 | 8 | Number of *Trichoptera* (caddisfly) taxa |
| Non-Insect Taxa | 4 | 4 | 6 | Number of non-insect taxa |
| Taxa Richness | 11 | 10 | 31 | Total number of invertebrate taxa |
| EPT Taxa | 1 | 2 | 14 | Number of *Ephemeroptera*, *Plecoptera*, and *Trichoptera* taxa |
| | | | | |
| Abundance (#/sample) | 2545 | 10752 | 672 | Estimated number of organisms collected in entire sample |
| | | | | |
| % EPT | 45 | 65 | 60 | Percent composition of *Ephemeroptera, Plecoptera,* and *Trichoptera* |
| % Sensitive EPT | 0 | 1 | 35 | Percent composition of EPT with tolerance values <3 |
| % *Chironomidae* | 21 | 16 | 6 | Percent composition of *Chironomidae* (midges) |
| % *Coleoptera* | 1 | 0 | 26 | Percent composition of *Coleoptera* (beetles) |
| % *Oligochaeta* | 32 | 17 | 3 | Percent composition of *Oligochaeta* (worms) |
| % Non-Insect | 33 | 18 | 5 | Percent composition of non-insect organisms |
| % *Baetis* | 45 | 64 | 24 | Percent composition of *Baetis* |
| % *Simulium* | 0 | 1 | 0 | Percent composition of *Simulium* (black flies) |
| % COBS | 99 | 97 | 33 | Percent composition of *Chironomidae, Oligochaeta, Baetis,* and *Simulium* |
| | | | | |
| % Intolerant | 0 | 1 | 36 | Percent of organisms with tolerance values <3 |
| % Tolerant | 1 | 0 | 1 | Percent of organisms with tolerance values >7 |
| Tolerance Value | 5.23 | 5.13 | 3.45 | Average tolerance value of all organisms |
| | | | | |
| % Predator | 1 | 1 | 40 | Percent of organisms that feed on other organisms |
| % Collector-Filterer | 0 | 1 | 3 | Percent of organisms that filter fine particulate organic matter |
| % Collector-Gatherer | 99 | 97 | 36 | Percent of organisms that gather fine particulate organic matter |
| % Scraper | 0 | 0 | 27 | Percent of organisms that graze on periphyton |
| % Shredder | 0 | 1 | 24 | Percent of organisms that shred coarse particulate organic matter |
| % Other | 0 | 0 | 0 | Percent of organisms with other types of feeding |

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 40: SWAMP BMI and PHAB Sampling Substrate Characteristics for Sausal Creek**

| Station | Site Name | Date Sampled | BMI | PHAB | BMI plots substrate type distribution (Percent, average of 8 estimated values) | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Avg. % Fines & Sand | Avg. % Gravel | Avg. % Cobble | Avg. % Boulder | Avg. % Bedrock |
| SAU030 | Sausal Creek at E. 22nd St. | 4/14/2005 | X | X | 25 | 46 | 28 | 2 | 0 |
| SAU080 | Sausal Creek at Dimond Park | 4/14/2005 | X | X | 19 | 48 | 33 | 1 | 0 |
| SAU130 | Palo Seco | 4/14/2005 | X | X | 24 | 60 | 16 | 0 | 0 |

**Table 41: SWAMP BMI Sampling Physical Habitat Characteristics for Sausal Creek**

| Station | Date | Avg. Slope (%) | Avg. Width of Wetted Channel (m) | SD of Avg. Width | Avg. Water Depth (cm) | SD of Avg. Depth | Flow Discharge at Sampling Time ($m^3$/sec) | Flow Discharge at Sampling Time (cfs) | Channel Conditions – Estimated Scores (out of 20) | | | Flow Habitat Units Distribution (% of total reach length) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Epifaunal Substrate/ Available Cover | Sediment Deposition | Channel Alterations | Pools | Glides | Runs | Riffles | Cascades/ Falls | Dry Channel |
| SAU030 | 4/14/2005 | 1.5 | 4.3 | 0.8 | 18.9 | 10.5 | 0.0068 | 2.4 | 5 | 6 | 2 | 20 | 47 | 0 | 31 | 2 | 0 |
| SAU080 | 4/14/2005 | 3.0 | 3.3 | 0.6 | 12.5 | 8.3 | 0.049 | 1.7 | 16 | 14 | 17 | 13 | 29 | 0 | 55 | 6 | 0 |
| SAU130 | 4/14/2005 | 7.1 | 1.3 | 0.2 | 8.0 | 6.1 | 0.014 | 0.5 | 14 | 7 | 15 | 5 | 11 | 0 | 79 | 5 | 0 |

**Table 42: SWAMP BMI Sampling Physical Habitat Characteristics**

| Station | Date | Reach-Wide Substrate Composition (percent, derived from size-class determinations at each Transect and Intertransect Point) | | | | | | | | | | | | | Percent Substrate Smaller than Sand (<2mm) | Percent Substrate Fine Gravel or Smaller (<16mm) | Percent Substrate Larger than Fine Gravel (>16mm) | Percent Substrate as Bedrock |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % Bedrock – smooth | % Bedrock – rough | % Concrete/ asphalt | % Boulders – large (1000-4000mm) | % Boulders – small (250-1000mm) | % Cobble (64-250mm) | % Gravel – coarse (16-64mm) | % Gravel – fine (2-16mm) | % Sand (0.06-2mm) | % Fines (silts/ clay/ muck, <0.06 mm) | % Hardpan | % Wood (any size) | % Other Substrate | | | | |
| SAU030 | 4/14/2005 | 0 | 0 | 39 | 0 | 3 | 5 | 17 | 21 | 12 | 0 | 0 | 3 | 0 | 12 | 33 | 64 | 0 |
| SAU080 | 4/14/2005 | 0 | 0 | 0 | 3 | 27 | 26 | 13 | 13 | 6 | 1 | 3 | 9 | 0 | 7 | 20 | 69 | 0 |
| SAU130 | 4/14/2005 | 0 | 0 | 6 | 3 | 7 | 19 | 24 | 24 | 11 | 3 | 0 | 3 | 0 | 14 | 39 | 59 | 0 |

Tables from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 43: SWAMP BMI Sampling Physical Habitat Characteristics for Sausal Creek (continued)**

| Station | Date | Geometric Mean of Particulate Substrate Size[1] (mm) | Geometric Mean Substrate Diameter[2] (Dgm) | Estimated Geometric Mean Substrate Diameter[3] (mm) | Cobble Embeddedness (%) | Habitat & Shelter Value – Percent Cover of Habitat Elements (average of numeric-range-categories medians from 11 Habitat Plots) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (boulders to fines) | Per revised calc | Anti-log of LSUB_DMM | | Filamentous Algae Cover (%) | Macrophytes Cover (%) | Large Woody Debris Cover (%) | Small Woody Debris/ Bruch Cover (%) | Live Tree Roots Cover (%) | Over-hanging Vegetation Cover (%) | Undercut Banks Cover (%) | Boulders Cover (%) | Artificial Structures Cover (%) |
| SAU030 | 4/14/2005 | 18 | 11 | 10 | 25 | 1 | 0 | 0 | 0 | 1 | 4 | 1 | 3 | 59 |
| SAU080 | 4/14/2005 | 95 | 81 | 182 | 49 | 4 | 0 | 0 | 2 | 4 | 12 | 5 | 14 | 3 |
| SAU130 | 4/14/2005 | 26 | 19 | 23 | 55 | 0 | 0 | 1 | 5 | 3 | 10 | 2 | 15 | 1 |

[1] This represents the dominant size of bed material at the sample site

[2] Dgm=Geometric mean substrate diameter was calculated for all particulate substrate fractions plus bedrock and hardpan, per Kaufman 2008 (SWAMP 2008)

[3] Estimated geometric mean was calculated for all particulate substrate fractions plus bedrock and hardpan

**Table 44: SWAMP BMI Sampling Physical Habitat Characteristics for Sausal Creek (continued)**

| Station | Date | Shelter Types Present (count) | Natural Shelter Cover (sum LW, brush, overhang, boulders, undercut) (%) | Big Shelters Cover (sum LW, boulder, artificial) (%) |
|---|---|---|---|---|
| SAU030 | 4/14/2005 | 7 | 9 | 63 |
| SAU080 | 4/14/2005 | 7 | 33 | 17 |
| SAU130 | 4/14/2005 | 7 | 33 | 18 |

Table from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 45: SWAMP BMI Sampling Physical Habitat Characteristics for Sausal Creek**

| Station | Date | Average Shade and Canopy Cover (%& | Bank Vegetation Percent Cover on left bank and right bank, by Cover Type (Average of numeric-range-categories medians from 11 Riparian Plots) | | | | | | | Riparian Canopy Presence (proportion of reach) XPCAN |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Big Tree Canopy (%) | Small Tree Canopy (%) | Small Tree Understory (%) | Non-Wood Understory (%) | Woody Shrubs Ground Cover (%) | Non-Woody Ground Cover (%) | Barren Ground Cover (%) | |
| SAU030 | 4/14/2005 | 95 | 31 | 8 | 18 | 5 | 21 | 26 | 49 | 0.68 |
| SAU080 | 4/14/2005 | 91 | 34 | 13 | 24 | 7 | 35 | 35 | 24 | 0.91 |
| SAU130 | 4/14/2005 | 97 | 57 | 12 | 32 | 1 | 72 | 6 | 18 | 0.73 |

**Table 46: SWAMP BMI Sampling Physical Habitat Characteristics for Sausal Creek**

| Station | Date | Human Disturbance Index by Activity (proximity-weighted index) | | | | | | | | | | | Combined Human Disturbance Index (all types)[1] W1_HALL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Buildings | Landfill/ Trash | Logging Operations | Mining Activity | Park/ Lawn | Pasture/ Range/ Hayfield | Pavement/ Cleared Lot | Pipes (Inlets/ Outlets) | Roads/ Railroads | Row Crops | Wall/ Dyke/ Riprap/ Revetment/ Dam | |
| SAU030 | 4/14/2005 | 0.50 | 0.64 | 0.00 | 0.00 | 0.05 | 0.00 | 0.27 | 0.27 | 0.03 | 0.00 | 1.02 | 2.78 |
| SAU080 | 4/14/2005 | 0.00 | 0.61 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.52 | 1.14 |
| SAU130 | 4/14/2005 | 0.03 | 0.11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 0.23 |

[1] Combined human disturbance index ranges from 0 (i.e., no human influence) in open space sites to 3.77 in highly urbanized sites

Tables from Water Quality Monitoring and Bioassessment in Selected San Francisco Bay Region Watersheds in 2004-2006, San Francisco Bay Regional Water Quality Control Board, 2008.

**Table 47: Friends of Sausal Creek Aquatic Insect Volunteer Monitoring Results 1998-2006**

| Date | Palo Seco Creek | | Sausal Creek | |
|---|---|---|---|---|
| | Total Number of Organisms | Total EPT | Total Number of Organisms | Total EPT |
| 7/12/98 | | | 2722 | 152 |
| 8/16/98 | | | 430 | 198 |
| 9/20/98 | 444 | 398 | | |
| 11/15/98 | | | 276 | 202 |
| 2/27/99 | 93 | 89 | | |
| 3/27/99 | | | 65 | 43 |
| 4/25/99 | 510 | 485 | | |
| 5/23/99 | | | 505 | 182 |
| 6/20/99 | 408 | 319 | | |
| 8/15/99 | | | 113 | 80 |
| 10/24/99 | | | 599 | 219 |
| 11/21/99 | 665 | 608 | | |
| 2/20/00 | | | 24 | 16 |
| 3/26/00 | 166 | 145 | | |
| 4/30/00 | | | 804 | 165 |
| 5/21/00 | 378 | 298 | | |
| 7/16/00 | | | 344 | 143 |
| 8/20/00 | 268 | 230 | | |
| 9/17/00 | | | 235 | 97 |
| 11/19/00 | 242 | 225 | | |
| 1/21/01 | | | 240 | 93 |
| 2/25/01 | 104 | 33 | | |
| 3/18/01 | | | 64 | 28 |
| 4/22/01 | | | 280 | 103 |
| 5/20/01 | 299 | 233 | | |
| 4/21/02 | | | 1004 | 104 |
| 6/16/02 | 126 | 94 | | |
| 7/21/02 | | | 293 | 116 |
| 10/20/02 | 93 | 74 | | |
| 11/17/02 | | | 208 | 170 |
| 1/19/03 | | | 88 | 81 |
| 2/23/03 | 90 | 69 | | |
| 4/20/03 | | | 388 | 284 |
| 5/25/03 | 93 | 64 | | |
| 6/15/03 | | | 335 | 200 |
| 7/20/03 | 227 | 187 | | |
| 1/18/04 | | | 67 | 63 |
| 2/15/04 | 70 | 57 | | |
| 3/21/04 | | | 266 | 257 |
| 4/18/04 | 94 | 78 | | |
| 1/23/05 | | | 262 | 230 |
| 5/22/05 | 161 | 119 | | |
| 7/24/05 | | | 259 | 97 |
| 11/20/05 | | | 170 | 45 |
| 2/19/06 | 280 | 80 | | |
| 3/19/06 | | | 110 | 107 |
| 4/9/06 | 59 | 48 | | |
| 7/16/06 | | | 321 | 235 |

Fish

Remarkably, rainbow trout (*Oncorhynchus mykiss*), the non-anadromous form of steelhead trout, have been seen in Sausal Creek and lower Palo Seco and Shephard Creeks (FOSC 2009). The majority of recorded observations are of adults. Three Sausal Creek sites were sampled for fish in July 1981. No fish were collected (Leidy 1984). In 1998 an electro-fishing survey of Cobbledick and Shephard Creeks along Scout Road and of Sausal Creek from the Montclair Golf Course to Canon Avenue was done (Hagan and Demgen 1998). No fish were found. The 1998 report concluded that the culvert under Highway 13 was a passage barrier. A survey of Palo Seco Creek during this study found four trout and concluded that the culvert under the Montclair Golf Course is a major migration barrier (Hagan and Demgen 1998). Another electrofishing survey including Sausal Creek in Dimond Canyon up to its confluence with Palo Seco Creek and in Shephard Creek along Scout Road found no fish (Lowe 2000). In 2001, the California Department of Fish and Game conducted a partial survey of Sausal Creek but ended the survey due to "low potential to restore salmonids" (Cleugh 2002).

Adult fish have been seen in a number of locations (FOSC 2009) by a variety of observers, including Palo Seco Creek and Sausal Creek from the Leimert Bridge down to the Barry Place/Hickory Street area just upstream of the 27$^{th}$ Street crossing (FOSC 2009, CEMAR). In February 2008, 11 trout were found dead from paint thinner being washed into the storm drain and creek (FOSC 2000). Only one of these observations was of juvenile trout in Palo Seco Creek. Rainbow trout in Sausal Creek and its tributaries are at great risk from one pollution event or large scouring flood event. Additionally, high water refuge areas in Sausal Creek are probably provided by the few undercut banks, failing drop structures, and concrete aprons.

Birds

Bird monitoring throughout the watershed has been on-going since 1998 with many sites surveyed. This effort created inconsistent data in frequency of visits and numbers, but documents presence/absence of species. The survey work was unsustainable and a reduced effort was begun in 2002 with eight sites visited throughout the watershed, focusing on the El Centro restoration. Data are collected quarterly using a circular plot method in which all birds seen or heard around a point are recorded during ten minutes. The data average 25 records per site, but have only been roughly analyzed. It is stored in the database Ebird at the Cornell University under Mark Rauzon. Preliminary analysis shows neo-tropical birds started breeding in the restoration sites in 2005, after the complete restoration of 2001/2002 matured. Wilson's Warblers began using the El Centro Area in 2005 and the Meander Area of alders in 2007. In 2009, Black-headed Grosbeaks were recorded on survey in the Meander Site, after the trees matured to a 25-30 foot height. Warbling Vireos and Pacific-slope Flycatchers have been present throughout this period of restoration in the over story and are increasing. Song Sparrows and Spotted Towhees also benefit from the creation of native low bushy cover. Fish-eating birds such as Belted Kingfisher and Great Blue Heron are recorded in the El Centro restoration area now seeking to eat trout. Red-shouldered Hawks and Red-tailed Hawks are seen hunting here (FOSC 2009).

## EVALUATION OF WATERSHED EROSION SITES

A focused evaluation of several types of erosion sites was carried out in the Sausal Creek watershed. In general, the process of urbanization generates two phases of erosion. During the short-term development stage, grading and ground disturbance increases erosion. Once paved, the increased

Fish

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Adult fish have been seen in a number of locations (FOSC 2009) by a variety of observers, including Palo Seco Creek and Sausal Creek from the Leimert Bridge down to the Barry Place/Hickory Street area just upstream of the 27$^{th}$ Street crossing (FOSC 2009, CEMAR). In February 2008, 11 trout were found dead from paint thinner being washed into the storm drain and creek (FOSC 2000). Only one of these observations was of juvenile trout in Palo Seco Creek. Rainbow trout in Sausal Creek and its tributaries are at great risk from one pollution event or large scouring flood event. Additionally, high water refuge areas in Sausal Creek are probably provided by the few undercut banks, failing drop structures, and concrete aprons.

Birds

Bird monitoring throughout the watershed has been on-going since 1998 with many sites surveyed. This effort created inconsistent data in frequency of visits and numbers, but documents presence/absence of species. The survey work was unsustainable and a reduced effort was begun in 2002 with eight sites visited throughout the watershed, focusing on the El Centro restoration. Data are collected quarterly using a circular plot method in which all birds seen or heard around a point are recorded during ten minutes. The data average 25 records per site, but have only been roughly analyzed. It is stored in the database Ebird at the Cornell University under Mark Rauzon. Preliminary analysis shows neo-tropical birds started breeding in the restoration sites in 2005, after the complete restoration of 2001/2002 matured. Wilson's Warblers began using the El Centro Area in 2005 and the Meander Area of alders in 2007. In 2009, Black-headed Grosbeaks were recorded on survey in the Meander Site, after the trees matured to a 25-30 foot height. Warbling Vireos and Pacific-slope Flycatchers have been present throughout this period of restoration in the over story and are increasing. Song Sparrows and Spotted Towhees also benefit from the creation of native low bushy cover. Fish-eating birds such as Belted Kingfisher and Great Blue Heron are recorded in the El Centro restoration area now seeking to eat trout. Red-shouldered Hawks and Red-tailed Hawks are seen hunting here (FOSC 2009).

## EVALUATION OF WATERSHED EROSION SITES

A focused evaluation of several types of erosion sites was carried out in the Sausal Creek watershed. In general, the process of urbanization generates two phases of erosion. During the short-term development stage, grading and ground disturbance increases erosion. Once paved, the increased

stormwater volumes and large numbers of storm drain pipes produce long-term erosion of the unpaved areas of the watershed: natural slopes and unlined creek channels. Outlets of the stormdrain system were assessed for erosion. In urban areas with impervious surfaces even small amounts of rainfall produce runoff which is often conducted through pipes to outlet in natural channels. The concentrated flow at the storm drain outlets are a consistent source of potential erosion depending on the conditions at the pipe outlet.

As part of this plan, the City of Oakland GIS layer of storm drain pipes was used to assign letter/number identities to all of the storm drain outlets in the watershed (Figure 77). These outlets were then evaluated to create a list of priority outlets for field inspection. Priorities included outlets along major open channels, large pipe outlets, outlets in extremely steep areas, and outlets of storm drains which drain a large land area. The primary purpose of the field inspection was to identify major erosion problems associated with concentrated flow at outlets of storm drains. A number of features of each outlet was recorded—size and shape of pipe, pipe material, conditions of outlet, whether the culvert was plugged and, if so, by what percentage; whether the outlet was undercut and the number of feet of undercut, the material in the impact zone of outlet, the drop height from the outlet to the impact zone, the condition of the impact zone, the condition of the channel, whether a gully was present at the outlet and, if so, the length and depth of the gully; comments on the site, and a photograph.

The results were mapped with categories for the amount of erosion at the outlet: extreme, significant, or little to no erosion. The Sausal Creek watershed was separated into six sections in order to display the storm drain outlets and erosion along with natural creeks and roads (Figure 78). In total, there are 306 outlets included in Oakland's storm drain GIS layer (Figures 79-84). Not surprisingly, most of the erosion at the storm drain outlets occurs in the upper watershed and along Dimond Canyon. In these areas, most of the storm drains are set at a steep gradient or are set flat and drop storm water onto the slope or a creek bank. Erosion from concentrated flow sources is continuous, occurring with each runoff event until a repair project is done or until the erosion undercuts the pipe or causes significant slope erosion or failure. Table 48 lists the level of erosion of the outlets that were assessed.

Many of the storm drains on these maps have been in place since the development of the area. Figure 85 depicts typical erosion at a storm drain outlet which has no rock dissipater to break up the energy of the concentrated flow. One of the effects of storm water runoff, observed as part of the storm drain outlet assessment, was erosion of ephemeral and main stem creek channels. Figures 86-89 show some of this channel erosion and the effect of undercutting house and deck foundations on piers. Even one of the newest developments in the watershed, the Chabot Space and Science Center, has caused significant erosion to surrounding lands from its storm water outlets. This facility has large parking lots, roofs, and other paved areas which drain to a few outlets. There is significant erosion at these storm drain outlets and further downstream in the creek channels. The affected creeks are all on public property.

The erosion of creek channels is a cumulative effect of increases in impervious surfaces in the creek's drainage area and the proliferation of piped and concentrated runoff. As undeveloped parcels are built out in the upper Sausal Creek watershed, a number of factors affecting erosion are changed. These include: the area of impervious surfaces increases in the watershed of each ephemeral creek, and the volume and timing of storm water reaching the creek during a rainfall event will also increase. These changes become apparent during a large storm or wet winter when the most erosion occurs in the ephemeral creeks. The Castle Drive erosion site (Figures 95-98) in Joaquin Miller Park appears to have been caused by a storm drain outlet at the ridge top which releases storm water into the park.

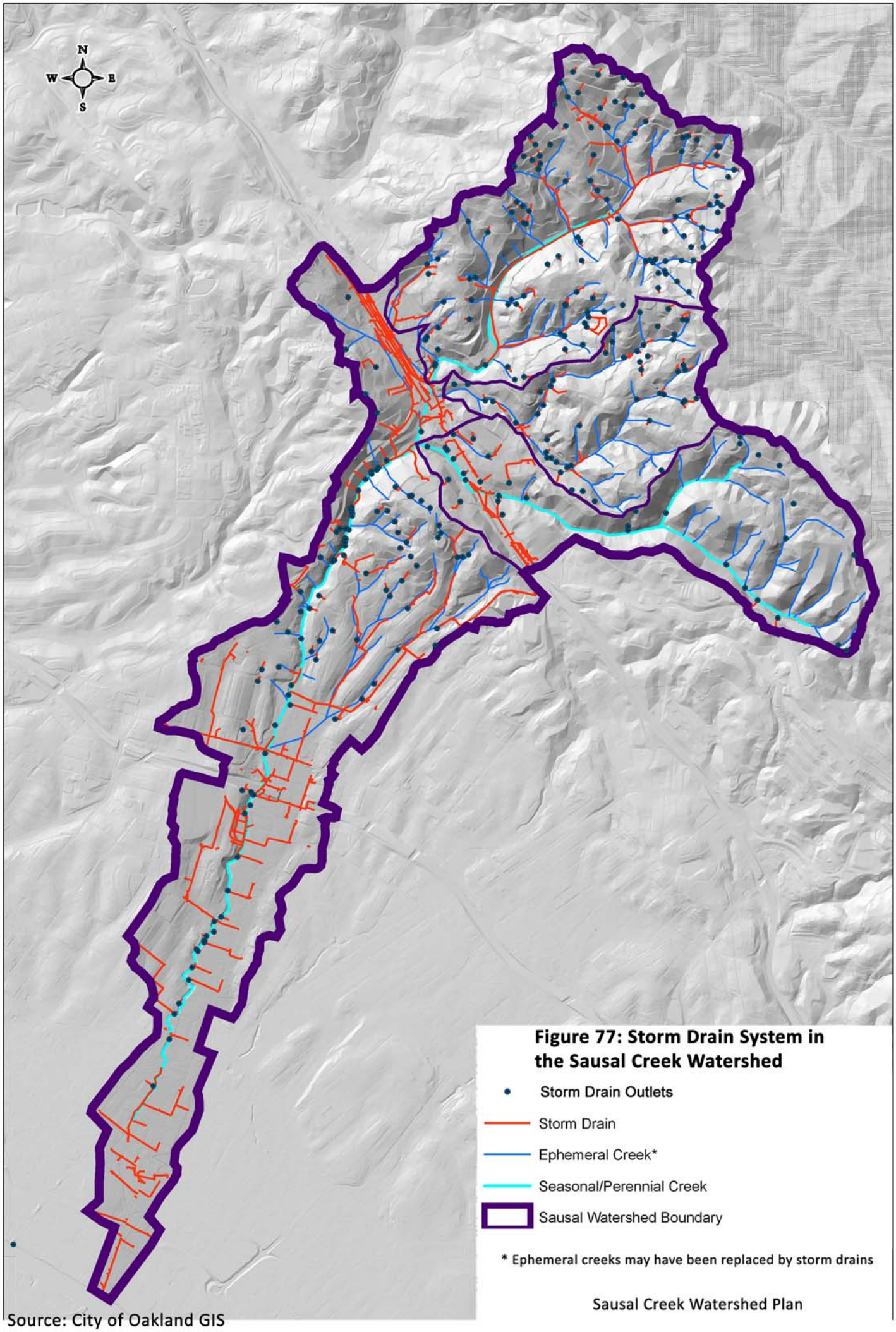
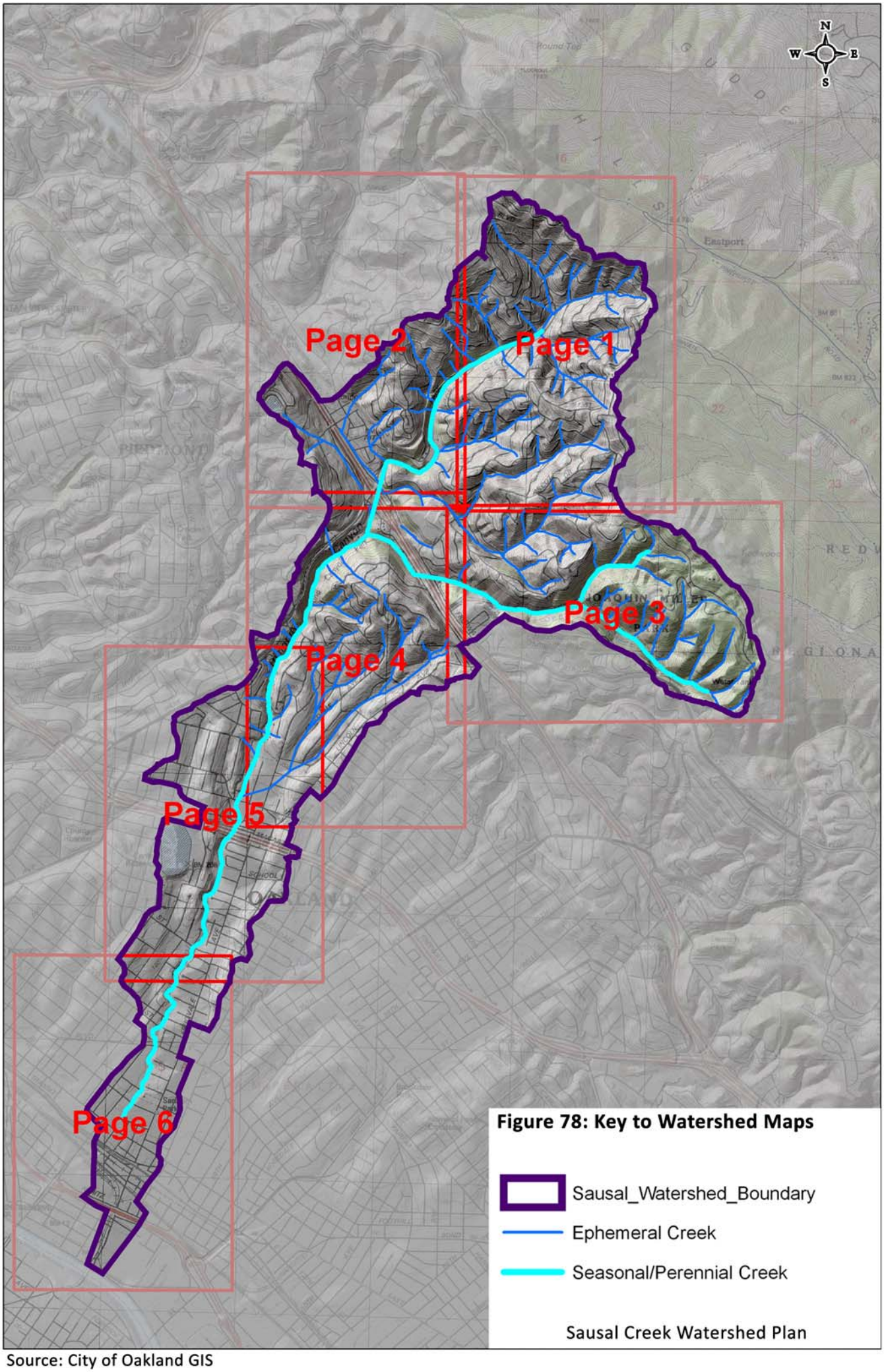



**Figure 77: Storm Drain System in the Sausal Creek Watershed**

Source: City of Oakland GIS




Source: City of Oakland GIS

# Figure 79: Storm Drain Map 1

**Storm Drain Outlet**

- Not assessed
- Little or No Erosion at Outlet
- Erosion at Outlet
- Extreme Erosion at Outlet

- Storm Drain
- Ephemeral Creeks*
- Seasonal/Perennial Creek
- Sausal Watershed Boundary

* Creek may have been replaced by storm drain

## Sausal Creek Watershed Plan

Source: City of Oakland GIS

## Figure 80: Storm Drain Map 2

**Storm Drain Outlet**

- Not assessed
- Little or No Erosion at Outlet
- Erosion at Outlet
- Extreme Erosion at Outlet

- Storm Drain
- Ephemeral Creeks*
- Seasonal/Perennial Creek
- Sausal Watershed Boundary

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan

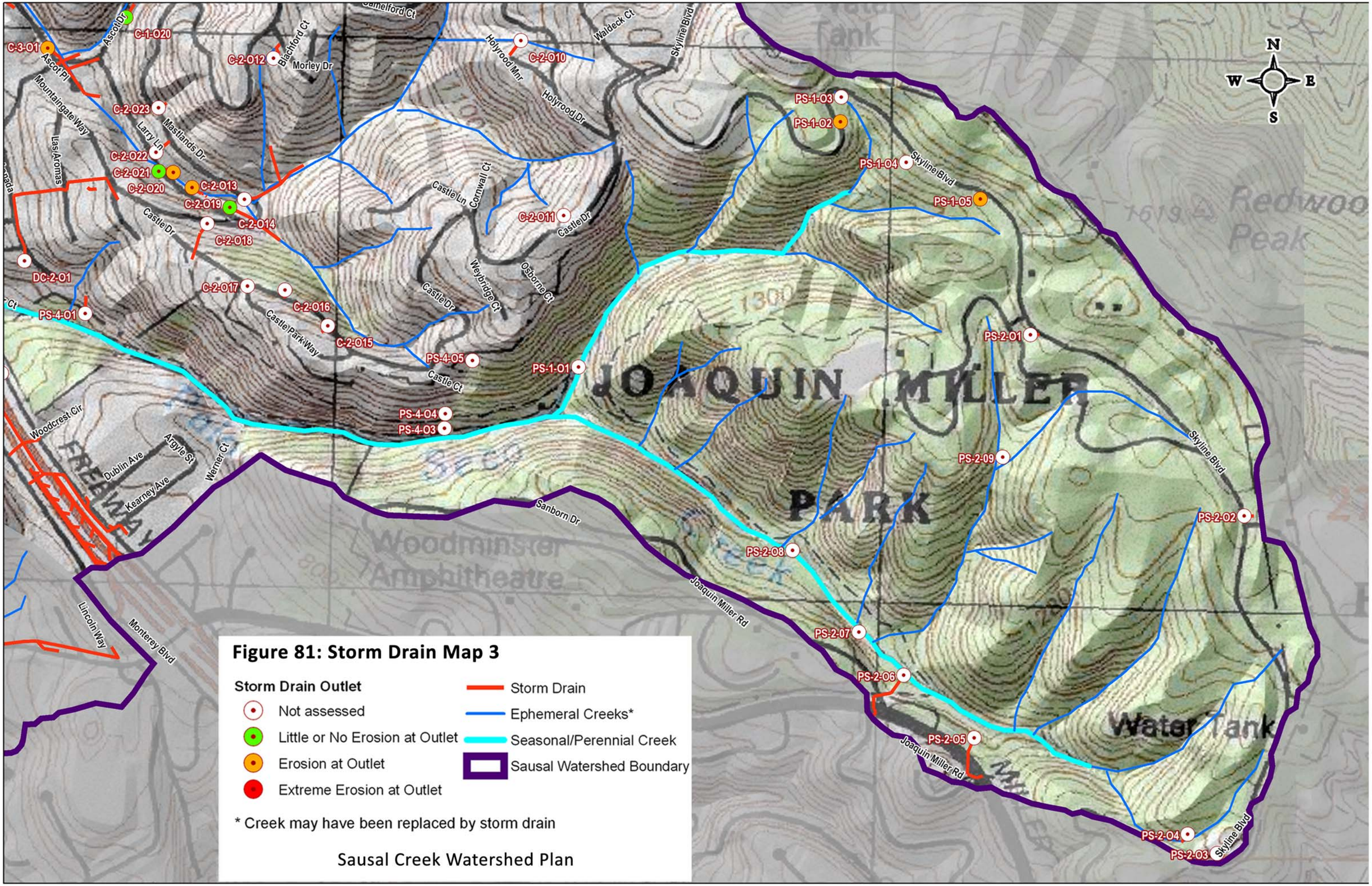



**Figure 81: Storm Drain Map 3**

**Storm Drain Outlet**

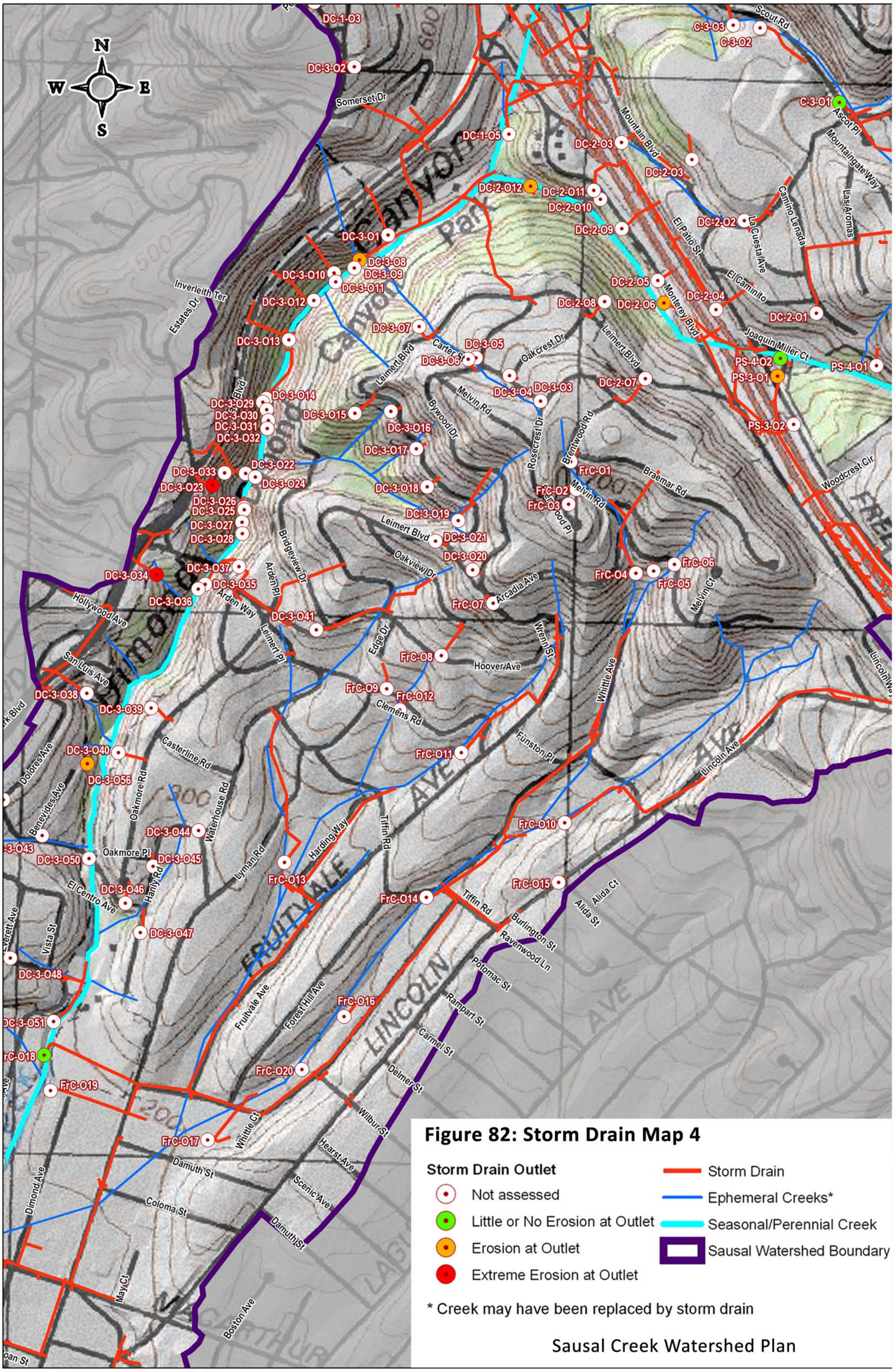
- Not assessed
- Little or No Erosion at Outlet
- Erosion at Outlet
- Extreme Erosion at Outlet

- Storm Drain
- Ephemeral Creeks*
- Seasonal/Perennial Creek
- Sausal Watershed Boundary

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan

Source: City of Oakland GIS




## Figure 82: Storm Drain Map 4

**Storm Drain Outlet**

- Not assessed
- Little or No Erosion at Outlet
- Erosion at Outlet
- Extreme Erosion at Outlet

- Storm Drain
- Ephemeral Creeks*
- Seasonal/Perennial Creek
- Sausal Watershed Boundary

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan

Source: City of Oakland GIS

# Figure 83: Storm Drain Map 5

**Storm Drain Outlet**

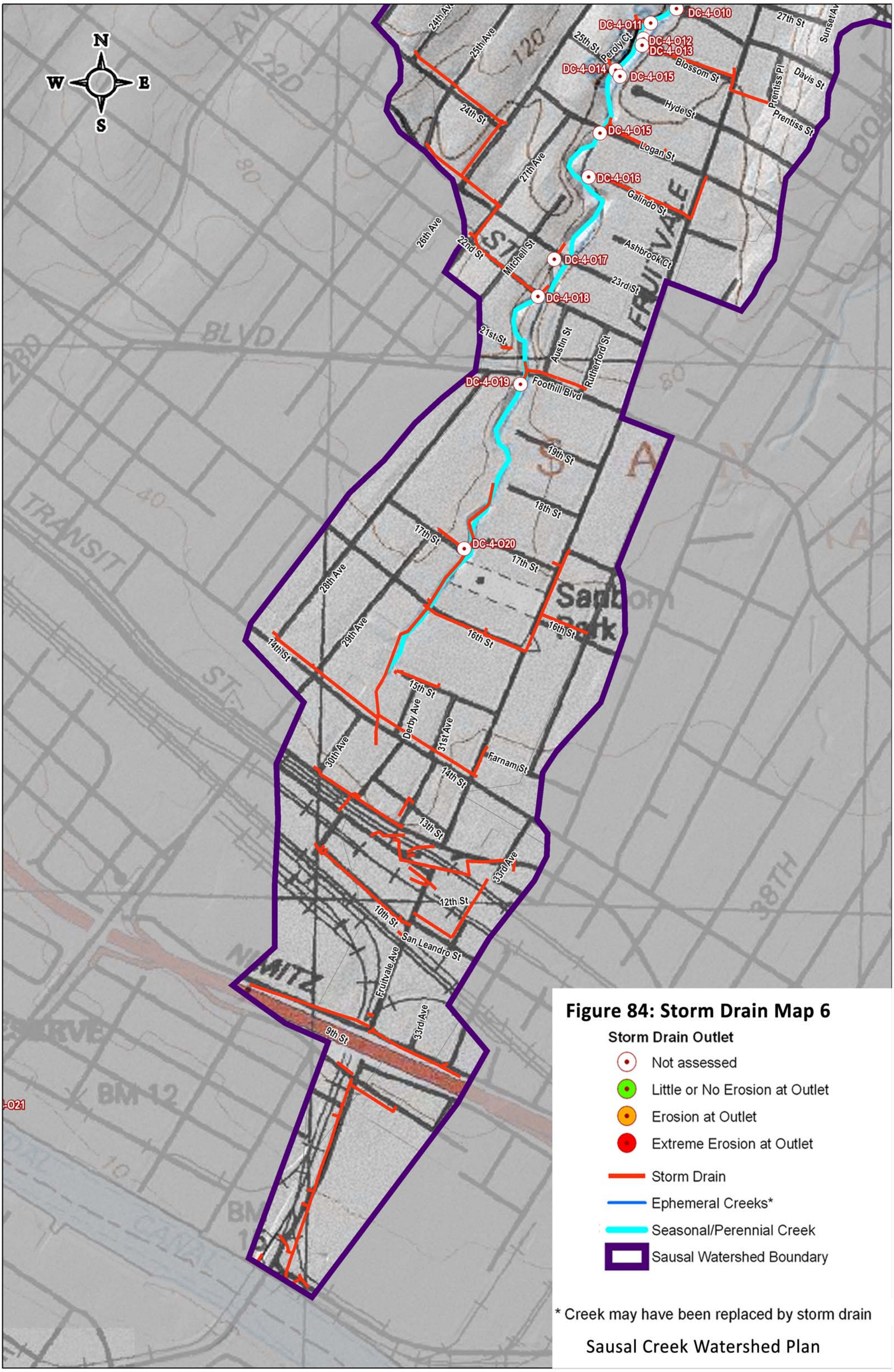
- Not assessed
- Little or No Erosion at Outlet
- Erosion at Outlet
- Extreme Erosion at Outlet

- Storm Drain
- Ephemeral Creeks*
- Seasonal/Perennial Creek
- Sausal Watershed Boundary

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan

Source: City of Oakland GIS




Source: City of Oakland GIS

**Table 48: Erosion Levels for Assessed Storm Drain Outlets**

| Storm Drain Outlet* | Gully Length | Gully Width | Gully Depth | Condition at Outlet |
|---|---|---|---|---|
| C-2-O7 | > 60 ft. | 5 ft. | 6 ft. | extreme erosion |
| DC-3-O23 | > 150 ft. | 15 ft. | 20 ft. | extreme erosion |
| DC-3-O34 | > 200 ft. | 15 ft. | 6 ft. | extreme erosion |
| SC-1-O12 | > 50 ft. | 4 ft. | 5 ft. | extreme erosion |
| SC-3-O22 | > 500 ft. | 3 ft. | 4 ft. | extreme erosion |
| SC-3-O23 | > 40 ft. | 4 ft. | 6 ft. | extreme erosion |
| SC-4-O9 | | 8 ft. | 8 ft. | extreme erosion |
| C-1-O10 | | | | eroding |
| C-1-O13 | | | 2 ft. | eroding |
| C-1-O21 | 15 ft. | 3 ft. | 2 ft. | eroding |
| C-2-O19 | | | | eroding |
| C-2-O20 | | | | eroding |
| C-2-O8 | 20 ft. | 2 ft. | 1 ft. | eroding |
| C-2-O9 | 20 ft. | 4 ft. | 3 ft. | eroding |
| C-3-O1 | | | | eroding |
| DC-2-O12 | | | | eroding |
| DC-2-O6 | | | | eroding |
| DC-3-O56 | | 3 ft. | 2 ft. | eroding |
| DC-3-O8 | | | | eroding |
| PS-1-O2 | > 100 ft. | 3 ft. | 3 ft. | eroding |
| PS-1-O5 | > 100 ft. | 3 ft. | 2 ft. | eroding |
| PS-3-O1 | | | | eroding |
| SC-1-O16 | 30 ft. | 3 ft. | 1 ft. | eroding |
| SC-1-O23 | > 30 ft. | 3 ft. | 4 ft. | eroding |
| SC-1-O31 | 12 ft. | 1 ft. | 1 ft. | eroding |
| SC-2-O25 | 3 ft. | 1 ft. | 1 ft. | eroding |
| SC-2-O26 | 30 ft. | 3 ft. | 3 ft. | eroding |
| SC-2-O27 | > 40 ft. | 8 ft. | 5 ft. | eroding |
| SC-3-O17 | | | | eroding |
| SC-3-O18 | | | | eroding |
| SC-4-O6 | 15 ft. | 6 ft. | 3 ft. | eroding |
| SC-4-O7 | > 40 ft. | 4 ft. | 3 ft. | eroding |
| SC-4-O8 | > 100 ft. | 6 ft. | 6 ft. | eroding |
| SC-5-O11 | | | | eroding |
| SC-5-O14 | > 50 ft. | 4 ft. | 3 ft. | eroding |
| SC-7-O5 | | | | eroding |
| C-1-O16 | | | | stable |
| C-1-O17 | | | | stable |
| C-1-O19 | | | | stable |

**Table 48: Erosion Levels for Assessed Storm Drain Outlets**

| Storm Drain Outlet* | Gully Length | Gully Width | Gully Depth | Condition at Outlet |
|---|---|---|---|---|
| C-1-O2 | | | | stable |
| C-1-O8 | | | | stable |
| C-2-O14 | | | | stable |
| C-2-O21 | | | | stable |
| FrC-O18 | | | | stable |
| PS-4-O2 | | | | stable |
| SC-1-O18 | | | | stable |
| SC-2-O14 | | | | stable |
| SC-2-O22 | 40 ft. | 3 ft. | 5 ft. | stable |
| SC-7-O3 | | | | stable |
| SC-7-O7 | | | | stable |

* See Figures 79-84 for location

The assessment also found that in many locations homeowners have installed plastic pipes on roof downspouts to extend the outlet onto adjacent lands, roads, or creeks. These pipes increase the volume of runoff reaching the creek and, if directed onto a road, may increase the volume of runoff into a nearby storm drain and the level of erosion at the outlet. On such steep lands as make up the upper Sausal Creek watershed, management of storm water, storm drains, and creek channels is essential to reduce ecological and water quality problems as well as private and public property damage.

**Figure 85: Erosion at storm drain outlet where concentrated flow is released onto the slope without a rock energy dissipater.**

**Figure 86: Top: House built over creek channel in Sausal Creek watershed. Bottom: Ephemeral creek with sanitary sewer and house foundation.**

**Figure 87: Ephemeral creek channels adjacent and under house with signs of erosion likely from increased volumes of runoff from urbanization of upper Sausal Creek watershed.**

**Figure 88: Top: Erosion of ephemeral creek from urban runoff in upper Sausal Creek watershed. Bottom: Erosion from storm drain outlet.**

**Figure 89: Lining creeks with cement or rock riprap to reduce erosion can result in storm flows undercutting or going around the improvement.**

**Soil Erosion in Parks**

Parks in the Sausal Creek watershed have several primary areas of erosion: recreational facilities such as trails and roads, outlets of concentrated flows from adjoining urban lands, and changes to creeks from watershed changes and management actions.

*Joaquin Miller Park:*

Many of the trails in Joaquin Miller Park date from prior logging activities and were not built for long-term use (Figure 90). There is a general lack of stream crossing culverts, waterbars, and proper drainage on trails. Table 51 lists the most significant erosion sites. These problems have been causing erosion and polluting Palo Seco Creek with fine sediment for a long time (Figure 91-99). City maintenance of these facilities is not funded most years, leading to continued degradation.

In 2000 the City had an assessment of trails and creeks completed (Lettis & Associates 2000). Many of the erosion problems identified in this report are included in Table 49 and have not been repaired.

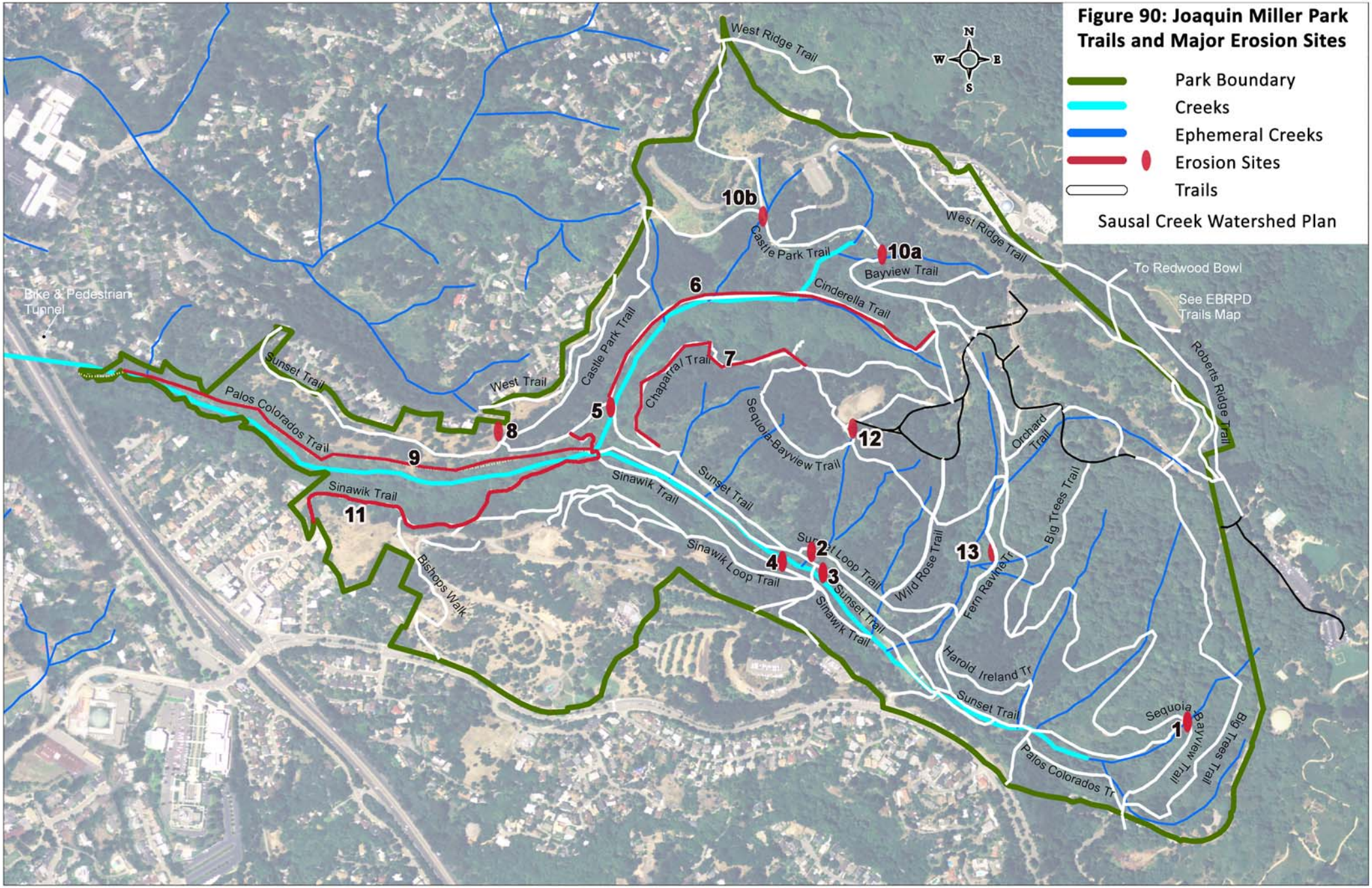


Figure 90: Joaquin Miller Park Trails and Major Erosion Sites
Park Boundary
Creeks
Ephemeral Creeks
Erosion Sites
Trails
Sausal Creek Watershed Plan
N
W
E
S
West Ridge Trail
10b
Castle Park Trail
10a
Bayview Trail
West Ridge Trail
To Redwood Bowl
See EBRPD Trails Map
Bike & Pedestrian Tunnel
6
Cinderella Trail
Castle Park Trail
Chaparral Trail
7
Sequoia-Bayview Trail
Roberts Ridge Trail
Sunset Trail
West Trail
Palos Colorados Trail
8
5
12
Orchard Trail
9
Sinawik Trail
Sunset Trail
Big Trees Trail
Sinawik Trail
11
Sunset Loop Trail
2
4
Sinawik Loop Trail
13
Wild Rose Trail
Fern Ravine Tr
3
Bishops Walk
Sunset Trail
Sinawik Trail
Harold Ireland Tr
Sunset Trail
Sequoia
1
Bayview Trail
Big Trees Trail
Palos Colorados Tr

**Table 49: High Priority Erosion Sites in Joaquin Miller Park**

| Erosion Site | Priority for Repair | Comments and Recommendations | Figure |
|---|---|---|---|
| 1 | High – direct delivery to creek; trail damage | Sequoia-Bayiew Trail crosses an ephemeral creek with no bridge or culvert. Creek flow is eroding trail and directly delivering fine sediment to Palo Seco Creek. Culvert needs to be installed and sized for 100-year flood event on creek, and set at the level of the streambed to minimize erosion at the outlet. At least 18 inches of trail fill over the culvert is needed. | |
| 2 | High – direct delivery to creek; damage to vegetation and trail | The Sunset Loop Trail crosses an ephemeral creek with no culvert and captures the creek flow. Consequently, creek flow courses down the trail, eroding 3-4 inch deep rills and delivering fine sediment to the base of the oak tree on Sunset Trail and into Palo Seco Creek. A culvert needs to be installed to route the stream flow under the trail and back into the creek. | 91 |
| 3 | High – direct delivery to the creek | This is the most upstream grade control on Palo Seco Creek and consists of a trail bridge with three 20-inch culverts and an upstream trash rack. Trails at this junction are rilling, particularly Sinawik Loop Trail. In addition, the ephemeral creek on the north side of Sunset Trail is actively eroding from storm drain runoff along Skyline Blvd. directed into this small creek. A major repair will be needed here as major runoff events deepen Palo Seco Creek at the downstream side of the bridge. Trail and ephemeral creek runoff flows down the creek banks, eroding and widening the channel. The channel bed is up to seven feet deeper below the bridge than in the areas upstream of the trash rack. The bridge and trash rack cannot simply be removed, as removal will cause the channel to adjust and undercut numerous redwoods along the creek banks. Any replacement structure should be designed as a grade control structure. Stream banks should be revegetated and the culvert under Sunset Trail between the northern ephemeral creek and Palo Seco Creek replaced with a much larger culvert which will not clog with rocks but will allow for the transport of rock into Palo Seco Creek. | 92; 62 |
| 4 | High – direct delivery to creek | This is another major knickpoint in Palo Seco Creek at a casual creek crossing. The knickpoint is over five vertical feet and has eroded approximately five feet upstream in the past ten years. Several tree roots are temporarily preventing the site from further erosion moving upstream. This site should have a rock grade control structure to avoid further upstream migration of this knickpoint. Downstream banks need to be set back to reduce erosive velocities and allow willow sprigging. Large wood debris in the channel should also be retained at this location. | 61 |
| 5 | Moderate | Sunset Trail crosses Cinderella Trail and a very large erosion site occurs in the channel of Cinderella Creek downstream of this crossing. The addition of urban runoff from Chabot Space & Science Center greatly increased the level of erosion at this site. The channel downstream of this crossing is over 20 ft. lower in elevation from the upstream side. Unfortunately, a culvert replacement completed in 2007 was installed incorrectly. Stream crossing culverts need to be installed at the same slope as the stream channel. The repair set the culvert at no slope, resulting in a large drop for the water at the outlet. The culvert also appears undersized, with flow overwhelming the culvert during the 2006 flood and flowing over the trail. This site should have a critical dip installed to avoid flow coursing down the trail and causing additional erosion. | 93 |

**Table 49: High Priority Erosion Sites in Joaquin Miller Park**

| Erosion Site | Priority for Repair | Comments and Recommendations | Figure |
|---|---|---|---|
| 6 | High – direct delivery to creek; trail damage | Cinderella Trail borders Cinderella Creek and probably was originally constructed as a skid trail for logs. This trail is very steep and highly eroded. It currently functions as a bucket road: the convex road surface concentrates flow in the low point at the center of the trail and erodes fine sediment in storms. These fines are deposited on Sunset Trail and in Cinderella Creek. This trail needs to be re-graded to an outsloped condition with rolling dips to intercept sheet flow from the road. Several ephemeral tributaries and one spring to Cinderella Creek also course over the trail, adding to the runoff on the trail. These tributaries need culverts to move the water to Cinderella Creek. This trail should be considered for closure due to the high cost to repair and stop the environmental damage it causes. | 94 |
| 7 | Moderate | Chaparral Trail has numerous rills and gullies and needs to be rebuilt in sections using new grade control steps to stabilize the trail and reduce erosion. | |
| 8 | Moderate – monitor repairs for downstream effects | A storm drain at the top of the ridge on Castle Drive combined with clearcutting of Eucalyptus caused a major erosion site in an ephemeral creek channel. An expensive repair was installed following over 10 years of erosion, ineffective repairs, direct delivery to Palo Seco Creek, and environmental damage. Several temporary repairs, installed prior to current project, failed. Current repair includes a pipe to move runoff through the gully and beneath the trail. The pipe outlets in the ephemeral creek channel just downslope from the trail crossing. This creek has significantly eroded and needs to be carefully monitored to avoid continued erosion. Pipe should be extended to culvert at Palos Colorados Trail to avoid eroding the creek. | 95-98 |
| 9 | Moderate | Palos Colorado Trail is eroding in numerous locations with direct delivery to Palo Seco Creek. Repairs should avoid filling or narrowing the creek to support the trail. | |
| 10 | High – direct delivery to creek; trail damage | Stormwater runoff from Chabot Space & Science Center parking lots is eroding the Castle Park Trail. Directly delivers sediment to Cinderella Creek. | |
| 11 | Moderate | Gully on Sinawik Trail | |
| 12 | Moderate | Rill erosion on short steep trail near Horse Arena | |
| 13 | Moderate | Rill erosion on steep section of Fern Ravine Trail | |

**Figure 91: Erosion site #2. Lack of a culverted stream crossing causes water to flow down Sunset Loop Trail, eroding the trail and creating a pile of mud on Sunset Trail (bottom)and in Palo Seco Creek.**

**Figure 92: Trail erosion (red arrows) flowing directly into Palo Seco Creek near Erosion Site #3.**

**Figure 93: Top: Cinderella Creek with culverted crossing at Sunset Trail erodes and overflows the culvert. Stormwater from the Chabot Space and Science Center has increased the volume of flow in Cinderella creek, increasing erosion. Bottom: Repair in 2007 was done incorrectly by setting the culvert at a flat angle; the proper method is to set the culvert at the slope of the creek bed to reduce downstream erosion. Culvert is also undersized and continues to be overwhelmed by storm flows.**

**Figure 94: Top: Cinderella Trail is a major erosion site and needs to be re-designed or re-located. Bottom: Casual trails cause soil erosion directly into Palo Seco Creek.**

**Figure 95: The headwaters of this small creek were clear-cut of Eucalyptus and had storm drain runoff from Castle Drive, causing a major erosion site to form. The erosion produced from this site filled in portions of Palo Seco Creek in the January 1, 2006 flood. Photos are from 2004 and 2006.**

**Figure 96: One of many temporary and ineffective repair projects done at Castle Drive erosion site.**

**Figure 97: Sunset Trail crossing of small ephemeral creek below Castle Drive erosion site in 2006. Logs indicate this is an historic Humboldt crossing from logging days. Despite rock and plastic pipe, water is flowing along right side of crossing and eroding slope. Humboldt crossing is failing and not able to support rock dumped on it as part of ineffective repair.**

**Figure 98: After over 10 years of erosion and several ineffective repairs, an engineered repair was implemented in 2008. Flow was placed in a pipe and buried in rock which fills the gully.**

**Figure 99: Two examples of ineffective trail crossing repairs. Plastic pipes are too small and can easily clog; both are not placed in the crossing at the proper angle, and are not covered with enough soil to avoid damage. Top: Ineffective repair to trail crossing creek in Joaquin Miller Park. Bottom: Creek can easily flow over trail in higher water events and erode soil and pollute Palo Seco Creek.**

The following observations of conditions in Dimond Canyon, Shepherd Canyon, and Cobbledick Basin were provided by Karen Paulsell of FOSC. Laurel Marcus & Associates did not validate these conclusions:

*Dimond Canyon*

- Two of the "extreme" culvert outlets; the first is the gigantic hole created by the "shotgun culvert" at Estates Drive on Park Blvd; the second is near Park Blvd, just south of the Leimert Bridge; water runs down the trail for a considerable distance, and has created numerous gullies.
- The storm drain outlet near San Luis Avenue creates a huge gully in the restoration area, shown in this photo

- The storm drain outlet at the end of Benevides Ave. has created a small landslide into the creek.
- There is a significant amount of erosion due to off-trail dogs; they've done a tremendous amount of damage to the native plantings in the El Centro restoration area, and there are denuded swathes between Sam's Trail and the creek, and also along the Bridgeview switchbacks.
- Montclair Golf Course uses a golf ball vacuum on the lower area of the driving range, creating a bare sediment source just above the culvert outfall.

*Shepherd Canyon and Montclair Railroad Trail Park*

- The Zinn Drive/trail area is the source of a lot of sediment. There are two or three shotgun culverts with large gullies below the trail, the deteriorating edge of the "fire road" has many small landslides, and the very large landslide below Cortez Court has blocked the creek channel, creating rills and gullies for about 150 feet along the fire road. The 500 feet of ephemeral creek channel above is basically an eroding gully, up to 3 feet deep and 5 feet wide. See photos at: http://picasaweb.google.com/KarenPaulsell/ZinnTrailErosion#.
- Escher Creek is eroding very quickly – former eroding ephemeral creek channels upstream were culverted a few years ago; I estimate that the creek has downcut at least 1 foot in about 5 years at one creek crossing.
- Partially due to the WPD vegetation management, a lot of the steep hillsides above and below Escher Drive are regularly denuded, with a lot of bare soil exposure. Erosion continues all the way down the Escher Creek channel, and is extreme between the restroom and the standpipe at Shepherd Canyon Road.
- Storm drain outlets SC-4-O4 and SC-4-O5 join up to form a large gully, 6 feet wide, 8 feet deep, at least 100 feet in length.
- Many homeowners also clear like the WPD does: down to bare soil, adding to the silt load.

*Cobbledick Basin*

- Due to the landslide at Haverhill Dr., the situation in Beaconsfield Canyon is rapidly growing worse, with the landslide deposition blocking the creek channel and flow diverted onto the fire road, due to landslide deposition blocking the creek channel.
- Upstream from Haverhill Dr., the creek is eroding soil from under the edge of the road
- A new and significant gully has appeared in Castle Canyon; a possible cause is a new storm drain installed on private property at the top of the canyon; it's very likely that this gully is responsible for the large amounts of deposition in the channel along Larry Lane.
- One of the "extreme" creek channels is located on Holyrood Dr. in the upper part of the watershed; the homes next to this creek channel have soil eroded from underneath their foundations.

## V. LAND USE AND MANAGEMENT

Sausal Creek watershed is home to about 80,000 residents and includes 2127.6 acres of urban land (Figure 43). The density of housing varies between the steep hills of the upper watershed and flatter lands of the lower watershed. Above and just below Highway 13, residential density has less than 49% cover of impervious surfaces. From Dimond Park downstream, high intensity urban areas have 50-100% impervious coverage. Most of this urban area is residential, with commercial areas in Montclair, along Fruitvale Ave., and along MacArthur Blvd. Parkland covers approximately 650 acres in the watershed.

### RELEVANT PLANS, POLICIES, AND PERMITTING

#### City of Oakland General Plan and Land Use Designations

Above Hwy. 13 the City of Oakland General Plan designates the primary land uses as Hillside Residential, Resource Conservation Areas, and Urban Open Space (Table 50). Most of the three major sub-basins are located above Highway 13. Shephard Creek flows through underground storm drains in Hillside Residential areas until it reaches Shepherd Canyon Park, designated as a Resource Conservation Area and Urban Open Space. Cobbledick Creek flows above ground and through storm drains through Hillside Residential areas and under Joaquin Miller Elementary/Montara Middle School. Palo Seco Creek flows almost entirely through Joaquin Miller Park, designated as a Resource Conservation Area and Urban Open Space.

Between Highway 13 and I-580 most of the watershed land use is designated as Hillside Residential and Detached Unit Residential, with the exception of Dimond Canyon, a Resource Conservation Area. Nearing I-580, however, these land uses transition to medium density Mixed Housing Type Residential, which is the dominant land use between I-580 and the neighborhood around I-880 and International Blvd. In this area, land use is designated for a mix of Urban Residential, Mixed Housing Type Residential, Community Commercial, and Neighborhood Center Mixed Use, including transit-oriented development.

*Cobbledick Basin*

- Due to the landslide at Haverhill Dr., the situation in Beaconsfield Canyon is rapidly growing worse, with the landslide deposition blocking the creek channel and flow diverted onto the fire road, due to landslide deposition blocking the creek channel.
- Upstream from Haverhill Dr., the creek is eroding soil from under the edge of the road
- A new and significant gully has appeared in Castle Canyon; a possible cause is a new storm drain installed on private property at the top of the canyon; it's very likely that this gully is responsible for the large amounts of deposition in the channel along Larry Lane.
- One of the "extreme" creek channels is located on Holyrood Dr. in the upper part of the watershed; the homes next to this creek channel have soil eroded from underneath their foundations.

## V. LAND USE AND MANAGEMENT

Sausal Creek watershed is home to about 80,000 residents and includes 2127.6 acres of urban land (Figure 43). The density of housing varies between the steep hills of the upper watershed and flatter lands of the lower watershed. Above and just below Highway 13, residential density has less than 49% cover of impervious surfaces. From Dimond Park downstream, high intensity urban areas have 50-100% impervious coverage. Most of this urban area is residential, with commercial areas in Montclair, along Fruitvale Ave., and along MacArthur Blvd. Parkland covers approximately 650 acres in the watershed.

### RELEVANT PLANS, POLICIES, AND PERMITTING

#### City of Oakland General Plan and Land Use Designations

Above Hwy. 13 the City of Oakland General Plan designates the primary land uses as Hillside Residential, Resource Conservation Areas, and Urban Open Space (Table 50). Most of the three major sub-basins are located above Highway 13. Shephard Creek flows through underground storm drains in Hillside Residential areas until it reaches Shepherd Canyon Park, designated as a Resource Conservation Area and Urban Open Space. Cobbledick Creek flows above ground and through storm drains through Hillside Residential areas and under Joaquin Miller Elementary/Montara Middle School. Palo Seco Creek flows almost entirely through Joaquin Miller Park, designated as a Resource Conservation Area and Urban Open Space.

Between Highway 13 and I-580 most of the watershed land use is designated as Hillside Residential and Detached Unit Residential, with the exception of Dimond Canyon, a Resource Conservation Area. Nearing I-580, however, these land uses transition to medium density Mixed Housing Type Residential, which is the dominant land use between I-580 and the neighborhood around I-880 and International Blvd. In this area, land use is designated for a mix of Urban Residential, Mixed Housing Type Residential, Community Commercial, and Neighborhood Center Mixed Use, including transit-oriented development.

**Table 50: Oakland Zoning Classifications and Definitions (currently being updated by City of Oakland)**

| Oakland Zoning Classification | Definition |
|---|---|
| Hillside Residential | • Low density development<br>• Slope protection and emergency vehicle access are key considerations<br>• Wall height restrictions differ between upslope and downslope lots |
| Resource Conservation Area | • Includes most publicly-owned hillsides, canyons, and wetland<br>• Parkland consisting of rugged terrain covered by woodland, grassland, or scrub vegetation<br>• Provides important area for groundwater recharge and habitat for wildlife<br>• Activities generally limited to passive recreation and vegetation management<br>• Has maximum impervious surface area standards: one percent of total park area or 2500 square feet, whichever is smaller, excluding parking areas which meet requirements |
| Open Space/Urban Open Space | • Any parcel or area of land or water which is essentially unimproved or devoted to an open space use, including land used for the preservation of natural resources, land used for the managed production of natural resources, and land used for outdoor recreation<br>• A general designation that includes Resource Conservation Areas |
| Detached Unit Residential | • This zone maintains areas with detached, single unit structures; a limited number of commercial uses are permitted or conditionally permitted in existing non-residential facilities.<br>• The density for Detached Unit Residential is one unit per 2,969 sq. ft. |
| Mixed Housing Type Residential | • Characterized by a mix of single-family homes, townhomes, small apartments and neighborhood serving businesses. |
| Urban Residential | • Primarily residential with multi-unit, mid-rise to high-rise buildings that may have some ground floor commercial uses and public facilities of compatible character in certain areas of the city where appropriate. |
| Community Commercial | |
| Neighborhood Center Mixed Use | |

**Oakland General Plan – Open Space, Conservation, and Recreation (OSCAR) Element**

The OSCAR Element of the Oakland General Plan, adopted in 1996, called for the designation of existing parks, including the parks in the upper Sausal Creek watershed, as “Resource Conservation Areas,”

replacing the previously un-zoned or residential-zoned status of the parks. Other directives of the OSCAR Element relevant to the Sausal Creek watershed include:

- Prioritizing flatland open space acquisition
- Promoting the conservation of ridges and knolls
- Promoting community-based gardening
- Conserving the rural character of large lot residential areas
- Continuing to require private open space in multi-family residential development
- Supporting an integrated network of bicycle and pedestrian trails
- Recommending access improvements to creeks on public properties
- Recommending requirements for erosion control, vegetation management, and building setbacks on creekside private properties
- Mandating public input and community involvement in creek planning
- Maintaining and enforcing grading, sedimentation, and erosion control ordinances
- Supporting measures to conserve groundwater, including the maintenance of open space in high recharge areas and minimizing the risks of groundwater pollution
- Supporting water conservation and recycling strategies
- Implementing the Alameda Countywide Clean Water Program, such as regular city maintenance of the storm drain system
- Endorsing the preparation of a Creeks Master Plan
- Conserving remaining oak woodlands, redwood forests, native perennial grasslands, and riparian areas, including precise mapping of these plant communities
- Encouraging plant diversity in wildland areas and the use of native and drought-tolerant plants in landscaping in developed areas
- Designating wildlife corridors on undeveloped properties in the Oakland hills
- Emphasizing strategies for fire prevention

The OSCAR Element, as with the General Plan, is intended for use as a guide for City staff in making decisions, as well as for residents of Oakland, local business and development, communities, and local landowners.

**Infill Development Policy**

The City of Oakland has no infill development policy; however, according to the Oakland General Plan, most of the City has been designated a Priority Development Area by the Association of Bay Area Governments (ABAG) for having existing infill development opportunities within communities easily accessible to transit, jobs, shopping and services. In addition, Oakland is considered to be “built-out,” meaning that most development opportunities consist of urban infill and redevelopment of under-utilized or vacant sites.

**City of Oakland Wildfire Prevention District**

Most of the upper Sausal Creek watershed has been designated by the Oakland Fire Department as a Very High Fire Hazard Severity Zone and falls within the Wildfire Prevention District (WPD), which includes both public and private land within the City of Oakland. The Wildfire District was established in 2004 as a response to the 1991 fire in the Oakland hills, and inspects properties for fire safety, provides resources and free services such as curbside tree and brush chipping, educates the public on fire safety compliance standards and recommends fire-resistant plants for landscaping.

The priorities of the Wildfire Prevention District for 2004-2014 are to:

- Establish and implement a strategic, cost-effective, sustainable, environmentally sensitive fuel management plan
- Encourage the involvement of and increase the knowledge of property owners, developers and the public-at-large in fire safe practices
- Enhance cooperation and communication with the community, City, other agencies and neighboring districts
- Establish and refine policies, procedures and regulations that improve fire safety

The Vegetation Management Program run by the Wildfire District provides lists of fire-resistant native plants and recommendations for ecologically sensitive landscaping as well as lists and photos of invasive plants and rare native plant species. As part of the Vegetation Management Program, the Wildfire District uses goat grazing to reduce fuel loads on public property. In the Sausal Creek watershed, goats are grazed throughout parts of Joaquin Miller Park and in Shepherd Canyon Park and Castle Canyon Park. The Friends of Sausal Creek, concerned about the possible destruction of rare native plants, has negotiated modifications to the goat grazing program to protect areas with rare natives (Appendix D).

Project sites for the future include non-native tree removal on the median strip along Skyline Blvd., continued invasive plant removal in Beaconsfield Canyon and goat grazing vegetation management in Joaquin Miller Park, and a LIDAR vegetation survey.

According to FOSC:

> The Wildfire Prevention District hires contractors to clear vegetation on city-owned properties, including roadsides, vacant lots, open space, and parkland. The general clearance regime is that all plants taller than six feet tall are limbed up to at least six feet, and all other vegetation is cut extremely short. On small lots, the entire lot is cleared; on larger parcels, clearing may be primarily around the perimeter. While the guidelines specify a minimum height of 4 inches for remaining vegetation, in practice contractors sometimes clear to bare mineral soil on steep slopes.

Other issues which FOSC has raised with the WPD include:

- Failure to comply with the creek ordinance provisions prohibiting the removal of all vegetation from the bed and banks of creek channels
- Use of ephemeral creek channels as debris chutes for hauling large woody debris down hillsides
- Leaving large amounts of debris in ephemeral creek channels, leading to blocked storm drains and flooding during the rainy season
- Failure to protect endangered plant species
- Extreme negative impacts on biodiversity and habitat values from their clear-cutting policies
- Failure to remove invasive species; many sites with broom, pampas grass, and other invasives are cut yearly; plants are not dug or pulled
- Spreading invasive species; for example, contractors weed-whack Cape ivy and cut broom plants while in seed
- Too much exposed and disturbed soil that leads to sediment in runoff

The Fire Department staff and Community Advisory Board of the WPD have been very responsive. Some of these problems have been addressed, in particular concerns about the creek ordinance and endangered species.

FOSC's efforts have led to two projects that involve FOSC and the WPD:

- Due to concerns about the loss of species in the grazed areas of Joaquin Miller Park, FOSC entered into a 5-year agreement with the WPD and Oakland Parks and Recreation
    - There is a pilot project in Beaconsfield Canyon with a yearly contract. Contractors work with a botanist who flags native species to preserve, recommends cutting times and methods, and encourages the use of pulling and digging rather than repeated cutting (FOSC 2010)."

**City of Oakland Creek Protection, Storm Water Management and Discharge Control Ordinance**

The purpose of the Creek Protection, Storm Water Management and Discharge Control Ordinance is to:

- Eliminate non-storm water discharges to the municipal storm drain system;
- Control the discharge to municipal storm drains from spills, dumping or disposal of materials other than storm water;
- Reduce pollutants in storm water discharges to the maximum extent practicable;
- Safeguard and preserve creeks and riparian corridors in a natural state;
- Preserve and enhance creekside vegetation and wildlife;
- Prevent activities that would contribute significantly to flooding, erosion or sedimentation, or that would destroy riparian areas or would inhibit their restoration;
- Enhance recreational and beneficial uses of creeks;
- Control erosion and sedimentation;
- Protect drainage facilities;
- Protect the public health and safety, and public and private property.

Under the ordinance, non-regulated non-storm water discharges and increases in flow to the City storm drain system are prohibited, except for managed releases of water line flushing and other discharges from potable water sources, landscape irrigation and lawn watering, irrigation water, diverted stream flows, rising ground waters, infiltration to separate storm drains, less than 1,000 gallons per day of uncontaminated pumped ground water, foundation and footing drains, water from crawl space pumps, air conditioning condensation, springs, individual residential car washings, flows from riparian habitats and wetlands, de-chlorinated swimming pool discharges, or flows from fire fighting.

In 1997 a creek component was added to Oakland's stormwater ordinance and provides guidelines for any construction or development on properties adjacent to creeks. The ordinance recommends the use of Best Management Practices (BMPs) for all development, requiring at minimum that filter materials at the catch basin be established to prevent any debris and dirt from flowing into the City's storm drain system, and that the ordinance for sediment and erosion control is followed. All construction on creekside properties are required to apply for a Creek Protection Permit, which in turn may require the creation of a Creek Protection Plan to ensure that adequate measures are taken to protect the creek.

According to FOSC:

> The watershed improvement program works closely with creek groups. It sponsors Creek-to-Bay Day, providing planning, publicity, and city resources that provide a very large volunteer turn out for FOSC's restoration efforts. Staff also assists when permits

are needed for creek projects, and responds to problems of illegal dumping, chemicals, and fish kills.

FOSC maintains a good working relationship with the City of Oakland Public Works Agency, in particular the Park and Building Services Division, who assists the organization's efforts by providing mulch for restoration efforts, removing plant debris after clearing of invasive plants, and working with FOSC to solve watershed problems. The Public Works agency is responsible for storm drain problems such as blocked drains. The agency also removes silt and debris from landslides onto roads, and responds to illegal dumping problems.

"The City of Oakland Office of Parks and Recreation (OPR) strongly supports FOSC's restoration efforts by providing space for the Native Plant Nursery in Joaquin Miller Park and help in the planning and staging of many work days. OPR also works with FOSC on removal of large, invasive trees, such as acacia, from our restoration sites (FOSC 2010)."

**San Francisco Bay Regional Water Quality Control Board**

*San Francisco Bay Basin Plan*

Sausal Creek is included in the San Francisco Bay Basin Plan as a tributary to the South Bay Basin area of the San Francisco Bay. Beneficial Uses of the South Basin include: Agricultural Supply (AGR); Areas of Special Biological Significance (ASBS); Cold Freshwater Habitat (COLD); Ocean, Commercial, and Sportfishing (COMM); Estuarine Habitat (EST); Freshwater Replenishment (FRSH); Groundwater Recharge (GWR); Industrial Service Supply (IND); Marine Habitat (MAR); Fish Migration (MIGR); Municipal and Domestic Supply (MUN); Navigation (NAV); Industrial Process Supply (PRO); Preservation of Rare and Endangered Species (RARE); Water Contact Recreation (REC1); Noncontact Water Recreation (REC2); Shellfish Harvesting (SHELL); Fish Spawning (SPWN); Warm Freshwater Habitat (WARM); and Wildlife Habitat (WILD). Sausal Creek is not one of the waterbodies identified in the Basin Plan for existing, limited, or potential Beneficial Uses.

In 2009 the San Francisco Bay Regional Water Quality Control Board approved listing Sausal Creek along with many other Bay area creeks for trash as a water contaminant under Section 303(d) of the Clean Water Act. The State Water Resources Control Board is currently considering the listing. Urban trash includes plastic and paper objects which wash off streets, sidewalks, parking lots, and yards into creeks. Trash has become so abundant in San Francisco Bay that it is now a pollutant. The primary beneficial use affected by trash is wildlife habitat.

*NPDES Permit*

In December 2009 the San Francisco Bay Regional Water Quality Control Board issued an updated Municipal Regional Storm Water NPDES Permit for the Alameda Countywide Clean Water Program, which includes the City of Oakland. The permit requires all municipalities, including Oakland, to comply with existing federal, state, and regional regulations regarding storm water discharge and storm drain systems. Included in the permit are specific BMPs for municipal operations, such as asphalt/concrete removal, sidewalk and plaza maintenance, graffiti removal, and corporation yard maintenance. The

permit also specifies requirements for public information and outreach in order to increase public knowledge of the impacts of storm water pollution.

In addition, the updated permit provides guidelines for source control, site design, and storm water treatment measures in development and redevelopment projects. The permit specifies the use of low impact development, or LID, techniques in reaching the goal of preventing increases in the volume of runoff flows. All regulated projects are required to implement LID source control, site design, and storm water treatment measures; non-regulated projects should be encouraged to include site design measure that minimize impervious surface construction and land disturbance, cluster structures and pavement, use micro-detention and landscape-based detention areas, preserve open space, restore or protect riparian corridors and wetlands, and direct roof runoff to vegetated areas among other recommendations. Regulated projects are defined as projects that create or replace 10,000 square feet or more of impervious surface, including road projects and creekside trail projects; and projects with alterations of more than 50% of the impervious surface of a previously existing development, with some exceptions.

Oakland and the other Alameda municipalities are required to complete a total of at least two "green street pilot projects" that incorporate LID techniques in site design and treatment.

## INFRASTRUCTURE

### Transportation Corridors

Major transportation corridors in the watershed include three highways: Interstate 880, Interstate 580, and State Highway 13. I-580 was constructed in the 1950s following the route of MacArthur Blvd., the historic route linking East Oakland to downtown (Figure 4). State Highway 13 follows a route through the rift valley of the Hayward fault zone. Park Boulevard and Lincoln and Fruitvale Avenues were developed as haul roads, first for timber and later for farm products.

### Storm Drain System

There are several different types of pipes in the watershed: water lines, storm drains and sanitary sewers. Figure 77 depicts the system of storm drain pipes in the entire Sausal Creek watershed as mapped by the City of Oakland. There are a number of locations where pipes exist but are not on this GIS layer. In addition, some of the drop structures in Dimond Canyon are indicated as storm drains.

Storm drains are installed in urban areas to replace natural creek channels and carry rain runoff from streets and houses. In the Oakland hills portion of the Sausal Creek watershed, the storm drain system is incomplete and has been installed piecemeal at various locations. Many locations have a few storm drains collecting runoff and releasing it into open creek channels. In the more urbanized lower area of the drainage basin, the storm drain system is very complete, with pipes replacing nearly all creek channels. Additional information on the storm drain system is included on pages 143-154.

### Sanitary Sewer System

The sanitary sewer system carries raw sewage from residential and commercial areas to the East Bay Municipal Utilities District (EBMUD) wastewater treatment facility in west Oakland. Figures 100-105

depict the City of Oakland sanitary sewer GIS layer. This layer indicates the diameter of the sewer pipe. One category in the GIS layer indicates a diameter of 0 inches, which has been mapped as “unknown.” The sanitary sewer system is depicted on six maps along with creeks and roads. The maze of sewer lines in the hilly residential areas of Shephard Creek and Cobbledick Creek sub-basins appear to feed into main lines along the major creek courses. This system of sewer pipes from the upper watershed feeds into the main sewer, which follows Sausal Creek through Dimond Canyon. Several major lateral pipes feed into the main sewer in Dimond Canyon. Sewer pipes also cross Sausal Creek at several points in the lower watershed. The route of the main sewer line leaves the Sausal Creek bed at the end of Dimond Park and follows Dimond Avenue and then Fruitvale Avenue.

There are several locations where the sanitary sewer system is known to overflow during large rainstorms. Where the main sewer extends down Sausal Creek from Highway 13 to Dimond Avenue, the manhole covers pop off the sewer in large storms and raw sewage flows into Sausal Creek (Figures 106-108). Sewage also flows into Palo Seco Creek out of the sewer manhole on Joaquin Miller Court just upstream of the Highway 13 crossing. There are likely additional locations where similar problems occur.

The City of Oakland and EBMUD have a program to replace older sewer pipes that are prone to stormwater infiltration with modern pipes. In most of the area of the Sausal Creek watershed above Highway 13 this process has been completed (pers. comm. Allan Law), but most of the lower watershed still retains the old pipes, including most of the main sewer line in Sausal Creek.

## Figure 100: Sanitary Sewer System Map 1

Sausal_Watershed_Boundary
Ephemeral Creek*
Seasonal/Perennial Creek

**Sewer Pipe Diameter**

Unknown
4"
6"
8"
10"
12"
14"
15"
16"
18"
21"
24"
30"

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan

Source: City of Oakland GIS

## Figure 101: Sanitary Sewer System Map 2

Sausal_Watershed_Boundary
Ephemeral Creek*
Seasonal/Perennial Creek

* Creek may have been replaced by storm drain

**Sewer Pipe Diameter**

Unknown
4"
6"
8"
10"
12"
14"
15"
16"
18"
21"
24"
30"

Sausal Creek Watershed Plan

Source: City of Oakland GIS

## Figure 102: Sanitary Sewer System Map 3

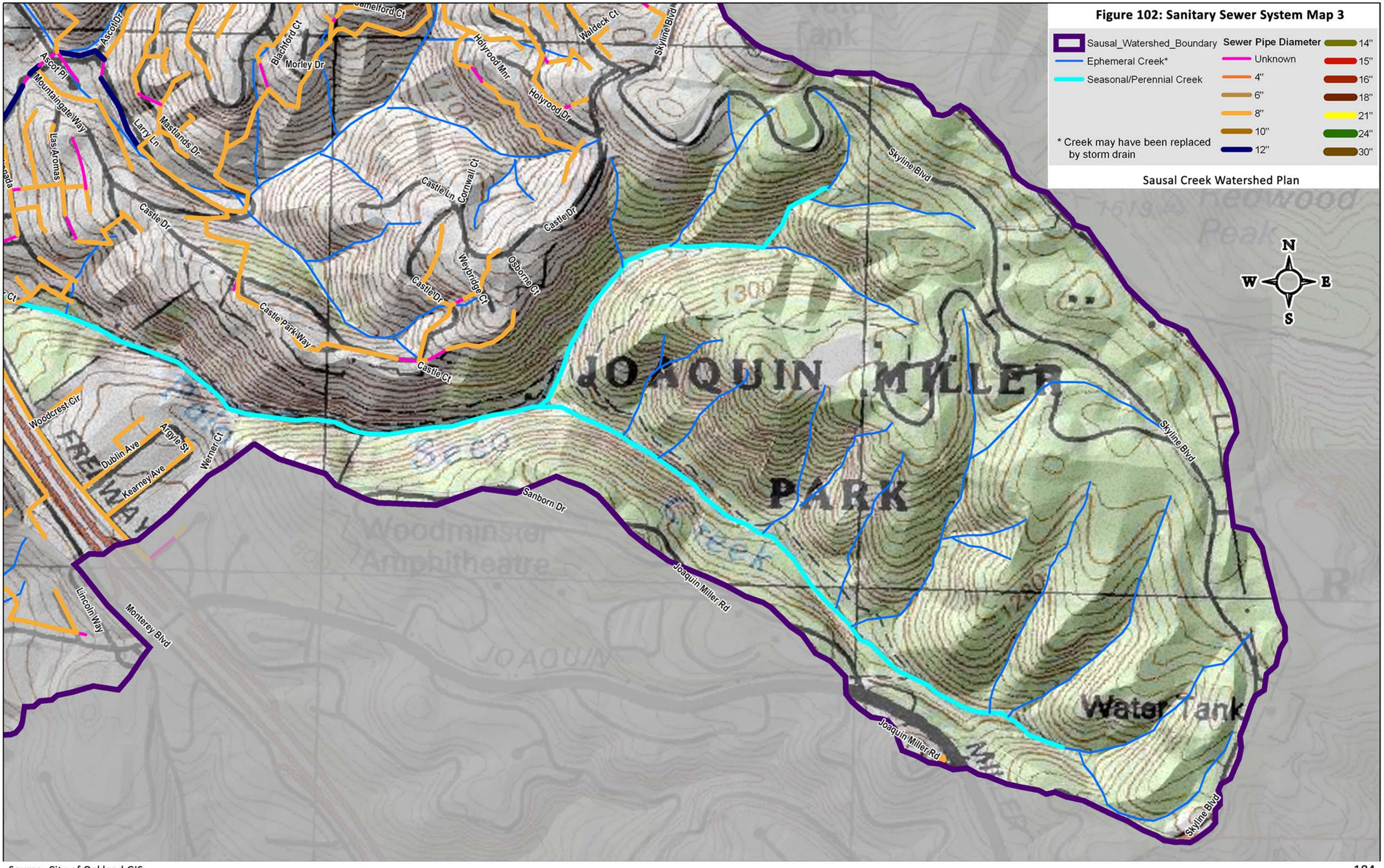
Sausal_Watershed_Boundary
Ephemeral Creek*
Seasonal/Perennial Creek

**Sewer Pipe Diameter**

Unknown
4"
6"
8"
10"
12"
14"
15"
16"
18"
21"
24"
30"

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan




Source: City of Oakland GIS

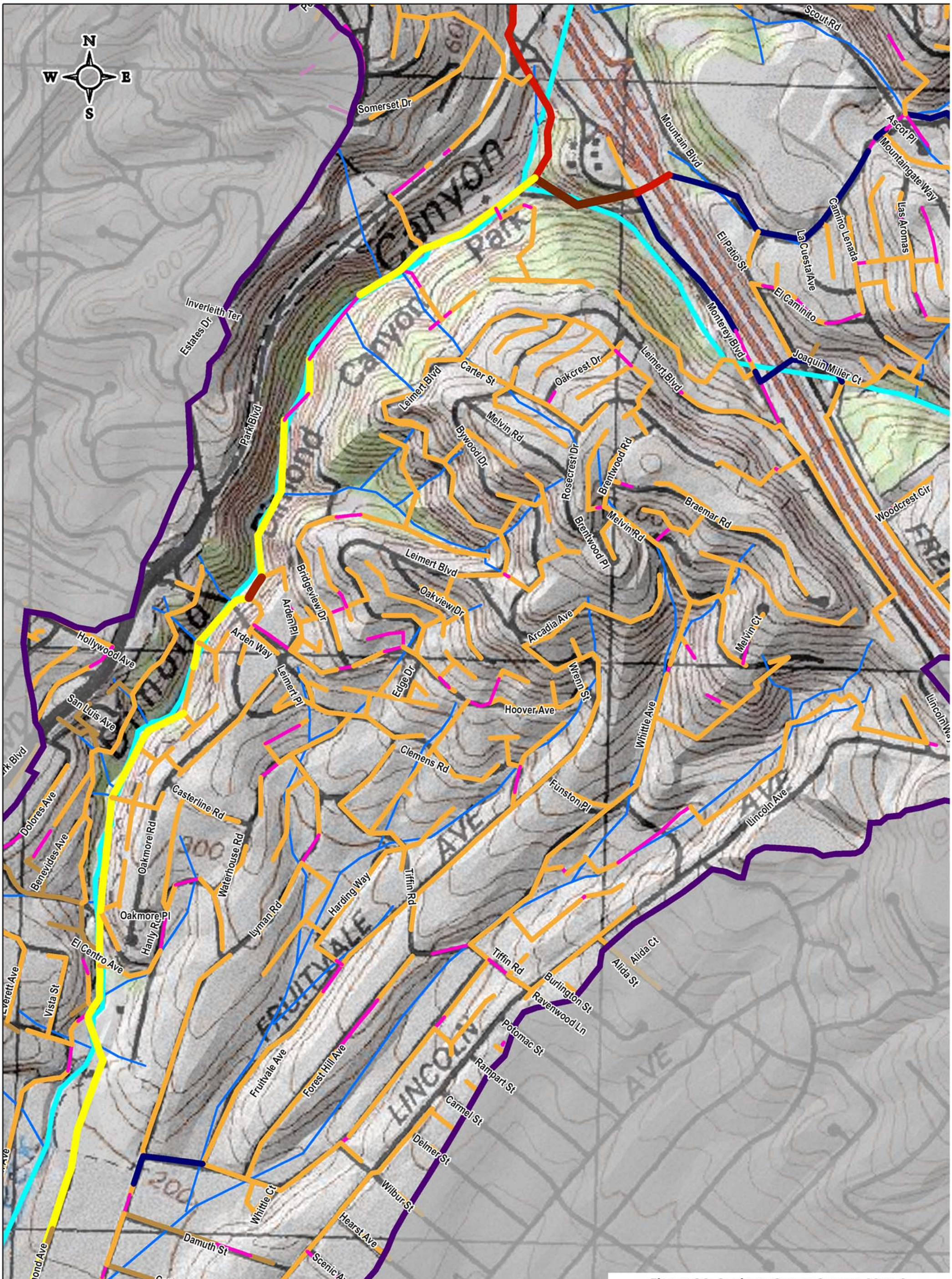



**Figure 94: Sanitary Sewer System Map 4**

Sausal_Watershed_Boundary
Ephemeral Creek*
Seasonal/Perennial Creek

Sewer Pipe Diameter
Unknown
4"
6"
8"
10"
12"
14"
15"
16"
18"
21"
24"
30"

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan

Source: City of Oakland GIS

**Figure 104: Sanitary Sewer System Map 5**

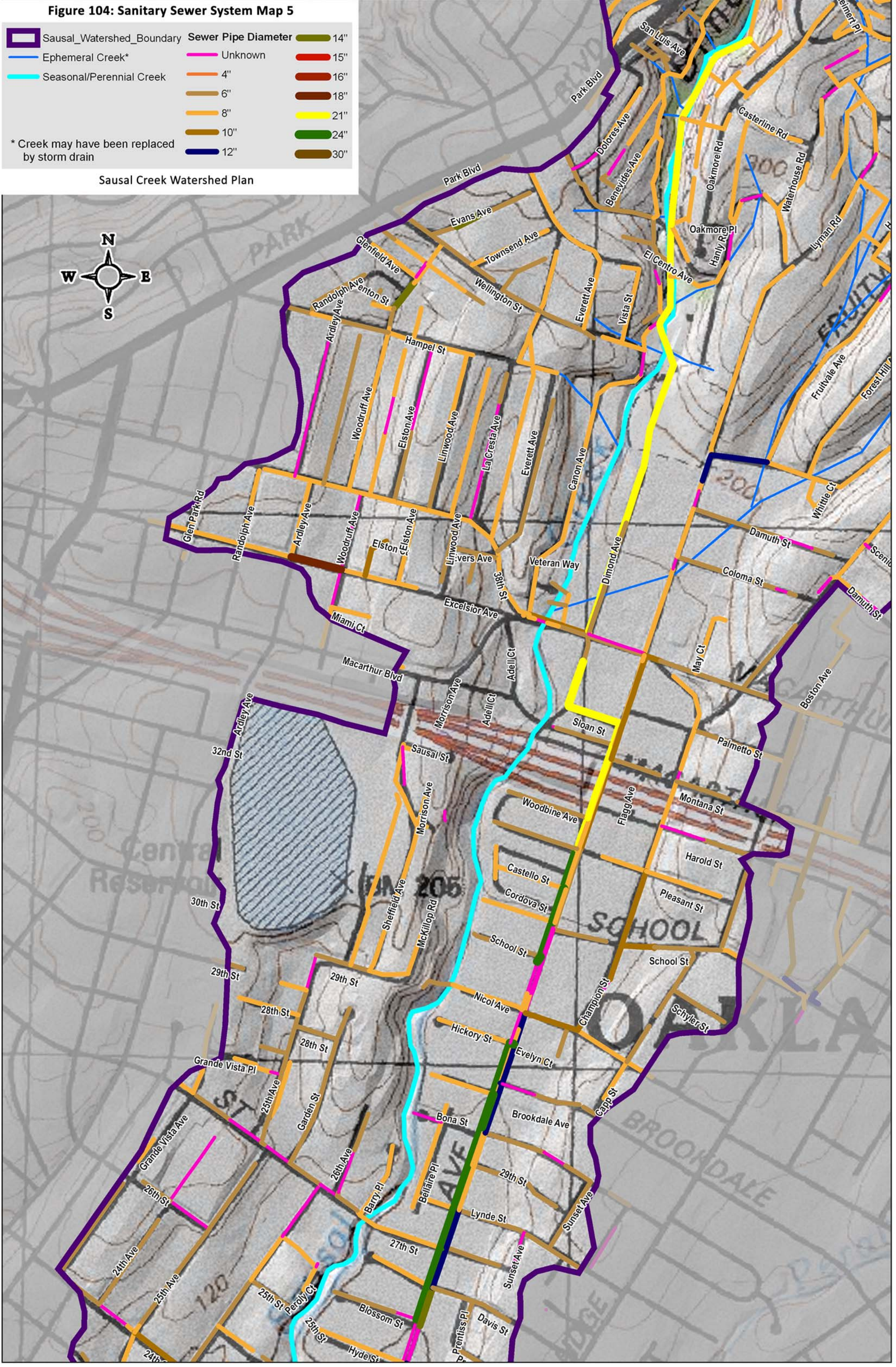
Sausal_Watershed_Boundary
Ephemeral Creek*
Seasonal/Perennial Creek

**Sewer Pipe Diameter**

Unknown
4"
6"
8"
10"
12"
14"
15"
16"
18"
21"
24"
30"

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan




Source: City of Oakland GIS

## Figure 105: Sanitary Sewer System Map 6

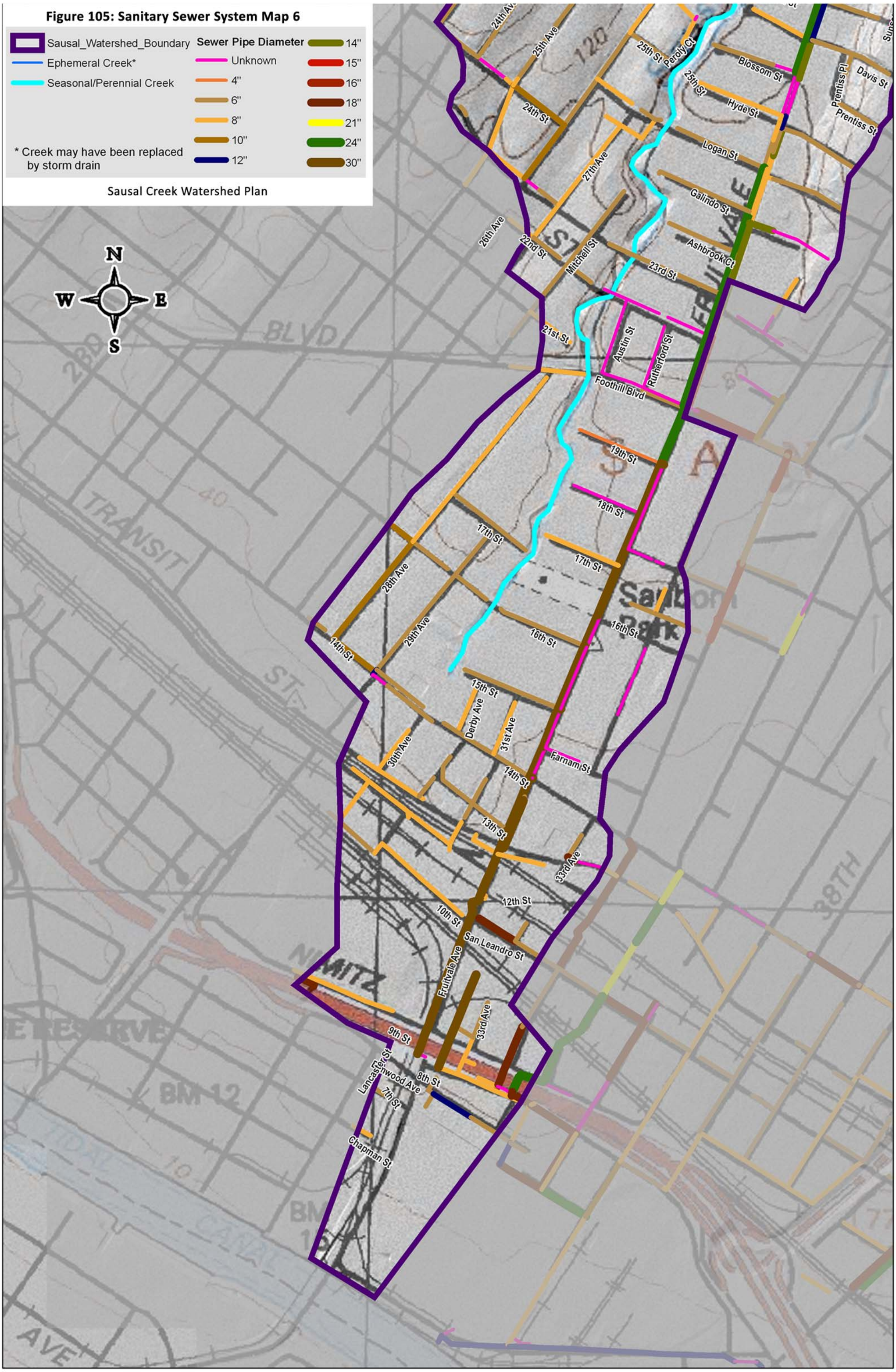
Sausal_Watershed_Boundary
Ephemeral Creek*
Seasonal/Perennial Creek

**Sewer Pipe Diameter**

Unknown
4"
6"
8"
10"
12"
14"
15"
16"
18"
21"
24"
30"

* Creek may have been replaced by storm drain

Sausal Creek Watershed Plan




Source: City of Oakland GIS

**Figure 106: Sanitary sewer overflow following the January 1, 2006 flood.**

**Figure 107: Manhole cover blown off the sanitary sewer, allowing raw sewage to enter Sausal Creek in Dimond Canyon Park following the January 1, 2006 flood.**

**Figure 108: Top: main sewer line in the bed of Sausal Creek This new pipe was installed during the creek restoration in 2001. Bottom: Sausal Creek in Dimond Park. A lateral sewer line is visible underneath the concrete apron (red arrow).**

**PARKS**

Several areas of the Sausal Creek watershed were made into parks by the City of Oakland (Figure 109).

**Joaquin Miller Park**

The City purchased 68 acres from Joaquin Miller's estate in 1919. Additional lands were added in 1928, creating Joaquin Miller Park at a total of 500 acres. In 1948 the Sequoia Lodge and Horse Arena were completed. During the period from 2000 to 2007, the Chabot Space and Science Center and Joaquin Miller Community Center were built. Joaquin Miller Park (JMP) encompasses second-growth redwood forest and several other types of native vegetation. Monterey pines and cypress, along with Eucalyptus trees, have been planted in the park and along with invasive plants such as French broom, Himalayan blackberry, pampas grass, and Algerian and cape ivy create a large non-native plant component to the park

Several Works Progress Administration (WPA) projects were completed in Joaquin Miller Park, including the Woodminster Amphitheater and Cascade, completed in 1941, which is outside of the Sausal Creek watershed. As part of the Cascade project, portions of Palo Seco Creek and Fern Ravine Creek were put into culverts and the streambed filled and developed into a meadow.

The Wildfire District grazes goats on about 60 acres in Joaquin Miller Park to clear weeds and reduce fire danger. FOSC was concerned the impacts of grazing on native and rare plants. Starting in spring 2008, FOSC entered into a 5-year agreement with the Oakland Fire Department and Parks and Recreation Department to reduce the impact of grazing on native plants in Joaquin Miller Park. Appendix F shows areas of the park and a grazing schedule for 2009-2012 designed to reduce impacts to rare and native plants. The plan's major components were:

- Eliminate grazing in areas where rare plants are present, and low fuel conditions or distance from structures present low fire risk;
- Reduce the frequency of grazing in many other areas from yearly grazing to grazing every 2-3 years;
- Reduce grazing on steep trailcuts to prevent erosion.

FOSC, the grazing contractors, and a City representative tour the grazed areas each spring to determine goat exclusion areas and assess each area. Park trails are discussed on pages 160-174.

According to FOSC:

> After a community meeting in 2005, the Joaquin Miller Working Group was formed to represent various park constituencies, and to recommend actions to improve the park's facilities and use. The group is currently in the process of morphing into Friends of Joaquin Miller Park, and is now soliciting memberships. Accomplishments include rerouting two eroding and dangerous trails, creating a fenced off-leash dog area (in a mulched parking lot), and initiating a restoration of the Abbey. There is some commitment to restoration; they've just started a Redwood Committee looking at problems at various redwood sites (Fern Ravine wetland, a trail problem in Big Trees, and the Holly near Palo Seco). Friends of Sausal Creek is currently working on the planning efforts in the Fern Ravine wetland and the redwoods along the stream below the wetland.

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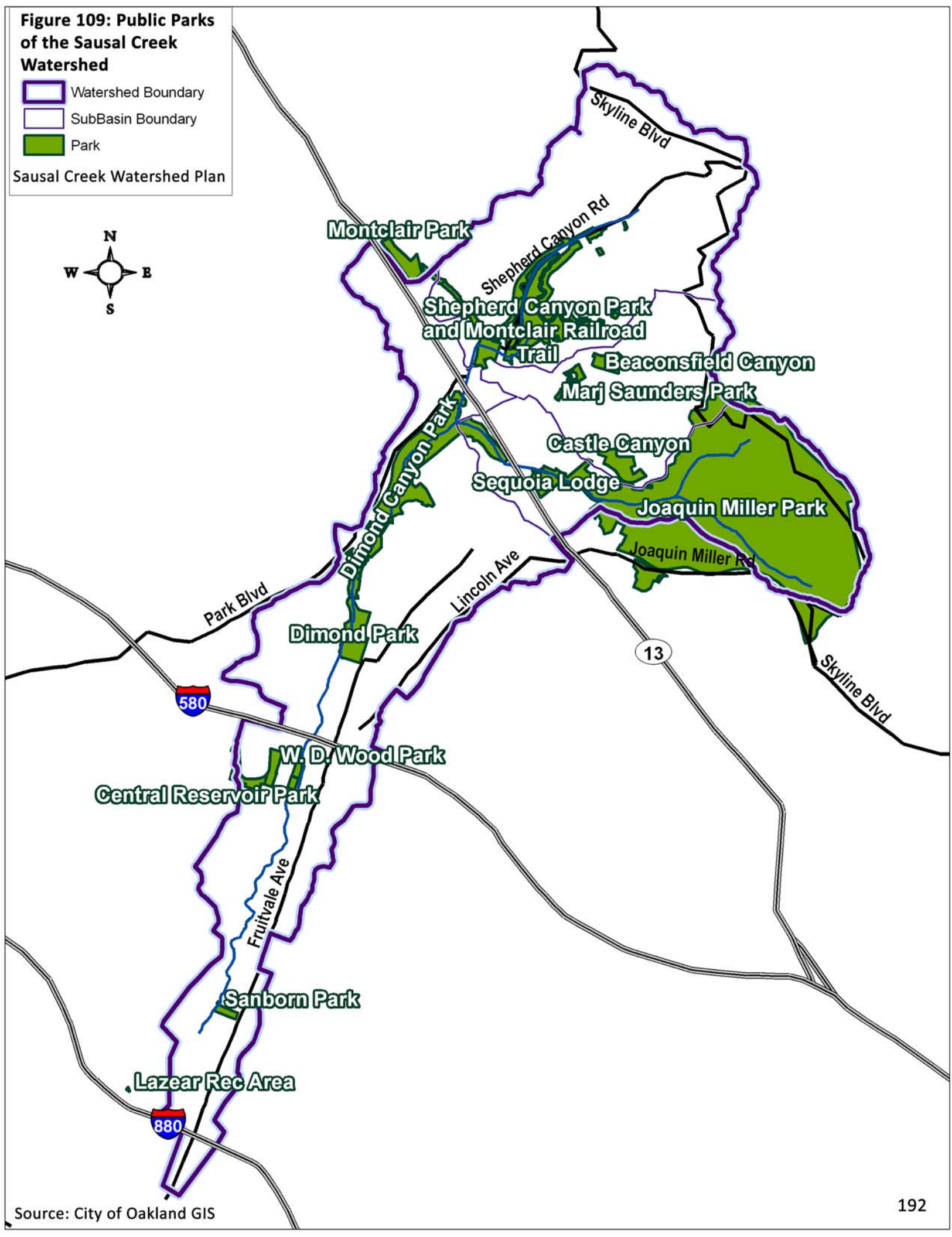


Figure 109: Public Parks of the Sausal Creek Watershed
Watershed Boundary
SubBasin Boundary
Park
Sausal Creek Watershed Plan
N
W
E
S
Skyline Blvd
Montclair Park
Shepherd Canyon Rd
Shepherd Canyon Park and Montclair Railroad Trail
Beaconsfield Canyon
Marj Saunders Park
Castle Canyon
Sequoia Lodge
Joaquin Miller Park
Joaquin Miller Rd
Dimond Canyon Park
Lincoln Ave
Park Blvd
Dimond Park
13
Skyline Blvd
580
W. D. Wood Park
Central Reservoir Park
Fruitvale Ave
Sanborn Park
Lazear Rec Area
880
Source: City of Oakland GIS

**Dimond Canyon and Dimond Park**

In 1850 Hugh Dimond purchased and named the land in Dimond Canyon from the Peralta family. This land became two parks: Dimond Canyon, which stretches from the Montclair Golf Course to the El Centro crossing, and Dimond Park, the more developed area stretching from El Centro to Dimond Ave. (see Figure 109). Dimond used the bricks of the Peralta's adobe house to create a playhouse for his son in the location where the Boy Scout Hut now stands. In 1917 the City of Oakland purchased 12 acres of this land as a park.

During the 1930s the Works Progress Administration (WPA) straightened the Sausal Creek channel, built cement walls, installed drop or grade control structures, and lined the streambed with cement in Dimond Canyon. A major sanitary sewer line is located in the creek bed in this canyon. This WPA project may have been done to protect the sewer line from erosion, or to protect the footings of the Leimert Bridge, or for some other reason. The WPA project may also have been a make-work project to provide employment during the Great Depression.

The creek channel and floodplain was filled to create a meadow, and the creek was channelized and culverted. The Lions pool was built in 1929 and remodeled in 1959. A recreation center was built in 1955 using community donations. In 2001 the Friends of Sausal Creek partnered with the City of Oakland to implement a creek restoration project on Sausal Creek in Dimond Canyon Park. Friends of Sausal Creek installed and maintains a native plant demonstration garden in Dimond Park, and works on removing invasives and planting natives along the creek.

According to FOSC:

> Friends of Sausal Creek has many restoration sites in Dimond Canyon. The channel restoration and revegetation project done in 2001 begins about ¼ mile upstream from El Centro; removal of invasives currently focuses on efforts in the first 600 feet of this reach. On the west bank of the creek, two large sites have been adopted by FOSC members, are being maintained clear of most non-native plants, and are becoming well-covered without planted natives. A project at the end of Benevides Street has created a street-side garden near the trailhead, and has cleared invasive understory and planted many native plants. A group has recently formed to work near the Bridgeview trailhead as well. At the opposite end of the Canyon, FOSC has worked on a redwood site since 2003; invasive plants have been cleared in the areas surrounding the switchback trail. A swale was created to move storm drain output away from the site, and eroding sections of the trail were rebuilt.

**Shepherd Canyon Park and Montclair Railroad Trail**

Shepherd Canyon Park was acquired by the City of Oakland in 1978 and includes approximately 34 acres of sports fields and natural lands. The Shephard Creek channel was filled to create the park, with a culvert installed for creek flow. An ephemeral tributary to Shephard Creek named Escher Creek was relocated to the edge of the fill.

According to FOSC:

> Shepherd Canyon Homeowners Association has been involved in strategic planning and stewardship of Shepherd Canyon Park since 2003. The Association hosts monthly park

cleanups and has cleared nonnative invasive plants and replanted with natives. Future priorities include addressing sediment and erosion problems from city storm drains and the creation of a long-planned trail to connect Shepherd Canyon Park with Dimond Canyon Park.

Across the road from the park, the Montclair Railroad Trail, a hiking/bike path, follows the former railroad route and connects Shepherd Canyon Park with Montclair Park. This land was recently transferred to the City of Oakland in a land-swap with the East Bay Regional Park District. A newly formed group, Friends of the Montclair Railroad Trail, has begun removing invasive plants and planting natives.

**Montclair Park**

Montclair Park, a small park of about 9 acres, sits above Highway 13 and is partly in the Sausal Creek watershed. The City of Oakland has plans to renovate play structures and create wheelchair access to the park.

**Montclair Golf Course**

The Montclair Golf Course is located atop a large culverted and filled section of Sausal Creek just downstream of Highway 13. The Golf Course was completed in 1960.

**Castle Canyon Park**

The 10 acres of Castle Canyon Park were purchased by the City of Oakland in 2004. The Piedmont Pines Neighborhood Association worked for over two decades to protect this area from development. The Association undertook a process to create a master plan for Castle Canyon Park in 2004 and 2005. A survey of residents resulted in the adoption of three ideas for the park: leave the canyon in its existing condition; create a trail to join Joaquin Miller Park; or replace non-native plants with fire-retardant landscaping. Volunteers hold two work days per year in Castle Canyon on Earth Day and on Creek-to-Bay Day.

**Marjorie Saunders Park**

Usually called Marj Saunders Park, this 2-acre site formerly known as Sulphur Springs was re-named in honor of a long-time local resident. Marj Saunders, who moved to the area in 1941, worked to preserve open space by fighting plans for a four-lane highway on Skyline Boulevard and helped in efforts to create Beaconsfield Canyon Park. Piedmont Pines Neighborhood Association has adopted this park and holds monthly work events. In addition, the Joaquin Miller Elementary School Ecology Club has adopted the butterfly garden, and has removed some invasives and planted native plants.

**Beaconsfield Canyon Park**

Most of the land for this park was purchased by the City of Oakland in the 1990s; in April 2008 the City purchased the remaining section of Beaconsfield Canyon, creating a 5-acre park. Cottonwood Creek, a tributary to Cobbledick Creek, runs along the bottom of the canyon. Black cottonwood and red elderberry grow along the creek.

According to FOSC:

> The Wildfire Protection District is using Beaconsfield Canyon as a pilot project for an improved model of fuel abatement that targets cutting or removal of invasive species just before they seed. By clearing individual species at various times of year, the program aims to prevent annual propagation of fire-prone plants and encourage the growth of natives. The goal is to reduce long-term fire maintenance costs and maximize habitat value, biodiversity, and park esthetics. Starting in 2009, the fuel management contract for Beaconsfield is the only year-round contract issued by the WPD. The contract requires a botanist to be on site whenever work is being performed, in order to protect native diversity and to recommend effective fuel treatment measures. With strong participation from Friends of Sausal Creek, volunteers hold workdays one Saturday per month to remove invasive vegetation and plant native plants. A project to remove the culvert and restore the creek channel is in the early planning stages.

**Central Reservoir Recreation Area**

This small park owned by the City of Oakland primarily consists of a playground.

**William D. Wood Park**

The Friends of Sausal Creek have removed invasive non-native broom on the site since 1996. A group of neighbors holds monthly work parties at W.D. Wood Park, mainly focused on removing invasive non-native French broom and planting native plants. Sausal Creek passes through the base of this park in a culvert.

**Sanborn Park/Josie D. de la Cruz Park**

Less than two acres in size, this park in the flatlands of the Sausal Creek watershed features a revitalized community center.

## VI. SUMMARY OF WATERSHED CONDITIONS

The following table provides a summary of the information and analysis completed for the Sausal Creek watershed. The table organizes the analysis in terms of opportunities and constraints for restoration.

**Table 51: Summary of Watershed Conditions**

| Feature | Opportunities | Constraints |
|---|---|---|
| Physical Features | Many of the creek channels in the upper watershed are open and unculverted.<br><br>Most of the Palo Seco Creek sub-basin is undeveloped.<br><br>Sausal Creek is largely unculverted from the Montclair Golf Course to just below Foothill Boulevard.<br><br>Palo Seco Creek and a large portion of Sausal Creek are in public parks.<br><br>Many of the ephemeral creeks in the upper watershed are natural channels. | The Sausal Creek watershed is "built out" as a residential area with some commercial areas. In a built out area it is more difficult to implement creek setbacks, low impact development (LID), stormwater detention, and other facilities to mitigate the pollutant and peak flow effects caused by urbanization than if an area is in the process of being developed.<br><br>The upper watershed is prone to landslides and erosion due to the steep slopes and highly fractured rock along the Hayward fault.<br><br>Most of the creeks downstream of I-580 are culverted.<br><br>Rainstorms of 1 inch precipitation or less cause a 1-year frequency flow event. This frequency flow disturbs aquatic habitats.<br><br>Trails in Joaquin Miller Park have numerous erosion sites.<br><br>Storm drains direct additional runoff into hillside ephemeral creeks, increasing erosion at the outlet of the culvert and in the creek channel. |
| Biological Features | Palo Seco Creek retains high quality aquatic habitat as demonstrated by the diversity, abundance, and pollution-sensitive taxa of aquatic insects sampled in the creek. | Sausal Creek watershed is 78% urban land uses with intensive development from the El Centro crossing downstream and less intensive development upstream.<br><br>Residential areas harbor numerous ornamental plants, some of |

**Table 51: Summary of Watershed Conditions**

| Feature | Opportunities | Constraints |
|---|---|---|
| | Although infested with invasive non-native plants in some locations, the parkland of the Sausal Creek watershed supports a diversity of native and rare plant species.<br><br>A small population of rainbow trout lives in Sausal Creek and lower Palo Seco Creek.<br><br>There are a number of city parks in the watershed where projects to improve creeks and habitats can be implemented. | which are invasive and can spread into natural creeks and out-compete native plants. These invasive non-native plants are widespread in the natural lands of Sausal Creek watershed. Urban areas are a never-ending source of infestation. Many invasive plants are fire hazards.<br><br>Water quality sampling at the five stations in the Sausal Creek watershed found excessive levels of nutrients, no persistent pollutants, and some negative effects from bioassay tests on sediment samples.<br><br>Aquatic insect sampling at all the Sausal stations found poor aquatic habitat conditions and limited aquatic insect abundance and diversity, with almost no pollution-sensitive taxa.<br><br>Bacteria sampling in Sausal Creek and Palo Seco Creek found levels of *E. coli* in excess of standards for water contact recreation in all but one sample. |
| Planning and Infrastructure | The City of Oakland has a creek protection ordinance.<br><br>Oakland has a Wildfire Prevention District works with residents to control invasive non-native plants that are also fire hazards.<br><br>FOSC has implemented a program of invasive non-native plant control and native plant installation involving and educating many residents. | The main sanitary sewer is located adjacent to and in Sausal Creek from below Highway 13 to Dimond Avenue. Raw sewage overflows occur during flood events and *E. coli* sampling indicates leaks may also be occurring.<br><br>Storm drain outlets in the Sausal Creek watershed create erosion in a number of locations.<br><br>The control methods used by the Wildfire Prevention District often cut the same vegetation numerous times and is believed to spread invasive plants through inappropriate management actions (FOSC 2010). |

## VII. EVALUATING WATERSHED STORMWATER IMPROVEMENTS

The assessment of existing conditions in the Sausal Creek watershed demonstrated that changing the volume and timing of stormwater entering the creek system could reduce the negative effects of urbanization on the aquatic and riparian system.

These conditions include:

- High levels of impervious surfaces (asphalt, cement, buildings) resulting in reduced infiltration of rainfall and increased runoff volumes over a shorter period of time.
- Small increments of rainfall produce larger runoff volumes. For example, a storm event with 0.5 inches of rainfall in a 24-hour period can generate a significant level of runoff.
- Poor habitat conditions for aquatic insects in Sausal Creek but good conditions in Palo Seco Creek, a largely undeveloped tributary basin.
- Frequent runoff events (1-year frequency) are capable of scouring the creek, moving gravel and reducing the ability of the creek to support aquatic insects and aquatic habitats.
- Channel entrenchment and the lack of functional floodplain limits riparian corridors to a narrow width and removes natural regeneration and ecological successional processes.
- Numerous erosion sites from storm drain outlets and erosion in many small creeks in the upper watershed.

The watershed was reviewed for locations where stormwater could be detained or temporarily held and released slowly to reduce the volume of peak flows in Sausal Creek. Figures 110 and 111 depict the locations of a series of watershed improvements. These figures also depict seasonal or intermittent creeks and perennial creeks with one shade of blue and ephemeral or temporary creeks in a different shade of blue. Seasonal/perennial creeks appear as “blue lines” on U.S. Geologic Survey topographic maps while ephemeral creeks are not indicated with blue lines due to the very short period of flow. Ephemeral creeks are delineated using topographic contours.

### PARKING LOT DETENTION

Large parking lots were reviewed in the field and measured to determine the volume of water potentially detained on the site. These sites include:

- Chabot Space & Science Center: 2 large parking lots which discharge directly into Joaquin Miller Park and have erosion at their outlets;
- Small parking area at the Metropolitan Horseman’s Association building on Skyline Boulevard
- Joaquin Miller Elementary School/Montara Middle School: large parking lots and fields. This site is constructed on fill in the channel of Cobbledick Creek and may also be appropriate for an underground water storage tank or cistern. The cistern was not included as this is the only large creek fill site with buildings on it and therefore would require considerable disturbance to install a cistern.
- Montclair shopping area parking lot: This small site is near the corner of Mountain Blvd. and Scout Rd.
- Zion Lutheran Church parking lot: This site is just off Park Blvd. near Highway 13.
- Joaquin Miller Park parking lots 1 and 2: These are near the Community Center and Native Plant Nursery.
- Fruitvale commercial areas near the intersection of Fruitvale and Coloma streets and Fruitvale and Montana streets. These four large parking lots drain directly into Sausal Creek.

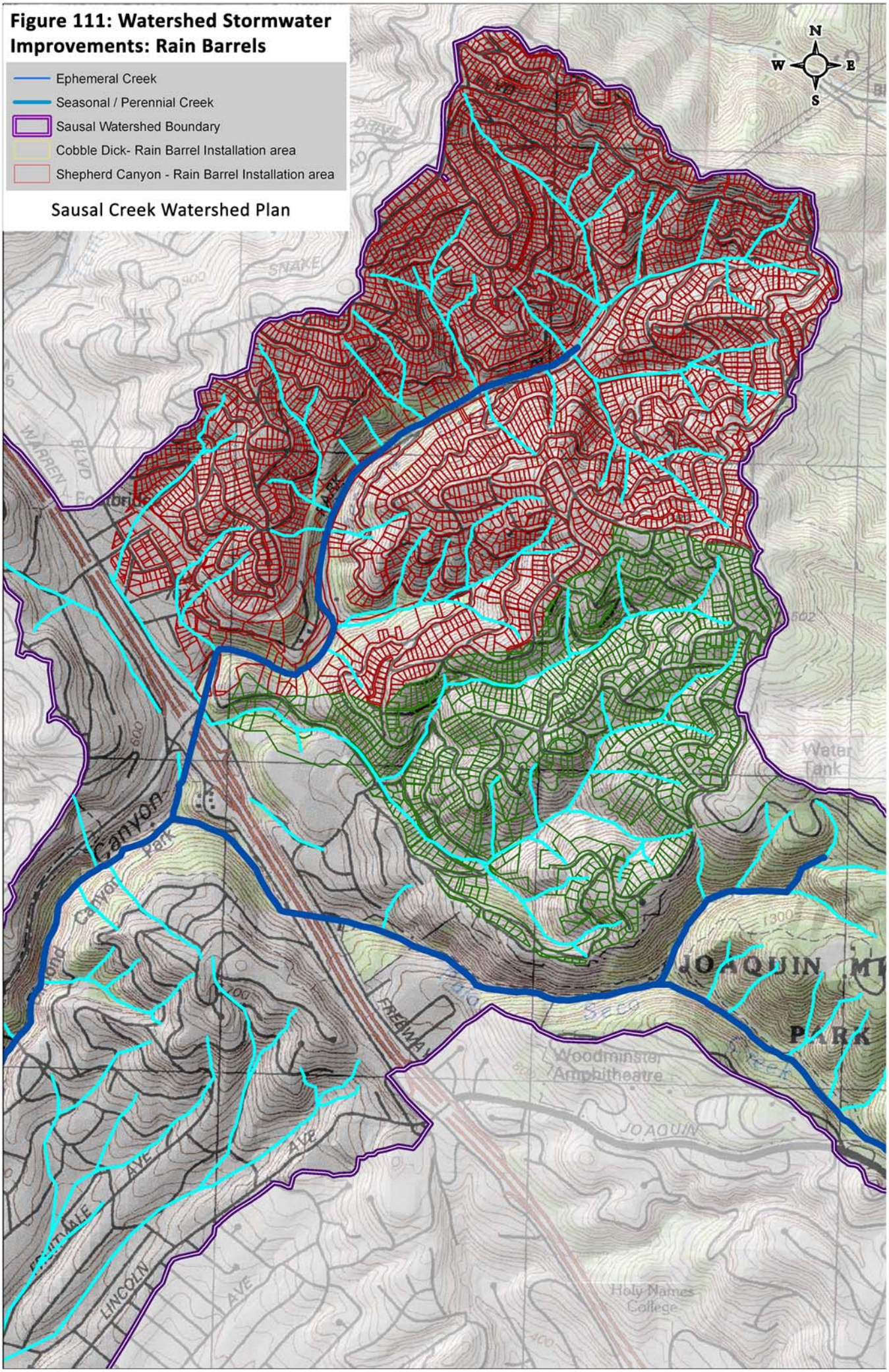
Montclair Railroad Trail 3
Montclair Railroad Trail 2
Montclair Railroad Trail 1
Shepherd Canyon Park
Montclair
Joaquin Miller Elementary School/
Montara Middle School
Zion Lutheran Church
Montclair Golf Course
Larry Lane
Chabot Space and
Science Center 1
Chabot Space and
Science Center 2
Metropolitan Horseman's
Association
Joaquin Miller Park 1
Joaquin Miller Park 2
Joaquin Miller Park – Lower
Meadow
Joaquin Miller Park – Middle
Meadow
Joaquin Miller Park – Upper
Meadow
Dimond Park Meadow
Fruitvale Commercial Area 1 & 2
Fruitvale Commercial Area 3 & 4

**Figure 110: Watershed Stormwater Improvements**

- In-line Underground Detention Site
- In-line Surface Detention Site
- Parking Lot Detention / Biofiltration Site
- Surface detention / Biofiltration Site
- Ephemeral Creek
- Seasonal/Perennial Creek
- Sausal Watershed Boundary

Sausal Creek Watershed Plan

**Figure 111: Watershed Stormwater Improvements: Rain Barrels**



**UNDERGROUND CISTERN DETENTION**

Three large creek channels that have been filled with dirt and culverts installed for the creek—Shepherd Canyon Park, Montclair Golf Course, and the Dimond Park field—were reviewed for installation of a water storage tank or cistern in place of a portion of the fill. The creek would pass through the cistern where water would be detained for a while (Figure 112).

**Park Detention/Recreation Areas**

The meadow areas in Joaquin Miller Park were analyzed as detention basins enclosed by berms that would hold water for a short period after rainstorms but be dry most of the time. This multipurpose use of this meadow allows both environmental and recreational use.

**Basins on Creeks**

Along the Montclair Railroad Trail, which follows the original railroad grade, there are three small basins. These basins are ephemeral creek swales which have been dammed by the railroad berm. Currently, none of them have an outlet and one swale shows signs of having overflowed and eroded the hillside below the trail. Each basin could be engineered to temporarily hold water, but also have a facility to release flows and avoid overflows. These basins could also serve as sediment basins for adjacent erosion; however, annual maintenance would be required for the detention function to work.

The Cobbledick Creek tributary bordering Larry Lane has a sediment/water detention basin with a standpipe (Figure 57). This site needs to be maintained by clearing accumulated sediment from the basin but could serve as a detention facility.

**Rain Barrels**

Another option is dispersed stormwater detention facilities using rain barrels installed at each house in the Shepherd and Cobbledick Creek sub-basins. Each barrel would be able to catch 75 gallons of runoff from the roof of a single home (Figure 113). Water is released from the barrel slowly or can be used in gardens.

**Biofiltration**

An additional water quality benefit can be gained through the installation of biofiltration facilities in the parking lots (Figure 114). Parking lots concentrate oil and grease residues, a persistent pollutant in urban stormwater. With the use of biofiltration facilities, stormwater runs off the parking lot and into biofiltration units before entering the storm drain. Each biofiltration facility has a surface mulch layer which catches particles. Shredded hardwood, pine bark, tree chips, or coarse peat moss are typical mulch materials. Leaf or grass compost is not recommended. Stormwater is directed into the biofiltration facility through a curb cut in the parking lot. Floatable trash is caught on the surface of the device. As the stormwater filters through the mulch layer, trash and particulates are caught. Beneath the mulch are rapid infiltration layers of coarse sand and gravel. It is important to limit clay and silt in this layer to less than five percent of the total volume. At the base is an underdrain which takes the

Figure 112: Water cistern is placed underground to hold stormwater runoff temporarily to reduce downstream effects.

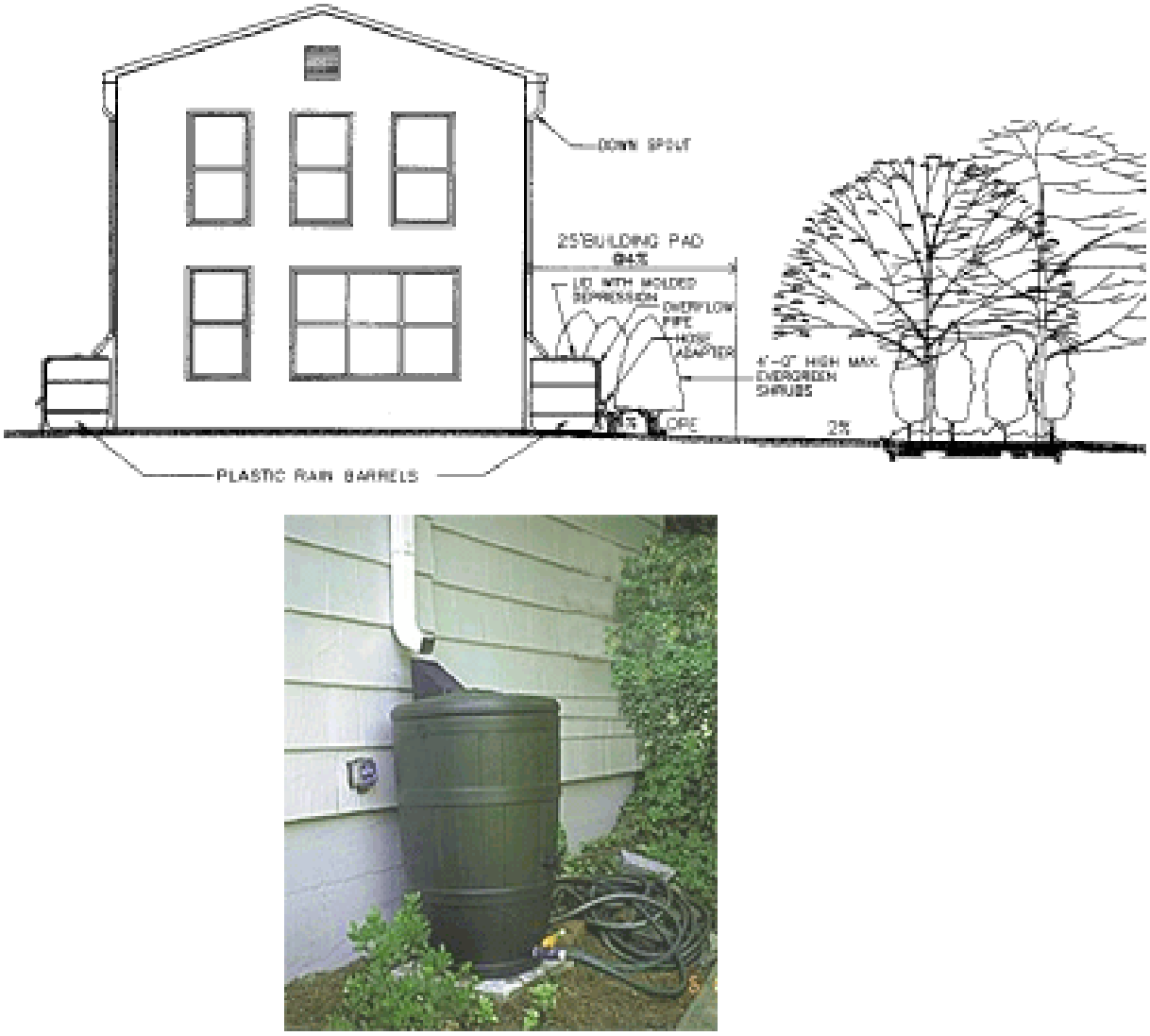



Figure 113: Rain barrels are used in many locations to collect runoff from roof areas for use in garden watering.

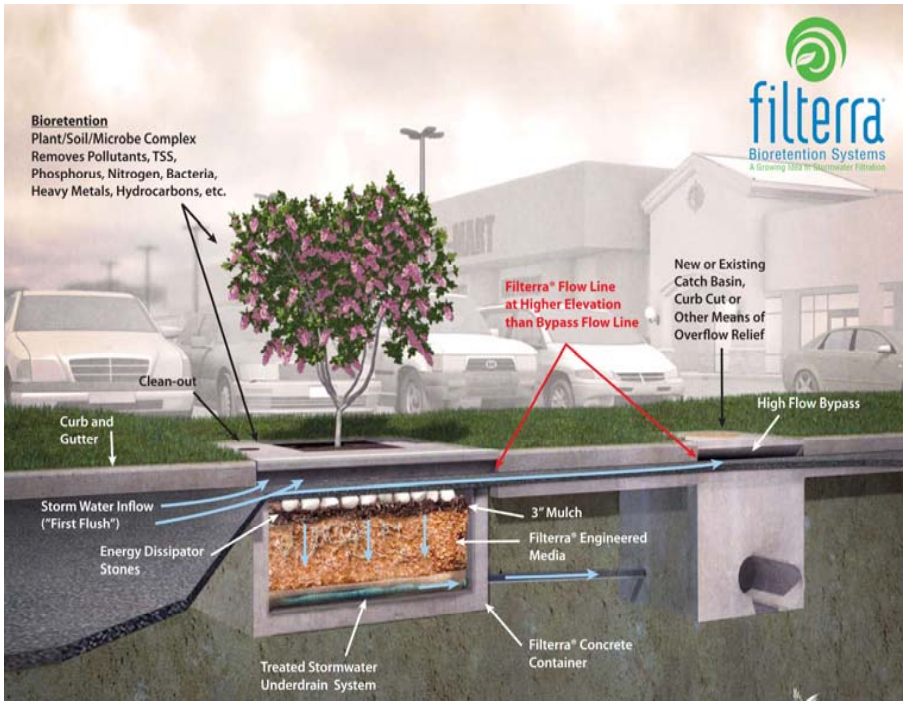


Figure 114: Biofiltration units for parking lots

filtered water to the storm drain system. It is also possible to infiltrate the filtered water if soil types and groundwater levels are appropriate. Each facility has plants, trees, shrubs, and low-growing herbs or rushes which are part of the filtration system. As nutrients such as nitrate fertilizers are filtered out, the plant roots uptake these materials. There needs to be a large number of these small facilities distributed over the drainage in order to have an impact on pollutant levels.

In addition to parking lots there are a number of roads with large turnouts where biofiltration facilities can be installed (Figure 115). Skyline Blvd. in the Sausal Creek watershed has a number of pullouts on the in-sloping side of the roadway where a storm drain inlet is located. A biofiltration unit can be installed around the inlet to reduce pollutants in the stormwater. Park Blvd. along Dimond Canyon also has a number of pullouts which could support biofiltration facilities. Leimert Ave. may also have adequate areas for biofiltration. There are numerous other locations where on-street parking could be changed to accommodate biofiltration facilities where storm drain inlets occur. The runoff from freeways also could be treated by installing biofiltration facilities. Downstream of I-580 in the intensely urbanized area of the watershed, biofiltration units can be installed along streets and sidewalks.

In other cities, the installation of biofiltration facilities has been done to beautify residential and commercial areas. The neighborhoods bordering Fruitvale Ave. just above and below Interstate 580 are relatively flat and have wide enough streets and sidewalks for biofiltration facilities. There are numerous other areas where biofiltration can be installed in the watershed and should be considered. The narrow width of many streets in the upper watershed may limit installation in these areas. Figures 116-119 show examples of biofiltration facilities from Seattle and Portland.

The San Francisco Bay Regional Water Quality Control Board recommends a minimum five inch per hour infiltration rate for these facilities and a minimum of 18 inches of media for filtration. The biofilters can accommodate a certain volume of runoff during rainstorms. When runoff volumes are high, a percentage of the stormwater flow bypasses the filters and directly enters the storm drain system. Most biofiltration facilities also have cleanout/observation wells.

**Other Measures**

Additional practices could be incorporated into the Sausal Creek watershed to reduce runoff. One is the use of porous pavement (Figure 120). Residential driveways, commercial and industrial area landscaping, walkways, and even parking lots can use paving stones set over base rock and sand which provide for infiltration of stormwater instead of runoff. Porous pavement can be incorporated into landscaping using biofiltration measures and rain gardens but is limited in use on steep slopes. Rain gardens can be built at the outlets of roof and gutter systems.

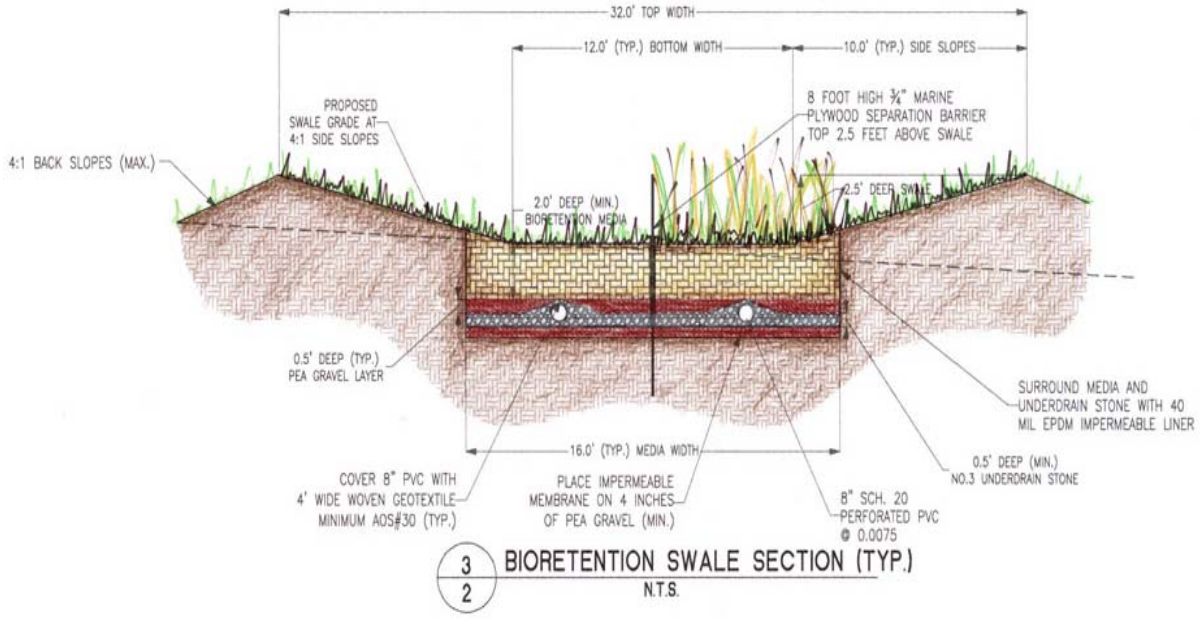


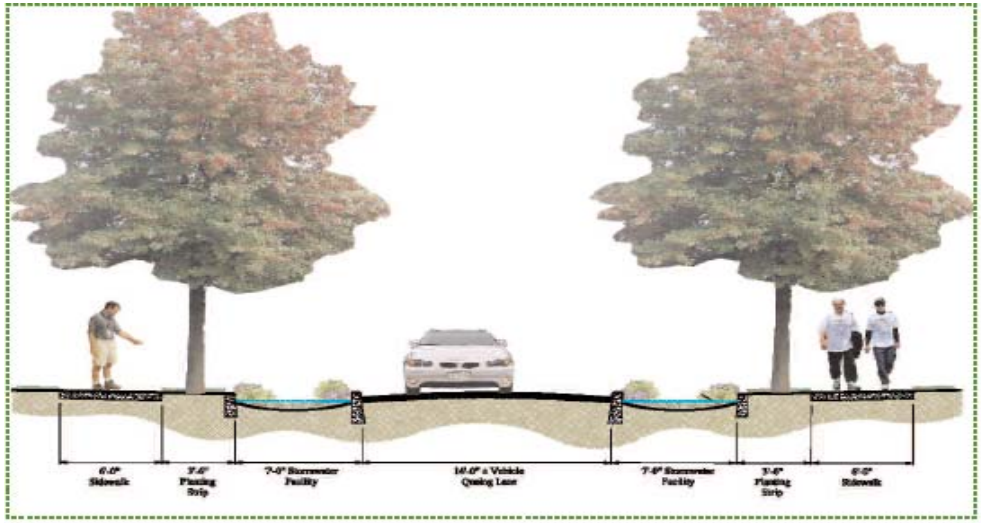

Figure 115: Top: Location along Skyline Blvd. where a biofiltration facility could be installed to improve water quality. Bottom: Drawing of bioretention facility which is defined as filtering storm water through a terrestrial aerobic plant/soil/microbe complex to capture, remove and cycle pollutants through a variety of physical, chemical and biological processes

NE Siskiyou Green Street stormwater curb extension

***Landscaped Storm water Curb Extensions:*** Historically Portland has built curb extensions to improve pedestrian safety. A new variation called a storm water curb extension is landscaped with plants that help filter pollutants from storm water runoff. They have similar benefits to the conventional curb extension but they also improve water quality, reduce storm water flow, and look good.

**Portland**

Stormwater slows as it enters the landscape area, water soaks into the ground, and wetland plants filter pollutants.



Typical Section of NE Siskiyou Street

Figure 116: Biofiltration improvements in residential areas of Portland, Oregon. These filtration areas take storm water from streets through a curb cut and return the filtered water into the storm drain system.

Figure 117: Bioswales on the edges of parking lots.

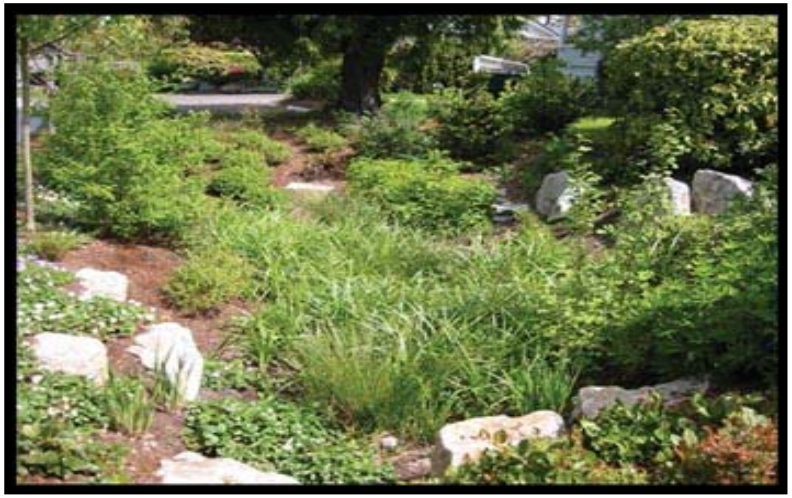
**Portland**

Figure 118: Biofiltration units in commercial area of Portland, Oregon.

## Seattle

Natural materials—plants and soils—slow, filter, and infiltrate storm water runoff… all within the space of the public right-of-way

Calm traffic by narrowing and curving the roadway; provide adequate parking for residents and guests; ensure safe access for emergency vehicles, bicycles and pedestrians



A combination of soils and plants to filter storm water and allow it to seep into the ground as it washes off the roadway and parking spaces.

Figure 119: Examples of biofiltration facilities in residential areas of Seattle.

Figure 120: Permeable pavement allows water to infiltrate into the ground through the spaces between the blocks filled with fine rock. Two layers of rock below the pavers provide a strong base for the street and help the infiltration process. Geotextile fabric layers below the base rock further reduce pollutants carried into the soil as the water infiltrates

downspouts. They provide a rock dissipater or stilling basin and biofiltration to treat the runoff depending on the site. Grass or bioswales are wide vegetated channels that allow stormwater to flow through and deposit particulates and infiltrate before leaving the site (Figure 118).

These practices can remove pollutants and reduce the volume of runoff reaching creeks. The application of these measures to individual home sites, however, needs to consider the slope and soil types of the site. Information on these BMPs is available at a number of websites listed in Table 52.

**Table 52: Low Impact Development (LID) and Urban BMP Resources**

| Resource | Web Address |
|---|---|
| EPA: Urban BMP Performance Tool | http://cfpub.epa.gov/npdes/stormwater/urbanbmp/bmpeffectiveness.cfm |
| EPA: Low Impact Development (LID) | http://epa.gov/nps/lid/ |
| Low Impact Development Center | http://www.lowimpactdevelopment.org |
| Low Impact Development (LID) Urban Design Tools Website | http://www.lid-stormwater.net/ |
| California Stormwater Quality Association: Stormwater Best Management Practice (BMPs) Handbooks | http://www.cabmphandbooks.com/ |
| The Stormwater Manager's Resource Center (SMRC): Bioretention | http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Filtering%20Practice/Bioretention.htm |
| University of Rhode Island: Healthy Landscapes | http://www.uri.edu/ce/healthylandscapes/index.html |
| Interlocking Concrete Pavement Institute: Permeable Pavement | http://icpi.org/design/permeable_pavers.cfm |
| Rain Gardens of West Michigan | http://www.raingardens.org/Index.php |
| Filterra Bioretention Systems | http://www.filterra.com/ - |

## EVALUATING WATERSHED IMPROVEMENTS WITH HYDROLOGIC AND HYDRAULIC MODELS

For the hydrology and hydraulics analysis, a subset of the watershed improvements that have the potential to significantly alter hydrologic and hydraulic processes in the watershed were modeled using the SWMM hydrologic model and the HEC-RAS hydraulic model. These improvements are listed in Table 53 and their locations displayed in Figures 110 and 111. For modeling and assessment purposes,

assumptions were made in terms of the physical dimensions, amount of storage each facility could achieve, available capture volume, infiltration rates of the facilities, and overflow devices such as the sizing and placement of weirs and orifices. These details are outlined in Table 54.

The watershed improvements were grouped into specific scenarios for the modeling runs, with each scenario then compared to existing conditions. Scenario 1 includes all of the surface detention sites. Scenario 2 includes all of the facilities in Scenario 1 and adds two in-line detention sites or basin/cistern sites in the upper watershed. Scenario 3 includes all of the facilities from Scenarios 1 and 2 and adds two in-line detention sites/cisterns in the lower watershed. These scenarios are listed in the following table.

**Table 53: Sausal Creek Watershed Stormwater Improvement Sites**

| Improvement | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Rain barrel at each house in the Shephard and Cobbledick Creek sub-basins | ✓ | ✓ | ✓ |
| Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Joaquin Miller Elementary School/Montara Middle School Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Montclair Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Joaquin Miller Park Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Zion Lutheran Church Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 1 | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 2 | ✓ | ✓ | ✓ |

**Table 53: Sausal Creek Watershed Stormwater Improvement Sites**

| Improvement | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Montclair Railroad Trail – Stormwater Detention Basin 3 | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Upper Meadow Detention Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Middle Meadow Detention Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Lower Meadow Detention Site | ✓ | ✓ | ✓ |
| Metropolitan Horseman's Association Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 3 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 4 | ✓ | ✓ | ✓ |
| Shepherd Canyon Park – Underground Cistern | | ✓ | ✓ |
| Larry Lane On-stream Detention Pond | | ✓ | ✓ |
| Montclair Golf Course – Underground Cistern | | | ✓ |
| Dimond Park Meadow – Underground Cistern | | | ✓ |

**Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis**

| Tributary Watershed | Sub-basin ID | Scenario | Location | Stormwater BMP | Assumptions | Capturing Drainage Area ($ft^2$) | Detention Basin Footprint ($ft^2$) | Detention Basin Berm Height / Cistern Max Depth (ft) | Number of Barrels Per Basin (1 Per Parcel) | Achieved Maximum Storage Volume ($ft^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Shephard Creek | In-line storage | 2 | Shepherd Canyon Park | Subsurface cistern | Available average subsurface depth of cistern is 6 ft., 25% of the footprint of park considered for subsurface detention | Shephard Creek sub-basin upstream of park | 32,100 | 6 | N/A | 192,600 |
| Shephard Creek | SC-13 | 1 | Bike trail Detention Basin 1 | Detention site | Surface facility with a berm, will capture upstream runoff | 96,703 | 2,325 | 12.5 | N/A | 29,063 |
| Shephard Creek | SC-10 | 1 | Bike trail Detention Basin 2 | Detention site | Surface facility with a berm, will capture upstream runoff | 83,200 | 6,000 | 15 | N/A | 90,000 |
| Shephard Creek | SC-10 | 1 | Bike trail Detention Basin 3 | Detention site | Surface facility with a berm, will capture upstream runoff | 308,405 | 8,640 | 12 | N/A | 103,680 |
| Shephard Creek | SC-13 | 1 | Montclair parking lot at Scout Rd. / Mountain Blvd. | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas, includes runoff from rooftops of adjacent commercial buildings, slope of .01% | 81,800 | 8,180 | 3 | N/A | 24,540 |

**Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis**

| Tributary Watershed | Sub-basin ID | Scenario | Location | Stormwater BMP | Assumptions | Capturing Drainage Area ($ft^2$) | Detention Basin Footprint ($ft^2$) | Detention Basin Berm Height / Cistern Max Depth (ft) | Number of Barrels Per Basin (1 Per Parcel) | Achieved Maximum Storage Volume ($ft^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Shephard Creek | Dispersed in SC-0, SC-1, SC-2, SC-3, SC-4, SC-5, SC-6, SC-7, SC-8, SC-9, SC-10, SC-11, SC-12, SC-13 | 1 | Per parcel | Rain Barrels | 1 rain barrel per parcel, assume maximum efficiency, assume 75 gallon capacity, assume 2,116 parcels in Shephard Creek tributary watershed, and 151.1 parcels per sub-basin | Varies | 505 | 3 | 2,116 | 21,160 |
| Cobbledick Creek | In-line storage C-3, C-4 | 2 | Larry Lane on-stream pond | Surface detention site | Surface detention pond with a dam, in-line with Cobbledick Creek channel, will capture flow from upstream watershed | Tributary to Cobbledick Creek sub-basin upstream of Larry Lane | 5,400 | 12.5 | N/A | 67,500 |
| Cobbledick Creek | DC-2 | 1 | Joaquin Miller Elementary/Montara Middle School parking lot | Parking lot detention basin / biofiltration | Will provide detention for max 24-hour runoff during 5-yr event, includes runoff from rooftops of school buildings, walkways, and asphalt playground | 524,400 | 33,803 | 5 | N/A | 169,015 |

**Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis**

| Tributary Watershed | Sub-basin ID | Scenario | Location | Stormwater BMP | Assumptions | Capturing Drainage Area ($ft^2$) | Detention Basin Footprint ($ft^2$) | Detention Basin Berm Height / Cistern Max Depth (ft) | Number of Barrels Per Basin (1 Per Parcel) | Achieved Maximum Storage Volume ($ft^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Cobbledick Creek | Dispersed in C-1, C-2, C-3, C-4, C-5 | 1 | Per parcel | Rain Barrels | 1 rain barrel per parcel, assume maximum efficiency, assume 75 gallon capacity, assume 732 parcels in Cobbledick Creek tributary watershed, and 146.4 parcels per sub-basin | N/A | 489 | 3 | 732 | 7,320 |
| Palo Seco Creek | PS-1 | 1 | Chabot Space & Science Center parking lot 1 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 16,350 | 1,635 | 5 | N/A | 8,175 |
| Palo Seco Creek | PS-1 | 1 | Chabot Space & Science Center parking lot 2 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 46,810 | 4,681 | 5 | N/A | 23,405 |
| Palo Seco Creek | PS-1 | 1 | Metropolitan Horseman's Association parking lot | Parking lot detention basin / biofiltration | Surface facility with a berm, will capture upstream runoff | 305,300 | 45,800 | 15 | N/A | 687,000 |
| Palo Seco Creek | PS-3 | 1 | Joaquin Miller Park parking lot 1 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 71,260 | 7,126 | 5 | N/A | 35,630 |
| Palo Seco Creek | PS-3 | 1 | Joaquin Miller Park parking lot 2 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 31,290 | 3,129 | 5 | N/A | 15,645 |

**Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis**

| Tributary Watershed | Sub-basin ID | Scenario | Location | Stormwater BMP | Assumptions | Capturing Drainage Area ($ft^2$) | Detention Basin Footprint ($ft^2$) | Detention Basin Berm Height / Cistern Max Depth (ft) | Number of Barrels Per Basin (1 Per Parcel) | Achieved Maximum Storage Volume ($ft^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Palo Seco Creek | PS-2 | 1 | Joaquin Miller Park –Upper Meadow | Detention site | Add berms to provide detention | 3,843,185 | 4,685 | 15 | N/A | 70,275 |
| Palo Seco Creek | PS-2 | 1 | Joaquin Miller Park – Middle Meadow | Detention site | Add berms to provide detention | 6,424,863 | 19,810 | 15 | N/A | 297,150 |
| Palo Seco Creek | PS-3 | 1 | Joaquin Miller Park Lower Meadow | Detention site | Add berms to provide detention | 6,424,863 | 30,680 | 15 | N/A | 460,200 |
| Sausal Creek | In-line storage | 3 | Montclair Golf Course | Subsurface cistern / detention | Available average subsurface depth of cistern is 10 ft., 50% of the footprint of area available for subsurface detention | Sausal Creek watershed upstream of golf course | 57,800 | 10 | N/A | 578,000 |
| Sausal Creek | DC-3 | 1 | Zion Lutheran Church parking lot | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 55,970 | 5,597 | 5 | N/A | 27,985 |
| Sausal Creek | In-line storage | 3 | Dimond Canyon Park lawn area | Subsurface cistern / detention | Available average subsurface depth of cistern is 6 ft., 75% of the footprint of park available for subsurface detention | Sausal Creek basin upstream of Dimond Park | 86,700 | 6 | N/A | 520,200 |

**Table 54: Watershed Stormwater Improvements in the Sausal Creek Watershed Evaluated in the Hydrologic & Hydraulic Analysis**

| Tributary Watershed | Sub-basin ID | Scenario | Location | Stormwater BMP | Assumptions | Capturing Drainage Area ($ft^2$) | Detention Basin Footprint ($ft^2$) | Detention Basin Berm Height / Cistern Max Depth (ft) | Number of Barrels Per Basin (1 Per Parcel) | Achieved Maximum Storage Volume ($ft^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| Sausal Creek | DC-6 | 1 | Fruitvale / Macarthur intersection commercial area parking lot site 1 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 132,500 | 13,250 | 5 | N/A | 66,250 |
| Sausal Creek | DC-6 | 1 | Fruitvale / Macarthur intersection commercial area parking lot site 2 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 177,000 | 17,700 | 5 | N/A | 88,500 |
| Sausal Creek | DC-6 | 1 | Fruitvale / Macarthur intersection commercial area parking lot site 3 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 71,280 | 7,128 | 5 | N/A | 35,640 |
| Sausal Creek | DC-6 | 1 | Fruitvale / Macarthur intersection commercial area parking lot site 4 | Parking lot detention basin / biofiltration | Will provide detention for adjacent impervious areas | 51,280 | 5,128 | 5 | N/A | 25,640 |

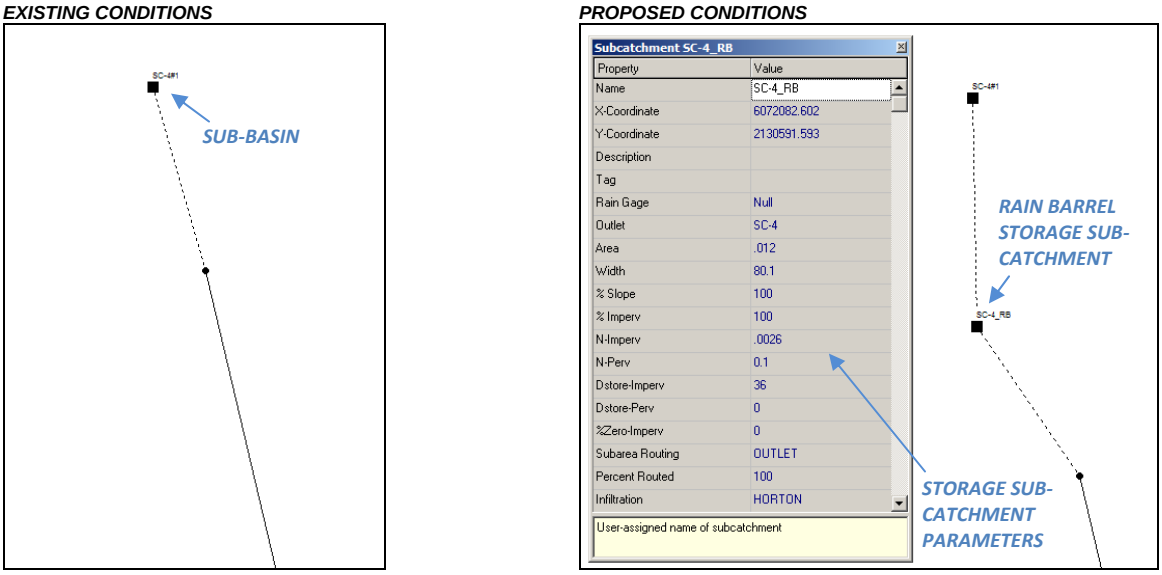
## Hydrologic Model

The Sausal Creek existing conditions SWMM model was used as a baseline framework, with proposed improvements "added on" as follows:

**Scenario 1**

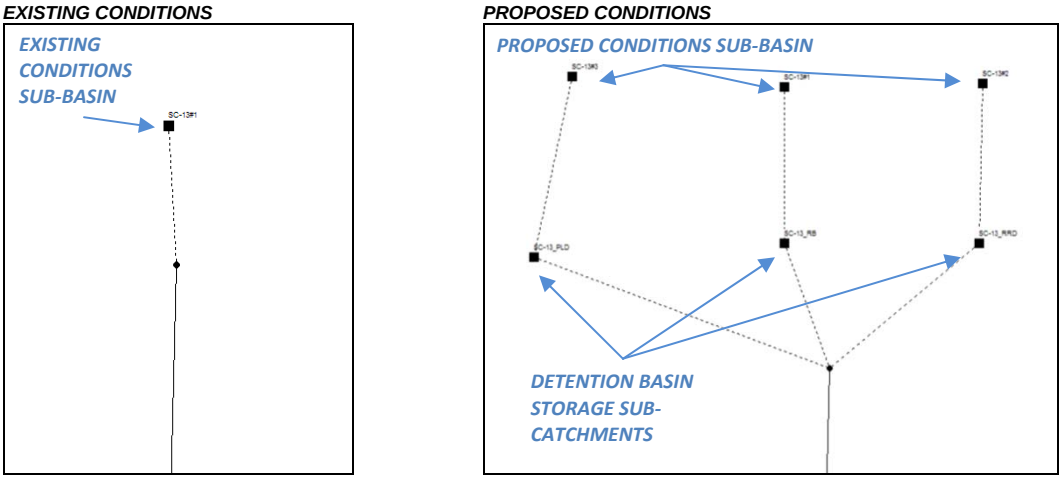
**Rain barrels**: An analysis of the number of parcels with a housing unit or structure in the Shephard and Cobbledick Creek watersheds was performed using current parcel GIS data from the City of Oakland. Under this improvement, one house could have numerous rain barrels, while other residents did not participate in the program. It was assumed that each housing unit would receive an average of one 75-gallon overflow rain barrel. From this analysis, a total number of rain barrels for each watershed was calculated, and then divided by the total number of sub-basins in each watershed to obtain a number of barrels for each sub-basin. Finally, a total rain barrel storage volume was calculated for each sub-basin. In the SWMM model, the rain barrels were simulated by adding an additional sub-basin to act as a storage node for the rain barrels. These "storage sub-basin" include a depression in the impervious area with a storage capacity equal to that of the total rain barrel storage volume; water is collected in the depression and the residual water is treated as overflow and routed towards the outlet (Figure 122). Sub-basin parameters were adjusted to mimic the performance of an overflowing rain barrel according to guidance from Aad (2009) on modeling green infrastructure using SWMM.

**Figure 121: Existing Conditions and Proposed Conditions Demonstrating the Rain Barrel Modeling Technique in EPA SWMM 5.0**




**Parking lot detention and other watershed detention sites:** For the sites that capture overland flow and shallow concentrated flow from adjacent impervious surfaces such as parking lots, rooftops, and sidewalks in a designated sub-basin, additional sub-basins were created that model these drainage areas. "Storage sub-basins" were then developed to model the storage capacities of the individual facilities, in a similar manner as described above (Figure 123). Storage facility dimensions were calculated by measuring available areas from aerial photographs in ESRI ArcMap and by taking field survey measurements.

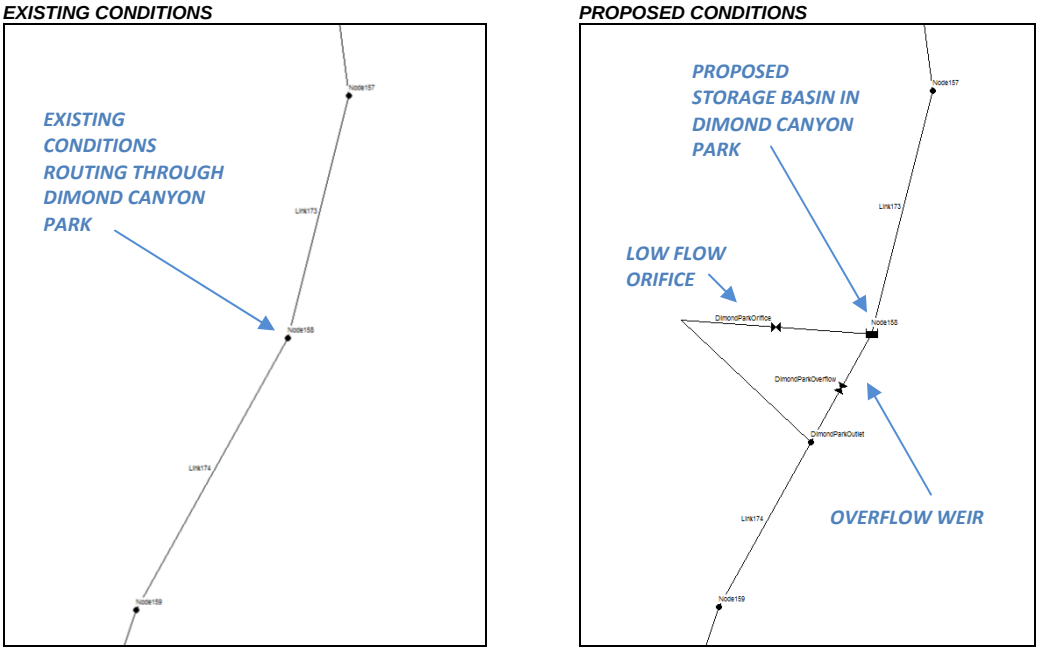
**Figure 122: Existing Conditions and Proposed Conditions Demonstrating the Upper Watershed Detention Basin Modeling Technique in EPA SWMM 5.0**




**Scenarios 1, 2, & 3**

**In-line detention sites:** The upper watershed in-line cistern in Shepherd Canyon Park and the surface detention basin at Larry Lane, as well as the lower watershed in-line cistern at the Montclair Golf Course and Dimond Canyon Park were simulated in EPA SWMM 5.0 by creating a storage basin node in the approximate location of the facility along the channel (Figure 124). EPA SWMM 5.0 requires these in-line storage facilities to have a storage curve that reflects the dimensions of the facility, as well as outlet orifices and weirs to determine how water routes through and overflows the facility. The storage basins were sized according to field measurements, with the assumptions noted in Table 54. Outlet orifices and weirs were designed to accommodate a maximum 100 year flow event without flooding (backwater) effects behind the facility, but to maximize the detention time for all flow events.

**Figure 123: Existing Conditions and Proposed Conditions Demonstrating the In-line Storage Basin Modeling Technique in EPA SWMM 5.0**




## Comparison of Existing Conditions and Proposed Conditions Using the Hydrologic Model

The Sausal Creek watershed EPA SWMM 5.0 model was run for the 1, 2, 5, 10, 25, and 100-year recurrence interval precipitation events under existing conditions and three different scenarios of watershed stormwater improvements (Table 55). Complete results from the hydrology modeling output are included as Excel tables in Appendix G, and are summarized in the following sections.

Existing conditions peak discharge values for each sub-basin in the watershed, as well as at the outlets of Shephard Creek, Cobbledick Creek, Palo Seco Creek, and Sausal Creek and other specific locations along the main channel, are provided in Table 14 (page 67). These are compared to Scenarios 1, 2, and 3 in the following sections and the percentage change of each scenario is compared to existing conditions values.

### Scenario 1

Results indicate that the implementation of watershed improvements listed under Scenario 1 (Table 53) leads to minor reductions to flow volumes in Sausal Creek by capturing and storing flows in the watershed. However, flow rates and volumes in Palo Seco Creek are significantly reduced (between 14% and 17% from existing conditions), and flow rates and volumes for the 1-year flow event are significantly reduced (Tables 55 and 56).

**Table 55: Scenario 1 Hydrology Modeling Results Showing Percent Change in Peak Runoff from Existing Conditions**

| PEAK RUNOFF (% CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet) | 0.3% | 2.3% | 0.1% | 1.5% | 2.3% | -3.1% |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 0.9% | 1.5% | 1.2% | 0.6% | 5.3% | -5.3% |
| Outlet of Cobbledick Creek (Node 30) | 1.1% | 1.6% | -0.3% | 1.0% | 4.7% | -2.0% |
| Outlet of Shephard Creek (Node SC-R) | -14.6% | 0.7% | 0.1% | 0.4% | -0.1% | -9.9% |
| Outlet of Palo Seco Creek (Node 121) | -15.7% | -16.6% | -16.2% | -16.9% | -17.0% | -13.8% |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -11.1% | 0.9% | -0.1% | 0.5% | 1.2% | -7.9% |
| Inlet to the Golf Course Culvert (Node 52) | -11.9% | -2.5% | -3.0% | -2.7% | -2.2% | -8.8% |
| Outlet of Dimond Canyon Park (Node 163) | -5.9% | -1.5% | -4.4% | -3.1% | -1.4% | -8.6% |
| Outlet to the Bay (Node 179) | -6.4% | -1.7% | -3.7% | -1.7% | -1.3% | -7.2% |

**Table 56: Scenario 1 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions**

| TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet) | 1.8% | 1.7% | -0.7% | 0.9% | 0.5% | -12.3% |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 2.1% | 2.5% | 1.8% | 1.7% | 1.3% | -8.9% |
| Outlet of Cobbledick Creek (Node 30) | -9.3% | 2.0% | -9.4% | 1.3% | 1.0% | -7.6% |
| Outlet of Shephard Creek (Node SC-R) | -16.0% | -0.1% | -2.1% | -0.7% | -1.3% | -16.2% |
| Outlet of Palo Seco Creek (Node 121) | -24.0% | -17.3% | -17.4% | -16.8% | -17.2% | -15.3% |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -14.2% | 0.5% | -8.2% | -0.2% | -0.7% | -13.7% |
| Inlet to the Golf Course Culvert (Node 52) | -16.0% | -2.7% | -6.5% | -3.1% | -3.6% | -14.0% |
| Outlet of Dimond Canyon Park (Node 163) | -14.2% | -2.0% | -8.9% | -2.0% | -2.4% | -8.6% |
| Outlet to the Bay (Node 179) | -11.0% | -1.8% | -6.9% | -1.9% | -2.1% | -6.9% |

**Scenario 2:**
The additional implementation of cisterns in Shepherd Canyon Park and a detention pond along Larry Lane significantly reduces flow rates in the upper watershed for the 1-year event (in Shephard and Cobbledick Creeks especially), and less so for the larger events. There are also additional reductions in flow volumes for the 1-year event (Tables 57 and 58).

**Table 57: Scenario 2 Hydrology Modeling Results Showing Percent Change in Peak Runoff from Existing Conditions**

| PEAK RUNOFF (% CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet) | -7.2% | -5.4% | -6.0% | -4.8% | -3.1% | -26.1% |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | -0.5% | 11.1% | 19.4% | 3.3% | 17.0% | -59.6% |
| Outlet of Cobbledick Creek (Node 30) | 0.7% | 4.6% | 9.5% | 2.6% | 10.0% | -46.6% |
| Outlet of Shephard Creek (Node SC-R) | -15.5% | -0.9% | -0.7% | -1.1% | -0.7% | -29.3% |
| Outlet of Palo Seco Creek (Node 121) | -15.7% | -16.6% | -16.2% | -17.0% | -18.2% | -14.4% |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -11.8% | 0.1% | 2.0% | -0.1% | 2.1% | -34.5% |
| Inlet to the Golf Course Culvert (Node 52) | -12.5% | -3.2% | -1.4% | -3.2% | -1.7% | -33.2% |
| Outlet of Dimond Canyon Park (Node 163) | -6.3% | -1.5% | -3.2% | -4.8% | -2.8% | -22.0% |
| Outlet to the Bay (Node 179) | -6.8% | -1.7% | -2.7% | -2.8% | -2.4% | -21.6% |

**Table 58: Scenario 2 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions**

| TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet) | 2.6% | 4.0% | 2.4% | -0.1% | -1.0% | -27.1% |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 27.4% | 37.4% | 49.7% | 16.2% | 19.4% | -30.2% |
| Outlet of Cobbledick Creek (Node 30) | 2.2% | 2.0% | 12.0% | 8.6% | 10.2% | -18.3% |
| Outlet of Shephard Creek (Node SC-R) | -15.9% | -0.1% | -0.4% | -2.2% | -3.2% | -26.2% |
| Outlet of Palo Seco Creek (Node 121) | -24.1% | -17.3% | -17.4% | -19.0% | -20.0% | -16.0% |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -11.1% | 0.5% | -1.0% | 0.7% | 0.4% | -24.0% |
| Inlet to the Golf Course Culvert (Node 52) | -13.4% | -2.7% | -0.3% | -2.7% | -3.2% | -22.7% |

**Table 58: Scenario 2 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions**

| TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Outlet of Dimond Canyon Park (Node 163) | -12.2% | -2.0% | -4.8% | -5.0% | -6.0% | -18.3% |
| Outlet to the Bay (Node 179) | -9.5% | -1.8% | -4.0% | -4.0% | -4.8% | -14.5% |

**Scenario 3:**

The additional implementation of cisterns at the Montclair Golf Course and Dimond Canyon Park along with Scenarios 1 and 2 reduces flow rates in Sausal Creek for the 1-year event and less so for the larger events. Only minor additional reductions in flow volumes occur in Sausal Creek in the lower watershed (Tables 59 and 60).

**Table 59: Scenario 3 Hydrology Modeling Results Showing Percent Change in Peak Runoff from Existing Conditions**

| PEAK RUNOFF (% CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet) | -7.2% | -5.4% | -6.6% | -4.8% | -4.2% | -26.1% |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | -0.6% | 12.8% | 16.3% | 3.1% | 11.3% | -59.6% |
| Outlet of Cobbledick Creek (Node 30) | 0.7% | 6.1% | 7.6% | 2.6% | 6.4% | -46.6% |
| Outlet of Shephard Creek (Node SC-R) | -15.5% | -0.8% | -1.3% | -1.1% | -1.6% | -29.3% |
| Outlet of Palo Seco Creek (Node 121) | -15.6% | -16.7% | -16.7% | -17.1% | -18.6% | -14.6% |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -11.8% | 0.9% | 1.1% | 0.0% | 0.4% | -34.5% |
| Outlet of the Golf Course Basin (GolfCourseOutlet) | -13.7% | -3.9% | -3.5% | -4.2% | -4.8% | -50.6% |
| Outlet of Dimond Canyon Park (Node 163) | -12.7% | -22.1% | -26.1% | -10.8% | -7.2% | -57.7% |
| Outlet to the Bay (Node 179) | -9.1% | -5.3% | -7.5% | -6.0% | -6.6% | -49.7% |

**Table 60: Scenario 3 Hydrology Modeling Results Showing Percent Change in Total Volume from Existing Conditions**

| TOTAL VOLUME (% CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shephard Creek Below Shepherd Canyon Park (Node SC-F / ShepParkOutlet) | 2.7% | 0.7% | -2.2% | -0.2% | -4.3% | -27.1% |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 26.6% | 17.9% | 22.5% | 16.2% | 1.6% | -30.2% |
| Outlet of Cobbledick Creek (Node 30) | 1.8% | 9.8% | -0.1% | 8.6% | 1.2% | -18.3% |
| Outlet of Shephard Creek (Node SC-R) | -15.8% | -1.3% | -3.7% | -2.2% | -5.4% | -26.2% |
| Outlet of Palo Seco Creek (Node 121) | -24.1% | -18.7% | -18.8% | -19.1% | -20.5% | -16.0% |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -11.2% | 1.7% | -6.7% | 0.7% | -3.7% | -23.9% |
| Outlet of the Golf Course Basin (GolfCourseOutlet) | -11.2% | -0.9% | -4.3% | -1.8% | -8.1% | -35.7% |
| Outlet of Dimond Canyon Park (Node 163) | -10.9% | -3.9% | -10.7% | -4.8% | -11.2% | -30.8% |
| Outlet to the Bay (Node 179) | -8.5% | -3.2% | -8.2% | -3.9% | -8.5% | -24.2% |

As shown in the preceding tables, there were small flow continuity errors in the model (created when nodes or conduits flood or surcharge) that caused minor increases in flow volumes and rates for some of the scenarios. These increases are small and do not indicate a significant problem with the model output. There is additional error associated with the model results for the 100-year event. When flooding or surcharging of nodes or conduits occurs, EPA SWMM 5.0 effectively deletes flow beyond a designated ponding value. Thus, flooding of storage basins associated with the 100-year event is expressed as reduced flow compared to existing conditions. Finally, the peak runoff and peak volume increases for Cobbledick Creek (below Larry Lane and at the sub-basin outlet) for flows above the 1-year recurrence interval event are attributed to the sizing of the detention facility at Larry Lane, as well as flow routing and continuity problems in the Cobbledick Creek basin.

**Comparison of Existing Conditions and Proposed Conditions Using the Hydraulic Model**

The hydraulic model uses the hydrologic model outputs to simulate stream flow and the velocity of flow, depth of flow, and shear stress of the flow on the stream bed.

NRBS ran the calibrated HEC-RAS model for the 1, 2, 5, 10, 25, and 100-year recurrence interval discharges under existing conditions and with the three different scenarios. Complete results from hydraulic modeling comparisons of existing (E) and proposed (P) conditions are summarized in standard HEC-RAS output tables in Appendix F.

The following sections present comparisons of existing and proposed conditions for each of the three proposed scenarios and highlight results that are most relevant to channel form, sediment transport, and habitat in the modeled reaches of Sausal Creek. For each scenario, the potential hydraulic improvements are reviewed by comparing water surface elevation, velocity, and shear stress results for

the existing and proposed hydrologic conditions. Water surface elevation changes indicate the impact that improvements in the watershed have on conveyance and flooding, while changes in velocity and shear stress indicate the impact of improvements on erosion, scour, sediment transport, and riparian vegetation regeneration, and therefore on the overall creation and maintenance of channel form and associated aquatic and riparian habitats.

**Figure 124: Existing conditions longitudinal shear stress plot. Dotted red line signifies approximate stability threshold for typical Sausal Creek sediment and vegetation characteristics. Velocities and shear stresses are largely controlled by channel geometry in this portion of Sausal Creek, with high velocities and shear stresses in narrow reaches.**

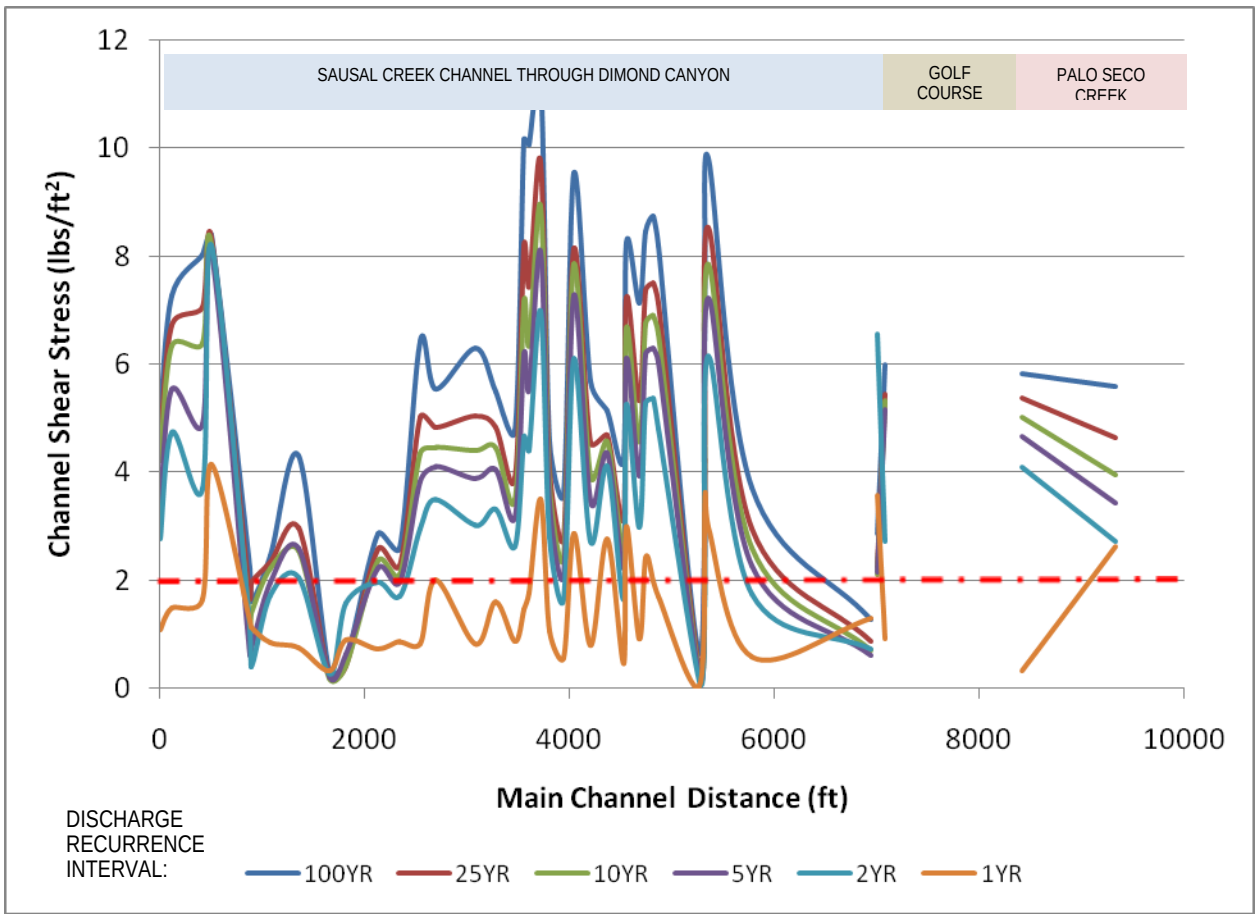



**Table 61: Permissible velocities and shear stresses for channel sediment and vegetation types similar to Sausal Creek (after Fischenich 2001)**

| Material | Permissible Velocity (ft/sec) | Permissible Shear Stress (lbs/ft$^2$) |
|---|---|---|
| Gravel (2 inch) | 3.0 – 6.0 | 0.67 |
| Cobble (6 inch) | 4.0 – 7.5 | 2.0 |
| Riprap (18 inch) | 12.0 – 16.0 | 7.6 |
| Emergents | n/a | 0.1 – 0.6 |
| Grasses | 3.0 – 6.0 | 0.7 – 1.7 |
| Woody Vegetation | 3.0 – 10.0 | 2.1 – 3.1 |

**Scenario 1**

The implementation of Scenario 1 results in minor reductions to flow volumes by capturing and storing flows in the watersheds before they are significantly channelized. Flow volumes in Palo Seco creek are significantly reduced, especially for the 1-year recurrence interval discharge event.

Water Surface Elevation

Figure 126 is a plot of existing and proposed water surface elevations in the modeled reaches of Sausal Creek and Palo Seco Creek for the 1-year recurrence interval discharge. The differences between existing and proposed water surface elevations are extremely small and are not discernible on this plot. The other modeled discharges showed similar small changes.

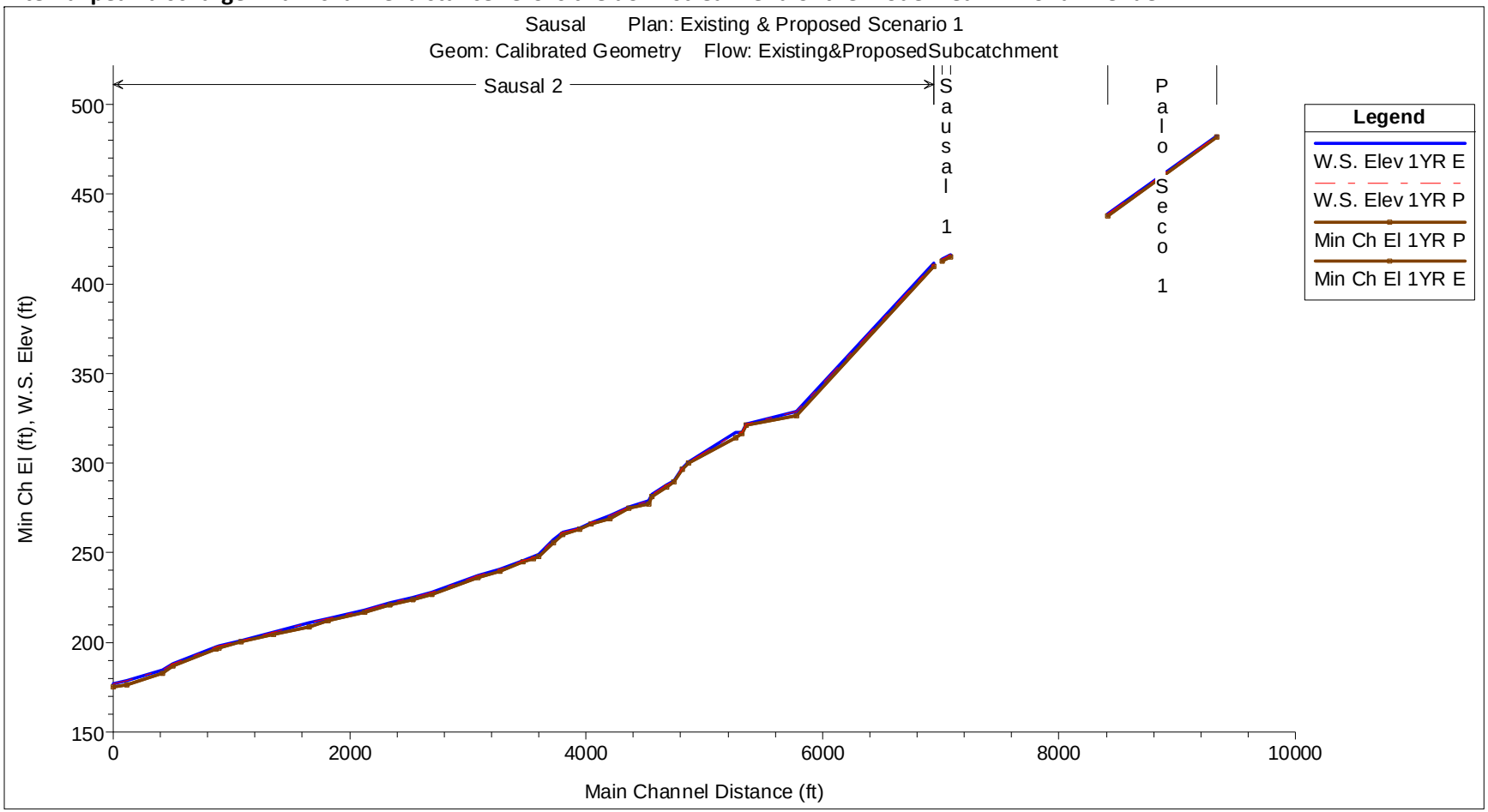
Table 62 is a summary of the average, minimum, and maximum difference between existing water surface elevations and water surface elevations with Scenario 1 improvements. Except for the 1-year and 100-year recurrence interval discharge, proposed water surface elevations are less than 2% smaller than existing water surface elevations. This suggests that Scenario 1 improvements alone would not yield significant conveyance improvements over existing conditions for most peak flows. However, proposed water surface elevations are more than 4% lower than existing conditions for the 1-year flow with Scenario 1 improvements. This is more than twice the reduction shown for all other recurrence intervals except the 100-year flow. Therefore, for smaller, more frequent annual flood peaks like the 1-year discharge event, the measures proposed for Scenario 1 could yield significant reductions in flow depths that make channel conditions closer to the natural hydrologic and hydraulic conditions present in the watershed before urbanization.

While the measures in Scenario 1 also reduce the water surface elevation for the 100-year discharge by 5.7%, conveyance capacity during such an extreme event has already been exceeded and is therefore not likely a critical consideration. The minimum and maximum water surface elevation reductions in Table 64 are presented to show the full range of potential change under Scenario 1. Extreme values in these two columns are typically a result of local hydraulic conditions and are therefore not representative of the entire project reach.

**Table 62: Summary of average, minimum, and maximum water surface elevation difference between existing and proposed conditions for all modeled reaches. Negative values indicate increases in water surface elevation under proposed conditions.**

| Discharge Recurrence Interval | Average Water Surface Elevation Reduction | | Minimum Water Surface Elevation Reduction | | Maximum Water Surface Elevation Reduction | |
|---|---|---|---|---|---|---|
| Years | ft | % | Ft | % | Ft | % |
| 1 | 0.05 | 4.2% | -0.07 | -8.0% | 0.13 | 9.2% |
| 2 | 0.03 | 1.4% | -0.06 | -2.0% | 0.14 | 7.4% |
| 5 | 0.06 | 1.8% | -0.01 | -0.3% | 0.15 | 8.3% |
| 10 | 0.07 | 1.9% | 0.02 | 0.3% | 0.20 | 8.1% |
| 25 | 0.05 | 1.3% | -0.05 | -0.8% | 0.15 | 8.4% |
| 100 | 0.27 | 5.7% | 0.13 | 2.4% | 0.91 | 12% |

**Figure 125: Longitudinal water surface elevation profile under existing (E) and Scenario 1 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

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Velocity

Figure 127 is a longitudinal plot of existing flow velocity under Scenario 1, and Table 63 summarizes these velocity reductions. Similar to water surface elevation, average velocities are only significantly reduced for the 1-year and 100- year flows. The flow reductions from Scenarios 1, 2, and 3 can locally reduce or eliminate backwater controls in some locations (e.g., at culverts or channel constrictions). Therefore, even though there is less flow volume, flow velocity can increase. These are extremely small increases in these locations. In general, channels with sediment and vegetation characteristics similar to Sausal Creek are eroded by flow velocities of greater than approximately 7 ft/sec (see Table 61). The 100-year discharge is not very important with respect to the long-term geomorphic conditions in Sausal Creek because it occurs so infrequently. The 3.5% average velocity reduction in peak flow from the 1-year discharge achieved under Scenario 1 could yield long-term geomorphic improvement in Sausal Creek in locations where flow velocities are slightly above the critical geomorphic stability thresholds of 7 ft./sec. This slight reduction could improve habitat creation and maintenance by reducing the frequency of damaging flow velocities.

**Table 63: Summary of average, minimum, and maximum velocity difference between existing and Scenario 1 conditions for all modeled reaches. Negative values indicate increases in velocity under Scenario 1 conditions.**

| Discharge Recurrence Interval | Average Velocity Reduction | | Minimum Velocity Reduction | | Maximum Velocity Reduction | |
|---|---|---|---|---|---|---|
| Years | ft/sec | % | ft/sec | % | ft/sec | % |
| 1 | 0.11 | 3.5% | -0.07 | -2.4% | 0.49 | 24.2% |
| 2 | 0.04 | 0.9% | -0.34 | -4.7% | 0.32 | 7.0% |
| 5 | 0.06 | 1.0% | -0.28 | -6.0% | 0.36 | 6.8% |
| 10 | 0.09 | 1.3% | -0.12 | -2.5% | 0.41 | 7.2% |
| 25 | 0.08 | 1.1% | -0.15 | -3.0% | 0.46 | 7.3% |
| 100 | 0.24 | 3.4% | -2.4 | -25.4% | 0.88 | 9.6% |

Shear Stress

Figure 128 is a longitudinal plot of existing channel shear stress and channel shear stress under Scenario 1, and Table 64 summarizes channel shear stress reductions. Similar to water surface elevation and velocity, average shear stresses are only significantly reduced for the 1-year and 100-year flows. In general, channels with sediment and vegetation characteristics similar to Sausal Creek experience erosion at channel shear stresses of greater than approximately 2.0 lbs/ft$^2$ (see Table 61). Similar to the results for flow velocity, the reduction in shear stress for the 100-year flow is not likely to change long-term geomorphic conditions significantly. However, the small (5.1%) average shear stress reduction under Scenario 1 conditions for the 1-year discharge could benefit long-term geomorphic conditions where shear stresses are at or just above critical thresholds for scour and erosion. In these locations, the reduced peak shear stresses produced by measures in Scenario 1 could yield improvements in channel form and habitat.

**Figure 126: Longitudinal velocity profile under existing (E) and Scenario 1 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

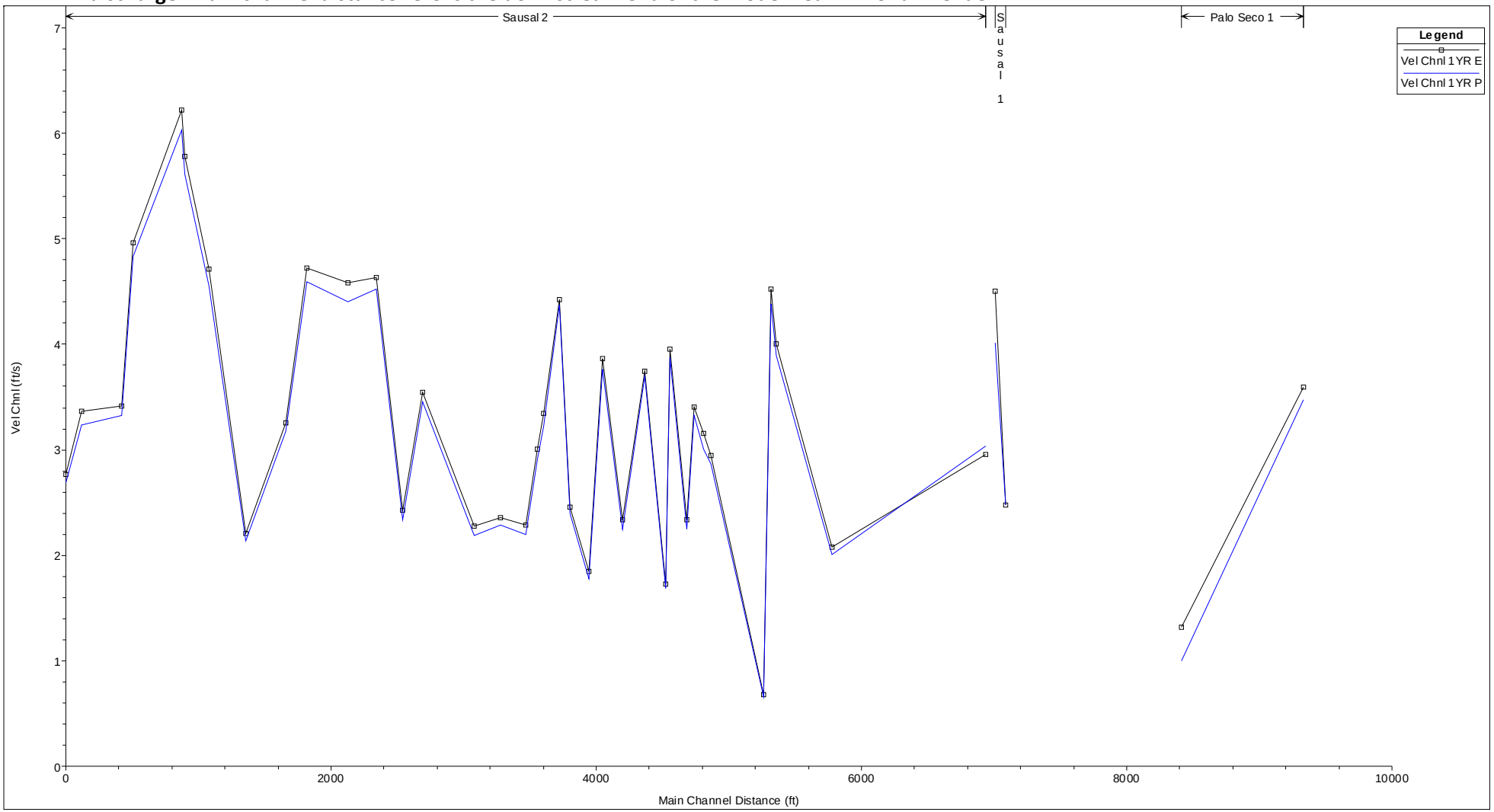

**Figure 127: Longitudinal shear stress profile under existing (E) and Scenario 1 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

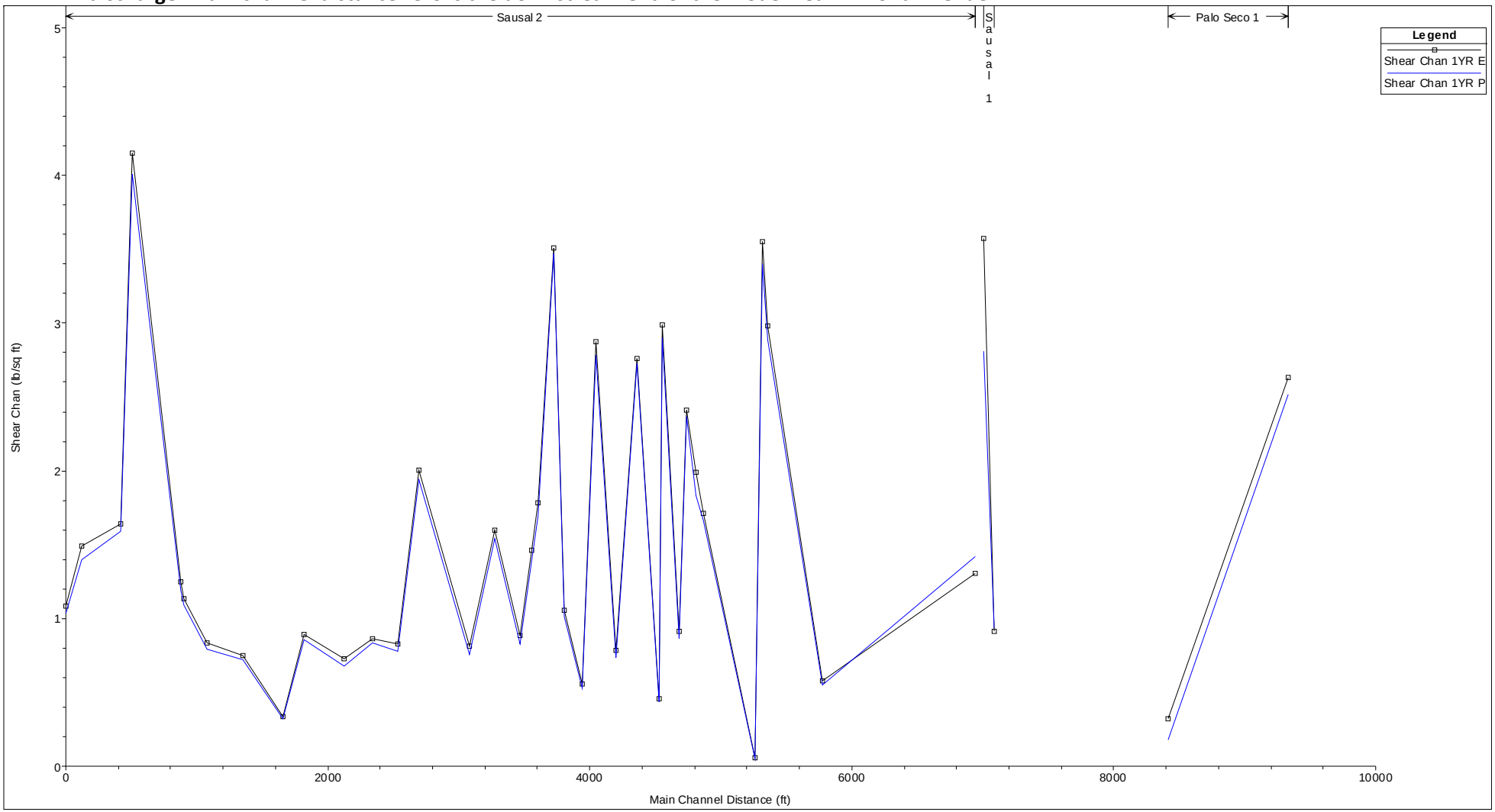

**Table 64: Summary of average, minimum, and maximum shear stress difference between existing and Scenario 1 conditions for all modeled reaches. Negative values indicate increases in shear stress under Scenario 1 conditions.**

| Discharge Recurrence Interval | Average Shear Stress Reduction | | Minimum Shear Stress Reduction | | Maximum Shear Stress Reduction | |
|---|---|---|---|---|---|---|
| Years | lbs/ft$^2$ | % | lbs/ft$^2$ | % | lbs/ft$^2$ | % |
| 1 | 0.07 | 5.1% | -0.12 | -9.2% | 0.76 | 43.8% |
| 2 | 0.03 | 1.1% | -0.72 | -11.0% | 0.29 | 10.3% |
| 5 | 0.06 | 1.2% | -0.30 | -14.0% | 0.38 | 11.0% |
| 10 | 0.08 | 1.8% | -0.13 | -7.0% | 0.45 | 11.4% |
| 25 | 0.07 | 1.7% | -0.16 | -7.1% | 0.56 | 12.1% |
| 100 | 0.30 | 4.3% | -1.04 | -64.6% | 1.27 | 17.7% |

**Scenario 2**

Scenario 2 includes all of the watershed improvements in Scenario 1 as well as a cistern at Shepherd Canyon Park and a detention basin in the Cobbledick Creek sub-basin on Larry Lane. The implementation of Scenario 2 reduces peak flow rates in the upper watershed for the 1-year discharge event, especially in Shephard Creek. Peak flow rates for larger storm events are not reduced as significantly, however, total flow volumes for these larger events are significantly reduced.

Water Surface Elevation

Figure 128 and Table 65 both show that the hydrology under Scenario 2 translates into very small changes between existing and proposed water surface elevations for all recurrence intervals except the 1-year flow, for which water surface elevations were reduced by 15% on average. This change in peak flow depths could translate into meaningful improvements in long-term geomorphic conditions in Sausal Creek, as the 1 year discharge event is likely very important in the maintenance of channel conditions in Sausal Creek. This reduction in flow depths that could also facilitate channel and riparian habitat restoration by making riparian vegetation hydroperiods (i.e. the hydrologic conditions that can be tolerated by riparian vegetation) more similar to their pre-disturbance condition, and therefore more conducive to native vegetation.

**Figure 128: Longitudinal water surface elevation profile under existing (E) and Scenario 2 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

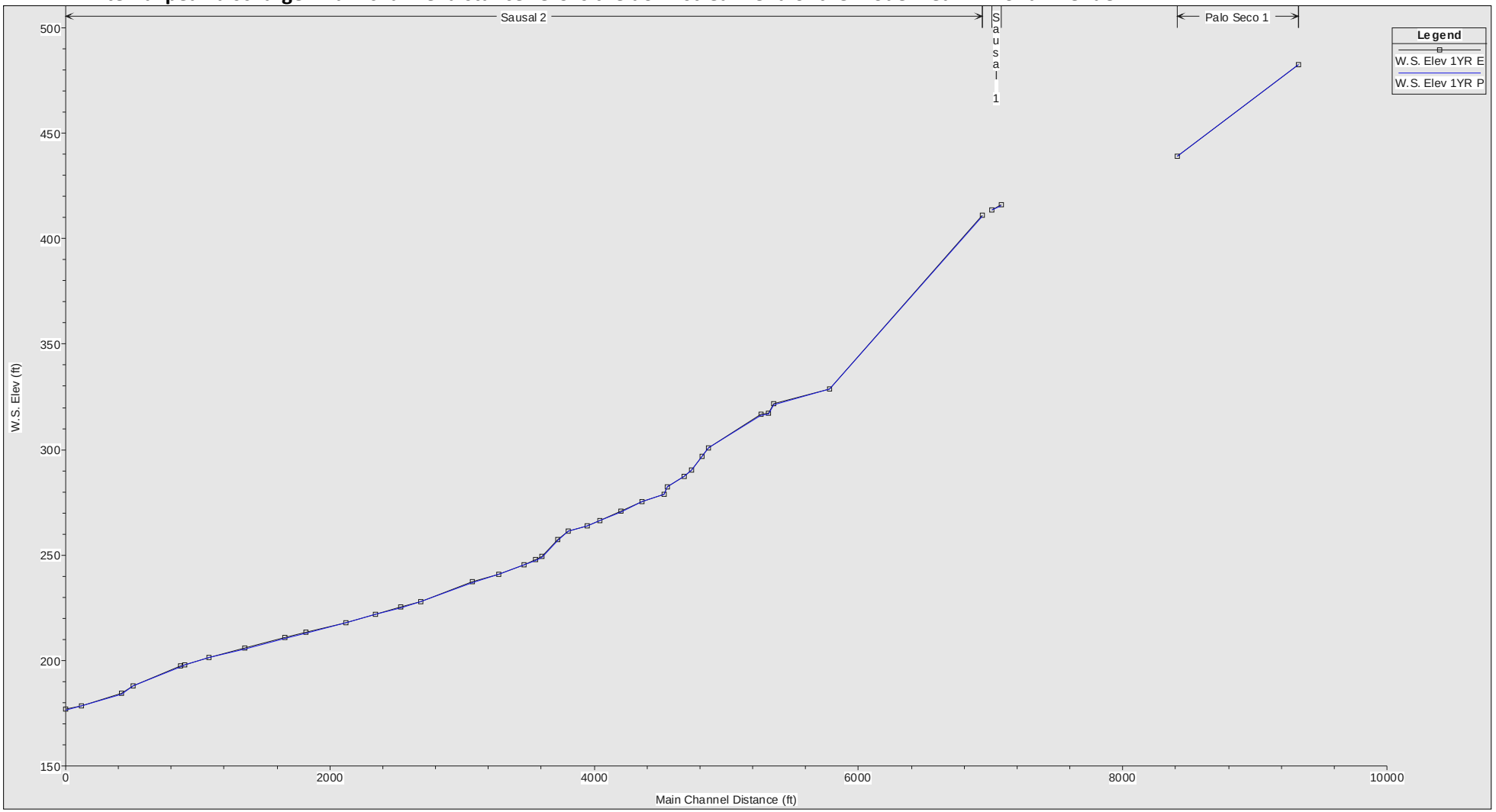

**Table 65: Summary of average, minimum, and maximum water surface elevation difference between existing and Scenario 2 conditions for all modeled reaches. Negative values indicate increases in water surface elevation under Scenario 2 conditions.**

| Discharge Recurrence Interval | Average Water Surface Elevation Reduction | | Minimum Water Surface Elevation Reduction | | Maximum Water Surface Elevation Reduction | |
|---|---|---|---|---|---|---|
| Years | ft | % | Ft | % | Ft | % |
| 1 | 0.18 | 15.0% | -0.37 | -42.5% | 0.58 | 44.3% |
| 2 | 0.03 | 1.3% | -0.07 | -2.3% | 0.16 | 8.2% |
| 5 | 0.07 | 2.1% | 0 | 0.0% | 0.18 | 8.3% |
| 10 | 0.04 | 1.1% | -0.04 | -0.6% | 0.15 | 8.1% |
| 25 | 0.05 | 1.6% | -0.05 | -0.8% | 0.15 | 8.4% |
| 100 | 0.29 | 6.0% | 0.13 | 2.4% | 0.92 | 13% |

Velocity

Figure 129 and Table 66 both show that the hydrology under Scenario 2 translates into very small changes between existing and proposed average velocity for all recurrence intervals except the 1-year flow, for which velocities were reduced by 11.5% on average. This reduction would certainly translate into meaningful improvements in the long-term geomorphic conditions in Sausal Creek. There are many locations where this magnitude of velocity reduction could change erosion and scour characteristics for frequent peak flows, and therefore returns the sediment transport regime closer to pre-disturbance conditions. This change could yield significant improvements in aquatic and riparian habitat as a new dynamic equilibrium would be established in Sausal Creek. In addition, the reduced velocities could also improve conditions of fish and macroinvertebrates during regular peak flows, potentially allowing them to remain in Sausal Creek for longer periods than under current conditions.

**Figure 129: Longitudinal velocity profile under existing (E) and Scenario 2 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

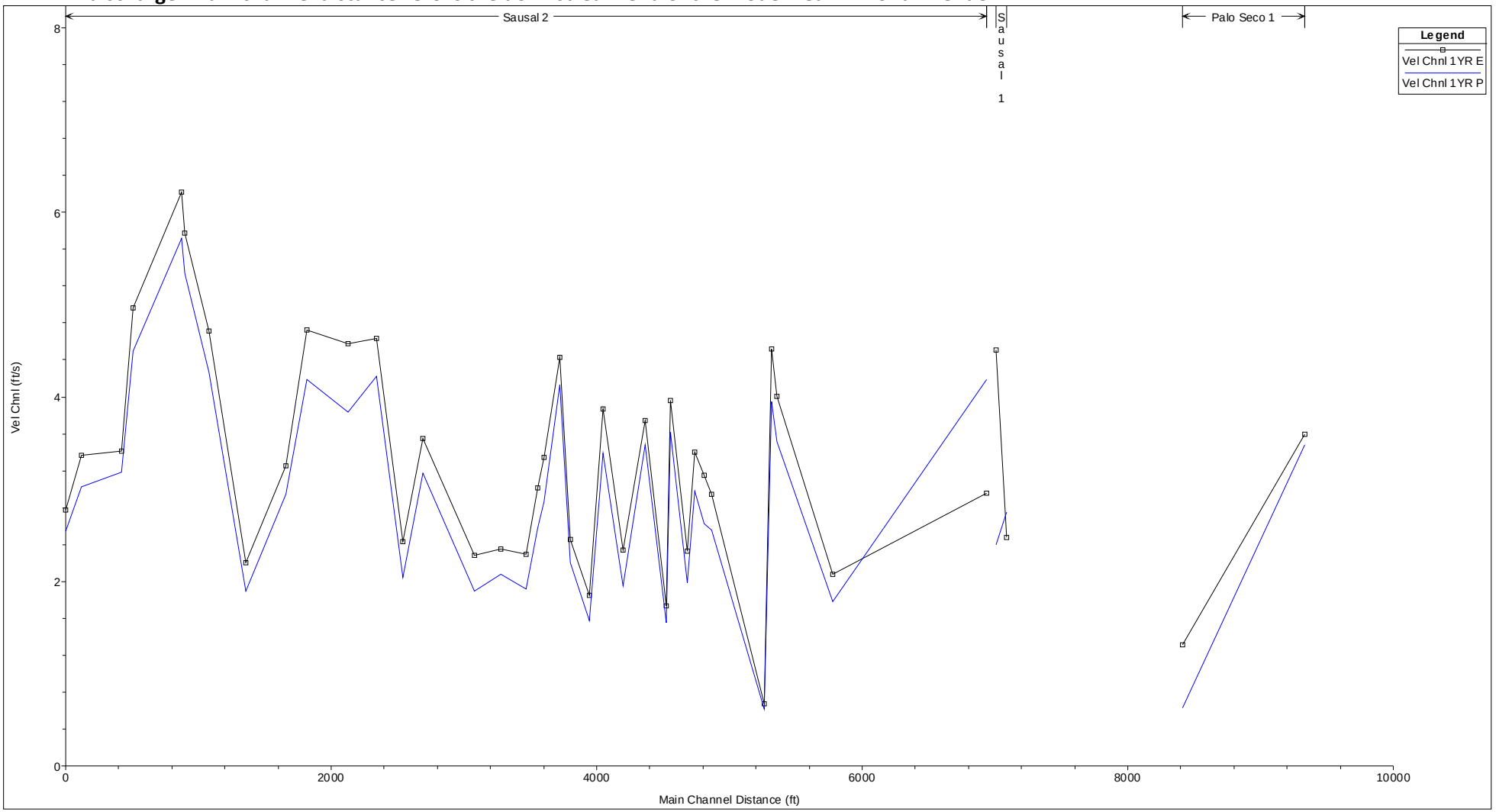

**Table 66: Summary of average, minimum, and maximum velocity difference between existing and Scenario 2 conditions for all modeled reaches. Negative values indicate increases in velocity under Scenario 2 conditions.**

| Discharge Recurrence Interval | Average Velocity Reduction | | Minimum Velocity Reduction | | Maximum Velocity Reduction | |
|---|---|---|---|---|---|---|
| Years | ft/sec | % | ft/sec | % | ft/sec | % |
| 1 | 0.37 | 11.5% | -1.23 | -41.6% | 2.11 | 52.3% |
| 2 | 0.04 | 0.8% | -0.36 | -5.0% | 0.34 | 7.5% |
| 5 | 0.08 | 1.2% | -0.30 | -6.5% | 0.37 | 7.0% |
| 10 | 0.06 | 0.8% | -0.16 | -3.4% | 0.41 | 7.2% |
| 25 | 0.09 | 1.4% | -0.13 | -2.6% | 0.46 | 7.3% |
| 100 | 0.26 | 3.6% | -2.36 | -25.0% | 0.94 | 10.3% |

Shear Stress

Figure 130 and Table 67 both show that the hydrology under Scenario 2 also translates into very small changes between existing and proposed average shear stress for all recurrence intervals except the 1-year flow, for which shear stresses were reduced by 13.4% on average. Similar to velocity, this reduction would certainly translate into meaningful improvements in long-term geomorphic conditions in Sausal Creek. There are many locations where this magnitude of shear stress reduction could change erosion and scour characteristics for frequent peak flows, and therefore return the sediment transport regime closer to pre-disturbance conditions. In addition, the reduced shear stress regime could also allow vegetation, fish, and aquatic insect species with lower shear stress tolerances to return to Sausal Creek. This could increase the overall diversity of organisms in this urbanized watershed.

**Figure 130: Longitudinal shear stress profile under existing (E) and Scenario 2 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

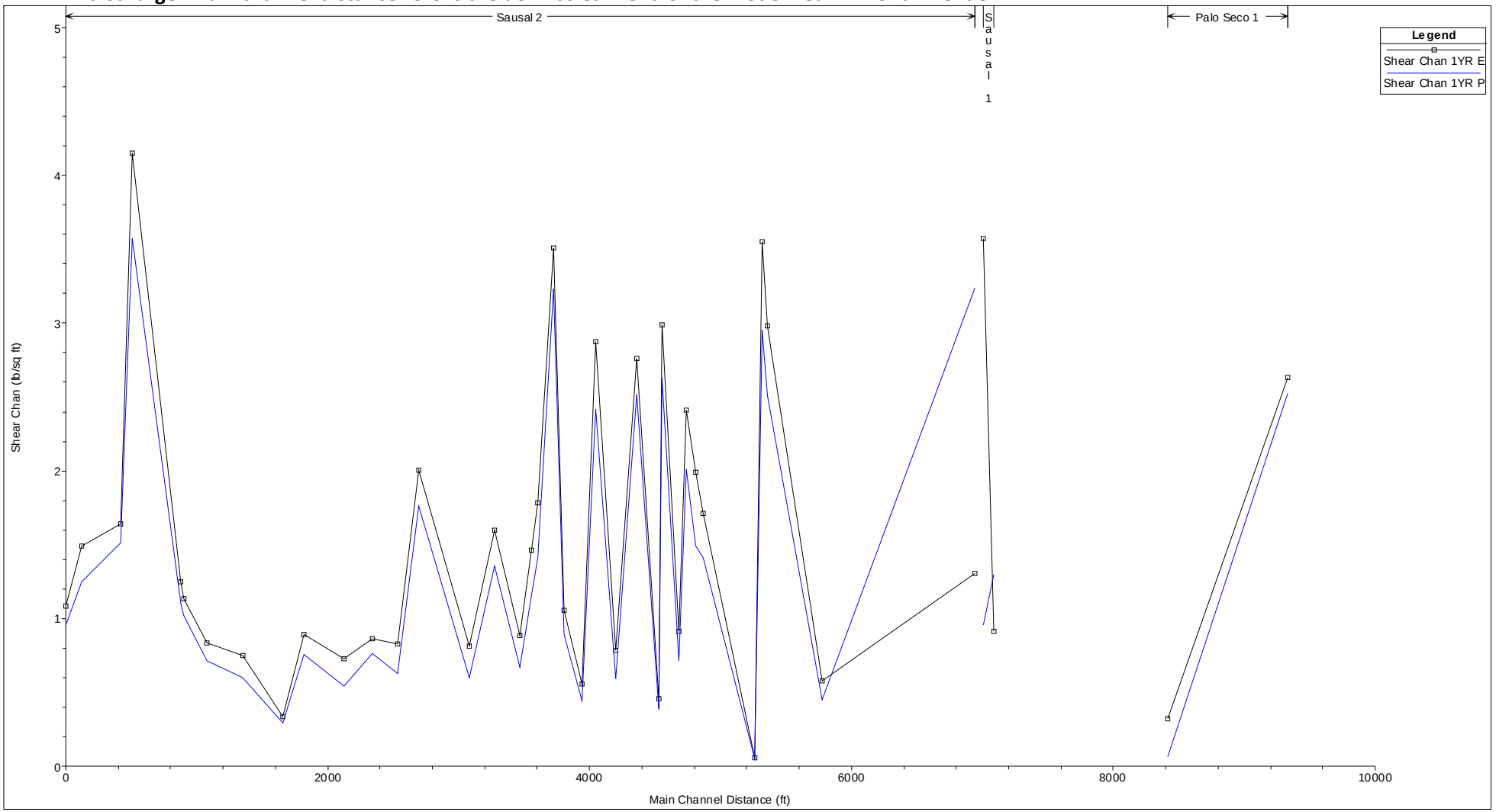

**Table 67: Summary of average, minimum, and maximum shear stress difference between existing and Scenario 2 conditions for all modeled reaches. Negative values indicate increases in shear stress under Scenario 2 conditions.**

| Discharge Recurrence Interval | Average Shear Stress Reduction | | Minimum Shear Stress Reduction | | Maximum Shear Stress Reduction | |
|---|---|---|---|---|---|---|
| years | lbs/ft$^2$ | % | lbs/ft$^2$ | % | lbs/ft$^2$ | % |
| 1 | 0.22 | 13.4% | -1.94 | -149.2% | 2.62 | 78.1% |
| 2 | 0.03 | 1.0% | -0.74 | -11.3% | 0.31 | 11.4% |
| 5 | 0.07 | 1.7% | -0.33 | -15.4% | 0.38 | 11.0% |
| 10 | 0.04 | 1.1% | -0.16 | -7.6% | 0.45 | 11.4% |
| 25 | 0.08 | 2.0% | -0.14 | -6.2% | 0.56 | 12.1% |
| 100 | 0.32125 | 4.6% | -1.02 | -63.4% | 1.35 | 18.9% |

**Scenario 3**

Scenario 3 includes the watershed improvements in Scenarios 1 and 2 as well as cisterns in the Montclair Golf Course and in Dimond Park. The implementation of Scenario 3 reduces peak flow rates in the main channel for the 1-year frequency discharge event, especially in Sausal Creek. Scenario 3 does not reduce peak flow rates as significantly for larger events, but does reduce total flow volumes.

Water Surface Elevation

Figure 131 and Table 68 both show that the hydrology under Scenario 3 translates into relatively small changes between existing and proposed water surface elevations for all recurrence intervals except the 1-year flow, for which water surface elevations were reduced by 27.5% on average. This scenario produces a substantial reduction in frequent peak flow depths and would certainly improve long-term geomorphic conditions by making the hydraulic conditions more like natural hydraulic conditions for small peak flows in Sausal Creek.

**Figure 131: Longitudinal water surface elevation profile under existing (E) and Scenario 3 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

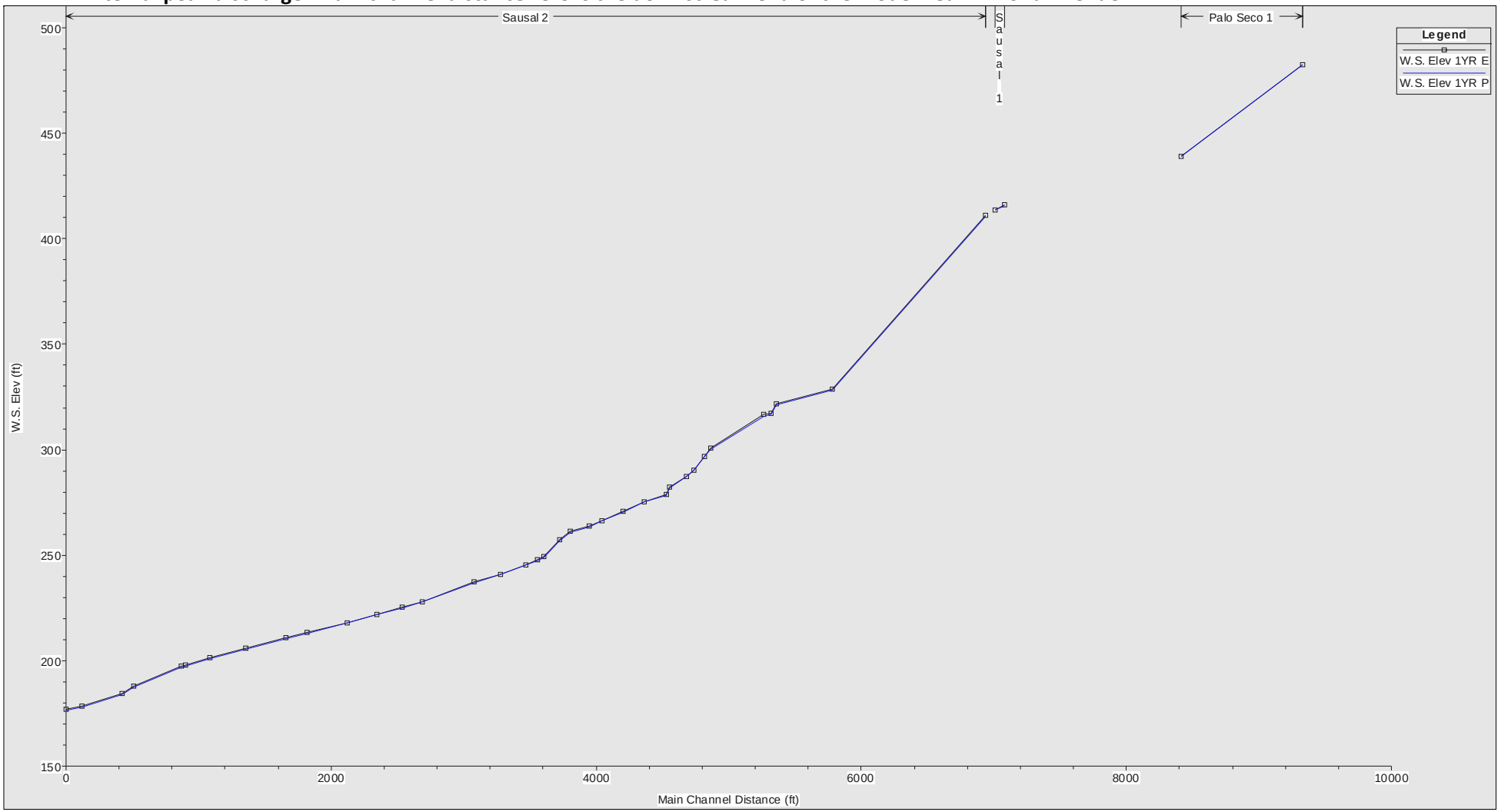

**Table 68: Summary of average, minimum, and maximum water surface elevation difference between existing and Scenario 3 conditions for all modeled reaches. Negative values indicate increases in water surface elevation under proposed conditions.**

| Discharge Recurrence Interval | Average Water Surface Elevation Reduction | | Minimum Water Surface Elevation Reduction | | Maximum Water Surface Elevation Reduction | |
|---|---|---|---|---|---|---|
| years | Ft | % | ft | % | ft | % |
| 1 | 0.33 | 27.5% | -0.27 | -31.0% | 0.86 | 52.7% |
| 2 | 0.08 | 2.9% | -0.05 | -1.7% | 0.20 | 8.2% |
| 5 | 0.11 | 3.0% | -0.01 | -0.3% | 0.33 | 8.3% |
| 10 | 0.17 | 3.8% | 0.01 | 0.3% | 0.90 | 18.9% |
| 25 | 0.15 | 3.4% | -0.12 | -1.7% | 0.81 | 15.7% |
| 100 | 0.33 | 6.9% | 0.15 | 2.8% | 0.96 | 13% |

Velocity

Figure 132 and Table 69 both show that the hydrology under Scenario 3 translates into substantial velocity reductions (average 20.5%) during the 1-year flow, and still relatively small velocity reductions for all other recurrence intervals. The improvements in long-term geomorphic conditions under this scenario would be similar to those expected under Scenario 2, except the improvement would occur in Sausal Creek.

**Figure 132: Longitudinal velocity profile under existing (E) and Scenario 3 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

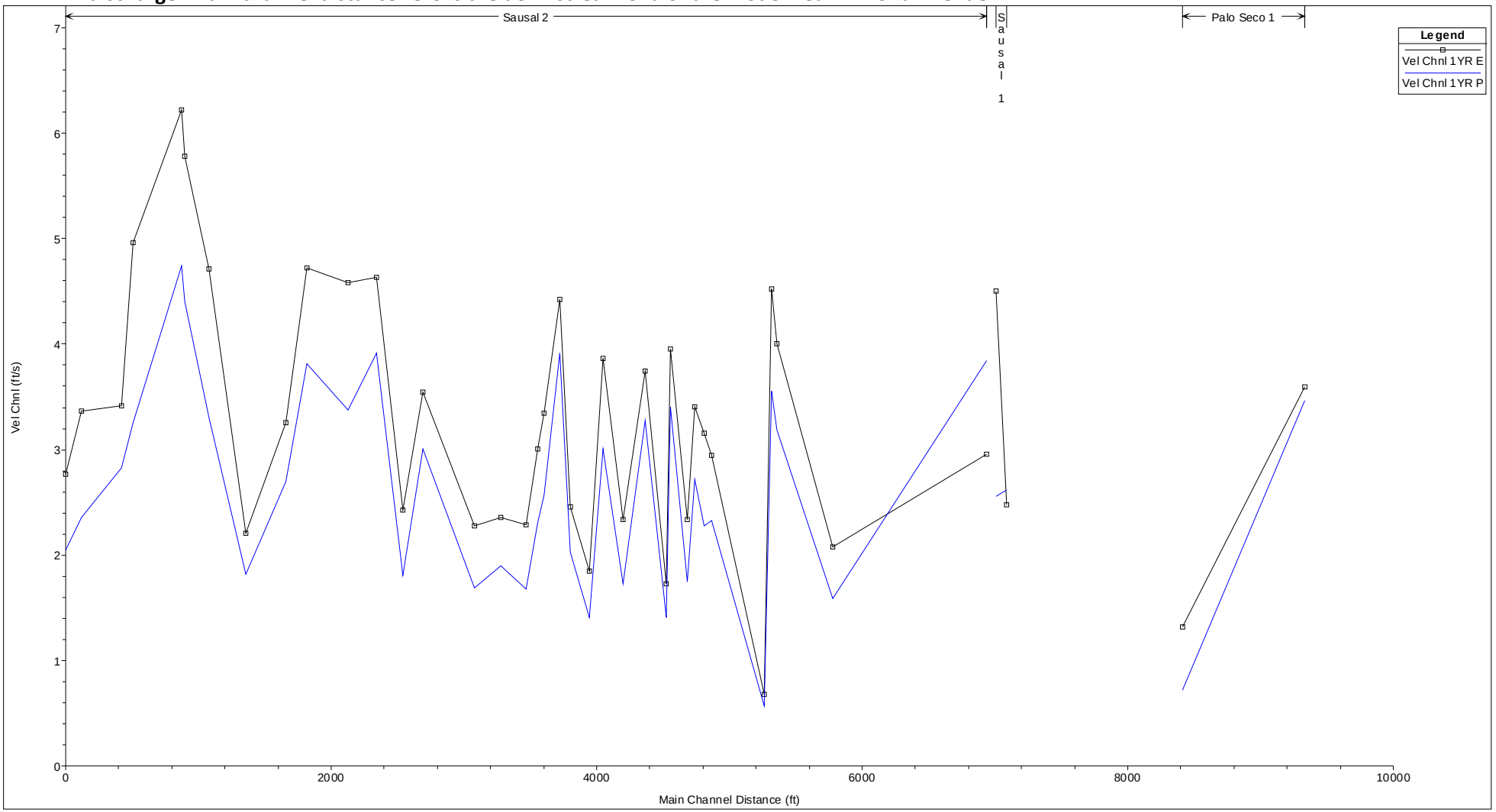

**Table 69: Summary of average, minimum, and maximum velocity difference between existing and Scenario 3 conditions for all modeled reaches. Negative values indicate increases in velocity under Scenario 3 conditions.**

| Discharge Recurrence Interval | Average Velocity Reduction | | Minimum Velocity Reduction | | Maximum Velocity Reduction | |
|---|---|---|---|---|---|---|
| years | ft/sec | % | ft/sec | % | ft/sec | % |
| 1 | 0.68 | 20.5% | -0.89 | -30.1% | 1.95 | 46.2% |
| 2 | 0.10 | 1.9% | -0.38 | -5.1% | 0.56 | 7.7% |
| 5 | 0.12 | 1.8% | -0.43 | -9.2% | 0.53 | 9.0% |
| 10 | 0.24 | 3.1% | -0.38 | -7.7% | 2.06 | 24.1% |
| 25 | 0.28 | 3.3% | -0.32 | -5.9% | 2.50 | 24.4% |
| 100 | 0.36 | 4.6% | -1.67 | -17.7% | 1.02 | 11.1% |

Shear Stress

Figure 133 and Table 70 both show that, similar to the velocity results, Scenario 3 yields a major reduction (26%) in average shear stress for the 1-year discharge event. This suggests that the improvements in long-term geomorphic conditions under Scenario 3 would be similar to those expected under Scenario 2, except in Sausal Creek where the improvements would be greater under Scenario 3 than under Scenario 2.

**Figure 133: Longitudinal shear stress profile under existing (E) and Scenario 3 (P) hydrologic conditions for the 1-year recurrence interval peak discharge. Main channel distance zero is the downstream end of the model near Dimond Avenue.**

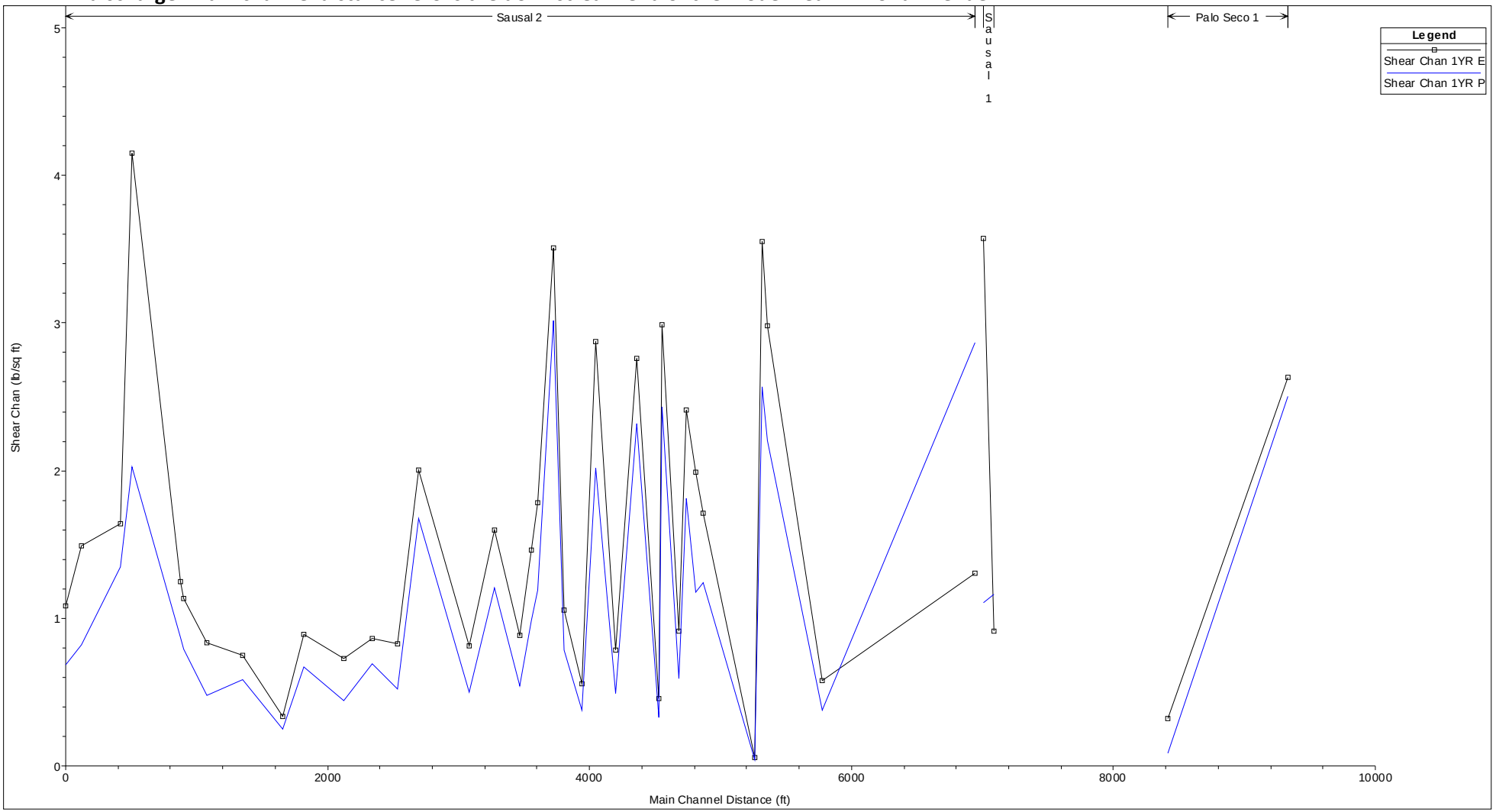

**Table 70: Summary of average, minimum, and maximum shear stress difference between existing and Scenario 3 conditions for all modeled reaches. Negative values indicate increases in shear stress under Scenario 3 conditions.**

| Discharge Recurrence Interval | Average Shear Stress Reduction | | Minimum Shear Stress Reduction | | Maximum Shear Stress Reduction | |
|---|---|---|---|---|---|---|
| years | lbs/ft$^2$ | % | lbs/ft$^2$ | % | lbs/ft$^2$ | % |
| 1 | 0.41 | 26.0% | -1.57 | -120.8% | 2.46 | 71.9% |
| 2 | 0.08 | 2.6% | -0.70 | -14.6% | 0.32 | 14.2% |
| 5 | 0.09 | 2.4% | -0.47 | -22.0% | 0.39 | 16.7% |
| 10 | 0.15 | 4.2% | -0.51 | -20.0% | 1.23 | 41.7% |
| 25 | 0.18 | 4.7% | -0.45 | -15.2% | 1.11 | 43.1% |
| 100 | 0.38525 | 6.5% | -0.73 | -45.3% | 1.45 | 20.3% |

**CONCLUSIONS**

The watershed improvements under Scenarios 1, 2, and 3 for Sausal Creek watershed would result in localized reductions to flow rates and flow volumes in Sausal Creek and tributaries. The hydrology results indicate that while all three scenarios would reduce runoff rates and volumes in the Sausal Creek watershed, the specific types of stormwater facilities and their locations in the watershed have a great bearing on localized hydrologic patterns. Comparing the three scenarios to existing conditions reveals the following trends:

- Stormwater source control practices such as the rain barrels, parking lot detention, and small detention basins simulated in Scenario 1 have a significant effect on reducing flow rates and volumes for the 1-year event. Larger storm events produce larger quantities of runoff, which quickly overflow these facilities; thus reductions in flow rates and volumes are minor for the 2 to 100 year events.

- Cisterns and detention basins significantly reduce flow rates in the reaches below the facilities for the 1-year event, and less so for the larger events. However, as other, uncontrolled tributaries join the channel downstream of the detention facility, the flow dampening effect becomes less pronounced. Flow volumes are less affected by the detention facilities.

- The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

- In relation to the other sub-basins, Palo Seco Creek is relatively undeveloped. The proposed improvements in that sub-basins included in Scenario 1 reduce flow rates by 14% to 17%, and flow volumes by 15% to 24% compared to existing conditions for the range of storm events. Because the majority of the improvements occur on publicly-owned lands, implementation of these measures may be simpler and less expensive. For these reasons, it is recommended that the Palo Seco Creek sub-basins be considered for a demonstration project.

An additional consideration not addressed in this analysis is the cost-benefit ratio of the proposed stormwater facilities. For example, the strategies included in Scenario 1 tend to be smaller, distributed practices that are low-cost. However, improvements like rain barrels and parking lot detention facilities are located on private properties, are not controlled by a public entity, and potentially could be more difficult to maintain. But with current local and state budget problems, the ability of public agencies to regularly maintain stormwater facilities is also unreliable. In contrast, the larger detention basins are much more expensive to design and install, especially considering that the proposed basins in Shepherd Canyon Park, the Montclair Golf Course, and Dimond Park would require an underground detention facility.

The reductions in flow rates and flow volumes from the watershed improvements have an effect on hydraulic processes in the creek channels, including the depth of storm flows, velocity of flow and the level of scour or shear stress on the channel bed.

## Hydraulics

Creek channel beds and banks can withstand certain inundation depths, flow velocities, and channel shear stresses. When peak discharges increase in a watershed, as they do in urban watersheds like Sausal Creek, depth, velocity, and shear stress thresholds for channel stability are exceeded more frequently. Under these urbanized conditions the creek system has an altered sediment transport regime and a more pronounced geomorphic change that typically reduces long-term aquatic and riparian habitat quantity and quality. Therefore, implementing management measures to reduce the magnitudes of peak flows and associated flow depths, velocities, and shear stresses can help restore more natural habitat conditions in and along creek corridors.

### Water Surface Elevation

Table 71 summarizes the average reduction in water surface elevations under floods of all recurrence intervals for each of the three proposed scenarios. The table shows clearly that water surface elevations for a given recurrence interval flow event are reduced as watershed improvements are added to the system. However, as noted above, significant reductions occur only for the 1-year and 100-year flow events. The potential reductions in water surface elevation for a frequent peak flow could facilitate establishment of more diverse and natural riparian vegetation and aquatic conditions that are suitable to a wider range of fish and invertebrate species.

**Table 71: Summary of average water surface elevation reductions for all three scenarios.**

| Discharge Recurrence Interval | Average Water Surface Elevation Reduction (%) | | |
|---|---|---|---|
| years | Scenario 1 | Scenario 2 | Scenario 3 |
| 1 | 4.2% | 15.0% | 27.5% |
| 2 | 1.4% | 1.3% | 2.9% |
| 5 | 1.8% | 2.1% | 3.0% |
| 10 | 1.9% | 1.1% | 3.8% |
| 25 | 1.3% | 1.6% | 3.4% |
| 100 | 5.7% | 6.0% | 6.9% |

**Velocity**

Table 72 summarizes average reductions in velocity under floods of all recurrence intervals for each of the three scenarios. The table shows clearly that velocity for a given recurrence interval runoff event is reduced as watershed improvements are added to the system. Such reductions could be extremely beneficial with respect to channel and riparian habitat restoration, as artificially high flow velocities that occur frequently in urbanized watersheds can be extremely disruptive to aquatic and riparian species and their habitat. These velocity reductions would also likely yield more natural sediment transport dynamics in Sausal Creek, possibly returning geomorphic conditions closer to pre-urbanization conditions.

**Table 72: Summary of average velocity reductions for all three scenarios**

| Discharge Recurrence Interval | Average Velocity Reduction (%) | | |
|---|---|---|---|
| years | Scenario 1 | Scenario 2 | Scenario 3 |
| 1 | 3.5% | 11.5% | 20.5% |
| 2 | 0.9% | 0.8% | 1.9% |
| 5 | 1.0% | 1.2% | 1.8% |
| 10 | 1.3% | 0.8% | 3.1% |
| 25 | 1.1% | 1.4% | 3.3% |
| 100 | 3.4% | 3.6% | 4.6% |

**Shear Stress**

Table 73 summarizes average reductions in shear stress for floods of all recurrence intervals for each of the three scenarios. As with water surface elevation and velocity, shear stress reductions generally increase as measures are added under each scenario. Similar to velocity, these shear stress reductions would likely yield more natural sediment transport dynamics in Sausal Creek, leading to long-term geomorphic conditions closer to pre-urbanization conditions.

**Table 73: Summary of average shear stress reductions for all three scenarios**

| Discharge Recurrence Interval | Average Shear Stress Reduction (%) | | |
|---|---|---|---|
| years | Scenario 1 | Scenario 2 | Scenario 3 |
| 1 | 5.1% | 13.4% | 26.0% |
| 2 | 1.1% | 1.0% | 2.6% |
| 5 | 1.2% | 1.7% | 2.4% |
| 10 | 1.8% | 1.1% | 4.2% |
| 25 | 1.7% | 2.0% | 4.7% |
| 100 | 4.3% | 4.6% | 6.5% |

In an urbanized watershed like Sausal Creek, reductions in peak water depths, velocities, and shear stresses can lead to habitat improvements in the creeks. However, it can be extremely difficult to identify and acquire adequate space to implement measures that can have meaningful impacts on watershed hydrology in an urbanized watershed. The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, based on our evaluation of potential hydraulic change, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

As a first step in implementing the watershed stormwater improvements of Scenario 3 the proposed improvements in Palo Seco Creek sub-basin should be completed as a demonstration projects

This analysis is intended to provide some initial, planning-level estimates of the potential environmental benefits associated with specific improvements in the Sausal Creek watershed. It is intended that the tools developed during this study, specifically the working, calibrated SWMM and HEC-RAS models, be used to continue both planning-level and design-level studies to inform future actions in the watershed.

NRBS recommends that these models be improved and refined to add additional certainty to the results of the hydrologic and hydraulic analyses. Potential improvements should include:

- Verify existing conditions data including culvert dimensions, lengths, channel transects, sub-basin widths, and sub-basin impervious areas
- Refine the level of detail for the specific BMPs in the SWMM model
- Improve hydrology model calibration with a flow gage at the El Centro culvert
- Improve hydraulic model calibration with additional high water mark surveys
- Expand the HEC-RAS model into the upper reaches of the watershed

## VII. RECOMMENDED ACTIONS

### INTRODUCTION

The summary of watershed conditions outlined the opportunities for improvements of the Sausal Creek watershed and the constraints to making improvements. This section outlines recommendations for major erosion sites, watershed stormwater improvements, invasive non-native plants, water quality monitoring and improvement, and stream restoration projects.

The recommendations include some actions to be implemented by FOSC and community and neighborhood groups. However the scale of many of the environmental problems in the Sausal Creek watershed, however, cannot be remedied with volunteers alone. Some of these recommendations will require major engineering and construction and should be carried out by the City of Oakland or other organizations. Larger public works projects are needed to mitigate the hydrologic effects of urbanization and reduce creek erosion so that volunteer efforts to revegetate creek corridors are sustainable.

The Palo Seco Creek sub-basin is an exception in the drainage because it is largely undeveloped and doesn't have the large peak flow problems of the other tributaries. Palo Seco Creek has aquatic and riparian habitat conditions that reflect this difference with a high diversity of aquatic insects and the occurrence of taxa that are sensitive to pollution.

### MAJOR EROSION SITES

The watershed assessment identified a number of storm drain outlets with erosion problems. Many of these erosion sites are in public parks. Each one of the erosion sites requires a site-specific repair and the involvement of the City of Oakland Public Works Department. The storm drain system is owned and maintained by the City and repairs are their responsibilities. FOSC, homeowner groups, park advocates, and local elected officials should meet with city staff to determine a schedule for repair implementation.

One of the features documented in the stormdrain assessment were plastic flex pipes attached to downspouts to move stormwater away from houses. Depending on where the flex pipe outlet is placed this practice can cause erosion at the outlet. Homeowners could benefit from workshops on storm water management to reduce erosion and increase slope stability. This workshop could be combined with workshops on rain barrel installation and maintenance.

The erosion sites documented for Joaquin Miller Park (Table 49) point to a need for re-design and maintenance of many of the park trails. When repair projects are designed, a professional with the needed understanding of hydrology and erosion should be involved. The use of ineffective repairs in several locations speaks to the need for improved designs. In addition, several of these erosion sites were caused by urban stormwater runoff released into public lands from residential areas (Castle Drive) and new developments (Chabot Space & Science Center).

The City's approval of a large development like the Chabot Space & Science Center with no provision to reduce the effects of storm water runoff from large parking lots built on top of a slope indicates the need for the City of Oakland to specifically evaluate this impact when permitting new development in the Oakland hills. The degradation and erosion in small hill creeks due to increased urban runoff from additional building can potentially damage existing houses built near tributary creeks (Figure 88).

**WATERSHED STORMWATER IMPROVEMENTS**

Urban development causes a permanent change in the watershed processes of infiltration of rainfall and runoff of stormwater. These system-wide changes in the drainage basin produce larger volumes of stormwater delivered into creek channels over a short time frame. In response, ephemeral creeks in the steep hills of the watershed erode and can initiate a slide on the hillslope. Larger tributary creeks in the upper watershed are also eroding, particularly in the Cobbledick Creek sub-basin. The main tributary channel of Shephard Creek has already been culverted. In the Sausal Creek sub-basin, the main creek has eroded and deepened, losing riffles, pools and riparian forest due to urban runoff. All of the aquatic insect studies in Sausal Creek show poor aquatic habitat conditions. While urban creeks can be daylighted and enhanced with vegetation, studies of urban creek restoration projects in numerous locations show only small improvements in aquatic habitat conditions (p. 105). This lack of habitat improvement occurs because the urban watershed still produces high velocity flows which scour creeks and greatly reduce aquatic habitat values. Mitigating the effects of urbanization through watershed stormwater improvements can greatly improve aquatic conditions, reduce bank erosion and sustain riparian habitat. The proximity of houses and roads limit the ability of the channel to adjust to the changed urban watershed conditions and regenerate aquatic and riparian habitats.

A broad variety of stormwater facilities were evaluated for their effectiveness in reducing streamflow volumes and velocities in Sausal Creek. These facilities are listed below.

**Table 74: Sausal Creek Watershed Stormwater Improvement Sites**

| Improvement | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Rain barrel at each house in the Shephard and Cobbledick Creek sub-basins | ✓ | ✓ | ✓ |
| Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Chabot Space & Science Center Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Joaquin Miller Elementary School/Montara Middle School Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Montclair Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Joaquin Miller Park Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |

**Table 74: Sausal Creek Watershed Stormwater Improvement Sites**

| Improvement | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Zion Lutheran Church Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 1 | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 2 | ✓ | ✓ | ✓ |
| Montclair Railroad Trail – Stormwater Detention Basin 3 | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Upper Meadow Detention Site | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Middle Meadow Detention Site and Fern Ravine Creek Daylighting | ✓ | ✓ | ✓ |
| Joaquin Miller Park – Lower Meadow Detention Site | ✓ | ✓ | ✓ |
| Metropolitan Horseman's Association Parking Lot Detention and Biofiltration Site | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 1 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 2 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 3 | ✓ | ✓ | ✓ |
| Fruitvale Commercial Area Parking Lot Detention and Biofiltration Site 4 | ✓ | ✓ | ✓ |
| Shepherd Canyon Park – Underground Cistern | | ✓ | ✓ |
| Larry Lane On-stream Detention Pond | | ✓ | ✓ |

**Table 74: Sausal Creek Watershed Stormwater Improvement Sites**

| Improvement | Scenario 1 | Scenario 2 | Scenario 3 |
|---|---|---|---|
| Montclair Golf Course – Underground Cistern | | | ✓ |
| Dimond Park Meadow – Underground Cistern | | | ✓ |

Analyses using both a hydrologic and hydraulic model concluded that:

- Stormwater source control practices such as the rain barrels, parking lot detention, and small detention basins simulated in Scenario 1 have a significant effect on reducing flow rates and volumes for the 1-year runoff event. Larger storm events produce larger quantities of runoff, which quickly overflow these facilities producing only minor reductions in flow rates and volumes for the 2- to 100-year events.

- Cisterns and detention basins significantly reduce flow rates in the reaches below the facilities for the 1-year event, and less so for the larger events. However, as additional tributaries join the channel downstream of the detention facility, the flow dampening effect becomes less pronounced. Flow volumes are less affected by the detention facilities.

- The three scenarios evaluated in this analysis would change the configuration and use of different areas in the watershed and have a range of potential benefits for downstream hydrologic and hydraulic conditions in Sausal Creek. Based on the improved hydraulic conditions, Scenario 3 yields the most substantial improvements over the largest extent of the creek system. Scenario 2 also yields significant improvements. Scenario 1 yields small hydraulic improvements, which may not be sufficient to produce noticeable changes in aquatic and riparian habitat in Sausal Creek but could produce improvements in the Palo Seco Creek sub-basin. Therefore, Scenario 3 appears to be the most beneficial with respect to the long-term geomorphic and sediment transport conditions in Sausal Creek.

- In relation to the other sub-basins, Palo Seco Creek is relatively undeveloped. The proposed improvements included in Scenario 1 within the sub-basin reduce flow rates by 14% to 17%, and flow volumes by 15% to 24% compared to existing conditions for the range of storm events. Because the majority of the improvements occur on publicly-owned lands, implementation of these measures may be simpler and less expensive. For these reasons, it is recommended that implementation of watershed stormwater improvements in the Palo Seco Creek sub-basin be considered as a demonstration project.

- The larger program of watershed stormwater improvements in the other sub-basins can be phased over a 10-year period as grant funds become available.

- Installation of biofiltration facilities along roads and in parking lots should be implemented in as many locations as possible as part of the pilot green street projects required by the Regional Board NPDES permit.

These improvements will require leadership from the City of Oakland, the San Francisco Bay Regional Water Quality Control Board, and the Alameda Countywide Clean Water Program, combined with community input and oversight from groups like Friends of Sausal Creek. These watershed improvements are an integral part of creek restoration efforts and should be proposed as part of a watershed restoration approach to aquatic habitat restoration.

**INVASIVE NON-NATIVE PLANTS**

The abundance and broad distribution of invasive non-native plants in the Sausal Creek watershed is a major threat to native habitat in public parkland and creeks. This problem is further exacerbated by the purchase and planting of many of these invasive species by uninformed homeowners, creating an infinite source of infestation in the watershed.

The main actions recommended to address the invasive plant problem are as follows:

1) Eradication of invasives in the Palo Seco Creek sub-basin;
2) Homeowner education throughout the watershed on invasive garden plants;
3) Work with state and local agencies and organizations to restrict the sale of known invasive non-native plants in the state;
4) Maintenance of revegetation sites free of invasive non-native plants;
5) Focused eradication of fire hazard invasive plants in the entire watershed.

**Eradicating Invasive Non-Native Plants in the Palo Seco Creek Sub-Basin**

Palo Seco Creek sub-basin is primarily public land and offers the best opportunity for improvement of both upland and creek habitats. This effort, while involving FOSC and the Friends of Joaquin Miller Park, will require grant funding and contracts with companies who specialize in invasive plant mapping and eradication projects. This is a major ecological restoration project and requires a larger-scale, more difficult work effort than community volunteers can provide.

The watershed lands outside the park need to be included to evaluate all infested locations on ridge tops and upstream locations. The ridge tops and headwaters are sources of infestation to downhill and downstream areas and should be treated first. Using GPS/GIS, map invasive plants listed in Table 75 and devise an eradication strategy, taking into account the rate of spread, population size, and proximity to at-risk stands of rare plants or intact stands of native vegetation. Using GPS/GIS, also map and identify any rare, unusual or significant plants at risk from invasive plant populations and identify native plant "hotspots" at risk from invasive plant populations. Determine creek and hillside locations most susceptible to bank failure or erosion due to invasive plant infestations.

In Joaquin Miller Park many non-native species are also fire-prone plants. The map of infestations can be used to determine labor hours needed to remove the current infestation. Costs should be compared for removal through mechanical methods only and removal through mechanical methods with herbicide use. The majority of park management agencies including the National Park Service now make careful use of herbicides to eradicate invasive plants. This change has occurred as the result of many years of failing to control invasive plants through using mechanical means only. Since invasive plants are a major threat to native habitats and ecosystem processes, their control outweighs the potential environmental effect of careful use of herbicide. Appendix C provides information on each invasive species.

Given the large number of acres of invasive species in the Palo Seco Creek sub-basin the largest infestations should be cleared from the outside and working toward the center. Areas along trails and roads are priority control areas due to the spread of seed and stem materials by hikers, dogs, and bicyclists.

FOSC, Friends of Joaquin Miller Park, the Oakland Parks and Recreation Department, and the Wildfire Prevention District should form a working group to plan removal of the Eucalyptus, Acacia, broom, and pampas grass as a multi-year effort. The use of herbicide as a cut-and-paint method will be needed to make eradication efforts effective. The use of controlled burns may also be evaluated, especially for Algerian ivy infestations. Work should be done by paid contractors.

The eradication effort needs to be well-publicized to neighboring homeowners and park users. Both fire hazards and ecological issues need to be explained thoroughly. Neighboring homeowners with these species on their property should be encouraged to participate in the eradication effort. For the other invasive species—Cape ivy, Algerian ivy, yellow star thistle, Himalayan blackberry, holly, and various grasses—a broad-based community outreach effort is needed. For each species, the upslope/upstream extent of the plant will need to be determined exactly. Table 77 lists some known locations of invasives. FOSC, in conjunction with weed warriors and other service groups, could be involved along with community members, neighborhood associations, and local landowners in planning and publicizing the program. As with the eradication of fire hazard plants, these efforts should be broadly publicized in Oakland with detailed information about the plants. Work should be done by paid contractors.

By focusing on invasive plant eradication in Joaquin Miller Park, public funding may be available, particularly if the program can describe this effort in terms of acres of each habitat type improved and number of private landowners involved. The eradication of non-natives in the Palo Seco Creek watershed will need to extend over at least a 5- to 10-year period.

**Homeowner Education**

Homeowners provide the primary infestation mechanism of invasive non-native plants in the Sausal Creek watershed through their planting, cultivation, and disposal of garden waste in creeks and empty lots. It is likely that most homeowners do not realize the long-term negative effects of their actions.

FOSC in conjunction with the City, Wildfire Prevention District, the local chapter of the California Native Plant Society, the California Invasive Plant Council, and other organizations need to develop a full media approach: brochures, mailers, Internet, hikes, and events to increase homeowner awareness of common invasive plants. Similar to the “green” movement which has changed consumer attitudes about many products, garden decisions involving invasive plants need to be “greened” and made a part of the popular dialogue. Additional actions include:

- Develop training program/materials for training leaders in active homeowner groups: Beaconsfield, Marj Saunders/Piedmont Pines, Shepherd Canyon Homeowners Association, Castle Canyon, Bridgeview, Barry Place, W. D. Wood Park, plus Adopt-a-Spot leaders and crew leaders.
- Purchase copies of *Invasive Plants of the California Wildlands* and *Vegetation Almanac for the East Bay Hills* for project leads for above areas.
- Develop a section of FOSC website to educate homeowners on invasives ID, problems, and best practices for removal.

**Ban the Sale of Invasive Non-Native Plants**

It is difficult to take on a major plant eradication effort in an urban area knowing that the plants being dug up and removed are available for sale at nurseries and garden centers. The City of Oakland, Friends of Joaquin Miller Park, FOSC, and other groups should discuss involvement in statewide efforts to ban the sale of the worst weeds in California.

**Maintain Revegetation Sites Free from Invasive Plants**

The locations where FOSC has completed revegtation with native plants need to be maintained to avoid infestation with invasives. This effort can be done with community volunteers and should include broom, Algerian ivy, thornless blackberry, cape ivy and American elm. Development of a system to track treament of specific areas and invasive species, especially cape ivy, broom, Algerian ivy and blackberry would allow for practices to be evaluated for effectiveness.

| Table 75: Some Recommended Invasive Plant Removal Projects in Joaquin Miller Park* |
|---|
| ***Yellow Star Thistle (YST)*** |
| Lookout Point – some control has occurred but additional work and yearly follow-up is needed |
| Joaquin Miller Road and Skyline Blvd. – just as the Skyline Blvd. right-turn lane onto Joaquin Miller Road starts: patch of YST at roadside, then up the road cut, and some up on top as well. This is an area with some rare natives, including Tiburon Buckwheat. |
| Sunset Trail – goats graze most of the western portion of the Sunset Trail; YST control needed between the trail and the electric fence and on ungrazed portions near Sinawik Cabin |
| ***Broom-all species*** |
| Below Lookout Pont – starts under Eucalyptus providing fire ladder and is moving downhill toward very good native plant hotspot |
| Along Sanborn Road-starts near the west end of the one-way loop; scattered plants down to Lookout Point |
| Joaquin Miller Road and Skyline Blvd. – broom patch up on top of the road cut expanding |
| Along Chaparral Trail, Sunset Trail, and Sinawik Trail |
| ***Cape Ivy*** |
| 2 patches, each fairly small, along paved road parallel to Skyline; first is at the fire gate; 2nd is about 250 ft. east of Orchard Trail. Someone removed most above-ground parts sometime in 2008; needs follow-up |
| Patch along Skyline, from roadside edge down to creek |
| Large patch near Castle Park Trail in Cinderella Creek headwaters; this patch will take extensive work and many repeat visits to control |
| Small patch near Sanborn Road and Sinawik Loop Trail |
| ***Acacia*** |
| Seedling/sapling control is needed to protect native plant and wetland area on Cinderella Creek |
| Continue to expand clearing efforts below nursery and control re-sprouts |
| Clear serpentine outcrop near Joaquin Miller House |
| Continue clearing along Sanborn Road, where zoo harvesting has taken place |
| Horse Arena area – vast amounts of all 3 kinds of Acacia; priority area is between Castle Park Trail and tributary to Cinderella Creek. Infestation is moving toward good riparian area with significant native plant populations |
| ***Holly*** |
| Dense patches along Palo Seco Creek need to be removed to protect downstream riparian areas in the park and assure regeneration of shade canopy |
| ***Eucalyptus*** |
| Dense along Sunset and Castle Park Trails |
| ***Veldt Grass*** |
| Ranger Station Trail to stone bridge |
| Sinawik Loop Trail – currently lots of small patches are present, and some larger nearby areas |
| Sequoia-Bayview Trail – many small patches along trail; it has moved densely downhill from the trail |
| ***Himalayan Blackberry*** |
| Remove along creeks prior to planting native trees and shrubs |
| ***Other Species*** |
| As Monterey pines senesce and die they create canopy openings subject to infestation. Remove nearby invasives in the opening area and remove pine seedlings and cut young pines in the area. Replant native trees and shrubs |

* This is not a comprehensive list. Mapping and comprehensive control is recommended.

**Control of Fire Hazard Plants throughout the Watershed**

While it will be nearly impossible to control invasive plants in all areas of the watershed, controlling fire hazard plants throughout the watershed is a necessity. The Wildfire District, working with local groups, is evaluating control of the primary fire hazard plants: Eucalyptus, Acacia, broom, and pampas grass. When these species are removed, some provisions need to be made for erosion on cleared steep sites. The example of the Eucalyptus removal in Joaquin Miller Park next to Castle Drive, which has become a major erosion site (Figures 95-98) should inform current and future eradication efforts. Figure 134 shows a Eucalyptus clearcut on Skyline Blvd. at the headwaters of an ephemeral creek. This figure also shows a small creek cleared of broom with no erosion control installed. Effects on natives plants in these eradication sites also needs to be carefully evaluated.

**WATER QUALITY**

The most serious water quality problem identified from the monitoring data is high *E. coli* levels in Sausal Creek and raw sewage spills and overflows from the sanitary sewer system. In the short-term when sewage spills occur in open creek areas where children have access to the water, the City of Oakland must post closure signs. *E. coli* measured at high levels by the water quality monitoring indicates a potential health hazard for water contact recreation. A watershed-wide program of bacterial monitoring and monitoring of the location of sewage spills and overflows need to be implemented by the City in conjunction with the San Francisco Bay Regional Water Quality Control Board and the Environmental Protection Agency. Identifying the locations of sewage spills will assist in implementing a control program.

In the long-term, the sewer system needs to be upgraded so that stormwater infiltration into the sewer pipes, a major cause of overflows, is eliminated. Dry season leaks indicated by the monitoring results also need to be identified and repaired.

In addition to bacteria monitoring, monitoring of aquatic insects in creeks in the watershed can provide a long-term basis for comparison of conditions and improvements. As discussed on page 105, aquatic insects are an excellent indicator of the condition of aquatic habitats. Sausal and Palo Seco Creeks have had aquatic insect monitoring from 1999-2004/2005 to set a baseline for current watershed conditions. As watershed stormwater improvements are implemented, continued aquatic insect monitoring can document the change in aquatic habitat conditions resulting from reduced scour and lower flow velocities. Aquatic insect monitoring should be done using the SWAMP protocols and a professional lab. A spring and fall sampling at all the SWAMP stations with an additional station in the upstream area of Palo Seco Creek would provide adequate review of changes and improvements.

The implementation of biofiltration improvements, if completed in enough locations, can effectively remove nutrients and persistent pollutants typical of urban runoff. These facilities also collect floatable trash. Biofiltration facilities, however, require maintenance annually or they are not effective.

Reducing pollutants at the source is by far the most cost effective solution, but also the most difficult as it involves changing human behavior. Homeowners in the watershed can play a major role in improving the water quality and habitats in Sausal creek and its tributaries. As part of the series of workshops for homeowners a workshop on recommended measures for the home and garden to reduce pollutants should be included. Subjects that should be included are: revising the location of car washing to avoid

soap pollution (nutrients) into creeks, proper locations and methods for cleaning paint brushes and accessories, cleaning up the oil and grease on driveways and streets, low chemical pest control and reduced fertilizer use in gardens, transforming water hungry lawns into low water landscaping with less runoff, and other topics.

Trash as a pollutant also can be reduced through the work of volunteers, neighborhood groups, and businesses. It can also be controlled through enforcement of littering and dumping laws. The City of Oakland has tried using citations to reduce littering.

Figure 134: Removal of fire-prone invasive plants in ephemeral creek swales can cause erosion.

**AQUATIC AND RIPARIAN HABITATS**

Except for Palo Seco Creek, the aquatic and riparian habitats of the Sausal Creek watershed have been significantly degraded by urbanization of the watershed and the increase in storm flow volumes and velocities, and the resulting scour of the channel. The first and most important step in restoring aquatic habitats in the Sausal Creek watershed is implementation of watershed stormwater improvements to reduce the scouring high velocity flows caused by urbanization of the watershed.

By focusing on creek restoration, invasive plant removal, and watershed stormwater improvements in Palo Seco Creek, the greatest degree of habitat enhancement can be achieved. This approach could create high quality aquatic habitat in Palo Seco Creek and provide a genuine refuge for a resident population of rainbow trout. This same goal cannot be met on Sausal Creek. With implementation of all of the watershed stormwater improvements in Scenario 3, flow velocities and channel scour in Sausal Creek still exceed thresholds needed to support high quality aquatic habitat conditions under most flood levels. Implementation of Scenario 3, however, does represent a major improvement in creek conditions under the most frequent 1-year flow event.

Table 76 outlines recommended actions in the creek reaches available for revegetation and improvement. Most of the restoration recommendations will require designs by qualified professionals: civil engineers, geomorphologists, hydrologists, and riparian ecologists. They will also require implementation by contractors with experience in stream restoration. Community groups like FOSC and Friends of Joaquin Miller Park can supply assistance to grant efforts, grow native plants in the Joaquin Miller nursery, coordinate volunteer assistance with planting native plants, and maintain creek areas after restoration.

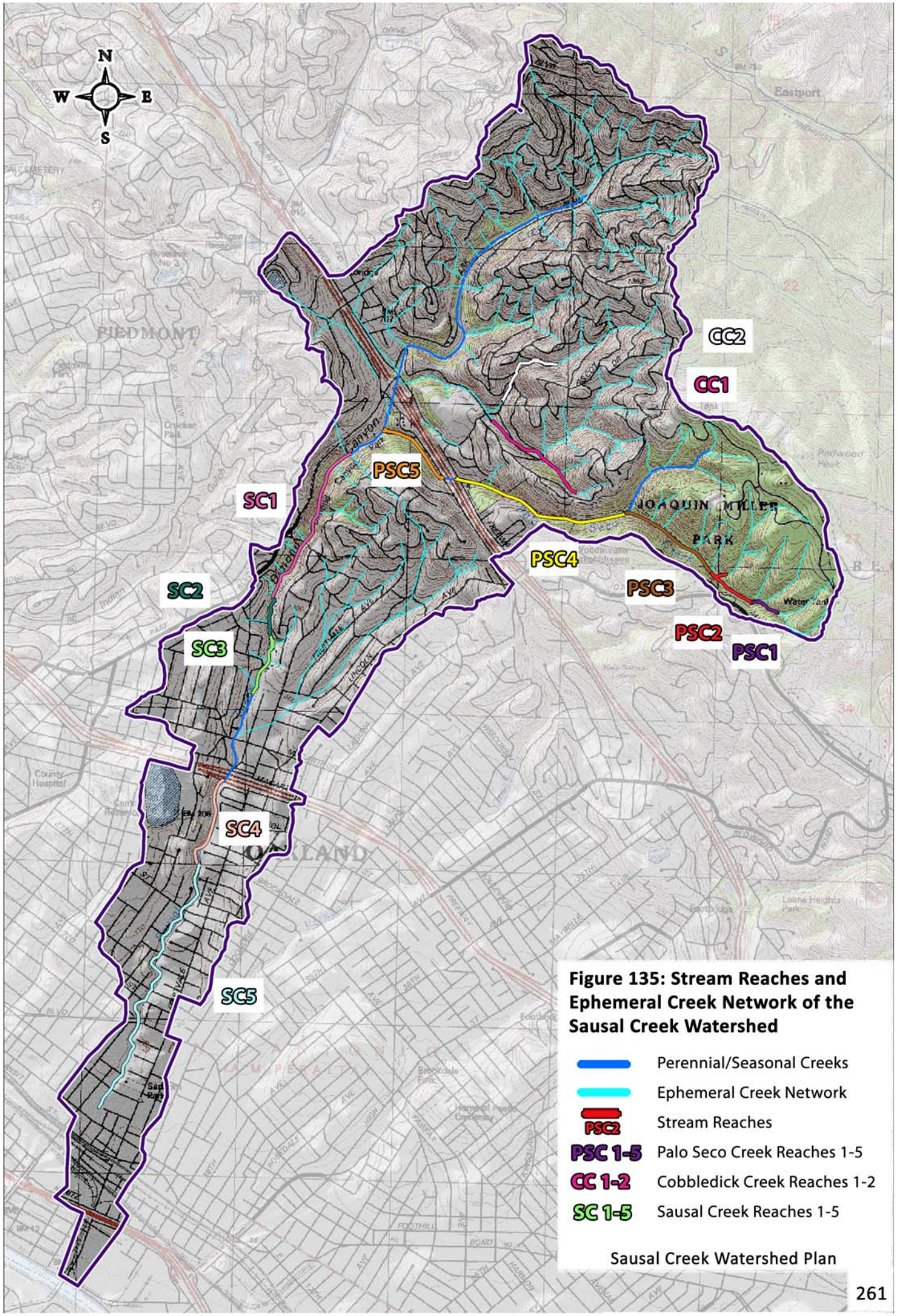


**Figure 135: Stream Reaches and Ephemeral Creek Network of the Sausal Creek Watershed**

**Table76: Restoration Recommendations for Stream Reaches**

| Reach | Priority | Recommendations |
|---|---|---|
| PSC1 | High | • Repair Erosion Site 1 by installing culvert where the trail crosses an ephemeral creek. Culvert must be set in the channel at the slope of the stream to minimize erosion at the culvert outlet and have a minimum of 18 inches of trail fill on top to avoid damage to culvert. Fine sediment from this erosion site is filling the creek.<br>• Relocate trail out of meadow and direct traffic onto Sunset Trail. Restrict bikes and hikers to allow stream restoration.<br>• Install berm at downstream end of Upper Meadow with standpipe connected to culvert under trail. Eradicate Himalayan blackberry and revegetate the floodplain with native trees.<br>• This reach offers one of the only locations for a floodplain riparian restoration with a detention and sediment basin. This site is part of the overall watershed improvements to reduce velocity and volume of stormwater and improve Palo Seco Creek aquatic habitat. |
| PSC2 | High | • The creek is culverted through a meadow likely created during the WPA era when recreational areas were created at the expense of environmental protection.<br>• This reach is a major candidate for daylighting and restoration, especially as the culverts are old and will require replacement in the near future.<br>• Install berm at downstream end to detain stormwater during peak runoff events.<br>• The downstream portion of Fern Ravine Creek now runs overland during nearly every rainfall event as the culvert outlet clogs. The creek should be daylighted and directed into the proposed stormwater detention area and eventually integrated with a daylighted and restored Palo Seco Creek. |
| PSC3 | High | • Improved grade control structures need to be installed at the two knickpoints (Erosion Sites 3 and 4) to avoid the migration of the knickpoints upstream and the undercutting of large trees. Downstream of the bridge a number of trees along the banks have been eroded. The banks should be set back and revegetated once the Himalayan blackberry is removed. |
| PSC4 | High | • Invasive non-native plants are degrading the redwood/California bay laurel forest riparian habitat and weakening the trees. Holly trees are the only species regenerating in the corridor. The holly and ivy need to be eradicated to restore the health of the forest. Ivy should be cut around the base of each tree, and the stumps immediately painted with herbicide to kill the ivy quickly and effectively. If the trees along the steep-sided gorge become weakened by the parasitic ivy and fall, the slopes may fail due to the ground disturbance. The holly needs to be cut and the stumps painted with herbicide to quickly remove this invader before it becomes established and dominates the corridor. |
| PSC5 | Moderate | • FOSC has completed an erosion control project and an invasive plant removal/native plant revegetation project here. Continued maintenance will be needed.<br>• Replace bridge at stream level or re-route trail. |

**Table76: Restoration Recommendations for Stream Reaches**

| Reach | Priority | Recommendations |
|---|---|---|
| CC1 | Low | • Houses line the upstream portion of this reach, leaving few opportunities for restoration. The sediment/stormwater detention basin on this reach needs to be cleaned out and retrofitted in order to function better. A large gully in this sub-basin requires repair. |
| CC2 | Moderate | • The Beaconsfield Canyon reach needs to have the rusted culvert removed and a geomorphic /revegetation restoration plan that includes a riparian floodplain area completed.<br>• Downstream drop inlet to storm drain needs to be repaired/replaced. |
| SC1 | Low | • This reach presents a real challenge for restoration. There are two major culverts and numerous concrete structures including a cement wall protecting the sanitary sewer pipe.<br>• California bay laurel trees have eroded off the canyon wall and into the creek. Replanting these trees will maintain shade cover for the creek.<br>• Eradicate ivy and other invasives to retain health of native trees.<br>• Work with the City of Oakland to repair erosion from storm drains, especially the major erosion sites along Park Blvd.<br>• Sanitary sewer overflows into Sausal Creek occur during major storms and need to be alleviated to avoid both contamination of the creek and a public health problem. |
| SC2 | Low | • This reach is a restoration project completed in 2001. Control of invasive plants and revegetation are necessary both along the channel and along side channels. The channel does not provide adequate room for regeneration of riparian species, and replanting will be required. Installing white alder along the channel could diversify the vegetation and provide some stability to the undercut bank areas, which provide refuge to wildlife in floods. |
| SC3 | Moderate | • Replanting of white alder and removal of waste cement and asphalt is needed along this reach. Riparian shade cover over the El Centro pool is also needed to maintain cool water temperatures.<br>• Recreation uses preclude the option of daylighting the creek through Dimond Canyon Park.<br>• Future City of Oakland project to stabilize private property and revegetate stream banks. |
| SC4 | Low | • Creek is entrenched with steep banks and fill from the McKillop slide. With this slide affecting the creek it is difficult to implement revegetation. Houses are very close to the channel, further restricting restoration options. Community-based invasive plant removal and native plant installations would provide local educational opportunities. |
| SC5 | Low | • Creek is entrenched with steep banks and numerous houses. Channel is hardpan clay and revegetation will be difficult in most locations. Community-based invasive plant removal and native plant installations would provide local educational opportunities. |

**IMPLEMENTING THE WATERSHED PLAN**

There are recommended actions in this plan that are suitable for community groups such as Friends of Sausal Creek (FOSC), Friends of Joaquin Miller Park, Shepherd Canyon Homeowners' Association, and others. Many of the actions needed to restore productive aquatic habitat to Sausal Creek and its tributaries, however, require a significant change to storm drain and sanitary sewer infrastructure, including construction of both stormwater detention facilities and creek restoration. This change requires the involvement of the owner of the infrastructure: the City of Oakland. Many areas of Oakland have old and deteriorating infrastructure such as storm drain and sewer systems. The construction of stormwater detention and biofiltration facilities may be able to attract grant funds and allow for the upgrade of storm pipes as part of water quality and creek improvements. The recent municipal stormwater permit from the San Francisco Bay Regional Water Quality Control Board to Alameda County requires implementation of LID (low impact development) practices. This permit also requires the construction of two pilot green street projects. The recommended focus on Palo Seco Creek sub-basin as a demonstration project includes a number of stormwater detention facilities on City property. Table 77 outlines lead and supporting agencies and organizations for each of the recommended actions in the watershed plan.

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| **Major Erosion Sites** | | | |
| Repair extreme and eroded sites at outlets of City storm drain system | City of Oakland | San Francisco Bay Regional Water Quality Control Board<br><br>FOSC and neighborhood groups | Adopt-a-Stormdrain program could be used to maintain repaired outlets and repaired erosion sites. |
| Homeowner workshops on stormwater management | Alameda Countywide Clean Water Program | FOSC and neighborhood groups | |
| Repair erosion sites in City parks, including relocation and re-grading of trail | City of Oakland | FOSC, Friends of Joaquin Miller Park, Friends of Beaconsfield Canyon, Piedmont Pines Neighborhood Association, and other neighborhood groups | Volunteer groups can play a major role in implementing improvements in parks but designs need to be done by professionals. |
| **Watershed Stormwater Improvements** | | | |
| *High Priority* | | | |
| Implement Scenario 1 improvements in Palo Seco Creek sub-basin including:<br>• Retrofit Chabot Space & Science Center parking lots 1 and 2 to detain stormwater and install biofiltration units<br>• Retrofit Joaquin Miller Park parking lots to detain stormwater and install biofiltration units | Chabot Space and Science Center Joint Powers Agency<br><br>City of Oakland | FOSC<br><br>San Francisco Bay Regional Water Quality Control Board<br><br>Alameda Countywide Clean Water Program<br><br>Friends of Joaquin Miller Park | Due to the low level of development in this sub-basin, the greatest level of creek habitat improvement can be achieved by installing stormwater facilities. Detention facilities can also reduce the need for replacement of undersized storm drains.<br>The ridgetop parking lots near the Joaquin Miller Community Center drain toward Joaquin Miller Park.<br>The stormwater runoff from the Chabot Space and Science Center is actively eroding areas of the park. |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Joaquin Miller Park – Upper, Middle, and Lower Meadow detention sites | City of Oakland<br><br>FOSC | Friends of Joaquin Miller Park<br><br>Alameda Countywide Clean Water Program | These facilities include daylighting lower Fern Ravine Creek. Daylighting Palo Seco Creek through the meadow can also be included in the detention design. |
| Metropolitan Horsemen's Association parking lot detention and biofiltration site | City of Oakland | Friends of Joaquin Miller Park<br><br>Alameda Countywide Clean Water Program<br><br>FOSC | |
| Implementation of biofiltration facilities along streets and in parking lots | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | Alameda Countywide Clean Water Program<br><br>FOSC and other community organizations | |
| *Long-Term Priority* | | | |
| Implementation of watershed stormwater improvements in Scenario 3 for Sausal Creek | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | Alameda Countywide Clean Water Program<br><br>FOSC and other community organizations | The only long-term option for sustainable improvement in Sausal Creek requires the implementation of Scenario 3 of watershed stormwater improvements. |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| **Invasive Non-Native Plants** | | | |
| Implement a comprehensive mapping, invasive plant eradication/native planting program in the Palo Seco Creek sub-basin | FOSC<br><br>City of Oakland | Wildfire Prevention District | This program should be implemented with grants and contractors skilled in invasive plant eradication (i.e., Shelterbelt Builders, California Conservation Corps). Relying on community volunteers limits the extent and location of invasives removed and cannot accomplish a comprehensive program. Palo Seco Creek sub-basin offers the best opportunity for large-scale restoration of upland and wetland/riparian habitats. |
| Homeowner education | Wildfire Prevention District<br><br>FOSC<br><br>City of Oakland | Homeowner and community groups | Urban gardens are the primary infestation mechanism for invasive non-native plants. Most homeowners are not aware of the problem and could be convinced to avoid planting them. |
| Ban the sale of invasive plants for gardens | City of Oakland<br><br>FOSC and Friends of Joaquin Miller Park<br><br>Wildfire Prevention District | Homeowner and community groups<br><br>California Native Plant Society<br><br>California Invasive Plant Council | The continued sale of invasive plants in California is a state-wide issue. |
| Maintain FOSC revegetation projects | FOSC | Community volunteers | Invasives have affected FOSC revegetation projects in several locations. |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Control fire hazard plants | Wildfire Prevention District | FOSC, Friends of Joaquin Miller Park, Friends of Beaconsfield Canyon, Piedmont Pines Neighborhood Association, and other neighborhood groups | Eradicating fire hazards and not planting these species are important actions in fire reduction. |
| **Water Quality** | | | |
| Monitor creeks for *E. coli* | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | EPA, FOSC, and community groups | |
| Monitor location and frequency of sewage spills | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | EPA, FOSC, and community groups | |
| Post creek areas in parks when sewage overflows occur | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | EPA, FOSC, and community groups | |
| Twice annual monitoring of aquatic insects at a number of stations in the watershed | San Francisco Bay Regional Water Quality Control Board<br><br>FOSC | City of Oakland | A long-term study of changes in aquatic insect communities as watershed improvements are implemented may attract academic interest. |
| Implement biofiltration projects to reduce nutrients, trash, and other pollutants | City of Oakland<br><br>San Francisco Bay Regional Water Quality Control Board | Alameda Countywide Clean Water Program<br><br>FOSC and other community groups | |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| **Aquatic and Riparian Habitats** | | | |
| *High Priority* | | | |
| Implement Watershed Stormwater Improvements, Scenario 1 | | | |
| Creek Reach PSC1<br>• Repair Erosion Site 1 by installing culvert where the trail crosses an ephemeral creek. Culvert must be set in the channel at the slope of the stream to minimize erosion at the culvert outlet and have a minimum of 18 inches of trail fill on top to avoid damage to culvert. Fine sediment from this erosion site is filling the creek.<br>• Relocate trail out of meadow and direct traffic onto Sunset Trail. Restrict bikers and hikers to allow stream restoration.<br>• Install berm at downstream end of Upper Meadow with standpipe connected to culvert under trail. Eradicate Himalayan blackberry and revegetate the floodplain with native trees.<br>• This reach offers one of the only locations for a floodplain riparian restoration with a detention and sediment basin. This site is part of the overall watershed improvements to reduce velocity and volume of stormwater and improve Palo Seco | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Community groups | Palo Seco Creek has the greatest potential for major improvement in aquatic habitat conditions through a combined program of watershed stormwater improvements, creek restoration, and invasive plant eradication. This focus would create a sustainable habitat area to provide refuge for resident rainbow trout. |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Creek aquatic habitat. | | | |
| Creek Reach PSC2<br>• The creek is culverted through a meadow likely created during the WPA era when recreational areas were created at the expense of environmental protection.<br>• This reach is a major candidate for daylighting and restoration, especially as the culverts are old and will require replacement in the near future.<br>• Install berm at downstream end to detain stormwater during peak runoff events.<br>• The downstream portion of Fern Ravine Creek now runs overland during nearly every rainfall event as the culvert outlet clogs. The creek should be daylighted and directed into the proposed stormwater detention area and eventually integrated with a daylighted and restored Palo Seco Creek. | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Urban Creeks Council and other community groups | Daylighting Palo Seco and Fern Ravine Creeks would be one of the largest habitat improvements in the watershed; however, it would require a major re-design of recreational uses of a part of Joaquin Miller Park |
| Creek Reach PSC3<br>• Improved grade control structures need to be installed at the two knickpoints (Erosion Sites 3 and 4) to avoid the migration of the knickpoints upstream and the undercutting of large trees. | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Community groups | |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| Downstream of the bridge a number of trees along the banks have been eroded. The banks should be set back and revegetated once the Himalayan blackberry is removed. | | | |
| Creek Reach PSC4<br>• Invasive non-native plants are degrading the redwood/California bay laurel forest riparian habitat and weakening the trees. Holly trees are the only species regenerating in the corridor. The holly and ivy need to be eradicated to restore the health of the forest. Ivy should be cut around the base of each tree, and the stumps immediately painted with herbicide to kill the ivy quickly and effectively. If the trees along the steep-sided gorge become weakened by the parasitic ivy and fall, the slopes may fail due to the ground disturbance. The holly needs to be cut and the stumps painted with herbicide to quickly remove this invader before it becomes established and dominates the corridor. | City of Oakland<br><br>FOSC, Friends of Joaquin Miller Park | San Francisco Bay Regional Water Quality Control Board<br><br>Community groups | |
| *Moderate Priority* | | | |
| Creek ReachPSC5<br>• FOSC has completed an erosion control project and an invasive plant removal/native plant revegetation | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| project here. Continued maintenance will be needed.<br>• Replace bridge at stream level or re-route trail. | | | stormwater improvements are implemented. |
| Creek Reach CC2<br>• The Beaconsfield Canyon reach needs to have the rusted culvert removed and a geomorphic /revegetation restoration plan that includes a riparian floodplain area completed.<br>• Downstream drop inlet to storm drain needs to be repaired/ replaced. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach SC3<br>• Replanting of white alder and removal of waste cement and asphalt is needed along this reach. Riparian shade cover over the El Centro pool is also needed to maintain cool water temperatures.<br>• Recreation uses preclude the option of daylighting the creek through Dimond Canyon Park.<br>• Future City of Oakland project to stabilize private property and revegetate stream banks. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| *Low Priority* | | | |
| Creek Reach CC1<br>• Houses line the upstream portion of this reach, leaving few opportunities for restoration. The sediment/ stormwater detention basin on this | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| reach needs to be cleaned out and retrofitted in order to function better. A large gully in this sub-basin requires repair. | | | implemented. |
| Creek Reach SC1<br>• This reach presents a real challenge for restoration. There are two major culverts and numerous concrete structures including a cement wall protecting the sanitary sewer pipe.<br>• California bay laurel trees have eroded off the canyon wall and into the creek. Replanting these trees will maintain shade cover for the creek.<br>• Eradicate ivy and other invasives to retain health of native trees.<br>• Work with the City of Oakland to repair erosion from storm drains, especially the major erosion sites along Park Blvd.<br>• Sanitary sewer overflows into Sausal Creek occur during major storms and need to be alleviated to avoid both contamination of the creek and a public health problem. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach SC2<br>• This reach is a restoration project completed in 2001. Control of invasive plants and revegetation are necessary both along the channel and alongside channels. The channel does | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |

**Table 77: Implementation of Recommended Actions in the Sausal Creek Watershed**

| Recommendations | Lead Entity | Supporting Entities | Comments |
|---|---|---|---|
| not provide adequate room for regeneration of riparian species, and replanting will be required. Installing white alder along the channel could diversify the vegetation and provide some stability to the undercut bank areas, which provide refuge to wildlife in floods. | | | |
| Creek Reach SC4<br>• Creek is entrenched with steep banks and fill from the McKillop slide. With this slide affecting the creek it is difficult to implement revegetation. Houses are very close to the channel, further restricting restoration options. Community-based invasive plant removal and native plant installations would provide local educational opportunities. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |
| Creek Reach SC5<br>Creek is entrenched with steep banks and numerous houses. Channel is hardpan clay and revegetation will be difficult in most locations. Community-based invasive plant removal and native plant installations would provide local educational opportunities. | City of Oakland<br><br>FOSC | San Francisco Bay Regional Water Quality Control Board<br><br>Other community groups | These projects have a much lower ability to provide sustainable, high quality aquatic and riparian habitats unless Scenario 3 watershed stormwater improvements are implemented. |

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Sausal Landslide

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2. Oakland City Boundary, Oakland city_landsld.shp- from the shapefile received from Karen Paulsell, cty_lmts.shp, and modified to look like the boundary shown in Tom Burke's report.
3. Hydrologic Systems, Inc. 2009. Sausal Watershed Boundary, Sausal_Watershed_Boundary.shp
4. Graymer, R.W. 2000. Water line, Oakland_waterline.shp extracted from oak_geol.shp-"Geologic map and map database of the Oakland metropolitan area, Alameda, Contra Costa, and San Francisco Counties, California. http://www-laep.ced.berkeley.edu/classes/gisc/raphael/em_respo/layers/geoldesrci.pdf

Sausal Land Use

1. USGS 2001 National Land Cover Database. 2001. Land cover, landcover.tif, derived from 2000 vintage Landsat 7 Satellite imagery, 30m resolution. http://www.mrlc.gov/nlcd.php
2. Hydrologic Systems, Inc. 2009. Sausal Watershed Boundary, Sausal_Watershed_Boundary.shp
3. Hydrologic Systems, Inc. 2009. Sub-Basins, SubBasins – 33 Basins.shp
4. USGS. 2009. Key roads, USGS DLG data
5. USGS. 2009. Highways, USGS DLG data

Sausal Monitoring Sites

1. Monitoring site, monitoring_sites.shp- digitized from JPG, Excel files and pdf from Laurel Marcus. SWAMP sites- monitoring stations.xls. FOSC sites- FOSC water quality stations.xls, FOSC water quality monitoring stations copy.jpg, FOSC aquatic insect monitoring stations copy.jpg,

bacteria monitoring stations copy.jpg, Sausal monitoring sites with Lacan in purple.jpg, sausal monitoring sites

2. USGS. 2009. Key roads, USGS DLG data
3. USGS. 2009. Highways, USGS DLG data
4. USGS. 2009 Streams, delineated_streams.shp (modified by Lisa Lackey, using contour lines of 7.5 Topos)
5. Hydrologic Systems, Inc. 2009. Sausal Watershed Boundary, Sausal_Watershed_Boundary.shp
6. Hydrologic Systems, Inc. 2009. Sub-Basins, SubBasins – 33 Basins.shp
7. City of Oakland. 2009. USGS. 2009. Hillshade created from oakdem5ft GRID and the USGS National Elevation Dataset (NED) 1 arc second
8. California Spatial Information Library (CASIL). 2009. Mosaic of Digital Raster Graphics (DRG) scanned from USGS 7.5' topo map.

Sausal Parks

1. Park Boundaries- Extracted from Parks.shp received from Karen Paulsell.
2. Hydrologic Systems, Inc. 2009. Sausal Watershed Boundary, Sausal_Watershed_Boundary.shp
3. Hydrologic Systems, Inc. 2009. Sub-Basins, SubBasins – 33 Basins.shp
4. USGS. 2009. Key roads, USGS DLG data
5. USGS. 2009. Highways, USGS DLG data

Sausal Soils

1. Soils, soils.shp- from Natural Resources Conservation Service (NRCS) soils, Alameda County
2. Hydrologic Systems, Inc. 2009. Sausal Watershed Boundary, Sausal_Watershed_Boundary.shp

Sausal Sub-Basins

1. Hydrologic Systems, Inc. 2009. Sub-Basins, SubBasins – 33 Basins.shp
2. Hydrologic Systems, Inc. 2009. Sausal Watershed Boundary, Sausal_Watershed_Boundary.shp
3. USGS. 2009. Key roads, USGS DLG data
4. USGS. 2009. Highways, USGS DLG data

5. USGS. 2009 Streams, delineated_streams.shp (modified by Lisa Lackey, using contour lines of 7.5 Topos)

6. City of Oakland. 2009. USGS. 2009. Hillshade created from oakdem5ft GRID and the USGS National Elevation Dataset (NED) 1 arc second

**FINAL**

# SAUSAL CREEK WATERSHED ENHANCEMENT PLAN

# APPENDICES

Sausal Creek "Restoration Reach" in 2003

Prepared by Laurel Marcus and Associates, NewFields River Basin Services, Hydrologic Systems Inc.

For

Friends of Sausal Creek

March 2010

Funding provided by the State Water Resources Control Board

# Appendix A

## Precipitation Data

```
 Program: LOGPER.EXE LOG Pearson Type III Analysis.
          HSI  Hydrologic Systems, San Rafael, California 94901
          (415) 454-6056  water@hydrologic-systems.com
          Version 2.6, November 2007


Run Date:  Tue Nov 20 2007 03:22 PM

Input File = USLFP1HR.txt


This is the input data:
```

**Title: 1 Hr**

```
    1949.00 ;       0.31
    1950.00 ;       0.35
    1951.00 ;       0.43
    1952.00 ;       1.20
    1953.00 ;       0.31
    1954.00 ;       0.71
    1955.00 ;       0.41
    1956.00 ;       0.43
    1957.00 ;       0.52
    1958.00 ;       0.60
    1959.00 ;       0.66
    1960.00 ;       0.29
    1961.00 ;       0.60
    1962.00 ;       0.52
    1963.00 ;       0.80
    1964.00 ;       0.91
    1965.00 ;       0.42
    1966.00 ;       0.50
    1967.00 ;       1.05
    1968.00 ;       0.60
    1969.00 ;       0.40
    1970.00 ;       0.60
    1971.00 ;       0.84
    1972.00 ;       0.21
    1973.00 ;       0.87
```

```
     1974.00 ;       0.56
     1975.00 ;       0.49
     1976.00 ;       0.54
     1977.00 ;       0.46
     1978.00 ;       0.80
     1979.00 ;       0.69
     1980.00 ;       0.60
     1981.00 ;       0.29
     1982.00 ;       0.53
     1983.00 ;       0.67
     1984.00 ;       0.58
     1985.00 ;       0.61
     1986.00 ;       0.70
     1987.00 ;       0.50
     1988.00 ;       0.50
     1989.00 ;       0.41

End of file encountered.

41 Data points were read.


Statistics of Data:

   Mean of Data      =       0.57
   Min  of Data      =       0.21
   Max  of Data      =       1.20
   Std. Dev. of Data =       0.21

Statistics of Logged Data:

   Mean of LOG Data                 =     -0.270
   Std. Dev. of LOG Data            =      0.159
   Standard Skew of LOG Data        =     -0.229

   Generalized Skew Coef.  Pub 17B  =     -0.300

Skew Weighting factors:

   A    =     -0.312
```

```
   B    =      0.880
   C    =      0.613
   MSEg    = Estimate of Error of Station Skew  =      0.141

   MESgbar = Estimate of Error of Regional Skew =      0.302

   Weighting of Station Skew  =       68.2 percent
   Weighting of Regional Skew =       31.8 percent

Weighted Generalized Skew Value Used In The Analysis =     -0.252


The following points are considered high outliers:

   The 10 pct Level of Significance Kn =      2.692

   No High Outliers

The following points are considered Low outliers:

   No Low Outliers


The Results of The Frequency Analysis:


The 500 YR Frequency Factor Kt   =      2.575
The 500 year precipitation       =      1.381

The 200 YR Frequency Factor Kt   =      2.339
The 200 year precipitation       =      1.267

The 100 YR Frequency Factor Kt   =      2.140
The 100 year precipitation       =      1.177

The 50 YR Frequency Factor Kt    =      1.921
The 50 year precipitation        =      1.086

The 25 YR Frequency Factor Kt    =      1.661
The 25 year precipitation        =      0.988
```

```
The 10 YR Frequency Factor Kt    =      1.251
The 10 year precipitation        =      0.850

The 5 YR Frequency Factor Kt     =      0.852
The 5 year precipitation         =      0.734

The 2 YR Frequency Factor Kt     =      0.042
The 2 year precipitation         =      0.545

The 1.5-Year Frequency Factor Kt =     -0.399
The 1.5-Year precipitation       =      0.464

The 1.43-Year return Flow
The 70 pct. Exceedence Factor Kt     =     -0.492
The 70 pct. Exceedence precipitation =      0.448

The 1.25-Year return Flow
The 80 pct. Exceedence Factor Kt     =     -0.827
The 80 pct. Exceedence precipitation =      0.396

The 1.11-Year return Flow
The 90 pct. Exceedence Factor Kt     =     -1.305
The 90 pct. Exceedence precipitation =      0.333

The 1.0-Year return Flow
The 99.99 pct. Exceedence Factor Kt  =     -4.267
The 1-Year precipitation             =      0.112
```

```
 Program: LOGPER.EXE LOG Pearson Type III Analysis.
          HSI  Hydrologic Systems, San Rafael, California 94901
          (415) 454-6056  water@hydrologic-systems.com
          Version 2.6, November 2007


Run Date:  Tue Nov 20 2007 03:23 PM

Input File = USLFP2HR.txt


This is the input data:
```

**Title: 2 Hr**

```
    1945.00 ;       0.67
    1946.00 ;       0.79
    1947.00 ;       0.50
    1948.00 ;       0.61
    1949.00 ;       0.42
    1950.00 ;       0.62
    1951.00 ;       0.57
    1952.00 ;       1.42
    1953.00 ;       0.74
    1954.00 ;       0.80
    1955.00 ;       0.44
    1956.00 ;       0.71
    1957.00 ;       0.83
    1958.00 ;       0.71
    1959.00 ;       1.02
    1960.00 ;       0.53
    1961.00 ;       1.13
    1962.00 ;       0.70
    1963.00 ;       1.35
    1964.00 ;       1.13
    1965.00 ;       0.65
    1966.00 ;       0.60
    1967.00 ;       1.15
    1968.00 ;       1.15
    1969.00 ;       0.55
```

```
     1970.00 ;       0.91
     1971.00 ;       0.92
     1972.00 ;       0.34
     1973.00 ;       1.08
     1974.00 ;       0.84
     1975.00 ;       0.85
     1976.00 ;       0.80
     1977.00 ;       0.77
     1978.00 ;       1.02
     1979.00 ;       0.95
     1980.00 ;       0.90
     1981.00 ;       0.54
     1982.00 ;       0.96
     1983.00 ;       1.16
     1984.00 ;       0.68
     1985.00 ;       1.05
     1986.00 ;       0.80
     1987.00 ;       0.81
     1988.00 ;       0.59
     1989.00 ;       0.71

End of file encountered.

45 Data points were read.


Statistics of Data:

   Mean of Data      =       0.81
   Min  of Data      =       0.34
   Max  of Data      =       1.42
   Std. Dev. of Data =       0.25

Statistics of Logged Data:

   Mean of LOG Data                =     -0.112
   Std. Dev. of LOG Data           =      0.137
   Standard Skew of LOG Data       =     -0.337

   Generalized Skew Coef.  Pub 17B  =     -0.300
```

```
Skew Weighting factors:

   A    =     -0.303
   B    =      0.852
   C    =      0.653
   MSEg    = Estimate of Error of Station Skew  =      0.138

   MESgbar = Estimate of Error of Regional Skew =      0.302

   Weighting of Station Skew  =       68.6 percent
   Weighting of Regional Skew =       31.4 percent

Weighted Generalized Skew Value Used In The Analysis =     -0.325


The following points are considered high outliers:

   The 10 pct Level of Significance Kn =      2.727

   No High Outliers

The following points are considered Low outliers:

   No Low Outliers


The Results of The Frequency Analysis:


The 500 YR Frequency Factor Kt   =      2.488
The 500 year precipitation       =      1.695

The 200 YR Frequency Factor Kt   =      2.271
The 200 year precipitation       =      1.583

The 100 YR Frequency Factor Kt   =      2.085
The 100 year precipitation       =      1.493

The 50 YR Frequency Factor Kt    =      1.876
```

```
The 50 year precipitation        =      1.398

The 25 YR Frequency Factor Kt    =      1.634
The 25 year precipitation        =      1.295

The 10 YR Frequency Factor Kt    =      1.241
The 10 year precipitation        =      1.144

The 5 YR Frequency Factor Kt     =      0.854
The 5 year precipitation         =      1.012

The 2 YR Frequency Factor Kt     =      0.054
The 2 year precipitation         =      0.787

The 1.5-Year Frequency Factor Kt =     -0.389
The 1.5-Year precipitation       =      0.684

The 1.43-Year return Flow
The 70 pct. Exceedence Factor Kt     =     -0.483
The 70 pct. Exceedence precipitation =      0.664

The 1.25-Year return Flow
The 80 pct. Exceedence Factor Kt     =     -0.822
The 80 pct. Exceedence precipitation =      0.597

The 1.11-Year return Flow
The 90 pct. Exceedence Factor Kt     =     -1.311
The 90 pct. Exceedence precipitation =      0.511

The 1.0-Year return Flow
The 99.99 pct. Exceedence Factor Kt  =     -4.430
The 1-Year precipitation             =      0.191
```

```
 Program: LOGPER.EXE LOG Pearson Type III Analysis.
          HSI  Hydrologic Systems, San Rafael, California 94901
          (415) 454-6056  water@hydrologic-systems.com
          Version 2.6, November 2007


Run Date:  Tue Nov 20 2007 03:23 PM

Input File = USLFP3HR.txt


This is the input data:
```

**Title: 3 Hr**

```
    1945.00 ;       0.81
    1946.00 ;       0.87
    1947.00 ;       0.67
    1948.00 ;       0.73
    1949.00 ;       0.57
    1950.00 ;       0.87
    1951.00 ;       0.73
    1952.00 ;       1.72
    1953.00 ;       0.97
    1954.00 ;       0.99
    1955.00 ;       0.62
    1956.00 ;       0.91
    1957.00 ;       1.10
    1958.00 ;       0.90
    1959.00 ;       1.33
    1960.00 ;       0.66
    1961.00 ;       1.58
    1962.00 ;       0.95
    1963.00 ;       1.90
    1964.00 ;       1.43
    1965.00 ;       0.75
    1966.00 ;       0.75
    1967.00 ;       1.25
    1968.00 ;       1.40
    1969.00 ;       0.70
```

```
     1970.00 ;       1.10
     1971.00 ;       1.10
     1972.00 ;       0.45
     1973.00 ;       1.30
     1974.00 ;       1.10
     1975.00 ;       0.90
     1976.00 ;       0.99
     1977.00 ;       0.97
     1978.00 ;       1.16
     1979.00 ;       1.10
     1980.00 ;       1.10
     1981.00 ;       0.63
     1982.00 ;       1.32
     1983.00 ;       1.45
     1984.00 ;       0.91
     1985.00 ;       1.30
     1986.00 ;       0.88
     1987.00 ;       1.05
     1988.00 ;       0.76
     1989.00 ;       0.91

End of file encountered.

45 Data points were read.


Statistics of Data:

   Mean of Data      =       1.01
   Min  of Data      =       0.45
   Max  of Data      =       1.90
   Std. Dev. of Data =       0.31

Statistics of Logged Data:

   Mean of LOG Data                =     -0.014
   Std. Dev. of LOG Data           =      0.133
   Standard Skew of LOG Data       =     -0.070

   Generalized Skew Coef.  Pub 17B  =     -0.300
```

```
Skew Weighting factors:

   A    =     -0.324
   B    =      0.922
   C    =      0.653
   MSEg    = Estimate of Error of Station Skew  =      0.118

   MESgbar = Estimate of Error of Regional Skew =      0.302

   Weighting of Station Skew  =       71.8 percent
   Weighting of Regional Skew =       28.2 percent

Weighted Generalized Skew Value Used In The Analysis =     -0.135


The following points are considered high outliers:

   The 10 pct Level of Significance Kn =      2.727

   No High Outliers

The following points are considered Low outliers:

   No Low Outliers


The Results of The Frequency Analysis:


The 500 YR Frequency Factor Kt   =      2.715
The 500 year precipitation       =      2.225

The 200 YR Frequency Factor Kt   =      2.449
The 200 year precipitation       =      2.051

The 100 YR Frequency Factor Kt   =      2.227
The 100 year precipitation       =      1.916

The 50 YR Frequency Factor Kt    =      1.984
```

```
The 50 year precipitation        =      1.779

The 25 YR Frequency Factor Kt    =      1.703
The 25 year precipitation        =      1.633

The 10 YR Frequency Factor Kt    =      1.266
The 10 year precipitation        =      1.428

The 5 YR Frequency Factor Kt     =      0.847
The 5 year precipitation         =      1.256

The 2 YR Frequency Factor Kt     =      0.023
The 2 year precipitation         =      0.976

The 1.5-Year Frequency Factor Kt =     -0.416
The 1.5-Year precipitation       =      0.853

The 1.43-Year return Flow
The 70 pct. Exceedence Factor Kt     =     -0.508
The 70 pct. Exceedence precipitation =      0.830

The 1.25-Year return Flow
The 80 pct. Exceedence Factor Kt     =     -0.834
The 80 pct. Exceedence precipitation =      0.751

The 1.11-Year return Flow
The 90 pct. Exceedence Factor Kt     =     -1.295
The 90 pct. Exceedence precipitation =      0.652

The 1.0-Year return Flow
The 99.99 pct. Exceedence Factor Kt  =     -4.011
The 1-Year precipitation             =      0.284
```

```
 Program: LOGPER.EXE LOG Pearson Type III Analysis.
          HSI  Hydrologic Systems, San Rafael, California 94901
          (415) 454-6056  water@hydrologic-systems.com
          Version 2.6, November 2007


Run Date:  Tue Nov 20 2007 03:24 PM

Input File = USLFP6HR.txt


This is the input data:
```

**Title: 6 Hr**

```
    1945.00 ;       1.08
    1946.00 ;       1.28
    1947.00 ;       0.94
    1948.00 ;       0.86
    1949.00 ;       0.89
    1950.00 ;       1.54
    1951.00 ;       1.04
    1952.00 ;       2.11
    1953.00 ;       1.54
    1954.00 ;       1.52
    1955.00 ;       0.95
    1956.00 ;       1.66
    1957.00 ;       1.64
    1958.00 ;       1.49
    1959.00 ;       1.77
    1960.00 ;       0.81
    1961.00 ;       2.21
    1962.00 ;       1.25
    1963.00 ;       3.25
    1964.00 ;       1.95
    1965.00 ;       0.94
    1966.00 ;       1.16
    1967.00 ;       1.55
    1968.00 ;       2.15
    1969.00 ;       1.08
```

```
     1970.00 ;       1.54
     1971.00 ;       1.46
     1972.00 ;       0.65
     1973.00 ;       2.00
     1974.00 ;       1.81
     1975.00 ;       1.11
     1976.00 ;       1.60
     1977.00 ;       1.27
     1978.00 ;       1.46
     1979.00 ;       1.62
     1980.00 ;       1.51
     1981.00 ;       0.89
     1982.00 ;       1.98
     1983.00 ;       2.35
     1984.00 ;       1.55
     1985.00 ;       1.83
     1986.00 ;       1.36
     1987.00 ;       1.59
     1988.00 ;       0.99
     1989.00 ;       1.28

End of file encountered.

45 Data points were read.


Statistics of Data:

   Mean of Data      =       1.48
   Min  of Data      =       0.65
   Max  of Data      =       3.25
   Std. Dev. of Data =       0.49

Statistics of Logged Data:

   Mean of LOG Data                =      0.147
   Std. Dev. of LOG Data           =      0.143
   Standard Skew of LOG Data       =     -0.054

   Generalized Skew Coef.  Pub 17B  =     -0.300
```

```
Skew Weighting factors:

   A    =     -0.326
   B    =      0.926
   C    =      0.653
   MSEg    = Estimate of Error of Station Skew  =      0.117

   MESgbar = Estimate of Error of Regional Skew =      0.302

   Weighting of Station Skew  =       72.0 percent
   Weighting of Regional Skew =       28.0 percent

Weighted Generalized Skew Value Used In The Analysis =     -0.123


The following points are considered high outliers:

   The 10 pct Level of Significance Kn =      2.727

   No High Outliers

The following points are considered Low outliers:

   No Low Outliers


The Results of The Frequency Analysis:


The 500 YR Frequency Factor Kt   =      2.730
The 500 year precipitation       =      3.436

The 200 YR Frequency Factor Kt   =      2.461
The 200 year precipitation       =      3.146

The 100 YR Frequency Factor Kt   =      2.236
The 100 year precipitation       =      2.922

The 50 YR Frequency Factor Kt    =      1.990
```

```
The 50 year precipitation        =      2.695

The 25 YR Frequency Factor Kt    =      1.708
The 25 year precipitation        =      2.457

The 10 YR Frequency Factor Kt    =      1.267
The 10 year precipitation        =      2.126

The 5 YR Frequency Factor Kt     =      0.847
The 5 year precipitation         =      1.852

The 2 YR Frequency Factor Kt     =      0.021
The 2 year precipitation         =      1.412

The 1.5-Year Frequency Factor Kt =     -0.417
The 1.5-Year precipitation       =      1.223

The 1.43-Year return Flow
The 70 pct. Exceedence Factor Kt     =     -0.509
The 70 pct. Exceedence precipitation =      1.187

The 1.25-Year return Flow
The 80 pct. Exceedence Factor Kt     =     -0.835
The 80 pct. Exceedence precipitation =      1.066

The 1.11-Year return Flow
The 90 pct. Exceedence Factor Kt     =     -1.294
The 90 pct. Exceedence precipitation =      0.917

The 1.0-Year return Flow
The 99.99 pct. Exceedence Factor Kt  =     -3.984
The 1-Year precipitation             =      0.379
```

# APPENDIX B
# NATIVE AND RARE PLANT SPECIES OF THE SAUSAL CREEK WATERSHED

# Sausal Creek Watershed Native Plant Species

| | | | | Locations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Code** | **Scientific Name** | **Common Name** | **Type** | **Joaquin Miller** | **Dimond Canyon** | **Shepherd Canyon** | **Castle Canyons** | **Beacons field** | **Other** | **EB-CNPS Rank** |
| ACAPIN | *Acaena pinnatifida var. californica* | California sheepburr | P | ✓ | | | | | | C |
| ACENEG | *Acer negundo var. californicum* | box-elder | T | ✓ | ☑ | ☑ | | | | W |
| ACTRUB | *Actaea rubra* | baneberry | P | ✓ | ✓ | | | | | B |
| ADEFAS | *Adenostoma fasciculatum* | chamise | S | ✓ | | | | 🖇 | | W |
| ALNRUB | *Alnus rubra* | red alder | T | ☑ | ☑ | | | | | A1 |
| ANAMAR | *Anaphalis margaritacea* | pearly everlasting | P | ✓ | | | | | | W |
| ANGTOM | *Angelica tomentosa* | woolly angelica | P | ✓ | ✓ | | | | | C |
| ANTVEX | *Antirrhinum vexillo-calyculatum ssp. vexillo-calyculatum* | wiry snapdragon | A | ✓ | | | | | | B |
| APOAND | *Apocynum androsaemifolium* | bitter dogbane | P | | ✓ | | | | | B |
| AQUFOR | *Aquilegia formosa* | columbine | P | ✓ | | | | | | C |
| ARACAL | *Aralia californica* | elk-clover | P | ✓ | ☑ | | ✓ | | Ascot | B |
| ARBMEN | *Arbutus menziesii* | Pacific madrone | T | ✓ | ✓ | ✓ | | ✓ | | C |
| ARCPAL | *Arctostaphylos pallida* | pallid manzanita | S | ✓ | | ✓ | | | | FS |
| ARCTOM | *Arctostaphylos tomentosa ssp. crustacea* | brittleleaf manzanita | S | ✓ | | | | | | C |
| ASACAU | *Asarum caudatum* | wild ginger | P | ✓ | ✓ ☑ | | | | | B |
| ASTCHI | *Aster chilensis* | common aster | P | ✓ | | | | | | W |
| BARORT | *Barbarea orthoceras* | winter cress | A | ✓ | ☑ | | | ☑ | | W |
| BERPIN | *Berberis pinnata ssp. pinnata* | California barberry | S | ✓ | | ✓ | | | | C |
| BROELE | *Brodiaea elegans ssp. elegans* | harvest brodiaea | P | ✓ | | | | | | W |
| CALLUT | *Calochortus luteus* | yellow mariposa lily | P | ✓ | | | | | | C |
| CALUMB | *Calochortus umbellatus* | Oakland star-tulip | P | ✓ | | | | | | *A2 |
| CAMOVA | *Camissonia ovata* | suncups | P | ✓ | | | | | | C |
| CARBAR | *Carex barbarae* | Santa Barbara sedge | P | ✓ | ✓ | | | | | B |
| CARDEW | *Carex deweyana ssp. leptopoda* | short-scale sedge | P | ✓ | | | | | | A1 |
| CARGLO | *Carex globosa* | round-fruit sedge | P | ✓ | | | | | | A1 |
| CAROBN | *Carex obnupta* | slough sedge | P | | ✓ | | | | | A1 |
| CARSUB | *Carex subbracteata* | small-bracted sedge | P | ✓ | ☑ | | | 🖇 | | B |
| CERBET | *Cercocarpus betuloides var. betuloides* | mountain mahogany | S | | ✓ | | | | | C |
| CHRCHR | *Chrysolepis chrysophylla var. minor* | golden chinquapin | S | ✓ | | | | | | A2 |
| CIROCC | *Cirsium occidentale var. venustum* | Venus thistle | A | ✓ | | | | | | C |
| CLARUB | *Clarkia rubicunda* | farewell-to-spring | A | ✓ | ☑ | | | | | W |
| CLELAS | *Clematis lasiantha* | pipestems | V | | ✓ | | | | | W |
| CORSER | *Cornus sericea ssp. sericea* | western creek dogwood | S | ✓ | ☑ | | ✓ | | Ascot | C |
| CYNGRA | *Cynoglossum grande* | hound's tongue | P | ✓ | | | | | | C |
| DIROCC | *Dirca occidentalis* | western leatherwood | S | ✓ | | | | | | *A2 |
| DISHOO | *Disporum hookeri* | fairy bells | P | ✓ | ✓ | ✓ | | | | C |
| ELYMUL | *Elymus multisetus* | big squirreltail | G | ✓ | | | | | | C |
| ERILUTC | *Eriogonum luteolum var. caninum* | Tiburon buckwheat | A | ✓ | | | | | | *A1 |
| FESCAL | *Festuca californica* | California fescue | G | ✓ | ☑ | | | | | W |
| FRIAFF | *Fritillaria affinis var. affinis* | checker lily | P | ✓ | | | | | | W |

| | Sausal Creek Watershed Native Plant Species | | | Locations | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Code** | **Scientific Name** | **Common Name** | **Type** | **Joaquin Miller** | **Dimond Canyon** | **Shepherd Canyon** | **Castle Canyons** | **Beacons field** | **Other** | **EB-CNPS Rank** |
| GALCAL | *Galium californicum ssp. californicum* | California bedstraw | P | ✓ | | | | | | C |
| GALTRI | *Galium triflorum* | sweet-scented bedstraw | A | ✓ | | | | | | B |
| GARELL | *Garrya elliptica* | coast silk-tassle | S | ✓ | ✓ | | ✓ | | | B |
| GAUSHA | *Gaultheria shallon* | salal | S | ✓ | | | | | | A1 |
| GNABIC | *Gnaphalium bicolor* | cudweed | P | ✓ | | | | | | A2 |
| GNACAN | *Gnaphalium canescens ssp. beneolens* | cudweed | P | ✓ | | | | | | C |
| GRIHIR | *Grindelia hirsutula var. hirsutula* | gumplant | P | ✓ | ☑ | | | | | C |
| GRISTR | *Grindelia stricta var. angustifolia* | gumplant | P | | | | | | Estuary | C |
| HEUMIC | *Heuchera micrantha* | alumroot | P | ✓ | ☑ | ✓ | | | | C |
| IRIDOU | *Iris douglasiana* | Douglas' iris | P | ✓ | ☑ | | | | | A2 |
| KOEMAC | *Koeleria macrantha* | junegrass | G | ✓ | | | | | | C |
| LONINV | *Lonicera involucrata var. ledebourii* | black twinberry | S | ✓ | ☑ | ✓ | | ✓ | | B |
| LONSUB | *Lonicera subspicata var. denudata* | wild honeysuckle | V | ✓ | | | | | | B |
| LOTSCO | *Lotus scoparius var. scoparius* | California broom | S | ✓ | | ✓ | | | | W |
| LOTSTI | *Lotus stipularis var. stipularis* | balsam bird's-foot trefoil | P | ✓ | | | | | | A1 |
| LUPBIC | *Lupinus bicolor* | bicolored lupine | A | ✓ | ✓ | | | | | W |
| LUPSUC | *Lupinus succulentus* | arroyo lupine | A | ✓ | | ✓ | | | | W |
| MARORE | *Marah oreganus* | coast man-root | P | ✓ | 🖇 | 🖇 | | 🖇 | | B |
| MELCAL | *Melica californica* | California melic | G | ✓ | | | | ✓ | | C |
| MIMCAR | *Mimulus cardinalis* | red monkeyflower | P | ✓ | ☑ | | | | | C |
| MONVIL | *Monardella villosa* | coyote mint | P | ✓ | | | | | | W |
| NASLEP | *Nassella lepida* | foothill needlegrass | G | ✓ | | ✓ | | ✓ | | C |
| NASPUL | *Nassella pulchra* | purple needlegrass | G | ✓ | | | | ✓ | | C |
| OXAORE | *Oxalis oregana* | redwood sorrel | P | | ✓ | | | | | A1 |
| PERKEL | *Perideridia kelloggii* | yampah | P | ✓ | | | | | | W |
| PHOAUR | *Pholistoma auritum var. auritum* | fiesta flower | A | | ✓ | | | | | B |
| PHYCAP | *Physocarpus capitatus* | ninebark | S | ✓ | ☑ | | | ✓ | | C |
| PIPELE | *Piperia elegans* | rein orchid | P | ✓ | | | | | | B |
| PLAERE | *Plantago erecta* | California plantain | A | ✓ | | | | | | W |
| POLSCO | *Polypodium scouleri* | leather fern | F | | | | | | Exeter | A1 |
| POPBAL | *Populus balsamifera ssp. trichocarpa* | black cottonwood | T | | | | | ✓ | | B |
| QUECHR | *Quercus chrysolepis* | canyon live oak | T | ✓ | | | | | | C |
| QUESHR | *Quercus parvula var. shrevei* | Shreve oak | T | | | | | | Exeter | A1 |
| RAFCAL | *Rafinesquia californica* | California chicory | A | ✓ | | | | | | C |
| RHACRO | *Rhamnus crocea* | redberry buckthorn | S | | | ✓ | ✓ | | | C |
| RIBAMA | *Ribes amarum* | bitter gooseberry | S | ✕ | | | | | | A1 |
| RIBDIV | *Ribes divaricatum var. pubiflorum* | straggly gooseberry | S | ✓ | ✓ | | | | | B |
| RIBMEN | *Ribes menziesii* | canyon gooseberry | S | ✓ | ✓ | | | ✓ | | W |
| RIBSAN | *Ribes sanguineum var. glutinosum* | red-flowering currant | S | ✓ | ✓ | ✓ | | ✓ | | C |
| ROSCAL | *Rosa californica* | California wild rose | S | ✓ | ☑ | | | | | W |

# *Sausal Creek Watershed Native Plant Species*

| Code | Scientific Name | Common Name | Type | Locations: Joaquin Miller | Dimond Canyon | Shepherd Canyon | Castle Canyons | Beacons field | Other | EB-CNPS Rank |
|---|---|---|---|---|---|---|---|---|---|---|
| ROSSPI | *Rosa spithamea* | ground rose | S | ✓ | | | | | | C |
| RUPPHY | *Rupertia physodes* | California tea | P | ✓ | | ✓ | | | | W |
| SAMRAC | *Sambucus racemosa var. racemosa* | red elderberry | S | ✓ | | | | ✓ | Haverhill | A1 |
| SANLAC | *Sanicula laciniata* | coastal blacksnakeroot | P | ✓ | | | | | | A2 |
| SEQSEM | *Sequoia sempervirens* | coast redwood | T | ✓ | ✓ | ☑ | | ☑ | | B |
| SIDMAL | *Sidalcea malviflora ssp. laciniata* | checker mallow | P | ✓ | | | | | | C |
| SILCAL | *Silene californica* | Indian pink | P | ✓ | | | | | | B |
| SMIRAC | *Smilacina racemosa* | large false Solomon's seal | P | ✓ | ✓ | | | | | W |
| SOLUMB | *Solanum umbelliferum* | blue witch | S | ✓ | ✓ | | | | | W |
| STRGLA | *Streptanthus glandulosus ssp. glandulosus* | jewelflower | A | ✓ | | | | | | B |
| TELGRA | *Tellima grandiflora* | fringe cups | P | ✓ | ☑ | | | | | B |
| TRILAT | *Trientalis latifolia* | star flower | P | ✓ | | ✓ | | | | C |
| TRIALB | *Trifolium albopurpureum var. albopurpureum* | Indian clover | A | ✓ | | | | | | C |
| TRIMAC | *Trifolium macraei* | double-head clover | A | | | | | | | A2 |
| TRICHL | *Trillium chloropetalum* | giant trillium | P | ✓ | | | | ✓ | | C |
| TRIOVA | *Trillium ovatum ssp. ovatum* | white trillium | P | ✓ | | | | | | A2 |
| VACOVA | *Vaccinium ovatum* | California huckleberry | S | ✓ | ☑ | ✓ | | ✓ | | C |
| VERAME | *Veronica americana* | American brooklime | P | | ✓ | | | | | C |
| VICAME | *Vicia americana var. americana* | American vetch | V | | | | | | | C |
| VICGIG | *Vicia gigantea* | giant vetch | P | ✓ | ✓ | ✓ | | ✓ | | B |
| VIOGLA | *Viola glabella* | stream violet | P | ✓ | | | | | | A2 |
| VIOSEM | *Viola sempervirens* | evergreen violet | P | ✓ | ☑ | | | | | A1 |
| WOOFIM | *Woodwardia fimbriata* | giant chain fern | F | ✓ | | ✓ | | | | C |
| WYEANG | *Wyethia angustifolia* | narrowleaf mule-ears | P | ✓ | | | | | | W |

List maintained by Karen Paulsell, with information from many other native plant lovers. Original list by Martha Lowe, 2000.

Comments to: kpaulsell@pacbell.net

**Types:**
A - Annual
B - Biennial
F - Fern
G - Grass
P - Perennial
S - Shrub
T - Tree
V - Vine

**Location Symbols:**
✓ Found in the area
☑ Planted in the area
Possibly there, look
× Presumed extirpated

**East Bay CNPS Ranks:**
*A1: Very rare in CA
*A2: Rare in CA
A1: Very rare in East Bay
A2: Rare in East Bay
B: High priority watch list
C: Other watch list plants
FS: Federal/State listed
W: Rare in watershed (added by FOSC)

# APPENDIX C: INVASIVE PLANTS OF THE SAUSAL CREEK WATERSHED

Prepared by Karen Paulsell for FOSC
Edited by Laurel Marcus Associates

**Invasive Non-Native Trees of Sausal Creek Watershed**

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Acacia melanoxylon*<br>Blackwood acacia<br><br>Photo: ©2001 Joe DiTomaso | • Fast-growing, very tall tree that shades out and kills native trees, including alders and oaks<br>• Invades by seed<br>• Re-sprouts densely after cutting requiring repeat visits or use of herbicide to eradicate<br>• Nitrogen fixation by *Acacia* can encourage non-native understory<br>• Fire hazard | • Joaquin Miller Park: extensive along Sequoia-Bayview Trail below Horse Arena; present in many other areas<br>• Dimond Canyon: scattered stands with large number of trees<br>• Dimond Park: above Scout Hut; near parking lot; near creek below Wellington<br>• Shepherd Canyon: along creek north of meadow; downstream from soccer field<br>• W.D. Wood: in lower area of park<br>• Barry Place: many large trees<br>• Heavily planted along Highway 13 & other CalTrans right-of-ways<br>• Large number of trees on Oakland Unified School District property along Ascot | • Continue to work with Park Department on removal in restoration areas; El Centro/Benevides area is a top priority<br>• Consider treating stumps and root systems with herbicide if revisions to City of Oakland herbicide ordinance will allow<br>• Have plan for re-sprout control when removing any trees<br>• Encourage control by Wildfire District<br>• Educate homeowners, landscapers, and consultants not to plant and to remove from private land<br>• Encourage nurseries not to sell this plant<br>• Discuss invasive plant issues with CalTrans |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Acacia dealbata*<br>Silver wattle<br><br>Photo:<br>©2002 Dean Wm. Taylor | • Fast growing<br>• Invades by seed<br>• Tends towards monoculture<br>• Re-sprouts after cutting, requiring repeat visits or use of herbicide to eradicate<br>• Brittle in high winds, leading to fire danger from large amounts of downed debris<br>• Heavy debris plus dense shade greatly reduces native understory<br>• Nitrogen fixation by *Acacia* encourages non-native understory<br>• Fire hazard<br> | • Joaquin Miller Park: near Horse Arena parking area and along Castle-Park Trail, westward to Castle Drive; between Sanborn Drive and Joaquin Miller Drive below Funeral Pyre; adjacent to Lookout Point parking area and others<br>• Dimond Canyon: dense patch at Park Boulevard and Leimert Ave.<br>• Dimond Park: near parking lot; near creek below Wellington<br>• Shepherd Canyon: approx. 25 trees along Escher Creek; additional trees downstream from soccer field<br>• Beaconsfield: trees killed in 2007/2008; monitoring for seedlings continues<br>• Barry Place: at least one large tree<br>• Along Highway 13 | • Continue to control seedlings and resprouts from the upper and lower nursery hill areas in Joaquin Miller Park<br>• Continue building relationship with Oakland Zoo and providing acacia foliage for feeding to elephants and giraffes<br>• Continue to work with Oakland Parks and Recreation Department on removal in restoration areas; El Centro/Benevides area is a top priority<br>• Consider treating stumps and root systems with herbicide if revisions to City of Oakland herbicide ordinance allow<br>• Have plan for re-sprout control when removing any trees<br>• Encourage control by Wildfire District*<br>• Educate homeowners, landscapers, and consultants not to plant and to remove from private land<br>• Encourage nurseries not to sell this plant<br>• Discuss invasive plant issues with CalTrans |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Acacia sp.* (*A. mearnsii*) Black wattle | • Fast growing<br>• Invades by seed<br>• Tends towards monoculture<br>• Re-sprouts after cutting, requiring repeat visits or use of herbicide to eradicate<br>• Brittle in high winds, leading to fire danger from large amounts of downed debris<br>• Heavy debris plus dense shade greatly reduces native understory<br>• Nitrogen fixation by *Acacia* encourages non-native understory<br>• Fire hazard | • Joaquin Miller Park: near Horse Arena parking area and along Castle-Park Trail; some plants in lower nursery area and Woodminster Theater; possibly present on hill below nursery | • Continue to control seedlings and re-sprouts from the upper and lower nursery hill areas in Joaquin Miller Park<br>• Continue building relationship with Oakland Zoo and providing acacia foliage for feeding to elephants and giraffes<br>• Continue to work with Oakland Parks and Recreation Department on removal in restoration areas; El Centro/Benevides area is a top priority<br>• Consider treating stumps and root systems with herbicide if revisions to City of Oakland herbicide ordinance allow<br>• Have plan for re-sprout control when removing any trees<br>• Encourage control by Wildfire District*<br>• Educate homeowners, landscapers, and consultants not to plant and to remove from private land<br>• Encourage nurseries not to sell this plant<br>• Discuss invasive plant issues with CalTrans |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Eucalyptus globulus*<br>Blue gum | • Fast growing<br>• Can dewater streams and habitats<br>• Somewhat invasive by seed<br>• Re-sprouts heavily after cutting, requiring many repeat visits or the use of herbicides to eradicate<br>• Shed bark and heavy duff smothers understory; toxins reduce native plants<br>• Stickiness of sap & nectar may gum up beaks of birds feeding on nectar and insects<br>• Extreme fire danger: trees can explode in fires and spread fires via flaming brands; heavy duff is a potential ignition source<br> | • Joaquin Miller Park -- extensive stands between Castle-Park Trail and Cinderella Creek; large stand above Joaquin Miller Rd. below corporation yard; other smaller stands and individuals<br>• Dimond Canyon: mostly near golf course<br>• Shepherd Canyon -- very large stands on both public and private land<br>• Castle Canyon, along Castle Drive and upper creek<br>• Barry Place: at least one large tree | • Continue to support Wildfire District efforts to use herbicide stump treatments in removal efforts<br>• Encourage removal on private lands<br>• Discourage nurseries and landscapers from selling and planting this species<br>• Note: Starting in about 2005, there has been increasing insect damage to new leaf growth on E. globulus; damage can reach up to 50% of yearly new leaves. Seek information about defoliating insect affecting trees<br> |
| *Eucalyptus camaldulensis*<br>Red gum, Red river gum | • Fast growing<br>• Fire hazard<br>• Re-sprouts after cutting, requires repeated cutting or the use of herbicides to eradicate | • Joaquin Miller Park: Extensive monoculture along Sequoia-Bayview Trail below Horse Arena<br>• Dimond Canyon: isolated specimens | • Seek information about defoliating insect affecting trees<br>• Continue to support Wildfire District efforts to use herbicide stump treatments in removal efforts<br>• Encourage removal on private lands<br>• Discourage nurseries and landscapers from selling and planting this species |

Photos: ©2009 Neal Kramer
©1998 Ca. Academy of Sciences, Charles Webber

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Ulmus americana* American elm | • Extremely invasive in riparian areas<br>• Spreads rapidly from root sprouts<br>• Re-sprouts when cut, requiring repeated visits or use of herbicide<br>• Extremely difficult to remove roots and root sprouts<br> | • Joaquin Miller Park: several locations near Skyline<br> <br>• Dimond Canyon in El Centro restoration area volunteer efforts have failed to control; Bridgeview Trail: 1/3 acre area from trail to creek just downstream from Redwood site, many other extensive infestations<br>• Dimond Park: near creek above Wellington<br>• Shepherd Canyon: where trail crosses creek near Escher Gate; they have been cut to stumps and continually re-sprout<br>• Beaconsfield: along creek | • Enlist support in removal from the City of Oakland Parks Department or the Wildfire District<br>• Explore costs and feasibility of other means of removal, including heavy equipment, hiring Civic Corps, or herbicide, and seek source of funding for removal of El Centro infestation<br>• As a pilot project, plant redwoods along creek in the large Bridgeview infestation to determine whether they will survive to outgrow and shade the elms<br>• Encourage removal on private land<br>• Consider need for herbicide to control<br>• Educate landowners about removing this species on private land<br>• Discourage nurseries and landscapers from selling or planting this species |

Photos: ©2008 Jason Willand
©2005 Louis-M. Landry

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Pinus radiata* Monterey pine | • Invades by seed<br>• Displaces native oaks and madrones; large plantings in Joaquin Miller Park shade out much coastal scrub hillside and chaparral area<br>• Duff changes soil composition and structure, favoring invasive weeds<br>• Heavy shade reduces understory diversity<br>• Creates extensive "fog drip", supporting large stands of Veldt grass (*Ehrharta erecta)*<br>• High fire danger | • Joaquin Miller Park: original planted trees are dying, many young trees<br>• Dimond Canyon: few; mostly senescent<br>• Shepherd Canyon: on public and private properties; original planted trees are dying back<br>• Beaconsfield: several; many senescent<br>• Common in upper watershed neighborhoods<br> | • Advocate for Wildfire District and Park Department control of seedlings and young trees<br>• Continue FOSC seedling and small tree removal efforts<br>• Work with Park Department to remove trees affecting rare species habitats<br>• Encourage removal of diseased and old trees on private land<br>• As large trees die and seedlings germinate, remove seedlings and plant native shrubs<br> |
| *Cupressus microcarpa* Monterey cypress | • Mildly invasive from seed<br>• Duff changes soil composition and structure, favoring invasive weeds<br>• Moderate fire danger | • Joaquin Miller Park: heavily planted in coastal scrub areas and on serpentine hillsides<br>• Dimond Canyon<br>• Shepherd Canyon: Dense stands in park along Escher Drive; many stands on private property<br>• Beaconsfield: very dense in part of canyon<br>• Castle Canyon: dense on north-facing slope | • Remove all young plants<br>• Encourage Park Department to remove trees affecting rare species habitats<br> |

Photos: © Andrew J. Storer, ©1995 St. Mary's College of CA
© USGS

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Ilex aquifolium*<br>English holly | • Very invasive from seed; seed spread by birds<br>• Plants also spread by root sprouts<br>• Plants re-sprout after cutting, requiring excavation, repeat visits, or use of herbicide to eradicate<br>• Extremely prickly leaves make removal difficult<br>• Used in landscaping in urban/wildland interface | <br>• Joaquin Miller Park: Many fruiting trees along Palo Seco creek, smaller plants throughout<br>• Dimond Canyon: mostly in upper areas of canyon<br>• Beaconsfield Canyon: scattered small individuals | • Encourage removal on private land<br>• Map extent of current infestation and track rate of spread<br>• Seek funding for professional removal of Joaquin Miller Park infestation to remove seed source<br>• Remove from creek areas<br>• Discourage nurseries and landscapers from selling or planting this species |
| *Ailanthus altissima*<br>Tree of heaven | <br>• Fast growing<br>• Produces large amounts of seed<br>• Re-sprouts from trunk and roots after cutting, requiring repeat visists or use of herbicide to eradicate | <br>• Beaconsfield Canyon: 2 known trees; one cut, one possibly on private property<br>• W. D. Wood Park: large tree with seedlings in park | • Cut remaining tree in Beaconsfield; treat re-sprouts<br> |
| *Robinia pseudoacacia*<br>Black locust | • Spreads from root sprouts<br>• Produces viable seed<br>• Sprouts from roots after cutting, requiring repeat visits or use of herbicide to eradicate<br>• Most known plants in watershed occur in steep creek banks on private property | • W. D. Wood Park: Riparian areas downstream from park | • No current recommendations for work<br> |

Photos: ©2007 Luisa Arana Navaridas; © 2003 Laurel Marcus; ©2009 Thomas Stoughton; ©2009 Neal Kramer; ©2000 Joe DiTomaso

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Prunus cerasifera* Plum | • Invasive from seed<br>• Seeds distributed by birds and animals<br>• Re-sprouts after cutting, requiring repeat visits or use of herbicide to eradicate | • Scattered throughout watershed in suitable habitat | • Difficult to encourage removal, as it is seen as a “food” plant |

Photos: ©2002 James B. Gratiot; © 2008 Keir Morse

**Invasive Non-Native Shrubs of Sausal Creek Watershed**

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Genista monspessulana* French broom | <br>• Invades rapidly by seed; long-lived seed banks; requires long follow-up to completely eliminate<br>• Small seed easily spread along trails by traffic<br>• Re-sprouts when cut, requiring removal of root crown, repeat visits, or use of herbicide to eradicate<br>• Large amount of duff creates fire danger<br>• Tends to rapidly create monoculture in suitable habitat | • Joaquin Miller Park: large dense stands along Sunset and Chaparral trails, many additional smaller stands; invades where pine trees fall and opening is created<br>• Dimond Canyon: upland areas along Bridgeview & Old Canon Trails; scattered populations throughout park<br>• Dimond Park: above Scout Hut; in Stone Pine area near Fruitvale; many scattered small stands<br>• Shepherd Canyon: extensive stands along Escher Drive, along Bike Trail, and above Public Works yard<br>• Beaconsfield Canyon: scattered remaining plants in restoration area; seedlings<br>• Castle Canyon: high on slope<br>• W.D. Wood Park: sunny slopes densely covered | • Continue removal efforts at Dimond Park above Scout Hut and within the nursery and around nursery fence<br>• Target removal near good habitat or areas with rare plants; maintain visits to pallid manzanita area to control broom seedlings<br>• Encourage effective removal practices by Wildfire District<br>• Encourage Park Department & homeowner groups to control<br>• Develop tracking method for areas cleared of broom to help insure maintenance<br>• Focus removal on new seedlings and remove from edge of large infestations, moving inward<br>• Discourage homeowners, landscapers, and nurseries from planting or selling broom<br>• Encourage homeowners to remove on private land |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| Other species of broom (possibly *Cytisus striatus*, Portuguese broom) | • Invades rapidly by seed; long-lived seed banks; requires long follow-up to completely eliminate<br>• Small seed easily spread along trails by traffic<br>• Re-sprouts when cut, requiring removal of root crown, repeat visits, or use of herbicide to eradicate<br>• Large amount of duff creates fire danger<br>• Tends to rapidly create monoculture in suitable habitat | • Rapidly spreading patch near Chabot Space and Science Center, along Skyline Blvd.<br> | • Encourage Wildfire District to eliminate rather than cut or prune<br>• Possible project for Weed Warriors<br>• Focus removal on new seedlings and remove from edge of large infestations, moving inward<br>• Discourage homeowners, landscapers, and nurseries from planting or selling broom<br>• Encourage homeowners to remove on private land |
| *Ulex europaeus*<br>Gorse<br>Photo: © 2008 Gary McDonald | • Invades by seed<br>• Re-sprouts when cut, requiring removal of root crown, repeat visits, or use of herbicide to eradicate<br>• Extremely prickly leaves make removal work difficult | • Dimond Canyon: along Bridgeview Trail, along and within golf course fence<br>• Shepherd Canyon: small stand on Snake Road near pedestrian overpass | • Encourage volunteers to remove small individuals and seed pods from others to prevent spread<br> |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Rubus discolor* Himalayan blackberry | • Invades by seed, root sprouting, and tip-rooting<br>• Re-sprouts when cut, requiring removal of root crown and large spreading roots, repeat visits, or use of herbicide<br>• Many populations of long duration; root crowns large and root spread extensive, increasing difficulty of removal<br>• Large sharp thorns make removal difficult<br>• Tends to form monoculture in riparian and moist habitats<br>• Poor soil holding capacity allows erosion<br>• Can provide support for Cape ivy, allowing it to invade trees and increasing difficulty of removal of both species | • Throughout all moist areas of the watershed | • Encourage removal on private land<br>• Discourage nurseries and landscapers from selling or planting this species<br>• Determine areas where blackberry stands most threaten creek and slope stability or important native plant habitat or restoration projects<br>• Control spread by working from perimeters of identified patches inward and from upstream to downstream<br>• Near current restoration projects, stop tip-rooting to control expansion of stands<br>• Encourage Wildfire District to remove stands by digging out crowns rather than repeated cutting<br>• Explore possibility of one- time use of goats or using hired crews for first-pass removal in new restoration areas<br>• Work for complete removal in current restoration areas before expanding into new restoration projects |

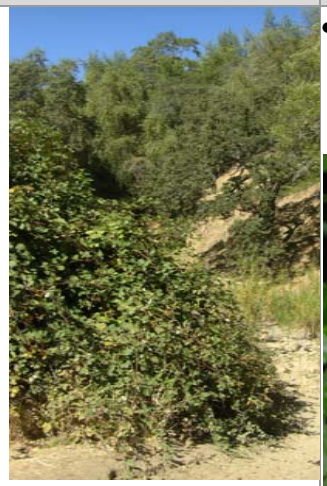


Photo: ©2007 CAS-JE & Bonnie McClellan; © 2008 Darcie Luce; ©2003 Penn Martin II

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Rubus ulmifolius var. inermis* Thornless blackberry, Elmleaf blackberry | • Invades by seed, root sprouting, and tip-rooting<br>• Re-sprouts when cut, requiring removal of root crown, repeat visits, or use of herbicide<br>• Tends to form monoculture in riparian and moist habitats<br>• Poor soil holding capacity allows erosion<br>• Can provide support for Cape ivy, allowing it to invade trees | • Dimond Canyon riparian area above El Centro<br> | • Encourage removal on private land<br>• Discourage nurseries and landscapers from selling or planting this species<br>• Determine areas where blackberry stands most threaten creek and slope stability or important native plant habitat or restoration projects<br>• Control spread by working from perimeters of identified patches inward and from upstream to downstream<br>• Near current restoration projects, stop tip-rooting to control expansion of stands<br>• Encourage Wildfire District to remove stands by digging out crowns rather than repeated cutting<br>• Explore possibility of one- time use of goats or using hired crews for first-pass removal in new restoration areas<br>• Work for complete removal in current restoration areas before expanding into new restoration projects |

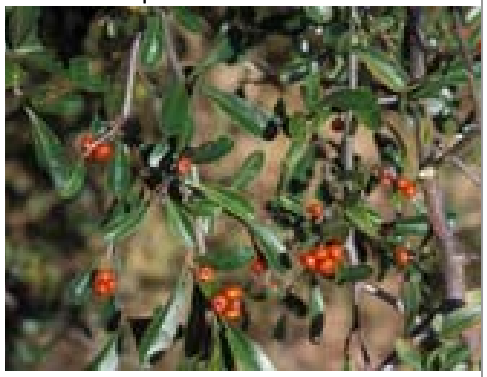
| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Cotoneaster* sp. and *Pyracantha sp.* | • Invades by seed; seed spread by birds<br>• Re-sprouts when cut, requiring tarping of root crown, repeat visits, or use of herbicides to eradicate<br> <br>***Cotoneaster sp.*** | • Mostly cotoneaster, scattered throughout watershed parks and private property; dense stands in W.D. Wood Park, Dimond Park, Horse Arena area in Joaquin Miller Park<br>  <br>***Pyracantha sp.*** | • Encourage removal by homeowners and replacement with native toyon<br>• Concentrate on removal near restored areas or sensitive habitats<br>• Discourage nurseries from selling these plants |
| *Ligustrum lucidum*<br>Glossy privet; Giant privet | • Invades by seed; mature specimens produce hundreds of fruits<br>• Can reportedly grow to 40 feet<br>• Mainly invades riparian areas | • Joaquin Miller Park, Dimond Canyon, Dimond Park, W.D. Wood Park: isolated specimens | • Not currently a serious problem; monitor known sites to track spread and learn fruiting times<br>• Remove plants in active restoration project areas |

Photo: ©2006 Peter Zika; © 2001 Joe DiTomaso

**Invasive Non-Native Vines of Sausal Creek Watershed**

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Delairea odorata* Cape ivy, German ivy | • Extremely invasive; spreads by seed & stolons; also broken vine fragments can root<br>• Very fast growing with combination of soil moisture and sun<br>• Tends to form monocultures, obliteraing understory, and climbing and killing trees<br>• After downing trees, green vines can hide large amounts of dead wood, posing a fire risk<br>• Poor soil holding capacity allows erosion<br>• Toxic to native insects and mammals<br> <br>Photo: ©2008 Neal Kramer | • Moist areas (and some drier areas) throughout watershed<br>• Joaquin Miller Park: at least 8 sites<br>• Dimond Canyon: riparian areas heavily infested<br>• Dimond Park: in riparian areas above Wellington<br>• Shepherd Canyon: riparian and moist areas heavily infested; one site cleared by volunteers now in maintenance mode; Fire Department regularly weed-whacks and spreads infestations<br>• Beaconsfield Canyon: first pass at removal in park area completed 2007; resprout control continues<br>• W. D. Wood Park: in lower moist areas<br>• Barry Place: infestations largely removed from trees; resprout control continues<br>• Infestations in many riparian and irrigated areas on private property | • Control resprouts in all active restoration areas<br>• Determine areas where Cape ivy most threatens creek and slope stability or important native plant habitat<br>• Seek funding for a major removal effort in Dimond Canyon, plus public education effort for nearby homeowners; remove from upstream to downstream<br>• Encourage Wildfire District to stop aiding in dispersal through poor management methods<br>• Establish links with IPM insect release efforts<br>• Discourage nurseries from selling this plant<br>• Educate homeowners to remove this plant<br> |
| | | | |

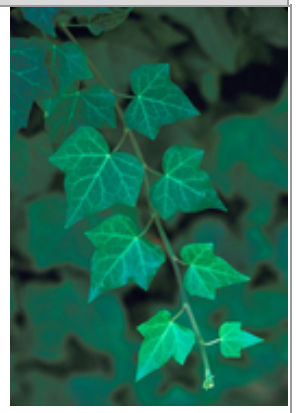
| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Hedera helix ssp. canariensis* Algerian ivy and *Hedera helix ssp. helix* English/Boston ivy[1] | <br>Very invasive; spreads by seed and by "running and rooting" of vines<br>• Tends to form a monoculture in shade, eliminating nearly all native understory and overstory tree seedlings<br>• Climbs trees, sending roots into the cambium layer and robbing them of nutrients, eventually weakening and toppling them with additional weight<br>• Occurs on many trees on extremely steep slopes, posing a risk to hillside stability if trees fall<br>• Poor soil holding capacity allows erosion | • Joaquin Miller Park: widespread in redwood and mixed hardwood forest understory and riparian areas<br>• Dimond Canyon: widespread in oak and redwood understory and riparian areas<br>• Dimond Park: throughout as understory; very heavy infestations into trees on steep slopes<br>• Shepherd Canyon: Dense areas along bike trail; other scattered infestations<br>• Beaconsfield Canyon: most removed from trees and soil surface<br>• W. D. Wood Park: in shaded areas, including under broom<br>• Barry Place: partially cleared; much remains on steepest slopes; heavily into trees just downstream on Gladman Hospital property<br>• Widely planted by CalTrans on highways in the watershed; many trees have blooming/fruiting infestations<br>• Joaquin Miller Park: along Siniwik Loop Trail<br>• Dimond Canyon: along Bridgeview Trail |  <br>• Maintain clearing in restoration areas<br>• Continue occasional "overstory maintenance" sweeps to remove vines climbing trees<br>• Encourage adjacent homeowners to join removal efforts<br>• Encourage Wildfire District to use more effective control measures<br>• Explore possibility of one-time use of goats for first-pass control in new restoration projects<br>• Seek funding to develop and execute a "No More Blooming Ivy" campaign; garner participation of parks, CalTrans, and homeowner groups to remove ivy from trees in watershed<br>• Discourage nurseries from selling this plant<br>• Educate homeowners to remove this plant |
| | | | |

Photo: ©2009 Barry Rice; ©1985 Joe DiTomaso

[1] There is considerable confusion in the identification of ivy varieties; these may also be known as *Hedera canariensis* and *Hedera helix*. In horticultural use, Algerian ivy is most commonly used outdoors; English/Boston ivy is more commonly a houseplant or used for topiary.

**Invasive Non-Native Perennials and Annuals of Sausal Creek Watershed**

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Vinca major*<br>Blue periwinkle | • Spreads from urban gardens and clippings thrown in creek<br>• Produces a chemical that inhibits growth of other understory plants and seedlings of overstory trees<br>• Tends to form monocultures<br>• Thrives in shady riparian areas<br>• Poor root structure allows erosion<br>• Hand removal efforts are labor-intensive and not effective | • Joaquin Miller Park: western end of Palos Colorados Trail<br>• Dimond Canyon: widespread in riparian areas<br>• Dimond Park: in riparian area and above Scout Hut<br>• Shepherd Canyon: several patches in lower, shady areas<br>• Beaconsfield: small patches near backyards | • Discourage the disposal of yard waste in creek by landscapers and residents<br>• Discourage nurseries from selling this plant<br>• Encourage homeowners to remove this plant<br>• Control re-sprouting in active restoration areas<br> |

Photo: ©2007 Neal Kramer

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Tradescantia flumenensis* Spiderwort | • Invades from urban gardens and clippings thrown in creek<br>• Tends to form monocultures<br>• Thrives in shady riparian areas<br>• Poor root structure allows erosion<br>• Stems break easily when pulled, making removal difficult; fragments easily re-root<br> | • Joaquin Miller Park: widespread along lower Palos Colorados Trail and in part of Big Trees areas; Palo Seco Creek<br>• Dimond Canyon: occurs in many locations; mixed with *Oxalis oregana* at Monterey site<br>• Dimond Park: riparian areas<br>• Shepherd Canyon | • Discourage the disposal of yard waste in creek by landscapers and residents<br>• Discourage nurseries from selling this plant<br>• Encourage homeowners to remove this plant<br>• Continue control efforts at current restoration project sites |
| *Oxalis pes-caprae* Bermuda buttercup | • Plants form many bulblets and spread by lateral underground shoots<br>• Bulbs are collected by pocket gophers who spread them via tunnels<br>• Other vectors poorly understood<br>• Removal is labor intensive, requiring deep digging and repeated visits to remove | • Joaquin Miller Park: large area near Lookout Point; other scattered areas, including mulch in Native Plant Nursery<br>• Dimond Canyon: scattered patches in restoration area; extensive infestations along Park Boulevard side of canyon<br>• Shepherd Canyon | • Not high priority; generally not occurring in restoration area sites or rare plant sites<br> |

Photos: ©2002 Tony Morosco; ©2009 Barry

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Oxalis incarnata* Scarlet woodsorrel | • Invades vegetatively and possibly by seed; also forms bulblets at axis of stems<br>• Hand-removal extremely tedious due to large numbers of tiny bulblets<br>• Inexperienced volunteers cannot distinguish from *Oxalis oregano* (Redwood sorrel) | • Joaquin Miller Park: along lower Palo Seco Creek and Palos Colorados Trail<br>• Dimond Canyon: occurs with native *Oxalis oregana* (a rare plant in East Bay) at Monterey Rd. redwoods site | • Continue control efforts at Monterey site<br> |
| *Foeniculum vulgare* Fennel | • Spreads by seed<br>• Re-grows rapidly after cutting or burning<br>• Large clumps are labor intensive to remove<br>• Produces chemicals that suppress the growth of other plants<br> | • Joaquin Miller Park: many scattered infestations<br>• Dimond Canyon: extensive infestation along Bridgeview Trail near PG&E landslide area; in landslide area below Estates along Park Boulevard; along El Centro above trailhead<br>• W.D. Wood Park: scattered stands<br>• Shepherd Canyon: Along Snake Rd. near footbridge and along trail towards village | • Encourage Wildfire District to remove rather than repeatedly cutting tops; encourage them to extend control to edges of grazed areas<br>• Remove plants in active restoration areas<br>• Encourage removal by homeowners<br> |
| *Fumaria capreolata* Fumitory | • Spreads by seed<br>• Perennial<br>• Single plants can cover many square feet, suppressing native plant populations<br> | • Dimond Canyon: under oaks just above El Centro<br>• Native Plant Nursery: infestation near entry has spread to many irrigated areas | • Adopt zero-tolerance efforts at Native Plant Nursery to avoid possible contamination of nursery stock<br>• Undertake annual control efforts before seed set in Dimond Park |

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| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Lepidium latifolium* Perennial pepperweed, Broadleaved pepperweed | • Extremely invasive; spreads by seed and rhizomes<br>• Even dried root fragments can resprout in winter rains or along creeks<br>• Forms dense monocultures of tall plants in moist habitats<br>• Poor root structure allows bank failures along creeks | • Native Plant Nursery: near shadehouse; apparently arrived in mulch<br> | • Continue control/eradication efforts, digging out roots along with above-ground biomass<br>• Never allow seed set |
| *Conium maculatum* Poison hemlock | • Spreads by seed; copious seed production<br>• Tall plants in dense stands can eliminate native understory by shading and crowding<br>• Tends to favor riparian and moist areas<br>• Poor root structure allows erosion | • Joaquin Miller Park: near Horse Arena; along Cinderella Creek; on hill above nursery<br>• Dimond Canyon: scattered locations<br>• Shepherd Canyon: near creek by soccer field<br>• Beaconsfield: on 2nd year of removal near creek; infestations on hill not yet addressed | • Continue control efforts in and near restoration areas<br>• Encourage removal by homeowners<br> |
| *Euphorbia* sp. Spurge | • Spreads by seed<br>• Establishes colonies via rhizomes<br>• Forms a monoculture<br>• Survives and spreads on hot dry hillsides<br>• White sap may cause skin and eye irritation<br> | • Joaquin Miller Park: not yet assessed<br>• Dimond Canyon: isolated patches<br>• Shepherd Canyon: extensive populations on public and private property<br>• Beaconsfield Canyon: most large plants removed; many small patches remain | • Encourage removal on private property<br>• Discourage nurseries and landscapers from selling or planting this species<br>• Continue volunteer control efforts in Beaconsfield Canyon<br>• Work with Wildfire District to schedule vegetation clearance before seed set<br>• Encourage Wildfire District to dig rather than cut and to control along edges of grazed areas to prevent re-infestation<br>• Map populations in Shepherd Canyon |

Photos: ©2002 Jennifer Forman; ©1999 CAS-Gerald & Buff Corsi; ©2009 Margo Bors; ©2007 Luigi Rignanese

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Allium triquetrum* Three-cornered leek | • Spreads by seeds and bulb division<br>• Tends to form monocultures<br>• Often occurs along creek banks; poor soil- holding capacity | • Joaquin Miller Park: lower Palos Colorados Trail<br>• Dimond Canyon and Dimond Park: patches in riparian areas<br>• Shepherd Canyon: extensive monoculture along Zinn Trail<br>• Beaconsfield: small patches between trail and creek | • Encourage removal on private property<br>• Discourage nurseries and landscapers from selling or planting this species<br>• Control in active restoration areas |
| *Centaurea solstitialis* Yellow star thistle | • Extremely invasive from seed<br>• Perennial<br>• Forms dense monocultures that displace native plants<br>• Matures late in summer, increasing fire risk<br>• Difficult to remove by hand due to thorny stems and flowers | • Joaquin Miller Park: Most grasslands; somewhat controlled by goat grazing<br>• Shepherd Canyon: meadow above soccer field; somewhat controlled by goat grazing | • Encourage Wildfire District to control along edges of grazed areas to prevent re-infestation<br>• Encourage appropriate timing of Fire District vegetation management<br>• Monitor grazing exclusion areas to check for infestations |
| *Tropaeolum majus* Garden nasturtium | • Forms monocultures, eliminating native species<br>• Creates copious seed bank<br>• Poor soil holding capacity | • Dimond Canyon: 1 or 2 areas above Old Canon Trail<br>• Dimond Park: west side of creek below houses on Vista | |

Photos: ©2008 Gary McDonald; ©2008 Luigi Rignanese; ©1995 St. Mary's College of CA

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| Other thistles:<br>*Carduus pycnocephalus*<br>Italian thistle<br>*Cirsium vulgare*<br>Bull thistle<br>*Cynara cardunculus*<br>Artichoke thistle<br>*Silybum marianum*<br>Milk thistle | • Very invasive from seed<br>• Tend to colonize bare disturbed areas following goat grazing and harsh vegetation management or landslides<br> <br>**Italian thistle** **Bull thistle** | • Throughout watershed<br>• Italian thistle is especially prevalent in grazed or heavily weed-whacked areas<br> <br>**Artichoke thistle** | • Encourage Wildfire District to control along edges of grazed areas to prevent re-infestation<br>• Monitor grazing exclusion areas to check for infestation<br>• Encourage removal on private land<br> <br>**Milk thistle** |
| *Impatiens balfourii*<br>Balfour's touch-me- not | • Perennial, spreads easily by seed | • Dimond Canyon: prevalent at top of Monterey Rd. redwood restoration area in prime *Oxalis oregana* area | • Continue eradication efforts<br> |
| *Myosotis latifolia*<br>Forget-me-not | • Spreads rapidly by seed<br>• Perennial<br>• Favors riparian understory areas | • Throughout watershed in suitable habitat<br> | • Continue eradication and control efforts in active restoration areas |

Photos: ©1995 St. Mary's College of CA; ©2008 Keir Morse; ©2008 Neal Kramer; ©2007 CAS-J.E. & Bonnie McClellan; ©2006 James B. Gratiot, ©2006 Jo-Ann Ordano

**Table 1: Invasive Non-Native Grasses of Sausal Creek Watershed**

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Arundo donax*<br>Giant reed | • Spreads vegetatively by rhizomes and plant fragments; even dried fragments can root in suitable habitat<br>• Extremely invasive in riparian habitats<br>• Can grow to 30 ft. or more<br>• Poor root structure can lead to bank failure and erosion<br> | • Joaquin Miller Park: one known site<br>• Cobbledick sub-basin: 2 sites between Scout Rd. and creek<br>• Shepherd Canyon: one small stand on private property below Westover near Pelham; large clump near Westover and Shelterwood | • Good project for Weed Warriors<br>• Obtain homeowner cooperation in removal on private property<br>• Discourage nurseries and landowners from selling or planting this species |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Cortaderia jubata*<br>*Cortaderia selloana*<br>Jubata grass, Pampas grass | • Spreads by seed; easily establishes in disturbed areas<br>• Over time, large clumps can coalesces to form monocultures<br>• Plumes are highly flammable and spread fires<br>• Plants re-grow quickly if cut to ground<br>• Removal of clumps is labor intensive | • Joaquin Miller Park: scattered populations<br>• Dimond Canyon: largest infestations on PG&E landslide and along Park Blvd.<br>• Shepherd Canyon: along Escher Drive and along Bike Path<br> | • Remove plumes before seed set when possible<br>• Encourage Wildfire District to dig out clumps rather than repeatedly cutting tops<br>• Discourage nurseries and landowners from selling or planting this species |
| *Phalaris aquatica*<br>Harding grass | • Spreads by seeds with heavy seed set<br>• Large tussocks labor intensive to remove<br>• Favors sunny, moist areas but can survive drier uplands<br>• Plants grow to 6 ft.<br>• Extreme fire danger | • Shepherd Canyon: in meadow above soccer field; invading uplands; grazing in past few years has reduced enormously; however, it has spread to ungrazed upland areas<br> | • Encourage Shepherd Canyon Homeowners Association and the Wildfire District to work to eradicate completely<br>• Discourage nurseries and landowners from selling or planting this species<br>• Encourage removal on private land |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Ehrharta erecta*<br>Veldt grass | • Spreads rapidly by seed; copious, tiny seeds are easily spread by traffic on trails<br>• Deep-rooted perennial clumps require digging to remove<br>• Long culms can spread seed up trail cuts and through shrub understory<br>• Can survive on fog drip in uplands, when shaded<br>• Planting natives after *Ehrharta* removal fails if copious re-seeding out-competes native plants for light and water | • Joaquin Miller Park: extensive infestation spreading rapidly in oak, redwood, and other understory areas<br>• Dimond Canyon: spreading rapidly in moist understory areas<br>• Dimond Park: many locations<br>• Shepherd Canyon: Near picnic area and along bike path<br>• Beaconsfield: in riparian areas and under pines and cypresses in uplands<br>• W. D. Wood Park: scattered locations<br> | • Eradication impossible; attempt to control spread near priority native plant areas and restoration areas<br>• When revegetating in areas with *Ehrharta*, use cardboard mulch around seedlings to reduce competition<br>• Discourage nurseries and landowners from selling or planting this species<br>• Remove flowering heads prior to seed set along trails and other traffic zones to reduce spread<br>• Encourage removal on private land |
| *Holcus lanatus*<br>Velvet grass | • Spreads by seeds<br>• Perennial<br> | • Joaquin Miller Park: spreading rapidly along Sequoia-Bayview Trail above Chaparral Trail intersection | • Initiate control program in most desirable native plant areas<br>• Cut flowering heads prior to seed set to limit spread along trails |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Cynodon dactylon* Bermuda grass | • Spreads rapidly by stolons<br>• Deep, easily-broken roots make eradication difficult<br>• Can survive on low levels of moisture<br> | • Native Plant Nursery: extensive throughout mulched areas; reduced by Fall 2008 construction work<br> | • Reduce mulching to eliminate nitrogen source<br>• Re-arrange busy work areas in nursery periodically to trample largest patches<br>• Establish a weed-free buffer zone around the shade house to avoid grass invading pots; if possible, adjust irrigation to reduce overspray onto invasives<br>• Initiate aggressive control measures to prevent transferring to riparian areas via seeds in nursery stock |
| *Pennisetum clandestinum* Kikuyu grass | • Spreads extremely rapidly via stolons<br>• Can survive on extremely low levels of moisture<br> | • Joaquin Miller Park: Invades seep area near lower end of Sanborn; in mulch at native plant nursery<br>• Dimond Park: near tot lot; invades Native Plant Demonstration Garden; west side of creek above Wellington<br>• Native plant nursery: scattered areas in mulch<br>• W. D. Wood Park: near irrigated lawn | • In Dimond Park, replace Tot Lot lawn with native meadow; minimize perimeter to improve chances for successful, long-term maintenance<br>• Continue control efforts in nursery<br>• Initiate aggressive control measures to prevent transferring to riparian areas via seeds in nursery stock |

| Species | Characteristics | Distribution | Recommendations |
|---|---|---|---|
| *Agrostis* sp. Bent grass | • Spreads by seeds and rhizomes | • Native plant nursery: surrounds shade house in areas that receive irrigation spray | • Initiate aggressive control measures to prevent transferring to riparian areas via seeds in nursery stock<br>• Establish a weed-free buffer zone around the shade house<br>• Check irrigation to determine if it is possible to reduce overspray onto invasives |
| Non-native grasses (see list below) | • Seed spread by wind<br>• Out competes native grasses and wildflowers<br>• High fire risk; almost all areas on public land grazed by goats, generally after annual grasses have set seed, but before natives have done so<br>• Outplanting natives in areas of heavy annual grass seedbank can fail due to competition for water and sunlight | • Dominate all grassland areas in watershed except for thin serpentine soil; also present in woodland understory | • Eradication impossible; attempt to control spread near priority native plant areas and restoration areas<br>• Use cardboard mulch around seedlings to reduce competition<br>• Encourage Wildfire District to graze earlier to reduce seed set |

**Non-native Grasses**

| Scientific Name | Common Name | Type |
|---|---|---|
| *Avena barbata* | slender wild oats | Annual |
| *Avena species* | wild oats | Annual |
| *Briza maxima* | quaking grass | Annual |
| *Bromus diandrus* | ripgut brome | Annual |
| *Bromus hordeaceus* | soft chess | Annual |
| *Cynosurus echinatus* | hedgehog dogtail | Annual |
| *Festuca arundinacea* | tall fescue | Perennial |
| *Hordeum murinum ssp. murinum* | wall barley; foxtail | Annual |
| *Hordeum species* | foxtail; barley | Annual |
| *Lolium multiflorum* | Italian ryegrass | Annual |
| *Poa annua* | annual bluegrass | Annual |
| *Poa secunda ssp. secunda* | one-side blue grass | Perennial |
| *Polypogon monspeliensis* | annual beard grass | Annual |
| *Vulpia myuros var. hirsuta* | foxtail fescue | Annual |

## APPENDIX D

# GOAT GRAZING FOR WEED CONTROL IN JOAQUIN MILLER PARK

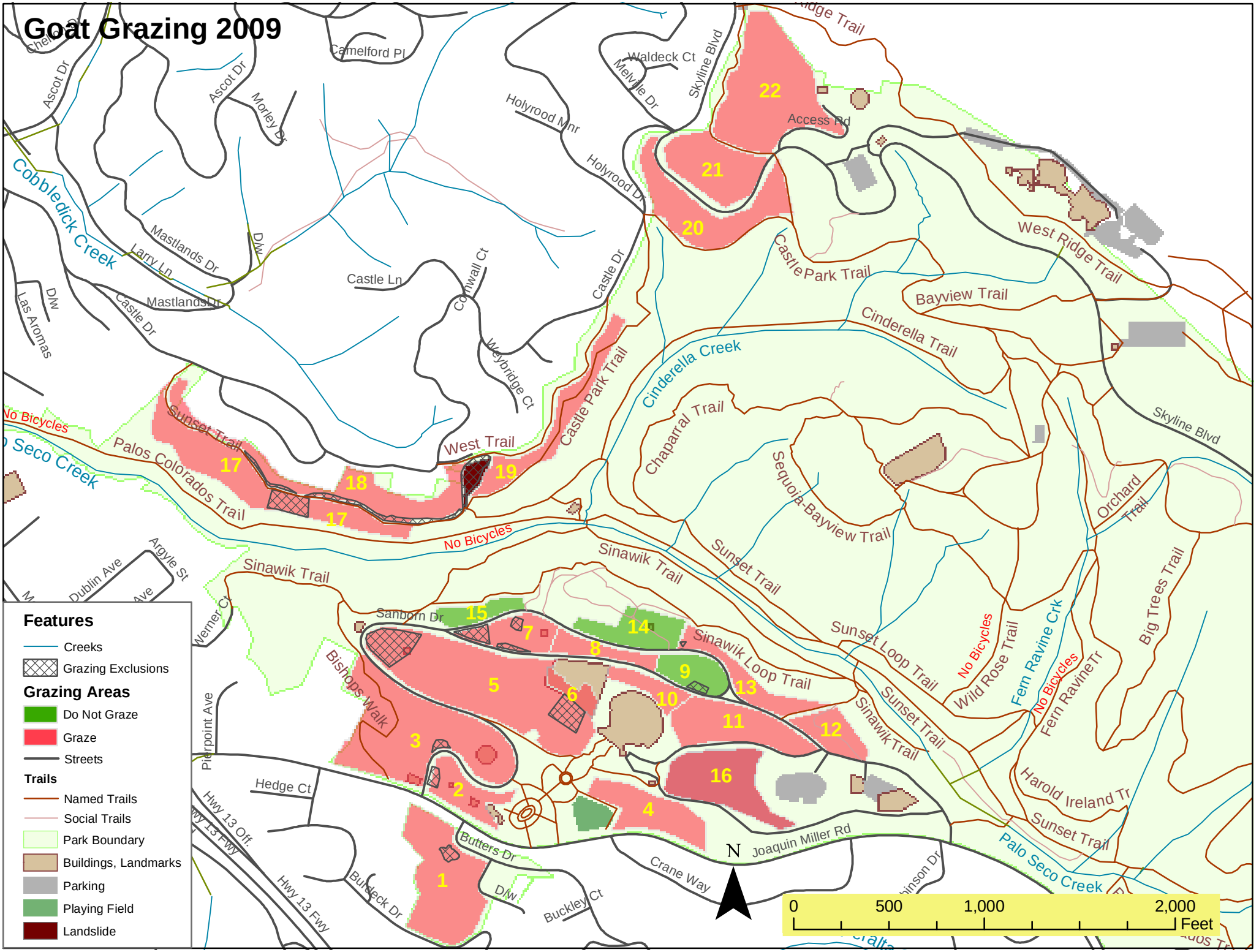
# Grazing Schedule 2008-2012

## Grazed Yearly

| ID | Acres (flat) | Location | Grazing Frequency | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|
| 1 | 4.79 | Butters Drive | Yearly | yes | yes | yes | yes | yes |
| 2 | 1.64 | Between Tot Lot and Sanborn | Yearly | yes | yes | yes | yes | yes |
| 3 | 7.48 | Around and behind JM Abbey (may be 2 areas, split at Bishop's Walk?) | Yearly | yes | yes | yes | yes | yes |
| 4 | 2.49 | Near Perry Field along JM Road | Yearly | yes | yes | yes | yes | yes |
| 5 | 7.85 | From Funeral Pyre to Cascades, below nursery | Yearly | yes | yes | yes | no | yes |
| 6 | 0.62 | Nursery | Yearly | yes | yes | yes | yes | yes |
| 10 | 0.97 | Between Sanborn and theater; picnic area | Yearly | yes | yes | yes | yes | yes |
| 11 | 3.15 | Between Sanborn and theater driveway; picnic area | Yearly | yes | yes | yes | yes | yes |
| 16 | 3.44 | Theater parking area/ dog park | Yearly | yes | yes | yes | yes | yes |
| 17 | 4.86 | Lower Sunset Grassland | Yearly | yes | yes | yes | yes | yes |
| 18 | 4.01 | Upper Sunset Grassland, west end of Sunset Trail to landslide area | Yearly | yes | yes | yes | yes | yes |
| 19 | 2.53 | Along Castle Park and WestTrails | Yearly | yes | yes | yes | yes | yes |
| 20 | 3.84 | Between Castle Park Trail and Skyline | Yearly | yes | yes | yes | yes | yes |
| 21 | 3.01 | Above Skyline to trail | Yearly | yes | yes | yes | yes | yes |
| 22 | 6.35 | Along Sklyine, from trail to Moon Gate | Yearly | yes | yes | yes | yes | yes |
| | 57.03 | | | | | | | |

## Grazed Less Frequently

| ID | Acres | Location | Grazing Frequency | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|
| 7 | 1.15 | Interior of Sanborn 1-way loop; west end | 2 years | no | yes | no | yes | no |
| 8 | 1.05 | Interior of Sanborn 1-way loop; center | 2 years | no | yes | no | yes | no |
| 9 | 1.46 | Interior of Sanborn 1-way loop; east end | 3 years | no | no | yes | no | no |
| 12 | 1.42 | North of Sanborn by fire gate, picnic area | 2 years | no | yes | no | yes | no |
| 13 | 1.65 | North of Sanborn, past trail | 2 years | no | yes | no | yes | no |
| 14 | 2.02 | Browning Monument area | 3-4 years | no | no | tbd | tbd | tbd |
| 15 | 1.02 | Between Sanborn & Siniwik Loop Trail; Clarkia meadow | 3-4 years | no | no | tbd | tbd | tbd |
| | 107.45 | | | | | | | |


Goat Grazing 2009
Features
Creeks
Grazing Exclusions
Grazing Areas
Do Not Graze
Graze
Streets
Trails
Named Trails
Social Trails
Park Boundary
Buildings, Landmarks
Parking
Playing Field
Landslide
Cobbledick Creek
Palo Seco Creek
Cinderella Creek
Ascot Dr
Camelford Pl
Morley Dr
Holyrood Mnr
Holyrood Dr
Melville Dr
Waldeck Ct
Skyline Blvd
Access Rd
Mastlands Dr
Larry Ln
Castle Ln
Cornwall Ct
Castle Dr
Weybridge Ct
Las Aromas
West Ridge Trail
Castle Park Trail
Bayview Trail
Cinderella Trail
Chaparral Trail
Sequoia-Bayview Trail
Orchard Trail
Big Trees Trail
Sunset Trail
Palos Colorados Trail
West Trail
No Bicycles
Sinawik Trail
Sinawik Loop Trail
Sunset Loop Trail
Wild Rose Trail
Fern Ravine Crk
Fern RavineTr
Harold Ireland Tr
Sanborn Dr
Bishops Walk
Pierpoint Ave
Werner Ct
Dublin Ave
Argyle St
Hedge Ct
Hwy 13 Off
Hwy 13 Fwy
Butters Dr
Burbeck Dr
Buckley Ct
Crane Way
Joaquin Miller Rd
Robinson Dr
1
2
3
4
5
6
7
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9
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11
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22
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0
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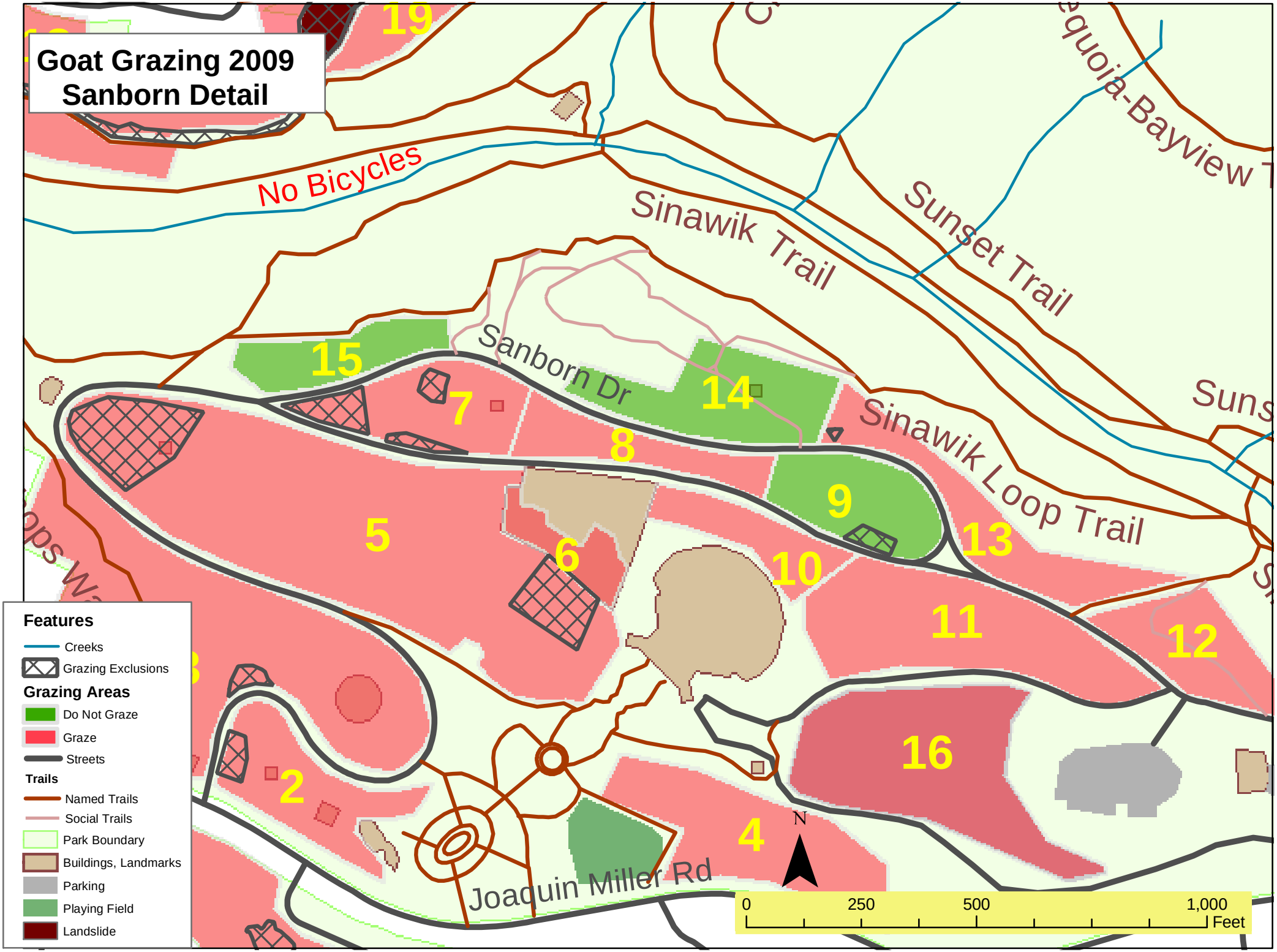
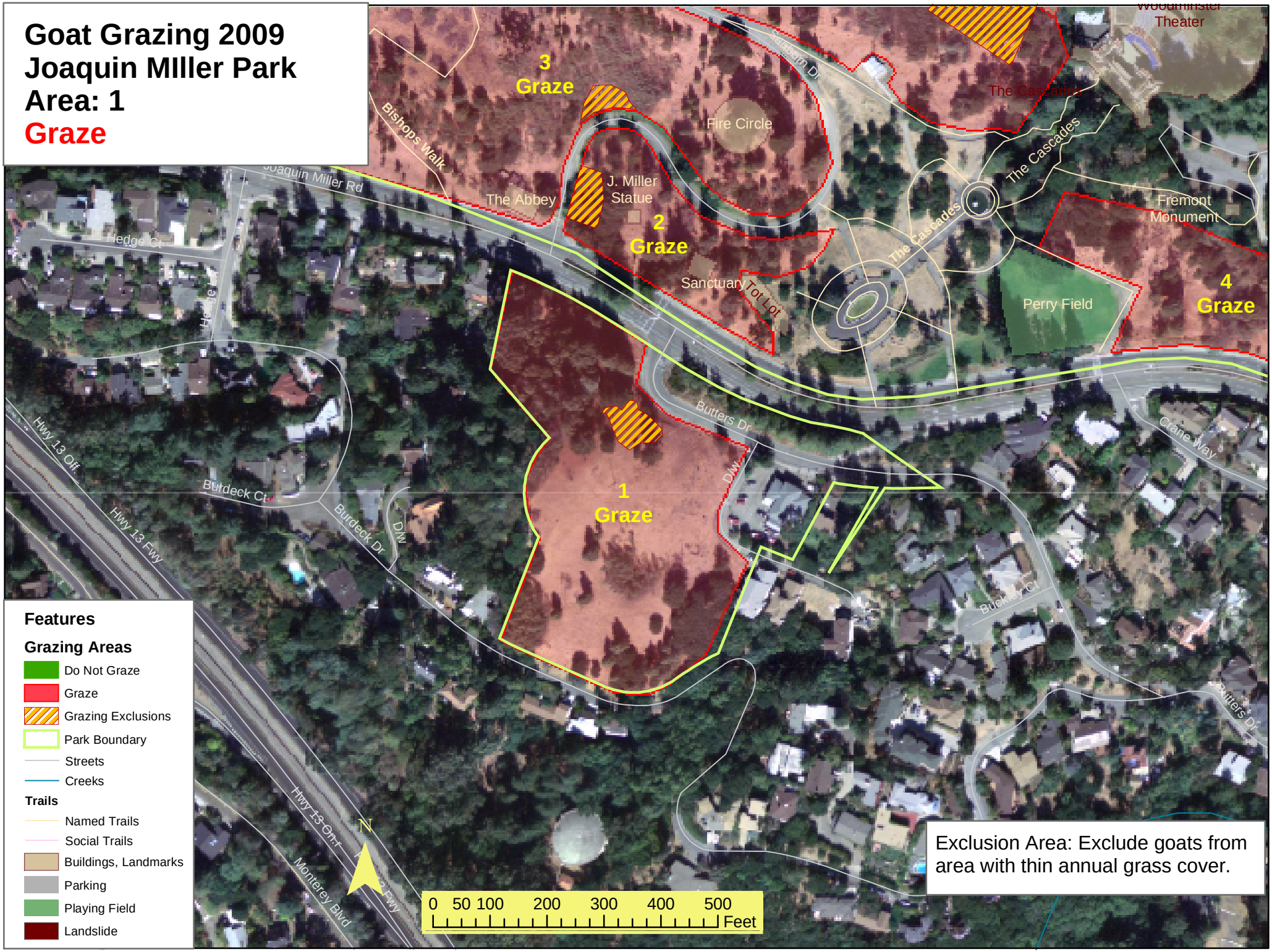
Feet


Goat Grazing 2009
Sanborn Detail
No Bicycles
Sinawik Trail
Sunset Trail
Sanborn Dr
Sinawik Loop Trail
Joaquin Miller Rd
19
15
7
14
8
9
5
6
10
13
11
12
16
2
4
N
0
250
500
1,000
Feet
Features
Creeks
Grazing Exclusions
Grazing Areas
Do Not Graze
Graze
Streets
Trails
Named Trails
Social Trails
Park Boundary
Buildings, Landmarks
Parking
Playing Field
Landslide

# Goat Grazing 2009
# Joaquin MIller Park
# Area: 1
# Graze




## Features

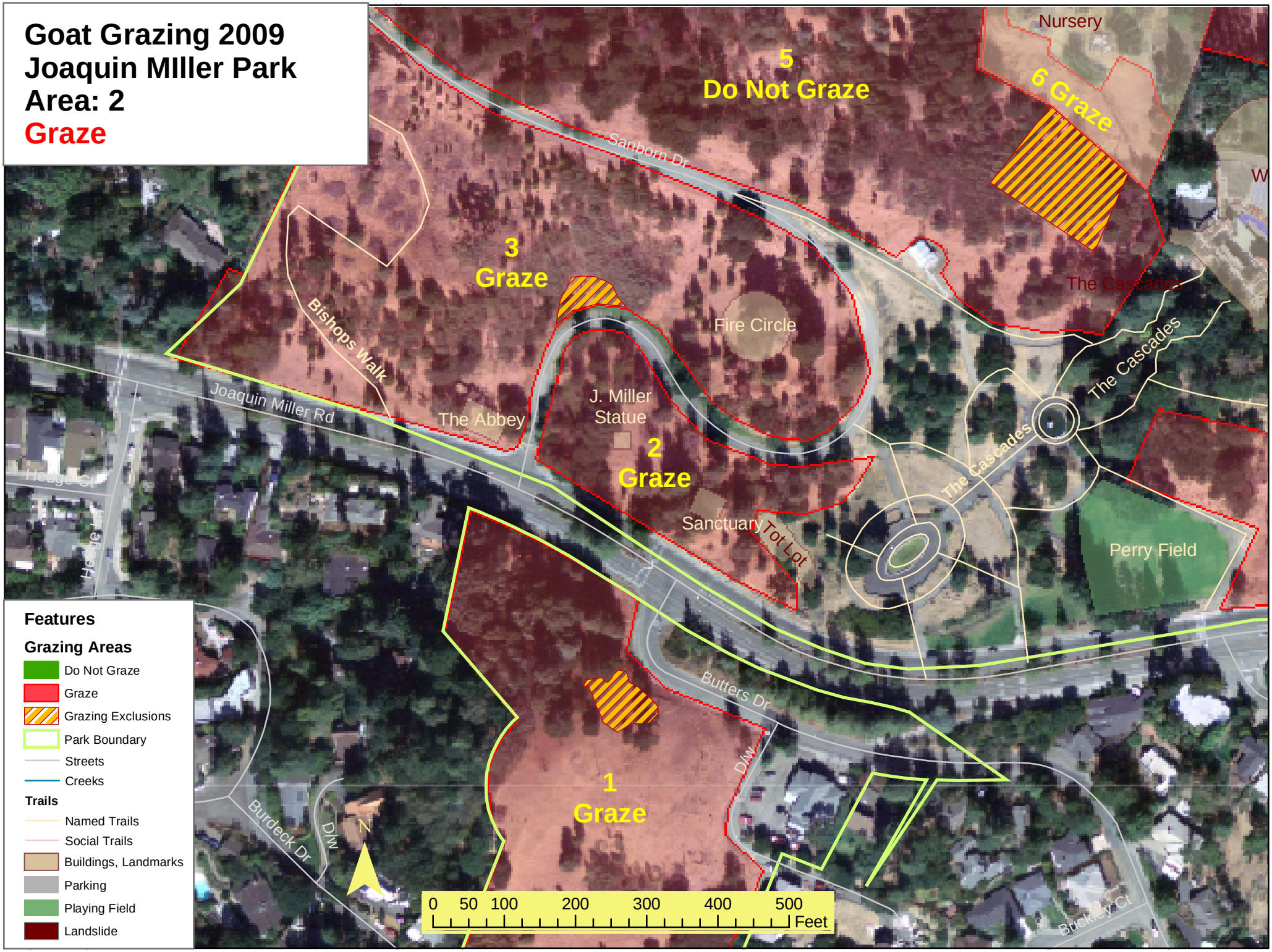
### Grazing Areas

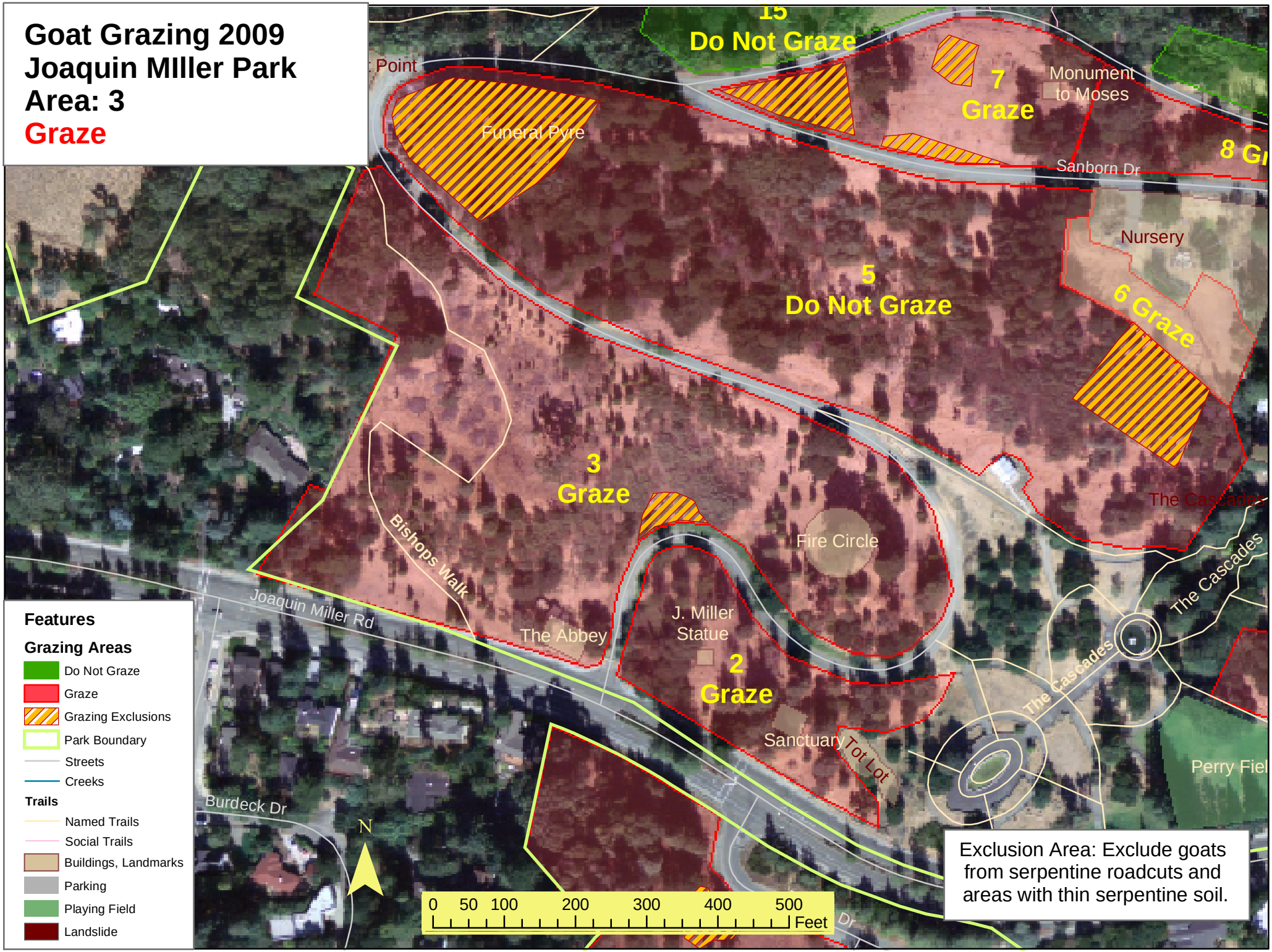
- Do Not Graze
- Graze
- Grazing Exclusions
- Park Boundary
- Streets
- Creeks

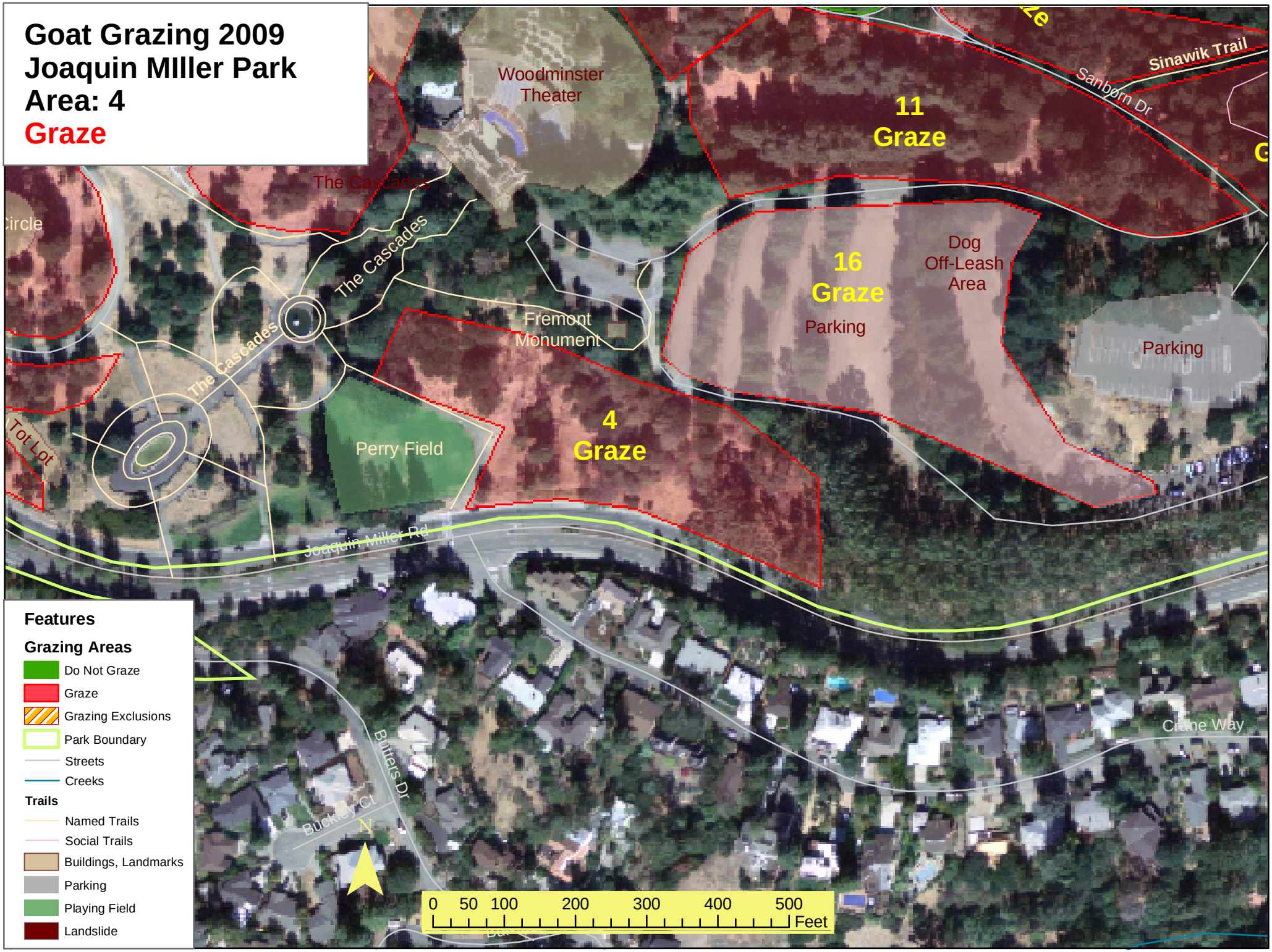
### Trails

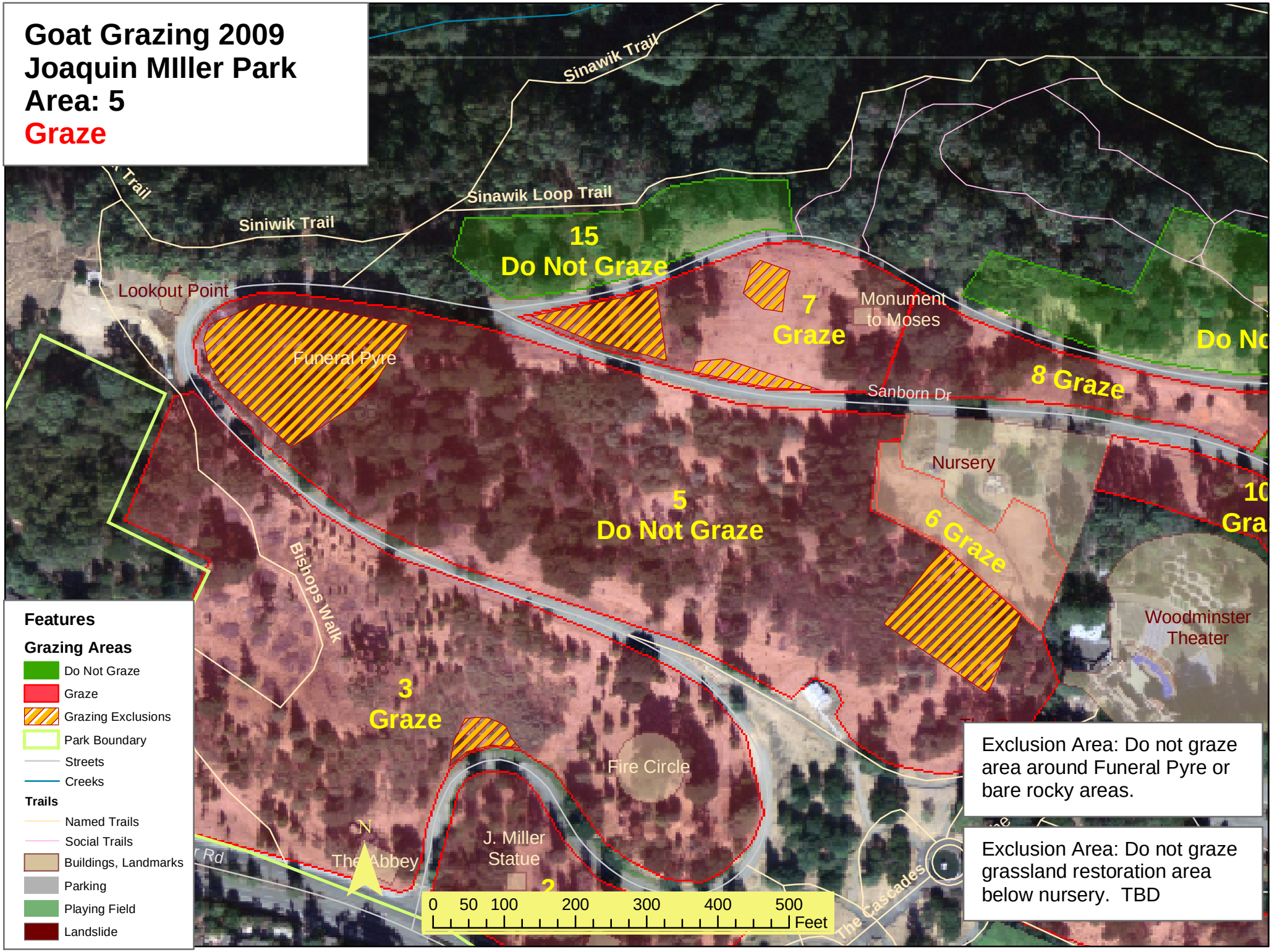
- Named Trails
- Social Trails
- Buildings, Landmarks
- Parking
- Playing Field
- Landslide

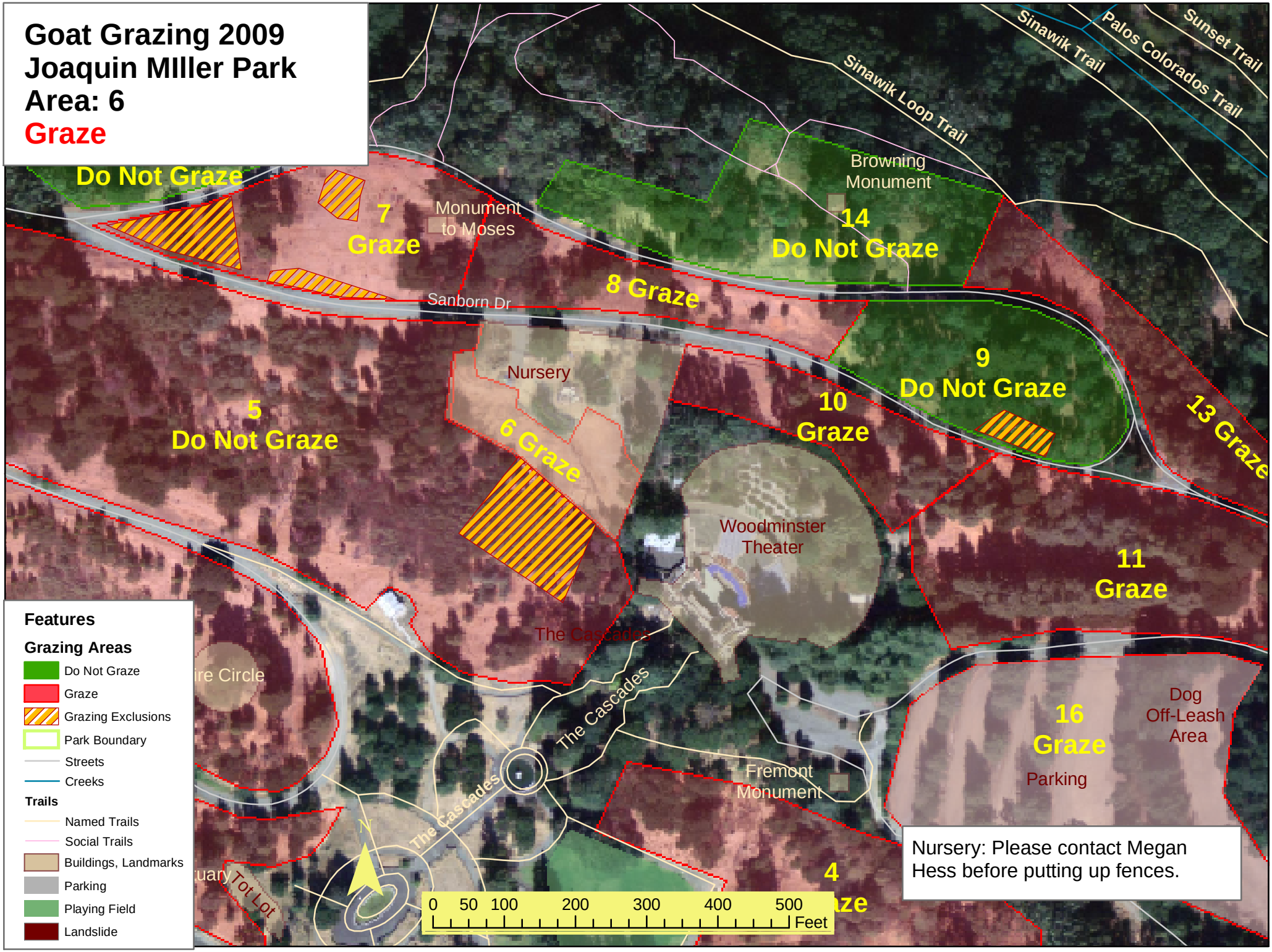
Exclusion Area: Exclude goats from area with thin annual grass cover.

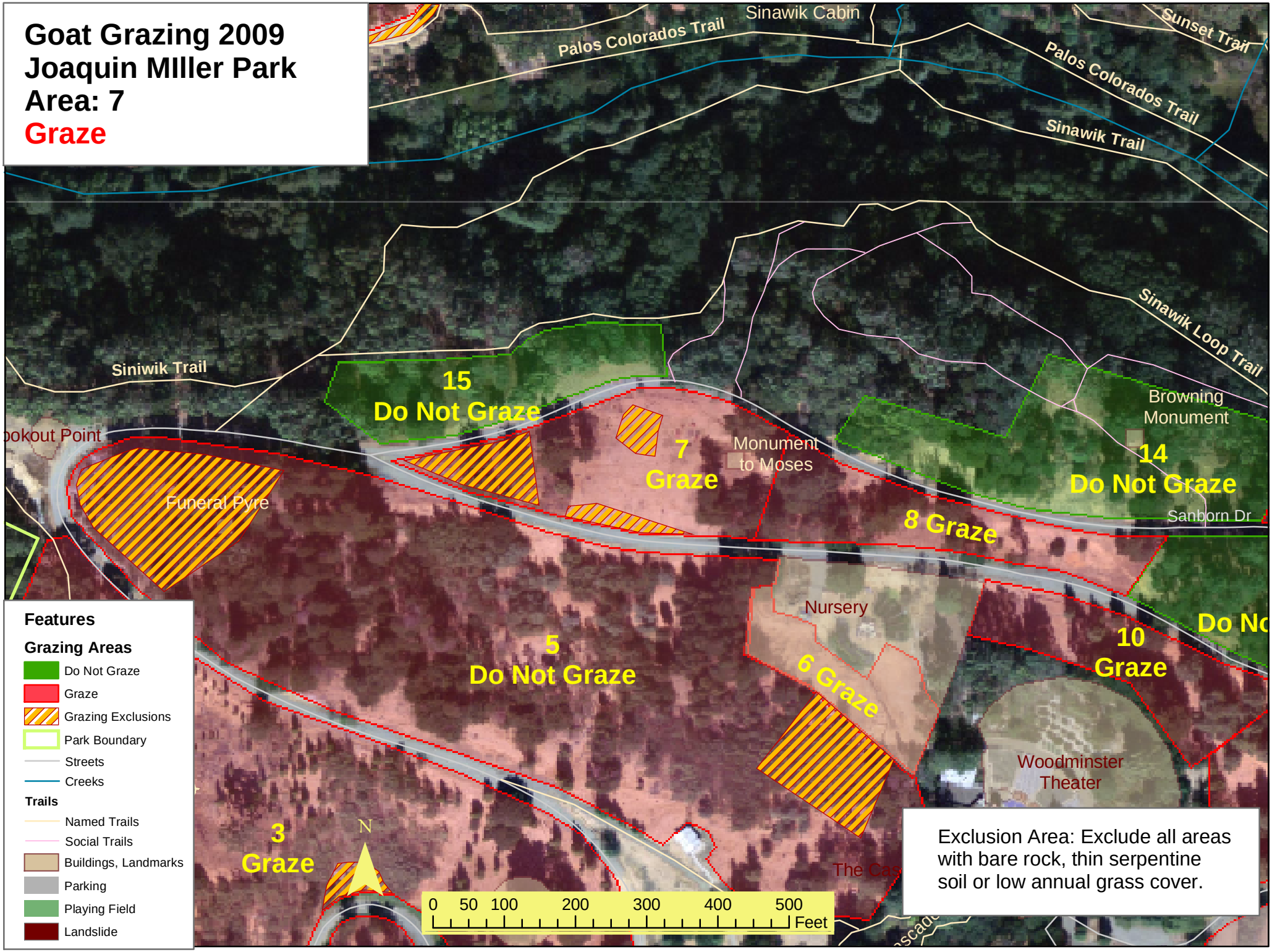

Goat Grazing 2009
Joaquin MIller Park
Area: 2
Graze
5
Do Not Graze
6 Graze
Nursery
Sanborn Dr
3
Graze
Bishops Walk
Fire Circle
The Cascades
The Cascades
Joaquin Miller Rd
The Abbey
J. Miller
Statue
2
Graze
The Cascades
Sanctuary
Tot Lot
Perry Field
Heage Ct
Heage
Butters Dr
D/w
1
Graze
Burdeck Dr
D/w
N
Buckley Ct
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide

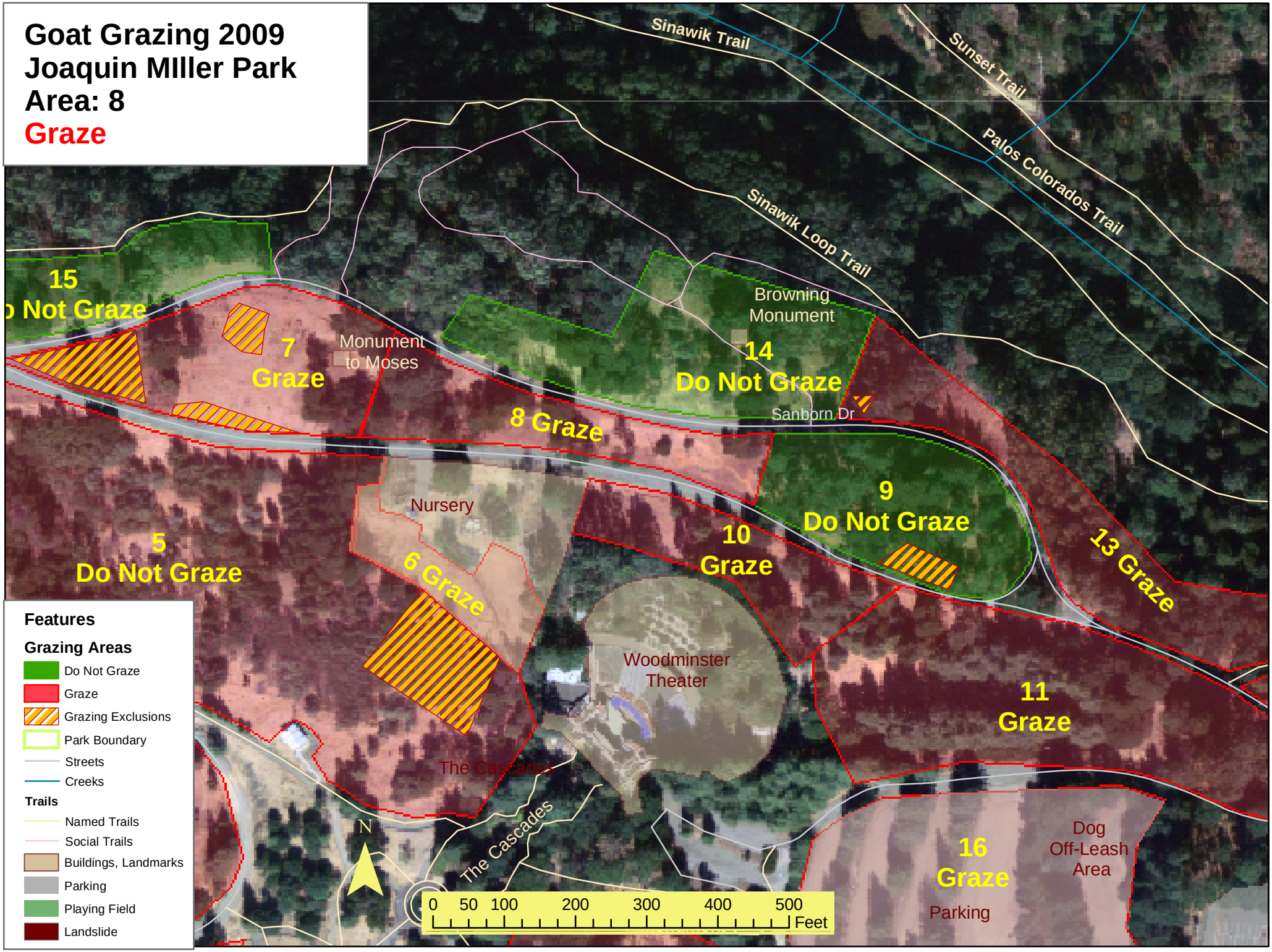

Goat Grazing 2009
Joaquin MIller Park
Area: 3
Graze
15
Do Not Graze
Point
Funeral Pyre
7
Graze
Monument
to Moses
8 Gr
Sanborn Dr
Nursery
5
Do Not Graze
6 Graze
3
Graze
Bishops Walk
Fire Circle
The Cascades
Joaquin Miller Rd
The Abbey
J. Miller
Statue
2
Graze
Sanctuary
Tot Lot
Perry Fiel
Burdeck Dr
N
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide
Exclusion Area: Exclude goats from serpentine roadcuts and areas with thin serpentine soil.

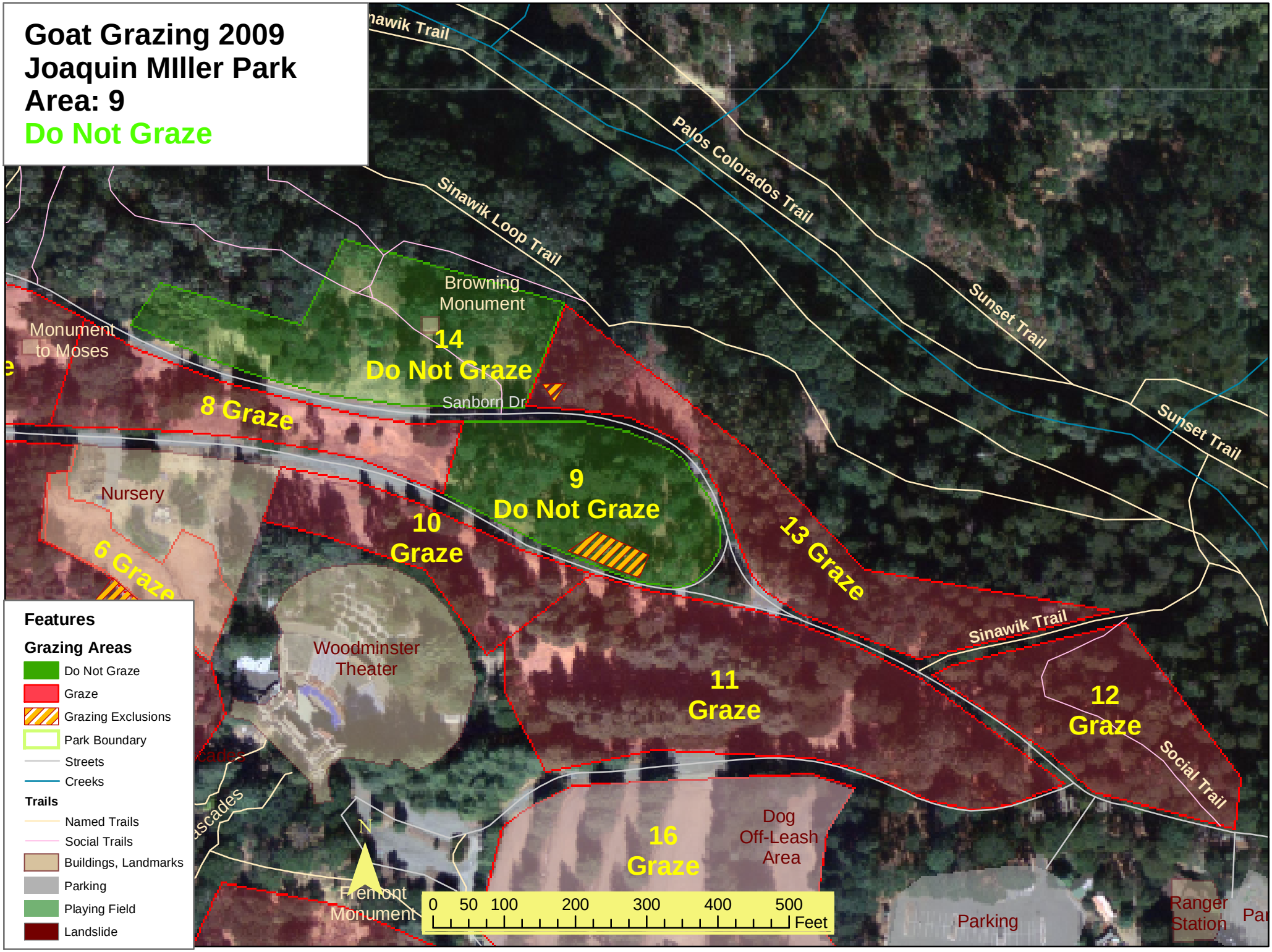

Goat Grazing 2009
Joaquin MIller Park
Area: 4
Graze
Woodminster Theater
11
Graze
Sinawik Trail
Sanborn Dr
The Cascades
16
Graze
Dog Off-Leash Area
Parking
Fremont Monument
Parking
4
Graze
Perry Field
Tot Lot
Joaquin Miller Rd
Crane Way
Briffers Dr
Buckley Ct
N
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide

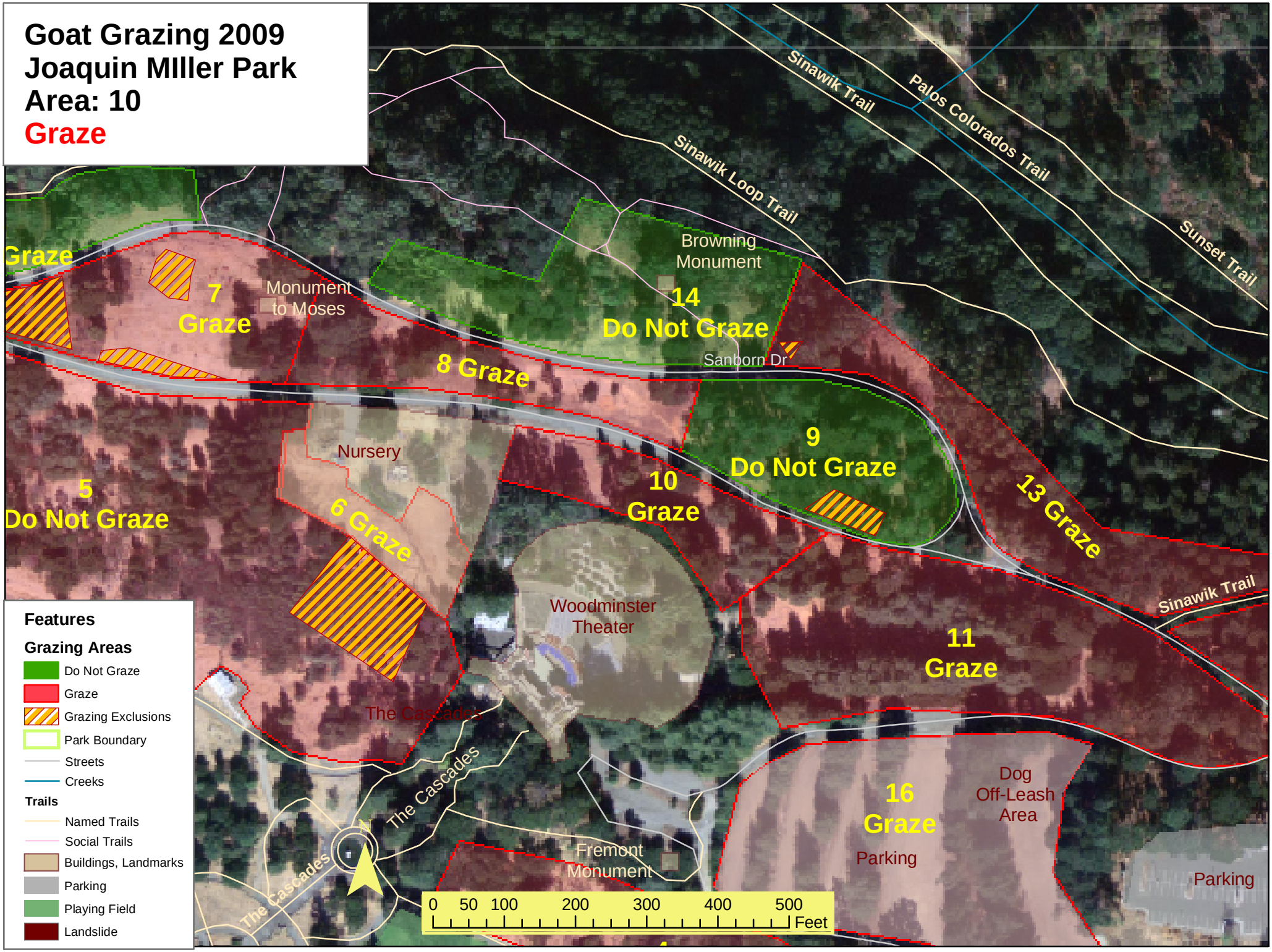

Goat Grazing 2009
Joaquin MIller Park
Area: 5
Graze
Sinawik Trail
Sinawik Loop Trail
Siniwik Trail
15
Do Not Graze
Lookout Point
Funeral Pyre
7
Graze
Monument
to Moses
Do No
8 Graze
Sanborn Dr
Nursery
5
Do Not Graze
6 Graze
10
Gra
Bishops Walk
Woodminster
Theater
3
Graze
Fire Circle
J. Miller
Statue
N
The Abbey
The Cascades
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide
Exclusion Area: Do not graze area around Funeral Pyre or bare rocky areas.
Exclusion Area: Do not graze grassland restoration area below nursery. TBD


Goat Grazing 2009
Joaquin MIller Park
Area: 6
Graze
Do Not Graze
7
Graze
Monument
to Moses
Browning
Monument
14
Do Not Graze
Sinawik Loop Trail
Sinawik Trail
Palos Colorados Trail
Sunset Trail
8 Graze
Sanborn Dr
Nursery
9
Do Not Graze
5
Do Not Graze
6 Graze
10
Graze
13 Graze
Woodminster
Theater
11
Graze
The Cascades
The Cascades
The Cascades
Fremont
Monument
16
Graze
Parking
Dog
Off-Leash
Area
4
Tot Lot
N
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide
Nursery: Please contact Megan
Hess before putting up fences.


Goat Grazing 2009
Joaquin MIller Park
Area: 7
Graze
Sinawik Cabin
Palos Colorados Trail
Sunset Trail
Palos Colorados Trail
Sinawik Trail
Sinawik Loop Trail
Siniwik Trail
15
Do Not Graze
7
Graze
Monument
to Moses
Browning
Monument
14
Do Not Graze
Sanborn Dr
Funeral Pyre
8 Graze
Nursery
5
Do Not Graze
6 Graze
10
Graze
Woodminster
Theater
3
Graze
N
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide
Exclusion Area: Exclude all areas with bare rock, thin serpentine soil or low annual grass cover.


Goat Grazing 2009
Joaquin MIller Park
Area: 8
Graze
Sinawik Trail
Sunset Trail
Palos Colorados Trail
Sinawik Loop Trail
15
o Not Graze
7
Graze
Monument
to Moses
Browning
Monument
14
Do Not Graze
Sanborn Dr
8 Graze
9
Do Not Graze
Nursery
5
Do Not Graze
6 Graze
10
Graze
13 Graze
Woodminster
Theater
11
Graze
The Cascades
The Cascades
16
Graze
Parking
Dog
Off-Leash
Area
N
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide


Goat Grazing 2009
Joaquin MIller Park
Area: 9
Do Not Graze
Palos Colorados Trail
Sinawik Loop Trail
Sunset Trail
Sunset Trail
Browning Monument
14
Do Not Graze
Monument to Moses
Sanborn Dr
8 Graze
9
Do Not Graze
Nursery
10
Graze
13 Graze
6 Graze
Sinawik Trail
Woodminster Theater
11
Graze
12
Graze
Social Trail
16
Graze
Dog Off-Leash Area
Fremont Monument
N
0 50 100 200 300 400 500
Feet
Parking
Ranger Station
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide


Goat Grazing 2009
Joaquin MIller Park
Area: 10
Graze
Sinawik Trail
Palos Colorados Trail
Sinawik Loop Trail
Sunset Trail
Graze
7
Graze
Monument
to Moses
Browning
Monument
14
Do Not Graze
Sanborn Dr
8 Graze
9
Do Not Graze
Nursery
5
Do Not Graze
6 Graze
10
Graze
13 Graze
Sinawik Trail
Woodminster
Theater
11
Graze
The Cascades
The Cascades
The Cascades
16
Graze
Parking
Dog
Off-Leash
Area
Fremont
Monument
Parking
0 50 100 200 300 400 500
Feet
Features
Grazing Areas
Do Not Graze
Graze
Grazing Exclusions
Park Boundary
Streets
Creeks
Trails
Named Trails
Social Trails
Buildings, Landmarks
Parking
Playing Field
Landslide

# APPENDIX E

# SAUSAL CREEK EPA SWMM 5.0 MODEL OUTPUT

## Sausal Creek Existing Conditions Hydrology

RUNOFF QUANTITY

| Return Interval | Total Precipitation Volume (acre-feet) | Total Precipitation Depth (in) | Surface Runoff (acre-feet) | Infiltration Loss (acre-feet) | Surface Storage (acre-feet) | Flow Continuity Error (%) | Routing |
|---|---|---|---|---|---|---|---|
| 100 Year | 1775.5 | 7.40 | 729.0 | 1033.0 | 13.5 | -8.0 | Dynamic Wave |
| 25 Year | 1363.1 | 5.68 | 534.2 | 815.9 | 12.9 | -4.2 | Dynamic Wave |
| 10 Year | 1108.2 | 4.62 | 424.3 | 671.3 | 12.5 | -9.7 | Dynamic Wave |
| 5 Year | 918.9 | 3.83 | 346.0 | 560.8 | 12.1 | -4.7 | Dynamic Wave |
| 2 Year | 652.6 | 2.72 | 240.8 | 400.3 | 11.4 | -5.7 | Dynamic Wave |
| 1 Year | 131.1 | 0.55 | 43.2 | 79.3 | 8.5 | -7.8 | Dynamic Wave |

| PEAK RUNOFF BY SUBBASIN (CFS) | | | | | | |
|---|---|---|---|---|---|---|
| Storm Return Frequency | | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 277.92 | 214.17 | 176.64 | 142.91 | 97.07 | 17.08 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 74.43 | 57.58 | 47.19 | 39.09 | 27.12 | 4.90 |
| Outlet of Cobbledick Creek (Node 30) | 138.9 | 108.4 | 91.9 | 76.3 | 53.9 | 9.35 |
| Outlet of Shepard Canyon (Node SC-R) | 472.3 | 312.5 | 254.5 | 208.7 | 142.0 | 26.46 |
| Outlet of Palo Seco Creek (Node 121) | 133.2 | 100.8 | 80.2 | 64.9 | 44.8 | 6.72 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 610.9 | 420.7 | 346.3 | 284.9 | 195.7 | 35.6 |
| Inlet to the Golf Course Culvert (Node 52) | 744.0 | 521.3 | 426.3 | 349.8 | 240.4 | 42.26 |
| Outlet of Dimond Canyon Park (Node 163) | 1106.1 | 913.1 | 789.7 | 538.3 | 363.2 | 58.85 |
| Outlet to the Bay (Node 179) | 1122.5 | 881.7 | 735.2 | 592.4 | 408.6 | 60.12 |

| TOTAL VOLUME (10^6 GAL) | | | | | | |
|---|---|---|---|---|---|---|
| Storm Return Frequency | | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 42.36 | 30.85 | 25.19 | 20.13 | 14.01 | 2.76 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 12.46 | 8.94 | 7.08 | 5.78 | 4.04 | 0.81 |
| Outlet of Cobbledick Creek (Node 30) | 27.40 | 17.71 | 15.78 | 11.50 | 8.03 | 1.57 |
| Outlet of Shepard Canyon (Node SC-R) | 76.54 | 46.74 | 37.91 | 30.40 | 21.20 | 4.40 |
| Outlet of Palo Seco Creek (Node 121) | 22.40 | 14.21 | 10.99 | 8.85 | 6.21 | 1.12 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 103.95 | 64.47 | 56.00 | 41.93 | 29.25 | 5.97 |
| Inlet to the Golf Course Culvert (Node 52) | 126.35 | 78.68 | 64.69 | 50.78 | 35.46 | 7.09 |
| Outlet of Dimond Canyon Park (Node 163) | 190.75 | 123.51 | 105.70 | 80.60 | 57.11 | 11.08 |
| Outlet to the Bay (Node 179) | 255.69 | 171.81 | 144.12 | 111.86 | 78.61 | 14.40 |

## Sausal Creek Proposed Conditions Hydrology

Scenario 1: Subwatershed LID Implementation (rain barrels, parking lot detention basins / biofiltration, other detention basins)

RUNOFF QUANTITY

| Return Interval | Total Precipitation Volume (acre-feet) | Total Precipitation Depth (in) | Surface Runoff (acre-feet) | Infiltration Loss (acre-feet) | Surface Storage (acre-feet) | Flow Continuity Error (%) | Routing |
|---|---|---|---|---|---|---|---|
| 100 Year | 1775.5 | 7.39 | 716.3 | 1031.5 | 33.3 | -3.1 | Dynamic Wave |
| 25 Year | 1363.1 | 5.67 | 525.5 | 815.0 | 26.3 | -4.1 | Dynamic Wave |
| 10 Year | 1108.2 | 4.61 | 417.1 | 670.8 | 22.8 | -4.3 | Dynamic Wave |
| 5 Year | 918.9 | 3.83 | 340.0 | 560.5 | 20.4 | -4.7 | Dynamic Wave |
| 2 Year | 652.6 | 2.72 | 236.2 | 400.3 | 17.1 | -5.6 | Dynamic Wave |
| 1 Year | 131.1 | 0.55 | 41.6 | 79.3 | 10.0 | -4.5 | Dynamic Wave |

| PEAK RUNOFF BY SUBBASIN (CFS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 278.78 | 219.02 | 176.85 | 145.07 | 99.32 | 16.55 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 75.08 | 58.43 | 47.77 | 39.32 | 28.56 | 4.64 |
| Outlet of Cobbledick Creek (Node 30) | 140.4 | 110.1 | 91.6 | 77.1 | 56.4 | 9.16 |
| Outlet of Shepard Canyon (Node SC-R) | 403.4 | 314.8 | 254.8 | 209.5 | 141.9 | 23.84 |
| Outlet of Palo Seco Creek (Node 121) | 112.3 | 84.0 | 67.2 | 54.0 | 37.2 | 5.79 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 543.0 | 424.6 | 346.2 | 286.4 | 198.0 | 32.79 |
| Inlet to the Golf Course Culvert (Node 52) | 655.2 | 508.3 | 413.3 | 340.3 | 235.1 | 38.53 |
| Outlet of Dimond Canyon Park (Node 163) | 1041.0 | 899.6 | 754.7 | 521.8 | 358.1 | 53.78 |
| Outlet to the Bay (Node 179) | 1051.1 | 867.0 | 708.1 | 582.3 | 403.1 | 55.78 |

| TOTAL VOLUME (10^6 GAL) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 43.14 | 31.36 | 25.00 | 20.32 | 14.08 | 2.42 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 12.72 | 9.16 | 7.22 | 5.88 | 4.10 | 0.73 |
| Outlet of Cobbledick Creek (Node 30) | 24.85 | 18.06 | 14.29 | 11.65 | 8.11 | 1.45 |
| Outlet of Shepard Canyon (Node SC-R) | 64.26 | 46.69 | 37.13 | 30.19 | 20.92 | 3.69 |
| Outlet of Palo Seco Creek (Node 121) | 17.02 | 11.75 | 9.08 | 7.36 | 5.14 | 0.95 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 89.14 | 64.77 | 51.43 | 41.86 | 29.04 | 5.15 |
| Inlet to the Golf Course Culvert (Node 52) | 106.16 | 76.52 | 60.51 | 49.22 | 34.19 | 6.10 |
| Outlet of Dimond Canyon Park (Node 163) | 163.75 | 121.10 | 96.34 | 78.97 | 55.74 | 10.12 |
| Outlet to the Bay (Node 179) | 227.69 | 168.66 | 134.19 | 109.77 | 76.93 | 13.41 |

## SCENARIO 1 CHANGE COMPARED TO EXISTING CONDITIONS

RUNOFF QUANTITY (CHANGE COMPARED TO EXISTING CONDITIONS)

| Return Interval | Total Precipitation Volume (acre-feet) | Total Precipitation Depth (in) | Surface Runoff (acre-feet) | Infiltration Loss (acre-feet) | Surface Storage (acre-feet) |
|---|---|---|---|---|---|
| 100 Year | 0.0 | 0.0 | -12.7 | -1.5 | 19.8 |
| 25 Year | 0.0 | 0.0 | -8.7 | -0.9 | 13.4 |
| 10 Year | 0.0 | 0.0 | -7.2 | -0.6 | 10.3 |
| 5 Year | 0.0 | 0.0 | -6.1 | -0.3 | 8.3 |
| 2 Year | 0.0 | 0.0 | -4.6 | 0.0 | 5.7 |
| 1 Year | 0.0 | 0.0 | -1.6 | 0.0 | 1.5 |

| PEAK RUNOFF BY SUBBASIN (CFS CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 0.9 | 4.9 | 0.2 | 2.2 | 2.3 | -0.5 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 0.6 | 0.9 | 0.6 | 0.2 | 1.4 | -0.3 |
| Outlet of Cobbledick Creek (Node 30) | 1.5 | 1.7 | -0.3 | 0.7 | 2.5 | -0.2 |
| Outlet of Shepard Canyon (Node SC-R) | -68.9 | 2.3 | 0.3 | 0.8 | -0.1 | -2.6 |
| Outlet of Palo Seco Creek (Node 121) | -20.9 | -16.8 | -13.0 | -11.0 | -7.6 | -0.9 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -67.9 | 3.9 | -0.2 | 1.5 | 2.3 | -2.8 |
| Inlet to the Golf Course Culvert (Node 52) | -88.8 | -13.0 | -13.0 | -9.4 | -5.4 | -3.7 |
| Outlet of Dimond Canyon Park (Node 163) | -65.2 | -13.5 | -35.0 | -16.5 | -5.1 | -5.1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Outlet to the Bay (Node 179) | -71.3 | -14.7 | -27.1 | -10.2 | -5.5 | -4.3 |

| TOTAL VOLUME (10^6 GAL CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 0.8 | 0.5 | -0.2 | 0.2 | 0.1 | -0.3 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 0.3 | 0.2 | 0.1 | 0.1 | 0.1 | -0.1 |
| Outlet of Cobbledick Creek (Node 30) | -2.5 | 0.3 | -1.5 | 0.1 | 0.1 | -0.1 |
| Outlet of Shepard Canyon (Node SC-R) | -12.3 | 0.0 | -0.8 | -0.2 | -0.3 | -0.7 |
| Outlet of Palo Seco Creek (Node 121) | -5.4 | -2.5 | -1.9 | -1.5 | -1.1 | -0.2 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -14.8 | 0.3 | -4.6 | -0.1 | -0.2 | -0.8 |
| Inlet to the Golf Course Culvert (Node 52) | -20.2 | -2.2 | -4.2 | -1.6 | -1.3 | -1.0 |
| Outlet of Dimond Canyon Park (Node 163) | -27.0 | -2.4 | -9.4 | -1.6 | -1.4 | -1.0 |
| Outlet to the Bay (Node 179) | -28.0 | -3.2 | -9.9 | -2.1 | -1.7 | -1.0 |

## Sausal Creek Proposed Conditions Hydrology

### Scenario 2: Subwatershed LID Implementation + Upper Watershed In-Line Detention Basins (Shepard Park Cistern, Larry Lane Basin)

RUNOFF QUANTITY

| Return Interval | Total Precipitation Volume (acre-feet) | Total Precipitation Depth (in) | Surface Runoff (acre-feet) | Infiltration Loss (acre-feet) | Surface Storage (acre-feet) | Flow Continuity Error (%) | Routing |
|---|---|---|---|---|---|---|---|
| 100 Year | 1775.5 | 7.39 | 716.3 | 1031.5 | 33.3 | -5.0 | Dynamic Wave |
| 25 Year | 1363.1 | 5.67 | 525.5 | 815.0 | 26.3 | -6.8 | Dynamic Wave |
| 10 Year | 1108.2 | 4.61 | 417.1 | 670.8 | 22.8 | -8.0 | Dynamic Wave |
| 5 Year | 918.9 | 3.83 | 340.0 | 560.5 | 20.4 | -3.2 | Dynamic Wave |
| 2 Year | 652.6 | 2.72 | 236.2 | 400.3 | 17.1 | -3.8 | Dynamic Wave |
| 1 Year | 131.1 | 0.55 | 41.6 | 79.3 | 10.0 | -1.7 | Dynamic Wave |

| PEAK RUNOFF BY SUBBASIN (CFS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 257.9 | 202.7 | 166.1 | 136.0 | 94.1 | 12.6 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 74.1 | 64.0 | 56.4 | 40.4 | 31.7 | 2.0 |
| Outlet of Cobbledick Creek (Node 30) | 139.9 | 113.4 | 100.6 | 78.3 | 59.2 | 5.0 |
| Outlet of Shepard Canyon (Node SC-R) | 399.0 | 309.7 | 252.7 | 206.5 | 141.0 | 18.7 |
| Outlet of Palo Seco Creek (Node 121) | 112.3 | 84.0 | 67.2 | 53.9 | 36.6 | 5.8 |

| PEAK RUNOFF BY SUBBASIN (CFS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 538.6 | 421.0 | 353.2 | 284.7 | 199.9 | 23.3 |
| Inlet to the Golf Course Culvert (Node 52) | 650.8 | 504.6 | 420.3 | 338.5 | 236.3 | 28.2 |
| Outlet of Dimond Canyon Park (Node 163) | 1035.9 | 899.6 | 764.2 | 512.4 | 352.9 | 45.9 |
| Outlet to the Bay (Node 179) | 1046.5 | 867.0 | 715.0 | 576.1 | 398.8 | 47.2 |

| TOTAL VOLUME (10^6 GAL) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 43.5 | 32.1 | 25.8 | 20.1 | 13.9 | 2.0 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 15.9 | 12.3 | 10.6 | 6.7 | 4.8 | 0.6 |
| Outlet of Cobbledick Creek (Node 30) | 28.0 | 18.1 | 17.7 | 12.5 | 8.8 | 1.3 |
| Outlet of Shepard Canyon (Node SC-R) | 64.4 | 46.7 | 37.7 | 29.7 | 20.5 | 3.2 |
| Outlet of Palo Seco Creek (Node 121) | 17.0 | 11.7 | 9.1 | 7.2 | 5.0 | 0.9 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 92.4 | 64.8 | 55.4 | 42.2 | 29.4 | 4.5 |
| Inlet to the Golf Course Culvert (Node 52) | 109.4 | 76.5 | 64.5 | 49.4 | 34.3 | 5.5 |
| Outlet of Dimond Canyon Park (Node 163) | 167.4 | 121.1 | 100.6 | 76.6 | 53.7 | 9.1 |
| Outlet to the Bay (Node 179) | 231.3 | 168.7 | 138.4 | 107.4 | 74.8 | 12.3 |

## SCENARIO 2 CHANGE COMPARED TO EXISTING CONDITIONS

RUNOFF QUANTITY (CHANGE COMPARED TO EXISTING CONDITIONS)

| Return Interval | Total Precipitation Volume (acre-feet) | Total Precipitation Depth (in) | Surface Runoff (acre-feet) | Infiltration Loss (acre-feet) | Surface Storage (acre-feet) |
|---|---|---|---|---|---|
| 100 Year | 0.0 | 0.0 | -12.7 | -1.5 | 19.8 |
| 25 Year | 0.0 | 0.0 | -8.7 | -0.9 | 13.4 |
| 10 Year | 0.0 | 0.0 | -7.2 | -0.6 | 10.3 |
| 5 Year | 0.0 | 0.0 | -6.1 | -0.3 | 8.3 |
| 2 Year | 0.0 | 0.0 | -4.6 | 0.0 | 5.7 |
| 1 Year | 0.0 | 0.0 | -1.6 | 0.0 | 1.5 |

| PEAK RUNOFF BY SUBBASIN (CFS CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | -20.1 | -11.5 | -10.5 | -6.9 | -3.0 | -4.5 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | -0.4 | 6.4 | 9.2 | 1.3 | 4.6 | -2.9 |

| PEAK RUNOFF BY SUBBASIN (CFS CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Outlet of Cobbledick Creek (Node 30) | 1.0 | 5.0 | 8.7 | 2.0 | 5.4 | -4.4 |
| Outlet of Shepard Canyon (Node SC-R) | -73.4 | -2.8 | -1.8 | -2.2 | -1.0 | -7.8 |
| Outlet of Palo Seco Creek (Node 121) | -20.9 | -16.8 | -13.0 | -11.0 | -8.1 | -1.0 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -72.4 | 0.3 | 6.8 | -0.2 | 4.1 | -12.3 |
| Inlet to the Golf Course Culvert (Node 52) | -93.2 | -16.6 | -6.0 | -11.2 | -4.1 | -14.0 |
| Outlet of Dimond Canyon Park (Node 163) | -70.2 | -13.5 | -25.5 | -25.9 | -10.3 | -12.9 |
| Outlet to the Bay (Node 179) | -76.0 | -14.7 | -20.2 | -16.3 | -9.8 | -13.0 |

| TOTAL VOLUME (10^6 GAL CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 1.1 | 1.2 | 0.6 | 0.0 | -0.1 | -0.7 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 3.4 | 3.3 | 3.5 | 0.9 | 0.8 | -0.2 |
| Outlet of Cobbledick Creek (Node 30) | 0.6 | 0.3 | 1.9 | 1.0 | 0.8 | -0.3 |
| Outlet of Shepard Canyon (Node SC-R) | -12.1 | 0.0 | -0.2 | -0.7 | -0.7 | -1.2 |
| Outlet of Palo Seco Creek (Node 121) | -5.4 | -2.5 | -1.9 | -1.7 | -1.2 | -0.2 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -11.5 | 0.3 | -0.6 | 0.3 | 0.1 | -1.4 |
| Inlet to the Golf Course Culvert (Node 52) | -16.9 | -2.2 | -0.2 | -1.4 | -1.1 | -1.6 |
| Outlet of Dimond Canyon Park (Node 163) | -23.3 | -2.4 | -5.1 | -4.0 | -3.5 | -2.0 |
| Outlet to the Bay (Node 179) | -24.4 | -3.2 | -5.7 | -4.5 | -3.8 | -2.1 |

## Sausal Creek Proposed Conditions Hydrology

### Scenario 3: Subwatershed LID Implementation + Upper Watershed In-Line Detention Basins (Shepard Park Cistern, Larry Lane Basin) + Lower Watershed In-Line Detention Basins (Golf Course, Dimond Park)

RUNOFF QUANTITY

| Return Interval | Total Precipitation Volume (acre-feet) | Total Precipitation Depth (in) | Surface Runoff (acre-feet) | Infiltration Loss (acre-feet) | Surface Storage (acre-feet) | Flow Continuity Error (%) | Routing |
|---|---|---|---|---|---|---|---|
| 100 Year | 1775.5 | 7.39 | 716.3 | 1031.5 | 33.3 | -6.7 | Dynamic Wave |
| 25 Year | 1363.1 | 5.67 | 525.5 | 815.0 | 26.3 | -3.9 | Dynamic Wave |
| 10 Year | 1108.2 | 4.61 | 417.1 | 670.8 | 22.8 | -4.5 | Dynamic Wave |
| 5 Year | 918.9 | 3.83 | 340.0 | 560.5 | 20.4 | -4.6 | Dynamic Wave |
| 2 Year | 652.6 | 2.72 | 236.2 | 400.3 | 17.1 | -1.8 | Dynamic Wave |
| 1 Year | 131.1 | 0.55 | 41.6 | 79.3 | 10.0 | -1.7 | Dynamic Wave |

| PEAK RUNOFF BY SUBBASIN (CFS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 257.8 | 202.6 | 165.1 | 136.0 | 93.0 | 12.6 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 74.0 | 64.9 | 54.9 | 40.3 | 30.2 | 2.0 |
| Outlet of Cobbledick Creek (Node 30) | 139.8 | 115.0 | 98.9 | 78.3 | 57.3 | 5.0 |
| Outlet of Shepard Canyon (Node SC-R) | 399.1 | 309.9 | 251.3 | 206.4 | 139.8 | 18.7 |
| Outlet of Palo Seco Creek (Node 121) | 112.4 | 83.9 | 66.8 | 53.9 | 36.4 | 5.7 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 538.9 | 424.7 | 350.3 | 284.8 | 196.6 | 23.3 |
| Outlet of the Golf Course Basin (GolfCourseOutlet) | 641.9 | 500.7 | 411.5 | 335.2 | 229.0 | 20.9 |
| Outlet of Dimond Canyon Park (Node 163) | 965.4 | 711.5 | 583.7 | 480.0 | 337.0 | 24.9 |
| Outlet to the Bay (Node 179) | 1020.6 | 835.4 | 679.9 | 556.9 | 381.7 | 30.2 |

| TOTAL VOLUME (10^6 GAL) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 43.5 | 31.1 | 24.6 | 20.1 | 13.4 | 2.0 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 15.8 | 10.5 | 8.7 | 6.7 | 4.1 | 0.6 |
| Outlet of Cobbledick Creek (Node 30) | 27.9 | 19.4 | 15.8 | 12.5 | 8.1 | 1.3 |
| Outlet of Shepard Canyon (Node SC-R) | 64.4 | 46.1 | 36.5 | 29.7 | 20.0 | 3.2 |
| Outlet of Palo Seco Creek (Node 121) | 17.0 | 11.6 | 8.9 | 7.2 | 4.9 | 0.9 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | 92.3 | 65.6 | 52.3 | 42.2 | 28.2 | 4.5 |
| Outlet of the Golf Course Basin (GolfCourseOutlet) | 112.2 | 77.9 | 61.9 | 49.9 | 32.6 | 4.6 |
| Outlet of Dimond Canyon Park (Node 163) | 170.0 | 118.8 | 94.4 | 76.7 | 50.7 | 7.7 |
| Outlet to the Bay (Node 179) | 233.9 | 166.3 | 132.2 | 107.5 | 71.9 | 10.9 |

## SCENARIO 3 CHANGE COMPARED TO EXISTING CONDITIONS

RUNOFF QUANTITY (CHANGE COMPARED TO EXISTING CONDITIONS)

| Return Interval | Total Precipitation Volume (acre-feet) | Total Precipitation Depth (in) | Surface Runoff (acre-feet) | Infiltration Loss (acre-feet) | Surface Storage (acre-feet) |
|---|---|---|---|---|---|
| 100 Year | 0.0 | 0.0 | -12.7 | -1.5 | 19.8 |
| 25 Year | 0.0 | 0.0 | -8.7 | -0.9 | 13.4 |
| 10 Year | 0.0 | 0.0 | -7.2 | -0.6 | 10.3 |
| 5 Year | 0.0 | 0.0 | -6.1 | -0.3 | 8.3 |
| 2 Year | 0.0 | 0.0 | -4.6 | 0.0 | 5.7 |

| | | | | | |
|---|---|---|---|---|---|
| 1 Year | 0.0 | 0.0 | -1.6 | 0.0 | 1.5 |

| PEAK RUNOFF BY SUBBASIN (CFS CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | -20.1 | -11.6 | -11.6 | -6.9 | -4.1 | -4.5 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | -0.5 | 7.4 | 7.7 | 1.2 | 3.1 | -2.9 |
| Outlet of Cobbledick Creek (Node 30) | 0.9 | 6.6 | 7.0 | 2.0 | 3.5 | -4.4 |
| Outlet of Shepard Canyon (Node SC-R) | -73.2 | -2.6 | -3.2 | -2.3 | -2.3 | -7.8 |
| Outlet of Palo Seco Creek (Node 121) | -20.8 | -16.9 | -13.4 | -11.1 | -8.3 | -1.0 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -72.1 | 4.0 | 3.9 | -0.1 | 0.8 | -12.3 |
| Outlet of the Golf Course Basin (GolfCourseOutlet) | -102.1 | -20.6 | -14.8 | -14.5 | -11.4 | -21.4 |
| Outlet of Dimond Canyon Park (Node 163) | -140.7 | -201.6 | -206.0 | -58.3 | -26.2 | -34.0 |
| Outlet to the Bay (Node 179) | -101.9 | -46.4 | -55.3 | -35.5 | -26.9 | -29.9 |

| TOTAL VOLUME (10^6 GAL CHANGE COMPARED TO EXISTING CONDITIONS) | | | | | | |
|---|---|---|---|---|---|---|
| | Storm Return Frequency | | | | | |
| Reach | 100 Year | 25 Year | 10 Year | 5 Year | 2 Year | 1 Year |
| Shepard Canyon Below Shepard Park (Node SC-F / ShepParkOutlet) | 1.1 | 0.2 | -0.5 | 0.0 | -0.6 | -0.7 |
| Cobbledick Creek Below Larry Lane Basin (Node 47) | 3.3 | 1.6 | 1.6 | 0.9 | 0.1 | -0.2 |
| Outlet of Cobbledick Creek (Node 30) | 0.5 | 1.7 | 0.0 | 1.0 | 0.1 | -0.3 |
| Outlet of Shepard Canyon (Node SC-R) | -12.1 | -0.6 | -1.4 | -0.7 | -1.2 | -1.2 |
| Outlet of Palo Seco Creek (Node 121) | -5.4 | -2.7 | -2.1 | -1.7 | -1.3 | -0.2 |
| Sausal Creek Upstream of Palo Seco Creek Confluence (Node 32) | -11.6 | 1.1 | -3.7 | 0.3 | -1.1 | -1.4 |
| Outlet of the Golf Course Basin (GolfCourseOutlet) | -14.1 | -0.7 | -2.8 | -0.9 | -2.9 | -2.5 |
| Outlet of Dimond Canyon Park (Node 163) | -20.7 | -4.8 | -11.3 | -3.9 | -6.4 | -3.4 |
| Outlet to the Bay (Node 179) | -21.8 | -5.5 | -11.9 | -4.4 | -6.7 | -3.5 |

# APPENDIX F

# HEC-RAS MODEL OUTPUT SAUSAL CREEK WATERSHED

HEC-RAS Plan: Scenario1

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 1 | 38.2 | 100YR E | 610.90 | 414.89 | 419.73 | | 420.62 | 0.023857 | 8.01 | 5.99 | 86.20 | 26.76 | 0.67 |
| Sausal | 1 | 38.2 | 100YR P | 543.00 | 414.89 | 419.40 | | 420.27 | 0.025190 | 7.83 | 5.87 | 77.67 | 25.87 | 0.68 |
| Sausal | 1 | 38.2 | 25YR E | 420.70 | 414.89 | 418.81 | | 419.60 | 0.027200 | 7.35 | 5.44 | 62.91 | 24.24 | 0.69 |
| Sausal | 1 | 38.2 | 25YR P | 424.60 | 414.89 | 418.80 | | 419.61 | 0.028088 | 7.45 | 5.60 | 62.60 | 24.21 | 0.70 |
| Sausal | 1 | 38.2 | 10YR E | 346.30 | 414.89 | 418.38 | | 419.12 | 0.030364 | 7.11 | 5.32 | 52.52 | 22.90 | 0.71 |
| Sausal | 1 | 38.2 | 10YR P | 346.20 | 414.89 | 418.36 | | 419.12 | 0.030988 | 7.16 | 5.40 | 52.13 | 22.82 | 0.72 |
| Sausal | 1 | 38.2 | 5YR E | 284.90 | 414.89 | 417.99 | | 418.69 | 0.033514 | 6.84 | 5.15 | 43.99 | 21.04 | 0.73 |
| Sausal | 1 | 38.2 | 5YR P | 286.40 | 414.89 | 418.00 | | 418.71 | 0.033293 | 6.84 | 5.14 | 44.27 | 21.11 | 0.73 |
| Sausal | 1 | 38.2 | 2YR E | 195.70 | 414.89 | 417.88 | 417.01 | 418.24 | 0.018351 | 4.92 | 2.71 | 41.71 | 20.52 | 0.54 |
| Sausal | 1 | 38.2 | 2YR P | 198.00 | 414.89 | 417.94 | 417.02 | 418.29 | 0.017305 | 4.85 | 2.61 | 42.95 | 20.81 | 0.52 |
| Sausal | 1 | 38.2 | 1YR E | 35.60 | 414.89 | 416.20 | | 416.30 | 0.014794 | 2.48 | 0.91 | 14.38 | 13.62 | 0.42 |
| Sausal | 1 | 38.2 | 1YR P | 32.79 | 414.89 | 416.12 | | 416.21 | 0.016169 | 2.48 | 0.94 | 13.24 | 13.46 | 0.44 |
| | | | | | | | | | | | | | | |
| Sausal | 1 | 38 | 100YR E | 610.90 | 412.89 | 419.03 | | 419.48 | 0.008824 | 5.77 | 2.86 | 123.43 | 30.36 | 0.42 |
| Sausal | 1 | 38 | 100YR P | 543.00 | 412.89 | 418.68 | | 419.10 | 0.008934 | 5.57 | 2.72 | 112.83 | 29.38 | 0.42 |
| Sausal | 1 | 38 | 25YR E | 420.70 | 412.89 | 418.11 | | 418.45 | 0.008274 | 4.98 | 2.25 | 96.48 | 27.80 | 0.40 |
| Sausal | 1 | 38 | 25YR P | 424.60 | 412.89 | 418.02 | | 418.39 | 0.009013 | 5.13 | 2.41 | 94.17 | 27.57 | 0.41 |
| Sausal | 1 | 38 | 10YR E | 346.30 | 412.89 | 417.59 | | 417.91 | 0.008639 | 4.72 | 2.10 | 82.58 | 26.39 | 0.40 |
| Sausal | 1 | 38 | 10YR P | 346.20 | 412.89 | 417.51 | | 417.84 | 0.009320 | 4.84 | 2.23 | 80.34 | 26.15 | 0.41 |
| Sausal | 1 | 38 | 5YR E | 284.90 | 412.89 | 417.02 | | 417.33 | 0.010135 | 4.65 | 2.14 | 67.78 | 24.79 | 0.42 |
| Sausal | 1 | 38 | 5YR P | 286.40 | 412.89 | 416.86 | | 417.21 | 0.012065 | 4.93 | 2.44 | 63.90 | 24.36 | 0.46 |
| Sausal | 1 | 38 | 2YR E | 195.70 | 412.89 | 415.09 | 415.01 | 415.90 | 0.063760 | 7.23 | 6.57 | 27.19 | 15.94 | 0.94 |
| Sausal | 1 | 38 | 2YR P | 198.00 | 412.89 | 415.03 | 415.03 | 415.91 | 0.073191 | 7.57 | 7.29 | 26.22 | 15.56 | 1.00 |
| Sausal | 1 | 38 | 1YR E | 35.60 | 412.89 | 413.71 | 413.71 | 414.03 | 0.094903 | 4.51 | 3.57 | 7.90 | 12.73 | 1.01 |
| Sausal | 1 | 38 | 1YR P | 32.79 | 412.89 | 413.73 | 413.67 | 413.98 | 0.072600 | 4.02 | 2.81 | 8.16 | 12.77 | 0.89 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35.5 | 100YR E | 744.00 | 409.89 | 418.90 | 414.44 | 419.11 | 0.002629 | 4.12 | 1.28 | 222.48 | 38.95 | 0.25 |
| Sausal | 2 | 35.5 | 100YR P | 655.20 | 409.89 | 418.56 | 414.16 | 418.75 | 0.002397 | 3.83 | 1.12 | 209.49 | 37.87 | 0.23 |
| Sausal | 2 | 35.5 | 25YR E | 521.30 | 409.89 | 418.01 | 413.70 | 418.15 | 0.002007 | 3.35 | 0.87 | 188.89 | 36.09 | 0.21 |
| Sausal | 2 | 35.5 | 25YR P | 508.30 | 409.89 | 417.94 | 413.66 | 418.08 | 0.001980 | 3.31 | 0.85 | 186.33 | 35.86 | 0.21 |
| Sausal | 2 | 35.5 | 10YR E | 426.30 | 409.89 | 417.51 | 413.29 | 417.63 | 0.001745 | 2.99 | 0.71 | 171.45 | 34.51 | 0.20 |
| Sausal | 2 | 35.5 | 10YR P | 413.30 | 409.89 | 417.44 | 413.23 | 417.55 | 0.001709 | 2.94 | 0.69 | 168.90 | 34.27 | 0.19 |
| Sausal | 2 | 35.5 | 5YR E | 349.80 | 409.89 | 416.95 | 412.93 | 417.05 | 0.001620 | 2.73 | 0.61 | 152.43 | 32.89 | 0.19 |
| Sausal | 2 | 35.5 | 5YR P | 340.30 | 409.89 | 416.80 | 412.88 | 416.90 | 0.001675 | 2.73 | 0.62 | 147.60 | 32.48 | 0.19 |
| Sausal | 2 | 35.5 | 2YR E | 240.40 | 409.89 | 415.12 | 412.30 | 415.23 | 0.002676 | 2.83 | 0.73 | 96.81 | 27.84 | 0.23 |
| Sausal | 2 | 35.5 | 2YR P | 235.10 | 409.89 | 415.03 | 412.27 | 415.14 | 0.002740 | 2.84 | 0.73 | 94.46 | 27.60 | 0.23 |
| Sausal | 2 | 35.5 | 1YR E | 42.26 | 409.89 | 411.20 | 410.79 | 411.33 | 0.021191 | 2.96 | 1.30 | 14.30 | 13.61 | 0.51 |
| Sausal | 2 | 35.5 | 1YR P | 38.53 | 409.89 | 411.08 | 410.74 | 411.22 | 0.025364 | 3.03 | 1.42 | 12.70 | 13.39 | 0.55 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35.4 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35 | 100YR E | 744.00 | 326.57 | 333.99 | 332.00 | 334.59 | 0.011608 | 6.57 | 3.72 | 129.86 | 33.92 | 0.47 |
| Sausal | 2 | 35 | 100YR P | 655.20 | 326.57 | 333.65 | | 334.20 | 0.011330 | 6.25 | 3.43 | 118.65 | 32.08 | 0.46 |
| Sausal | 2 | 35 | 25YR E | 521.30 | 326.57 | 333.07 | | 333.54 | 0.010885 | 5.71 | 2.96 | 100.85 | 28.93 | 0.44 |
| Sausal | 2 | 35 | 25YR P | 508.30 | 326.57 | 333.01 | | 333.47 | 0.010828 | 5.65 | 2.91 | 99.10 | 28.60 | 0.44 |
| Sausal | 2 | 35 | 10YR E | 426.30 | 326.57 | 332.59 | | 333.00 | 0.010468 | 5.26 | 2.59 | 87.72 | 26.37 | 0.42 |
| Sausal | 2 | 35 | 10YR P | 413.30 | 326.57 | 332.52 | | 332.92 | 0.010399 | 5.19 | 2.54 | 85.90 | 25.99 | 0.42 |
| Sausal | 2 | 35 | 5YR E | 349.80 | 326.57 | 332.15 | | 332.50 | 0.010083 | 4.84 | 2.27 | 76.68 | 24.03 | 0.41 |
| Sausal | 2 | 35 | 5YR P | 340.30 | 326.57 | 332.09 | | 332.44 | 0.010029 | 4.78 | 2.23 | 75.28 | 23.76 | 0.41 |
| Sausal | 2 | 35 | 2YR E | 240.40 | 326.57 | 331.41 | 329.60 | 331.67 | 0.009409 | 4.12 | 1.75 | 60.02 | 20.56 | 0.38 |
| Sausal | 2 | 35 | 2YR P | 235.10 | 326.57 | 331.36 | 329.55 | 331.62 | 0.009387 | 4.08 | 1.73 | 59.14 | 20.36 | 0.38 |
| Sausal | 2 | 35 | 1YR E | 42.26 | 326.57 | 328.94 | | 329.00 | 0.006819 | 2.08 | 0.58 | 20.33 | 13.39 | 0.30 |
| Sausal | 2 | 35 | 1YR P | 38.53 | 326.57 | 328.85 | | 328.92 | 0.006711 | 2.01 | 0.55 | 19.21 | 13.27 | 0.29 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 34 | 100YR E | 744.00 | 321.02 | 324.23 | 324.23 | 325.59 | 0.049890 | 9.85 | 9.82 | 83.39 | 31.82 | 0.98 |
| Sausal | 2 | 34 | 100YR P | 655.20 | 321.02 | 323.99 | 323.99 | 325.26 | 0.051575 | 9.49 | 9.38 | 75.77 | 31.06 | 0.98 |
| Sausal | 2 | 34 | 25YR E | 521.30 | 321.02 | 323.61 | 323.61 | 324.72 | 0.053972 | 8.84 | 8.53 | 64.16 | 29.87 | 0.98 |
| Sausal | 2 | 34 | 25YR P | 508.30 | 321.02 | 323.57 | 323.57 | 324.66 | 0.054239 | 8.77 | 8.44 | 63.00 | 29.75 | 0.98 |
| Sausal | 2 | 34 | 10YR E | 426.30 | 321.02 | 323.31 | 323.31 | 324.30 | 0.056276 | 8.31 | 7.85 | 55.44 | 28.95 | 0.98 |
| Sausal | 2 | 34 | 10YR P | 413.30 | 321.02 | 323.27 | 323.27 | 324.24 | 0.056666 | 8.23 | 7.75 | 54.21 | 28.81 | 0.98 |
| Sausal | 2 | 34 | 5YR E | 349.80 | 321.02 | 323.06 | 323.06 | 323.94 | 0.058499 | 7.81 | 7.22 | 48.11 | 28.15 | 0.98 |
| Sausal | 2 | 34 | 5YR P | 340.30 | 321.02 | 323.02 | 323.02 | 323.89 | 0.058813 | 7.74 | 7.14 | 47.18 | 28.04 | 0.98 |
| Sausal | 2 | 34 | 2YR E | 240.40 | 321.02 | 322.65 | 322.65 | 323.35 | 0.062821 | 6.94 | 6.15 | 36.86 | 26.85 | 0.98 |
| Sausal | 2 | 34 | 2YR P | 235.10 | 321.02 | 322.63 | 322.63 | 323.32 | 0.062731 | 6.87 | 6.07 | 36.35 | 26.79 | 0.97 |
| Sausal | 2 | 34 | 1YR E | 42.26 | 321.02 | 321.59 | 321.59 | 321.83 | 0.093716 | 4.00 | 2.98 | 10.79 | 22.29 | 0.99 |
| Sausal | 2 | 34 | 1YR P | 38.53 | 321.02 | 321.56 | 321.56 | 321.79 | 0.096693 | 3.90 | 2.89 | 10.09 | 22.15 | 0.99 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 33 | 100YR E | 744.00 | 316.37 | 321.77 | | 323.02 | 0.021837 | 9.15 | 7.16 | 88.07 | 18.73 | 0.70 |
| Sausal | 2 | 33 | 100YR P | 655.20 | 316.37 | 321.64 | | 322.66 | 0.018420 | 8.27 | 5.89 | 85.68 | 18.64 | 0.64 |
| Sausal | 2 | 33 | 25YR E | 521.30 | 316.37 | 321.38 | | 322.10 | 0.013942 | 6.95 | 4.23 | 80.83 | 18.44 | 0.55 |
| Sausal | 2 | 33 | 25YR P | 508.30 | 316.37 | 321.35 | | 322.05 | 0.013517 | 6.81 | 4.08 | 80.32 | 18.42 | 0.55 |
| Sausal | 2 | 33 | 10YR E | 426.30 | 316.37 | 321.13 | | 321.67 | 0.011153 | 6.00 | 3.21 | 76.26 | 18.25 | 0.49 |
| Sausal | 2 | 33 | 10YR P | 413.30 | 316.37 | 321.10 | | 321.62 | 0.010669 | 5.85 | 3.06 | 75.82 | 18.23 | 0.48 |
| Sausal | 2 | 33 | 5YR E | 349.80 | 316.37 | 320.90 | | 321.30 | 0.008928 | 5.19 | 2.44 | 72.10 | 18.08 | 0.44 |
| Sausal | 2 | 33 | 5YR P | 340.30 | 316.37 | 320.86 | | 321.25 | 0.008702 | 5.09 | 2.36 | 71.42 | 18.05 | 0.43 |
| Sausal | 2 | 33 | 2YR E | 240.40 | 316.37 | 320.43 | | 320.67 | 0.006187 | 4.01 | 1.51 | 63.71 | 17.73 | 0.36 |
| Sausal | 2 | 33 | 2YR P | 235.10 | 316.37 | 320.40 | | 320.63 | 0.006085 | 3.95 | 1.48 | 63.15 | 17.70 | 0.35 |
| Sausal | 2 | 33 | 1YR E | 42.26 | 316.37 | 317.14 | 317.14 | 317.45 | 0.090840 | 4.52 | 3.55 | 9.41 | 15.25 | 1.01 |
| Sausal | 2 | 33 | 1YR P | 38.53 | 316.37 | 317.10 | 317.10 | 317.40 | 0.092656 | 4.38 | 3.41 | 8.85 | 15.22 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 32 | 100YR E | 744.00 | 314.08 | 322.36 | 317.39 | 322.48 | 0.001388 | 2.93 | 0.65 | 287.21 | 53.40 | 0.19 |
| Sausal | 2 | 32 | 100YR P | 655.20 | 314.08 | 322.11 | 317.18 | 322.21 | 0.001219 | 2.69 | 0.55 | 274.10 | 51.64 | 0.17 |
| Sausal | 2 | 32 | 25YR E | 521.30 | 314.08 | 321.70 | 316.83 | 321.77 | 0.000955 | 2.29 | 0.41 | 253.32 | 48.71 | 0.15 |
| Sausal | 2 | 32 | 25YR P | 508.30 | 314.08 | 321.66 | 316.80 | 321.73 | 0.000927 | 2.24 | 0.39 | 251.31 | 48.41 | 0.15 |
| Sausal | 2 | 32 | 10YR E | 426.30 | 314.08 | 321.36 | 316.58 | 321.42 | 0.000765 | 1.98 | 0.31 | 237.25 | 46.32 | 0.14 |
| Sausal | 2 | 32 | 10YR P | 413.30 | 314.08 | 321.32 | 316.54 | 321.37 | 0.000734 | 1.93 | 0.30 | 235.51 | 46.05 | 0.13 |
| Sausal | 2 | 32 | 5YR E | 349.80 | 314.08 | 321.07 | 316.34 | 321.11 | 0.000605 | 1.71 | 0.24 | 224.00 | 44.25 | 0.12 |
| Sausal | 2 | 32 | 5YR P | 340.30 | 314.08 | 321.02 | 316.31 | 321.06 | 0.000587 | 1.67 | 0.23 | 222.04 | 43.93 | 0.12 |
| Sausal | 2 | 32 | 2YR E | 240.40 | 314.08 | 320.53 | 315.94 | 320.55 | 0.000390 | 1.29 | 0.14 | 201.12 | 40.82 | 0.10 |
| Sausal | 2 | 32 | 2YR P | 235.10 | 314.08 | 320.49 | 315.92 | 320.51 | 0.000381 | 1.27 | 0.13 | 199.70 | 40.75 | 0.09 |
| Sausal | 2 | 32 | 1YR E | 42.26 | 314.08 | 316.80 | 314.92 | 316.81 | 0.000432 | 0.68 | 0.05 | 63.95 | 32.87 | 0.08 |
| Sausal | 2 | 32 | 1YR P | 38.53 | 314.08 | 316.67 | 314.89 | 316.68 | 0.000451 | 0.66 | 0.05 | 59.59 | 32.59 | 0.08 |
| | | | | | | | | | | | | | | |

HEC-RAS Plan: Scenario1 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 31.5 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 30 | 100YR E | 744.00 | 300.16 | 302.61 | 302.61 | 303.70 | 0.054861 | 8.59 | 8.20 | 91.38 | 42.92 | 0.98 |
| Sausal | 2 | 30 | 100YR P | 655.20 | 300.16 | 302.42 | 302.42 | 303.43 | 0.056629 | 8.27 | 7.80 | 83.37 | 42.29 | 0.98 |
| Sausal | 2 | 30 | 25YR E | 521.30 | 300.16 | 302.11 | 302.11 | 303.00 | 0.060048 | 7.71 | 7.13 | 70.67 | 41.05 | 0.99 |
| Sausal | 2 | 30 | 25YR P | 508.30 | 300.16 | 302.09 | 302.09 | 302.96 | 0.060146 | 7.64 | 7.03 | 69.51 | 40.93 | 0.98 |
| Sausal | 2 | 30 | 10YR E | 426.30 | 300.16 | 301.88 | 301.88 | 302.67 | 0.063087 | 7.24 | 6.57 | 61.21 | 40.09 | 0.99 |
| Sausal | 2 | 30 | 10YR P | 413.30 | 300.16 | 301.85 | 301.85 | 302.62 | 0.063582 | 7.17 | 6.49 | 59.87 | 39.96 | 0.99 |
| Sausal | 2 | 30 | 5YR E | 349.80 | 300.16 | 301.68 | 301.68 | 302.38 | 0.065738 | 6.79 | 6.03 | 53.31 | 39.28 | 0.99 |
| Sausal | 2 | 30 | 5YR P | 340.30 | 300.16 | 301.65 | 301.65 | 302.34 | 0.066310 | 6.74 | 5.97 | 52.25 | 39.17 | 0.99 |
| Sausal | 2 | 30 | 2YR E | 240.40 | 300.16 | 301.40 | 301.36 | 301.91 | 0.064925 | 5.85 | 4.80 | 42.29 | 38.11 | 0.95 |
| Sausal | 2 | 30 | 2YR P | 235.10 | 300.16 | 301.38 | 301.35 | 301.89 | 0.064507 | 5.78 | 4.72 | 41.79 | 38.06 | 0.94 |
| Sausal | 2 | 30 | 1YR E | 42.26 | 300.16 | 300.64 | 300.58 | 300.77 | 0.064568 | 2.94 | 1.71 | 14.51 | 35.01 | 0.80 |
| Sausal | 2 | 30 | 1YR P | 38.53 | 300.16 | 300.61 | 300.56 | 300.74 | 0.067109 | 2.87 | 1.67 | 13.55 | 34.89 | 0.80 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 29 | 100YR E | 744.00 | 296.60 | 299.11 | 299.11 | 300.30 | 0.060017 | 8.84 | 8.75 | 85.84 | 36.55 | 1.00 |
| Sausal | 2 | 29 | 100YR P | 655.20 | 296.60 | 298.91 | 298.91 | 300.01 | 0.061645 | 8.50 | 8.30 | 78.54 | 36.26 | 1.00 |
| Sausal | 2 | 29 | 25YR E | 521.30 | 296.60 | 298.59 | 298.59 | 299.54 | 0.064064 | 7.89 | 7.50 | 67.19 | 35.81 | 1.00 |
| Sausal | 2 | 29 | 25YR P | 508.30 | 296.60 | 298.56 | 298.56 | 299.50 | 0.064378 | 7.82 | 7.42 | 66.03 | 35.77 | 1.00 |
| Sausal | 2 | 29 | 10YR E | 426.30 | 296.60 | 298.35 | 298.35 | 299.19 | 0.066932 | 7.41 | 6.90 | 58.41 | 35.42 | 1.00 |
| Sausal | 2 | 29 | 10YR P | 413.30 | 296.60 | 298.31 | 298.31 | 299.14 | 0.067317 | 7.33 | 6.80 | 57.18 | 35.35 | 1.00 |
| Sausal | 2 | 29 | 5YR E | 349.80 | 296.60 | 298.14 | 298.14 | 298.88 | 0.069003 | 6.93 | 6.29 | 51.13 | 35.04 | 1.00 |
| Sausal | 2 | 29 | 5YR P | 340.30 | 296.60 | 298.11 | 298.11 | 298.84 | 0.069580 | 6.88 | 6.23 | 50.13 | 34.98 | 1.00 |
| Sausal | 2 | 29 | 2YR E | 240.40 | 296.60 | 297.80 | 297.80 | 298.39 | 0.074982 | 6.15 | 5.37 | 39.47 | 34.42 | 1.00 |
| Sausal | 2 | 29 | 2YR P | 235.10 | 296.60 | 297.79 | 297.79 | 298.36 | 0.075310 | 6.11 | 5.32 | 38.88 | 34.38 | 1.00 |
| Sausal | 2 | 29 | 1YR E | 42.26 | 296.60 | 297.03 | 296.99 | 297.19 | 0.078240 | 3.15 | 1.99 | 13.45 | 32.99 | 0.87 |
| Sausal | 2 | 29 | 1YR P | 38.53 | 296.60 | 297.02 | | 297.15 | 0.074951 | 3.00 | 1.83 | 12.89 | 32.96 | 0.84 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 28 | 100YR E | 744.00 | 289.82 | 292.39 | 292.37 | 293.55 | 0.055568 | 8.75 | 8.45 | 87.36 | 37.79 | 0.99 |
| Sausal | 2 | 28 | 100YR P | 655.20 | 289.82 | 292.18 | 292.18 | 293.27 | 0.058379 | 8.44 | 8.11 | 79.50 | 37.46 | 1.00 |
| Sausal | 2 | 28 | 25YR E | 521.30 | 289.82 | 291.86 | 291.86 | 292.81 | 0.061644 | 7.84 | 7.36 | 67.85 | 36.96 | 1.00 |
| Sausal | 2 | 28 | 25YR P | 508.30 | 289.82 | 291.83 | 291.83 | 292.76 | 0.061983 | 7.78 | 7.28 | 66.69 | 36.91 | 1.00 |
| Sausal | 2 | 28 | 10YR E | 426.30 | 289.82 | 291.63 | 291.63 | 292.45 | 0.064437 | 7.34 | 6.74 | 59.12 | 36.59 | 1.00 |
| Sausal | 2 | 28 | 10YR P | 413.30 | 289.82 | 291.59 | 291.59 | 292.40 | 0.064952 | 7.27 | 6.66 | 57.86 | 36.53 | 1.00 |
| Sausal | 2 | 28 | 5YR E | 349.80 | 289.82 | 291.42 | 291.42 | 292.15 | 0.067519 | 6.88 | 6.19 | 51.60 | 36.26 | 1.00 |
| Sausal | 2 | 28 | 5YR P | 340.30 | 289.82 | 291.39 | 291.39 | 292.11 | 0.067784 | 6.82 | 6.11 | 50.68 | 36.22 | 1.00 |
| Sausal | 2 | 28 | 2YR E | 240.40 | 289.82 | 291.10 | 291.10 | 291.67 | 0.073628 | 6.09 | 5.27 | 39.94 | 35.75 | 1.00 |
| Sausal | 2 | 28 | 2YR P | 235.10 | 289.82 | 291.08 | 291.08 | 291.64 | 0.074034 | 6.05 | 5.22 | 39.33 | 35.72 | 1.00 |
| Sausal | 2 | 28 | 1YR E | 42.26 | 289.82 | 290.31 | 290.31 | 290.49 | 0.106307 | 3.40 | 2.41 | 12.45 | 34.51 | 0.99 |
| Sausal | 2 | 28 | 1YR P | 38.53 | 289.82 | 290.29 | 290.29 | 290.46 | 0.111910 | 3.33 | 2.36 | 11.59 | 34.47 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 27 | 100YR E | 744.00 | 286.78 | 290.07 | | 291.14 | 0.035203 | 8.43 | 7.13 | 92.80 | 31.30 | 0.82 |
| Sausal | 2 | 27 | 100YR P | 655.20 | 286.78 | 289.89 | | 290.82 | 0.033378 | 7.89 | 6.38 | 87.03 | 30.99 | 0.80 |
| Sausal | 2 | 27 | 25YR E | 521.30 | 286.78 | 289.56 | | 290.31 | 0.031215 | 7.07 | 5.32 | 76.89 | 30.44 | 0.75 |
| Sausal | 2 | 27 | 25YR P | 508.30 | 286.78 | 289.52 | | 290.26 | 0.030985 | 6.99 | 5.22 | 75.85 | 30.38 | 0.75 |
| Sausal | 2 | 27 | 10YR E | 426.30 | 286.78 | 289.29 | | 289.92 | 0.029634 | 6.44 | 4.56 | 68.83 | 29.99 | 0.72 |
| Sausal | 2 | 27 | 10YR P | 413.30 | 286.78 | 289.25 | | 289.86 | 0.029432 | 6.35 | 4.46 | 67.64 | 29.92 | 0.72 |
| Sausal | 2 | 27 | 5YR E | 349.80 | 286.78 | 289.05 | | 289.57 | 0.028408 | 5.88 | 3.94 | 61.59 | 29.58 | 0.70 |
| Sausal | 2 | 27 | 5YR P | 340.30 | 286.78 | 289.02 | | 289.53 | 0.028163 | 5.80 | 3.85 | 60.70 | 29.53 | 0.69 |
| Sausal | 2 | 27 | 2YR E | 240.40 | 286.78 | 288.65 | | 289.02 | 0.026129 | 4.95 | 2.98 | 50.00 | 28.92 | 0.65 |
| Sausal | 2 | 27 | 2YR P | 235.10 | 286.78 | 288.63 | | 288.99 | 0.026014 | 4.90 | 2.93 | 49.38 | 28.88 | 0.64 |
| Sausal | 2 | 27 | 1YR E | 42.26 | 286.78 | 287.52 | | 287.60 | 0.021164 | 2.33 | 0.91 | 18.30 | 27.03 | 0.49 |
| Sausal | 2 | 27 | 1YR P | 38.53 | 286.78 | 287.48 | | 287.56 | 0.021102 | 2.25 | 0.86 | 17.32 | 26.96 | 0.49 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 26 | 100YR E | 744.00 | 281.33 | 284.47 | 284.47 | 285.60 | 0.055120 | 8.61 | 8.24 | 88.67 | 40.09 | 0.98 |
| Sausal | 2 | 26 | 100YR P | 655.20 | 281.33 | 284.26 | 284.26 | 285.32 | 0.057949 | 8.32 | 7.93 | 80.53 | 39.49 | 0.99 |
| Sausal | 2 | 26 | 25YR E | 521.30 | 281.33 | 283.95 | 283.95 | 284.88 | 0.061521 | 7.75 | 7.23 | 68.43 | 38.58 | 0.99 |
| Sausal | 2 | 26 | 25YR P | 508.30 | 281.33 | 283.92 | 283.92 | 284.83 | 0.061965 | 7.69 | 7.16 | 67.21 | 38.49 | 0.99 |
| Sausal | 2 | 26 | 10YR E | 426.30 | 281.33 | 283.72 | 283.72 | 284.53 | 0.064864 | 7.28 | 6.66 | 59.36 | 37.88 | 1.00 |
| Sausal | 2 | 26 | 10YR P | 413.30 | 281.33 | 283.68 | 283.68 | 284.48 | 0.065287 | 7.20 | 6.57 | 58.11 | 37.79 | 1.00 |
| Sausal | 2 | 26 | 5YR E | 349.80 | 281.33 | 283.52 | 283.52 | 284.23 | 0.067586 | 6.81 | 6.10 | 51.83 | 37.29 | 1.00 |
| Sausal | 2 | 26 | 5YR P | 340.30 | 281.33 | 283.49 | 283.49 | 284.19 | 0.068314 | 6.76 | 6.05 | 50.78 | 37.21 | 1.00 |
| Sausal | 2 | 26 | 2YR E | 240.40 | 281.33 | 283.19 | 283.19 | 283.76 | 0.075034 | 6.06 | 5.25 | 39.83 | 36.34 | 1.01 |
| Sausal | 2 | 26 | 2YR P | 235.10 | 281.33 | 283.17 | 283.17 | 283.73 | 0.075441 | 6.02 | 5.20 | 39.23 | 36.29 | 1.01 |
| Sausal | 2 | 26 | 1YR E | 42.26 | 281.33 | 282.27 | 282.27 | 282.52 | 0.101683 | 3.96 | 2.99 | 10.68 | 22.58 | 1.01 |
| Sausal | 2 | 26 | 1YR P | 38.53 | 281.33 | 282.24 | 282.24 | 282.47 | 0.102276 | 3.88 | 2.90 | 9.94 | 21.79 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 25 | 100YR E | 744.00 | 277.43 | 281.93 | | 282.60 | 0.017559 | 6.72 | 4.26 | 118.76 | 35.86 | 0.60 |
| Sausal | 2 | 25 | 100YR P | 655.20 | 277.43 | 281.72 | | 282.30 | 0.016657 | 6.30 | 3.82 | 111.06 | 35.23 | 0.58 |
| Sausal | 2 | 25 | 25YR E | 521.30 | 277.43 | 281.34 | | 281.81 | 0.015356 | 5.63 | 3.16 | 98.08 | 34.15 | 0.54 |
| Sausal | 2 | 25 | 25YR P | 508.30 | 277.43 | 281.31 | | 281.77 | 0.015184 | 5.56 | 3.09 | 96.82 | 34.04 | 0.54 |
| Sausal | 2 | 25 | 10YR E | 426.30 | 277.43 | 281.06 | | 281.44 | 0.014064 | 5.08 | 2.65 | 88.45 | 33.32 | 0.51 |
| Sausal | 2 | 25 | 10YR P | 413.30 | 277.43 | 281.02 | | 281.39 | 0.013891 | 5.00 | 2.58 | 87.03 | 33.20 | 0.51 |
| Sausal | 2 | 25 | 5YR E | 349.80 | 277.43 | 280.79 | | 281.11 | 0.013095 | 4.60 | 2.25 | 79.58 | 32.54 | 0.49 |
| Sausal | 2 | 25 | 5YR P | 340.30 | 277.43 | 280.75 | | 281.06 | 0.013029 | 4.55 | 2.20 | 78.29 | 32.43 | 0.49 |
| Sausal | 2 | 25 | 2YR E | 240.40 | 277.43 | 280.34 | | 280.56 | 0.011395 | 3.82 | 1.64 | 65.31 | 31.24 | 0.44 |
| Sausal | 2 | 25 | 2YR P | 235.10 | 277.43 | 280.32 | | 280.53 | 0.011280 | 3.77 | 1.61 | 64.59 | 31.18 | 0.44 |
| Sausal | 2 | 25 | 1YR E | 42.26 | 277.43 | 278.95 | | 278.99 | 0.007925 | 1.73 | 0.46 | 24.57 | 27.05 | 0.32 |
| Sausal | 2 | 25 | 1YR P | 38.53 | 277.43 | 278.89 | | 278.93 | 0.007804 | 1.69 | 0.44 | 22.99 | 26.02 | 0.31 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 24 | 100YR E | 744.00 | 274.71 | 278.20 | | 278.95 | 0.029080 | 6.99 | 5.14 | 109.54 | 41.75 | 0.73 |
| Sausal | 2 | 24 | 100YR P | 655.20 | 274.71 | 277.95 | | 278.65 | 0.030926 | 6.78 | 4.98 | 99.14 | 41.14 | 0.74 |
| Sausal | 2 | 24 | 25YR E | 521.30 | 274.71 | 277.56 | | 278.18 | 0.034307 | 6.40 | 4.69 | 83.13 | 40.18 | 0.76 |
| Sausal | 2 | 24 | 25YR P | 508.30 | 274.71 | 277.51 | | 278.14 | 0.034882 | 6.37 | 4.67 | 81.41 | 40.08 | 0.77 |
| Sausal | 2 | 24 | 10YR E | 426.30 | 274.71 | 277.24 | 276.97 | 277.82 | 0.039126 | 6.15 | 4.57 | 70.40 | 39.40 | 0.79 |
| Sausal | 2 | 24 | 10YR P | 413.30 | 274.71 | 277.19 | 276.94 | 277.77 | 0.039841 | 6.11 | 4.54 | 68.67 | 39.29 | 0.80 |
| Sausal | 2 | 24 | 5YR E | 349.80 | 274.71 | 276.98 | 276.77 | 277.51 | 0.043313 | 5.87 | 4.36 | 60.36 | 38.78 | 0.81 |
| Sausal | 2 | 24 | 5YR P | 340.30 | 274.71 | 276.95 | 276.74 | 277.47 | 0.043489 | 5.81 | 4.30 | 59.27 | 38.71 | 0.81 |
| Sausal | 2 | 24 | 2YR E | 240.40 | 274.71 | 276.57 | 276.46 | 277.02 | 0.054625 | 5.42 | 4.11 | 44.67 | 37.86 | 0.87 |
| Sausal | 2 | 24 | 2YR P | 235.10 | 274.71 | 276.55 | 276.44 | 277.00 | 0.055444 | 5.40 | 4.09 | 43.86 | 37.81 | 0.87 |
| Sausal | 2 | 24 | 1YR E | 42.26 | 274.71 | 275.57 | 275.57 | 275.79 | 0.103043 | 3.74 | 2.76 | 11.30 | 26.30 | 1.01 |
| Sausal | 2 | 24 | 1YR P | 38.53 | 274.71 | 275.53 | 275.53 | 275.75 | 0.106004 | 3.69 | 2.73 | 10.43 | 25.27 | 1.01 |
| | | | | | | | | | | | | | | |

HEC-RAS Plan: Scenario1 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 23 | 100YR E | 744.00 | 269.26 | 274.25 | 273.46 | 275.12 | 0.019405 | 8.00 | 5.68 | 107.15 | 30.08 | 0.65 |
| Sausal | 2 | 23 | 100YR P | 655.20 | 269.26 | 273.98 | 273.23 | 274.77 | 0.019042 | 7.61 | 5.25 | 98.88 | 29.80 | 0.64 |
| Sausal | 2 | 23 | 25YR E | 521.30 | 269.26 | 273.52 | 272.82 | 274.20 | 0.018413 | 6.96 | 4.55 | 85.45 | 29.34 | 0.61 |
| Sausal | 2 | 23 | 25YR P | 508.30 | 269.26 | 273.48 | 272.70 | 274.14 | 0.018307 | 6.89 | 4.48 | 84.13 | 29.30 | 0.61 |
| Sausal | 2 | 23 | 10YR E | 426.30 | 269.26 | 273.19 | 272.30 | 273.77 | 0.017292 | 6.37 | 3.93 | 75.87 | 29.01 | 0.59 |
| Sausal | 2 | 23 | 10YR P | 413.30 | 269.26 | 273.14 | 272.24 | 273.71 | 0.017163 | 6.29 | 3.84 | 74.42 | 28.96 | 0.58 |
| Sausal | 2 | 23 | 5YR E | 349.80 | 269.26 | 272.87 | 271.87 | 273.38 | 0.016728 | 5.90 | 3.47 | 66.64 | 28.69 | 0.57 |
| Sausal | 2 | 23 | 5YR P | 340.30 | 269.26 | 272.82 | 271.84 | 273.32 | 0.016808 | 5.85 | 3.43 | 65.20 | 28.64 | 0.57 |
| Sausal | 2 | 23 | 2YR E | 240.40 | 269.26 | 272.30 | 271.41 | 272.68 | 0.015787 | 5.06 | 2.71 | 51.41 | 24.23 | 0.54 |
| Sausal | 2 | 23 | 2YR P | 235.10 | 269.26 | 272.27 | 271.38 | 272.65 | 0.015699 | 5.01 | 2.67 | 50.68 | 23.96 | 0.53 |
| Sausal | 2 | 23 | 1YR E | 42.26 | 269.26 | 270.64 | | 270.72 | 0.011504 | 2.34 | 0.79 | 18.35 | 17.61 | 0.39 |
| Sausal | 2 | 23 | 1YR P | 38.53 | 269.26 | 270.58 | | 270.66 | 0.011354 | 2.24 | 0.74 | 17.39 | 17.49 | 0.39 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 22 | 100YR E | 744.00 | 265.90 | 269.08 | 269.08 | 270.47 | 0.049376 | 9.67 | 9.54 | 82.07 | 30.64 | 0.97 |
| Sausal | 2 | 22 | 100YR P | 655.20 | 265.90 | 268.85 | 268.85 | 270.13 | 0.050462 | 9.28 | 9.02 | 74.98 | 30.23 | 0.97 |
| Sausal | 2 | 22 | 25YR E | 521.30 | 265.90 | 268.47 | 268.47 | 269.59 | 0.052520 | 8.62 | 8.15 | 63.71 | 29.57 | 0.96 |
| Sausal | 2 | 22 | 25YR P | 508.30 | 265.90 | 268.43 | 268.43 | 269.53 | 0.052942 | 8.56 | 8.08 | 62.49 | 29.45 | 0.96 |
| Sausal | 2 | 22 | 10YR E | 426.30 | 265.90 | 268.12 | 268.12 | 269.15 | 0.058819 | 8.25 | 7.86 | 53.77 | 27.71 | 0.99 |
| Sausal | 2 | 22 | 10YR P | 413.30 | 265.90 | 268.07 | 268.07 | 269.09 | 0.059627 | 8.19 | 7.79 | 52.47 | 27.45 | 1.00 |
| Sausal | 2 | 22 | 5YR E | 349.80 | 265.90 | 267.85 | 267.85 | 268.77 | 0.062345 | 7.77 | 7.28 | 46.50 | 26.45 | 1.00 |
| Sausal | 2 | 22 | 5YR P | 340.30 | 265.90 | 267.83 | 267.83 | 268.72 | 0.061550 | 7.66 | 7.10 | 45.89 | 26.41 | 0.99 |
| Sausal | 2 | 22 | 2YR E | 240.40 | 265.90 | 267.45 | 267.45 | 268.17 | 0.066528 | 6.84 | 6.11 | 36.06 | 25.77 | 0.99 |
| Sausal | 2 | 22 | 2YR P | 235.10 | 265.90 | 267.43 | 267.43 | 268.13 | 0.067041 | 6.79 | 6.06 | 35.48 | 25.73 | 0.99 |
| Sausal | 2 | 22 | 1YR E | 42.26 | 265.90 | 266.45 | 266.45 | 266.68 | 0.098956 | 3.87 | 2.87 | 11.00 | 24.05 | 1.00 |
| Sausal | 2 | 22 | 1YR P | 38.53 | 265.90 | 266.42 | 266.42 | 266.64 | 0.102195 | 3.76 | 2.78 | 10.30 | 24.00 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 21 | 100YR E | 744.00 | 263.02 | 266.80 | | 267.36 | 0.015384 | 6.13 | 3.59 | 128.14 | 38.09 | 0.56 |
| Sausal | 2 | 21 | 100YR P | 655.20 | 263.02 | 266.56 | | 267.06 | 0.014962 | 5.78 | 3.27 | 119.14 | 37.54 | 0.54 |
| Sausal | 2 | 21 | 25YR E | 521.30 | 263.02 | 266.16 | | 266.57 | 0.014346 | 5.23 | 2.78 | 104.33 | 36.72 | 0.52 |
| Sausal | 2 | 21 | 25YR P | 508.30 | 263.02 | 266.12 | | 266.52 | 0.014288 | 5.17 | 2.73 | 102.79 | 36.63 | 0.52 |
| Sausal | 2 | 21 | 10YR E | 426.30 | 263.02 | 265.84 | | 266.19 | 0.013970 | 4.79 | 2.43 | 92.58 | 36.06 | 0.51 |
| Sausal | 2 | 21 | 10YR P | 413.30 | 263.02 | 265.80 | | 266.13 | 0.013889 | 4.73 | 2.37 | 90.95 | 35.97 | 0.50 |
| Sausal | 2 | 21 | 5YR E | 349.80 | 263.02 | 265.56 | | 265.85 | 0.013536 | 4.39 | 2.11 | 82.51 | 35.49 | 0.49 |
| Sausal | 2 | 21 | 5YR P | 340.30 | 263.02 | 265.53 | | 265.81 | 0.013409 | 4.33 | 2.07 | 81.34 | 35.43 | 0.49 |
| Sausal | 2 | 21 | 2YR E | 240.40 | 263.02 | 265.09 | | 265.30 | 0.013018 | 3.75 | 1.65 | 66.00 | 34.54 | 0.46 |
| Sausal | 2 | 21 | 2YR P | 235.10 | 263.02 | 265.06 | | 265.27 | 0.012999 | 3.71 | 1.63 | 65.11 | 34.48 | 0.46 |
| Sausal | 2 | 21 | 1YR E | 42.26 | 263.02 | 263.80 | | 263.85 | 0.012088 | 1.84 | 0.56 | 23.12 | 31.91 | 0.38 |
| Sausal | 2 | 21 | 1YR P | 38.53 | 263.02 | 263.76 | | 263.81 | 0.012142 | 1.78 | 0.53 | 21.83 | 31.83 | 0.37 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 20 | 100YR E | 744.00 | 260.09 | 264.12 | | 264.81 | 0.022088 | 6.78 | 4.58 | 115.71 | 41.01 | 0.65 |
| Sausal | 2 | 20 | 100YR P | 655.20 | 260.09 | 263.84 | | 264.49 | 0.023345 | 6.57 | 4.43 | 104.34 | 39.59 | 0.66 |
| Sausal | 2 | 20 | 25YR E | 521.30 | 260.09 | 263.41 | | 263.98 | 0.024853 | 6.13 | 4.05 | 87.95 | 37.23 | 0.67 |
| Sausal | 2 | 20 | 25YR P | 508.30 | 260.09 | 263.37 | | 263.93 | 0.025020 | 6.08 | 4.01 | 86.34 | 37.02 | 0.67 |
| Sausal | 2 | 20 | 10YR E | 426.30 | 260.09 | 263.09 | | 263.59 | 0.026086 | 5.75 | 3.73 | 76.11 | 35.84 | 0.67 |
| Sausal | 2 | 20 | 10YR P | 413.30 | 260.09 | 263.04 | | 263.54 | 0.026217 | 5.69 | 3.67 | 74.51 | 35.72 | 0.67 |
| Sausal | 2 | 20 | 5YR E | 349.80 | 260.09 | 262.81 | | 263.25 | 0.027296 | 5.40 | 3.43 | 66.22 | 35.12 | 0.67 |
| Sausal | 2 | 20 | 5YR P | 340.30 | 260.09 | 262.77 | | 263.21 | 0.027405 | 5.35 | 3.38 | 65.00 | 35.03 | 0.67 |
| Sausal | 2 | 20 | 2YR E | 240.40 | 260.09 | 262.39 | | 262.73 | 0.027994 | 4.69 | 2.80 | 51.95 | 34.06 | 0.65 |
| Sausal | 2 | 20 | 2YR P | 235.10 | 260.09 | 262.37 | | 262.71 | 0.028028 | 4.65 | 2.76 | 51.22 | 34.00 | 0.65 |
| Sausal | 2 | 20 | 1YR E | 42.26 | 260.09 | 261.32 | | 261.41 | 0.027646 | 2.45 | 1.06 | 17.22 | 28.06 | 0.55 |
| Sausal | 2 | 20 | 1YR P | 38.53 | 260.09 | 261.28 | | 261.37 | 0.027443 | 2.39 | 1.01 | 16.11 | 27.14 | 0.55 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 19 | 100YR E | 744.00 | 255.79 | 260.21 | 260.21 | 261.96 | 0.052958 | 10.71 | 11.31 | 71.95 | 21.33 | 1.00 |
| Sausal | 2 | 19 | 100YR P | 655.20 | 255.79 | 259.93 | 259.93 | 261.54 | 0.054095 | 10.25 | 10.65 | 65.99 | 21.14 | 1.00 |
| Sausal | 2 | 19 | 25YR E | 521.30 | 255.79 | 259.45 | 259.45 | 260.85 | 0.057870 | 9.56 | 9.75 | 56.02 | 20.82 | 1.00 |
| Sausal | 2 | 19 | 25YR P | 508.30 | 255.79 | 259.41 | 259.41 | 260.79 | 0.058190 | 9.48 | 9.64 | 55.06 | 20.79 | 1.00 |
| Sausal | 2 | 19 | 10YR E | 426.30 | 255.79 | 259.10 | 259.10 | 260.33 | 0.060422 | 8.94 | 8.92 | 48.79 | 20.58 | 1.00 |
| Sausal | 2 | 19 | 10YR P | 413.30 | 255.79 | 259.05 | 259.05 | 260.26 | 0.060996 | 8.85 | 8.81 | 47.72 | 20.55 | 1.00 |
| Sausal | 2 | 19 | 5YR E | 349.80 | 255.79 | 258.81 | 258.81 | 259.88 | 0.062181 | 8.34 | 8.09 | 42.79 | 20.38 | 1.00 |
| Sausal | 2 | 19 | 5YR P | 340.30 | 255.79 | 258.77 | 258.77 | 259.82 | 0.062619 | 8.26 | 7.99 | 41.97 | 20.36 | 1.00 |
| Sausal | 2 | 19 | 2YR E | 240.40 | 255.79 | 258.32 | 258.32 | 259.17 | 0.069470 | 7.43 | 6.99 | 32.83 | 20.05 | 1.01 |
| Sausal | 2 | 19 | 2YR P | 235.10 | 255.79 | 258.29 | 258.29 | 259.13 | 0.069883 | 7.37 | 6.93 | 32.33 | 20.03 | 1.01 |
| Sausal | 2 | 19 | 1YR E | 42.26 | 255.79 | 257.12 | 257.12 | 257.42 | 0.098454 | 4.43 | 3.51 | 9.57 | 16.05 | 1.01 |
| Sausal | 2 | 19 | 1YR P | 38.53 | 255.79 | 257.07 | 257.07 | 257.36 | 0.101518 | 4.38 | 3.48 | 8.82 | 15.35 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 18 | 100YR E | 744.00 | 247.75 | 252.62 | 252.32 | 254.29 | 0.039737 | 10.39 | 10.06 | 72.60 | 17.87 | 0.90 |
| Sausal | 2 | 18 | 100YR P | 655.20 | 247.75 | 252.38 | 252.02 | 253.84 | 0.037602 | 9.71 | 8.97 | 68.31 | 17.83 | 0.87 |
| Sausal | 2 | 18 | 25YR E | 521.30 | 247.75 | 251.96 | 251.51 | 253.12 | 0.034935 | 8.67 | 7.43 | 60.76 | 17.74 | 0.82 |
| Sausal | 2 | 18 | 25YR P | 508.30 | 247.75 | 251.91 | 251.46 | 253.05 | 0.034685 | 8.57 | 7.28 | 59.96 | 17.73 | 0.81 |
| Sausal | 2 | 18 | 10YR E | 426.30 | 247.75 | 251.61 | 251.14 | 252.57 | 0.033232 | 7.88 | 6.36 | 54.58 | 17.67 | 0.78 |
| Sausal | 2 | 18 | 10YR P | 413.30 | 247.75 | 251.55 | 251.08 | 252.49 | 0.033049 | 7.77 | 6.22 | 53.65 | 17.66 | 0.78 |
| Sausal | 2 | 18 | 5YR E | 349.80 | 247.75 | 251.28 | 250.80 | 252.09 | 0.032267 | 7.22 | 5.53 | 48.83 | 17.61 | 0.76 |
| Sausal | 2 | 18 | 5YR P | 340.30 | 247.75 | 251.23 | 250.75 | 252.03 | 0.032255 | 7.14 | 5.44 | 48.02 | 17.60 | 0.76 |
| Sausal | 2 | 18 | 2YR E | 240.40 | 247.75 | 250.72 | | 251.31 | 0.032226 | 6.21 | 4.41 | 38.90 | 17.50 | 0.73 |
| Sausal | 2 | 18 | 2YR P | 235.10 | 247.75 | 250.69 | | 251.27 | 0.032225 | 6.16 | 4.36 | 38.38 | 17.50 | 0.73 |
| Sausal | 2 | 18 | 1YR E | 42.26 | 247.75 | 249.16 | 248.94 | 249.33 | 0.035257 | 3.34 | 1.78 | 12.64 | 15.41 | 0.65 |
| Sausal | 2 | 18 | 1YR P | 38.53 | 247.75 | 249.11 | 248.90 | 249.28 | 0.035074 | 3.23 | 1.69 | 11.95 | 15.30 | 0.64 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 17 | 100YR E | 744.00 | 246.75 | 250.67 | 250.67 | 252.14 | 0.048143 | 10.13 | 10.16 | 81.48 | 29.16 | 0.91 |
| Sausal | 2 | 17 | 100YR P | 655.20 | 246.75 | 250.43 | 250.41 | 251.78 | 0.047895 | 9.67 | 9.47 | 74.50 | 28.32 | 0.90 |
| Sausal | 2 | 17 | 25YR E | 521.30 | 246.75 | 250.05 | 249.96 | 251.19 | 0.046305 | 8.83 | 8.19 | 63.98 | 26.99 | 0.86 |
| Sausal | 2 | 17 | 25YR P | 508.30 | 246.75 | 250.01 | 249.91 | 251.13 | 0.046144 | 8.75 | 8.07 | 62.90 | 26.85 | 0.86 |
| Sausal | 2 | 17 | 10YR E | 426.30 | 246.75 | 249.75 | 249.57 | 250.73 | 0.044523 | 8.12 | 7.15 | 56.10 | 25.37 | 0.83 |
| Sausal | 2 | 17 | 10YR P | 413.30 | 246.75 | 249.70 | 249.51 | 250.66 | 0.044189 | 8.01 | 6.99 | 55.01 | 25.12 | 0.83 |
| Sausal | 2 | 17 | 5YR E | 349.80 | 246.75 | 249.48 | 249.23 | 250.32 | 0.042324 | 7.43 | 6.18 | 49.59 | 23.85 | 0.80 |
| Sausal | 2 | 17 | 5YR P | 340.30 | 246.75 | 249.45 | 249.18 | 250.26 | 0.042002 | 7.34 | 6.06 | 48.76 | 23.65 | 0.80 |
| Sausal | 2 | 17 | 2YR E | 240.40 | 246.75 | 249.04 | 248.67 | 249.64 | 0.038092 | 6.25 | 4.65 | 39.58 | 21.31 | 0.74 |
| Sausal | 2 | 17 | 2YR P | 235.10 | 246.75 | 249.01 | 248.64 | 249.60 | 0.037909 | 6.19 | 4.57 | 39.05 | 21.17 | 0.73 |
| Sausal | 2 | 17 | 1YR E | 42.26 | 246.75 | 247.63 | | 247.77 | 0.030094 | 3.01 | 1.46 | 14.04 | 16.67 | 0.58 |
| Sausal | 2 | 17 | 1YR P | 38.53 | 246.75 | 247.58 | | 247.71 | 0.030043 | 2.91 | 1.39 | 13.26 | 16.65 | 0.57 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 16 | 100YR E | 744.00 | 244.75 | 248.52 | | 249.24 | 0.020844 | 7.04 | 4.78 | 114.33 | 38.25 | 0.65 |
| Sausal | 2 | 16 | 100YR P | 655.20 | 244.75 | 248.27 | | 248.93 | 0.020902 | 6.73 | 4.46 | 104.75 | 37.81 | 0.64 |

HEC-RAS Plan: Scenario1 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 16 | 25YR E | 521.30 | 244.75 | 247.86 | | 248.42 | 0.020813 | 6.17 | 3.91 | 89.66 | 35.67 | 0.63 |
| Sausal | 2 | 16 | 25YR P | 508.30 | 244.75 | 247.82 | | 248.37 | 0.020798 | 6.11 | 3.86 | 88.15 | 35.41 | 0.62 |
| Sausal | 2 | 16 | 10YR E | 426.30 | 244.75 | 247.53 | | 248.02 | 0.020946 | 5.72 | 3.50 | 78.16 | 33.57 | 0.62 |
| Sausal | 2 | 16 | 10YR P | 413.30 | 244.75 | 247.48 | | 247.96 | 0.021007 | 5.66 | 3.45 | 76.51 | 33.26 | 0.62 |
| Sausal | 2 | 16 | 5YR E | 349.80 | 244.75 | 247.22 | | 247.65 | 0.021434 | 5.34 | 3.18 | 68.18 | 31.54 | 0.61 |
| Sausal | 2 | 16 | 5YR P | 340.30 | 244.75 | 247.18 | | 247.60 | 0.021525 | 5.29 | 3.13 | 66.90 | 31.26 | 0.61 |
| Sausal | 2 | 16 | 2YR E | 240.40 | 244.75 | 246.73 | | 247.06 | 0.022425 | 4.67 | 2.63 | 53.06 | 30.08 | 0.60 |
| Sausal | 2 | 16 | 2YR P | 235.10 | 244.75 | 246.70 | | 247.03 | 0.022425 | 4.63 | 2.60 | 52.32 | 30.03 | 0.60 |
| Sausal | 2 | 16 | 1YR E | 42.26 | 244.75 | 245.53 | | 245.62 | 0.020552 | 2.29 | 0.88 | 18.64 | 27.73 | 0.49 |
| Sausal | 2 | 16 | 1YR P | 38.53 | 244.75 | 245.50 | | 245.57 | 0.020318 | 2.20 | 0.83 | 17.68 | 27.66 | 0.48 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 15 | 100YR E | 744.00 | 239.86 | 245.07 | | 245.48 | 0.017773 | 5.76 | 5.50 | 156.75 | 46.03 | 0.46 |
| Sausal | 2 | 15 | 100YR P | 655.20 | 239.86 | 244.76 | | 245.15 | 0.018060 | 5.56 | 5.24 | 142.54 | 45.08 | 0.45 |
| Sausal | 2 | 15 | 25YR E | 521.30 | 239.86 | 244.24 | | 244.59 | 0.018784 | 5.24 | 4.84 | 119.48 | 43.49 | 0.45 |
| Sausal | 2 | 15 | 25YR P | 508.30 | 239.86 | 244.18 | | 244.53 | 0.018859 | 5.20 | 4.80 | 117.17 | 43.33 | 0.45 |
| Sausal | 2 | 15 | 10YR E | 426.30 | 239.86 | 243.81 | | 244.14 | 0.019272 | 4.94 | 4.46 | 101.72 | 39.94 | 0.45 |
| Sausal | 2 | 15 | 10YR P | 413.30 | 239.86 | 243.75 | | 244.07 | 0.019320 | 4.89 | 4.39 | 99.24 | 39.21 | 0.45 |
| Sausal | 2 | 15 | 5YR E | 349.80 | 239.86 | 243.43 | | 243.71 | 0.019498 | 4.62 | 4.04 | 87.12 | 35.41 | 0.45 |
| Sausal | 2 | 15 | 5YR P | 340.30 | 239.86 | 243.37 | | 243.66 | 0.019520 | 4.57 | 3.98 | 85.28 | 34.80 | 0.45 |
| Sausal | 2 | 15 | 2YR E | 240.40 | 239.86 | 242.78 | | 243.00 | 0.019824 | 4.03 | 3.31 | 66.25 | 30.33 | 0.43 |
| Sausal | 2 | 15 | 2YR P | 235.10 | 239.86 | 242.74 | | 242.96 | 0.019904 | 4.00 | 3.28 | 65.19 | 30.23 | 0.43 |
| Sausal | 2 | 15 | 1YR E | 42.26 | 239.86 | 241.05 | | 241.13 | 0.027150 | 2.35 | 1.60 | 18.77 | 22.87 | 0.43 |
| Sausal | 2 | 15 | 1YR P | 38.53 | 239.86 | 240.99 | | 241.07 | 0.027730 | 2.29 | 1.54 | 17.55 | 22.50 | 0.43 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 14 | 100YR E | 744.00 | 236.10 | 240.35 | | 241.34 | 0.025262 | 8.19 | 6.29 | 98.99 | 33.95 | 0.72 |
| Sausal | 2 | 14 | 100YR P | 655.20 | 236.10 | 240.09 | | 241.00 | 0.024900 | 7.79 | 5.81 | 90.55 | 31.91 | 0.71 |
| Sausal | 2 | 14 | 25YR E | 521.30 | 236.10 | 239.65 | | 240.42 | 0.024458 | 7.10 | 5.04 | 77.33 | 28.42 | 0.69 |
| Sausal | 2 | 14 | 25YR P | 508.30 | 236.10 | 239.61 | | 240.36 | 0.024406 | 7.03 | 4.96 | 76.04 | 28.05 | 0.68 |
| Sausal | 2 | 14 | 10YR E | 426.30 | 236.10 | 239.30 | | 239.95 | 0.023895 | 6.52 | 4.41 | 67.93 | 25.64 | 0.67 |
| Sausal | 2 | 14 | 10YR P | 413.30 | 236.10 | 239.25 | | 239.88 | 0.023848 | 6.44 | 4.32 | 66.59 | 25.26 | 0.66 |
| Sausal | 2 | 14 | 5YR E | 349.80 | 236.10 | 238.99 | | 239.54 | 0.023487 | 6.01 | 3.88 | 60.10 | 24.66 | 0.65 |
| Sausal | 2 | 14 | 5YR P | 340.30 | 236.10 | 238.95 | | 239.49 | 0.023415 | 5.94 | 3.81 | 59.11 | 24.56 | 0.65 |
| Sausal | 2 | 14 | 2YR E | 240.40 | 236.10 | 238.49 | | 238.89 | 0.022544 | 5.12 | 3.02 | 48.00 | 23.63 | 0.61 |
| Sausal | 2 | 14 | 2YR P | 235.10 | 236.10 | 238.47 | | 238.86 | 0.022334 | 5.06 | 2.96 | 47.47 | 23.60 | 0.61 |
| Sausal | 2 | 14 | 1YR E | 42.26 | 236.10 | 237.19 | | 237.27 | 0.015182 | 2.28 | 0.81 | 18.56 | 21.71 | 0.43 |
| Sausal | 2 | 14 | 1YR P | 38.53 | 236.10 | 237.15 | | 237.22 | 0.014885 | 2.18 | 0.76 | 17.66 | 21.65 | 0.42 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 13 | 100YR E | 744.00 | 226.99 | 232.34 | | 233.18 | 0.017430 | 8.00 | 5.53 | 110.38 | 30.49 | 0.62 |
| Sausal | 2 | 13 | 100YR P | 655.20 | 226.99 | 231.98 | | 232.77 | 0.017957 | 7.73 | 5.29 | 99.53 | 29.06 | 0.63 |
| Sausal | 2 | 13 | 25YR E | 521.30 | 226.99 | 231.40 | | 232.11 | 0.018655 | 7.23 | 4.83 | 83.32 | 27.01 | 0.62 |
| Sausal | 2 | 13 | 25YR P | 508.30 | 226.99 | 231.34 | | 232.04 | 0.018732 | 7.17 | 4.78 | 81.72 | 26.80 | 0.62 |
| Sausal | 2 | 13 | 10YR E | 426.30 | 226.99 | 230.94 | | 231.58 | 0.019387 | 6.81 | 4.46 | 71.26 | 25.43 | 0.62 |
| Sausal | 2 | 13 | 10YR P | 413.30 | 226.99 | 230.87 | | 231.50 | 0.019457 | 6.75 | 4.40 | 69.63 | 25.21 | 0.62 |
| Sausal | 2 | 13 | 5YR E | 349.80 | 226.99 | 230.54 | | 231.11 | 0.019942 | 6.40 | 4.10 | 61.40 | 24.06 | 0.62 |
| Sausal | 2 | 13 | 5YR P | 340.30 | 226.99 | 230.49 | | 231.05 | 0.020036 | 6.35 | 4.05 | 60.13 | 23.87 | 0.62 |
| Sausal | 2 | 13 | 2YR E | 240.40 | 226.99 | 229.88 | | 230.35 | 0.021316 | 5.71 | 3.50 | 46.26 | 21.79 | 0.62 |
| Sausal | 2 | 13 | 2YR P | 235.10 | 226.99 | 229.84 | | 230.30 | 0.021562 | 5.68 | 3.49 | 45.38 | 21.65 | 0.62 |
| Sausal | 2 | 13 | 1YR E | 42.26 | 226.99 | 228.05 | | 228.24 | 0.039478 | 3.55 | 2.00 | 12.14 | 15.71 | 0.69 |
| Sausal | 2 | 13 | 1YR P | 38.53 | 226.99 | 228.00 | | 228.18 | 0.040768 | 3.45 | 1.94 | 11.35 | 15.56 | 0.70 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 12 | 100YR E | 744.00 | 223.66 | 229.22 | 228.27 | 230.23 | 0.020976 | 8.57 | 6.43 | 100.02 | 25.75 | 0.66 |
| Sausal | 2 | 12 | 100YR P | 655.20 | 223.66 | 228.94 | 227.98 | 229.84 | 0.020050 | 8.08 | 5.82 | 92.86 | 25.14 | 0.64 |
| Sausal | 2 | 12 | 25YR E | 521.30 | 223.66 | 228.42 | 227.48 | 229.18 | 0.019331 | 7.37 | 5.02 | 80.02 | 23.99 | 0.61 |
| Sausal | 2 | 12 | 25YR P | 508.30 | 223.66 | 228.37 | 227.42 | 229.11 | 0.019259 | 7.30 | 4.94 | 78.71 | 23.86 | 0.61 |
| Sausal | 2 | 12 | 10YR E | 426.30 | 223.66 | 228.02 | 227.04 | 228.67 | 0.018435 | 6.76 | 4.36 | 70.59 | 23.11 | 0.59 |
| Sausal | 2 | 12 | 10YR P | 413.30 | 223.66 | 227.96 | 226.98 | 228.59 | 0.018405 | 6.69 | 4.28 | 69.11 | 22.96 | 0.59 |
| Sausal | 2 | 12 | 5YR E | 349.80 | 223.66 | 227.64 | 226.67 | 228.21 | 0.017870 | 6.24 | 3.84 | 62.07 | 22.28 | 0.57 |
| Sausal | 2 | 12 | 5YR P | 340.30 | 223.66 | 227.60 | 226.62 | 228.15 | 0.017756 | 6.17 | 3.76 | 61.02 | 22.18 | 0.57 |
| Sausal | 2 | 12 | 2YR E | 240.40 | 223.66 | 227.03 | 226.08 | 227.45 | 0.016478 | 5.31 | 2.95 | 48.97 | 20.35 | 0.53 |
| Sausal | 2 | 12 | 2YR P | 235.10 | 223.66 | 227.00 | 226.04 | 227.41 | 0.016405 | 5.26 | 2.91 | 48.28 | 20.23 | 0.53 |
| Sausal | 2 | 12 | 1YR E | 42.26 | 223.66 | 225.20 | | 225.30 | 0.011120 | 2.43 | 0.83 | 17.61 | 14.49 | 0.38 |
| Sausal | 2 | 12 | 1YR P | 38.53 | 223.66 | 225.14 | | 225.22 | 0.011017 | 2.34 | 0.78 | 16.65 | 14.40 | 0.38 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 11 | 100YR E | 744.00 | 220.94 | 225.45 | 225.45 | 227.10 | 0.012088 | 10.63 | 2.60 | 74.54 | 23.39 | 0.96 |
| Sausal | 2 | 11 | 100YR P | 655.20 | 220.94 | 225.14 | 225.14 | 226.70 | 0.012657 | 10.28 | 2.50 | 67.47 | 22.64 | 0.97 |
| Sausal | 2 | 11 | 25YR E | 521.30 | 220.94 | 224.67 | 224.67 | 226.04 | 0.013107 | 9.59 | 2.27 | 57.16 | 21.45 | 0.97 |
| Sausal | 2 | 11 | 25YR P | 508.30 | 220.94 | 224.62 | 224.62 | 225.97 | 0.013136 | 9.52 | 2.24 | 56.10 | 21.32 | 0.97 |
| Sausal | 2 | 11 | 10YR E | 426.30 | 220.94 | 224.28 | 224.28 | 225.52 | 0.013589 | 9.10 | 2.11 | 48.98 | 20.38 | 0.97 |
| Sausal | 2 | 11 | 10YR P | 413.30 | 220.94 | 224.23 | 224.23 | 225.44 | 0.013652 | 9.02 | 2.09 | 47.85 | 20.22 | 0.97 |
| Sausal | 2 | 11 | 5YR E | 349.80 | 220.94 | 223.94 | 223.94 | 225.06 | 0.014018 | 8.61 | 1.96 | 42.21 | 19.44 | 0.97 |
| Sausal | 2 | 11 | 5YR P | 340.30 | 220.94 | 223.90 | 223.90 | 225.00 | 0.014105 | 8.55 | 1.95 | 41.32 | 19.32 | 0.98 |
| Sausal | 2 | 11 | 2YR E | 240.40 | 220.94 | 223.39 | 223.39 | 224.30 | 0.015035 | 7.77 | 1.71 | 31.85 | 17.92 | 0.98 |
| Sausal | 2 | 11 | 2YR P | 235.10 | 220.94 | 223.36 | 223.36 | 224.26 | 0.015098 | 7.72 | 1.70 | 31.33 | 17.84 | 0.98 |
| Sausal | 2 | 11 | 1YR E | 42.26 | 220.94 | 221.96 | 221.96 | 222.30 | 0.021771 | 4.63 | 0.86 | 9.12 | 13.86 | 1.01 |
| Sausal | 2 | 11 | 1YR P | 38.53 | 220.94 | 221.92 | 221.92 | 222.24 | 0.021855 | 4.52 | 0.83 | 8.52 | 13.49 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 10 | 100YR E | 744.00 | 216.69 | 222.35 | 222.35 | 224.09 | 0.009241 | 11.86 | 2.86 | 78.61 | 22.86 | 0.90 |
| Sausal | 2 | 10 | 100YR P | 655.20 | 216.69 | 221.98 | 221.98 | 223.65 | 0.009597 | 11.54 | 2.77 | 70.39 | 21.69 | 0.90 |
| Sausal | 2 | 10 | 25YR E | 521.30 | 216.69 | 221.39 | 221.39 | 222.92 | 0.010097 | 10.89 | 2.57 | 58.13 | 19.81 | 0.91 |
| Sausal | 2 | 10 | 25YR P | 508.30 | 216.69 | 221.32 | 221.32 | 222.85 | 0.010167 | 10.83 | 2.55 | 56.89 | 19.61 | 0.91 |
| Sausal | 2 | 10 | 10YR E | 426.30 | 216.69 | 220.94 | 220.94 | 222.34 | 0.010362 | 10.28 | 2.37 | 49.52 | 18.38 | 0.90 |
| Sausal | 2 | 10 | 10YR P | 413.30 | 216.69 | 220.85 | 220.85 | 222.25 | 0.010590 | 10.25 | 2.38 | 47.99 | 18.11 | 0.91 |
| Sausal | 2 | 10 | 5YR E | 349.80 | 216.69 | 220.52 | 220.52 | 221.80 | 0.010806 | 9.75 | 2.22 | 42.07 | 17.04 | 0.91 |
| Sausal | 2 | 10 | 5YR P | 340.30 | 216.69 | 220.46 | 220.46 | 221.73 | 0.010877 | 9.69 | 2.20 | 41.12 | 16.87 | 0.91 |
| Sausal | 2 | 10 | 2YR E | 240.40 | 216.69 | 219.80 | 219.80 | 220.91 | 0.011993 | 8.87 | 1.97 | 30.72 | 14.78 | 0.92 |
| Sausal | 2 | 10 | 2YR P | 235.10 | 216.69 | 219.76 | 219.76 | 220.86 | 0.012069 | 8.82 | 1.96 | 30.15 | 14.65 | 0.92 |
| Sausal | 2 | 10 | 1YR E | 42.26 | 216.69 | 218.01 | 217.84 | 218.34 | 0.011542 | 4.58 | 0.72 | 9.39 | 9.10 | 0.77 |
| Sausal | 2 | 10 | 1YR P | 38.53 | 216.69 | 217.96 | 217.78 | 218.26 | 0.011418 | 4.40 | 0.68 | 8.89 | 8.92 | 0.76 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 9 | 100YR E | 744.00 | 212.30 | 219.48 | | 219.80 | 0.001391 | 5.13 | 0.51 | 186.07 | 53.42 | 0.35 |
| Sausal | 2 | 9 | 100YR P | 655.20 | 212.30 | 219.18 | | 219.48 | 0.001350 | 4.90 | 0.47 | 170.40 | 51.62 | 0.34 |
| Sausal | 2 | 9 | 25YR E | 521.30 | 212.30 | 218.66 | | 218.92 | 0.001296 | 4.54 | 0.41 | 144.27 | 48.47 | 0.33 |
| Sausal | 2 | 9 | 25YR P | 508.30 | 212.30 | 218.60 | | 218.87 | 0.001288 | 4.49 | 0.41 | 141.70 | 48.15 | 0.33 |

HEC-RAS Plan: Scenario1 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 9 | 10YR E | 426.30 | 212.30 | 218.00 | | 218.29 | 0.001534 | 4.56 | 0.43 | 113.80 | 44.52 | 0.35 |
| Sausal | 2 | 9 | 10YR P | 413.30 | 212.30 | 217.80 | | 218.10 | 0.001689 | 4.66 | 0.46 | 105.36 | 39.08 | 0.37 |
| Sausal | 2 | 9 | 5YR E | 349.80 | 212.30 | 216.77 | | 217.17 | 0.002941 | 5.26 | 0.63 | 73.51 | 27.39 | 0.47 |
| Sausal | 2 | 9 | 5YR P | 340.30 | 212.30 | 216.62 | | 217.04 | 0.003247 | 5.38 | 0.67 | 69.36 | 26.52 | 0.49 |
| Sausal | 2 | 9 | 2YR E | 240.40 | 212.30 | 214.92 | 214.79 | 215.78 | 0.013808 | 7.45 | 1.57 | 32.42 | 16.91 | 0.91 |
| Sausal | 2 | 9 | 2YR P | 235.10 | 212.30 | 214.81 | 214.76 | 215.73 | 0.015683 | 7.67 | 1.70 | 30.70 | 16.32 | 0.96 |
| Sausal | 2 | 9 | 1YR E | 42.26 | 212.30 | 213.31 | 213.31 | 213.66 | 0.021773 | 4.73 | 0.89 | 8.94 | 13.05 | 1.01 |
| Sausal | 2 | 9 | 1YR P | 38.53 | 212.30 | 213.27 | 213.27 | 213.60 | 0.022040 | 4.59 | 0.85 | 8.40 | 12.97 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 8 | 100YR E | 744.00 | 208.57 | 219.44 | 214.81 | 219.61 | 0.000643 | 4.07 | 0.30 | 258.38 | 61.66 | 0.23 |
| Sausal | 2 | 8 | 100YR P | 655.20 | 208.57 | 219.14 | 214.47 | 219.29 | 0.000609 | 3.89 | 0.27 | 239.98 | 61.66 | 0.22 |
| Sausal | 2 | 8 | 25YR E | 521.30 | 208.57 | 218.63 | 213.86 | 218.76 | 0.000522 | 3.47 | 0.22 | 209.58 | 53.54 | 0.20 |
| Sausal | 2 | 8 | 25YR P | 508.30 | 208.57 | 218.58 | 213.82 | 218.70 | 0.000507 | 3.40 | 0.21 | 206.93 | 51.93 | 0.20 |
| Sausal | 2 | 8 | 10YR E | 426.30 | 208.57 | 218.00 | 213.42 | 218.11 | 0.000482 | 3.18 | 0.19 | 179.62 | 43.05 | 0.19 |
| Sausal | 2 | 8 | 10YR P | 413.30 | 208.57 | 217.80 | 213.35 | 217.91 | 0.000499 | 3.18 | 0.19 | 171.40 | 40.49 | 0.20 |
| Sausal | 2 | 8 | 5YR E | 349.80 | 208.57 | 216.76 | 213.01 | 216.89 | 0.000667 | 3.36 | 0.22 | 132.86 | 35.56 | 0.22 |
| Sausal | 2 | 8 | 5YR P | 340.30 | 208.57 | 216.61 | 212.97 | 216.74 | 0.000699 | 3.39 | 0.23 | 127.41 | 34.78 | 0.23 |
| Sausal | 2 | 8 | 2YR E | 240.40 | 208.57 | 214.97 | 212.40 | 215.14 | 0.001089 | 3.54 | 0.27 | 79.72 | 23.86 | 0.27 |
| Sausal | 2 | 8 | 2YR P | 235.10 | 208.57 | 214.89 | 212.37 | 215.05 | 0.001117 | 3.55 | 0.28 | 77.62 | 23.52 | 0.27 |
| Sausal | 2 | 8 | 1YR E | 42.26 | 208.57 | 210.92 | 210.08 | 211.09 | 0.004087 | 3.25 | 0.33 | 12.99 | 7.91 | 0.45 |
| Sausal | 2 | 8 | 1YR P | 38.53 | 208.57 | 210.81 | 210.00 | 210.97 | 0.004100 | 3.18 | 0.32 | 12.12 | 7.70 | 0.45 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 7.8 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 7 | 100YR E | 744.00 | 204.66 | 209.26 | | 209.94 | 0.018524 | 6.71 | 4.31 | 116.56 | 36.95 | 0.60 |
| Sausal | 2 | 7 | 100YR P | 655.20 | 204.66 | 209.06 | | 209.65 | 0.017319 | 6.26 | 3.83 | 109.24 | 35.90 | 0.57 |
| Sausal | 2 | 7 | 25YR E | 521.30 | 204.66 | 208.77 | | 209.22 | 0.014546 | 5.44 | 2.97 | 99.13 | 34.40 | 0.52 |
| Sausal | 2 | 7 | 25YR P | 508.30 | 204.66 | 208.73 | | 209.17 | 0.014367 | 5.37 | 2.90 | 97.85 | 34.21 | 0.51 |
| Sausal | 2 | 7 | 10YR E | 426.30 | 204.66 | 208.44 | | 208.82 | 0.013793 | 4.96 | 2.55 | 88.11 | 32.69 | 0.49 |
| Sausal | 2 | 7 | 10YR P | 413.30 | 204.66 | 208.36 | | 208.74 | 0.014178 | 4.94 | 2.55 | 85.52 | 32.27 | 0.50 |
| Sausal | 2 | 7 | 5YR E | 349.80 | 204.66 | 207.95 | | 208.32 | 0.016702 | 4.87 | 2.60 | 72.69 | 30.13 | 0.53 |
| Sausal | 2 | 7 | 5YR P | 340.30 | 204.66 | 207.90 | | 208.26 | 0.016738 | 4.82 | 2.56 | 71.35 | 29.90 | 0.53 |
| Sausal | 2 | 7 | 2YR E | 240.40 | 204.66 | 207.42 | | 207.69 | 0.016135 | 4.20 | 2.06 | 57.37 | 27.61 | 0.50 |
| Sausal | 2 | 7 | 2YR P | 235.10 | 204.66 | 207.39 | | 207.66 | 0.015995 | 4.15 | 2.03 | 56.70 | 27.50 | 0.50 |
| Sausal | 2 | 7 | 1YR E | 42.26 | 204.66 | 205.85 | | 205.92 | 0.013628 | 2.20 | 0.75 | 19.18 | 21.19 | 0.41 |
| Sausal | 2 | 7 | 1YR P | 38.53 | 204.66 | 205.79 | | 205.86 | 0.013729 | 2.14 | 0.72 | 18.02 | 20.97 | 0.41 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 6 | 100YR E | 1106.10 | 200.31 | 205.22 | 205.22 | 206.72 | 0.008728 | 10.81 | 2.45 | 122.71 | 39.40 | 0.88 |
| Sausal | 2 | 6 | 100YR P | 1041.00 | 200.31 | 205.09 | 205.09 | 206.54 | 0.008682 | 10.58 | 2.37 | 117.78 | 39.18 | 0.88 |
| Sausal | 2 | 6 | 25YR E | 913.10 | 200.31 | 204.76 | 204.76 | 206.18 | 0.009225 | 10.37 | 2.34 | 104.86 | 38.29 | 0.89 |
| Sausal | 2 | 6 | 25YR P | 899.60 | 200.31 | 204.73 | 204.73 | 206.13 | 0.009258 | 10.33 | 2.32 | 103.56 | 38.07 | 0.89 |
| Sausal | 2 | 6 | 10YR E | 789.70 | 200.31 | 204.44 | 204.44 | 205.78 | 0.009501 | 9.98 | 2.22 | 93.01 | 36.20 | 0.89 |
| Sausal | 2 | 6 | 10YR P | 754.70 | 200.31 | 204.35 | 204.35 | 205.66 | 0.009555 | 9.85 | 2.18 | 89.72 | 35.60 | 0.89 |
| Sausal | 2 | 6 | 5YR E | 538.30 | 200.31 | 203.68 | 203.68 | 204.83 | 0.010463 | 9.06 | 1.97 | 67.45 | 31.22 | 0.90 |
| Sausal | 2 | 6 | 5YR P | 521.80 | 200.31 | 203.63 | 203.63 | 204.76 | 0.010532 | 8.98 | 1.95 | 65.75 | 30.86 | 0.91 |
| Sausal | 2 | 6 | 2YR E | 363.20 | 200.31 | 203.03 | 203.03 | 204.01 | 0.011662 | 8.18 | 1.73 | 48.51 | 26.94 | 0.92 |
| Sausal | 2 | 6 | 2YR P | 358.10 | 200.31 | 203.01 | 203.01 | 203.98 | 0.011716 | 8.15 | 1.73 | 47.93 | 26.80 | 0.92 |
| Sausal | 2 | 6 | 1YR E | 58.85 | 200.31 | 201.30 | 201.26 | 201.64 | 0.017226 | 4.72 | 0.84 | 12.61 | 16.46 | 0.93 |
| Sausal | 2 | 6 | 1YR P | 53.78 | 200.31 | 201.25 | 201.21 | 201.57 | 0.017169 | 4.55 | 0.79 | 11.92 | 16.33 | 0.92 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 5.1 | 100YR E | 1106.10 | 196.68 | 204.03 | 204.03 | 204.93 | 0.003632 | 9.45 | 1.61 | 190.65 | 121.97 | 0.62 |
| Sausal | 2 | 5.1 | 100YR P | 1041.00 | 196.68 | 203.12 | 203.12 | 204.76 | 0.006848 | 11.85 | 2.65 | 113.22 | 38.23 | 0.84 |
| Sausal | 2 | 5.1 | 25YR E | 913.10 | 196.68 | 203.17 | 202.77 | 204.40 | 0.005062 | 10.24 | 1.97 | 115.27 | 39.53 | 0.72 |
| Sausal | 2 | 5.1 | 25YR P | 899.60 | 196.68 | 203.22 | 202.74 | 204.37 | 0.004743 | 9.96 | 1.86 | 117.28 | 45.96 | 0.70 |
| Sausal | 2 | 5.1 | 10YR E | 789.70 | 196.68 | 203.26 | | 204.13 | 0.003537 | 8.64 | 1.40 | 119.40 | 51.87 | 0.60 |
| Sausal | 2 | 5.1 | 10YR P | 754.70 | 196.68 | 203.24 | | 204.04 | 0.003277 | 8.30 | 1.29 | 118.45 | 49.32 | 0.58 |
| Sausal | 2 | 5.1 | 5YR E | 538.30 | 196.68 | 203.09 | | 203.54 | 0.001863 | 6.16 | 0.72 | 112.35 | 38.04 | 0.44 |
| Sausal | 2 | 5.1 | 5YR P | 521.80 | 196.68 | 203.07 | | 203.49 | 0.001790 | 6.02 | 0.69 | 111.25 | 37.79 | 0.43 |
| Sausal | 2 | 5.1 | 2YR E | 363.20 | 196.68 | 202.79 | | 203.03 | 0.001073 | 4.52 | 0.39 | 101.08 | 35.41 | 0.33 |
| Sausal | 2 | 5.1 | 2YR P | 358.10 | 196.68 | 202.78 | | 203.02 | 0.001050 | 4.47 | 0.38 | 100.76 | 35.34 | 0.32 |
| Sausal | 2 | 5.1 | 1YR E | 58.85 | 196.68 | 197.97 | 197.97 | 198.47 | 0.017023 | 5.78 | 1.13 | 10.50 | 10.75 | 0.98 |
| Sausal | 2 | 5.1 | 1YR P | 53.78 | 196.68 | 197.91 | 197.91 | 198.39 | 0.017342 | 5.61 | 1.09 | 9.86 | 10.64 | 0.98 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 5 | 100YR E | 1106.10 | 196.09 | 203.42 | 203.42 | 204.74 | 0.004864 | 11.14 | 2.22 | 131.96 | 60.99 | 0.73 |
| Sausal | 2 | 5 | 100YR P | 1041.00 | 196.09 | 202.84 | 202.84 | 204.52 | 0.006160 | 11.88 | 2.59 | 107.79 | 32.53 | 0.81 |
| Sausal | 2 | 5 | 25YR E | 913.10 | 196.09 | 203.17 | 202.77 | 204.24 | 0.003820 | 9.65 | 1.68 | 119.11 | 37.87 | 0.64 |
| Sausal | 2 | 5 | 25YR P | 899.60 | 196.09 | 203.22 | 202.77 | 204.22 | 0.003602 | 9.42 | 1.60 | 120.92 | 44.15 | 0.62 |
| Sausal | 2 | 5 | 10YR E | 789.70 | 196.09 | 203.27 | 202.76 | 204.01 | 0.002691 | 8.17 | 1.20 | 123.19 | 50.92 | 0.54 |
| Sausal | 2 | 5 | 10YR P | 754.70 | 196.09 | 203.25 | 202.76 | 203.94 | 0.002489 | 7.85 | 1.11 | 122.22 | 48.16 | 0.52 |
| Sausal | 2 | 5 | 5YR E | 538.30 | 196.09 | 203.10 | 201.41 | 203.48 | 0.001395 | 5.79 | 0.61 | 116.33 | 35.49 | 0.39 |
| Sausal | 2 | 5 | 5YR P | 521.80 | 196.09 | 203.07 | 201.30 | 203.44 | 0.001336 | 5.65 | 0.58 | 115.30 | 35.09 | 0.38 |
| Sausal | 2 | 5 | 2YR E | 363.20 | 196.09 | 201.91 | 200.20 | 202.92 | 0.003136 | 7.67 | 1.13 | 45.94 | 24.77 | 0.56 |
| Sausal | 2 | 5 | 2YR P | 358.10 | 196.09 | 201.94 | 200.15 | 202.91 | 0.003001 | 7.53 | 1.09 | 46.16 | 25.00 | 0.55 |
| Sausal | 2 | 5 | 1YR E | 58.85 | 196.09 | 197.36 | 197.36 | 197.96 | 0.016062 | 6.22 | 1.25 | 9.49 | 10.02 | 0.98 |
| Sausal | 2 | 5 | 1YR P | 53.78 | 196.09 | 197.29 | 197.29 | 197.85 | 0.016281 | 6.03 | 1.19 | 8.96 | 9.84 | 0.98 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 4.5 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 4 | 100YR E | 1106.10 | 187.02 | 192.63 | | 193.92 | 0.028544 | 9.72 | 8.38 | 128.28 | 29.73 | 0.74 |
| Sausal | 2 | 4 | 100YR P | 1041.00 | 187.02 | 192.40 | | 193.67 | 0.029758 | 9.63 | 8.36 | 121.38 | 29.28 | 0.75 |
| Sausal | 2 | 4 | 25YR E | 913.10 | 187.02 | 191.92 | | 193.16 | 0.032724 | 9.47 | 8.33 | 107.57 | 28.34 | 0.77 |
| Sausal | 2 | 4 | 25YR P | 899.60 | 187.02 | 191.87 | | 193.10 | 0.033080 | 9.45 | 8.33 | 106.11 | 28.24 | 0.77 |
| Sausal | 2 | 4 | 10YR E | 789.70 | 187.02 | 191.46 | | 192.64 | 0.035798 | 9.24 | 8.22 | 94.67 | 27.44 | 0.79 |
| Sausal | 2 | 4 | 10YR P | 754.70 | 187.02 | 191.32 | | 192.49 | 0.036863 | 9.17 | 8.19 | 90.94 | 27.17 | 0.80 |
| Sausal | 2 | 4 | 5YR E | 538.30 | 187.02 | 190.42 | 190.21 | 191.50 | 0.046685 | 8.73 | 8.06 | 67.15 | 25.40 | 0.86 |
| Sausal | 2 | 4 | 5YR P | 521.80 | 187.02 | 190.34 | 190.15 | 191.42 | 0.047835 | 8.69 | 8.07 | 65.25 | 25.24 | 0.87 |
| Sausal | 2 | 4 | 2YR E | 363.20 | 187.02 | 189.58 | 189.58 | 190.59 | 0.064538 | 8.36 | 8.20 | 46.61 | 23.58 | 0.97 |
| Sausal | 2 | 4 | 2YR P | 358.10 | 187.02 | 189.56 | 189.56 | 190.56 | 0.064660 | 8.32 | 8.14 | 46.15 | 23.54 | 0.96 |
| Sausal | 2 | 4 | 1YR E | 58.85 | 187.02 | 187.94 | 187.94 | 188.32 | 0.097196 | 4.96 | 4.15 | 11.96 | 16.25 | 1.00 |
| Sausal | 2 | 4 | 1YR P | 53.78 | 187.02 | 187.89 | 187.89 | 188.25 | 0.099136 | 4.83 | 4.01 | 11.21 | 15.95 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 3 | 100YR E | 1106.10 | 182.75 | 190.31 | | 191.76 | 0.021110 | 9.92 | 8.02 | 126.61 | 23.90 | 0.66 |
| Sausal | 2 | 3 | 100YR P | 1041.00 | 182.75 | 190.10 | | 191.48 | 0.020924 | 9.68 | 7.71 | 121.58 | 23.46 | 0.65 |

HEC-RAS Plan: Scenario1 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 3 | 25YR E | 913.10 | 182.75 | 189.66 | | 190.91 | 0.020506 | 9.17 | 7.06 | 111.46 | 22.56 | 0.64 |
| Sausal | 2 | 3 | 25YR P | 899.60 | 182.75 | 189.61 | | 190.84 | 0.020456 | 9.11 | 6.99 | 110.38 | 22.46 | 0.64 |
| Sausal | 2 | 3 | 10YR E | 789.70 | 182.75 | 189.21 | | 190.32 | 0.020001 | 8.61 | 6.40 | 101.42 | 21.63 | 0.62 |
| Sausal | 2 | 3 | 10YR P | 754.70 | 182.75 | 189.07 | | 190.14 | 0.019837 | 8.45 | 6.20 | 98.51 | 21.35 | 0.62 |
| Sausal | 2 | 3 | 5YR E | 538.30 | 182.75 | 188.14 | | 188.95 | 0.018665 | 7.29 | 4.89 | 79.57 | 19.44 | 0.58 |
| Sausal | 2 | 3 | 5YR P | 521.80 | 182.75 | 188.07 | | 188.85 | 0.018526 | 7.19 | 4.78 | 78.11 | 19.34 | 0.58 |
| Sausal | 2 | 3 | 2YR E | 363.20 | 182.75 | 187.21 | | 187.78 | 0.017474 | 6.12 | 3.70 | 62.09 | 17.98 | 0.55 |
| Sausal | 2 | 3 | 2YR P | 358.10 | 182.75 | 187.18 | | 187.74 | 0.017461 | 6.08 | 3.67 | 61.53 | 17.92 | 0.54 |
| Sausal | 2 | 3 | 1YR E | 58.85 | 182.75 | 184.38 | | 184.56 | 0.022373 | 3.41 | 1.64 | 17.30 | 13.96 | 0.54 |
| Sausal | 2 | 3 | 1YR P | 53.78 | 182.75 | 184.30 | | 184.47 | 0.023027 | 3.33 | 1.59 | 16.19 | 13.85 | 0.54 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 2 | 100YR E | 1106.10 | 176.58 | 184.58 | | 185.68 | 0.018574 | 9.51 | 7.28 | 143.26 | 29.05 | 0.60 |
| Sausal | 2 | 2 | 100YR P | 1041.00 | 176.58 | 184.36 | | 185.43 | 0.018648 | 9.34 | 7.10 | 136.87 | 28.70 | 0.60 |
| Sausal | 2 | 2 | 25YR E | 913.10 | 176.58 | 183.90 | | 184.91 | 0.018805 | 9.00 | 6.72 | 124.00 | 27.98 | 0.60 |
| Sausal | 2 | 2 | 25YR P | 899.60 | 176.58 | 183.85 | | 184.85 | 0.018827 | 8.96 | 6.68 | 122.60 | 27.90 | 0.60 |
| Sausal | 2 | 2 | 10YR E | 789.70 | 176.58 | 183.43 | | 184.37 | 0.019054 | 8.64 | 6.35 | 110.95 | 27.22 | 0.60 |
| Sausal | 2 | 2 | 10YR P | 754.70 | 176.58 | 183.29 | | 184.21 | 0.019146 | 8.54 | 6.25 | 107.13 | 27.00 | 0.60 |
| Sausal | 2 | 2 | 5YR E | 538.30 | 176.58 | 182.32 | | 183.13 | 0.019964 | 7.82 | 5.53 | 81.89 | 24.68 | 0.59 |
| Sausal | 2 | 2 | 5YR P | 521.80 | 176.58 | 182.23 | | 183.03 | 0.020096 | 7.76 | 5.47 | 79.74 | 24.34 | 0.59 |
| Sausal | 2 | 2 | 2YR E | 363.20 | 176.58 | 181.33 | | 182.01 | 0.020947 | 7.00 | 4.74 | 59.40 | 20.77 | 0.59 |
| Sausal | 2 | 2 | 2YR P | 358.10 | 176.58 | 181.30 | | 181.98 | 0.020956 | 6.97 | 4.71 | 58.75 | 20.65 | 0.59 |
| Sausal | 2 | 2 | 1YR E | 58.85 | 176.58 | 178.63 | | 178.80 | 0.016440 | 3.37 | 1.49 | 17.53 | 10.51 | 0.45 |
| Sausal | 2 | 2 | 1YR P | 53.78 | 176.58 | 178.54 | | 178.70 | 0.016103 | 3.24 | 1.40 | 16.63 | 10.25 | 0.44 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 1 | 100YR E | 1106.10 | 175.30 | 182.78 | 180.57 | 183.67 | 0.015003 | 7.74 | 5.07 | 153.91 | 29.79 | 0.52 |
| Sausal | 2 | 1 | 100YR P | 1041.00 | 175.30 | 182.56 | 180.30 | 183.41 | 0.015004 | 7.57 | 4.91 | 147.34 | 29.28 | 0.52 |
| Sausal | 2 | 1 | 25YR E | 913.10 | 175.30 | 182.10 | 179.93 | 182.88 | 0.015009 | 7.22 | 4.57 | 134.11 | 28.21 | 0.51 |
| Sausal | 2 | 1 | 25YR P | 899.60 | 175.30 | 182.05 | 179.89 | 182.82 | 0.015009 | 7.18 | 4.54 | 132.69 | 28.09 | 0.51 |
| Sausal | 2 | 1 | 10YR E | 789.70 | 175.30 | 181.62 | 179.55 | 182.33 | 0.015018 | 6.85 | 4.22 | 120.85 | 27.10 | 0.50 |
| Sausal | 2 | 1 | 10YR P | 754.70 | 175.30 | 181.47 | 179.44 | 182.17 | 0.015023 | 6.74 | 4.12 | 116.99 | 26.77 | 0.50 |
| Sausal | 2 | 1 | 5YR E | 538.30 | 175.30 | 180.49 | 178.70 | 181.03 | 0.015008 | 5.93 | 3.40 | 91.77 | 23.15 | 0.49 |
| Sausal | 2 | 1 | 5YR P | 521.80 | 175.30 | 180.40 | 178.65 | 180.93 | 0.015018 | 5.86 | 3.34 | 89.80 | 20.56 | 0.49 |
| Sausal | 2 | 1 | 2YR E | 363.20 | 175.30 | 179.46 | 178.02 | 179.87 | 0.015017 | 5.16 | 2.76 | 70.73 | 20.07 | 0.48 |
| Sausal | 2 | 1 | 2YR P | 358.10 | 175.30 | 179.43 | 178.00 | 179.83 | 0.015018 | 5.13 | 2.74 | 70.08 | 20.05 | 0.48 |
| Sausal | 2 | 1 | 1YR E | 58.85 | 175.30 | 176.83 | 176.25 | 176.95 | 0.015024 | 2.77 | 1.09 | 21.24 | 16.74 | 0.43 |
| Sausal | 2 | 1 | 1YR P | 53.78 | 175.30 | 176.76 | 176.21 | 176.87 | 0.015019 | 2.69 | 1.04 | 20.02 | 16.60 | 0.43 |
| | | | | | | | | | | | | | | |
| Palo Seco | 1 | 37 | 100YR E | 133.20 | 481.72 | 484.61 | 484.55 | 485.23 | 0.039095 | 7.03 | 5.58 | 23.68 | 16.17 | 0.79 |
| Palo Seco | 1 | 37 | 100YR P | 112.30 | 481.72 | 484.46 | 484.37 | 485.01 | 0.037160 | 6.57 | 4.97 | 21.23 | 15.83 | 0.76 |
| Palo Seco | 1 | 37 | 25YR E | 100.80 | 481.72 | 484.36 | 484.19 | 484.88 | 0.036003 | 6.29 | 4.63 | 19.78 | 15.62 | 0.75 |
| Palo Seco | 1 | 37 | 25YR P | 84.00 | 481.72 | 484.21 | 484.00 | 484.66 | 0.034062 | 5.83 | 4.07 | 17.45 | 14.51 | 0.72 |
| Palo Seco | 1 | 37 | 10YR E | 80.20 | 481.72 | 484.17 | 483.95 | 484.61 | 0.033735 | 5.73 | 3.95 | 16.87 | 14.20 | 0.71 |
| Palo Seco | 1 | 37 | 10YR P | 67.20 | 481.72 | 484.02 | 483.76 | 484.41 | 0.032177 | 5.32 | 3.50 | 14.89 | 13.10 | 0.69 |
| Palo Seco | 1 | 37 | 5YR E | 64.90 | 481.72 | 483.99 | 483.72 | 484.37 | 0.032137 | 5.26 | 3.44 | 14.48 | 12.86 | 0.68 |
| Palo Seco | 1 | 37 | 5YR P | 54.00 | 481.72 | 483.84 | 483.53 | 484.18 | 0.031159 | 4.90 | 3.06 | 12.65 | 11.73 | 0.66 |
| Palo Seco | 1 | 37 | 2YR E | 44.80 | 481.72 | 483.70 | 483.35 | 483.99 | 0.030325 | 4.55 | 2.72 | 11.02 | 10.63 | 0.64 |
| Palo Seco | 1 | 37 | 2YR P | 37.20 | 481.72 | 483.56 | 483.20 | 483.82 | 0.029835 | 4.23 | 2.44 | 9.60 | 9.56 | 0.63 |
| Palo Seco | 1 | 37 | 1YR E | 6.72 | 481.72 | 482.42 | 482.42 | 482.62 | 0.108057 | 3.60 | 2.63 | 1.90 | 4.95 | 1.00 |
| Palo Seco | 1 | 37 | 1YR P | 5.79 | 481.72 | 482.38 | 482.38 | 482.56 | 0.110279 | 3.48 | 2.51 | 1.69 | 4.70 | 1.00 |
| | | | | | | | | | | | | | | |
| Palo Seco | 1 | 36 | 100YR E | 133.20 | 438.09 | 440.15 | 440.15 | 440.83 | 0.061643 | 6.71 | 5.82 | 20.86 | 16.76 | 0.95 |
| Palo Seco | 1 | 36 | 100YR P | 112.30 | 438.09 | 439.98 | 439.98 | 440.61 | 0.065832 | 6.42 | 5.54 | 18.11 | 15.69 | 0.96 |
| Palo Seco | 1 | 36 | 25YR E | 100.80 | 438.09 | 439.88 | 439.88 | 440.48 | 0.068705 | 6.24 | 5.37 | 16.59 | 15.07 | 0.97 |
| Palo Seco | 1 | 36 | 25YR P | 84.00 | 438.09 | 439.73 | 439.73 | 440.27 | 0.074348 | 5.96 | 5.11 | 14.31 | 14.09 | 0.99 |
| Palo Seco | 1 | 36 | 10YR E | 80.20 | 438.09 | 439.69 | 439.69 | 440.23 | 0.075380 | 5.87 | 5.02 | 13.83 | 13.87 | 0.99 |
| Palo Seco | 1 | 36 | 10YR P | 67.20 | 438.09 | 439.56 | 439.56 | 440.05 | 0.080991 | 5.60 | 4.76 | 12.08 | 13.06 | 1.00 |
| Palo Seco | 1 | 36 | 5YR E | 64.90 | 438.09 | 439.54 | 439.54 | 440.02 | 0.081116 | 5.53 | 4.67 | 11.80 | 12.95 | 1.00 |
| Palo Seco | 1 | 36 | 5YR P | 54.00 | 438.09 | 439.42 | 439.42 | 439.85 | 0.085137 | 5.27 | 4.39 | 10.28 | 12.42 | 1.01 |
| Palo Seco | 1 | 36 | 2YR E | 44.80 | 438.09 | 439.31 | 439.31 | 439.70 | 0.088917 | 4.99 | 4.10 | 8.97 | 11.95 | 1.01 |
| Palo Seco | 1 | 36 | 2YR P | 37.20 | 438.09 | 439.22 | 439.22 | 439.57 | 0.091248 | 4.74 | 3.81 | 7.85 | 11.44 | 1.01 |
| Palo Seco | 1 | 36 | 1YR E | 6.72 | 438.09 | 438.96 | 438.61 | 438.98 | 0.009925 | 1.32 | 0.32 | 5.11 | 9.66 | 0.32 |
| Palo Seco | 1 | 36 | 1YR P | 5.79 | 438.09 | 439.03 | 438.57 | 439.04 | 0.005130 | 1.00 | 0.18 | 5.81 | 10.14 | 0.23 |

HEC-RAS Plan: Scenario2

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 1 | 38.2 | 100YR E | 610.90 | 414.89 | 419.73 | | 420.62 | 0.023857 | 8.01 | 5.99 | 86.20 | 26.76 | 0.67 |
| Sausal | 1 | 38.2 | 100YR P | 538.60 | 414.89 | 419.38 | | 420.25 | 0.025230 | 7.81 | 5.85 | 77.17 | 25.82 | 0.68 |
| Sausal | 1 | 38.2 | 25YR E | 420.70 | 414.89 | 418.81 | | 419.60 | 0.027200 | 7.35 | 5.44 | 62.91 | 24.24 | 0.69 |
| Sausal | 1 | 38.2 | 25YR P | 421.00 | 414.89 | 418.79 | | 419.59 | 0.028119 | 7.43 | 5.58 | 62.19 | 24.16 | 0.70 |
| Sausal | 1 | 38.2 | 10YR E | 346.30 | 414.89 | 418.38 | | 419.12 | 0.030364 | 7.11 | 5.32 | 52.52 | 22.90 | 0.71 |
| Sausal | 1 | 38.2 | 10YR P | 353.20 | 414.89 | 418.40 | | 419.16 | 0.030794 | 7.19 | 5.44 | 53.01 | 23.00 | 0.71 |
| Sausal | 1 | 38.2 | 5YR E | 284.90 | 414.89 | 417.99 | | 418.69 | 0.033514 | 6.84 | 5.15 | 43.99 | 21.04 | 0.73 |
| Sausal | 1 | 38.2 | 5YR P | 284.70 | 414.89 | 417.99 | | 418.69 | 0.033251 | 6.82 | 5.12 | 44.10 | 21.07 | 0.73 |
| Sausal | 1 | 38.2 | 2YR E | 195.70 | 414.89 | 417.88 | 417.01 | 418.24 | 0.018351 | 4.92 | 2.71 | 41.71 | 20.52 | 0.54 |
| Sausal | 1 | 38.2 | 2YR P | 199.90 | 414.89 | 417.95 | 417.04 | 418.31 | 0.017335 | 4.87 | 2.63 | 43.22 | 20.87 | 0.52 |
| Sausal | 1 | 38.2 | 1YR E | 35.60 | 414.89 | 416.20 | | 416.30 | 0.014794 | 2.48 | 0.91 | 14.38 | 13.62 | 0.42 |
| Sausal | 1 | 38.2 | 1YR P | 23.30 | 414.89 | 415.76 | | 415.87 | 0.032538 | 2.75 | 1.30 | 8.48 | 12.82 | 0.60 |
| | | | | | | | | | | | | | | |
| Sausal | 1 | 38 | 100YR E | 610.90 | 412.89 | 419.03 | | 419.48 | 0.008824 | 5.77 | 2.86 | 123.43 | 30.36 | 0.42 |
| Sausal | 1 | 38 | 100YR P | 538.60 | 412.89 | 418.66 | | 419.08 | 0.008902 | 5.55 | 2.70 | 112.31 | 29.33 | 0.42 |
| Sausal | 1 | 38 | 25YR E | 420.70 | 412.89 | 418.11 | | 418.45 | 0.008274 | 4.98 | 2.25 | 96.48 | 27.80 | 0.40 |
| Sausal | 1 | 38 | 25YR P | 421.00 | 412.89 | 418.01 | | 418.37 | 0.008950 | 5.11 | 2.39 | 93.83 | 27.54 | 0.41 |
| Sausal | 1 | 38 | 10YR E | 346.30 | 412.89 | 417.59 | | 417.91 | 0.008639 | 4.72 | 2.10 | 82.58 | 26.39 | 0.40 |
| Sausal | 1 | 38 | 10YR P | 353.20 | 412.89 | 417.55 | | 417.88 | 0.009382 | 4.88 | 2.26 | 81.31 | 26.25 | 0.42 |
| Sausal | 1 | 38 | 5YR E | 284.90 | 412.89 | 417.02 | | 417.33 | 0.010135 | 4.65 | 2.14 | 67.78 | 24.79 | 0.42 |
| Sausal | 1 | 38 | 5YR P | 284.70 | 412.89 | 416.83 | | 417.18 | 0.012318 | 4.95 | 2.47 | 63.16 | 24.27 | 0.46 |
| Sausal | 1 | 38 | 2YR E | 195.70 | 412.89 | 415.09 | 415.01 | 415.90 | 0.063760 | 7.23 | 6.57 | 27.19 | 15.94 | 0.94 |
| Sausal | 1 | 38 | 2YR P | 199.90 | 412.89 | 415.04 | 415.04 | 415.93 | 0.072834 | 7.59 | 7.31 | 26.42 | 15.64 | 1.00 |
| Sausal | 1 | 38 | 1YR E | 35.60 | 412.89 | 413.71 | 413.71 | 414.03 | 0.094903 | 4.51 | 3.57 | 7.90 | 12.73 | 1.01 |
| Sausal | 1 | 38 | 1YR P | 23.30 | 412.89 | 413.85 | | 413.94 | 0.021256 | 2.40 | 0.95 | 9.72 | 12.99 | 0.49 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35.5 | 100YR E | 744.00 | 409.89 | 418.90 | 414.44 | 419.11 | 0.002629 | 4.12 | 1.28 | 222.48 | 38.95 | 0.25 |
| Sausal | 2 | 35.5 | 100YR P | 650.80 | 409.89 | 418.55 | 414.15 | 418.73 | 0.002385 | 3.82 | 1.11 | 208.83 | 37.82 | 0.23 |
| Sausal | 2 | 35.5 | 25YR E | 521.30 | 409.89 | 418.01 | 413.70 | 418.15 | 0.002007 | 3.35 | 0.87 | 188.89 | 36.09 | 0.21 |
| Sausal | 2 | 35.5 | 25YR P | 504.60 | 409.89 | 417.92 | 413.64 | 418.06 | 0.001963 | 3.29 | 0.84 | 185.91 | 35.82 | 0.21 |
| Sausal | 2 | 35.5 | 10YR E | 426.30 | 409.89 | 417.51 | 413.29 | 417.63 | 0.001745 | 2.99 | 0.71 | 171.45 | 34.51 | 0.20 |
| Sausal | 2 | 35.5 | 10YR P | 420.30 | 409.89 | 417.48 | 413.26 | 417.59 | 0.001732 | 2.97 | 0.70 | 170.15 | 34.39 | 0.19 |
| Sausal | 2 | 35.5 | 5YR E | 349.80 | 409.89 | 416.95 | 412.93 | 417.05 | 0.001620 | 2.73 | 0.61 | 152.43 | 32.89 | 0.19 |
| Sausal | 2 | 35.5 | 5YR P | 338.50 | 409.89 | 416.77 | 412.87 | 416.87 | 0.001688 | 2.74 | 0.62 | 146.60 | 32.40 | 0.19 |
| Sausal | 2 | 35.5 | 2YR E | 240.40 | 409.89 | 415.12 | 412.30 | 415.23 | 0.002676 | 2.83 | 0.73 | 96.81 | 27.84 | 0.23 |
| Sausal | 2 | 35.5 | 2YR P | 236.30 | 409.89 | 415.05 | 412.28 | 415.16 | 0.002728 | 2.84 | 0.73 | 94.96 | 27.65 | 0.23 |
| Sausal | 2 | 35.5 | 1YR E | 42.26 | 409.89 | 411.20 | 410.79 | 411.33 | 0.021191 | 2.96 | 1.30 | 14.30 | 13.61 | 0.51 |
| Sausal | 2 | 35.5 | 1YR P | 28.20 | 409.89 | 410.62 | 410.62 | 410.89 | 0.099007 | 4.19 | 3.24 | 6.73 | 12.57 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35.4 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35 | 100YR E | 744.00 | 326.57 | 333.99 | 332.00 | 334.59 | 0.011608 | 6.57 | 3.72 | 129.86 | 33.92 | 0.47 |
| Sausal | 2 | 35 | 100YR P | 650.80 | 326.57 | 333.63 | | 334.18 | 0.011314 | 6.23 | 3.41 | 118.09 | 31.99 | 0.46 |
| Sausal | 2 | 35 | 25YR E | 521.30 | 326.57 | 333.07 | | 333.54 | 0.010885 | 5.71 | 2.96 | 100.85 | 28.93 | 0.44 |
| Sausal | 2 | 35 | 25YR P | 504.60 | 326.57 | 332.99 | | 333.45 | 0.010812 | 5.63 | 2.90 | 98.60 | 28.51 | 0.44 |
| Sausal | 2 | 35 | 10YR E | 426.30 | 326.57 | 332.59 | | 333.00 | 0.010468 | 5.26 | 2.59 | 87.72 | 26.37 | 0.42 |
| Sausal | 2 | 35 | 10YR P | 420.30 | 326.57 | 332.56 | | 332.96 | 0.010439 | 5.22 | 2.57 | 86.87 | 26.20 | 0.42 |
| Sausal | 2 | 35 | 5YR E | 349.80 | 326.57 | 332.15 | | 332.50 | 0.010083 | 4.84 | 2.27 | 76.68 | 24.03 | 0.41 |
| Sausal | 2 | 35 | 5YR P | 338.50 | 326.57 | 332.08 | | 332.43 | 0.010016 | 4.77 | 2.22 | 75.03 | 23.71 | 0.41 |
| Sausal | 2 | 35 | 2YR E | 240.40 | 326.57 | 331.41 | 329.60 | 331.67 | 0.009409 | 4.12 | 1.75 | 60.02 | 20.56 | 0.38 |
| Sausal | 2 | 35 | 2YR P | 236.30 | 326.57 | 331.37 | 329.56 | 331.63 | 0.009389 | 4.09 | 1.73 | 59.34 | 20.40 | 0.38 |
| Sausal | 2 | 35 | 1YR E | 42.26 | 326.57 | 328.94 | | 329.00 | 0.006819 | 2.08 | 0.58 | 20.33 | 13.39 | 0.30 |
| Sausal | 2 | 35 | 1YR P | 28.20 | 326.57 | 328.60 | 327.73 | 328.65 | 0.006433 | 1.78 | 0.45 | 15.85 | 12.88 | 0.28 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 34 | 100YR E | 744.00 | 321.02 | 324.23 | 324.23 | 325.59 | 0.049890 | 9.85 | 9.82 | 83.39 | 31.82 | 0.98 |
| Sausal | 2 | 34 | 100YR P | 650.80 | 321.02 | 323.98 | 323.98 | 325.24 | 0.051668 | 9.47 | 9.35 | 75.39 | 31.02 | 0.98 |
| Sausal | 2 | 34 | 25YR E | 521.30 | 321.02 | 323.61 | 323.61 | 324.72 | 0.053972 | 8.84 | 8.53 | 64.16 | 29.87 | 0.98 |
| Sausal | 2 | 34 | 25YR P | 504.60 | 321.02 | 323.56 | 323.56 | 324.65 | 0.054307 | 8.75 | 8.41 | 62.67 | 29.72 | 0.98 |
| Sausal | 2 | 34 | 10YR E | 426.30 | 321.02 | 323.31 | 323.31 | 324.30 | 0.056276 | 8.31 | 7.85 | 55.44 | 28.95 | 0.98 |
| Sausal | 2 | 34 | 10YR P | 420.30 | 321.02 | 323.29 | 323.29 | 324.27 | 0.056485 | 8.28 | 7.81 | 54.86 | 28.88 | 0.98 |
| Sausal | 2 | 34 | 5YR E | 349.80 | 321.02 | 323.06 | 323.06 | 323.94 | 0.058499 | 7.81 | 7.22 | 48.11 | 28.15 | 0.98 |
| Sausal | 2 | 34 | 5YR P | 338.50 | 321.02 | 323.02 | 323.02 | 323.88 | 0.058898 | 7.73 | 7.12 | 46.99 | 28.02 | 0.98 |
| Sausal | 2 | 34 | 2YR E | 240.40 | 321.02 | 322.65 | 322.65 | 323.35 | 0.062821 | 6.94 | 6.15 | 36.86 | 26.85 | 0.98 |
| Sausal | 2 | 34 | 2YR P | 236.30 | 321.02 | 322.63 | 322.63 | 323.33 | 0.062793 | 6.89 | 6.09 | 36.46 | 26.81 | 0.97 |
| Sausal | 2 | 34 | 1YR E | 42.26 | 321.02 | 321.59 | 321.59 | 321.83 | 0.093716 | 4.00 | 2.98 | 10.79 | 22.29 | 0.99 |
| Sausal | 2 | 34 | 1YR P | 28.20 | 321.02 | 321.47 | 321.47 | 321.66 | 0.103037 | 3.51 | 2.51 | 8.16 | 21.77 | 0.99 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 33 | 100YR E | 744.00 | 316.37 | 321.77 | | 323.02 | 0.021837 | 9.15 | 7.16 | 88.07 | 18.73 | 0.70 |
| Sausal | 2 | 33 | 100YR P | 650.80 | 316.37 | 321.64 | | 322.65 | 0.018141 | 8.21 | 5.81 | 85.73 | 18.64 | 0.64 |
| Sausal | 2 | 33 | 25YR E | 521.30 | 316.37 | 321.38 | | 322.10 | 0.013942 | 6.95 | 4.23 | 80.83 | 18.44 | 0.55 |
| Sausal | 2 | 33 | 25YR P | 504.60 | 316.37 | 321.35 | | 322.04 | 0.013314 | 6.76 | 4.02 | 80.33 | 18.42 | 0.54 |
| Sausal | 2 | 33 | 10YR E | 426.30 | 316.37 | 321.13 | | 321.67 | 0.011153 | 6.00 | 3.21 | 76.26 | 18.25 | 0.49 |
| Sausal | 2 | 33 | 10YR P | 420.30 | 316.37 | 321.11 | | 321.64 | 0.010941 | 5.93 | 3.14 | 76.03 | 18.24 | 0.49 |
| Sausal | 2 | 33 | 5YR E | 349.80 | 316.37 | 320.90 | | 321.30 | 0.008928 | 5.19 | 2.44 | 72.10 | 18.08 | 0.44 |
| Sausal | 2 | 33 | 5YR P | 338.50 | 316.37 | 320.86 | | 321.25 | 0.008619 | 5.07 | 2.34 | 71.39 | 18.05 | 0.43 |
| Sausal | 2 | 33 | 2YR E | 240.40 | 316.37 | 320.43 | | 320.67 | 0.006187 | 4.01 | 1.51 | 63.71 | 17.73 | 0.36 |
| Sausal | 2 | 33 | 2YR P | 236.30 | 316.37 | 320.41 | | 320.65 | 0.006064 | 3.95 | 1.48 | 63.42 | 17.72 | 0.35 |
| Sausal | 2 | 33 | 1YR E | 42.26 | 316.37 | 317.14 | 317.14 | 317.45 | 0.090840 | 4.52 | 3.55 | 9.41 | 15.25 | 1.01 |
| Sausal | 2 | 33 | 1YR P | 28.20 | 316.37 | 316.99 | 316.99 | 317.23 | 0.098847 | 3.94 | 2.96 | 7.18 | 15.14 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 32 | 100YR E | 744.00 | 314.08 | 322.36 | 317.39 | 322.48 | 0.001388 | 2.93 | 0.65 | 287.21 | 53.40 | 0.19 |
| Sausal | 2 | 32 | 100YR P | 650.80 | 314.08 | 322.11 | 317.17 | 322.21 | 0.001206 | 2.67 | 0.55 | 273.86 | 51.60 | 0.17 |
| Sausal | 2 | 32 | 25YR E | 521.30 | 314.08 | 321.70 | 316.83 | 321.77 | 0.000955 | 2.29 | 0.41 | 253.32 | 48.71 | 0.15 |
| Sausal | 2 | 32 | 25YR P | 504.60 | 314.08 | 321.65 | 316.79 | 321.72 | 0.000916 | 2.23 | 0.39 | 251.11 | 48.39 | 0.15 |
| Sausal | 2 | 32 | 10YR E | 426.30 | 314.08 | 321.36 | 316.58 | 321.42 | 0.000765 | 1.98 | 0.31 | 237.25 | 46.32 | 0.14 |
| Sausal | 2 | 32 | 10YR P | 420.30 | 314.08 | 321.34 | 316.56 | 321.40 | 0.000750 | 1.96 | 0.30 | 236.42 | 46.19 | 0.13 |
| Sausal | 2 | 32 | 5YR E | 349.80 | 314.08 | 321.07 | 316.34 | 321.11 | 0.000605 | 1.71 | 0.24 | 224.00 | 44.25 | 0.12 |
| Sausal | 2 | 32 | 5YR P | 338.50 | 314.08 | 321.02 | 316.30 | 321.06 | 0.000582 | 1.67 | 0.22 | 221.91 | 43.91 | 0.12 |
| Sausal | 2 | 32 | 2YR E | 240.40 | 314.08 | 320.53 | 315.94 | 320.55 | 0.000390 | 1.29 | 0.14 | 201.12 | 40.82 | 0.10 |
| Sausal | 2 | 32 | 2YR P | 236.30 | 314.08 | 320.51 | 315.93 | 320.53 | 0.000382 | 1.27 | 0.14 | 200.34 | 40.78 | 0.09 |
| Sausal | 2 | 32 | 1YR E | 42.26 | 314.08 | 316.80 | 314.92 | 316.81 | 0.000432 | 0.68 | 0.05 | 63.95 | 32.87 | 0.08 |
| Sausal | 2 | 32 | 1YR P | 28.20 | 314.08 | 316.27 | 314.80 | 316.27 | 0.000498 | 0.61 | 0.05 | 46.82 | 30.61 | 0.09 |
| | | | | | | | | | | | | | | |

HEC-RAS Plan: Scenario2 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 31.5 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 30 | 100YR E | 744.00 | 300.16 | 302.61 | 302.61 | 303.70 | 0.054861 | 8.59 | 8.20 | 91.38 | 42.92 | 0.98 |
| Sausal | 2 | 30 | 100YR P | 650.80 | 300.16 | 302.41 | 302.41 | 303.42 | 0.056794 | 8.25 | 7.79 | 82.94 | 42.25 | 0.98 |
| Sausal | 2 | 30 | 25YR E | 521.30 | 300.16 | 302.11 | 302.11 | 303.00 | 0.060048 | 7.71 | 7.13 | 70.67 | 41.05 | 0.99 |
| Sausal | 2 | 30 | 25YR P | 504.60 | 300.16 | 302.08 | 302.08 | 302.94 | 0.060259 | 7.62 | 7.01 | 69.14 | 40.89 | 0.98 |
| Sausal | 2 | 30 | 10YR E | 426.30 | 300.16 | 301.88 | 301.88 | 302.67 | 0.063087 | 7.24 | 6.57 | 61.21 | 40.09 | 0.99 |
| Sausal | 2 | 30 | 10YR P | 420.30 | 300.16 | 301.86 | 301.86 | 302.64 | 0.063348 | 7.21 | 6.54 | 60.58 | 40.03 | 0.99 |
| Sausal | 2 | 30 | 5YR E | 349.80 | 300.16 | 301.68 | 301.68 | 302.38 | 0.065738 | 6.79 | 6.03 | 53.31 | 39.28 | 0.99 |
| Sausal | 2 | 30 | 5YR P | 338.50 | 300.16 | 301.65 | 301.65 | 302.33 | 0.066436 | 6.73 | 5.96 | 52.05 | 39.15 | 0.99 |
| Sausal | 2 | 30 | 2YR E | 240.40 | 300.16 | 301.40 | 301.36 | 301.91 | 0.064925 | 5.85 | 4.80 | 42.29 | 38.11 | 0.95 |
| Sausal | 2 | 30 | 2YR P | 236.30 | 300.16 | 301.39 | 301.34 | 301.90 | 0.064488 | 5.80 | 4.73 | 41.93 | 38.08 | 0.94 |
| Sausal | 2 | 30 | 1YR E | 42.26 | 300.16 | 300.64 | 300.58 | 300.77 | 0.064568 | 2.94 | 1.71 | 14.51 | 35.01 | 0.80 |
| Sausal | 2 | 30 | 1YR P | 28.20 | 300.16 | 300.54 | 300.49 | 300.64 | 0.069142 | 2.56 | 1.41 | 11.11 | 34.61 | 0.79 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 29 | 100YR E | 744.00 | 296.60 | 299.11 | 299.11 | 300.30 | 0.060017 | 8.84 | 8.75 | 85.84 | 36.55 | 1.00 |
| Sausal | 2 | 29 | 100YR P | 650.80 | 296.60 | 298.90 | 298.90 | 300.00 | 0.061702 | 8.48 | 8.28 | 78.18 | 36.25 | 1.00 |
| Sausal | 2 | 29 | 25YR E | 521.30 | 296.60 | 298.59 | 298.59 | 299.54 | 0.064064 | 7.89 | 7.50 | 67.19 | 35.81 | 1.00 |
| Sausal | 2 | 29 | 25YR P | 504.60 | 296.60 | 298.55 | 298.55 | 299.48 | 0.064076 | 7.79 | 7.36 | 65.82 | 35.76 | 1.00 |
| Sausal | 2 | 29 | 10YR E | 426.30 | 296.60 | 298.35 | 298.35 | 299.19 | 0.066932 | 7.41 | 6.90 | 58.41 | 35.42 | 1.00 |
| Sausal | 2 | 29 | 10YR P | 420.30 | 296.60 | 298.33 | 298.33 | 299.16 | 0.067125 | 7.37 | 6.86 | 57.84 | 35.39 | 1.00 |
| Sausal | 2 | 29 | 5YR E | 349.80 | 296.60 | 298.14 | 298.14 | 298.88 | 0.069003 | 6.93 | 6.29 | 51.13 | 35.04 | 1.00 |
| Sausal | 2 | 29 | 5YR P | 338.50 | 296.60 | 298.11 | 298.11 | 298.83 | 0.069671 | 6.86 | 6.22 | 49.94 | 34.97 | 1.00 |
| Sausal | 2 | 29 | 2YR E | 240.40 | 296.60 | 297.80 | 297.80 | 298.39 | 0.074982 | 6.15 | 5.37 | 39.47 | 34.42 | 1.00 |
| Sausal | 2 | 29 | 2YR P | 236.30 | 296.60 | 297.79 | 297.79 | 298.37 | 0.075329 | 6.12 | 5.34 | 39.00 | 34.39 | 1.00 |
| Sausal | 2 | 29 | 1YR E | 42.26 | 296.60 | 297.03 | 296.99 | 297.19 | 0.078240 | 3.15 | 1.99 | 13.45 | 32.99 | 0.87 |
| Sausal | 2 | 29 | 1YR P | 28.20 | 296.60 | 296.95 | | 297.06 | 0.072700 | 2.63 | 1.49 | 10.77 | 32.84 | 0.81 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 28 | 100YR E | 744.00 | 289.82 | 292.39 | 292.37 | 293.55 | 0.055568 | 8.75 | 8.45 | 87.36 | 37.79 | 0.99 |
| Sausal | 2 | 28 | 100YR P | 650.80 | 289.82 | 292.17 | 292.17 | 293.25 | 0.058496 | 8.43 | 8.09 | 79.12 | 37.44 | 1.00 |
| Sausal | 2 | 28 | 25YR E | 521.30 | 289.82 | 291.86 | 291.86 | 292.81 | 0.061644 | 7.84 | 7.36 | 67.85 | 36.96 | 1.00 |
| Sausal | 2 | 28 | 25YR P | 504.60 | 289.82 | 291.82 | 291.82 | 292.75 | 0.062060 | 7.76 | 7.26 | 66.36 | 36.90 | 1.00 |
| Sausal | 2 | 28 | 10YR E | 426.30 | 289.82 | 291.63 | 291.63 | 292.45 | 0.064437 | 7.34 | 6.74 | 59.12 | 36.59 | 1.00 |
| Sausal | 2 | 28 | 10YR P | 420.30 | 289.82 | 291.61 | 291.61 | 292.43 | 0.064660 | 7.31 | 6.70 | 58.54 | 36.56 | 1.00 |
| Sausal | 2 | 28 | 5YR E | 349.80 | 289.82 | 291.42 | 291.42 | 292.15 | 0.067519 | 6.88 | 6.19 | 51.60 | 36.26 | 1.00 |
| Sausal | 2 | 28 | 5YR P | 338.50 | 289.82 | 291.39 | 291.39 | 292.10 | 0.067948 | 6.81 | 6.10 | 50.47 | 36.21 | 1.00 |
| Sausal | 2 | 28 | 2YR E | 240.40 | 289.82 | 291.10 | 291.10 | 291.67 | 0.073628 | 6.09 | 5.27 | 39.94 | 35.75 | 1.00 |
| Sausal | 2 | 28 | 2YR P | 236.30 | 289.82 | 291.08 | 291.08 | 291.65 | 0.073856 | 6.05 | 5.22 | 39.49 | 35.73 | 1.00 |
| Sausal | 2 | 28 | 1YR E | 42.26 | 289.82 | 290.31 | 290.31 | 290.49 | 0.106307 | 3.40 | 2.41 | 12.45 | 34.51 | 0.99 |
| Sausal | 2 | 28 | 1YR P | 28.20 | 289.82 | 290.23 | 290.23 | 290.36 | 0.116192 | 2.97 | 2.01 | 9.50 | 34.38 | 0.99 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 27 | 100YR E | 744.00 | 286.78 | 290.07 | | 291.14 | 0.035203 | 8.43 | 7.13 | 92.80 | 31.30 | 0.82 |
| Sausal | 2 | 27 | 100YR P | 650.80 | 286.78 | 289.88 | | 290.81 | 0.033299 | 7.87 | 6.34 | 86.73 | 30.97 | 0.79 |
| Sausal | 2 | 27 | 25YR E | 521.30 | 286.78 | 289.56 | | 290.31 | 0.031215 | 7.07 | 5.32 | 76.89 | 30.44 | 0.75 |
| Sausal | 2 | 27 | 25YR P | 504.60 | 286.78 | 289.51 | | 290.24 | 0.030920 | 6.97 | 5.19 | 75.55 | 30.36 | 0.75 |
| Sausal | 2 | 27 | 10YR E | 426.30 | 286.78 | 289.29 | | 289.92 | 0.029634 | 6.44 | 4.56 | 68.83 | 29.99 | 0.72 |
| Sausal | 2 | 27 | 10YR P | 420.30 | 286.78 | 289.27 | | 289.89 | 0.029547 | 6.40 | 4.51 | 68.28 | 29.96 | 0.72 |
| Sausal | 2 | 27 | 5YR E | 349.80 | 286.78 | 289.05 | | 289.57 | 0.028408 | 5.88 | 3.94 | 61.59 | 29.58 | 0.70 |
| Sausal | 2 | 27 | 5YR P | 338.50 | 286.78 | 289.01 | | 289.52 | 0.028132 | 5.79 | 3.84 | 60.52 | 29.52 | 0.69 |
| Sausal | 2 | 27 | 2YR E | 240.40 | 286.78 | 288.65 | | 289.02 | 0.026129 | 4.95 | 2.98 | 50.00 | 28.92 | 0.65 |
| Sausal | 2 | 27 | 2YR P | 236.30 | 286.78 | 288.63 | | 289.00 | 0.026054 | 4.91 | 2.94 | 49.51 | 28.89 | 0.64 |
| Sausal | 2 | 27 | 1YR E | 42.26 | 286.78 | 287.52 | | 287.60 | 0.021164 | 2.33 | 0.91 | 18.30 | 27.03 | 0.49 |
| Sausal | 2 | 27 | 1YR P | 28.20 | 286.78 | 287.37 | | 287.43 | 0.020966 | 1.98 | 0.71 | 14.35 | 26.78 | 0.47 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 26 | 100YR E | 744.00 | 281.33 | 284.47 | 284.47 | 285.60 | 0.055120 | 8.61 | 8.24 | 88.67 | 40.09 | 0.98 |
| Sausal | 2 | 26 | 100YR P | 650.80 | 281.33 | 284.25 | 284.25 | 285.31 | 0.058076 | 8.31 | 7.91 | 80.13 | 39.46 | 0.99 |
| Sausal | 2 | 26 | 25YR E | 521.30 | 281.33 | 283.95 | 283.95 | 284.88 | 0.061521 | 7.75 | 7.23 | 68.43 | 38.58 | 0.99 |
| Sausal | 2 | 26 | 25YR P | 504.60 | 281.33 | 283.91 | 283.91 | 284.82 | 0.062089 | 7.67 | 7.14 | 66.86 | 38.46 | 0.99 |
| Sausal | 2 | 26 | 10YR E | 426.30 | 281.33 | 283.72 | 283.72 | 284.53 | 0.064864 | 7.28 | 6.66 | 59.36 | 37.88 | 1.00 |
| Sausal | 2 | 26 | 10YR P | 420.30 | 281.33 | 283.70 | 283.70 | 284.51 | 0.065038 | 7.24 | 6.62 | 58.79 | 37.84 | 1.00 |
| Sausal | 2 | 26 | 5YR E | 349.80 | 281.33 | 283.52 | 283.52 | 284.23 | 0.067586 | 6.81 | 6.10 | 51.83 | 37.29 | 1.00 |
| Sausal | 2 | 26 | 5YR P | 338.50 | 281.33 | 283.48 | 283.48 | 284.19 | 0.068390 | 6.75 | 6.03 | 50.60 | 37.20 | 1.00 |
| Sausal | 2 | 26 | 2YR E | 240.40 | 281.33 | 283.19 | 283.19 | 283.76 | 0.075034 | 6.06 | 5.25 | 39.83 | 36.34 | 1.01 |
| Sausal | 2 | 26 | 2YR P | 236.30 | 281.33 | 283.18 | 283.18 | 283.74 | 0.075327 | 6.03 | 5.21 | 39.37 | 36.30 | 1.01 |
| Sausal | 2 | 26 | 1YR E | 42.26 | 281.33 | 282.27 | 282.27 | 282.52 | 0.101683 | 3.96 | 2.99 | 10.68 | 22.58 | 1.01 |
| Sausal | 2 | 26 | 1YR P | 28.20 | 281.33 | 282.14 | 282.14 | 282.34 | 0.104613 | 3.62 | 2.63 | 7.80 | 19.30 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 25 | 100YR E | 744.00 | 277.43 | 281.93 | | 282.60 | 0.017559 | 6.72 | 4.26 | 118.76 | 35.86 | 0.60 |
| Sausal | 2 | 25 | 100YR P | 650.80 | 277.43 | 281.71 | | 282.29 | 0.016609 | 6.28 | 3.80 | 110.67 | 35.20 | 0.58 |
| Sausal | 2 | 25 | 25YR E | 521.30 | 277.43 | 281.34 | | 281.81 | 0.015356 | 5.63 | 3.16 | 98.08 | 34.15 | 0.54 |
| Sausal | 2 | 25 | 25YR P | 504.60 | 277.43 | 281.30 | | 281.75 | 0.015124 | 5.54 | 3.07 | 96.48 | 34.01 | 0.54 |
| Sausal | 2 | 25 | 10YR E | 426.30 | 277.43 | 281.06 | | 281.44 | 0.014064 | 5.08 | 2.65 | 88.45 | 33.32 | 0.51 |
| Sausal | 2 | 25 | 10YR P | 420.30 | 277.43 | 281.04 | | 281.42 | 0.013984 | 5.04 | 2.62 | 87.80 | 33.26 | 0.51 |
| Sausal | 2 | 25 | 5YR E | 349.80 | 277.43 | 280.79 | | 281.11 | 0.013095 | 4.60 | 2.25 | 79.58 | 32.54 | 0.49 |
| Sausal | 2 | 25 | 5YR P | 338.50 | 277.43 | 280.74 | | 281.05 | 0.013028 | 4.54 | 2.20 | 78.03 | 32.40 | 0.49 |
| Sausal | 2 | 25 | 2YR E | 240.40 | 277.43 | 280.34 | | 280.56 | 0.011395 | 3.82 | 1.64 | 65.31 | 31.24 | 0.44 |
| Sausal | 2 | 25 | 2YR P | 236.30 | 277.43 | 280.32 | | 280.54 | 0.011328 | 3.79 | 1.62 | 64.71 | 31.19 | 0.44 |
| Sausal | 2 | 25 | 1YR E | 42.26 | 277.43 | 278.95 | | 278.99 | 0.007925 | 1.73 | 0.46 | 24.57 | 27.05 | 0.32 |
| Sausal | 2 | 25 | 1YR P | 28.20 | 277.43 | 278.69 | | 278.73 | 0.007497 | 1.55 | 0.38 | 18.26 | 22.66 | 0.30 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 24 | 100YR E | 744.00 | 274.71 | 278.20 | | 278.95 | 0.029080 | 6.99 | 5.14 | 109.54 | 41.75 | 0.73 |
| Sausal | 2 | 24 | 100YR P | 650.80 | 274.71 | 277.94 | | 278.64 | 0.031036 | 6.77 | 4.98 | 98.61 | 41.11 | 0.74 |
| Sausal | 2 | 24 | 25YR E | 521.30 | 274.71 | 277.56 | | 278.18 | 0.034307 | 6.40 | 4.69 | 83.13 | 40.18 | 0.76 |
| Sausal | 2 | 24 | 25YR P | 504.60 | 274.71 | 277.50 | | 278.12 | 0.035103 | 6.36 | 4.67 | 80.88 | 40.04 | 0.77 |
| Sausal | 2 | 24 | 10YR E | 426.30 | 274.71 | 277.24 | 276.97 | 277.82 | 0.039126 | 6.15 | 4.57 | 70.40 | 39.40 | 0.79 |
| Sausal | 2 | 24 | 10YR P | 420.30 | 274.71 | 277.22 | 276.96 | 277.79 | 0.039453 | 6.13 | 4.55 | 69.60 | 39.35 | 0.79 |
| Sausal | 2 | 24 | 5YR E | 349.80 | 274.71 | 276.98 | 276.77 | 277.51 | 0.043313 | 5.87 | 4.36 | 60.36 | 38.78 | 0.81 |
| Sausal | 2 | 24 | 5YR P | 338.50 | 274.71 | 276.95 | 276.74 | 277.46 | 0.043438 | 5.80 | 4.29 | 59.10 | 38.70 | 0.81 |
| Sausal | 2 | 24 | 2YR E | 240.40 | 274.71 | 276.57 | 276.46 | 277.02 | 0.054625 | 5.42 | 4.11 | 44.67 | 37.86 | 0.87 |
| Sausal | 2 | 24 | 2YR P | 236.30 | 274.71 | 276.55 | 276.44 | 277.00 | 0.055244 | 5.40 | 4.10 | 44.05 | 37.82 | 0.87 |
| Sausal | 2 | 24 | 1YR E | 42.26 | 274.71 | 275.57 | 275.57 | 275.79 | 0.103043 | 3.74 | 2.76 | 11.30 | 26.30 | 1.01 |
| Sausal | 2 | 24 | 1YR P | 28.20 | 274.71 | 275.44 | 275.44 | 275.62 | 0.110954 | 3.48 | 2.52 | 8.11 | 22.29 | 1.02 |
| | | | | | | | | | | | | | | |

HEC-RAS Plan: Scenario2 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 23 | 100YR E | 744.00 | 269.26 | 274.25 | 273.46 | 275.12 | 0.019405 | 8.00 | 5.68 | 107.15 | 30.08 | 0.65 |
| Sausal | 2 | 23 | 100YR P | 650.80 | 269.26 | 273.96 | 273.22 | 274.75 | 0.019018 | 7.59 | 5.22 | 98.46 | 29.79 | 0.64 |
| Sausal | 2 | 23 | 25YR E | 521.30 | 269.26 | 273.52 | 272.82 | 274.20 | 0.018413 | 6.96 | 4.55 | 85.45 | 29.34 | 0.61 |
| Sausal | 2 | 23 | 25YR P | 504.60 | 269.26 | 273.47 | 272.69 | 274.13 | 0.018233 | 6.87 | 4.45 | 83.82 | 29.29 | 0.61 |
| Sausal | 2 | 23 | 10YR E | 426.30 | 269.26 | 273.19 | 272.30 | 273.77 | 0.017292 | 6.37 | 3.93 | 75.87 | 29.01 | 0.59 |
| Sausal | 2 | 23 | 10YR P | 420.30 | 269.26 | 273.17 | 272.27 | 273.74 | 0.017233 | 6.34 | 3.89 | 75.20 | 28.99 | 0.59 |
| Sausal | 2 | 23 | 5YR E | 349.80 | 269.26 | 272.87 | 271.87 | 273.38 | 0.016728 | 5.90 | 3.47 | 66.64 | 28.69 | 0.57 |
| Sausal | 2 | 23 | 5YR P | 338.50 | 269.26 | 272.81 | 271.84 | 273.31 | 0.016850 | 5.85 | 3.43 | 64.89 | 28.63 | 0.57 |
| Sausal | 2 | 23 | 2YR E | 240.40 | 269.26 | 272.30 | 271.41 | 272.68 | 0.015787 | 5.06 | 2.71 | 51.41 | 24.23 | 0.54 |
| Sausal | 2 | 23 | 2YR P | 236.30 | 269.26 | 272.28 | 271.39 | 272.66 | 0.015721 | 5.02 | 2.68 | 50.85 | 24.02 | 0.53 |
| Sausal | 2 | 23 | 1YR E | 42.26 | 269.26 | 270.64 | | 270.72 | 0.011504 | 2.34 | 0.79 | 18.35 | 17.61 | 0.39 |
| Sausal | 2 | 23 | 1YR P | 28.20 | 269.26 | 270.41 | | 270.47 | 0.010873 | 1.96 | 0.59 | 14.52 | 17.13 | 0.37 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 22 | 100YR E | 744.00 | 265.90 | 269.08 | 269.08 | 270.47 | 0.049376 | 9.67 | 9.54 | 82.07 | 30.64 | 0.97 |
| Sausal | 2 | 22 | 100YR P | 650.80 | 265.90 | 268.83 | 268.83 | 270.11 | 0.050548 | 9.26 | 9.00 | 74.61 | 30.21 | 0.97 |
| Sausal | 2 | 22 | 25YR E | 521.30 | 265.90 | 268.47 | 268.47 | 269.59 | 0.052520 | 8.62 | 8.15 | 63.71 | 29.57 | 0.96 |
| Sausal | 2 | 22 | 25YR P | 504.60 | 265.90 | 268.41 | 268.41 | 269.51 | 0.053321 | 8.55 | 8.09 | 62.04 | 29.36 | 0.97 |
| Sausal | 2 | 22 | 10YR E | 426.30 | 265.90 | 268.12 | 268.12 | 269.15 | 0.058819 | 8.25 | 7.86 | 53.77 | 27.71 | 0.99 |
| Sausal | 2 | 22 | 10YR P | 420.30 | 265.90 | 268.10 | 268.10 | 269.12 | 0.059187 | 8.22 | 7.83 | 53.17 | 27.59 | 1.00 |
| Sausal | 2 | 22 | 5YR E | 349.80 | 265.90 | 267.85 | 267.85 | 268.77 | 0.062345 | 7.77 | 7.28 | 46.50 | 26.45 | 1.00 |
| Sausal | 2 | 22 | 5YR P | 338.50 | 265.90 | 267.83 | 267.83 | 268.71 | 0.061199 | 7.63 | 7.05 | 45.82 | 26.41 | 0.99 |
| Sausal | 2 | 22 | 2YR E | 240.40 | 265.90 | 267.45 | 267.45 | 268.17 | 0.066528 | 6.84 | 6.11 | 36.06 | 25.77 | 0.99 |
| Sausal | 2 | 22 | 2YR P | 236.30 | 265.90 | 267.44 | 267.44 | 268.14 | 0.066903 | 6.80 | 6.07 | 35.62 | 25.74 | 0.99 |
| Sausal | 2 | 22 | 1YR E | 42.26 | 265.90 | 266.45 | 266.45 | 266.68 | 0.098956 | 3.87 | 2.87 | 11.00 | 24.05 | 1.00 |
| Sausal | 2 | 22 | 1YR P | 28.20 | 265.90 | 266.34 | 266.34 | 266.51 | 0.109356 | 3.39 | 2.42 | 8.35 | 23.86 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 21 | 100YR E | 744.00 | 263.02 | 266.80 | | 267.36 | 0.015384 | 6.13 | 3.59 | 128.14 | 38.09 | 0.56 |
| Sausal | 2 | 21 | 100YR P | 650.80 | 263.02 | 266.55 | | 267.05 | 0.014943 | 5.77 | 3.26 | 118.67 | 37.51 | 0.54 |
| Sausal | 2 | 21 | 25YR E | 521.30 | 263.02 | 266.16 | | 266.57 | 0.014346 | 5.23 | 2.78 | 104.33 | 36.72 | 0.52 |
| Sausal | 2 | 21 | 25YR P | 504.60 | 263.02 | 266.11 | | 266.51 | 0.014271 | 5.15 | 2.72 | 102.35 | 36.61 | 0.52 |
| Sausal | 2 | 21 | 10YR E | 426.30 | 263.02 | 265.84 | | 266.19 | 0.013970 | 4.79 | 2.43 | 92.58 | 36.06 | 0.51 |
| Sausal | 2 | 21 | 10YR P | 420.30 | 263.02 | 265.82 | | 266.16 | 0.013934 | 4.76 | 2.40 | 91.83 | 36.02 | 0.50 |
| Sausal | 2 | 21 | 5YR E | 349.80 | 263.02 | 265.56 | | 265.85 | 0.013536 | 4.39 | 2.11 | 82.51 | 35.49 | 0.49 |
| Sausal | 2 | 21 | 5YR P | 338.50 | 263.02 | 265.51 | | 265.80 | 0.013493 | 4.33 | 2.07 | 80.90 | 35.40 | 0.49 |
| Sausal | 2 | 21 | 2YR E | 240.40 | 263.02 | 265.09 | | 265.30 | 0.013018 | 3.75 | 1.65 | 66.00 | 34.54 | 0.46 |
| Sausal | 2 | 21 | 2YR P | 236.30 | 263.02 | 265.07 | | 265.28 | 0.013002 | 3.72 | 1.63 | 65.32 | 34.49 | 0.46 |
| Sausal | 2 | 21 | 1YR E | 42.26 | 263.02 | 263.80 | | 263.85 | 0.012088 | 1.84 | 0.56 | 23.12 | 31.91 | 0.38 |
| Sausal | 2 | 21 | 1YR P | 28.20 | 263.02 | 263.64 | | 263.67 | 0.012301 | 1.58 | 0.44 | 17.99 | 31.59 | 0.37 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 20 | 100YR E | 744.00 | 260.09 | 264.12 | | 264.81 | 0.022088 | 6.78 | 4.58 | 115.71 | 41.01 | 0.65 |
| Sausal | 2 | 20 | 100YR P | 650.80 | 260.09 | 263.82 | | 264.47 | 0.023411 | 6.56 | 4.42 | 103.78 | 39.51 | 0.66 |
| Sausal | 2 | 20 | 25YR E | 521.30 | 260.09 | 263.41 | | 263.98 | 0.024853 | 6.13 | 4.05 | 87.95 | 37.23 | 0.67 |
| Sausal | 2 | 20 | 25YR P | 504.60 | 260.09 | 263.35 | | 263.91 | 0.025068 | 6.07 | 4.00 | 85.88 | 36.96 | 0.67 |
| Sausal | 2 | 20 | 10YR E | 426.30 | 260.09 | 263.09 | | 263.59 | 0.026086 | 5.75 | 3.73 | 76.11 | 35.84 | 0.67 |
| Sausal | 2 | 20 | 10YR P | 420.30 | 260.09 | 263.07 | | 263.56 | 0.026135 | 5.72 | 3.70 | 75.38 | 35.79 | 0.67 |
| Sausal | 2 | 20 | 5YR E | 349.80 | 260.09 | 262.81 | | 263.25 | 0.027296 | 5.40 | 3.43 | 66.22 | 35.12 | 0.67 |
| Sausal | 2 | 20 | 5YR P | 338.50 | 260.09 | 262.77 | | 263.20 | 0.027427 | 5.34 | 3.37 | 64.77 | 35.02 | 0.67 |
| Sausal | 2 | 20 | 2YR E | 240.40 | 260.09 | 262.39 | | 262.73 | 0.027994 | 4.69 | 2.80 | 51.95 | 34.06 | 0.65 |
| Sausal | 2 | 20 | 2YR P | 236.30 | 260.09 | 262.38 | | 262.71 | 0.028018 | 4.66 | 2.77 | 51.39 | 34.02 | 0.65 |
| Sausal | 2 | 20 | 1YR E | 42.26 | 260.09 | 261.32 | | 261.41 | 0.027646 | 2.45 | 1.06 | 17.22 | 28.06 | 0.55 |
| Sausal | 2 | 20 | 1YR P | 28.20 | 260.09 | 261.15 | 260.91 | 261.23 | 0.027037 | 2.20 | 0.89 | 12.82 | 24.21 | 0.53 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 19 | 100YR E | 744.00 | 255.79 | 260.21 | 260.21 | 261.96 | 0.052958 | 10.71 | 11.31 | 71.95 | 21.33 | 1.00 |
| Sausal | 2 | 19 | 100YR P | 650.80 | 255.79 | 259.91 | 259.91 | 261.52 | 0.054147 | 10.23 | 10.61 | 65.69 | 21.13 | 1.00 |
| Sausal | 2 | 19 | 25YR E | 521.30 | 255.79 | 259.45 | 259.45 | 260.85 | 0.057870 | 9.56 | 9.75 | 56.02 | 20.82 | 1.00 |
| Sausal | 2 | 19 | 25YR P | 504.60 | 255.79 | 259.39 | 259.39 | 260.77 | 0.058278 | 9.45 | 9.61 | 54.78 | 20.78 | 1.00 |
| Sausal | 2 | 19 | 10YR E | 426.30 | 255.79 | 259.10 | 259.10 | 260.33 | 0.060422 | 8.94 | 8.92 | 48.79 | 20.58 | 1.00 |
| Sausal | 2 | 19 | 10YR P | 420.30 | 255.79 | 259.08 | 259.08 | 260.30 | 0.060729 | 8.90 | 8.87 | 48.28 | 20.57 | 1.00 |
| Sausal | 2 | 19 | 5YR E | 349.80 | 255.79 | 258.81 | 258.81 | 259.88 | 0.062181 | 8.34 | 8.09 | 42.79 | 20.38 | 1.00 |
| Sausal | 2 | 19 | 5YR P | 338.50 | 255.79 | 258.76 | 258.76 | 259.81 | 0.062695 | 8.25 | 7.98 | 41.82 | 20.35 | 1.00 |
| Sausal | 2 | 19 | 2YR E | 240.40 | 255.79 | 258.32 | 258.32 | 259.17 | 0.069470 | 7.43 | 6.99 | 32.83 | 20.05 | 1.01 |
| Sausal | 2 | 19 | 2YR P | 236.30 | 255.79 | 258.30 | 258.30 | 259.14 | 0.069790 | 7.38 | 6.94 | 32.44 | 20.04 | 1.01 |
| Sausal | 2 | 19 | 1YR E | 42.26 | 255.79 | 257.12 | 257.12 | 257.42 | 0.098454 | 4.43 | 3.51 | 9.57 | 16.05 | 1.01 |
| Sausal | 2 | 19 | 1YR P | 28.20 | 255.79 | 256.93 | 256.93 | 257.19 | 0.106806 | 4.13 | 3.23 | 6.83 | 13.31 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 18 | 100YR E | 744.00 | 247.75 | 252.62 | 252.32 | 254.29 | 0.039737 | 10.39 | 10.06 | 72.60 | 17.87 | 0.90 |
| Sausal | 2 | 18 | 100YR P | 650.80 | 247.75 | 252.37 | 252.01 | 253.82 | 0.037514 | 9.68 | 8.92 | 68.08 | 17.82 | 0.86 |
| Sausal | 2 | 18 | 25YR E | 521.30 | 247.75 | 251.96 | 251.51 | 253.12 | 0.034935 | 8.67 | 7.43 | 60.76 | 17.74 | 0.82 |
| Sausal | 2 | 18 | 25YR P | 504.60 | 247.75 | 251.90 | 251.45 | 253.03 | 0.034616 | 8.54 | 7.24 | 59.73 | 17.73 | 0.81 |
| Sausal | 2 | 18 | 10YR E | 426.30 | 247.75 | 251.61 | 251.14 | 252.57 | 0.033232 | 7.88 | 6.36 | 54.58 | 17.67 | 0.78 |
| Sausal | 2 | 18 | 10YR P | 420.30 | 247.75 | 251.58 | 251.11 | 252.53 | 0.033148 | 7.83 | 6.29 | 54.15 | 17.67 | 0.78 |
| Sausal | 2 | 18 | 5YR E | 349.80 | 247.75 | 251.28 | 250.80 | 252.09 | 0.032267 | 7.22 | 5.53 | 48.83 | 17.61 | 0.76 |
| Sausal | 2 | 18 | 5YR P | 338.50 | 247.75 | 251.23 | 250.75 | 252.01 | 0.032141 | 7.12 | 5.41 | 47.92 | 17.60 | 0.75 |
| Sausal | 2 | 18 | 2YR E | 240.40 | 247.75 | 250.72 | | 251.31 | 0.032226 | 6.21 | 4.41 | 38.90 | 17.50 | 0.73 |
| Sausal | 2 | 18 | 2YR P | 236.30 | 247.75 | 250.69 | | 251.28 | 0.032218 | 6.17 | 4.37 | 38.50 | 17.50 | 0.73 |
| Sausal | 2 | 18 | 1YR E | 42.26 | 247.75 | 249.16 | 248.94 | 249.33 | 0.035257 | 3.34 | 1.78 | 12.64 | 15.41 | 0.65 |
| Sausal | 2 | 18 | 1YR P | 28.20 | 247.75 | 248.97 | 248.77 | 249.10 | 0.034937 | 2.87 | 1.41 | 9.83 | 14.96 | 0.62 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 17 | 100YR E | 744.00 | 246.75 | 250.67 | 250.67 | 252.14 | 0.048143 | 10.13 | 10.16 | 81.48 | 29.16 | 0.91 |
| Sausal | 2 | 17 | 100YR P | 650.80 | 246.75 | 250.42 | 250.39 | 251.76 | 0.047835 | 9.65 | 9.43 | 74.18 | 28.27 | 0.89 |
| Sausal | 2 | 17 | 25YR E | 521.30 | 246.75 | 250.05 | 249.96 | 251.19 | 0.046305 | 8.83 | 8.19 | 63.98 | 26.99 | 0.86 |
| Sausal | 2 | 17 | 25YR P | 504.60 | 246.75 | 250.00 | 249.89 | 251.12 | 0.046100 | 8.72 | 8.03 | 62.59 | 26.79 | 0.86 |
| Sausal | 2 | 17 | 10YR E | 426.30 | 246.75 | 249.75 | 249.57 | 250.73 | 0.044523 | 8.12 | 7.15 | 56.10 | 25.37 | 0.83 |
| Sausal | 2 | 17 | 10YR P | 420.30 | 246.75 | 249.73 | 249.54 | 250.70 | 0.044366 | 8.07 | 7.08 | 55.60 | 25.25 | 0.83 |
| Sausal | 2 | 17 | 5YR E | 349.80 | 246.75 | 249.48 | 249.23 | 250.32 | 0.042324 | 7.43 | 6.18 | 49.59 | 23.85 | 0.80 |
| Sausal | 2 | 17 | 5YR P | 338.50 | 246.75 | 249.44 | 249.17 | 250.25 | 0.042026 | 7.33 | 6.04 | 48.57 | 23.60 | 0.80 |
| Sausal | 2 | 17 | 2YR E | 240.40 | 246.75 | 249.04 | 248.67 | 249.64 | 0.038092 | 6.25 | 4.65 | 39.58 | 21.31 | 0.74 |
| Sausal | 2 | 17 | 2YR P | 236.30 | 246.75 | 249.02 | 248.65 | 249.61 | 0.037962 | 6.20 | 4.59 | 39.17 | 21.20 | 0.73 |
| Sausal | 2 | 17 | 1YR E | 42.26 | 246.75 | 247.63 | | 247.77 | 0.030094 | 3.01 | 1.46 | 14.04 | 16.67 | 0.58 |
| Sausal | 2 | 17 | 1YR P | 28.20 | 246.75 | 247.44 | | 247.55 | 0.029856 | 2.58 | 1.16 | 10.94 | 16.58 | 0.56 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 16 | 100YR E | 744.00 | 244.75 | 248.52 | | 249.24 | 0.020844 | 7.04 | 4.78 | 114.33 | 38.25 | 0.65 |
| Sausal | 2 | 16 | 100YR P | 650.80 | 244.75 | 248.25 | | 248.92 | 0.020907 | 6.71 | 4.45 | 104.26 | 37.79 | 0.64 |

HEC-RAS Plan: Scenario2 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 16 | 25YR E | 521.30 | 244.75 | 247.86 | | 248.42 | 0.020813 | 6.17 | 3.91 | 89.66 | 35.67 | 0.63 |
| Sausal | 2 | 16 | 25YR P | 504.60 | 244.75 | 247.80 | | 248.36 | 0.020790 | 6.09 | 3.84 | 87.73 | 35.33 | 0.62 |
| Sausal | 2 | 16 | 10YR E | 426.30 | 244.75 | 247.53 | | 248.02 | 0.020946 | 5.72 | 3.50 | 78.16 | 33.57 | 0.62 |
| Sausal | 2 | 16 | 10YR P | 420.30 | 244.75 | 247.50 | | 247.99 | 0.020976 | 5.69 | 3.48 | 77.40 | 33.42 | 0.62 |
| Sausal | 2 | 16 | 5YR E | 349.80 | 244.75 | 247.22 | | 247.65 | 0.021434 | 5.34 | 3.18 | 68.18 | 31.54 | 0.61 |
| Sausal | 2 | 16 | 5YR P | 338.50 | 244.75 | 247.17 | | 247.59 | 0.021478 | 5.27 | 3.12 | 66.72 | 31.22 | 0.61 |
| Sausal | 2 | 16 | 2YR E | 240.40 | 244.75 | 246.73 | | 247.06 | 0.022425 | 4.67 | 2.63 | 53.06 | 30.08 | 0.60 |
| Sausal | 2 | 16 | 2YR P | 236.30 | 244.75 | 246.71 | | 247.03 | 0.022417 | 4.64 | 2.60 | 52.50 | 30.05 | 0.60 |
| Sausal | 2 | 16 | 1YR E | 42.26 | 244.75 | 245.53 | | 245.62 | 0.020552 | 2.29 | 0.88 | 18.64 | 27.73 | 0.49 |
| Sausal | 2 | 16 | 1YR P | 28.20 | 244.75 | 245.40 | | 245.45 | 0.019550 | 1.92 | 0.67 | 14.80 | 27.45 | 0.46 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 15 | 100YR E | 744.00 | 239.86 | 245.07 | | 245.48 | 0.017773 | 5.76 | 5.50 | 156.75 | 46.03 | 0.46 |
| Sausal | 2 | 15 | 100YR P | 650.80 | 239.86 | 244.74 | | 245.13 | 0.018071 | 5.55 | 5.22 | 141.83 | 45.03 | 0.45 |
| Sausal | 2 | 15 | 25YR E | 521.30 | 239.86 | 244.24 | | 244.59 | 0.018784 | 5.24 | 4.84 | 119.48 | 43.49 | 0.45 |
| Sausal | 2 | 15 | 25YR P | 504.60 | 239.86 | 244.17 | | 244.52 | 0.018889 | 5.19 | 4.78 | 116.49 | 43.28 | 0.45 |
| Sausal | 2 | 15 | 10YR E | 426.30 | 239.86 | 243.81 | | 244.14 | 0.019272 | 4.94 | 4.46 | 101.72 | 39.94 | 0.45 |
| Sausal | 2 | 15 | 10YR P | 420.30 | 239.86 | 243.79 | | 244.10 | 0.019288 | 4.92 | 4.43 | 100.59 | 39.61 | 0.45 |
| Sausal | 2 | 15 | 5YR E | 349.80 | 239.86 | 243.43 | | 243.71 | 0.019498 | 4.62 | 4.04 | 87.12 | 35.41 | 0.45 |
| Sausal | 2 | 15 | 5YR P | 338.50 | 239.86 | 243.36 | | 243.64 | 0.019522 | 4.56 | 3.97 | 84.94 | 34.69 | 0.45 |
| Sausal | 2 | 15 | 2YR E | 240.40 | 239.86 | 242.78 | | 243.00 | 0.019824 | 4.03 | 3.31 | 66.25 | 30.33 | 0.43 |
| Sausal | 2 | 15 | 2YR P | 236.30 | 239.86 | 242.75 | | 242.97 | 0.019899 | 4.01 | 3.28 | 65.41 | 30.25 | 0.43 |
| Sausal | 2 | 15 | 1YR E | 42.26 | 239.86 | 241.05 | | 241.13 | 0.027150 | 2.35 | 1.60 | 18.77 | 22.87 | 0.43 |
| Sausal | 2 | 15 | 1YR P | 28.20 | 239.86 | 240.83 | | 240.90 | 0.029828 | 2.08 | 1.35 | 14.00 | 21.40 | 0.43 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 14 | 100YR E | 744.00 | 236.10 | 240.35 | | 241.34 | 0.025262 | 8.19 | 6.29 | 98.99 | 33.95 | 0.72 |
| Sausal | 2 | 14 | 100YR P | 650.80 | 236.10 | 240.08 | | 240.98 | 0.024886 | 7.76 | 5.78 | 90.12 | 31.80 | 0.71 |
| Sausal | 2 | 14 | 25YR E | 521.30 | 236.10 | 239.65 | | 240.42 | 0.024458 | 7.10 | 5.04 | 77.33 | 28.42 | 0.69 |
| Sausal | 2 | 14 | 25YR P | 504.60 | 236.10 | 239.59 | | 240.34 | 0.024376 | 7.01 | 4.93 | 75.68 | 27.95 | 0.68 |
| Sausal | 2 | 14 | 10YR E | 426.30 | 236.10 | 239.30 | | 239.95 | 0.023895 | 6.52 | 4.41 | 67.93 | 25.64 | 0.67 |
| Sausal | 2 | 14 | 10YR P | 420.30 | 236.10 | 239.28 | | 239.92 | 0.023890 | 6.49 | 4.37 | 67.29 | 25.44 | 0.67 |
| Sausal | 2 | 14 | 5YR E | 349.80 | 236.10 | 238.99 | | 239.54 | 0.023487 | 6.01 | 3.88 | 60.10 | 24.66 | 0.65 |
| Sausal | 2 | 14 | 5YR P | 338.50 | 236.10 | 238.94 | | 239.48 | 0.023403 | 5.92 | 3.79 | 58.92 | 24.54 | 0.65 |
| Sausal | 2 | 14 | 2YR E | 240.40 | 236.10 | 238.49 | | 238.89 | 0.022544 | 5.12 | 3.02 | 48.00 | 23.63 | 0.61 |
| Sausal | 2 | 14 | 2YR P | 236.30 | 236.10 | 238.47 | | 238.87 | 0.022348 | 5.07 | 2.97 | 47.61 | 23.61 | 0.61 |
| Sausal | 2 | 14 | 1YR E | 42.26 | 236.10 | 237.19 | | 237.27 | 0.015182 | 2.28 | 0.81 | 18.56 | 21.71 | 0.43 |
| Sausal | 2 | 14 | 1YR P | 28.20 | 236.10 | 237.02 | | 237.08 | 0.013932 | 1.89 | 0.60 | 14.90 | 21.38 | 0.40 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 13 | 100YR E | 744.00 | 226.99 | 232.34 | | 233.18 | 0.017430 | 8.00 | 5.53 | 110.38 | 30.49 | 0.62 |
| Sausal | 2 | 13 | 100YR P | 650.80 | 226.99 | 231.96 | | 232.75 | 0.017980 | 7.72 | 5.28 | 99.00 | 28.99 | 0.63 |
| Sausal | 2 | 13 | 25YR E | 521.30 | 226.99 | 231.40 | | 232.11 | 0.018655 | 7.23 | 4.83 | 83.32 | 27.01 | 0.62 |
| Sausal | 2 | 13 | 25YR P | 504.60 | 226.99 | 231.32 | | 232.02 | 0.018767 | 7.16 | 4.77 | 81.24 | 26.74 | 0.62 |
| Sausal | 2 | 13 | 10YR E | 426.30 | 226.99 | 230.94 | | 231.58 | 0.019387 | 6.81 | 4.46 | 71.26 | 25.43 | 0.62 |
| Sausal | 2 | 13 | 10YR P | 420.30 | 226.99 | 230.91 | | 231.54 | 0.019401 | 6.78 | 4.43 | 70.53 | 25.33 | 0.62 |
| Sausal | 2 | 13 | 5YR E | 349.80 | 226.99 | 230.54 | | 231.11 | 0.019942 | 6.40 | 4.10 | 61.40 | 24.06 | 0.62 |
| Sausal | 2 | 13 | 5YR P | 338.50 | 226.99 | 230.48 | | 231.04 | 0.020054 | 6.34 | 4.04 | 59.89 | 23.84 | 0.62 |
| Sausal | 2 | 13 | 2YR E | 240.40 | 226.99 | 229.88 | | 230.35 | 0.021316 | 5.71 | 3.50 | 46.26 | 21.79 | 0.62 |
| Sausal | 2 | 13 | 2YR P | 236.30 | 226.99 | 229.85 | | 230.31 | 0.021541 | 5.69 | 3.50 | 45.56 | 21.67 | 0.62 |
| Sausal | 2 | 13 | 1YR E | 42.26 | 226.99 | 228.05 | | 228.24 | 0.039478 | 3.55 | 2.00 | 12.14 | 15.71 | 0.69 |
| Sausal | 2 | 13 | 1YR P | 28.20 | 226.99 | 227.85 | | 228.00 | 0.046367 | 3.17 | 1.76 | 9.00 | 15.11 | 0.71 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 12 | 100YR E | 744.00 | 223.66 | 229.22 | 228.27 | 230.23 | 0.020976 | 8.57 | 6.43 | 100.02 | 25.75 | 0.66 |
| Sausal | 2 | 12 | 100YR P | 650.80 | 223.66 | 228.93 | 227.96 | 229.82 | 0.020017 | 8.06 | 5.79 | 92.47 | 25.10 | 0.64 |
| Sausal | 2 | 12 | 25YR E | 521.30 | 223.66 | 228.42 | 227.48 | 229.18 | 0.019331 | 7.37 | 5.02 | 80.02 | 23.99 | 0.61 |
| Sausal | 2 | 12 | 25YR P | 504.60 | 223.66 | 228.35 | 227.40 | 229.09 | 0.019218 | 7.27 | 4.91 | 78.36 | 23.83 | 0.61 |
| Sausal | 2 | 12 | 10YR E | 426.30 | 223.66 | 228.02 | 227.04 | 228.67 | 0.018435 | 6.76 | 4.36 | 70.59 | 23.11 | 0.59 |
| Sausal | 2 | 12 | 10YR P | 420.30 | 223.66 | 227.99 | 227.02 | 228.63 | 0.018458 | 6.73 | 4.33 | 69.86 | 23.04 | 0.59 |
| Sausal | 2 | 12 | 5YR E | 349.80 | 223.66 | 227.64 | 226.67 | 228.21 | 0.017870 | 6.24 | 3.84 | 62.07 | 22.28 | 0.57 |
| Sausal | 2 | 12 | 5YR P | 338.50 | 223.66 | 227.59 | 226.61 | 228.13 | 0.017735 | 6.15 | 3.75 | 60.81 | 22.16 | 0.57 |
| Sausal | 2 | 12 | 2YR E | 240.40 | 223.66 | 227.03 | 226.08 | 227.45 | 0.016478 | 5.31 | 2.95 | 48.97 | 20.35 | 0.53 |
| Sausal | 2 | 12 | 2YR P | 236.30 | 223.66 | 227.01 | 226.05 | 227.42 | 0.016415 | 5.27 | 2.91 | 48.44 | 20.26 | 0.53 |
| Sausal | 2 | 12 | 1YR E | 42.26 | 223.66 | 225.20 | | 225.30 | 0.011120 | 2.43 | 0.83 | 17.61 | 14.49 | 0.38 |
| Sausal | 2 | 12 | 1YR P | 28.20 | 223.66 | 224.94 | | 225.01 | 0.010438 | 2.05 | 0.63 | 13.89 | 14.13 | 0.36 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 11 | 100YR E | 744.00 | 220.94 | 225.45 | 225.45 | 227.10 | 0.012088 | 10.63 | 2.60 | 74.54 | 23.39 | 0.96 |
| Sausal | 2 | 11 | 100YR P | 650.80 | 220.94 | 225.13 | 225.13 | 226.68 | 0.012678 | 10.26 | 2.49 | 67.14 | 22.61 | 0.97 |
| Sausal | 2 | 11 | 25YR E | 521.30 | 220.94 | 224.67 | 224.67 | 226.04 | 0.013107 | 9.59 | 2.27 | 57.16 | 21.45 | 0.97 |
| Sausal | 2 | 11 | 25YR P | 504.60 | 220.94 | 224.61 | 224.61 | 225.95 | 0.013160 | 9.50 | 2.24 | 55.77 | 21.27 | 0.97 |
| Sausal | 2 | 11 | 10YR E | 426.30 | 220.94 | 224.28 | 224.28 | 225.52 | 0.013589 | 9.10 | 2.11 | 48.98 | 20.38 | 0.97 |
| Sausal | 2 | 11 | 10YR P | 420.30 | 220.94 | 224.26 | 224.26 | 225.48 | 0.013618 | 9.06 | 2.10 | 48.46 | 20.31 | 0.97 |
| Sausal | 2 | 11 | 5YR E | 349.80 | 220.94 | 223.94 | 223.94 | 225.06 | 0.014018 | 8.61 | 1.96 | 42.21 | 19.44 | 0.97 |
| Sausal | 2 | 11 | 5YR P | 338.50 | 220.94 | 223.89 | 223.89 | 224.99 | 0.014120 | 8.54 | 1.94 | 41.16 | 19.29 | 0.98 |
| Sausal | 2 | 11 | 2YR E | 240.40 | 220.94 | 223.39 | 223.39 | 224.30 | 0.015035 | 7.77 | 1.71 | 31.85 | 17.92 | 0.98 |
| Sausal | 2 | 11 | 2YR P | 236.30 | 220.94 | 223.37 | 223.37 | 224.27 | 0.015081 | 7.73 | 1.70 | 31.45 | 17.86 | 0.98 |
| Sausal | 2 | 11 | 1YR E | 42.26 | 220.94 | 221.96 | 221.96 | 222.30 | 0.021771 | 4.63 | 0.86 | 9.12 | 13.86 | 1.01 |
| Sausal | 2 | 11 | 1YR P | 28.20 | 220.94 | 221.78 | 221.78 | 222.05 | 0.023238 | 4.23 | 0.77 | 6.67 | 12.25 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 10 | 100YR E | 744.00 | 216.69 | 222.35 | 222.35 | 224.09 | 0.009241 | 11.86 | 2.86 | 78.61 | 22.86 | 0.90 |
| Sausal | 2 | 10 | 100YR P | 650.80 | 216.69 | 221.96 | 221.96 | 223.63 | 0.009611 | 11.52 | 2.76 | 69.99 | 21.63 | 0.90 |
| Sausal | 2 | 10 | 25YR E | 521.30 | 216.69 | 221.39 | 221.39 | 222.92 | 0.010097 | 10.89 | 2.57 | 58.13 | 19.81 | 0.91 |
| Sausal | 2 | 10 | 25YR P | 504.60 | 216.69 | 221.31 | 221.31 | 222.82 | 0.010187 | 10.81 | 2.55 | 56.54 | 19.56 | 0.91 |
| Sausal | 2 | 10 | 10YR E | 426.30 | 216.69 | 220.94 | 220.94 | 222.34 | 0.010362 | 10.28 | 2.37 | 49.52 | 18.38 | 0.90 |
| Sausal | 2 | 10 | 10YR P | 420.30 | 216.69 | 220.89 | 220.89 | 222.30 | 0.010547 | 10.29 | 2.39 | 48.67 | 18.23 | 0.91 |
| Sausal | 2 | 10 | 5YR E | 349.80 | 216.69 | 220.52 | 220.52 | 221.80 | 0.010806 | 9.75 | 2.22 | 42.07 | 17.04 | 0.91 |
| Sausal | 2 | 10 | 5YR P | 338.50 | 216.69 | 220.45 | 220.45 | 221.72 | 0.010891 | 9.67 | 2.19 | 40.94 | 16.83 | 0.91 |
| Sausal | 2 | 10 | 2YR E | 240.40 | 216.69 | 219.80 | 219.80 | 220.91 | 0.011993 | 8.87 | 1.97 | 30.72 | 14.78 | 0.92 |
| Sausal | 2 | 10 | 2YR P | 236.30 | 216.69 | 219.77 | 219.77 | 220.87 | 0.012051 | 8.83 | 1.96 | 30.28 | 14.68 | 0.92 |
| Sausal | 2 | 10 | 1YR E | 42.26 | 216.69 | 218.01 | 217.84 | 218.34 | 0.011542 | 4.58 | 0.72 | 9.39 | 9.10 | 0.77 |
| Sausal | 2 | 10 | 1YR P | 28.20 | 216.69 | 217.79 | 217.62 | 218.02 | 0.010609 | 3.83 | 0.54 | 7.44 | 8.70 | 0.72 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 9 | 100YR E | 744.00 | 212.30 | 219.48 | | 219.80 | 0.001391 | 5.13 | 0.51 | 186.07 | 53.42 | 0.35 |
| Sausal | 2 | 9 | 100YR P | 650.80 | 212.30 | 219.17 | | 219.47 | 0.001339 | 4.88 | 0.47 | 170.04 | 51.58 | 0.34 |
| Sausal | 2 | 9 | 25YR E | 521.30 | 212.30 | 218.66 | | 218.92 | 0.001296 | 4.54 | 0.41 | 144.27 | 48.47 | 0.33 |
| Sausal | 2 | 9 | 25YR P | 504.60 | 212.30 | 218.59 | | 218.85 | 0.001284 | 4.48 | 0.41 | 141.03 | 48.07 | 0.33 |

HEC-RAS Plan: Scenario2 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 9 | 10YR E | 426.30 | 212.30 | 218.00 | | 218.29 | 0.001534 | 4.56 | 0.43 | 113.80 | 44.52 | 0.35 |
| Sausal | 2 | 9 | 10YR P | 420.30 | 212.30 | 217.92 | | 218.21 | 0.001602 | 4.61 | 0.45 | 110.09 | 42.93 | 0.36 |
| Sausal | 2 | 9 | 5YR E | 349.80 | 212.30 | 216.77 | | 217.17 | 0.002941 | 5.26 | 0.63 | 73.51 | 27.39 | 0.47 |
| Sausal | 2 | 9 | 5YR P | 338.50 | 212.30 | 216.59 | | 217.02 | 0.003310 | 5.41 | 0.68 | 68.59 | 26.36 | 0.49 |
| Sausal | 2 | 9 | 2YR E | 240.40 | 212.30 | 214.92 | 214.79 | 215.78 | 0.013808 | 7.45 | 1.57 | 32.42 | 16.91 | 0.91 |
| Sausal | 2 | 9 | 2YR P | 236.30 | 212.30 | 214.84 | 214.76 | 215.74 | 0.015219 | 7.62 | 1.67 | 31.09 | 16.45 | 0.95 |
| Sausal | 2 | 9 | 1YR E | 42.26 | 212.30 | 213.31 | 213.31 | 213.66 | 0.021773 | 4.73 | 0.89 | 8.94 | 13.05 | 1.01 |
| Sausal | 2 | 9 | 1YR P | 28.20 | 212.30 | 213.14 | 213.14 | 213.41 | 0.023660 | 4.19 | 0.76 | 6.74 | 12.73 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 8 | 100YR E | 744.00 | 208.57 | 219.44 | 214.81 | 219.61 | 0.000643 | 4.07 | 0.30 | 258.38 | 61.66 | 0.23 |
| Sausal | 2 | 8 | 100YR P | 650.80 | 208.57 | 219.13 | 214.45 | 219.29 | 0.000604 | 3.87 | 0.27 | 239.58 | 61.66 | 0.22 |
| Sausal | 2 | 8 | 25YR E | 521.30 | 208.57 | 218.63 | 213.86 | 218.76 | 0.000522 | 3.47 | 0.22 | 209.58 | 53.54 | 0.20 |
| Sausal | 2 | 8 | 25YR P | 504.60 | 208.57 | 218.56 | 213.80 | 218.69 | 0.000502 | 3.38 | 0.21 | 206.25 | 51.51 | 0.20 |
| Sausal | 2 | 8 | 10YR E | 426.30 | 208.57 | 218.00 | 213.42 | 218.11 | 0.000482 | 3.18 | 0.19 | 179.62 | 43.05 | 0.19 |
| Sausal | 2 | 8 | 10YR P | 420.30 | 208.57 | 217.91 | 213.39 | 218.02 | 0.000488 | 3.17 | 0.19 | 176.14 | 41.98 | 0.19 |
| Sausal | 2 | 8 | 5YR E | 349.80 | 208.57 | 216.76 | 213.01 | 216.89 | 0.000667 | 3.36 | 0.22 | 132.86 | 35.56 | 0.22 |
| Sausal | 2 | 8 | 5YR P | 338.50 | 208.57 | 216.58 | 212.96 | 216.72 | 0.000705 | 3.39 | 0.23 | 126.40 | 34.58 | 0.23 |
| Sausal | 2 | 8 | 2YR E | 240.40 | 208.57 | 214.97 | 212.40 | 215.14 | 0.001089 | 3.54 | 0.27 | 79.72 | 23.86 | 0.27 |
| Sausal | 2 | 8 | 2YR P | 236.30 | 208.57 | 214.91 | 212.38 | 215.07 | 0.001110 | 3.55 | 0.28 | 78.09 | 23.60 | 0.27 |
| Sausal | 2 | 8 | 1YR E | 42.26 | 208.57 | 210.92 | 210.08 | 211.09 | 0.004087 | 3.25 | 0.33 | 12.99 | 7.91 | 0.45 |
| Sausal | 2 | 8 | 1YR P | 28.20 | 208.57 | 210.47 | 209.78 | 210.60 | 0.004179 | 2.95 | 0.29 | 9.56 | 7.02 | 0.45 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 7.8 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 7 | 100YR E | 744.00 | 204.66 | 209.26 | | 209.94 | 0.018524 | 6.71 | 4.31 | 116.56 | 36.95 | 0.60 |
| Sausal | 2 | 7 | 100YR P | 650.80 | 204.66 | 209.04 | | 209.63 | 0.017309 | 6.25 | 3.81 | 108.75 | 35.83 | 0.57 |
| Sausal | 2 | 7 | 25YR E | 521.30 | 204.66 | 208.77 | | 209.22 | 0.014546 | 5.44 | 2.97 | 99.13 | 34.40 | 0.52 |
| Sausal | 2 | 7 | 25YR P | 504.60 | 204.66 | 208.73 | | 209.16 | 0.014234 | 5.34 | 2.87 | 97.68 | 34.18 | 0.51 |
| Sausal | 2 | 7 | 10YR E | 426.30 | 204.66 | 208.44 | | 208.82 | 0.013793 | 4.96 | 2.55 | 88.11 | 32.69 | 0.49 |
| Sausal | 2 | 7 | 10YR P | 420.30 | 204.66 | 208.39 | | 208.77 | 0.014201 | 4.98 | 2.58 | 86.43 | 32.42 | 0.50 |
| Sausal | 2 | 7 | 5YR E | 349.80 | 204.66 | 207.95 | | 208.32 | 0.016702 | 4.87 | 2.60 | 72.69 | 30.13 | 0.53 |
| Sausal | 2 | 7 | 5YR P | 338.50 | 204.66 | 207.89 | | 208.25 | 0.016921 | 4.83 | 2.57 | 70.83 | 29.82 | 0.53 |
| Sausal | 2 | 7 | 2YR E | 240.40 | 204.66 | 207.42 | | 207.69 | 0.016135 | 4.20 | 2.06 | 57.37 | 27.61 | 0.50 |
| Sausal | 2 | 7 | 2YR P | 236.30 | 204.66 | 207.39 | | 207.66 | 0.016186 | 4.18 | 2.05 | 56.67 | 27.49 | 0.50 |
| Sausal | 2 | 7 | 1YR E | 42.26 | 204.66 | 205.85 | | 205.92 | 0.013628 | 2.20 | 0.75 | 19.18 | 21.19 | 0.41 |
| Sausal | 2 | 7 | 1YR P | 28.20 | 204.66 | 205.64 | | 205.70 | 0.013358 | 1.90 | 0.60 | 14.87 | 20.37 | 0.39 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 6 | 100YR E | 1106.10 | 200.31 | 205.22 | 205.22 | 206.72 | 0.008728 | 10.81 | 2.45 | 122.71 | 39.40 | 0.88 |
| Sausal | 2 | 6 | 100YR P | 1035.90 | 200.31 | 205.08 | 205.08 | 206.53 | 0.008678 | 10.57 | 2.37 | 117.39 | 39.16 | 0.88 |
| Sausal | 2 | 6 | 25YR E | 913.10 | 200.31 | 204.76 | 204.76 | 206.18 | 0.009225 | 10.37 | 2.34 | 104.86 | 38.29 | 0.89 |
| Sausal | 2 | 6 | 25YR P | 899.60 | 200.31 | 204.73 | 204.73 | 206.13 | 0.009258 | 10.33 | 2.32 | 103.56 | 38.07 | 0.89 |
| Sausal | 2 | 6 | 10YR E | 789.70 | 200.31 | 204.44 | 204.44 | 205.78 | 0.009501 | 9.98 | 2.22 | 93.01 | 36.20 | 0.89 |
| Sausal | 2 | 6 | 10YR P | 764.20 | 200.31 | 204.38 | 204.38 | 205.69 | 0.009544 | 9.89 | 2.19 | 90.60 | 35.76 | 0.89 |
| Sausal | 2 | 6 | 5YR E | 538.30 | 200.31 | 203.68 | 203.68 | 204.83 | 0.010463 | 9.06 | 1.97 | 67.45 | 31.22 | 0.90 |
| Sausal | 2 | 6 | 5YR P | 512.40 | 200.31 | 203.60 | 203.60 | 204.72 | 0.010574 | 8.94 | 1.93 | 64.78 | 30.65 | 0.91 |
| Sausal | 2 | 6 | 2YR E | 363.20 | 200.31 | 203.03 | 203.03 | 204.01 | 0.011662 | 8.18 | 1.73 | 48.51 | 26.94 | 0.92 |
| Sausal | 2 | 6 | 2YR P | 352.90 | 200.31 | 202.99 | 202.99 | 203.95 | 0.011771 | 8.12 | 1.72 | 47.34 | 26.66 | 0.92 |
| Sausal | 2 | 6 | 1YR E | 58.85 | 200.31 | 201.30 | 201.26 | 201.64 | 0.017226 | 4.72 | 0.84 | 12.61 | 16.46 | 0.93 |
| Sausal | 2 | 6 | 1YR P | 45.90 | 200.31 | 201.19 | 201.14 | 201.47 | 0.016860 | 4.27 | 0.72 | 10.85 | 16.13 | 0.90 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 5.1 | 100YR E | 1106.10 | 196.68 | 204.03 | 204.03 | 204.93 | 0.003632 | 9.45 | 1.61 | 190.65 | 121.97 | 0.62 |
| Sausal | 2 | 5.1 | 100YR P | 1035.90 | 196.68 | 203.11 | 203.11 | 204.75 | 0.006810 | 11.81 | 2.63 | 113.01 | 38.19 | 0.83 |
| Sausal | 2 | 5.1 | 25YR E | 913.10 | 196.68 | 203.17 | 202.77 | 204.40 | 0.005062 | 10.24 | 1.97 | 115.27 | 39.53 | 0.72 |
| Sausal | 2 | 5.1 | 25YR P | 899.60 | 196.68 | 203.22 | 202.74 | 204.37 | 0.004743 | 9.96 | 1.86 | 117.28 | 45.96 | 0.70 |
| Sausal | 2 | 5.1 | 10YR E | 789.70 | 196.68 | 203.26 | | 204.13 | 0.003537 | 8.64 | 1.40 | 119.40 | 51.87 | 0.60 |
| Sausal | 2 | 5.1 | 10YR P | 764.20 | 196.68 | 203.30 | | 204.09 | 0.003217 | 8.28 | 1.28 | 121.50 | 57.14 | 0.58 |
| Sausal | 2 | 5.1 | 5YR E | 538.30 | 196.68 | 203.09 | | 203.54 | 0.001863 | 6.16 | 0.72 | 112.35 | 38.04 | 0.44 |
| Sausal | 2 | 5.1 | 5YR P | 512.40 | 196.68 | 203.05 | | 203.47 | 0.001746 | 5.94 | 0.67 | 110.66 | 37.66 | 0.42 |
| Sausal | 2 | 5.1 | 2YR E | 363.20 | 196.68 | 202.79 | | 203.03 | 0.001073 | 4.52 | 0.39 | 101.08 | 35.41 | 0.33 |
| Sausal | 2 | 5.1 | 2YR P | 352.90 | 196.68 | 202.74 | | 202.98 | 0.001055 | 4.46 | 0.38 | 99.25 | 34.97 | 0.33 |
| Sausal | 2 | 5.1 | 1YR E | 58.85 | 196.68 | 197.97 | 197.97 | 198.47 | 0.017023 | 5.78 | 1.13 | 10.50 | 10.75 | 0.98 |
| Sausal | 2 | 5.1 | 1YR P | 45.90 | 196.68 | 197.81 | 197.81 | 198.24 | 0.018098 | 5.35 | 1.02 | 8.80 | 10.46 | 0.99 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 5 | 100YR E | 1106.10 | 196.09 | 203.42 | 203.42 | 204.74 | 0.004864 | 11.14 | 2.22 | 131.96 | 60.99 | 0.73 |
| Sausal | 2 | 5 | 100YR P | 1035.90 | 196.09 | 202.83 | 202.83 | 204.51 | 0.006159 | 11.86 | 2.58 | 107.32 | 32.41 | 0.81 |
| Sausal | 2 | 5 | 25YR E | 913.10 | 196.09 | 203.17 | 202.77 | 204.24 | 0.003820 | 9.65 | 1.68 | 119.11 | 37.87 | 0.64 |
| Sausal | 2 | 5 | 25YR P | 899.60 | 196.09 | 203.22 | 202.77 | 204.22 | 0.003602 | 9.42 | 1.60 | 120.92 | 44.15 | 0.62 |
| Sausal | 2 | 5 | 10YR E | 789.70 | 196.09 | 203.27 | 202.76 | 204.01 | 0.002691 | 8.17 | 1.20 | 123.19 | 50.92 | 0.54 |
| Sausal | 2 | 5 | 10YR P | 764.20 | 196.09 | 203.30 | 202.76 | 203.99 | 0.002519 | 7.94 | 1.13 | 125.19 | 56.11 | 0.52 |
| Sausal | 2 | 5 | 5YR E | 538.30 | 196.09 | 203.10 | 201.41 | 203.48 | 0.001395 | 5.79 | 0.61 | 116.33 | 35.49 | 0.39 |
| Sausal | 2 | 5 | 5YR P | 512.40 | 196.09 | 203.05 | 201.24 | 203.41 | 0.001301 | 5.57 | 0.56 | 114.76 | 34.87 | 0.37 |
| Sausal | 2 | 5 | 2YR E | 363.20 | 196.09 | 201.91 | 200.20 | 202.92 | 0.003136 | 7.67 | 1.13 | 45.94 | 24.77 | 0.56 |
| Sausal | 2 | 5 | 2YR P | 352.90 | 196.09 | 201.92 | 200.12 | 202.87 | 0.002948 | 7.45 | 1.07 | 46.00 | 24.83 | 0.54 |
| Sausal | 2 | 5 | 1YR E | 58.85 | 196.09 | 197.36 | 197.36 | 197.96 | 0.016062 | 6.22 | 1.25 | 9.49 | 10.02 | 0.98 |
| Sausal | 2 | 5 | 1YR P | 45.90 | 196.09 | 197.18 | 197.18 | 197.68 | 0.016652 | 5.72 | 1.11 | 8.09 | 9.55 | 0.98 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 4.5 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 4 | 100YR E | 1106.10 | 187.02 | 192.63 | | 193.92 | 0.028544 | 9.72 | 8.38 | 128.28 | 29.73 | 0.74 |
| Sausal | 2 | 4 | 100YR P | 1035.90 | 187.02 | 192.38 | | 193.65 | 0.029861 | 9.63 | 8.35 | 120.83 | 29.24 | 0.75 |
| Sausal | 2 | 4 | 25YR E | 913.10 | 187.02 | 191.92 | | 193.16 | 0.032724 | 9.47 | 8.33 | 107.57 | 28.34 | 0.77 |
| Sausal | 2 | 4 | 25YR P | 899.60 | 187.02 | 191.87 | | 193.10 | 0.033080 | 9.45 | 8.33 | 106.11 | 28.24 | 0.77 |
| Sausal | 2 | 4 | 10YR E | 789.70 | 187.02 | 191.46 | | 192.64 | 0.035798 | 9.24 | 8.22 | 94.67 | 27.44 | 0.79 |
| Sausal | 2 | 4 | 10YR P | 764.20 | 187.02 | 191.36 | | 192.53 | 0.036564 | 9.19 | 8.19 | 91.96 | 27.24 | 0.80 |
| Sausal | 2 | 4 | 5YR E | 538.30 | 187.02 | 190.42 | 190.21 | 191.50 | 0.046685 | 8.73 | 8.06 | 67.15 | 25.40 | 0.86 |
| Sausal | 2 | 4 | 5YR P | 512.40 | 187.02 | 190.30 | 190.12 | 191.37 | 0.048521 | 8.68 | 8.07 | 64.17 | 25.15 | 0.88 |
| Sausal | 2 | 4 | 2YR E | 363.20 | 187.02 | 189.58 | 189.58 | 190.59 | 0.064538 | 8.36 | 8.20 | 46.61 | 23.58 | 0.97 |
| Sausal | 2 | 4 | 2YR P | 352.90 | 187.02 | 189.54 | 189.54 | 190.53 | 0.064821 | 8.28 | 8.09 | 45.67 | 23.50 | 0.96 |
| Sausal | 2 | 4 | 1YR E | 58.85 | 187.02 | 187.94 | 187.94 | 188.32 | 0.097196 | 4.96 | 4.15 | 11.96 | 16.25 | 1.00 |
| Sausal | 2 | 4 | 1YR P | 45.90 | 187.02 | 187.83 | 187.82 | 188.15 | 0.095366 | 4.50 | 3.57 | 10.26 | 15.76 | 0.98 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 3 | 100YR E | 1106.10 | 182.75 | 190.31 | | 191.76 | 0.021110 | 9.92 | 8.02 | 126.61 | 23.90 | 0.66 |
| Sausal | 2 | 3 | 100YR P | 1035.90 | 182.75 | 190.08 | | 191.46 | 0.020908 | 9.66 | 7.68 | 121.18 | 23.43 | 0.65 |

HEC-RAS Plan: Scenario2 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 3 | 25YR E | 913.10 | 182.75 | 189.66 | | 190.91 | 0.020506 | 9.17 | 7.06 | 111.46 | 22.56 | 0.64 |
| Sausal | 2 | 3 | 25YR P | 899.60 | 182.75 | 189.61 | | 190.84 | 0.020456 | 9.11 | 6.99 | 110.38 | 22.46 | 0.64 |
| Sausal | 2 | 3 | 10YR E | 789.70 | 182.75 | 189.21 | | 190.32 | 0.020001 | 8.61 | 6.40 | 101.42 | 21.63 | 0.62 |
| Sausal | 2 | 3 | 10YR P | 764.20 | 182.75 | 189.11 | | 190.19 | 0.019883 | 8.49 | 6.25 | 99.31 | 21.42 | 0.62 |
| Sausal | 2 | 3 | 5YR E | 538.30 | 182.75 | 188.14 | | 188.95 | 0.018665 | 7.29 | 4.89 | 79.57 | 19.44 | 0.58 |
| Sausal | 2 | 3 | 5YR P | 512.40 | 182.75 | 188.02 | | 188.79 | 0.018450 | 7.13 | 4.72 | 77.25 | 19.28 | 0.58 |
| Sausal | 2 | 3 | 2YR E | 363.20 | 182.75 | 187.21 | | 187.78 | 0.017474 | 6.12 | 3.70 | 62.09 | 17.98 | 0.55 |
| Sausal | 2 | 3 | 2YR P | 352.90 | 182.75 | 187.15 | | 187.71 | 0.017449 | 6.05 | 3.63 | 60.95 | 17.86 | 0.54 |
| Sausal | 2 | 3 | 1YR E | 58.85 | 182.75 | 184.38 | | 184.56 | 0.022373 | 3.41 | 1.64 | 17.30 | 13.96 | 0.54 |
| Sausal | 2 | 3 | 1YR P | 45.90 | 182.75 | 184.17 | | 184.33 | 0.024242 | 3.19 | 1.51 | 14.42 | 13.69 | 0.54 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 2 | 100YR E | 1106.10 | 176.58 | 184.58 | | 185.68 | 0.018574 | 9.51 | 7.28 | 143.26 | 29.05 | 0.60 |
| Sausal | 2 | 2 | 100YR P | 1035.90 | 176.58 | 184.34 | | 185.41 | 0.018654 | 9.33 | 7.09 | 136.36 | 28.67 | 0.60 |
| Sausal | 2 | 2 | 25YR E | 913.10 | 176.58 | 183.90 | | 184.91 | 0.018805 | 9.00 | 6.72 | 124.00 | 27.98 | 0.60 |
| Sausal | 2 | 2 | 25YR P | 899.60 | 176.58 | 183.85 | | 184.85 | 0.018827 | 8.96 | 6.68 | 122.60 | 27.90 | 0.60 |
| Sausal | 2 | 2 | 10YR E | 789.70 | 176.58 | 183.43 | | 184.37 | 0.019054 | 8.64 | 6.35 | 110.95 | 27.22 | 0.60 |
| Sausal | 2 | 2 | 10YR P | 764.20 | 176.58 | 183.33 | | 184.26 | 0.019120 | 8.57 | 6.28 | 108.17 | 27.06 | 0.60 |
| Sausal | 2 | 2 | 5YR E | 538.30 | 176.58 | 182.32 | | 183.13 | 0.019964 | 7.82 | 5.53 | 81.89 | 24.68 | 0.59 |
| Sausal | 2 | 2 | 5YR P | 512.40 | 176.58 | 182.18 | | 182.98 | 0.020167 | 7.72 | 5.44 | 78.53 | 24.14 | 0.59 |
| Sausal | 2 | 2 | 2YR E | 363.20 | 176.58 | 181.33 | | 182.01 | 0.020947 | 7.00 | 4.74 | 59.40 | 20.77 | 0.59 |
| Sausal | 2 | 2 | 2YR P | 352.90 | 176.58 | 181.27 | | 181.94 | 0.020963 | 6.94 | 4.68 | 58.09 | 20.52 | 0.58 |
| Sausal | 2 | 2 | 1YR E | 58.85 | 176.58 | 178.63 | | 178.80 | 0.016440 | 3.37 | 1.49 | 17.53 | 10.51 | 0.45 |
| Sausal | 2 | 2 | 1YR P | 45.90 | 176.58 | 178.39 | | 178.54 | 0.015552 | 3.03 | 1.25 | 15.17 | 9.85 | 0.43 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 1 | 100YR E | 1106.10 | 175.30 | 182.78 | 180.57 | 183.67 | 0.015003 | 7.74 | 5.07 | 153.91 | 29.79 | 0.52 |
| Sausal | 2 | 1 | 100YR P | 1035.90 | 175.30 | 182.54 | 180.31 | 183.39 | 0.015004 | 7.56 | 4.90 | 146.82 | 29.24 | 0.52 |
| Sausal | 2 | 1 | 25YR E | 913.10 | 175.30 | 182.10 | 179.93 | 182.88 | 0.015009 | 7.22 | 4.57 | 134.11 | 28.21 | 0.51 |
| Sausal | 2 | 1 | 25YR P | 899.60 | 175.30 | 182.05 | 179.89 | 182.82 | 0.015009 | 7.18 | 4.54 | 132.69 | 28.09 | 0.51 |
| Sausal | 2 | 1 | 10YR E | 789.70 | 175.30 | 181.62 | 179.55 | 182.33 | 0.015018 | 6.85 | 4.22 | 120.85 | 27.10 | 0.50 |
| Sausal | 2 | 1 | 10YR P | 764.20 | 175.30 | 181.51 | 179.47 | 182.21 | 0.015021 | 6.77 | 4.15 | 118.04 | 26.86 | 0.50 |
| Sausal | 2 | 1 | 5YR E | 538.30 | 175.30 | 180.49 | 178.70 | 181.03 | 0.015008 | 5.93 | 3.40 | 91.77 | 23.15 | 0.49 |
| Sausal | 2 | 1 | 5YR P | 512.40 | 175.30 | 180.34 | 178.61 | 180.87 | 0.015007 | 5.82 | 3.31 | 88.74 | 20.53 | 0.48 |
| Sausal | 2 | 1 | 2YR E | 363.20 | 175.30 | 179.46 | 178.02 | 179.87 | 0.015017 | 5.16 | 2.76 | 70.73 | 20.07 | 0.48 |
| Sausal | 2 | 1 | 2YR P | 352.90 | 175.30 | 179.39 | 177.98 | 179.80 | 0.015020 | 5.10 | 2.72 | 69.41 | 20.03 | 0.48 |
| Sausal | 2 | 1 | 1YR E | 58.85 | 175.30 | 176.83 | 176.25 | 176.95 | 0.015023 | 2.77 | 1.09 | 21.24 | 16.74 | 0.43 |
| Sausal | 2 | 1 | 1YR P | 45.90 | 175.30 | 176.64 | 176.13 | 176.74 | 0.015010 | 2.54 | 0.95 | 18.06 | 16.38 | 0.43 |
| | | | | | | | | | | | | | | |
| Palo Seco | 1 | 37 | 100YR E | 133.20 | 481.72 | 484.61 | 484.55 | 485.23 | 0.039095 | 7.03 | 5.58 | 23.68 | 16.17 | 0.79 |
| Palo Seco | 1 | 37 | 100YR P | 112.30 | 481.72 | 484.46 | 484.37 | 485.01 | 0.037160 | 6.57 | 4.97 | 21.23 | 15.83 | 0.76 |
| Palo Seco | 1 | 37 | 25YR E | 100.80 | 481.72 | 484.36 | 484.19 | 484.88 | 0.036003 | 6.29 | 4.63 | 19.78 | 15.62 | 0.75 |
| Palo Seco | 1 | 37 | 25YR P | 84.00 | 481.72 | 484.21 | 484.00 | 484.66 | 0.034062 | 5.83 | 4.07 | 17.45 | 14.51 | 0.72 |
| Palo Seco | 1 | 37 | 10YR E | 80.20 | 481.72 | 484.17 | 483.95 | 484.61 | 0.033735 | 5.73 | 3.95 | 16.87 | 14.20 | 0.71 |
| Palo Seco | 1 | 37 | 10YR P | 67.20 | 481.72 | 484.02 | 483.76 | 484.41 | 0.032177 | 5.32 | 3.50 | 14.89 | 13.10 | 0.69 |
| Palo Seco | 1 | 37 | 5YR E | 64.90 | 481.72 | 483.99 | 483.72 | 484.37 | 0.032137 | 5.26 | 3.44 | 14.48 | 12.86 | 0.68 |
| Palo Seco | 1 | 37 | 5YR P | 53.90 | 481.72 | 483.84 | 483.53 | 484.18 | 0.031141 | 4.89 | 3.06 | 12.63 | 11.72 | 0.66 |
| Palo Seco | 1 | 37 | 2YR E | 44.80 | 481.72 | 483.70 | 483.35 | 483.99 | 0.030325 | 4.55 | 2.72 | 11.02 | 10.63 | 0.64 |
| Palo Seco | 1 | 37 | 2YR P | 36.60 | 481.72 | 483.54 | 483.19 | 483.80 | 0.029788 | 4.21 | 2.41 | 9.49 | 9.47 | 0.63 |
| Palo Seco | 1 | 37 | 1YR E | 6.72 | 481.72 | 482.42 | 482.42 | 482.62 | 0.108057 | 3.60 | 2.63 | 1.90 | 4.95 | 1.00 |
| Palo Seco | 1 | 37 | 1YR P | 5.80 | 481.72 | 482.38 | 482.38 | 482.56 | 0.110686 | 3.48 | 2.52 | 1.69 | 4.70 | 1.00 |
| | | | | | | | | | | | | | | |
| Palo Seco | 1 | 36 | 100YR E | 133.20 | 438.09 | 440.15 | 440.15 | 440.83 | 0.061643 | 6.71 | 5.82 | 20.86 | 16.76 | 0.95 |
| Palo Seco | 1 | 36 | 100YR P | 112.30 | 438.09 | 439.98 | 439.98 | 440.61 | 0.065832 | 6.42 | 5.54 | 18.11 | 15.69 | 0.96 |
| Palo Seco | 1 | 36 | 25YR E | 100.80 | 438.09 | 439.88 | 439.88 | 440.48 | 0.068705 | 6.24 | 5.37 | 16.59 | 15.07 | 0.97 |
| Palo Seco | 1 | 36 | 25YR P | 84.00 | 438.09 | 439.73 | 439.73 | 440.27 | 0.074348 | 5.96 | 5.11 | 14.31 | 14.09 | 0.99 |
| Palo Seco | 1 | 36 | 10YR E | 80.20 | 438.09 | 439.69 | 439.69 | 440.23 | 0.075380 | 5.87 | 5.02 | 13.83 | 13.87 | 0.99 |
| Palo Seco | 1 | 36 | 10YR P | 67.20 | 438.09 | 439.56 | 439.56 | 440.05 | 0.080991 | 5.60 | 4.76 | 12.08 | 13.06 | 1.00 |
| Palo Seco | 1 | 36 | 5YR E | 64.90 | 438.09 | 439.54 | 439.54 | 440.02 | 0.081116 | 5.53 | 4.67 | 11.80 | 12.95 | 1.00 |
| Palo Seco | 1 | 36 | 5YR P | 53.90 | 438.09 | 439.42 | 439.42 | 439.85 | 0.085213 | 5.26 | 4.39 | 10.26 | 12.41 | 1.01 |
| Palo Seco | 1 | 36 | 2YR E | 44.80 | 438.09 | 439.31 | 439.31 | 439.70 | 0.088917 | 4.99 | 4.10 | 8.97 | 11.95 | 1.01 |
| Palo Seco | 1 | 36 | 2YR P | 36.60 | 438.09 | 439.21 | 439.21 | 439.56 | 0.091478 | 4.72 | 3.79 | 7.76 | 11.38 | 1.01 |
| Palo Seco | 1 | 36 | 1YR E | 6.72 | 438.09 | 438.96 | 438.61 | 438.98 | 0.009925 | 1.32 | 0.32 | 5.11 | 9.66 | 0.32 |
| Palo Seco | 1 | 36 | 1YR P | 5.80 | 438.09 | 439.33 | 438.58 | 439.34 | 0.001394 | 0.63 | 0.07 | 9.17 | 12.02 | 0.13 |

HEC-RAS Plan: Scenario3

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 1 | 38.2 | 100YR E | 610.90 | 414.89 | 419.73 | | 420.62 | 0.023857 | 8.01 | 5.99 | 86.20 | 26.76 | 0.67 |
| Sausal | 1 | 38.2 | 100YR P | 538.90 | 414.89 | 419.37 | | 420.24 | 0.025534 | 7.84 | 5.91 | 76.87 | 25.78 | 0.68 |
| Sausal | 1 | 38.2 | 25YR E | 420.70 | 414.89 | 418.81 | | 419.60 | 0.027200 | 7.35 | 5.44 | 62.91 | 24.24 | 0.69 |
| Sausal | 1 | 38.2 | 25YR P | 424.70 | 414.89 | 418.79 | | 419.60 | 0.028417 | 7.48 | 5.65 | 62.35 | 24.18 | 0.70 |
| Sausal | 1 | 38.2 | 10YR E | 346.30 | 414.89 | 418.38 | | 419.12 | 0.030364 | 7.11 | 5.32 | 52.52 | 22.90 | 0.71 |
| Sausal | 1 | 38.2 | 10YR P | 350.30 | 414.89 | 418.37 | | 419.14 | 0.031145 | 7.20 | 5.46 | 52.48 | 22.89 | 0.72 |
| Sausal | 1 | 38.2 | 5YR E | 284.90 | 414.89 | 417.99 | | 418.69 | 0.033514 | 6.84 | 5.15 | 43.99 | 21.04 | 0.73 |
| Sausal | 1 | 38.2 | 5YR P | 284.80 | 414.89 | 418.00 | | 418.70 | 0.032878 | 6.80 | 5.08 | 44.29 | 21.11 | 0.72 |
| Sausal | 1 | 38.2 | 2YR E | 195.70 | 414.89 | 417.88 | 417.01 | 418.24 | 0.018351 | 4.92 | 2.71 | 41.71 | 20.52 | 0.54 |
| Sausal | 1 | 38.2 | 2YR P | 196.60 | 414.89 | 417.93 | 417.02 | 418.28 | 0.017291 | 4.84 | 2.60 | 42.74 | 20.76 | 0.52 |
| Sausal | 1 | 38.2 | 1YR E | 35.60 | 414.89 | 416.20 | | 416.30 | 0.014794 | 2.48 | 0.91 | 14.38 | 13.62 | 0.42 |
| Sausal | 1 | 38.2 | 1YR P | 23.30 | 414.89 | 415.79 | | 415.90 | 0.027772 | 2.61 | 1.16 | 8.92 | 12.88 | 0.55 |
| | | | | | | | | | | | | | | |
| Sausal | 1 | 38 | 100YR E | 610.90 | 412.89 | 419.03 | | 419.48 | 0.008824 | 5.77 | 2.86 | 123.43 | 30.36 | 0.42 |
| Sausal | 1 | 38 | 100YR P | 538.90 | 412.89 | 418.63 | | 419.05 | 0.009123 | 5.59 | 2.75 | 111.36 | 29.24 | 0.43 |
| Sausal | 1 | 38 | 25YR E | 420.70 | 412.89 | 418.11 | | 418.45 | 0.008274 | 4.98 | 2.25 | 96.48 | 27.80 | 0.40 |
| Sausal | 1 | 38 | 25YR P | 424.70 | 412.89 | 417.98 | | 418.36 | 0.009304 | 5.19 | 2.47 | 93.11 | 27.47 | 0.42 |
| Sausal | 1 | 38 | 10YR E | 346.30 | 412.89 | 417.59 | | 417.91 | 0.008639 | 4.72 | 2.10 | 82.58 | 26.39 | 0.40 |
| Sausal | 1 | 38 | 10YR P | 350.30 | 412.89 | 417.48 | | 417.83 | 0.009755 | 4.93 | 2.32 | 79.70 | 26.08 | 0.42 |
| Sausal | 1 | 38 | 5YR E | 284.90 | 412.89 | 417.02 | | 417.33 | 0.010135 | 4.65 | 2.14 | 67.78 | 24.79 | 0.42 |
| Sausal | 1 | 38 | 5YR P | 284.80 | 412.89 | 416.76 | | 417.13 | 0.013280 | 5.08 | 2.61 | 61.49 | 24.08 | 0.48 |
| Sausal | 1 | 38 | 2YR E | 195.70 | 412.89 | 415.09 | 415.01 | 415.90 | 0.063760 | 7.23 | 6.57 | 27.19 | 15.94 | 0.94 |
| Sausal | 1 | 38 | 2YR P | 196.60 | 412.89 | 415.02 | 415.02 | 415.90 | 0.073365 | 7.55 | 7.27 | 26.08 | 15.51 | 1.00 |
| Sausal | 1 | 38 | 1YR E | 35.60 | 412.89 | 413.71 | 413.71 | 414.03 | 0.094903 | 4.51 | 3.57 | 7.90 | 12.73 | 1.01 |
| Sausal | 1 | 38 | 1YR P | 23.30 | 412.89 | 413.80 | 413.55 | 413.91 | 0.026059 | 2.56 | 1.11 | 9.10 | 12.90 | 0.54 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35.5 | 100YR E | 744.00 | 409.89 | 418.90 | 414.44 | 419.11 | 0.002629 | 4.12 | 1.28 | 222.48 | 38.95 | 0.25 |
| Sausal | 2 | 35.5 | 100YR P | 641.90 | 409.89 | 418.52 | 414.12 | 418.70 | 0.002349 | 3.78 | 1.09 | 207.88 | 37.74 | 0.23 |
| Sausal | 2 | 35.5 | 25YR E | 521.30 | 409.89 | 418.01 | 413.70 | 418.15 | 0.002007 | 3.35 | 0.87 | 188.89 | 36.09 | 0.21 |
| Sausal | 2 | 35.5 | 25YR P | 500.70 | 409.89 | 417.90 | 413.63 | 418.04 | 0.001953 | 3.28 | 0.84 | 185.18 | 35.76 | 0.21 |
| Sausal | 2 | 35.5 | 10YR E | 426.30 | 409.89 | 417.51 | 413.29 | 417.63 | 0.001745 | 2.99 | 0.71 | 171.45 | 34.51 | 0.20 |
| Sausal | 2 | 35.5 | 10YR P | 411.50 | 409.89 | 417.42 | 413.22 | 417.53 | 0.001712 | 2.94 | 0.69 | 168.23 | 34.21 | 0.19 |
| Sausal | 2 | 35.5 | 5YR E | 349.80 | 409.89 | 416.95 | 412.93 | 417.05 | 0.001620 | 2.73 | 0.61 | 152.43 | 32.89 | 0.19 |
| Sausal | 2 | 35.5 | 5YR P | 335.20 | 409.89 | 416.70 | 412.85 | 416.80 | 0.001723 | 2.75 | 0.62 | 144.48 | 32.22 | 0.19 |
| Sausal | 2 | 35.5 | 2YR E | 240.40 | 409.89 | 415.12 | 412.30 | 415.23 | 0.002676 | 2.83 | 0.73 | 96.81 | 27.84 | 0.23 |
| Sausal | 2 | 35.5 | 2YR P | 229.00 | 409.89 | 414.93 | 412.23 | 415.04 | 0.002835 | 2.84 | 0.74 | 91.56 | 27.31 | 0.23 |
| Sausal | 2 | 35.5 | 1YR E | 42.26 | 409.89 | 411.20 | 410.79 | 411.33 | 0.021191 | 2.96 | 1.30 | 14.30 | 13.61 | 0.51 |
| Sausal | 2 | 35.5 | 1YR P | 20.90 | 409.89 | 410.51 | 410.51 | 410.74 | 0.101330 | 3.85 | 2.87 | 5.43 | 11.76 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35.4 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 35 | 100YR E | 744.00 | 326.57 | 333.99 | 332.00 | 334.59 | 0.011608 | 6.57 | 3.72 | 129.86 | 33.92 | 0.47 |
| Sausal | 2 | 35 | 100YR P | 641.90 | 326.57 | 333.60 | | 334.14 | 0.011285 | 6.20 | 3.38 | 116.94 | 31.79 | 0.45 |
| Sausal | 2 | 35 | 25YR E | 521.30 | 326.57 | 333.07 | | 333.54 | 0.010885 | 5.71 | 2.96 | 100.85 | 28.93 | 0.44 |
| Sausal | 2 | 35 | 25YR P | 500.70 | 326.57 | 332.97 | | 333.43 | 0.010822 | 5.62 | 2.89 | 97.98 | 28.39 | 0.44 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 35 | 10YR E | 426.30 | 326.57 | 332.59 | | 333.00 | 0.010468 | 5.26 | 2.59 | 87.72 | 26.37 | 0.42 |
| Sausal | 2 | 35 | 10YR P | 411.50 | 326.57 | 332.51 | | 332.91 | 0.010391 | 5.18 | 2.53 | 85.64 | 25.94 | 0.42 |
| Sausal | 2 | 35 | 5YR E | 349.80 | 326.57 | 332.15 | | 332.50 | 0.010083 | 4.84 | 2.27 | 76.68 | 24.03 | 0.41 |
| Sausal | 2 | 35 | 5YR P | 335.20 | 326.57 | 332.06 | | 332.40 | 0.010001 | 4.75 | 2.20 | 74.53 | 23.61 | 0.41 |
| Sausal | 2 | 35 | 2YR E | 240.40 | 326.57 | 331.41 | 329.60 | 331.67 | 0.009409 | 4.12 | 1.75 | 60.02 | 20.56 | 0.38 |
| Sausal | 2 | 35 | 2YR P | 229.00 | 326.57 | 331.32 | 329.53 | 331.57 | 0.009318 | 4.03 | 1.69 | 58.22 | 20.15 | 0.38 |
| Sausal | 2 | 35 | 1YR E | 42.26 | 326.57 | 328.94 | | 329.00 | 0.006819 | 2.08 | 0.58 | 20.33 | 13.39 | 0.30 |
| Sausal | 2 | 35 | 1YR P | 20.90 | 326.57 | 328.39 | 327.59 | 328.42 | 0.006222 | 1.59 | 0.38 | 13.17 | 12.56 | 0.27 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 34 | 100YR E | 744.00 | 321.02 | 324.23 | 324.23 | 325.59 | 0.049890 | 9.85 | 9.82 | 83.39 | 31.82 | 0.98 |
| Sausal | 2 | 34 | 100YR P | 641.90 | 321.02 | 323.95 | 323.95 | 325.21 | 0.051823 | 9.43 | 9.30 | 74.63 | 30.95 | 0.98 |
| Sausal | 2 | 34 | 25YR E | 521.30 | 321.02 | 323.61 | 323.61 | 324.72 | 0.053972 | 8.84 | 8.53 | 64.16 | 29.87 | 0.98 |
| Sausal | 2 | 34 | 25YR P | 500.70 | 321.02 | 323.55 | 323.55 | 324.63 | 0.054067 | 8.71 | 8.35 | 62.44 | 29.69 | 0.98 |
| Sausal | 2 | 34 | 10YR E | 426.30 | 321.02 | 323.31 | 323.31 | 324.30 | 0.056276 | 8.31 | 7.85 | 55.44 | 28.95 | 0.98 |
| Sausal | 2 | 34 | 10YR P | 411.50 | 321.02 | 323.27 | 323.27 | 324.23 | 0.056697 | 8.22 | 7.74 | 54.04 | 28.80 | 0.98 |
| Sausal | 2 | 34 | 5YR E | 349.80 | 321.02 | 323.06 | 323.06 | 323.94 | 0.058499 | 7.81 | 7.22 | 48.11 | 28.15 | 0.98 |
| Sausal | 2 | 34 | 5YR P | 335.20 | 321.02 | 323.01 | 323.01 | 323.86 | 0.058924 | 7.70 | 7.09 | 46.69 | 27.99 | 0.98 |
| Sausal | 2 | 34 | 2YR E | 240.40 | 321.02 | 322.65 | 322.65 | 323.35 | 0.062821 | 6.94 | 6.15 | 36.86 | 26.85 | 0.98 |
| Sausal | 2 | 34 | 2YR P | 229.00 | 321.02 | 322.60 | 322.60 | 323.28 | 0.063495 | 6.83 | 6.03 | 35.60 | 26.70 | 0.98 |
| Sausal | 2 | 34 | 1YR E | 42.26 | 321.02 | 321.59 | 321.59 | 321.83 | 0.093716 | 4.00 | 2.98 | 10.79 | 22.29 | 0.99 |
| Sausal | 2 | 34 | 1YR P | 20.90 | 321.02 | 321.40 | 321.40 | 321.56 | 0.109862 | 3.18 | 2.20 | 6.66 | 21.46 | 0.99 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 33 | 100YR E | 744.00 | 316.37 | 321.77 | | 323.02 | 0.021837 | 9.15 | 7.16 | 88.07 | 18.73 | 0.70 |
| Sausal | 2 | 33 | 100YR P | 641.90 | 316.37 | 321.62 | | 322.61 | 0.017911 | 8.13 | 5.71 | 85.32 | 18.62 | 0.63 |
| Sausal | 2 | 33 | 25YR E | 521.30 | 316.37 | 321.38 | | 322.10 | 0.013942 | 6.95 | 4.23 | 80.83 | 18.44 | 0.55 |
| Sausal | 2 | 33 | 25YR P | 500.70 | 316.37 | 321.34 | | 322.02 | 0.013203 | 6.72 | 3.98 | 80.15 | 18.41 | 0.54 |
| Sausal | 2 | 33 | 10YR E | 426.30 | 316.37 | 321.13 | | 321.67 | 0.011153 | 6.00 | 3.21 | 76.26 | 18.25 | 0.49 |
| Sausal | 2 | 33 | 10YR P | 411.50 | 316.37 | 321.09 | | 321.61 | 0.010641 | 5.83 | 3.04 | 75.67 | 18.23 | 0.48 |
| Sausal | 2 | 33 | 5YR E | 349.80 | 316.37 | 320.90 | | 321.30 | 0.008928 | 5.19 | 2.44 | 72.10 | 18.08 | 0.44 |
| Sausal | 2 | 33 | 5YR P | 335.20 | 316.37 | 320.85 | | 321.23 | 0.008539 | 5.03 | 2.31 | 71.16 | 18.04 | 0.43 |
| Sausal | 2 | 33 | 2YR E | 240.40 | 316.37 | 320.43 | | 320.67 | 0.006187 | 4.01 | 1.51 | 63.71 | 17.73 | 0.36 |
| Sausal | 2 | 33 | 2YR P | 229.00 | 316.37 | 320.37 | | 320.60 | 0.005924 | 3.88 | 1.43 | 62.62 | 17.68 | 0.35 |
| Sausal | 2 | 33 | 1YR E | 42.26 | 316.37 | 317.14 | 317.14 | 317.45 | 0.090840 | 4.52 | 3.55 | 9.41 | 15.25 | 1.01 |
| Sausal | 2 | 33 | 1YR P | 20.90 | 316.37 | 316.90 | 316.90 | 317.10 | 0.104433 | 3.56 | 2.57 | 5.89 | 15.07 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 32 | 100YR E | 744.00 | 314.08 | 322.36 | 317.39 | 322.48 | 0.001388 | 2.93 | 0.65 | 287.21 | 53.40 | 0.19 |
| Sausal | 2 | 32 | 100YR P | 641.90 | 314.08 | 322.07 | 317.15 | 322.17 | 0.001192 | 2.65 | 0.54 | 272.21 | 51.38 | 0.17 |
| Sausal | 2 | 32 | 25YR E | 521.30 | 314.08 | 321.70 | 316.83 | 321.77 | 0.000955 | 2.29 | 0.41 | 253.32 | 48.71 | 0.15 |
| Sausal | 2 | 32 | 25YR P | 500.70 | 314.08 | 321.64 | 316.78 | 321.71 | 0.000908 | 2.22 | 0.39 | 250.45 | 48.29 | 0.15 |
| Sausal | 2 | 32 | 10YR E | 426.30 | 314.08 | 321.36 | 316.58 | 321.42 | 0.000765 | 1.98 | 0.31 | 237.25 | 46.32 | 0.14 |
| Sausal | 2 | 32 | 10YR P | 411.50 | 314.08 | 321.31 | 316.54 | 321.36 | 0.000731 | 1.93 | 0.30 | 235.07 | 45.98 | 0.13 |
| Sausal | 2 | 32 | 5YR E | 349.80 | 314.08 | 321.07 | 316.34 | 321.11 | 0.000605 | 1.71 | 0.24 | 224.00 | 44.25 | 0.12 |
| Sausal | 2 | 32 | 5YR P | 335.20 | 314.08 | 321.00 | 316.29 | 321.04 | 0.000575 | 1.65 | 0.22 | 221.23 | 43.80 | 0.12 |
| Sausal | 2 | 32 | 2YR E | 240.40 | 314.08 | 320.53 | 315.94 | 320.55 | 0.000390 | 1.29 | 0.14 | 201.12 | 40.82 | 0.10 |
| Sausal | 2 | 32 | 2YR P | 229.00 | 314.08 | 320.46 | 315.90 | 320.48 | 0.000369 | 1.25 | 0.13 | 198.35 | 40.67 | 0.09 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 32 | 1YR E | 42.26 | 314.08 | 316.80 | 314.92 | 316.81 | 0.000432 | 0.68 | 0.05 | 63.95 | 32.87 | 0.08 |
| Sausal | 2 | 32 | 1YR P | 20.90 | 314.08 | 315.94 | 314.73 | 315.95 | 0.000545 | 0.57 | 0.04 | 37.13 | 28.75 | 0.09 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 31.5 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 30 | 100YR E | 744.00 | 300.16 | 302.61 | 302.61 | 303.70 | 0.054861 | 8.59 | 8.20 | 91.38 | 42.92 | 0.98 |
| Sausal | 2 | 30 | 100YR P | 641.90 | 300.16 | 302.39 | 302.39 | 303.39 | 0.057168 | 8.23 | 7.76 | 82.03 | 42.16 | 0.98 |
| Sausal | 2 | 30 | 25YR E | 521.30 | 300.16 | 302.11 | 302.11 | 303.00 | 0.060048 | 7.71 | 7.13 | 70.67 | 41.05 | 0.99 |
| Sausal | 2 | 30 | 25YR P | 500.70 | 300.16 | 302.07 | 302.07 | 302.93 | 0.060408 | 7.60 | 6.99 | 68.75 | 40.85 | 0.98 |
| Sausal | 2 | 30 | 10YR E | 426.30 | 300.16 | 301.88 | 301.88 | 302.67 | 0.063087 | 7.24 | 6.57 | 61.21 | 40.09 | 0.99 |
| Sausal | 2 | 30 | 10YR P | 411.50 | 300.16 | 301.84 | 301.84 | 302.61 | 0.063645 | 7.16 | 6.48 | 59.69 | 39.94 | 0.99 |
| Sausal | 2 | 30 | 5YR E | 349.80 | 300.16 | 301.68 | 301.68 | 302.38 | 0.065738 | 6.79 | 6.03 | 53.31 | 39.28 | 0.99 |
| Sausal | 2 | 30 | 5YR P | 335.20 | 300.16 | 301.64 | 301.64 | 302.32 | 0.066615 | 6.71 | 5.94 | 51.68 | 39.11 | 0.99 |
| Sausal | 2 | 30 | 2YR E | 240.40 | 300.16 | 301.40 | 301.36 | 301.91 | 0.064925 | 5.85 | 4.80 | 42.29 | 38.11 | 0.95 |
| Sausal | 2 | 30 | 2YR P | 229.00 | 300.16 | 301.37 | 301.32 | 301.86 | 0.064356 | 5.72 | 4.64 | 41.14 | 37.99 | 0.94 |
| Sausal | 2 | 30 | 1YR E | 42.26 | 300.16 | 300.64 | 300.58 | 300.77 | 0.064568 | 2.94 | 1.71 | 14.51 | 35.01 | 0.80 |
| Sausal | 2 | 30 | 1YR P | 20.90 | 300.16 | 300.48 | | 300.56 | 0.074495 | 2.32 | 1.24 | 9.05 | 34.36 | 0.79 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 29 | 100YR E | 744.00 | 296.60 | 299.11 | 299.11 | 300.30 | 0.060017 | 8.84 | 8.75 | 85.84 | 36.55 | 1.00 |
| Sausal | 2 | 29 | 100YR P | 641.90 | 296.60 | 298.88 | 298.88 | 299.97 | 0.061871 | 8.44 | 8.23 | 77.44 | 36.22 | 1.00 |
| Sausal | 2 | 29 | 25YR E | 521.30 | 296.60 | 298.59 | 298.59 | 299.54 | 0.064064 | 7.89 | 7.50 | 67.19 | 35.81 | 1.00 |
| Sausal | 2 | 29 | 25YR P | 500.70 | 296.60 | 298.54 | 298.54 | 299.47 | 0.064198 | 7.77 | 7.34 | 65.46 | 35.75 | 1.00 |
| Sausal | 2 | 29 | 10YR E | 426.30 | 296.60 | 298.35 | 298.35 | 299.19 | 0.066932 | 7.41 | 6.90 | 58.41 | 35.42 | 1.00 |
| Sausal | 2 | 29 | 10YR P | 411.50 | 296.60 | 298.31 | 298.31 | 299.13 | 0.067396 | 7.32 | 6.79 | 57.01 | 35.35 | 1.00 |
| Sausal | 2 | 29 | 5YR E | 349.80 | 296.60 | 298.14 | 298.14 | 298.88 | 0.069003 | 6.93 | 6.29 | 51.13 | 35.04 | 1.00 |
| Sausal | 2 | 29 | 5YR P | 335.20 | 296.60 | 298.10 | 298.10 | 298.82 | 0.069884 | 6.85 | 6.20 | 49.59 | 34.96 | 1.00 |
| Sausal | 2 | 29 | 2YR E | 240.40 | 296.60 | 297.80 | 297.80 | 298.39 | 0.074982 | 6.15 | 5.37 | 39.47 | 34.42 | 1.00 |
| Sausal | 2 | 29 | 2YR P | 229.00 | 296.60 | 297.77 | 297.77 | 298.33 | 0.075702 | 6.06 | 5.26 | 38.19 | 34.35 | 1.00 |
| Sausal | 2 | 29 | 1YR E | 42.26 | 296.60 | 297.03 | 296.99 | 297.19 | 0.078240 | 3.15 | 1.99 | 13.45 | 32.99 | 0.87 |
| Sausal | 2 | 29 | 1YR P | 20.90 | 296.60 | 296.90 | | 296.98 | 0.067177 | 2.28 | 1.18 | 9.20 | 32.75 | 0.76 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 28 | 100YR E | 744.00 | 289.82 | 292.39 | 292.37 | 293.55 | 0.055568 | 8.75 | 8.45 | 87.36 | 37.79 | 0.99 |
| Sausal | 2 | 28 | 100YR P | 641.90 | 289.82 | 292.15 | 292.15 | 293.22 | 0.058718 | 8.39 | 8.05 | 78.35 | 37.41 | 1.00 |
| Sausal | 2 | 28 | 25YR E | 521.30 | 289.82 | 291.86 | 291.86 | 292.81 | 0.061644 | 7.84 | 7.36 | 67.85 | 36.96 | 1.00 |
| Sausal | 2 | 28 | 25YR P | 500.70 | 289.82 | 291.81 | 291.81 | 292.73 | 0.062129 | 7.74 | 7.23 | 66.02 | 36.89 | 1.00 |
| Sausal | 2 | 28 | 10YR E | 426.30 | 289.82 | 291.63 | 291.63 | 292.45 | 0.064437 | 7.34 | 6.74 | 59.12 | 36.59 | 1.00 |
| Sausal | 2 | 28 | 10YR P | 411.50 | 289.82 | 291.59 | 291.59 | 292.40 | 0.065004 | 7.26 | 6.64 | 57.69 | 36.53 | 1.00 |
| Sausal | 2 | 28 | 5YR E | 349.80 | 289.82 | 291.42 | 291.42 | 292.15 | 0.067519 | 6.88 | 6.19 | 51.60 | 36.26 | 1.00 |
| Sausal | 2 | 28 | 5YR P | 335.20 | 289.82 | 291.38 | 291.38 | 292.09 | 0.068042 | 6.78 | 6.07 | 50.15 | 36.20 | 1.00 |
| Sausal | 2 | 28 | 2YR E | 240.40 | 289.82 | 291.10 | 291.10 | 291.67 | 0.073628 | 6.09 | 5.27 | 39.94 | 35.75 | 1.00 |
| Sausal | 2 | 28 | 2YR P | 229.00 | 289.82 | 291.06 | 291.06 | 291.61 | 0.074378 | 5.99 | 5.15 | 38.65 | 35.69 | 1.00 |
| Sausal | 2 | 28 | 1YR E | 42.26 | 289.82 | 290.31 | 290.31 | 290.49 | 0.106307 | 3.40 | 2.41 | 12.45 | 34.51 | 0.99 |
| Sausal | 2 | 28 | 1YR P | 20.90 | 289.82 | 290.17 | 290.17 | 290.29 | 0.128760 | 2.72 | 1.81 | 7.69 | 34.30 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 27 | 100YR E | 744.00 | 286.78 | 290.07 | | 291.14 | 0.035203 | 8.43 | 7.13 | 92.80 | 31.30 | 0.82 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 27 | 100YR P | 641.90 | 286.78 | 289.86 | | 290.77 | 0.033173 | 7.82 | 6.28 | 86.07 | 30.94 | 0.79 |
| Sausal | 2 | 27 | 25YR E | 521.30 | 286.78 | 289.56 | | 290.31 | 0.031215 | 7.07 | 5.32 | 76.89 | 30.44 | 0.75 |
| Sausal | 2 | 27 | 25YR P | 500.70 | 286.78 | 289.50 | | 290.23 | 0.030845 | 6.94 | 5.15 | 75.23 | 30.34 | 0.75 |
| Sausal | 2 | 27 | 10YR E | 426.30 | 286.78 | 289.29 | | 289.92 | 0.029634 | 6.44 | 4.56 | 68.83 | 29.99 | 0.72 |
| Sausal | 2 | 27 | 10YR P | 411.50 | 286.78 | 289.25 | | 289.85 | 0.029383 | 6.33 | 4.44 | 67.49 | 29.91 | 0.72 |
| Sausal | 2 | 27 | 5YR E | 349.80 | 286.78 | 289.05 | | 289.57 | 0.028408 | 5.88 | 3.94 | 61.59 | 29.58 | 0.70 |
| Sausal | 2 | 27 | 5YR P | 335.20 | 286.78 | 289.00 | | 289.50 | 0.028036 | 5.76 | 3.81 | 60.21 | 29.50 | 0.69 |
| Sausal | 2 | 27 | 2YR E | 240.40 | 286.78 | 288.65 | | 289.02 | 0.026129 | 4.95 | 2.98 | 50.00 | 28.92 | 0.65 |
| Sausal | 2 | 27 | 2YR P | 229.00 | 286.78 | 288.60 | | 288.96 | 0.026096 | 4.85 | 2.89 | 48.53 | 28.84 | 0.64 |
| Sausal | 2 | 27 | 1YR E | 42.26 | 286.78 | 287.52 | | 287.60 | 0.021164 | 2.33 | 0.91 | 18.30 | 27.03 | 0.49 |
| Sausal | 2 | 27 | 1YR P | 20.90 | 286.78 | 287.28 | | 287.33 | 0.020664 | 1.75 | 0.59 | 12.02 | 26.63 | 0.46 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 26 | 100YR E | 744.00 | 281.33 | 284.47 | 284.47 | 285.60 | 0.055120 | 8.61 | 8.24 | 88.67 | 40.09 | 0.98 |
| Sausal | 2 | 26 | 100YR P | 641.90 | 281.33 | 284.23 | 284.23 | 285.28 | 0.058250 | 8.27 | 7.86 | 79.36 | 39.40 | 0.99 |
| Sausal | 2 | 26 | 25YR E | 521.30 | 281.33 | 283.95 | 283.95 | 284.88 | 0.061521 | 7.75 | 7.23 | 68.43 | 38.58 | 0.99 |
| Sausal | 2 | 26 | 25YR P | 500.70 | 281.33 | 283.90 | 283.90 | 284.80 | 0.062246 | 7.66 | 7.12 | 66.48 | 38.43 | 1.00 |
| Sausal | 2 | 26 | 10YR E | 426.30 | 281.33 | 283.72 | 283.72 | 284.53 | 0.064864 | 7.28 | 6.66 | 59.36 | 37.88 | 1.00 |
| Sausal | 2 | 26 | 10YR P | 411.50 | 281.33 | 283.68 | 283.68 | 284.48 | 0.065417 | 7.19 | 6.57 | 57.91 | 37.77 | 1.00 |
| Sausal | 2 | 26 | 5YR E | 349.80 | 281.33 | 283.52 | 283.52 | 284.23 | 0.067586 | 6.81 | 6.10 | 51.83 | 37.29 | 1.00 |
| Sausal | 2 | 26 | 5YR P | 335.20 | 281.33 | 283.47 | 283.47 | 284.17 | 0.068683 | 6.73 | 6.02 | 50.23 | 37.17 | 1.00 |
| Sausal | 2 | 26 | 2YR E | 240.40 | 281.33 | 283.19 | 283.19 | 283.76 | 0.075034 | 6.06 | 5.25 | 39.83 | 36.34 | 1.01 |
| Sausal | 2 | 26 | 2YR P | 229.00 | 281.33 | 283.16 | 283.16 | 283.71 | 0.074762 | 5.94 | 5.09 | 38.71 | 36.25 | 1.00 |
| Sausal | 2 | 26 | 1YR E | 42.26 | 281.33 | 282.27 | 282.27 | 282.52 | 0.101683 | 3.96 | 2.99 | 10.68 | 22.58 | 1.01 |
| Sausal | 2 | 26 | 1YR P | 20.90 | 281.33 | 282.04 | 282.04 | 282.22 | 0.109076 | 3.41 | 2.43 | 6.13 | 17.12 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 25 | 100YR E | 744.00 | 277.43 | 281.93 | | 282.60 | 0.017559 | 6.72 | 4.26 | 118.76 | 35.86 | 0.60 |
| Sausal | 2 | 25 | 100YR P | 641.90 | 277.43 | 281.68 | | 282.26 | 0.016518 | 6.23 | 3.75 | 109.86 | 35.13 | 0.57 |
| Sausal | 2 | 25 | 25YR E | 521.30 | 277.43 | 281.34 | | 281.81 | 0.015356 | 5.63 | 3.16 | 98.08 | 34.15 | 0.54 |
| Sausal | 2 | 25 | 25YR P | 500.70 | 277.43 | 281.29 | | 281.74 | 0.015062 | 5.51 | 3.05 | 96.12 | 33.98 | 0.54 |
| Sausal | 2 | 25 | 10YR E | 426.30 | 277.43 | 281.06 | | 281.44 | 0.014064 | 5.08 | 2.65 | 88.45 | 33.32 | 0.51 |
| Sausal | 2 | 25 | 10YR P | 411.50 | 277.43 | 281.01 | | 281.38 | 0.013867 | 4.99 | 2.57 | 86.83 | 33.18 | 0.51 |
| Sausal | 2 | 25 | 5YR E | 349.80 | 277.43 | 280.79 | | 281.11 | 0.013095 | 4.60 | 2.25 | 79.58 | 32.54 | 0.49 |
| Sausal | 2 | 25 | 5YR P | 335.20 | 277.43 | 280.73 | | 281.03 | 0.012997 | 4.52 | 2.18 | 77.59 | 32.36 | 0.48 |
| Sausal | 2 | 25 | 2YR E | 240.40 | 277.43 | 280.34 | | 280.56 | 0.011395 | 3.82 | 1.64 | 65.31 | 31.24 | 0.44 |
| Sausal | 2 | 25 | 2YR P | 229.00 | 277.43 | 280.29 | | 280.50 | 0.011185 | 3.73 | 1.57 | 63.68 | 31.09 | 0.44 |
| Sausal | 2 | 25 | 1YR E | 42.26 | 277.43 | 278.95 | | 278.99 | 0.007925 | 1.73 | 0.46 | 24.57 | 27.05 | 0.32 |
| Sausal | 2 | 25 | 1YR P | 20.90 | 277.43 | 278.53 | | 278.56 | 0.007243 | 1.41 | 0.33 | 14.84 | 20.54 | 0.29 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 24 | 100YR E | 744.00 | 274.71 | 278.20 | | 278.95 | 0.029080 | 6.99 | 5.14 | 109.54 | 41.75 | 0.73 |
| Sausal | 2 | 24 | 100YR P | 641.90 | 274.71 | 277.91 | | 278.61 | 0.031243 | 6.75 | 4.96 | 97.55 | 41.05 | 0.74 |
| Sausal | 2 | 24 | 25YR E | 521.30 | 274.71 | 277.56 | | 278.18 | 0.034307 | 6.40 | 4.69 | 83.13 | 40.18 | 0.76 |
| Sausal | 2 | 24 | 25YR P | 500.70 | 274.71 | 277.49 | 277.15 | 278.11 | 0.035340 | 6.35 | 4.67 | 80.32 | 40.01 | 0.77 |
| Sausal | 2 | 24 | 10YR E | 426.30 | 274.71 | 277.24 | 276.97 | 277.82 | 0.039126 | 6.15 | 4.57 | 70.40 | 39.40 | 0.79 |
| Sausal | 2 | 24 | 10YR P | 411.50 | 274.71 | 277.19 | 276.93 | 277.76 | 0.039938 | 6.10 | 4.54 | 68.44 | 39.28 | 0.80 |
| Sausal | 2 | 24 | 5YR E | 349.80 | 274.71 | 276.98 | 276.77 | 277.51 | 0.043313 | 5.87 | 4.36 | 60.36 | 38.78 | 0.81 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 24 | 5YR P | 335.20 | 274.71 | 276.94 | 276.73 | 277.45 | 0.043579 | 5.78 | 4.27 | 58.68 | 38.67 | 0.81 |
| Sausal | 2 | 24 | 2YR E | 240.40 | 274.71 | 276.57 | 276.46 | 277.02 | 0.054625 | 5.42 | 4.11 | 44.67 | 37.86 | 0.87 |
| Sausal | 2 | 24 | 2YR P | 229.00 | 274.71 | 276.53 | 276.42 | 276.97 | 0.056266 | 5.37 | 4.07 | 42.97 | 37.77 | 0.88 |
| Sausal | 2 | 24 | 1YR E | 42.26 | 274.71 | 275.57 | 275.57 | 275.79 | 0.103043 | 3.74 | 2.76 | 11.30 | 26.30 | 1.01 |
| Sausal | 2 | 24 | 1YR P | 20.90 | 274.71 | 275.36 | 275.36 | 275.52 | 0.115349 | 3.27 | 2.32 | 6.39 | 19.77 | 1.01 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 23 | 100YR E | 744.00 | 269.26 | 274.25 | 273.46 | 275.12 | 0.019405 | 8.00 | 5.68 | 107.15 | 30.08 | 0.65 |
| Sausal | 2 | 23 | 100YR P | 641.90 | 269.26 | 273.93 | 273.20 | 274.72 | 0.018984 | 7.55 | 5.18 | 97.60 | 29.76 | 0.63 |
| Sausal | 2 | 23 | 25YR E | 521.30 | 269.26 | 273.52 | 272.82 | 274.20 | 0.018413 | 6.96 | 4.55 | 85.45 | 29.34 | 0.61 |
| Sausal | 2 | 23 | 25YR P | 500.70 | 269.26 | 273.45 | 272.63 | 274.11 | 0.018158 | 6.84 | 4.42 | 83.49 | 29.28 | 0.61 |
| Sausal | 2 | 23 | 10YR E | 426.30 | 269.26 | 273.19 | 272.30 | 273.77 | 0.017292 | 6.37 | 3.93 | 75.87 | 29.01 | 0.59 |
| Sausal | 2 | 23 | 10YR P | 411.50 | 269.26 | 273.14 | 272.23 | 273.70 | 0.017146 | 6.28 | 3.83 | 74.22 | 28.95 | 0.58 |
| Sausal | 2 | 23 | 5YR E | 349.80 | 269.26 | 272.87 | 271.87 | 273.38 | 0.016728 | 5.90 | 3.47 | 66.64 | 28.69 | 0.57 |
| Sausal | 2 | 23 | 5YR P | 335.20 | 269.26 | 272.80 | 271.83 | 273.29 | 0.016852 | 5.83 | 3.41 | 64.42 | 28.61 | 0.57 |
| Sausal | 2 | 23 | 2YR E | 240.40 | 269.26 | 272.30 | 271.41 | 272.68 | 0.015787 | 5.06 | 2.71 | 51.41 | 24.23 | 0.54 |
| Sausal | 2 | 23 | 2YR P | 229.00 | 269.26 | 272.24 | 271.35 | 272.60 | 0.015598 | 4.95 | 2.62 | 49.84 | 23.64 | 0.53 |
| Sausal | 2 | 23 | 1YR E | 42.26 | 269.26 | 270.64 | | 270.72 | 0.011504 | 2.34 | 0.79 | 18.35 | 17.61 | 0.39 |
| Sausal | 2 | 23 | 1YR P | 20.90 | 269.26 | 270.27 | | 270.32 | 0.010700 | 1.73 | 0.49 | 12.14 | 16.82 | 0.35 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 22 | 100YR E | 744.00 | 265.90 | 269.08 | 269.08 | 270.47 | 0.049376 | 9.67 | 9.54 | 82.07 | 30.64 | 0.97 |
| Sausal | 2 | 22 | 100YR P | 641.90 | 265.90 | 268.81 | 268.81 | 270.08 | 0.050645 | 9.22 | 8.94 | 73.89 | 30.17 | 0.97 |
| Sausal | 2 | 22 | 25YR E | 521.30 | 265.90 | 268.47 | 268.47 | 269.59 | 0.052520 | 8.62 | 8.15 | 63.71 | 29.57 | 0.96 |
| Sausal | 2 | 22 | 25YR P | 500.70 | 265.90 | 268.39 | 268.39 | 269.50 | 0.053919 | 8.56 | 8.12 | 61.49 | 29.26 | 0.97 |
| Sausal | 2 | 22 | 10YR E | 426.30 | 265.90 | 268.12 | 268.12 | 269.15 | 0.058819 | 8.25 | 7.86 | 53.77 | 27.71 | 0.99 |
| Sausal | 2 | 22 | 10YR P | 411.50 | 265.90 | 268.07 | 268.07 | 269.08 | 0.059734 | 8.18 | 7.78 | 52.29 | 27.41 | 1.00 |
| Sausal | 2 | 22 | 5YR E | 349.80 | 265.90 | 267.85 | 267.85 | 268.77 | 0.062345 | 7.77 | 7.28 | 46.50 | 26.45 | 1.00 |
| Sausal | 2 | 22 | 5YR P | 335.20 | 265.90 | 267.81 | 267.81 | 268.69 | 0.061421 | 7.61 | 7.03 | 45.49 | 26.38 | 0.99 |
| Sausal | 2 | 22 | 2YR E | 240.40 | 265.90 | 267.45 | 267.45 | 268.17 | 0.066528 | 6.84 | 6.11 | 36.06 | 25.77 | 0.99 |
| Sausal | 2 | 22 | 2YR P | 229.00 | 265.90 | 267.40 | 267.40 | 268.10 | 0.067610 | 6.74 | 6.00 | 34.82 | 25.68 | 1.00 |
| Sausal | 2 | 22 | 1YR E | 42.26 | 265.90 | 266.45 | 266.45 | 266.68 | 0.098956 | 3.87 | 2.87 | 11.00 | 24.05 | 1.00 |
| Sausal | 2 | 22 | 1YR P | 20.90 | 265.90 | 266.28 | 266.27 | 266.42 | 0.109147 | 3.01 | 2.02 | 6.97 | 23.76 | 0.97 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 21 | 100YR E | 744.00 | 263.02 | 266.80 | | 267.36 | 0.015384 | 6.13 | 3.59 | 128.14 | 38.09 | 0.56 |
| Sausal | 2 | 21 | 100YR P | 641.90 | 263.02 | 266.53 | | 267.02 | 0.014907 | 5.73 | 3.23 | 117.72 | 37.45 | 0.54 |
| Sausal | 2 | 21 | 25YR E | 521.30 | 263.02 | 266.16 | | 266.57 | 0.014346 | 5.23 | 2.78 | 104.33 | 36.72 | 0.52 |
| Sausal | 2 | 21 | 25YR P | 500.70 | 263.02 | 266.10 | | 266.49 | 0.014254 | 5.13 | 2.70 | 101.89 | 36.58 | 0.52 |
| Sausal | 2 | 21 | 10YR E | 426.30 | 263.02 | 265.84 | | 266.19 | 0.013970 | 4.79 | 2.43 | 92.58 | 36.06 | 0.51 |
| Sausal | 2 | 21 | 10YR P | 411.50 | 263.02 | 265.79 | | 266.13 | 0.013879 | 4.72 | 2.37 | 90.72 | 35.96 | 0.50 |
| Sausal | 2 | 21 | 5YR E | 349.80 | 263.02 | 265.56 | | 265.85 | 0.013536 | 4.39 | 2.11 | 82.51 | 35.49 | 0.49 |
| Sausal | 2 | 21 | 5YR P | 335.20 | 263.02 | 265.50 | | 265.78 | 0.013465 | 4.31 | 2.05 | 80.46 | 35.38 | 0.49 |
| Sausal | 2 | 21 | 2YR E | 240.40 | 263.02 | 265.09 | | 265.30 | 0.013018 | 3.75 | 1.65 | 66.00 | 34.54 | 0.46 |
| Sausal | 2 | 21 | 2YR P | 229.00 | 263.02 | 265.03 | | 265.24 | 0.012982 | 3.68 | 1.60 | 64.08 | 34.42 | 0.46 |
| Sausal | 2 | 21 | 1YR E | 42.26 | 263.02 | 263.80 | | 263.85 | 0.012088 | 1.84 | 0.56 | 23.12 | 31.91 | 0.38 |
| Sausal | 2 | 21 | 1YR P | 20.90 | 263.02 | 263.54 | 263.30 | 263.57 | 0.012660 | 1.41 | 0.38 | 14.87 | 31.39 | 0.36 |
| | | | | | | | | | | | | | | |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 20 | 100YR E | 744.00 | 260.09 | 264.12 | | 264.81 | 0.022088 | 6.78 | 4.58 | 115.71 | 41.01 | 0.65 |
| Sausal | 2 | 20 | 100YR P | 641.90 | 260.09 | 263.79 | | 264.44 | 0.023535 | 6.53 | 4.40 | 102.65 | 39.35 | 0.66 |
| Sausal | 2 | 20 | 25YR E | 521.30 | 260.09 | 263.41 | | 263.98 | 0.024853 | 6.13 | 4.05 | 87.95 | 37.23 | 0.67 |
| Sausal | 2 | 20 | 25YR P | 500.70 | 260.09 | 263.34 | | 263.90 | 0.025121 | 6.05 | 3.99 | 85.39 | 36.89 | 0.67 |
| Sausal | 2 | 20 | 10YR E | 426.30 | 260.09 | 263.09 | | 263.59 | 0.026086 | 5.75 | 3.73 | 76.11 | 35.84 | 0.67 |
| Sausal | 2 | 20 | 10YR P | 411.50 | 260.09 | 263.03 | | 263.53 | 0.026228 | 5.68 | 3.67 | 74.30 | 35.71 | 0.67 |
| Sausal | 2 | 20 | 5YR E | 349.80 | 260.09 | 262.81 | | 263.25 | 0.027296 | 5.40 | 3.43 | 66.22 | 35.12 | 0.67 |
| Sausal | 2 | 20 | 5YR P | 335.20 | 260.09 | 262.75 | | 263.19 | 0.027454 | 5.32 | 3.36 | 64.35 | 34.98 | 0.67 |
| Sausal | 2 | 20 | 2YR E | 240.40 | 260.09 | 262.39 | | 262.73 | 0.027994 | 4.69 | 2.80 | 51.95 | 34.06 | 0.65 |
| Sausal | 2 | 20 | 2YR P | 229.00 | 260.09 | 262.35 | | 262.67 | 0.028055 | 4.61 | 2.72 | 50.37 | 33.94 | 0.65 |
| Sausal | 2 | 20 | 1YR E | 42.26 | 260.09 | 261.32 | | 261.41 | 0.027646 | 2.45 | 1.06 | 17.22 | 28.06 | 0.55 |
| Sausal | 2 | 20 | 1YR P | 20.90 | 260.09 | 261.04 | 260.82 | 261.11 | 0.026608 | 2.03 | 0.79 | 10.30 | 21.70 | 0.52 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 19 | 100YR E | 744.00 | 255.79 | 260.21 | 260.21 | 261.96 | 0.052958 | 10.71 | 11.31 | 71.95 | 21.33 | 1.00 |
| Sausal | 2 | 19 | 100YR P | 641.90 | 255.79 | 259.88 | 259.88 | 261.47 | 0.054280 | 10.18 | 10.54 | 65.08 | 21.11 | 0.99 |
| Sausal | 2 | 19 | 25YR E | 521.30 | 255.79 | 259.45 | 259.45 | 260.85 | 0.057870 | 9.56 | 9.75 | 56.02 | 20.82 | 1.00 |
| Sausal | 2 | 19 | 25YR P | 500.70 | 255.79 | 259.38 | 259.38 | 260.74 | 0.058363 | 9.43 | 9.57 | 54.49 | 20.77 | 1.00 |
| Sausal | 2 | 19 | 10YR E | 426.30 | 255.79 | 259.10 | 259.10 | 260.33 | 0.060422 | 8.94 | 8.92 | 48.79 | 20.58 | 1.00 |
| Sausal | 2 | 19 | 10YR P | 411.50 | 255.79 | 259.04 | 259.04 | 260.25 | 0.061096 | 8.84 | 8.80 | 47.57 | 20.54 | 1.00 |
| Sausal | 2 | 19 | 5YR E | 349.80 | 255.79 | 258.81 | 258.81 | 259.88 | 0.062181 | 8.34 | 8.09 | 42.79 | 20.38 | 1.00 |
| Sausal | 2 | 19 | 5YR P | 335.20 | 255.79 | 258.75 | 258.75 | 259.79 | 0.062875 | 8.22 | 7.94 | 41.53 | 20.34 | 1.00 |
| Sausal | 2 | 19 | 2YR E | 240.40 | 255.79 | 258.32 | 258.32 | 259.17 | 0.069470 | 7.43 | 6.99 | 32.83 | 20.05 | 1.01 |
| Sausal | 2 | 19 | 2YR P | 229.00 | 255.79 | 258.26 | 258.26 | 259.09 | 0.070426 | 7.31 | 6.85 | 31.73 | 20.01 | 1.01 |
| Sausal | 2 | 19 | 1YR E | 42.26 | 255.79 | 257.12 | 257.12 | 257.42 | 0.098454 | 4.43 | 3.51 | 9.57 | 16.05 | 1.01 |
| Sausal | 2 | 19 | 1YR P | 20.90 | 255.79 | 256.81 | 256.81 | 257.05 | 0.112108 | 3.92 | 3.02 | 5.33 | 11.55 | 1.02 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 18 | 100YR E | 744.00 | 247.75 | 252.62 | 252.32 | 254.29 | 0.039737 | 10.39 | 10.06 | 72.60 | 17.87 | 0.90 |
| Sausal | 2 | 18 | 100YR P | 641.90 | 247.75 | 252.34 | 251.98 | 253.77 | 0.037253 | 9.61 | 8.80 | 67.65 | 17.82 | 0.86 |
| Sausal | 2 | 18 | 25YR E | 521.30 | 247.75 | 251.96 | 251.51 | 253.12 | 0.034935 | 8.67 | 7.43 | 60.76 | 17.74 | 0.82 |
| Sausal | 2 | 18 | 25YR P | 500.70 | 247.75 | 251.88 | 251.43 | 253.01 | 0.034545 | 8.50 | 7.19 | 59.49 | 17.73 | 0.81 |
| Sausal | 2 | 18 | 10YR E | 426.30 | 247.75 | 251.61 | 251.14 | 252.57 | 0.033232 | 7.88 | 6.36 | 54.58 | 17.67 | 0.78 |
| Sausal | 2 | 18 | 10YR P | 411.50 | 247.75 | 251.55 | 251.08 | 252.48 | 0.033025 | 7.76 | 6.20 | 53.52 | 17.66 | 0.78 |
| Sausal | 2 | 18 | 5YR E | 349.80 | 247.75 | 251.28 | 250.80 | 252.09 | 0.032267 | 7.22 | 5.53 | 48.83 | 17.61 | 0.76 |
| Sausal | 2 | 18 | 5YR P | 335.20 | 247.75 | 251.21 | 250.73 | 251.99 | 0.032138 | 7.09 | 5.38 | 47.63 | 17.60 | 0.75 |
| Sausal | 2 | 18 | 2YR E | 240.40 | 247.75 | 250.72 | | 251.31 | 0.032226 | 6.21 | 4.41 | 38.90 | 17.50 | 0.73 |
| Sausal | 2 | 18 | 2YR P | 229.00 | 247.75 | 250.65 | | 251.23 | 0.032273 | 6.10 | 4.29 | 37.76 | 17.49 | 0.73 |
| Sausal | 2 | 18 | 1YR E | 42.26 | 247.75 | 249.16 | 248.94 | 249.33 | 0.035257 | 3.34 | 1.78 | 12.64 | 15.41 | 0.65 |
| Sausal | 2 | 18 | 1YR P | 20.90 | 247.75 | 248.86 | 248.65 | 248.96 | 0.034297 | 2.56 | 1.19 | 8.15 | 14.51 | 0.60 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 17 | 100YR E | 744.00 | 246.75 | 250.67 | 250.67 | 252.14 | 0.048143 | 10.13 | 10.16 | 81.48 | 29.16 | 0.91 |
| Sausal | 2 | 17 | 100YR P | 641.90 | 246.75 | 250.39 | 250.37 | 251.72 | 0.047734 | 9.60 | 9.35 | 73.50 | 28.19 | 0.89 |
| Sausal | 2 | 17 | 25YR E | 521.30 | 246.75 | 250.05 | 249.96 | 251.19 | 0.046305 | 8.83 | 8.19 | 63.98 | 26.99 | 0.86 |
| Sausal | 2 | 17 | 25YR P | 500.70 | 246.75 | 249.98 | 249.87 | 251.10 | 0.046054 | 8.69 | 7.99 | 62.26 | 26.72 | 0.86 |
| Sausal | 2 | 17 | 10YR E | 426.30 | 246.75 | 249.75 | 249.57 | 250.73 | 0.044523 | 8.12 | 7.15 | 56.10 | 25.37 | 0.83 |
| Sausal | 2 | 17 | 10YR P | 411.50 | 246.75 | 249.70 | 249.51 | 250.65 | 0.044142 | 7.99 | 6.97 | 54.86 | 25.09 | 0.83 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 17 | 5YR E | 349.80 | 246.75 | 249.48 | 249.23 | 250.32 | 0.042324 | 7.43 | 6.18 | 49.59 | 23.85 | 0.80 |
| Sausal | 2 | 17 | 5YR P | 335.20 | 246.75 | 249.43 | 249.16 | 250.23 | 0.041913 | 7.29 | 6.00 | 48.28 | 23.53 | 0.79 |
| Sausal | 2 | 17 | 2YR E | 240.40 | 246.75 | 249.04 | 248.67 | 249.64 | 0.038092 | 6.25 | 4.65 | 39.58 | 21.31 | 0.74 |
| Sausal | 2 | 17 | 2YR P | 229.00 | 246.75 | 248.99 | 248.60 | 249.56 | 0.037618 | 6.11 | 4.48 | 38.45 | 21.01 | 0.73 |
| Sausal | 2 | 17 | 1YR E | 42.26 | 246.75 | 247.63 | | 247.77 | 0.030094 | 3.01 | 1.46 | 14.04 | 16.67 | 0.58 |
| Sausal | 2 | 17 | 1YR P | 20.90 | 246.75 | 247.33 | | 247.41 | 0.030241 | 2.31 | 0.98 | 9.06 | 16.53 | 0.55 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 16 | 100YR E | 744.00 | 244.75 | 248.52 | | 249.24 | 0.020844 | 7.04 | 4.78 | 114.33 | 38.25 | 0.65 |
| Sausal | 2 | 16 | 100YR P | 641.90 | 244.75 | 248.23 | | 248.89 | 0.020904 | 6.68 | 4.41 | 103.28 | 37.74 | 0.64 |
| Sausal | 2 | 16 | 25YR E | 521.30 | 244.75 | 247.86 | | 248.42 | 0.020813 | 6.17 | 3.91 | 89.66 | 35.67 | 0.63 |
| Sausal | 2 | 16 | 25YR P | 500.70 | 244.75 | 247.79 | | 248.34 | 0.020781 | 6.07 | 3.82 | 87.28 | 35.25 | 0.62 |
| Sausal | 2 | 16 | 10YR E | 426.30 | 244.75 | 247.53 | | 248.02 | 0.020946 | 5.72 | 3.50 | 78.16 | 33.57 | 0.62 |
| Sausal | 2 | 16 | 10YR P | 411.50 | 244.75 | 247.47 | | 247.95 | 0.021015 | 5.65 | 3.44 | 76.28 | 33.21 | 0.61 |
| Sausal | 2 | 16 | 5YR E | 349.80 | 244.75 | 247.22 | | 247.65 | 0.021434 | 5.34 | 3.18 | 68.18 | 31.54 | 0.61 |
| Sausal | 2 | 16 | 5YR P | 335.20 | 244.75 | 247.16 | | 247.58 | 0.021509 | 5.26 | 3.10 | 66.27 | 31.12 | 0.61 |
| Sausal | 2 | 16 | 2YR E | 240.40 | 244.75 | 246.73 | | 247.06 | 0.022425 | 4.67 | 2.63 | 53.06 | 30.08 | 0.60 |
| Sausal | 2 | 16 | 2YR P | 229.00 | 244.75 | 246.67 | | 246.99 | 0.022482 | 4.59 | 2.56 | 51.43 | 29.97 | 0.60 |
| Sausal | 2 | 16 | 1YR E | 42.26 | 244.75 | 245.53 | | 245.62 | 0.020552 | 2.29 | 0.88 | 18.64 | 27.73 | 0.49 |
| Sausal | 2 | 16 | 1YR P | 20.90 | 244.75 | 245.31 | | 245.36 | 0.018642 | 1.68 | 0.54 | 12.51 | 27.29 | 0.43 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 15 | 100YR E | 744.00 | 239.86 | 245.07 | | 245.48 | 0.017773 | 5.76 | 5.50 | 156.75 | 46.03 | 0.46 |
| Sausal | 2 | 15 | 100YR P | 641.90 | 239.86 | 244.71 | | 245.09 | 0.018117 | 5.53 | 5.20 | 140.33 | 44.93 | 0.45 |
| Sausal | 2 | 15 | 25YR E | 521.30 | 239.86 | 244.24 | | 244.59 | 0.018784 | 5.24 | 4.84 | 119.48 | 43.49 | 0.45 |
| Sausal | 2 | 15 | 25YR P | 500.70 | 239.86 | 244.15 | | 244.50 | 0.018922 | 5.19 | 4.77 | 115.77 | 43.23 | 0.45 |
| Sausal | 2 | 15 | 10YR E | 426.30 | 239.86 | 243.81 | | 244.14 | 0.019272 | 4.94 | 4.46 | 101.72 | 39.94 | 0.45 |
| Sausal | 2 | 15 | 10YR P | 411.50 | 239.86 | 243.74 | | 244.06 | 0.019327 | 4.88 | 4.38 | 98.90 | 39.11 | 0.45 |
| Sausal | 2 | 15 | 5YR E | 349.80 | 239.86 | 243.43 | | 243.71 | 0.019498 | 4.62 | 4.04 | 87.12 | 35.41 | 0.45 |
| Sausal | 2 | 15 | 5YR P | 335.20 | 239.86 | 243.35 | | 243.62 | 0.019530 | 4.55 | 3.95 | 84.30 | 34.47 | 0.44 |
| Sausal | 2 | 15 | 2YR E | 240.40 | 239.86 | 242.78 | | 243.00 | 0.019824 | 4.03 | 3.31 | 66.25 | 30.33 | 0.43 |
| Sausal | 2 | 15 | 2YR P | 229.00 | 239.86 | 242.70 | | 242.92 | 0.019919 | 3.96 | 3.23 | 64.04 | 30.13 | 0.43 |
| Sausal | 2 | 15 | 1YR E | 42.26 | 239.86 | 241.05 | | 241.13 | 0.027150 | 2.35 | 1.60 | 18.77 | 22.87 | 0.43 |
| Sausal | 2 | 15 | 1YR P | 20.90 | 239.86 | 240.70 | | 240.75 | 0.032333 | 1.89 | 1.21 | 11.27 | 20.51 | 0.43 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 14 | 100YR E | 744.00 | 236.10 | 240.35 | | 241.34 | 0.025262 | 8.19 | 6.29 | 98.99 | 33.95 | 0.72 |
| Sausal | 2 | 14 | 100YR P | 641.90 | 236.10 | 240.05 | | 240.94 | 0.024856 | 7.72 | 5.73 | 89.26 | 31.59 | 0.71 |
| Sausal | 2 | 14 | 25YR E | 521.30 | 236.10 | 239.65 | | 240.42 | 0.024458 | 7.10 | 5.04 | 77.33 | 28.42 | 0.69 |
| Sausal | 2 | 14 | 25YR P | 500.70 | 236.10 | 239.58 | | 240.32 | 0.024337 | 6.98 | 4.91 | 75.32 | 27.85 | 0.68 |
| Sausal | 2 | 14 | 10YR E | 426.30 | 236.10 | 239.30 | | 239.95 | 0.023895 | 6.52 | 4.41 | 67.93 | 25.64 | 0.67 |
| Sausal | 2 | 14 | 10YR P | 411.50 | 236.10 | 239.24 | | 239.87 | 0.023839 | 6.43 | 4.31 | 66.41 | 25.25 | 0.66 |
| Sausal | 2 | 14 | 5YR E | 349.80 | 236.10 | 238.99 | | 239.54 | 0.023487 | 6.01 | 3.88 | 60.10 | 24.66 | 0.65 |
| Sausal | 2 | 14 | 5YR P | 335.20 | 236.10 | 238.93 | | 239.46 | 0.023376 | 5.90 | 3.77 | 58.57 | 24.51 | 0.64 |
| Sausal | 2 | 14 | 2YR E | 240.40 | 236.10 | 238.49 | | 238.89 | 0.022544 | 5.12 | 3.02 | 48.00 | 23.63 | 0.61 |
| Sausal | 2 | 14 | 2YR P | 229.00 | 236.10 | 238.43 | | 238.82 | 0.022290 | 5.01 | 2.91 | 46.72 | 23.55 | 0.61 |
| Sausal | 2 | 14 | 1YR E | 42.26 | 236.10 | 237.19 | | 237.27 | 0.015182 | 2.28 | 0.81 | 18.56 | 21.71 | 0.43 |
| Sausal | 2 | 14 | 1YR P | 20.90 | 236.10 | 236.90 | | 236.95 | 0.013151 | 1.68 | 0.50 | 12.41 | 20.33 | 0.38 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 13 | 100YR E | 744.00 | 226.99 | 232.34 | | 233.18 | 0.017430 | 8.00 | 5.53 | 110.38 | 30.49 | 0.62 |
| Sausal | 2 | 13 | 100YR P | 641.90 | 226.99 | 231.92 | | 232.71 | 0.018028 | 7.69 | 5.25 | 97.92 | 28.84 | 0.63 |
| Sausal | 2 | 13 | 25YR E | 521.30 | 226.99 | 231.40 | | 232.11 | 0.018655 | 7.23 | 4.83 | 83.32 | 27.01 | 0.62 |
| Sausal | 2 | 13 | 25YR P | 500.70 | 226.99 | 231.30 | | 232.00 | 0.018811 | 7.14 | 4.76 | 80.73 | 26.68 | 0.62 |
| Sausal | 2 | 13 | 10YR E | 426.30 | 226.99 | 230.94 | | 231.58 | 0.019387 | 6.81 | 4.46 | 71.26 | 25.43 | 0.62 |
| Sausal | 2 | 13 | 10YR P | 411.50 | 226.99 | 230.86 | | 231.49 | 0.019472 | 6.74 | 4.39 | 69.40 | 25.17 | 0.62 |
| Sausal | 2 | 13 | 5YR E | 349.80 | 226.99 | 230.54 | | 231.11 | 0.019942 | 6.40 | 4.10 | 61.40 | 24.06 | 0.62 |
| Sausal | 2 | 13 | 5YR P | 335.20 | 226.99 | 230.46 | | 231.02 | 0.020086 | 6.32 | 4.03 | 59.45 | 23.78 | 0.62 |
| Sausal | 2 | 13 | 2YR E | 240.40 | 226.99 | 229.88 | | 230.35 | 0.021316 | 5.71 | 3.50 | 46.26 | 21.79 | 0.62 |
| Sausal | 2 | 13 | 2YR P | 229.00 | 226.99 | 229.80 | | 230.26 | 0.021638 | 5.63 | 3.45 | 44.52 | 21.51 | 0.62 |
| Sausal | 2 | 13 | 1YR E | 42.26 | 226.99 | 228.05 | | 228.24 | 0.039478 | 3.55 | 2.00 | 12.14 | 15.71 | 0.69 |
| Sausal | 2 | 13 | 1YR P | 20.90 | 226.99 | 227.71 | | 227.85 | 0.052040 | 3.01 | 1.68 | 7.02 | 13.86 | 0.74 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 12 | 100YR E | 744.00 | 223.66 | 229.22 | 228.27 | 230.23 | 0.020976 | 8.57 | 6.43 | 100.02 | 25.75 | 0.66 |
| Sausal | 2 | 12 | 100YR P | 641.90 | 223.66 | 228.90 | 227.93 | 229.78 | 0.019948 | 8.01 | 5.73 | 91.69 | 25.03 | 0.63 |
| Sausal | 2 | 12 | 25YR E | 521.30 | 223.66 | 228.42 | 227.48 | 229.18 | 0.019331 | 7.37 | 5.02 | 80.02 | 23.99 | 0.61 |
| Sausal | 2 | 12 | 25YR P | 500.70 | 223.66 | 228.34 | 227.38 | 229.07 | 0.019168 | 7.25 | 4.88 | 78.00 | 23.80 | 0.61 |
| Sausal | 2 | 12 | 10YR E | 426.30 | 223.66 | 228.02 | 227.04 | 228.67 | 0.018435 | 6.76 | 4.36 | 70.59 | 23.11 | 0.59 |
| Sausal | 2 | 12 | 10YR P | 411.50 | 223.66 | 227.95 | 226.97 | 228.58 | 0.018392 | 6.67 | 4.27 | 68.91 | 22.95 | 0.59 |
| Sausal | 2 | 12 | 5YR E | 349.80 | 223.66 | 227.64 | 226.67 | 228.21 | 0.017870 | 6.24 | 3.84 | 62.07 | 22.28 | 0.57 |
| Sausal | 2 | 12 | 5YR P | 335.20 | 223.66 | 227.57 | 226.60 | 228.11 | 0.017698 | 6.13 | 3.72 | 60.44 | 22.12 | 0.57 |
| Sausal | 2 | 12 | 2YR E | 240.40 | 223.66 | 227.03 | 226.08 | 227.45 | 0.016478 | 5.31 | 2.95 | 48.97 | 20.35 | 0.53 |
| Sausal | 2 | 12 | 2YR P | 229.00 | 223.66 | 226.95 | 226.00 | 227.36 | 0.016401 | 5.21 | 2.86 | 47.40 | 20.07 | 0.53 |
| Sausal | 2 | 12 | 1YR E | 42.26 | 223.66 | 225.20 | | 225.30 | 0.011120 | 2.43 | 0.83 | 17.61 | 14.49 | 0.38 |
| Sausal | 2 | 12 | 1YR P | 20.90 | 223.66 | 224.78 | | 224.83 | 0.010075 | 1.81 | 0.52 | 11.63 | 13.91 | 0.34 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 11 | 100YR E | 744.00 | 220.94 | 225.45 | 225.45 | 227.10 | 0.012088 | 10.63 | 2.60 | 74.54 | 23.39 | 0.96 |
| Sausal | 2 | 11 | 100YR P | 641.90 | 220.94 | 225.10 | 225.10 | 226.63 | 0.012722 | 10.22 | 2.48 | 66.45 | 22.53 | 0.97 |
| Sausal | 2 | 11 | 25YR E | 521.30 | 220.94 | 224.67 | 224.67 | 226.04 | 0.013107 | 9.59 | 2.27 | 57.16 | 21.45 | 0.97 |
| Sausal | 2 | 11 | 25YR P | 500.70 | 220.94 | 224.59 | 224.59 | 225.93 | 0.013190 | 9.48 | 2.23 | 55.42 | 21.23 | 0.97 |
| Sausal | 2 | 11 | 10YR E | 426.30 | 220.94 | 224.28 | 224.28 | 225.52 | 0.013589 | 9.10 | 2.11 | 48.98 | 20.38 | 0.97 |
| Sausal | 2 | 11 | 10YR P | 411.50 | 220.94 | 224.22 | 224.22 | 225.43 | 0.013660 | 9.01 | 2.09 | 47.69 | 20.20 | 0.97 |
| Sausal | 2 | 11 | 5YR E | 349.80 | 220.94 | 223.94 | 223.94 | 225.06 | 0.014018 | 8.61 | 1.96 | 42.21 | 19.44 | 0.97 |
| Sausal | 2 | 11 | 5YR P | 335.20 | 220.94 | 223.87 | 223.87 | 224.96 | 0.014148 | 8.52 | 1.94 | 40.85 | 19.25 | 0.98 |
| Sausal | 2 | 11 | 2YR E | 240.40 | 220.94 | 223.39 | 223.39 | 224.30 | 0.015035 | 7.77 | 1.71 | 31.85 | 17.92 | 0.98 |
| Sausal | 2 | 11 | 2YR P | 229.00 | 220.94 | 223.33 | 223.33 | 224.22 | 0.015068 | 7.64 | 1.67 | 30.80 | 17.76 | 0.98 |
| Sausal | 2 | 11 | 1YR E | 42.26 | 220.94 | 221.96 | 221.96 | 222.30 | 0.021771 | 4.63 | 0.86 | 9.12 | 13.86 | 1.01 |
| Sausal | 2 | 11 | 1YR P | 20.90 | 220.94 | 221.66 | 221.66 | 221.90 | 0.024033 | 3.92 | 0.69 | 5.33 | 11.27 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 10 | 100YR E | 744.00 | 216.69 | 222.35 | 222.35 | 224.09 | 0.009241 | 11.86 | 2.86 | 78.61 | 22.86 | 0.90 |
| Sausal | 2 | 10 | 100YR P | 641.90 | 216.69 | 221.92 | 221.92 | 223.58 | 0.009640 | 11.48 | 2.75 | 69.19 | 21.51 | 0.90 |
| Sausal | 2 | 10 | 25YR E | 521.30 | 216.69 | 221.39 | 221.39 | 222.92 | 0.010097 | 10.89 | 2.57 | 58.13 | 19.81 | 0.91 |
| Sausal | 2 | 10 | 25YR P | 500.70 | 216.69 | 221.30 | 221.30 | 222.80 | 0.010068 | 10.74 | 2.52 | 56.46 | 19.54 | 0.90 |
| Sausal | 2 | 10 | 10YR E | 426.30 | 216.69 | 220.94 | 220.94 | 222.34 | 0.010362 | 10.28 | 2.37 | 49.52 | 18.38 | 0.90 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 10 | 10YR P | 411.50 | 216.69 | 220.84 | 220.84 | 222.24 | 0.010601 | 10.24 | 2.37 | 47.82 | 18.08 | 0.91 |
| Sausal | 2 | 10 | 5YR E | 349.80 | 216.69 | 220.52 | 220.52 | 221.80 | 0.010806 | 9.75 | 2.22 | 42.07 | 17.04 | 0.91 |
| Sausal | 2 | 10 | 5YR P | 335.20 | 216.69 | 220.43 | 220.43 | 221.70 | 0.010917 | 9.65 | 2.19 | 40.61 | 16.77 | 0.91 |
| Sausal | 2 | 10 | 2YR E | 240.40 | 216.69 | 219.80 | 219.80 | 220.91 | 0.011993 | 8.87 | 1.97 | 30.72 | 14.78 | 0.92 |
| Sausal | 2 | 10 | 2YR P | 229.00 | 216.69 | 219.72 | 219.72 | 220.81 | 0.012159 | 8.76 | 1.94 | 29.50 | 14.51 | 0.92 |
| Sausal | 2 | 10 | 1YR E | 42.26 | 216.69 | 218.01 | 217.84 | 218.34 | 0.011542 | 4.58 | 0.72 | 9.39 | 9.10 | 0.77 |
| Sausal | 2 | 10 | 1YR P | 20.90 | 216.69 | 217.66 | 217.48 | 217.83 | 0.010083 | 3.38 | 0.44 | 6.24 | 8.53 | 0.68 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 9 | 100YR E | 744.00 | 212.30 | 219.48 | | 219.80 | 0.001391 | 5.13 | 0.51 | 186.07 | 53.42 | 0.35 |
| Sausal | 2 | 9 | 100YR P | 641.90 | 212.30 | 219.15 | | 219.44 | 0.001326 | 4.84 | 0.46 | 168.84 | 51.44 | 0.34 |
| Sausal | 2 | 9 | 25YR E | 521.30 | 212.30 | 218.66 | | 218.92 | 0.001296 | 4.54 | 0.41 | 144.27 | 48.47 | 0.33 |
| Sausal | 2 | 9 | 25YR P | 500.70 | 212.30 | 218.57 | | 218.83 | 0.001292 | 4.48 | 0.41 | 139.81 | 47.92 | 0.33 |
| Sausal | 2 | 9 | 10YR E | 426.30 | 212.30 | 218.00 | | 218.29 | 0.001534 | 4.56 | 0.43 | 113.80 | 44.52 | 0.35 |
| Sausal | 2 | 9 | 10YR P | 411.50 | 212.30 | 217.77 | | 218.08 | 0.001710 | 4.67 | 0.46 | 104.23 | 38.10 | 0.37 |
| Sausal | 2 | 9 | 5YR E | 349.80 | 212.30 | 216.77 | | 217.17 | 0.002941 | 5.26 | 0.63 | 73.51 | 27.39 | 0.47 |
| Sausal | 2 | 9 | 5YR P | 335.20 | 212.30 | 216.54 | | 216.97 | 0.003430 | 5.45 | 0.70 | 67.18 | 26.05 | 0.50 |
| Sausal | 2 | 9 | 2YR E | 240.40 | 212.30 | 214.92 | 214.79 | 215.78 | 0.013808 | 7.45 | 1.57 | 32.42 | 16.91 | 0.91 |
| Sausal | 2 | 9 | 2YR P | 229.00 | 212.30 | 214.72 | 214.72 | 215.68 | 0.017366 | 7.83 | 1.80 | 29.25 | 15.87 | 1.01 |
| Sausal | 2 | 9 | 1YR E | 42.26 | 212.30 | 213.31 | 213.31 | 213.66 | 0.021773 | 4.73 | 0.89 | 8.94 | 13.05 | 1.01 |
| Sausal | 2 | 9 | 1YR P | 20.90 | 212.30 | 213.04 | 213.04 | 213.27 | 0.025054 | 3.81 | 0.67 | 5.48 | 12.54 | 1.02 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 8 | 100YR E | 744.00 | 208.57 | 219.44 | 214.81 | 219.61 | 0.000643 | 4.07 | 0.30 | 258.38 | 61.66 | 0.23 |
| Sausal | 2 | 8 | 100YR P | 641.90 | 208.57 | 219.11 | 214.41 | 219.26 | 0.000597 | 3.84 | 0.27 | 238.16 | 61.66 | 0.22 |
| Sausal | 2 | 8 | 25YR E | 521.30 | 208.57 | 218.63 | 213.86 | 218.76 | 0.000522 | 3.47 | 0.22 | 209.58 | 53.54 | 0.20 |
| Sausal | 2 | 8 | 25YR P | 500.70 | 208.57 | 218.54 | 213.79 | 218.66 | 0.000499 | 3.37 | 0.21 | 205.02 | 50.73 | 0.20 |
| Sausal | 2 | 8 | 10YR E | 426.30 | 208.57 | 218.00 | 213.42 | 218.11 | 0.000482 | 3.18 | 0.19 | 179.62 | 43.05 | 0.19 |
| Sausal | 2 | 8 | 10YR P | 411.50 | 208.57 | 217.77 | 213.34 | 217.88 | 0.000501 | 3.18 | 0.19 | 170.22 | 40.11 | 0.20 |
| Sausal | 2 | 8 | 5YR E | 349.80 | 208.57 | 216.76 | 213.01 | 216.89 | 0.000667 | 3.36 | 0.22 | 132.86 | 35.56 | 0.22 |
| Sausal | 2 | 8 | 5YR P | 335.20 | 208.57 | 216.52 | 212.94 | 216.66 | 0.000716 | 3.40 | 0.23 | 124.56 | 34.22 | 0.23 |
| Sausal | 2 | 8 | 2YR E | 240.40 | 208.57 | 214.97 | 212.40 | 215.14 | 0.001089 | 3.54 | 0.27 | 79.72 | 23.86 | 0.27 |
| Sausal | 2 | 8 | 2YR P | 229.00 | 208.57 | 214.78 | 212.33 | 214.95 | 0.001149 | 3.55 | 0.28 | 75.22 | 23.13 | 0.28 |
| Sausal | 2 | 8 | 1YR E | 42.26 | 208.57 | 210.92 | 210.08 | 211.09 | 0.004087 | 3.25 | 0.33 | 12.99 | 7.91 | 0.45 |
| Sausal | 2 | 8 | 1YR P | 20.90 | 208.57 | 210.20 | 209.60 | 210.31 | 0.004090 | 2.70 | 0.25 | 7.75 | 6.49 | 0.44 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 7.8 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 7 | 100YR E | 744.00 | 204.66 | 209.26 | | 209.94 | 0.018524 | 6.71 | 4.31 | 116.56 | 36.95 | 0.60 |
| Sausal | 2 | 7 | 100YR P | 641.90 | 204.66 | 208.92 | | 209.54 | 0.018921 | 6.39 | 4.03 | 104.47 | 35.20 | 0.59 |
| Sausal | 2 | 7 | 25YR E | 521.30 | 204.66 | 208.77 | | 209.22 | 0.014546 | 5.44 | 2.97 | 99.13 | 34.40 | 0.52 |
| Sausal | 2 | 7 | 25YR P | 500.70 | 204.66 | 208.47 | | 208.98 | 0.018328 | 5.76 | 3.42 | 89.22 | 32.86 | 0.57 |
| Sausal | 2 | 7 | 10YR E | 426.30 | 204.66 | 208.44 | | 208.82 | 0.013793 | 4.96 | 2.55 | 88.11 | 32.69 | 0.49 |
| Sausal | 2 | 7 | 10YR P | 411.50 | 204.66 | 208.13 | | 208.57 | 0.018431 | 5.34 | 3.06 | 78.22 | 31.07 | 0.56 |
| Sausal | 2 | 7 | 5YR E | 349.80 | 204.66 | 207.95 | | 208.32 | 0.016702 | 4.87 | 2.60 | 72.69 | 30.13 | 0.53 |
| Sausal | 2 | 7 | 5YR P | 335.20 | 204.66 | 207.84 | | 208.21 | 0.017604 | 4.87 | 2.64 | 69.43 | 29.60 | 0.54 |
| Sausal | 2 | 7 | 2YR E | 240.40 | 204.66 | 207.42 | | 207.69 | 0.016135 | 4.20 | 2.06 | 57.37 | 27.61 | 0.50 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 7 | 2YR P | 229.00 | 204.66 | 207.35 | | 207.61 | 0.016251 | 4.13 | 2.02 | 55.47 | 27.29 | 0.50 |
| Sausal | 2 | 7 | 1YR E | 42.26 | 204.66 | 205.85 | | 205.92 | 0.013628 | 2.20 | 0.75 | 19.18 | 21.19 | 0.41 |
| Sausal | 2 | 7 | 1YR P | 20.90 | 204.66 | 205.47 | | 205.52 | 0.016338 | 1.81 | 0.59 | 11.53 | 19.71 | 0.42 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 6 | 100YR E | 1106.10 | 200.31 | 205.22 | 205.22 | 206.72 | 0.008728 | 10.81 | 2.45 | 122.71 | 39.40 | 0.88 |
| Sausal | 2 | 6 | 100YR P | 965.40 | 200.31 | 204.94 | 204.94 | 206.33 | 0.008687 | 10.34 | 2.29 | 111.61 | 38.89 | 0.87 |
| Sausal | 2 | 6 | 25YR E | 913.10 | 200.31 | 204.76 | 204.76 | 206.18 | 0.009225 | 10.37 | 2.34 | 104.86 | 38.29 | 0.89 |
| Sausal | 2 | 6 | 25YR P | 711.50 | 200.31 | 204.22 | 204.22 | 205.51 | 0.009802 | 9.74 | 2.16 | 85.04 | 34.73 | 0.90 |
| Sausal | 2 | 6 | 10YR E | 789.70 | 200.31 | 204.44 | 204.44 | 205.78 | 0.009501 | 9.98 | 2.22 | 93.01 | 36.20 | 0.89 |
| Sausal | 2 | 6 | 10YR P | 583.70 | 200.31 | 203.84 | 203.84 | 205.02 | 0.010112 | 9.21 | 2.00 | 72.54 | 32.27 | 0.90 |
| Sausal | 2 | 6 | 5YR E | 538.30 | 200.31 | 203.68 | 203.68 | 204.83 | 0.010463 | 9.06 | 1.97 | 67.45 | 31.22 | 0.90 |
| Sausal | 2 | 6 | 5YR P | 480.00 | 200.31 | 203.48 | 203.48 | 204.58 | 0.010749 | 8.79 | 1.89 | 61.35 | 29.91 | 0.91 |
| Sausal | 2 | 6 | 2YR E | 363.20 | 200.31 | 203.03 | 203.03 | 204.01 | 0.011662 | 8.18 | 1.73 | 48.51 | 26.94 | 0.92 |
| Sausal | 2 | 6 | 2YR P | 337.00 | 200.31 | 202.92 | 202.92 | 203.87 | 0.011934 | 8.02 | 1.69 | 45.55 | 26.21 | 0.92 |
| Sausal | 2 | 6 | 1YR E | 58.85 | 200.31 | 201.30 | 201.26 | 201.64 | 0.017226 | 4.72 | 0.84 | 12.61 | 16.46 | 0.93 |
| Sausal | 2 | 6 | 1YR P | 24.90 | 200.31 | 200.98 | 200.92 | 201.15 | 0.015647 | 3.30 | 0.48 | 7.57 | 15.51 | 0.83 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 5.1 | 100YR E | 1106.10 | 196.68 | 204.03 | 204.03 | 204.93 | 0.003632 | 9.45 | 1.61 | 190.65 | 121.97 | 0.62 |
| Sausal | 2 | 5.1 | 100YR P | 965.40 | 196.68 | 203.07 | 202.91 | 204.53 | 0.006094 | 11.12 | 2.34 | 111.51 | 37.85 | 0.79 |
| Sausal | 2 | 5.1 | 25YR E | 913.10 | 196.68 | 203.17 | 202.77 | 204.40 | 0.005062 | 10.24 | 1.97 | 115.28 | 39.54 | 0.72 |
| Sausal | 2 | 5.1 | 25YR P | 711.50 | 196.68 | 203.28 | | 203.97 | 0.002824 | 7.74 | 1.12 | 120.57 | 54.87 | 0.54 |
| Sausal | 2 | 5.1 | 10YR E | 789.70 | 196.68 | 203.26 | | 204.12 | 0.003540 | 8.65 | 1.40 | 119.34 | 51.73 | 0.60 |
| Sausal | 2 | 5.1 | 10YR P | 583.70 | 196.68 | 203.14 | | 203.65 | 0.002109 | 6.59 | 0.82 | 114.27 | 38.47 | 0.46 |
| Sausal | 2 | 5.1 | 5YR E | 538.30 | 196.68 | 203.09 | | 203.54 | 0.001863 | 6.16 | 0.72 | 112.35 | 38.04 | 0.44 |
| Sausal | 2 | 5.1 | 5YR P | 480.00 | 196.68 | 203.00 | | 203.38 | 0.001587 | 5.63 | 0.60 | 108.94 | 37.26 | 0.40 |
| Sausal | 2 | 5.1 | 2YR E | 363.20 | 196.68 | 202.79 | | 203.03 | 0.001073 | 4.52 | 0.39 | 101.08 | 35.41 | 0.33 |
| Sausal | 2 | 5.1 | 2YR P | 337.00 | 196.68 | 202.65 | | 202.89 | 0.001025 | 4.35 | 0.37 | 96.44 | 34.06 | 0.32 |
| Sausal | 2 | 5.1 | 1YR E | 58.85 | 196.68 | 197.97 | 197.97 | 198.47 | 0.017023 | 5.78 | 1.13 | 10.50 | 10.75 | 0.98 |
| Sausal | 2 | 5.1 | 1YR P | 24.90 | 196.68 | 197.51 | 197.51 | 197.80 | 0.021055 | 4.41 | 0.80 | 5.73 | 9.90 | 1.00 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 5 | 100YR E | 1106.10 | 196.09 | 203.42 | 203.42 | 204.74 | 0.004864 | 11.14 | 2.22 | 131.96 | 60.99 | 0.73 |
| Sausal | 2 | 5 | 100YR P | 965.40 | 196.09 | 203.08 | 202.77 | 204.34 | 0.004538 | 10.43 | 1.97 | 115.72 | 35.25 | 0.70 |
| Sausal | 2 | 5 | 25YR E | 913.10 | 196.09 | 203.17 | 202.77 | 204.24 | 0.003819 | 9.65 | 1.68 | 119.11 | 37.88 | 0.64 |
| Sausal | 2 | 5 | 25YR P | 711.50 | 196.09 | 203.29 | 202.49 | 203.89 | 0.002152 | 7.32 | 0.96 | 124.37 | 54.12 | 0.48 |
| Sausal | 2 | 5 | 10YR E | 789.70 | 196.09 | 203.26 | 202.76 | 204.01 | 0.002693 | 8.18 | 1.20 | 123.13 | 50.76 | 0.54 |
| Sausal | 2 | 5 | 10YR P | 583.70 | 196.09 | 203.15 | 201.71 | 203.59 | 0.001588 | 6.21 | 0.70 | 118.12 | 36.18 | 0.41 |
| Sausal | 2 | 5 | 5YR E | 538.30 | 196.09 | 203.10 | 201.41 | 203.48 | 0.001395 | 5.79 | 0.61 | 116.33 | 35.49 | 0.39 |
| Sausal | 2 | 5 | 5YR P | 480.00 | 196.09 | 203.01 | 201.02 | 203.33 | 0.001176 | 5.27 | 0.51 | 113.22 | 34.26 | 0.35 |
| Sausal | 2 | 5 | 2YR E | 363.20 | 196.09 | 201.91 | 200.20 | 202.92 | 0.003136 | 7.67 | 1.13 | 45.94 | 24.77 | 0.56 |
| Sausal | 2 | 5 | 2YR P | 337.00 | 196.09 | 201.92 | 200.01 | 202.78 | 0.002685 | 7.11 | 0.97 | 46.02 | 24.85 | 0.52 |
| Sausal | 2 | 5 | 1YR E | 58.85 | 196.09 | 197.36 | 197.36 | 197.96 | 0.016062 | 6.22 | 1.25 | 9.49 | 10.02 | 0.98 |
| Sausal | 2 | 5 | 1YR P | 24.90 | 196.09 | 196.83 | 196.83 | 197.18 | 0.019383 | 4.74 | 0.87 | 5.32 | 8.63 | 0.99 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 4.5 | | Culvert | | | | | | | | | | |
| | | | | | | | | | | | | | | |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 4 | 100YR E | 1106.10 | 187.02 | 192.63 | | 193.92 | 0.028544 | 9.72 | 8.38 | 128.28 | 29.73 | 0.74 |
| Sausal | 2 | 4 | 100YR P | 965.40 | 187.02 | 192.12 | | 193.37 | 0.031405 | 9.53 | 8.34 | 113.25 | 28.73 | 0.76 |
| Sausal | 2 | 4 | 25YR E | 913.10 | 187.02 | 191.92 | | 193.16 | 0.032724 | 9.47 | 8.33 | 107.57 | 28.34 | 0.77 |
| Sausal | 2 | 4 | 25YR P | 711.50 | 187.02 | 191.15 | | 192.30 | 0.038338 | 9.08 | 8.15 | 86.29 | 26.84 | 0.81 |
| Sausal | 2 | 4 | 10YR E | 789.70 | 187.02 | 191.46 | | 192.64 | 0.035798 | 9.24 | 8.22 | 94.67 | 27.44 | 0.79 |
| Sausal | 2 | 4 | 10YR P | 583.70 | 187.02 | 190.62 | | 191.72 | 0.043969 | 8.82 | 8.07 | 72.27 | 25.80 | 0.85 |
| Sausal | 2 | 4 | 5YR E | 538.30 | 187.02 | 190.42 | 190.21 | 191.50 | 0.046686 | 8.73 | 8.06 | 67.15 | 25.40 | 0.86 |
| Sausal | 2 | 4 | 5YR P | 480.00 | 187.02 | 190.15 | 190.01 | 191.21 | 0.051092 | 8.61 | 8.08 | 60.42 | 24.82 | 0.89 |
| Sausal | 2 | 4 | 2YR E | 363.20 | 187.02 | 189.58 | 189.58 | 190.59 | 0.064538 | 8.36 | 8.20 | 46.61 | 23.58 | 0.97 |
| Sausal | 2 | 4 | 2YR P | 337.00 | 187.02 | 189.48 | 189.48 | 190.44 | 0.065254 | 8.16 | 7.93 | 44.22 | 23.36 | 0.96 |
| Sausal | 2 | 4 | 1YR E | 58.85 | 187.02 | 187.94 | 187.94 | 188.32 | 0.097196 | 4.96 | 4.15 | 11.96 | 16.25 | 1.00 |
| Sausal | 2 | 4 | 1YR P | 24.90 | 187.02 | 187.67 | 187.60 | 187.83 | 0.069911 | 3.25 | 2.03 | 7.69 | 15.55 | 0.81 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 3 | 100YR E | 1106.10 | 182.75 | 190.31 | | 191.76 | 0.021110 | 9.92 | 8.02 | 126.61 | 23.90 | 0.66 |
| Sausal | 2 | 3 | 100YR P | 965.40 | 182.75 | 189.85 | | 191.15 | 0.020680 | 9.38 | 7.33 | 115.65 | 22.94 | 0.65 |
| Sausal | 2 | 3 | 25YR E | 913.10 | 182.75 | 189.66 | | 190.91 | 0.020506 | 9.17 | 7.06 | 111.46 | 22.56 | 0.64 |
| Sausal | 2 | 3 | 25YR P | 711.50 | 182.75 | 188.90 | | 189.92 | 0.019620 | 8.23 | 5.95 | 94.88 | 20.99 | 0.61 |
| Sausal | 2 | 3 | 10YR E | 789.70 | 182.75 | 189.21 | | 190.32 | 0.020001 | 8.61 | 6.40 | 101.42 | 21.63 | 0.62 |
| Sausal | 2 | 3 | 10YR P | 583.70 | 182.75 | 188.36 | | 189.22 | 0.018903 | 7.55 | 5.17 | 83.75 | 19.87 | 0.59 |
| Sausal | 2 | 3 | 5YR E | 538.30 | 182.75 | 188.14 | | 188.95 | 0.018666 | 7.29 | 4.89 | 79.57 | 19.44 | 0.58 |
| Sausal | 2 | 3 | 5YR P | 480.00 | 182.75 | 187.87 | | 188.59 | 0.018204 | 6.92 | 4.50 | 74.24 | 19.07 | 0.57 |
| Sausal | 2 | 3 | 2YR E | 363.20 | 182.75 | 187.21 | | 187.78 | 0.017474 | 6.12 | 3.70 | 62.09 | 17.98 | 0.55 |
| Sausal | 2 | 3 | 2YR P | 337.00 | 182.75 | 187.05 | | 187.59 | 0.017422 | 5.93 | 3.53 | 59.17 | 17.66 | 0.54 |
| Sausal | 2 | 3 | 1YR E | 58.85 | 182.75 | 184.38 | | 184.56 | 0.022373 | 3.41 | 1.64 | 17.30 | 13.96 | 0.54 |
| Sausal | 2 | 3 | 1YR P | 24.90 | 182.75 | 183.74 | | 183.87 | 0.031192 | 2.83 | 1.35 | 8.80 | 12.10 | 0.58 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 2 | 100YR E | 1106.10 | 176.58 | 184.58 | | 185.68 | 0.018574 | 9.51 | 7.28 | 143.26 | 29.05 | 0.60 |
| Sausal | 2 | 2 | 100YR P | 965.40 | 176.58 | 184.09 | | 185.12 | 0.018747 | 9.14 | 6.88 | 129.29 | 28.27 | 0.60 |
| Sausal | 2 | 2 | 25YR E | 913.10 | 176.58 | 183.90 | | 184.91 | 0.018805 | 9.00 | 6.72 | 124.00 | 27.98 | 0.60 |
| Sausal | 2 | 2 | 25YR P | 711.50 | 176.58 | 183.11 | | 184.01 | 0.019275 | 8.41 | 6.11 | 102.32 | 26.71 | 0.59 |
| Sausal | 2 | 2 | 10YR E | 789.70 | 176.58 | 183.43 | | 184.37 | 0.019054 | 8.64 | 6.35 | 110.95 | 27.22 | 0.60 |
| Sausal | 2 | 2 | 10YR P | 583.70 | 176.58 | 182.54 | | 183.38 | 0.019761 | 7.99 | 5.69 | 87.46 | 25.46 | 0.59 |
| Sausal | 2 | 2 | 5YR E | 538.30 | 176.58 | 182.32 | | 183.13 | 0.019964 | 7.82 | 5.53 | 81.89 | 24.68 | 0.59 |
| Sausal | 2 | 2 | 5YR P | 480.00 | 176.58 | 182.01 | | 182.78 | 0.020401 | 7.59 | 5.32 | 74.34 | 23.44 | 0.59 |
| Sausal | 2 | 2 | 2YR E | 363.20 | 176.58 | 181.33 | | 182.01 | 0.020947 | 7.00 | 4.74 | 59.40 | 20.77 | 0.59 |
| Sausal | 2 | 2 | 2YR P | 337.00 | 176.58 | 181.17 | | 181.82 | 0.020974 | 6.83 | 4.57 | 56.06 | 20.13 | 0.58 |
| Sausal | 2 | 2 | 1YR E | 58.85 | 176.58 | 178.63 | | 178.80 | 0.016440 | 3.37 | 1.49 | 17.53 | 10.51 | 0.45 |
| Sausal | 2 | 2 | 1YR P | 24.90 | 176.58 | 177.91 | | 178.00 | 0.013217 | 2.35 | 0.82 | 10.58 | 9.22 | 0.39 |
| | | | | | | | | | | | | | | |
| Sausal | 2 | 1 | 100YR E | 1106.10 | 175.30 | 182.78 | 180.57 | 183.67 | 0.015003 | 7.74 | 5.07 | 153.91 | 29.79 | 0.52 |
| Sausal | 2 | 1 | 100YR P | 965.40 | 175.30 | 182.29 | 180.09 | 183.10 | 0.015006 | 7.37 | 4.71 | 139.58 | 28.66 | 0.51 |
| Sausal | 2 | 1 | 25YR E | 913.10 | 175.30 | 182.10 | 179.93 | 182.88 | 0.015009 | 7.22 | 4.57 | 134.11 | 28.21 | 0.51 |
| Sausal | 2 | 1 | 25YR P | 711.50 | 175.30 | 181.29 | 179.31 | 181.96 | 0.015030 | 6.59 | 3.99 | 112.15 | 26.35 | 0.50 |
| Sausal | 2 | 1 | 10YR E | 789.70 | 175.30 | 181.62 | 179.55 | 182.33 | 0.015018 | 6.85 | 4.22 | 120.85 | 27.10 | 0.50 |
| Sausal | 2 | 1 | 10YR P | 583.70 | 175.30 | 180.72 | 178.88 | 181.29 | 0.015004 | 6.11 | 3.56 | 97.37 | 25.02 | 0.49 |

HEC-RAS Plan: Scenario3 (Continued)

| River | Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Vel Chnl | Shear Chan | Flow Area | Top Width | Froude # Chl |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft/ft) | (ft/s) | (lb/sq ft) | (sq ft) | (ft) | |
| Sausal | 2 | 1 | 5YR E | 538.30 | 175.30 | 180.49 | 178.72 | 181.03 | 0.015007 | 5.93 | 3.40 | 91.78 | 23.15 | 0.49 |
| Sausal | 2 | 1 | 5YR P | 480.00 | 175.30 | 180.16 | 178.49 | 180.66 | 0.015000 | 5.69 | 3.20 | 84.98 | 20.44 | 0.48 |
| Sausal | 2 | 1 | 2YR E | 363.20 | 175.30 | 179.46 | 178.02 | 179.87 | 0.015017 | 5.16 | 2.76 | 70.73 | 20.07 | 0.48 |
| Sausal | 2 | 1 | 2YR P | 337.00 | 175.30 | 179.29 | 177.91 | 179.68 | 0.015027 | 5.02 | 2.65 | 67.35 | 19.98 | 0.48 |
| Sausal | 2 | 1 | 1YR E | 58.85 | 175.30 | 176.83 | 176.25 | 176.95 | 0.015023 | 2.77 | 1.09 | 21.24 | 16.74 | 0.43 |
| Sausal | 2 | 1 | 1YR P | 24.90 | 175.30 | 176.27 | 175.91 | 176.34 | 0.015005 | 2.04 | 0.69 | 12.19 | 15.67 | 0.41 |
| | | | | | | | | | | | | | | |
| Palo Seco | 1 | 37 | 100YR E | 133.20 | 481.72 | 484.61 | 484.55 | 485.23 | 0.039095 | 7.03 | 5.58 | 23.68 | 16.17 | 0.79 |
| Palo Seco | 1 | 37 | 100YR P | 112.40 | 481.72 | 484.46 | 484.37 | 485.01 | 0.037190 | 6.57 | 4.98 | 21.24 | 15.83 | 0.76 |
| Palo Seco | 1 | 37 | 25YR E | 100.80 | 481.72 | 484.36 | 484.19 | 484.88 | 0.036003 | 6.29 | 4.63 | 19.78 | 15.62 | 0.75 |
| Palo Seco | 1 | 37 | 25YR P | 83.90 | 481.72 | 484.21 | 484.00 | 484.66 | 0.034046 | 5.83 | 4.07 | 17.43 | 14.50 | 0.72 |
| Palo Seco | 1 | 37 | 10YR E | 80.20 | 481.72 | 484.17 | 483.95 | 484.61 | 0.033735 | 5.73 | 3.95 | 16.87 | 14.20 | 0.71 |
| Palo Seco | 1 | 37 | 10YR P | 66.80 | 481.72 | 484.02 | 483.75 | 484.41 | 0.032132 | 5.31 | 3.49 | 14.83 | 13.06 | 0.68 |
| Palo Seco | 1 | 37 | 5YR E | 64.90 | 481.72 | 483.99 | 483.72 | 484.37 | 0.032169 | 5.26 | 3.44 | 14.48 | 12.86 | 0.68 |
| Palo Seco | 1 | 37 | 5YR P | 53.90 | 481.72 | 483.84 | 483.53 | 484.18 | 0.031141 | 4.89 | 3.06 | 12.63 | 11.72 | 0.66 |
| Palo Seco | 1 | 37 | 2YR E | 44.80 | 481.72 | 483.70 | 483.35 | 483.99 | 0.030325 | 4.55 | 2.72 | 11.02 | 10.63 | 0.64 |
| Palo Seco | 1 | 37 | 2YR P | 36.40 | 481.72 | 483.54 | 483.18 | 483.80 | 0.029781 | 4.20 | 2.40 | 9.45 | 9.44 | 0.63 |
| Palo Seco | 1 | 37 | 1YR E | 6.72 | 481.72 | 482.42 | 482.42 | 482.62 | 0.108057 | 3.60 | 2.63 | 1.90 | 4.95 | 1.00 |
| Palo Seco | 1 | 37 | 1YR P | 5.70 | 481.72 | 482.37 | 482.37 | 482.56 | 0.110683 | 3.47 | 2.51 | 1.67 | 4.68 | 1.00 |
| | | | | | | | | | | | | | | |
| Palo Seco | 1 | 36 | 100YR E | 133.20 | 438.09 | 440.15 | 440.15 | 440.83 | 0.061643 | 6.71 | 5.82 | 20.86 | 16.76 | 0.95 |
| Palo Seco | 1 | 36 | 100YR P | 112.40 | 438.09 | 439.98 | 439.98 | 440.61 | 0.065762 | 6.42 | 5.54 | 18.13 | 15.70 | 0.96 |
| Palo Seco | 1 | 36 | 25YR E | 100.80 | 438.09 | 439.88 | 439.88 | 440.48 | 0.068705 | 6.24 | 5.37 | 16.59 | 15.07 | 0.97 |
| Palo Seco | 1 | 36 | 25YR P | 83.90 | 438.09 | 439.73 | 439.73 | 440.27 | 0.074417 | 5.96 | 5.11 | 14.30 | 14.08 | 0.99 |
| Palo Seco | 1 | 36 | 10YR E | 80.20 | 438.09 | 439.69 | 439.69 | 440.23 | 0.075380 | 5.87 | 5.02 | 13.83 | 13.87 | 0.99 |
| Palo Seco | 1 | 36 | 10YR P | 66.80 | 438.09 | 439.56 | 439.56 | 440.04 | 0.081168 | 5.59 | 4.75 | 12.02 | 13.03 | 1.00 |
| Palo Seco | 1 | 36 | 5YR E | 64.90 | 438.09 | 439.54 | 439.54 | 440.02 | 0.080986 | 5.53 | 4.66 | 11.81 | 12.95 | 1.00 |
| Palo Seco | 1 | 36 | 5YR P | 53.90 | 438.09 | 439.42 | 439.42 | 439.85 | 0.085213 | 5.26 | 4.39 | 10.26 | 12.41 | 1.01 |
| Palo Seco | 1 | 36 | 2YR E | 44.80 | 438.09 | 439.31 | 439.31 | 439.70 | 0.088917 | 4.99 | 4.10 | 8.97 | 11.95 | 1.01 |
| Palo Seco | 1 | 36 | 2YR P | 36.40 | 438.09 | 439.21 | 439.21 | 439.55 | 0.091478 | 4.71 | 3.79 | 7.72 | 11.36 | 1.01 |
| Palo Seco | 1 | 36 | 1YR E | 6.72 | 438.09 | 438.96 | 438.61 | 438.98 | 0.009925 | 1.32 | 0.32 | 5.11 | 9.66 | 0.32 |
| Palo Seco | 1 | 36 | 1YR P | 5.70 | 438.09 | 439.23 | 438.57 | 439.24 | 0.002053 | 0.71 | 0.09 | 7.97 | 11.51 | 0.15 |

# APPENDIX B

# SEDIMENT LOADING ANALYSIS

# 3 Sediment Loading Analysis

## 3.1 Approach

A sediment loading analysis was conducted for the Sausal Creek watershed. The loading analysis provided information on the amount of sediment that is being delivered to the creek from the watershed. Sediment is entering the creek from 5 basic sources; hillslope erosion from the open and developed landscape, mass wasting from landslides, erosion at culvert outlets, erosion from developed trails within the watershed, and observed channel bed and bank erosion. There is also a wind blown sediment contribution to the creek, but very little information is available to quantify that source.

The amount of sediment from each of the different sources is a function of land use and cover, surface soil types, topography, geology and culvert outlet conditions. The soils within the watershed are dominated by silty clay loams, gradually transitioning to a more sandier complex with decreasing elevation. These silty clay loams are easily eroded when exposed to weathering by rain or creek flow. The distribution of soil types was described in Section 2. The existing geology, dominated by numerous faults also influences hillslope stability and contributes to the sediment load. Figure 3-1 is a regional geologic map of the Oakland area. Figure 3-2 shows the geologic structure in the Sausal Watershed.

## 3.2 Hillslope Erosion

Hillslope erosion consists of surface erosion that originates from overland flow along vegetated or unvegetated hillslopes. Those areas of the watershed that are heavily developed will typically generate less sediment than open space vegetated areas. Also, the condition of the vegetated slope contributes significantly to the sediment load from the rainfall-runoff process.

The Revised Universal Soil Loss Equation (RUSLE) was used to develop an estimate of the hillslope erosion that is occurring within the watershed. The RUSLE is an improved implementation of the original USLE that has been used for many years across the country. The USLE and subsequent RUSLE were developed primarily for estimating the soil loss from agricultural areas. Through a selection of appropriate coefficients, the methodology has been used in urban and forested areas. Figure 3-3 is a schematic showing the basic mass balance approach to developing the surface erosion component to the creek sediment load.

For many years the RUSLE procedure has been used to guide conservation planning, inventory erosion rates and estimate sediment delivery. Values computed by RUSLE are supported by accepted scientific knowledge and technical judgment, are consistent with sound principles of conservation planning. and can be used to evaluate conservation plans. The RUSLE2 computer model (USDA 2002) was used for the analysis. The RUSLE 2 program is based on additional analysis and knowledge that were not available when the original RUSLE was developed. RUSLE2 is based on science and judgment that is considered superior to that of RUSLE.

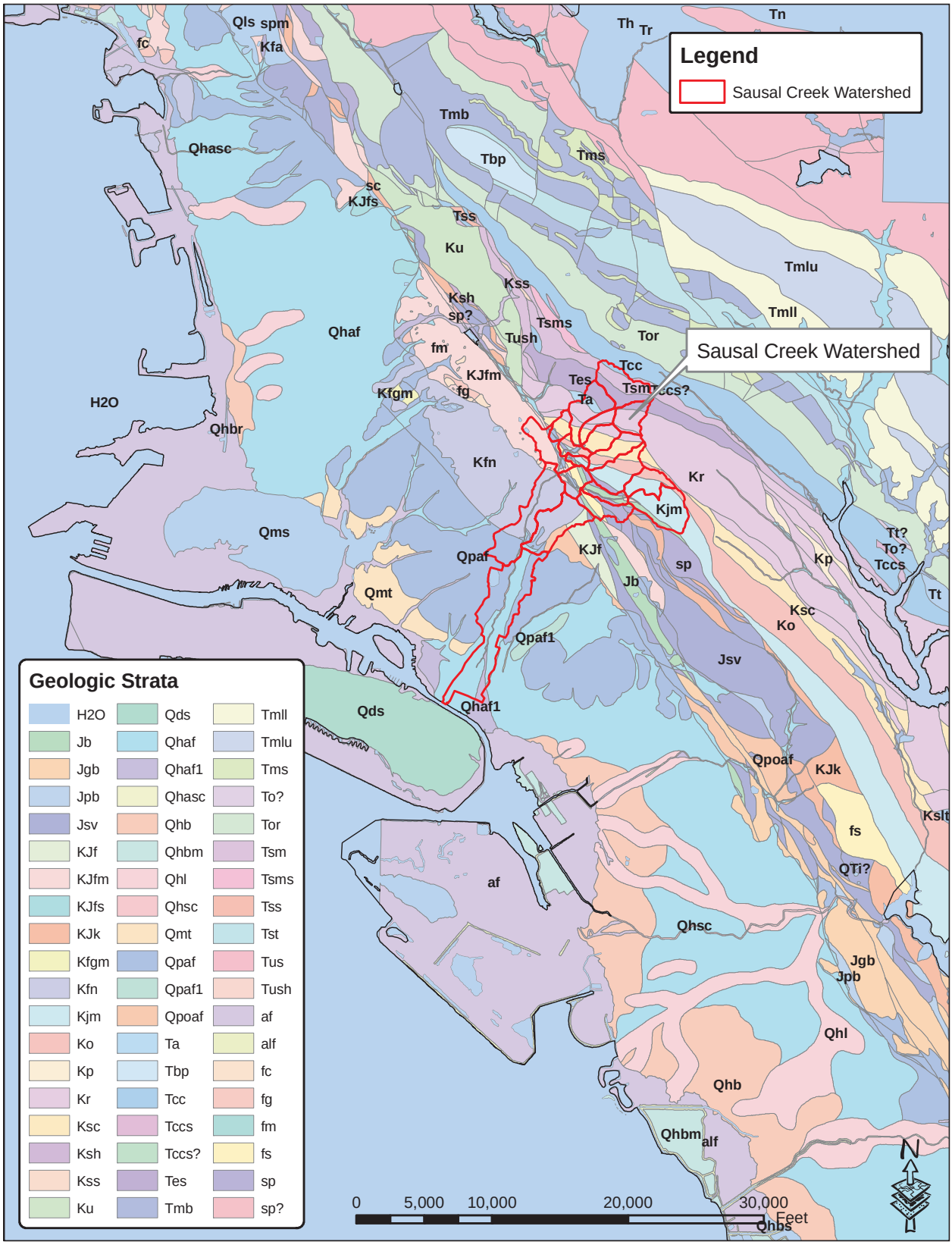



Figure 3-1 Oakland Regional Geology Map.

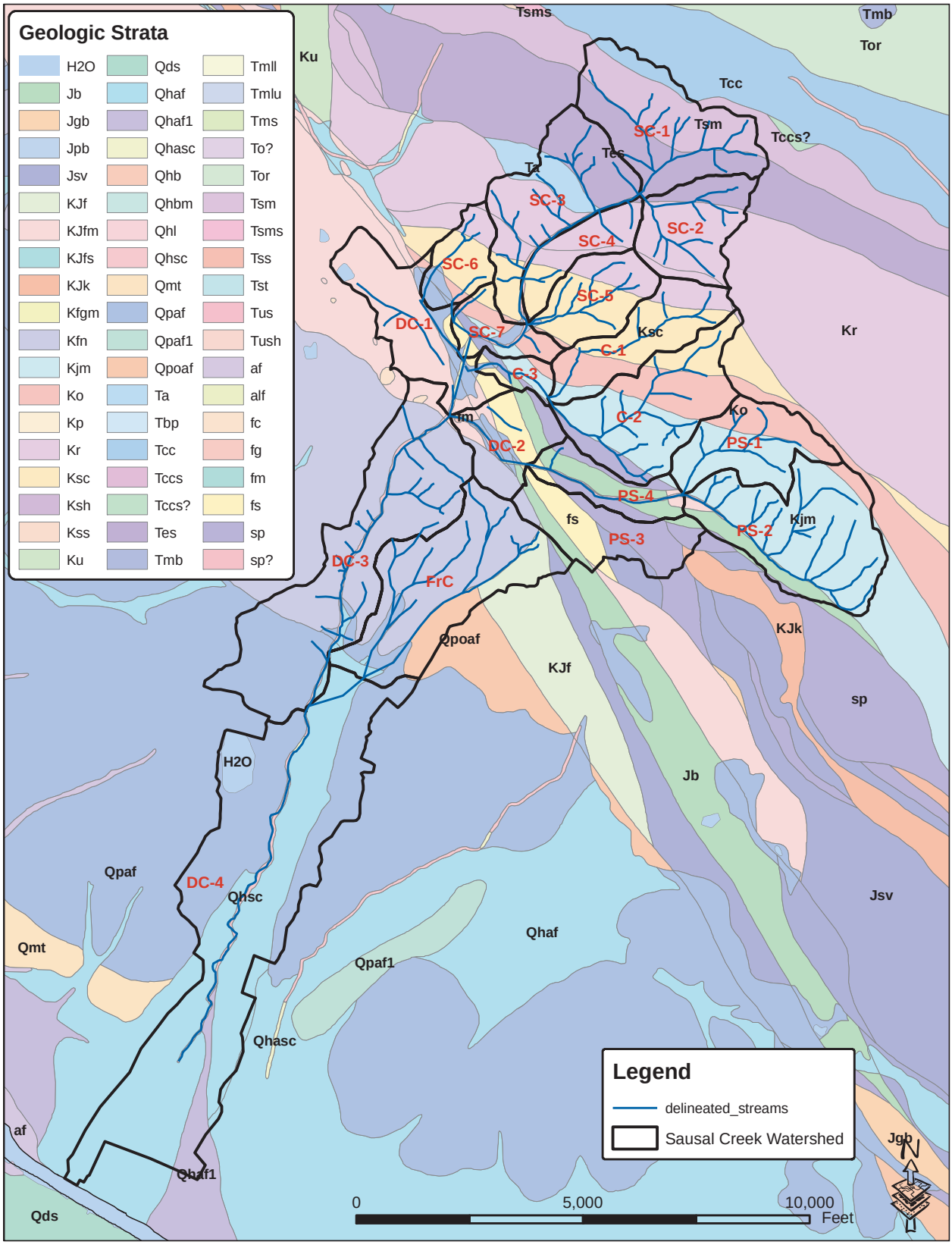



Figure 3-2 Sausal Creek Geology.

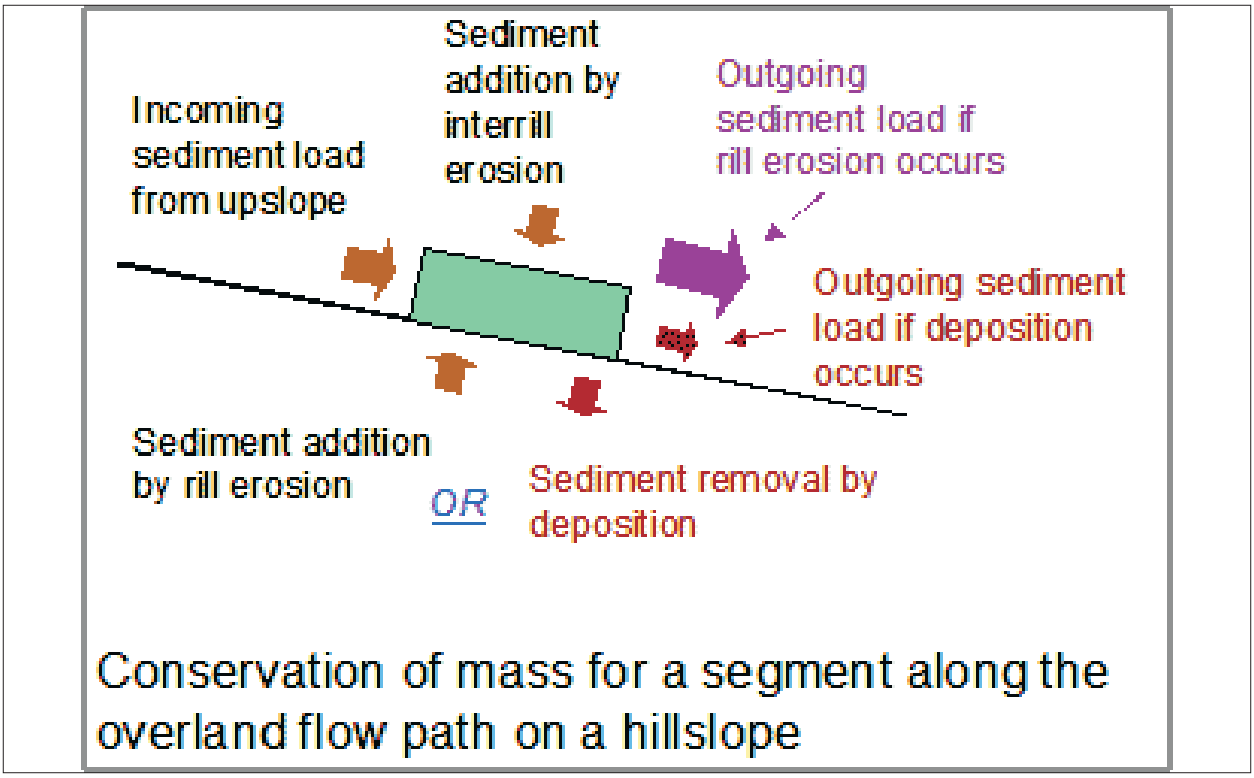



Figure 3-3 Soil Erosion Process.

RUSLE2 has evolved from a series of previous erosion prediction technologies. The USLE was entirely an empirically based equation and was limited in its application to conditions where experimental data were available for deriving factor values. A major advancement in RUSLE is the use of subfactor relationships to compute C factor values from basic features of land cover types. While RUSLE retained the basic structure of the USLE, process-based relationships were added where empirical data and relationships were inadequate, such as computing the effect of buffer strips and modern conservation tillage systems.

While RUSLE2 uses the RUSLE basic formulation of the unit plot, the mathematics of RUSLE2 are on a daily basis. Improved landcover-management subfactor relationships are used in RUSLE2, a new ridge subfactor has been added, and the deposition equations have been extended to consider sediment characteristics and how deposition changes these characteristics. It also includes new relationships for handling ground cover residue, including resurfacing of residue by implements like field cultivators.

The original USLE equation is shown below in Equation 3-1.

$$E = R \cdot K \cdot T \cdot C \cdot P \qquad \text{Eqn. 3-1}$$

Where:
- E = The soil loading in tons/acre/year
- R = the soil erosivity index
- K = the soil erodability factor
- T = the watershed topographic factor
- C = the crop management factor
- P = a soil conservation practice factor

The erosivity index is a summation of the individual storm products kinetic energy of the rainfall and the maximum 30-minute rainfall intensity for all significant storms in a year. The remaining factors are specific to the land use, vegetation type, vegetation condition, and topography of the hillslope.

RUSLE2 computes net detachment each day using a variation of the familiar USLE factors:

$$a = r \cdot k \cdot l \cdot S \cdot c \cdot p \qquad \text{Eqn 3-2}$$

where:
- a = net detachment (mass/unit area)
- r = erosivity factor,
- k = soil erodability factor,
- l = slope length factor,
- S = slope steepness factor,
- c = cover-management factor, and
- p = supporting practices factor

Deposition is computed with the equation:

$$D = \left(Vf / q\right) \cdot \left(T_c - g\right) \qquad \text{Eqn 3-3}$$

where:
- D = deposition rate (mass/unit area),
- Vf = fall velocity of the sediment,
- q = runoff rate,
- Tc = transport capacity of the runoff, and
- g = sediment load (mass/ unit width).

RUSLE2 divides the sediment load into five sediment classes: primary clay, silt, sand, small aggregates, and large aggregates. The difference between the different classes are based on grain size and density. Table 3-1 is a tabulation of the erosion for each of the subbasins in the watershed.

| Table 3-1 Mean Annual Sediment Loading From Hillslope Erosion | | | | |
|---|---|---|---|---|
| Basin Name | Area | Open Space | Mean Annual Erosion | |
| | (ac) | (%) | (tons) | (cy) |
| C-1 | 110.6 | 77% | 2.5 | 3,709 |
| C-2 | 172.3 | 83% | 4.2 | 6,292 |
| C-3 | 25.8 | 85% | 0.6 | 963 |
| Total | 308.7 | | 7.3 | 10,965 |
| | | | | |
| DC-1 | 132.8 | 64% | 2.5 | 3,722 |
| DC-2 | 82.2 | 74% | 1.8 | 2,674 |
| DC-3 | 332.0 | 76% | 7.4 | 11,095 |
| DC-4 | 592.9 | 73% | 12.6 | 18,951 |
| Total | 1139.9 | | 21.7 | 32,720 |
| | | | | |
| FrC | 232.7 | 21% | 1.4 | 2,139 |
| | | | | |
| PS-1 | 107.3 | 95% | 3.0 | 4,476 |
| PS-2 | 214.1 | 97% | 6.0 | 9,053 |
| PS-3 | 105.7 | 77% | 2.4 | 3,550 |
| PS-4 | 66.9 | 96% | 1.9 | 2,827 |
| Total | 494.1 | | 10.2 | 15,430 |
| | | | | |
| SC-1 | 182.7 | 75% | 4.0 | 5,987 |
| SC-2 | 104.1 | 71% | 2.1 | 3,240 |
| SC-3 | 163.6 | 78% | 3.7 | 5,606 |
| SC-4 | 61.5 | 78% | 1.4 | 2,112 |
| SC-5 | 86.1 | 77% | 1.9 | 2,891 |
| SC-6 | 56.7 | 75% | 1.2 | 1,857 |
| SC-7 | 50.2 | 83% | 1.2 | 1,830 |
| Total | 704.9 | | 4.4 | 6,578 |
| Grand Total | 2,880.2 | | 44.9 | 67832 |

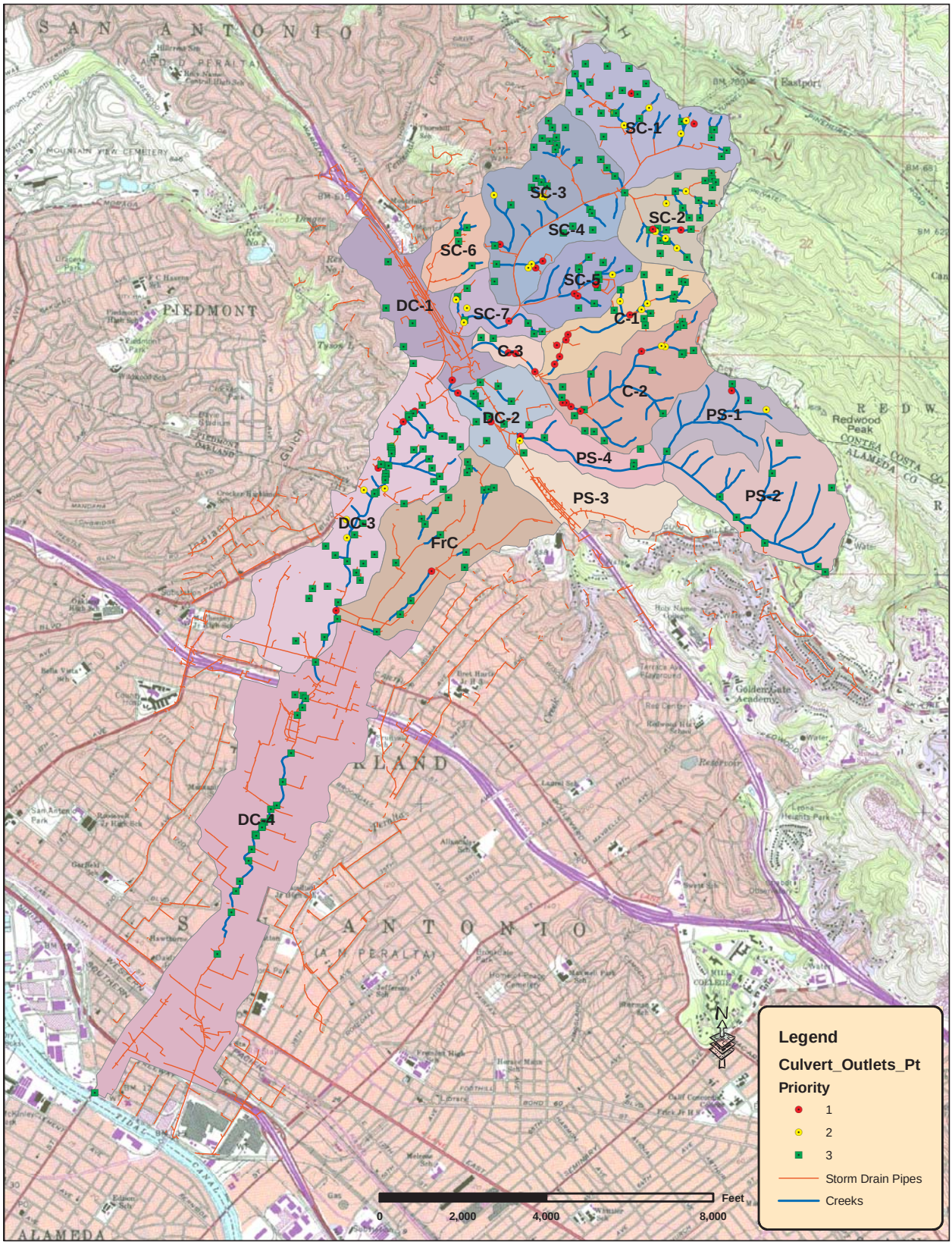



Figure 3-4 Sausal Creek - Culvert Outlet Map.

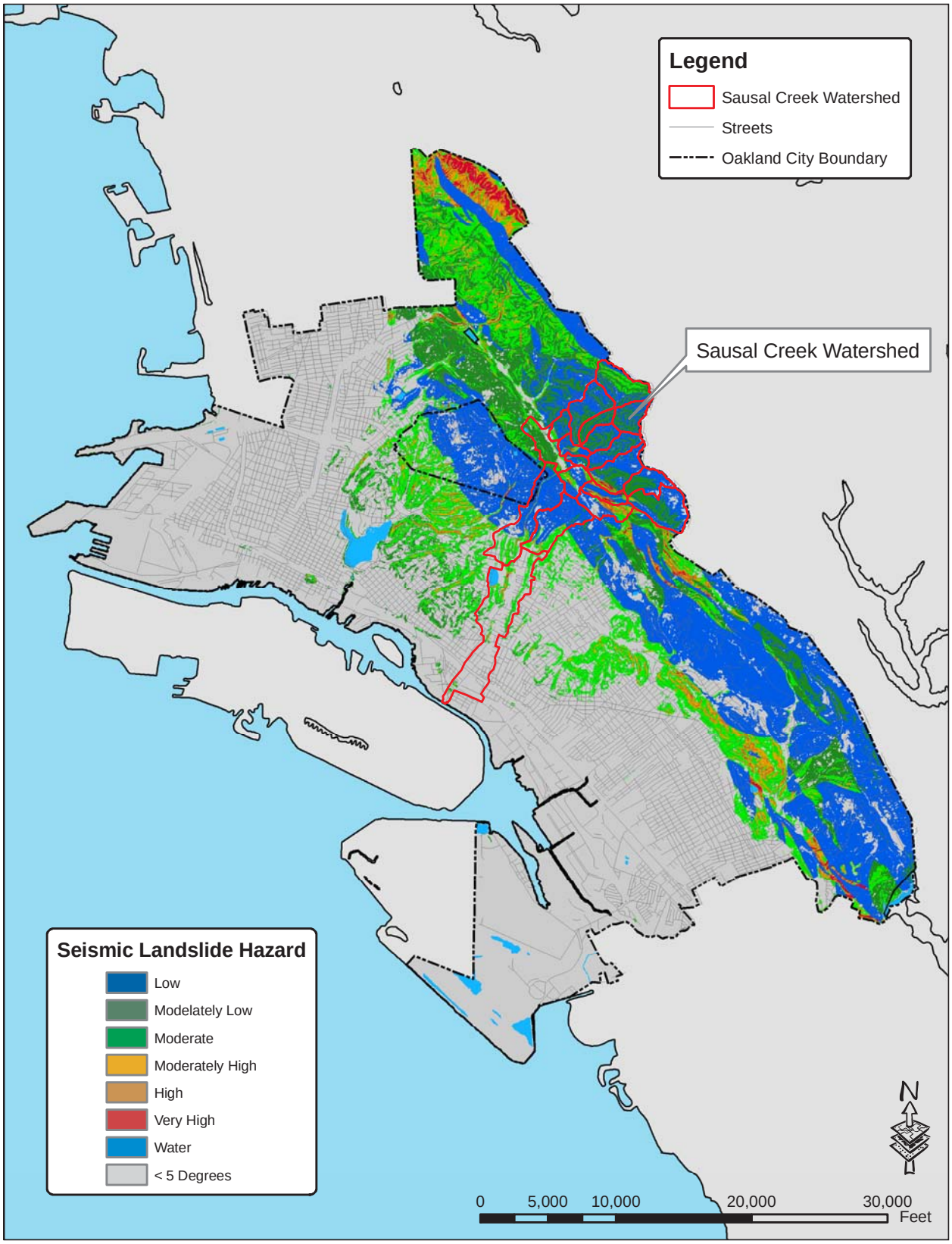



Figure 3-5 Oakland Area Landscape Hazard Map.

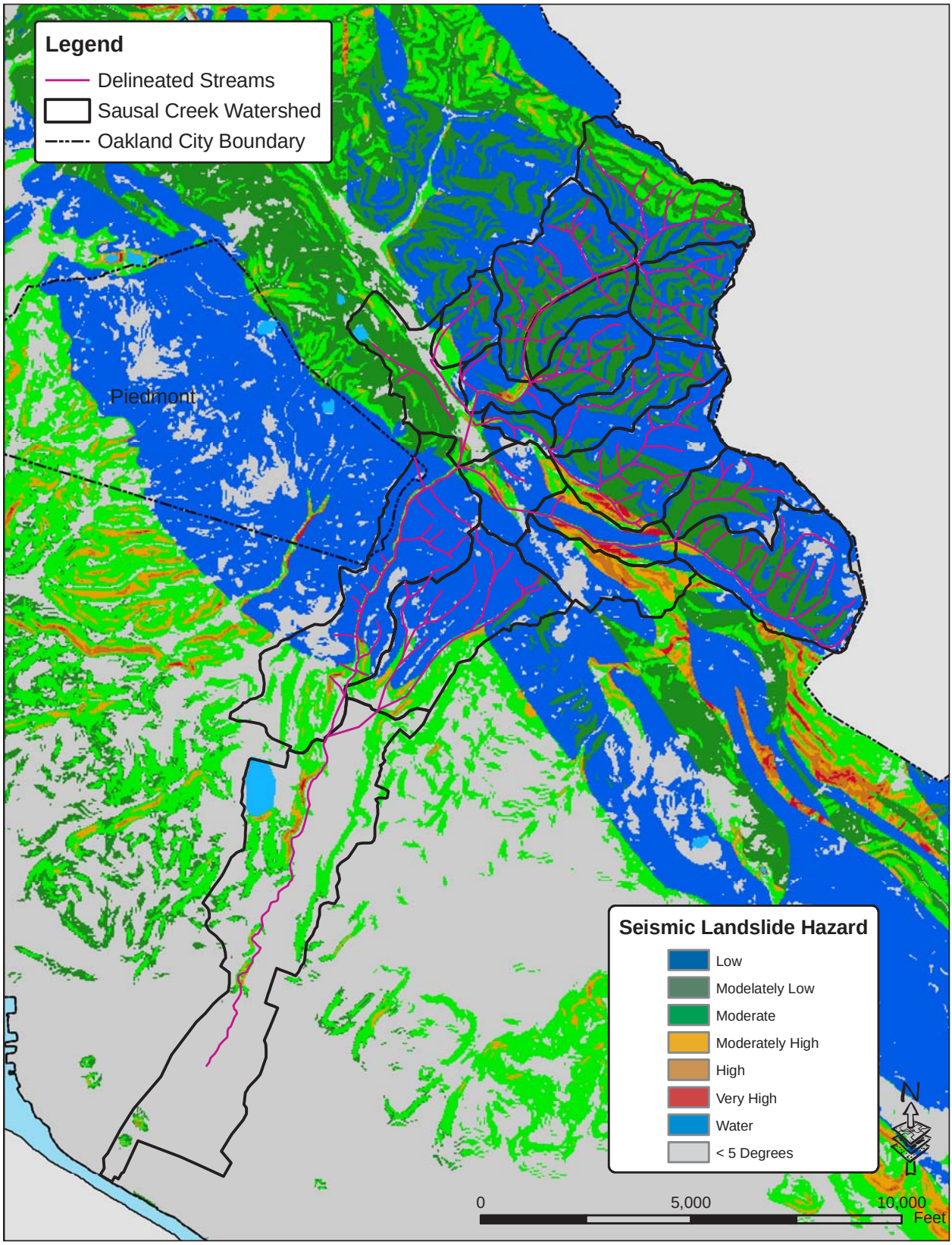



Figure 3-6 Sausal Creek - Landslide Hazard Map.

## 3.3 Culvert Outlet Erosion

Erosion generated from the scour at the downstream ends of culverts within the existing drainage system are a significant source of loading to Sausal Creek. A field survey was conducted of culvert outlets within the watershed. The culvert outlets were identified and classified into high, medium and low erosion potential. The erosion potential was based on channel slope and watershed area upstream of the outlet. Culvert outlets within the high and medium priority sites were surveyed and the existing erosion at the culvert outlet and downstream of the culvert was identified.

The documented erosion was used to estimate the erosion at the remaining culvert locations. Table 3-2 is a tabulation of the culvert outlet erosion tabulated for each of the subbasins in the watershed.

**Table 3-2 Average Annual Sediment Loading From Scour at Culvert Outlets**

| Basin | Area | No of | Ave Erosion Rate | Erosion | | |
|---|---|---|---|---|---|---|
| | (ac) | Culverts | (ft3/yr/culvert) | (ft3) | (tons) | (cy) |
| C-1 | 111 | 20 | 11 | 228 | 0.15 | 8.46 |
| C-2 | 172 | 23 | 11 | 263 | 0.17 | 9.73 |
| C-3 | 26 | 5 | 11 | 57 | 0.04 | 2.12 |
| Total | 309 | 48 | | 548 | 0.36 | 20.30 |
| | | | | | | |
| DC-1 | 133 | 5 | 1,981 | 9,906 | 6.56 | 366.89 |
| DC-2 | 82 | 0 | 1,981 | 0 | 0.00 | 0.00 |
| DC-3 | 332 | 56 | 1,981 | 110,947 | 73.50 | 4,109.16 |
| DC-4 | 593 | 21 | 1,981 | 41,605 | 27.56 | 1,540.93 |
| Total | 1,140 | 77 | | 152,552 | 107.63 | 6,016.98 |
| | | | | | | |
| FrC | 233 | 20 | 0 | 0 | 0.00 | 0.00 |
| Total | 233 | 20 | | 0 | 0.00 | 0.00 |
| | | | | | | |
| PS-1 | 107 | 0 | 81 | 0 | 0.00 | 0.00 |
| PS-2 | 214 | 6 | 81 | 486 | 0.32 | 18.00 |
| PS-3 | 106 | 2 | 81 | 162 | 0.11 | 6.00 |
| PS-4 | 67 | 2 | 81 | 162 | 0.11 | 6.00 |

| Table 3-2 Average Annual Sediment Loading From Scour at Culvert Outlets | | | | | | |
|---|---|---|---|---|---|---|
| Basin | Area | No of | Ave Erosion Rate | Erosion | | |
| | (ac) | Culverts | (ft3/yr/culvert) | (ft3) | (tons) | (cy) |
| Total | 494 | 10 | | 810 | 0.54 | 30.00 |
| | | | | | | |
| SC-1 | 183 | 30 | 92 | 2,771 | 1.84 | 102.64 |
| SC-2 | 104 | 24 | 92 | 2,217 | 1.47 | 82.11 |
| SC-3 | 164 | 25 | 92 | 2,309 | 1.53 | 85.53 |
| SC-4 | 62 | 7 | 92 | 647 | 0.43 | 23.95 |
| SC-5 | 86 | 10 | 92 | 924 | 0.61 | 34.21 |
| SC-6 | 57 | 4 | 92 | 370 | 0.24 | 13.69 |
| SC-7 | 50 | 10 | 92 | 924 | 0.61 | 34.21 |
| Total | 705 | 24 | | 10,161 | 6.73 | 376.34 |
| | | | | | | |
| Total | 2,880 | 179 | | 164,072 | 115.26 | 6,443.62 |

## 3.4 Trail Erosion

Erosion along existing trails contributes sediment to the creek. A field survey was conducted of existing trails in various locations within the watershed. From this reconnaissance, a mean erosion rate was developed for the trails throughout the watershed. A total of 22.8 miles of trails were identified within the watershed. A summary of the trail erosion within each subbasin is provided in Table 3-3.

| Table 3-3 Average Annual Sediment Loading From Trail Erosion | | | | | |
|---|---|---|---|---|---|
| Basin | Area | Length | Erosion | | |
| | (ac) | | (ft3) | (tons) | (cy) |
| C-1 | 110.61 | 750 | 75.01 | 0.05 | 2.78 |
| C-2 | 172.27 | 4,047 | 404.67 | 0.27 | 14.99 |
| C-3 | 25.81 | 0 | 0.00 | 0.00 | 0.00 |
| Total | 308.69 | 4,797 | 479.68 | 0.32 | 17.77 |
| | | | | | |

| Table 3-3 Average Annual Sediment Loading From Trail Erosion | | | | | |
|---|---|---|---|---|---|
| Basin | Area | Length | Erosion | | |
| | (ac) | | (ft3) | (tons) | (cy) |
| DC-1 | 132.82 | 400 | 39.99 | 0.03 | 1.48 |
| DC-2 | 82.19 | 2,881 | 288.10 | 0.19 | 10.67 |
| DC-3 | 331.97 | 16,251 | 1,625.10 | 1.08 | 60.19 |
| DC-4 | 592.87 | 2 | 0.17 | 0.00 | 0.01 |
| Total | 1,139.86 | 19,534 | 1,953.36 | 1.29 | 72.35 |
| | | | | | |
| FrC | 232.71 | 1,754 | 175.36 | 0.12 | 6.49 |
| Total | 232.71 | 1,754 | 175.36 | 0.12 | 6.49 |
| | | | | | |
| PS-1 | 107.28 | 19,268 | 1,926.84 | 1.28 | 71.36 |
| PS-2 | 214.13 | 42,315 | 4,231.45 | 2.80 | 156.72 |
| PS-3 | 105.73 | 6,090 | 608.98 | 0.40 | 22.55 |
| PS-4 | 66.94 | 11,873 | 1,187.29 | 0.79 | 43.97 |
| Total | 494.08 | 79,546 | 7,954.56 | 5.27 | 294.61 |
| | | | | | |
| SC-1 | 182.67 | 0 | 0.00 | 0.00 | 0.00 |
| SC-2 | 104.08 | 8 | 0.82 | 0.00 | 0.03 |
| SC-3 | 163.63 | 6,457 | 645.72 | 0.43 | 23.92 |
| SC-4 | 61.55 | 1,316 | 131.56 | 0.09 | 4.87 |
| SC-5 | 86.10 | 2,902 | 290.18 | 0.19 | 10.75 |
| SC-6 | 56.65 | 1,702 | 170.21 | 0.11 | 6.30 |
| SC-7 | 50.19 | 2,569 | 256.92 | 0.17 | 9.52 |
| Total | 704.87 | 14,954 | 1,495.42 | 0.99 | 55.39 |
| | | | | | |
| Total | 2,880.20 | 120,584 | 12,058.38 | 7.99 | 446.61 |

## 3.5 Landslide Erosion

The Oakland Hills area is known for numerous landslides. A combination of soils, geology and numerous active faults contributes to very unstable hillslopes. Figure 3-5 is a map of the Oakland area showing the location of areas that are susceptible to landslides. Figure 3-6 is map of the landslide hazard through the Sausal Creek Watershed. A survey of existing landslides was developed from the Sausal Creek Watershed Management Plan developed by the City of Oakland. The location of the known landslides was compared to the landslide potential map. From this comparison, an estimate of an annual landslide rate was developed. Table 3-4 is a tabulation of the sediment loading from landslides for each of the subbasins in the watershed. The estimate assumes that 5% of the landslide mass is transported to the river.

**Table 3-4 Average Annual Sediment Loading From Landslides**

| Basin | Area | Area Susceptible to Landslides | Probability of Slide | Erosion | | |
|---|---|---|---|---|---|---|
| | (ac) | (ft2) | | (ft3) | (tons) | (cy) |
| C-1 | 110.6 | 0 | 0.05 | 0 | 0.00 | 0.0 |
| C-2 | 172.3 | 858,714 | 0.05 | 8,587 | 5.69 | 318.0 |
| C-3 | 25.8 | 89,973 | 0.05 | 900 | 0.60 | 33.3 |
| Total | 308.7 | 948,688 | | 9,487 | 6.29 | 351.4 |
| | | | | | | |
| DC-1 | 132.8 | 1,071,161 | 0.05 | 10,712 | 7.10 | 396.7 |
| DC-2 | 82.2 | 1,081,128 | 0.05 | 10,811 | 7.16 | 400.4 |
| DC-3 | 332.0 | 2,697,759 | 0.05 | 26,978 | 17.87 | 999.2 |
| DC-4 | 592.9 | 4,855,067 | 0.05 | 48,551 | 32.16 | 1,798.2 |
| Total | 1,139.9 | 9,705,116 | | 97,051 | 64.30 | 3,594.5 |
| | | | | | | |
| FrC | 232.7 | 1,872,412 | 0.05 | 18,724 | 12.40 | 693.5 |
| | | | | | | |
| PS-1 | 107.3 | 987 | 0.05 | 10 | 0.01 | 0.4 |
| PS-2 | 214.1 | 276,014 | 0.05 | 2,760 | 1.83 | 102.2 |
| PS-3 | 105.7 | 1,808,472 | 0.05 | 18,085 | 11.98 | 669.8 |
| PS-4 | 66.9 | 1,279,644 | 0.05 | 12,796 | 8.48 | 473.9 |
| Total | 494.1 | 3,365,116 | | 33,651 | 22.29 | 1,246.3 |
| | | | | | | |
| SC-1 | 182.7 | 1,925,636 | 0.05 | 19,256 | 12.76 | 713.2 |

| Table 3-4 Average Annual Sediment Loading From Landslides | | | | | | |
|---|---|---|---|---|---|---|
| Basin | Area | Area Susceptible to Landslides | Probability of Slide | Erosion | | |
| | (ac) | (ft2) | | (ft3) | (tons) | (cy) |
| SC-2 | 104.1 | 0 | 0.05 | 0 | 0.00 | 0.0 |
| SC-3 | 163.6 | 240,786 | 0.05 | 2,408 | 1.60 | 89.2 |
| SC-4 | 61.5 | 45,269 | 0.05 | 453 | 0.30 | 16.8 |
| SC-5 | 86.1 | 32,132 | 0.05 | 321 | 0.21 | 11.9 |
| SC-6 | 56.7 | 329,642 | 0.05 | 3,296 | 2.18 | 122.1 |
| SC-7 | 50.2 | 286,173 | 0.05 | 2,862 | 1.90 | 106.0 |
| Total | 704.9 | 2,859,638 | | 28,596 | 18.95 | 1,059.1 |
| | | | | | | |
| Total | 2,880.2 | 18,750,969 | | 187,510 | 124.23 | 6,944.8 |

## 3.6 Creek Erosion

Creek bed and bank scour is occurring through many areas of the watershed. The scour that has occurred historically has been a combination of bed scour with the channel downcutting through the bed material, and bank erosion. Many areas of the creek have downcut to bedrock material, resulting in a reduction in bed erosion and an increase in bank erosion. Field surveys were conducted to identify where ongoing erosion is occurring. From this survey, average erosion rates were established for each of the individual watersheds. Table 3-5 is a summary of the average annual sediment load from each of the subbasins.

| Table 3-5 Average Annual Sediment Loading From Creek Erosion | | | | | |
|---|---|---|---|---|---|
| Basin Name | Area | Length | Erosion | | |
| | (ac) | (ft) | (ft3) | (tons) | (cy) |
| C-1 | 110.6 | 750 | 840 | 0.56 | 31.1 |
| C-2 | 172.3 | 4,047 | 4,532 | 3.00 | 167.9 |
| C-3 | 25.8 | 0 | 0 | 0.00 | 0.0 |
| Total | 308.7 | 4,797 | 5,372 | 3.56 | 199.0 |
| | | | | | |
| DC-1 | 132.8 | 400 | 868 | 0.57 | 32.1 |
| DC-2 | 82.2 | 2,881 | 6,252 | 4.14 | 231.5 |
| DC-3 | 332.0 | 16,251 | 35,265 | 23.36 | 1,306.1 |

| Table 3-5 Average Annual Sediment Loading From Creek Erosion | | | | | |
|---|---|---|---|---|---|
| Basin Name | Area | Length | Erosion | | |
| | (ac) | (ft) | (ft3) | (tons) | (cy) |
| DC-4 | 592.9 | 2 | 4 | 0.00 | 0.1 |
| Total | 1,139.9 | 19,134 | 41,520 | 28.08 | 1,537.8 |
| | | | | | |
| FrC | 232.7 | 1,754 | 1,964 | 1.30 | 72.7 |
| Total | 232.7 | 20,887 | 43,484 | 1.30 | 1,610.5 |
| | | | | | |
| PS-1 | 107.3 | 19,268 | 28,325 | 18.76 | 1,049.1 |
| PS-2 | 214.1 | 42,315 | 62,202 | 41.21 | 2,303.8 |
| PS-3 | 105.7 | 6,090 | 11,083 | 7.34 | 410.5 |
| PS-4 | 66.9 | 11,873 | 21,609 | 14.32 | 800.3 |
| Total | 494.1 | 60,277 | 94,894 | 81.63 | 3,514.6 |
| | | | | | |
| SC-1 | 182.7 | 0 | 0 | 0.00 | 0.0 |
| SC-2 | 104.1 | 8 | 9 | 0.01 | 0.3 |
| SC-3 | 163.6 | 6,457 | 7,232 | 4.79 | 267.9 |
| SC-4 | 61.5 | 1,316 | 1,473 | 0.98 | 54.6 |
| SC-5 | 86.1 | 2,902 | 3,250 | 2.15 | 120.4 |
| SC-6 | 56.7 | 1,702 | 1,906 | 1.26 | 70.6 |
| SC-7 | 50.2 | 2,569 | 2,878 | 1.91 | 106.6 |
| Total | 704.9 | 7,173 | 8,034 | 11.10 | 297.6 |
| | | | | | |
| Total | 2,880.2 | 112,268 | 193,305 | 125.67 | 7,159.5 |

The sum of the individual components to the total sediment load on the is shown in Table 3-6. For the entire watershed, the sediment load to the creek averages 0.15 tons/acre. This is an average for the watershed, with some areas contributing much more and some areas contributing much less. It should also be noted that this is an average annual load based on observed scour and erosion that has occurred historically. For any particular year, this rate will vary considerably depending on rainfall, construction in the watershed, earthquakes, and disturbance of the creek system.

| Table 3-6 Sum of the Average Annual Sediment From All Sources | | | |
|---|---|---|---|
| Basin Name | Area | Erosion | Erosion |
| | (ac) | (cy) | (tons) |
| C-1 | 110.6 | 3,751.4 | 3.2 |
| C-2 | 172.3 | 6,803.0 | 13.3 |
| C-3 | 25.8 | 998.8 | 1.3 |
| Total | 308.7 | 11,553.3 | 17.8 |
| | | | |
| DC-1 | 132.8 | 4,519.6 | 16.7 |
| DC-2 | 82.2 | 3,316.9 | 13.3 |
| DC-3 | 332.0 | 17,569.6 | 123.2 |
| DC-4 | 592.9 | 22,290.3 | 72.3 |
| Total | 1,139.9 | 43,941.9 | 223.0 |
| | | | |
| FrC | 232.7 | 2,911.9 | 15.2 |
| | | | |
| PS-1 | 107.3 | 5,596.9 | 23.0 |
| PS-2 | 214.1 | 11,634.1 | 52.2 |
| PS-3 | 105.7 | 4,658.5 | 22.2 |
| PS-4 | 66.9 | 4,151.5 | 25.6 |
| Total | 494.1 | 20,515.9 | 120.0 |
| | | | |
| SC-1 | 182.7 | 6,802.4 | 18.6 |
| SC-2 | 104.1 | 3,322.6 | 3.6 |
| SC-3 | 163.6 | 6,073.0 | 12.1 |
| SC-4 | 61.5 | 2,212.6 | 3.2 |
| SC-5 | 86.1 | 3,067.9 | 5.1 |
| SC-6 | 56.7 | 2,069.7 | 5.0 |
| SC-7 | 50.2 | 2,086.5 | 5.8 |
| Total | 704.9 | 8,366.3 | 42.1 |
| | | | |
| Total | 2,880.2 | 88,827.0 | 418.1 |