

Conservation and Management Plan for Sausal Creek Wild Rainbow Trout



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Friends of Sausal Creek
PROMOTING WATERSHED AWARENESS



Sausal Creek flows through the homeland of the Chochenyo-speaking Ohlone who knew rainbow trout as haamuy. European occupation of Ohlone homelands beginning in the late-18th and early-19th centuries led to the degradation of rainbow trout habitat in the Sausal Creek watershed. Photo by Robert Leidy.

*Cover: Rainbow trout, *Oncorhynchus mykiss*. Original watercolor by Leana Zang-Rosetti. Leana is an Oakland resident and lives with her family in the Peralta Creek watershed.*

Frontispiece: Rainbow trout artwork adorning pathway along Sausal Creek in Oakland's Dimond Park.

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Sausal Creek rainbow trout. Top and middle photos by R. Leidy, bottom photo by Jeff Hagar.

Introduction

Sausal Creek is home to a genetically 'wild' population of resident rainbow trout (Figure 1). As such, these fish are a precious and rare resource that live entirely within the City of Oakland. Sausal Creek has only limited habitat supporting rainbow trout. Therefore, their population is relatively small and extremely vulnerable to multiple threats and stressors resulting from human activities, past and present.

People dump toxic materials directly into the creek, and contaminants flow into the stream from pipes (outfalls) connected to stormwater drains.¹ When raining, water flows across streets, down gutters, and via outfalls into the creek. This same drainage pattern applies when people spray-down patios and driveways, wash cars and trucks, or when lawns and landscapes are over-watered. Toxic constituents include trash, plastics, motor oil, soaps and cleansers, paint and solvents, domestic pet waste, fertilizers, herbicides, and pesticides.

In 2010, illegal dumping or negligent discharges of toxic materials have killed dozens of rainbow trout. Fish have also been harmed or killed when pipes carrying drinking water and sewage leak or break open. Drinking water contains chloramines added as a disinfectant, and while these chemicals protect human health, they are toxic to the trout. There are several documented cases of chloramines, as recently as 2020, from breaks in water mains that have killed trout in Sausal Creek.

Ongoing degradation of Sausal Creek is a result of the large-scale modification of the watershed over the last 150 years and the daily activities of thousands of people. The damage began with the alteration of natural landscapes, notably the removal of oak woodlands and redwood forests, the construction of roads and freeways, channelization of the stream, and the armoring of streambanks. Ultimately much of the creek has been forced into underground culverts beneath impervious streets and urban developments.

Impervious surfaces (e.g., sidewalks, streets, and parking lots) have changed watershed hydrology and stream hydraulics, resulting in the degradation of water quality and aquatic habitat, mainly through channel scour and excessive erosion. The removal of the streamside (riparian) forest has reduced canopy cover and shading, thereby increasing instream water temperatures and exposing the fish to predators and illegal fishing and decreasing invertebrate populations and the availability of diverse prey for fish.

This rainbow trout conservation and management plan describes the current environmental conditions of Sausal Creek, profiles the life history and habitat requirements of rainbow trout, and documents the historical and current distribution of rainbow trout. The plan then defines goals, objectives, and rationales for conserving the Sausal Creek ecosystem and the trout population and recommends actions necessary for decreasing and reversing the harmful effects of human activities, past and present, that continue to imperil the very existence of rainbow trout in Sausal Creek.



Figure 1. Juvenile (left) and adult (right) rainbow trout. Artwork by Joseph Tomerelli.

¹ Glossary of abbreviations and terms related to stormwater
<https://www.kingcounty.gov/services/environment/water-and-land/stormwater/glossary.aspx>

Environmental Setting and Ecological Attributes of Sausal Creek

Watershed Description

Residential, commercial, and industrial development covers about 76% of the Sausal Creek watershed. The remaining 24% of the catchment, mostly east of State Highway 580, is forested with native trees and shrubs, as well as non-native vegetation. This portion of the watershed receives some level of protection on parcels owned by the City of Oakland that are contiguous with vegetated residential and commercial properties. Urbanized land cover ranges from 41% in the Palo Seco sub-watershed that drains mostly public parks to 96% along Sausal Creek that flows mainly through the developed parts of Oakland (Sausal Creek Watershed Enhancement Plan; SCWEP, 2010).

The Sausal Creek watershed covers about 4.5 square miles (2,777 acres) (Figure 2). The watershed features three primary sub-watersheds (tributaries): Shepherd Canyon (705-acres), Cobbledick (309 acres), and Palo Seco (505 acres). The three streams converge near State Highway 13 to form the Sausal Creek mainstem basin that covers 1,258 acres (SCWEP 2010).

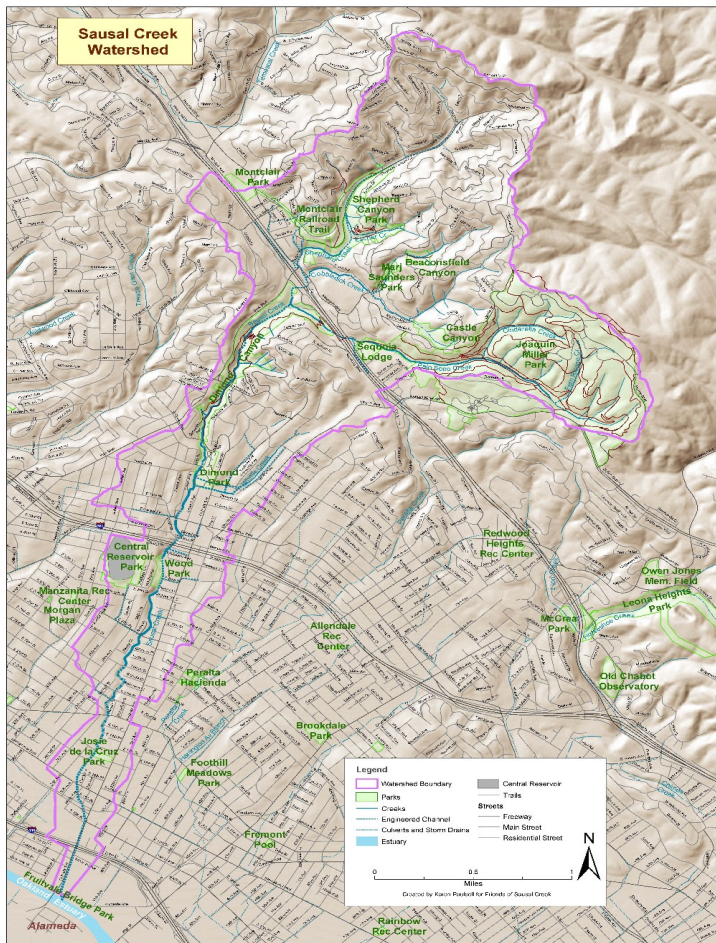


Figure 2. The Sausal Creek watershed boundaries.

² Sausal Creek Watershed Enhancement Plan (SCWEP), 2010 (summary document). http://www.documents.sausalcreek.org/SCWEP_Summary.pdf

Land Ownership, Administration and Access

Most of the Sausal Creek watershed is characterized by commercial and residential land uses. However, a significant length of the Sausal Creek runs through publicly accessible parks administered by the City of Oakland or as restricted-access flood control easements managed by Alameda County.

Water Sources and Quality

The headwaters of Sausal Creek drain both forested parklands and medium-to-high-density residential neighborhoods (Figure 3). Sources of streamflow include precipitation, year-round seeps, and springs that result from geologic faulting in the headwaters and along Dimond Canyon, and dry season “nuisance flows” from parcels that are landscaped and hardscaped. Mean annual precipitation ranges between about 19 inches in the lowermost watershed near the Oakland Estuary to 24 inches at the crest of the Oakland Hills (SCWEP 2010).

The most significant sources of pollution to Sausal Creek are from stormwater that collects contaminants from streets, driveways, lawns, roofs, leaky sewers, and other impervious surfaces. Water quality impairment comes from multiple land-based sources, including trash, pesticides, fertilizers, detergents, sediment, and oil and gas residues. Sausal Creek experiences seasonal variations in water quality due to changes in surface flows in the wet season (winter and spring) and dry season (summer and fall). High flows in the wet season generally dilute pollutants, while lower flows in the dry season typically result in high concentrations of contaminants with little opportunity for dilution. However, first flush events with the advent of Fall rains can have the highest levels of toxic pollutants, which can cause fish mortality. Generally, poor water quality conditions during the dry season pose the highest risk to the health of rainbow trout in Sausal Creek.

Water quality monitoring within the Sausal Creek watershed began in 1994. Monitored parameters include temperature, pH, turbidity, conductivity, and coliforms (samples analyzed by the federal Environmental Protection Agency, EPA). Additionally, the Surface Water and Ambient Monitoring Program (SWAMP) administered by the San Francisco Bay Regional Water Quality Control Board periodically conducts bioassessments and monitoring in Sausal Creek for water quality, sediment conditions, and benthic macroinvertebrates. Also, the Alameda County Clean Water Program has regularly performed bioassessment and basic water quality monitoring, most recently in 2018 and 2019. Water quality monitoring provides vital information about the overall watershed health and can be used to inform restoration decisions to benefit rainbow trout populations.

Hydrology

Urbanization has resulted in physical alteration of natural channels in the Sausal Creek watershed (Figure 4). Residential and commercial land uses increase the area of impervious surfaces that alters the volume and rate of stormwater runoff throughout the watershed. Stormwater drains, culverts, and pipes intercept and carry water from impervious surfaces into the creek during rainfall events. This drainage system rapidly and dramatically amplifies the volume and velocity of peak flows above the historical levels that formed the stream course and contributes to the destruction of the streambanks and the down-cutting of the stream bed. These changes to hydrology and the historical configuration of the landscape impair the quality of rainbow trout habitat.

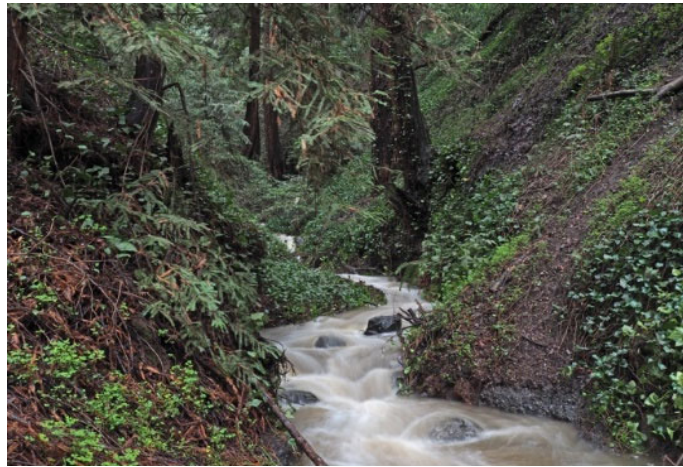


Figure 3. Palo Seco Creek is a major perennial tributary to Sausal Creek that originates from seeps and springs in Joaquin Miller Park and flows through redwood forest. Upper left and right photos by R. Leidy, lower left photo by Andrew Aldrich.



Figure 4. Urbanization has altered the natural channel forms and functions of Sausal Creek that affects the distribution and abundance rainbow trout. Clockwise from upper left: Underground culvert outlet in Dimond Canyon. High flows entering underground pipe in Dimond Park. Concrete-channelized reach flowing through residential backyards along Canon Ave. Rectangular concrete culvert downstream from Foothill Blvd. Photos by R. Leidy.

Physical Habitat

Geomorphology

The upper portion of the Sausal Creek watershed is part of the Central California Coast Range mountains. The area is comprised of steep hills (>30 percent slopes) uplifted primarily through the interactions of a network of faults, with narrow canyons containing a network of high-gradient ephemeral, intermittent, and perennial streams. The Hayward Fault bisects upper Sausal Creek and forms a valley-like depression traversed by Highway 13.

Various bedrock types, mostly sedimentary and ancient sea bed material, make up the upper watershed, and mudstone often occurs on the surface. Fault contact zones in the upper catchment create seismic fracturing and areas of abrupt changes in rock type, which influences vegetation type and moisture levels. Seeps and springs are common, and they provide a near-constant source of cold, clean water to Sausal Creek known as baseflow. This baseflow is very important for salmonids. The persistence of baseflow in Sausal Creek is one of the primary reasons why rainbow trout have survived in Oakland, despite multiple stressors and threats while mostly disappearing from other urban areas in California. Dimond Canyon forms a dramatic geologic feature below Highway 13, and Sausal Creek flows mostly year-round (perennially) through the Canyon, providing a critical “refugium” for the rainbow trout (Figure 5).

Downstream from Dimond Canyon, the gradient of Sausal Creek lessens as it travels over its alluvial fan across a Holocene terrace before emptying into the Oakland Estuary portion of San Francisco Bay. Alluvial fans consist of cobble, sand, and gravel carried down from the upper watershed and deposited on the relatively low-gradient bayland terraces. Soil types within the watershed are remarkably varied (SCWEP 2010).

Aquatic Habitat Distribution and Quality

Tributary System. In its pre-settlement, pre-modified condition, the Sausal Creek watershed was characterized by a complex network of small, ephemeral, intermittent, and perennial tributaries in the headwaters that converged into the mainstem of Sausal Creek just above Dimond Canyon. A series of photographs from May 1901 of Sausal Creek in Dimond Canyon prior to extensive channel modifications depicts high quality rainbow trout habitat, including pools shaded by riparian vegetation (white alder), interspersion of pools and riffles, and gravel free of excessive sediment (Figures 6a-c). Below the mouth of Dimond Canyon, Sausal Creek flowed across an alluvial terrace and into the tidal wetlands of the Oakland Estuary. The tributaries were adversely impacted by urbanization in three important ways. First, the length of the drainage network has significantly increased through the construction of stormwater drains aimed at managing urban runoff. Second, many tributaries are channelized, confined in underground culverts, or have their banks hardened, and floodplains developed. Third, impervious surfaces have disrupted the timing and delivery of water to the tributaries and the mainstem, resulting in increased peak flows and the scouring of the channel.



Figure 5. Perennial reaches of Sausal Creek in Dimond Canyon. Top photo by R. Leidy, bottom photo by Andrew Aldrich.



Figure 6a. View at *Diamonds Canon...May 19, 1901* by Henry King Nourse (source California State Library History Room). The banks of this well-shaded reach of Sausal Creek are lined with white alder and blackberries. Note the alternating sequence of riffles and shallow pools.



Figure 6b. *View at Diamonds Canon...May 19, 1901* by Henry King Nourse (source California State Library History Room). White alder lines both banks of Sausal Creek. The shallow pools would provide high-quality rearing habitat for young rainbow trout. This gravel substrate where riffles transition to pools is ideal spawning habitat for trout.



Figure 6c. *View at Diamonds Canon...May 19, 1901* by Henry King Nourse (source California State Library History Room). This high-gradient intermittent reach of Sausal Creek is lined with white alder and contains small pools that are visible near the top of the photo.

Floodplains. Floodplains provide lateral connectivity between streams, riparian forests, and terrestrial habitats. Human activities have destroyed and fragmented floodplains, and this has decreased the complexity, diversity, and ecological functions of floodplains. Consequences include altered stream hydrology and hydraulics, diminished water quality, and degraded habitats needed by rainbow trout for spawning, rearing, feeding, resting, and refuge. Floodplains bordering Sausal Creek have been mostly filled and converted to urban uses or remain as abandoned fragments due to channel incision or flood control structures. Remaining floodplains throughout the watershed are often constricted, with only narrow bands of native riparian or ornamental vegetation remaining (Figure 7).



Figure 7. Functioning natural floodplains adjacent to Sausal Creek have been mostly eliminated from urbanization, channel incision, and flood control structures (armored channels and banks, and underground culvert). Volunteers remove invasive, non-native vegetation on one of the few remaining floodplains at the mouth of Dimond Canyon near El Centro Avenue (photo by R. Leidy).

Pools and Riffles. A mix of pools to riffles and a diversity of pool and riffle depths provides vital habitat for rainbow trout populations (Figure 8). Also, high-quality riffles are typically characterized by oxygen-rich, clean gravels and cobbles with low percentages of embedded fine sediment (i.e., sand and silt). Urbanization has degraded pool and riffle habitats. Fine sediments mobilized by landslides and erosion within the watershed or pouring into the creek from roads and construction sites, can smother the gravels and cobbles, reducing habitat quality for trout eggs in spawning nests (redds). There is almost no high-quality riffle and pool habitat remaining within the Sausal Creek watershed. Suitable habitat is now restricted mostly to stream reaches within City-owned parklands in the headwaters, Dimond Canyon, and a few “daylighted” reaches in the lower catchment.³

³ The practice of daylighting streams was advanced by Urban Creek pioneers in the East Bay. <https://www.fivecreeks.org/background/MITReportCreekRestorationEastBayHistory.pdf>



Figure 8. Top: A well-shaded alternating sequence of shallow pools and riffles in Dimond Canyon. Bottom: The natural rock weir visible in the center of the photo was installed as part of a channel restoration project to improve pool formation for fish. Photos by R. Leidy.

Native Riparian Vegetation

The riparian vegetation growing in the Sausal Creek watershed is a combination of native plant species and non-native ornamental species within parks, and residential and commercial areas.

Commonly encountered native riparian species found along headwater tributaries and in Dimond Canyon and Park include coast redwood (*Sequoia sempervirens*), white alder (*Alnus rhombifolia*), red alder (*Alnus rubra*), big leaf maple (*Acer macrophyllum*), box elder (*Acer negundo* var. *californicum*), western creek dogwood (*Cornus sericea* ssp. *sericea*), arroyo willow (*Salix lasiolepis*), red willow (*Salix laevigata*), black cottonwood (*Populus trichocarpa*), coast live oak (*Quercus agrifolia*), ninebark (*Physocarpus capitatus*), elk clover (*Aralia californica*), California wild rose (*Rosa californica*), sedge species (*Carex* spp.), tallflat sedge (*Cyperus eragrostis*), rush species (*Juncus* spp.), small-fruited bullrush (*Scirpus microcarpus*), willow herb (*Epilobium ciliatum* subsp. *ciliatum*), horsetail species (*Equisetum* spp.), common woodrush (*Luzula comosa* var. *comosa*), stinging nettle (*Urtica dioica* subsp. *holosericea*), watercress (*Nasturtium officinale*), water parsley (*Oenanthe sarmentosa*), and giant chain fern (*Woodwardia fimbriata*).

Rainbow Trout Life History and Ecology

General Habitat Requirements

In small streams, rainbow trout typically inhabit accessible moderate-to-high gradient stream segments. Ideal reaches contain clear, cool/cold water, a gravel-cobble substrate in riffles free of excessive fine sediment, a mix of pools and riffles, relatively deep rearing/overwintering pools with abundant and complex cover such as submerged large-sized wood and boulders, stable, and well-vegetated undercut banks (Raleigh et al. 1984, NRCS 2000, Moyle 2002, Leidy 2007, Adams et al. 2008)(Figure 9a). The lack of pools > 1m depth is a significant limiting factor for trout, particularly during summer low- or no-flow conditions where pools serve as seasonal refuges in otherwise dry stream reaches (Leidy 2007, Adams et al. 2008). Ideal habitat includes sufficient flows and channel connectivity (i.e., lack of barriers) to allow for upstream and downstream movement and spawning and rearing.

Rainbow trout require “good” water quality with low contaminant and suspended sediment loads and other forms of pollution. Adult and juvenile rainbow trout can periodically tolerate high concentrations of suspended sediments (i.e., turbidity) generated by winter floods. However, chronic exposure to high turbidity from excessive erosion or other sources is detrimental to trout, especially newly emerged fry (Bjornn and Riser 1991).

Different size/age classes of rainbow trout exhibit preferences for different streamflow velocities, depths, substrate, and cover (Baltz and Moyle 1984, Moyle and Baltz 1985, Smith and Aceituno 1987, Baltz et al. 1987, Moyle 2002). Rainbow trout < 50 mm SL (i.e., fry) prefer shallow water depths along stream edges where water velocities are low (Moyle 2002). Larger juvenile fish (50-120 mm SL) occur in deeper (>50 cm) water with higher velocities, where they seek cover among boulders and logs (Moyle 2002). Larger fish (>120 mm SL), including adults, often prefer the head of deeper pools with inflowing water (Moyle 2002).

Water Temperature

Optimal water temperatures for rainbow trout growth range from 12-18° C (Bovee 1978, Raleigh et al. 1984, Baltz et al. 1987). Ideal temperatures for egg incubation range from 4°-12° C (Bjornn and Riser 1991). Prolonged exposure of fish to temperatures of 23-27° C becomes lethal (Hooper 1973, Bjornn and Riser 1991). Rainbow trout populations can tolerate local environmental conditions where preferred temperature conditions are periodically exceeded over prolonged periods, especially if food is plentiful (McEwan and Jackson 1996).

Cover

Diverse and well-developed natural instream and riparian cover are correlated with the abundance of rainbow trout (Bjornn and Riser 1991). Stable overhanging or undercut banks, instream (submerged or semi-submerged) large-woody-debris (LWD), overhanging riparian vegetation, aquatic vegetation, boulders, and deep and turbulent water provide cover from predators and shade that moderates water temperatures. See Figures 9a and b; Examples of riparian and instream cover (Bjornn and Riser 1991, NRCS 2000). Riparian vegetation and instream LWD are a source of insects and other invertebrates that serve as trout food while protecting streambanks from excessive erosion (Bjornn and Riser 1991, NRCS 2000)(Figure 9b).



Figure 9a. A well-shaded reach of Sausal Creek characterized by a dense riparian overstory of white alder and Pacific dogwood. Shading from riparian vegetation maintains cool water temperatures during warm summer and fall months. This reach exhibits a mixture of shallow pools and riffles. Cover for trout is provided by riparian vegetation and submerged boulders. Photo by R. Leidy.



Figure 9b. Large instream woody debris such as this fallen coast live oak in Sausal Creek created a deep, well-shaded pool with complex hiding cover for rainbow trout. These pools are ideal habitat during hot summers and typically support a diversity of terrestrial and aquatic invertebrate prey favored by trout. The photo illustrates the importance of large instream wood in creating diverse habitat for trout, a condition that is rare in most densely urbanized watersheds. Photo by R. Leidy.

Food Habits/Diet

Rainbow trout are opportunistic and feed primarily on drifting aquatic and terrestrial insects, mobile invertebrates found on the substrate, and occasionally small fish (Moyle 2000). Thus, stomach contents at any time may consist of a jumble of snails, amphipods, aquatic insect larvae, and emergent and adult terrestrial insects (Moyle 2002) (Figure 10). Rainbow trout aggressively defend feeding territories (Jenkins 1969).

Benthic macroinvertebrate (BMI) communities in Sausal Creek vary both spatially and seasonally (Figure 10). For example, in May 2020 the most abundant BMI in Dimond Park was the mayfly *Baetis* sp., while the most abundant taxon further upstream in Dimond Canyon was the stonefly *Malenka* sp. Most BMI are aquatic insects, which usually have aquatic larval stages and terrestrial, flying adult stages. As larvae, insects such as mayflies and stoneflies crawl on and within gravel and cobble on the streambed, and are major prey sources for rainbow trout.



Figure 10. The benthic macroinvertebrate community in Sausal Creek in Dimond Park, as seen in late May 2020. The community was dominated by the mayfly (Ephemeroptera) *Baetis* sp., shown at right. *Baetis* is one of the most common aquatic insect taxa in Bay Area streams, and is present in a wide range of habitat and water quality conditions. Also present was the stonefly (Plecoptera) *Malenka* sp. (left), the most common stonefly in moderately impacted streams in the East Bay. Additionally, non-insects including flatworms (*Turbellaria*) and aquatic mites (*Hydrachnida*) were present (visible in the in the middle left of the center photo). Photos and description provided by Matt Cover.

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Figure 11. These invertebrates from Sausal Creek are prized food for rainbow trout. Clockwise from upper left. Prong-gill mayfly (*Leptophlebiidae*). Three generations of small minnow mayflies (*Baetids*). Flat-headed mayfly (*Heptageniidae*). Stonefly (*Perlidae*). Photos and invertebrate identifications by Kathleen Harris.

Spawning Behavior and Requirements

Rainbow trout are capable of multiple reproductive cycles over a lifetime (i.e., iteroparous). Rainbow trout spawn in redds or spawning nests constructed by the female within the gravel/cobble substrate of the stream. Eggs are deposited by the female and fertilized by the male. Spawning in tributaries to the San Francisco Estuary typically begins in the late winter (December-February) and continues into early spring (March-April), depending on streamflows.

Rainbow trout typically spawn at the pool-riffle transition where the down-welling water through the gravel carries oxygen to the trout eggs and eliminates metabolic wastes related from incubation and hatching, and fine sediment. See Figure 3: Spawning Habitat at Pool Riffle Transition (Bjornn and Reiser 1991, NRCS 2000). Rainbow trout spawn in gravel ranging from 3-100 mm in diameter, with trout < 50 cm in total length showing a preference for gravel 15-60 mm diameter (Orcutt et al. 1968, Bovee 1978, Raleigh et al. 1984). High-quality spawning gravels are characterized by < 5% fines (sediment < 2 mm diameter); survival of trout embryos and fry declines as fines make up 20-30% of total substrate sediment (Raleigh et al. 1984). (Figure 12).



Figure 12. (Top) Rainbow trout typically spawn where pools transition to riffles as exemplified in the reach of Sausal Creek in Dimond Canyon upstream El Centro Avenue. (Bottom) Example of high-quality gravel substrate in Sausal Creek that is ideal for spawning rainbow trout. This substrate is characterized by small-to-medium-sized gravel with a low percentage of embedded fines such as silt and sand. Photos by R. Leidy.

Growth and Development

Egg incubation varies inversely with water temperature, typically ranging from 28-49 days at 10-15° C (Raleigh et al. 1984, Moyle 2002). After hatching rainbow trout larvae remain in the gravel substrate for two to three weeks (Bjornn and Reiser 1991, Moyle 2002). The growth rate of rainbow trout is extremely variable and depends on factors such as temperature, food abundance, flow conditions, and available habitat (Railsback and Rose 1999, Moyle 2002). At years end, in small, cold-water streams similar to Sausal Creek, rainbow trout are typically 75 mm FL their first year, 140 mm in year two, 190 mm in year three, and 235 mm in year four (Snider and Linden 1981, Moyle 2002). Rainbow trout likely mature and spawn in their second or third year, with females producing between 200-1000 eggs (Moyle 2002). Life expectancy for rainbow trout is 4-6 years (Moyle 2002).

Space and Habitat Interspersion

Rainbow trout require suitable space to carry out various life-history stages, which involve water of sufficient depth, quality, and velocities (Bjornn and Reiser 1991). Suitable space for rainbow trout depends on watershed area, stream flow, channel morphology, channel connectivity, and gradient, and instream cover (Bjornn and Reiser 1991). The spatial extent of stream channel fragmentation (i.e., barriers to the movement of fish) will largely control the ability of trout to access suitable habitats. Extensive habitat fragmentation will reduce the accessibility of trout to otherwise suitable habitat, which in turn may limit their abundance and health. Because trout are solitary by nature and defend territories, greater habitat connectivity and complexity will allow for higher trout densities.

The minimum habitat size required by rainbow trout is challenging to determine and may vary with food availability and water temperature. For example, trout in streams with limited food availability will likely require more space than trout in streams with plentiful food. Generally, the amount of space needed by rainbow trout increases with age and size. For example, Allen (1969) estimated that space requirements for juvenile salmon in their first year ranged from 0.25-10 m², depending on the quality of the available space, stream productivity, and the presence of other fish. Presumably, the availability of greater space means that fish will be more abundant. However, this is not always the case, especially if the additional space is of poor habitat quality.

Species Interactions

In most streams, rainbow trout are part of a fish assemblage that may include other native and non-native fishes that compete for food and space. There are two commonly encountered native fish species known from Sausal Creek that occur with rainbow trout in other small streams of the San Francisco Estuary (Leidy 2007). The threespine stickleback (*Gasterosteus aculeatus*) resides in the lowermost watershed. Riffle sculpin (*Cottus gulosus*) was recently discovered in Dimond Canyon. Other vertebrates, including birds, reptiles, mammals, and large predatory aquatic invertebrates may also prey on rainbow trout. For example, in Sausal Creek, smaller-sized trout fry and juveniles are likely preyed upon by native aquatic garter snakes and the non-native red-eared slider, a species of turtle made popular by the domestic pet industry. Trout are also preyed upon by native birds such as black-crowned night-heron (*Nycticorax nycticorax*), great blue heron (*Ardea herodias*), belted kingfisher (*Megaceryle alcyon*), and red-shouldered hawk (*Buteo lineatus*) (Mark Rauzon, pers. comm., Figure 13). Also, during incubation in redds, rainbow trout eggs are likely eaten by various aquatic invertebrates. Perhaps the most insidious predator on adult trout are humans that illegally catch fish from Sausal Creek.



Figure 13. Black-crowned night heron and great blue heron foraging in Sausal Creek. Photos by Mark Rauzon.

Historical and Current Description of Rainbow Trout in Sausal Creek

Rainbow trout and steelhead are the same species, *Oncorhynchus mykiss*. The anadromous (sea-run) form of *O. mykiss* are called steelhead, and the resident or non-anadromous type are called rainbow trout. Both forms can live and reproduce in the same stream, although all wild rainbow trout originate from steelhead.

Historically, Sausal Creek supported spawning migrations of steelhead, as did many small tributaries to the San Francisco Bay-Estuary (Leidy et al. 2005). After hatching, juvenile steelhead reared in the creek for 2-3 years before migrating into San Francisco Bay and the Pacific Ocean, where they continued to grow for several years before returning as large adults to spawn again in Sausal Creek. Some juvenile steelhead likely never migrated to sea, but they remained in Sausal Creek to live their lives as resident rainbow trout.

Urbanization created barriers (e.g., culverts, drop structures, road crossings) that effectively block steelhead-spawning migrations into Sausal Creek (Figure 14). While urbanization degraded or destroyed much of the historically suitable habitat for fish, small numbers of rainbow trout persist and reproduce within several relatively short, less disturbed stream reaches (e.g., the mainstem of Sausal Creek in Dimond Park and Dimond Canyon Park, and the Palo Seco Creek tributary in the City's Joaquin Miller Park). Scientists have determined that the Sausal Creek rainbow trout are genetically "wild" descendants of their steelhead ancestors (i.e., the fish did not originate from a fish hatchery)(Nielsen and Fountain 1999). Thus, Sausal Creek rainbow trout are a remarkable environmental asset for the City of Oakland, and a key conservation priority.

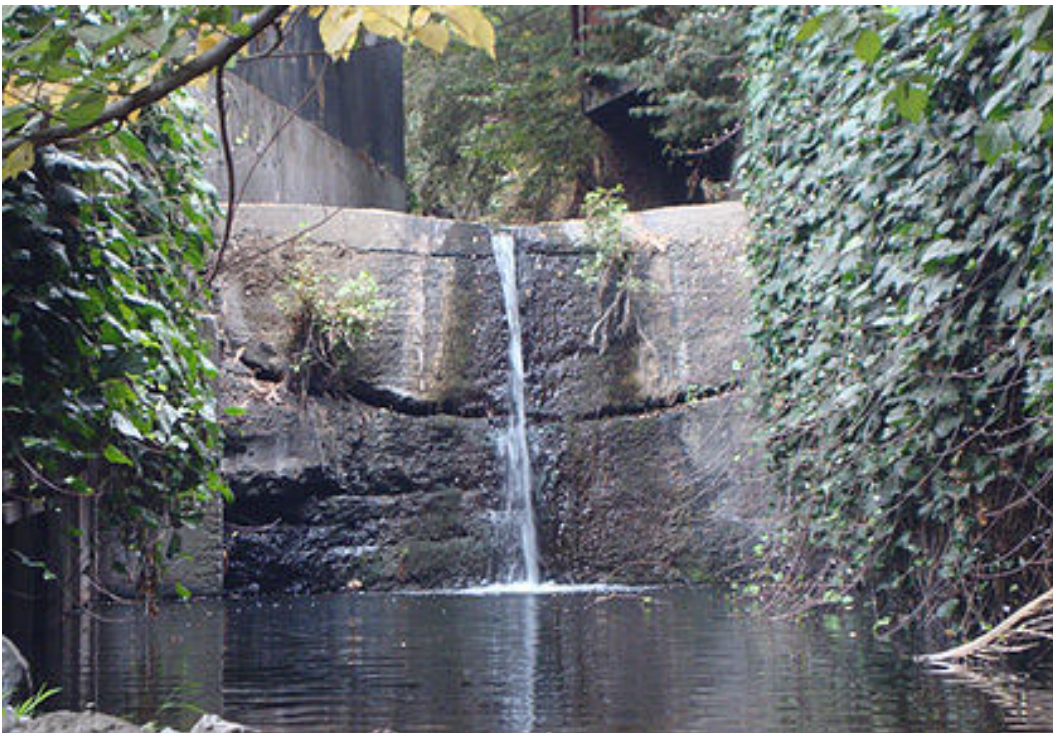


Figure 14. Grade-control structures such as this one at Barry Place are barriers to the upstream migration of rainbow trout.

Late summer and early fall are critical seasons for the survival of rainbow trout in Sausal Creek, especially during conditions of extreme drought. Trout become restricted to the few pools that remain during the dry season when natural baseflows from seeps and springs dwindle, and the potential

discharge of unnatural, contaminated nuisance flows are a tremendous threat to the already highly-stressed fish. These remaining undisturbed pools are habitat refuges critical to trout survival. With the loss of natural deep pools, pool forming factors such as concrete walls and structures can sometimes provide important deep-water habitat for juveniles (e.g., Civilian Conservation Corps structures constructed in the 1930s in Dimond Canyon). Water in quiet pools becomes thermally stratified with cooler water near the bottom and warmer water near the surface (Figure 15). Trout will seek out the zones of cold water near the pool bottoms. Also, rainbow trout rely on their keen eyesight in clear pools to locate and capture prey. Disturbances that mix the water in otherwise tranquil pools degrade trout habitat by eliminating areas of cooler water; reducing clear water needed for efficient feeding; and suspending fine sediment that may impair the ability of fish to breathe. Common disturbances to the creek, such as romping dogs, rowdy mountain bikers, and enthusiastic hikers, can be detrimental and even fatal to the fish.



Figure 15. This summer refuge pool for rainbow trout in Dimond Canyon is well-shaded by native dogwood and alder. Undercut banks tangled with alder root wads provide high-quality shelter for trout. Photo by R. Leidy.

Some of the earliest observations of rainbow trout in Sausal Creek were from the mid-19th Century as more people began to settle the watershed. An account from 1868 in the vicinity of MacArthur Blvd. and Fruitvale Avenue noted the many alders lining Sausal Creek and ... *the clear pools of the creek swarming with the recent hatch of the trout family...* (Oakland Daily Times, 1868). An additional account from near the same location states *Fruit Vale Creek [Sausal Creek] runs through this... the banks of which are some 15 or 20 feet high...[and clear, gravel bottomed pools]...swarming with small trout* (Oakland Daily Times, August 15, 1878).

Another late-19th Century account describes Sausal Creek and the construction of a fishing lodge:

In 1877, Hugh Dimond, an Irish gold prospector who had been successful in the liquor business in San Francisco, moved into his home on the 267 acres he had purchased ten years earlier along Sausal Creek, just above Fruitvale Avenue and MacArthur, at the foot of the canyon. Dimond's home (the site of the former Luelling estate) was a white, two-story, wooden structure surrounded by a verandah, and was situated just beyond the grove of redwoods in today's Dimond Park. The Dimond family dammed Sausal Creek to create a swimming hole 30 feet wide by 100 feet long. Although the swimming hole is long gone, children today swim near the site of the hole, in the Lions' Club swimming pool, built after the City acquired the Dimond property in 1917. The Dimonds used an iron pipe to divert water from Sausal Creek for their household use and built a fishing lodge downstream where they caught trout. (The fishing lodge is now a private home on Woodbine Avenue.) (Owens-Viani 1998, p.6).

At the turn of the 19th Century, Sausal Creek was a destination trout fishing stream. In 1899, *The San Francisco Call* newspaper listed the *Best Streams to Fish* for the opening of angling season:

The veteran angler need not be informed as to the most inviting streams [to catch trout], but the amateur will look to The Call for information, and for his special benefit the following streams are recommended...Sausal Creek. There are some nice pools on Sausal Creek up in Dimond Canyon. Follow the creek up from High Street bridge, Alameda (The San Francisco Call, May 31, 1899).

We are unaware of any accounts of rainbow trout in Sausal Creek during the intervening 100 years, a period characterized by the rapid degradation of Sausal Creek from urbanization. Rainbow trout likely persisted unnoticed during this period in Palo Seco Creek in the upper watershed and in large, relatively deep pools in scattered locations further downstream. Rainbow trout are known to persist in pools in small numbers if suitable habitat is available (Robert Leidy, pers. obser.). In 1997, 15 rainbow trout were observed in Palo Seco Creek, a headwater tributary to Sausal Creek (FOSC Newsletter 12/1997 and Pete Alexander, pers. comm.). During June 1998, five trout were collected during surveys in Palo Seco Creek, and subsequent genetic testing confirmed that these fish were 'wild' and not of hatchery origin (Hager and Demgen 1998, Nielsen and Fountain 1999). Rainbow trout have been observed, often multiple times, within Sausal Creek every year since 2000 (Sausal Creek Watershed Rainbow Trout Observation Log, accessed 6 June 2020, observation log available at www.FOSC.org). For example, in July 2009, thirty-three rainbow trout were collected in Dimond Canyon during fish sampling between El Centro Avenue and Leimert Bridge (SCW Rainbow Trout Observation Log).

In August of 2015, FOsc helped to collect 45 rainbow trout of various age classes in Sausal Creek in Dimond Park (Hager Environmental Science 2015). This trout rescue was part of an effort to relocate fish before dewatering of the stream as part of the Sausal Creek Restoration Project in Dimond Park (Figure 16). The rescued fish were safely moved and released into the El Centro Avenue pool (Robert Leidy, pers. comm.).

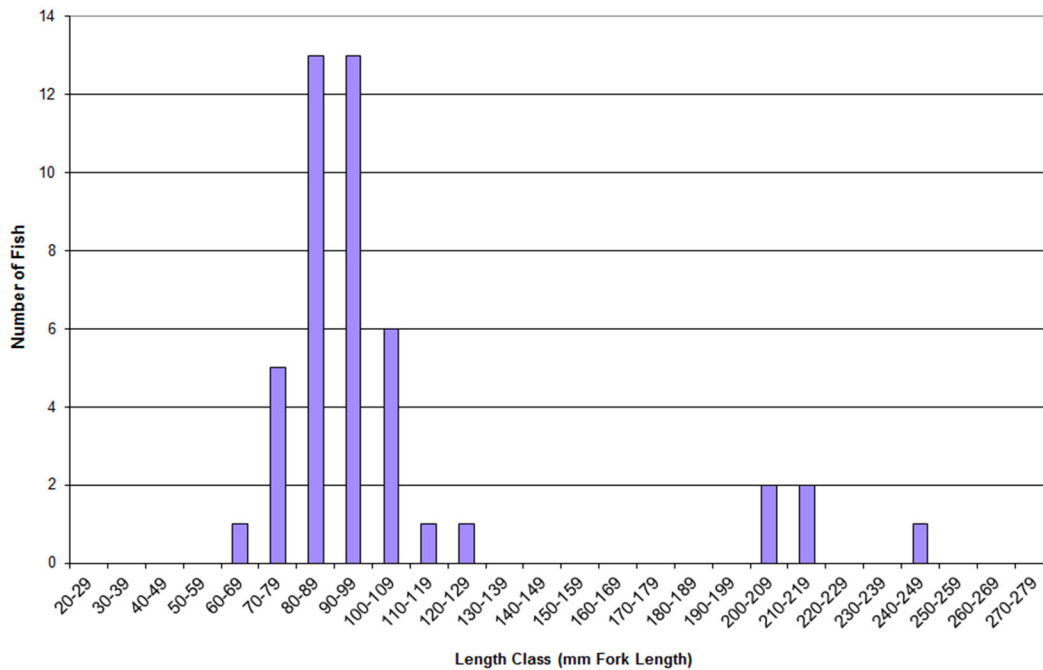
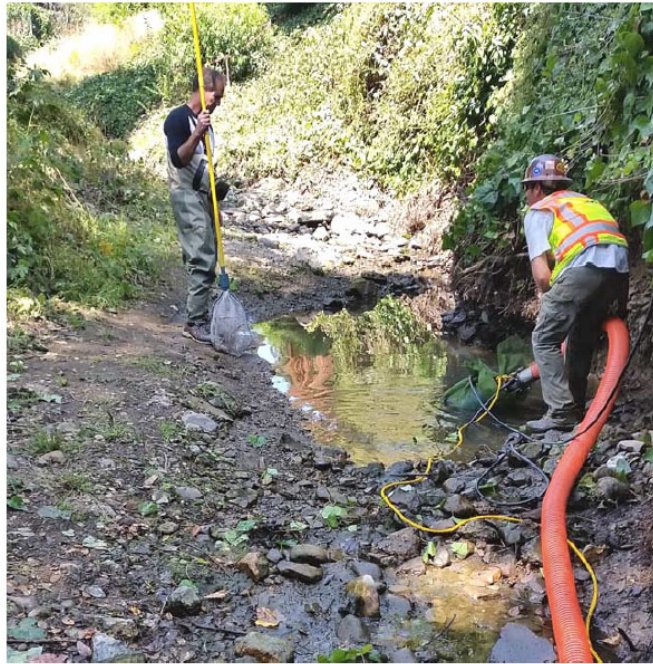


Figure 16. (Top photo). August 2015 stream dewatering and rainbow trout fish rescue/relocation effort in Sausal Creek’s Dimond Park, as part of the City of Oakland’s Sausal Creek Restoration Project in Dimond Park. (Bottom photo). Size distribution of captured and released rainbow trout. Photos and graph by Jeff Hager, Hager Environmental Science, 2015.

Major Threats to Rainbow Trout Habitat and Population Persistence

Physical Habitat Alteration

Rainbow trout require a complex variety of natural habitats and cool, clean water for survival. The loss of aquatic, riparian, and floodplain habitat complexity and diversity through human activities can degrade rainbow trout spawning, rearing, feeding, resting, and refuge habitats; and reduce stream connectivity through fragmentation. Urbanized land uses cover 78% of the Sausal Creek watershed, mostly downstream from Dimond Canyon (> 95% urbanized). Urban land uses have drastically altered the Sausal Creek watershed, with significant adverse cumulative effects on its watercourses. Changes to the Sausal Creek watershed include:

- Replacement of natural landscapes with impervious surfaces;
- Confinement of multiple reaches of the creek in underground culverts;
- Channelization and bank armoring to reduce flooding and erosion;
- Floodplain constriction through urban development;
- Placement of instream grade control/drop structures;
- Construction of road crossings, culverts, and stormwater drain outlets; and
- Replacement of native riparian species with non-native, invasive species.

Natural streams typically form a dendritic pattern on the landscape like the branching twigs of a tree that eventually connect to form a primary or trunk channel. A critical ecological characteristic of this natural dendritic pattern is connectivity or the state of being physically joined together. Sausal Creek was characterized by a dendritic pattern with strong longitudinal and lateral physical and ecological connections before the drastic changes brought to the watershed by European settlers. These connections allowed for the unimpaired movement of water, sediment, nutrients, and organisms longitudinally (up- and down-stream), laterally (across floodplains), and vertically (the hyporheic zone).

Fragmentation of once continuous, high-quality aquatic habitat in Sausal Creek has left splintered and discontinuous reaches of suitable living space for rainbow trout (Figure 17). In contrast to connectivity, fragmentation is the process of a larger whole being broken apart into smaller pieces that form isolated or incomplete parts. Stream networks are naturally fragmented (e.g., waterfalls that create fish migration barriers), but in urban settings, humans have accelerated the process of stream fragmentation. Examples of human activities that have fragmented Sausal Creek include the construction of roads, culverts, bridges, flood control channels, and dams.



Figure 17. Rainbow trout are prevented from venturing too far upstream or downstream by human-made structures including (counterclockwise from top left): a road culvert under El Centro Avenue; a drop structure at Barry Place; and a large culvert at the Oakland Estuary. The map depicts the lower fragmented reaches of Sausal Creek (left side of figure) where the creek was “channelized” (solid red line), “undergrounded” (dotted red line), not channelized but modified with stormwater infrastructure (blue line), and historical wetland features (green line).

Flow Alteration

Changes to the natural streamflow regime (e.g., frequency, duration, magnitude, and volume of flow) can adversely affect rainbow trout populations. Urbanization has altered the natural flow regime of Sausal Creek by increasing the area of impervious surfaces, and the length of the stormwater drainage network, as well as through changes in patterns of water usage. Impervious surfaces reduce the infiltration of water into the soil, which leads to increased runoff.

During the wet season, the timing, volume, and velocity of water flow throughout the Sausal Creek basin have changed dramatically when compared to historical norms. Increased quantities of water enter the creek over shorter periods may result in increased channel incision, bank erosion, loss of riparian vegetation, and higher substrate scour. The excessive loss and frequent movement of gravel from scouring can destabilize or reduce trout spawning and rearing habitat, thereby reducing the success of reproduction (recruitment), and decreasing the abundance and diversity of aquatic invertebrates that are important prey for the trout. Extreme stream flows may also physically flush rainbow trout into low-quality habitats and restrict their movements between habitats.

During the dry season, nuisance flows from yards, streets, and gutters drain into the creek via stormwater drain outfalls. Nuisance flows augment whatever freshwater is being contributed by seeps and springs. Still, the volume of natural, clean water is often not ample enough to dilute whatever contaminants are carried by the nuisance flows. Therefore, these flows often contain high levels of pollutants that are harmful to rainbow trout. Freshwater inputs from seeps and springs can be further diminished by the extraction of groundwater from residential wells and the diversion of surface waters for consumptive uses, and this can leave stream reaches dried out. If the trout manage to survive this further constriction of flow and aquatic habitat, they are placed at great risk within any deep-water pools that may remain along the stream course. Water temperatures can rise to lethal levels, while the trout are also exposed to disturbance and predation by animals and humans. Fortunately, water extraction within the Sausal Creek watershed is not currently a significant management issue, but should be closely monitored in the future.

Water Quality Degradation

Water quality degradation in Sausal Creek from “point and non-point” pollution sources can pose threats to the resident rainbow trout population. Perhaps the greatest threat to the survival of trout in Sausal Creek comes from illegal dumping of toxic substances such as paints, solvents, and oil. Harmful pollutants may originate in commercial and residential areas where they enter the storm drain system and eventually discharge into Sausal Creek or its tributaries. Several ‘fish kills’ in Sausal Creek have been traced to the dumping of toxic substances into Sausal Creek (Figure 18).



Figure 18. Examples of adult (left) and juvenile (right) rainbow trout killed by the illegal dumping of toxic substances into Sausal Creek. In 2009, at least thirteen adult trout were killed in El Centro Pool by paint solvents dumped into a residential storm drain that empties into the creek. Photos by R. Leidy.

FOSC currently collects data on water quality throughout the watershed to assess the status and trends of water quality in the basin. Sampling sites represent different kinds of discharges from different types of land-uses within the watershed. Samples for water quality analyses are taken at Barry Place, El Centro, Leimert, Cobbledick, Palo Seco, and Joaquin Miller Park. Since 2013, data collected during the wet and dry seasons have included electrical conductivity, temperature, pH, total dissolved solids (TDS), and dissolved oxygen. Additionally, FOSC has regularly sampled for coliform throughout the watershed.

Depletion of Dissolved Oxygen

Rainbow trout need dissolved oxygen (DO) in higher quantities during times of high metabolic activity (e.g., when water temperatures are elevated). Depleted levels of DO can slow growth, impair reproduction and rearing of juvenile trout, and become an acute cause of death. Depletion of DO in the

creek can be caused by the decomposition of algae, increased temperatures caused by diminished base flows during drought, the loss of tree canopy, water diversions, discharges of contaminants, and the alteration of the hydrological regime.

Dissolved oxygen is consumed when algae and phytoplankton die and decompose, and this can substantially deplete the levels of DO available to the trout, and result in fish kills. The growth of algae in the creek can be significantly accelerated by the discharge of nitrogen and phosphorous (nutrients) into the stream, and these are common elements within lawn and garden fertilizers. This type of oxygen depletion can be measured as biochemical oxygen demand (BOD).

Water Temperatures

Since 1977, water temperatures have been monitored in Sausal Creek at semi-regular intervals. Temperature is a crucial component of water quality indication for rainbow trout, as they require specific temperature ranges for survival and reproduction. High-water temperatures ($>23^{\circ}\text{C}$) can cause trout fatalities. Water has a maximum oxygen-holding capacity that varies with water temperature, with lower temperatures holding more oxygen and high temperatures retaining less. FOSC water quality monitoring data shows that some measurements of low dissolved oxygen ($<7.0\text{ mg/L}$) were associated with increased water temperature (SCWEP 2010).

Loss of riparian forest cover contributes to warm water temperatures, while an increase in riparian forest cover shades the waterway and maintains cooler temperatures during the summer and fall. Creek temperatures have generally remained cool in the summer and fall, likely due to the presence of base flows in the creek from seeps and springs. Water temperatures in Sausal Creek from 2013 to 2020 have not surpassed 16°C in the warmest months (Figure 19).

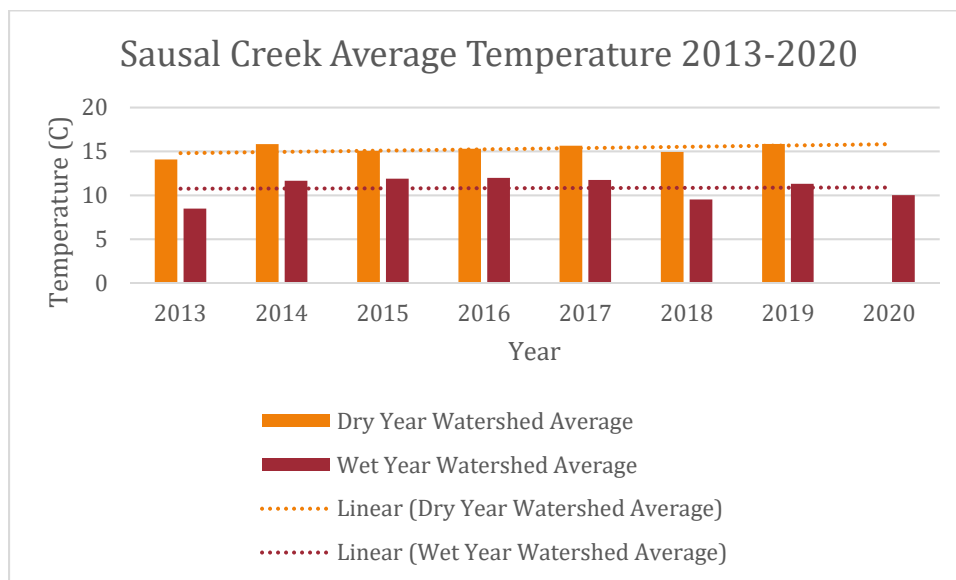


Figure 19. Average water temperatures in Sausal Creek through wet and dry seasons from 2013-2020.

Data from five sampling locations throughout the watershed has been collected annually over five consecutive weeks, both wet and dry seasons. They show that overall temperatures increased further downstream, with the coolest temperatures near the headwaters and warmest temperatures in the lower watershed. Average wet and dry season temperatures remain mostly within a healthy range for rainbow trout. The wet season did not show a significant increase in water temperatures ($y = 0.02x + 10.74$, $R^2 = 0.00$). There was a slightly more defined increase in average dry season water temperature from 2013 to 2020 in the watershed ($y = 0.15x + 14.66$, $R^2 = 0.25$).

To effectively manage the trout populations in Sausal Creek, we must continue monitoring stream temperatures and DO levels, and do so more frequently, so we can build a robust, long-term data set. This data will provide a scientifically-strong basis for guiding decisions about investments in conservation actions and infrastructure improvements.

Acidity

The “acidic” or “basic” nature of an aqueous solution is measured through the logarithmic pH scale. Most aquatic invertebrates require a pH range between 7 and 8.5. Major exceedances of this range can be lethal for trout and many other freshwater species. Sausal Creek appears to be experiencing an overall trend in decreasing pH throughout the watershed, resulting in a slightly more acidic environment than in past years ($y = -0.23x + 8.71$, $R^2 = 0.94$ dry year, $y = -0.23x + 8.93$, $R^2 = 0.89$ wet year); (Figure 20). Monitoring of water quality indicates that the most noticeable decrease in pH may have occurred in 2017, which could point to a significant change in land uses and human activities within the watershed. Continued year-round monitoring is needed to gain more insight into the origins of these changes in pH.

All sampling locations displayed a downward trend in pH (increasing acidity), some more sharply than others. The most substantial decrease and variation in pH was observed at Barry Place, the most downstream of all monitoring sites ($y = -0.37x + 9.03$, $R^2 = 0.87$ dry year, $y = -0.30x + 9.1$, $R^2 = 0.79$ wet year).

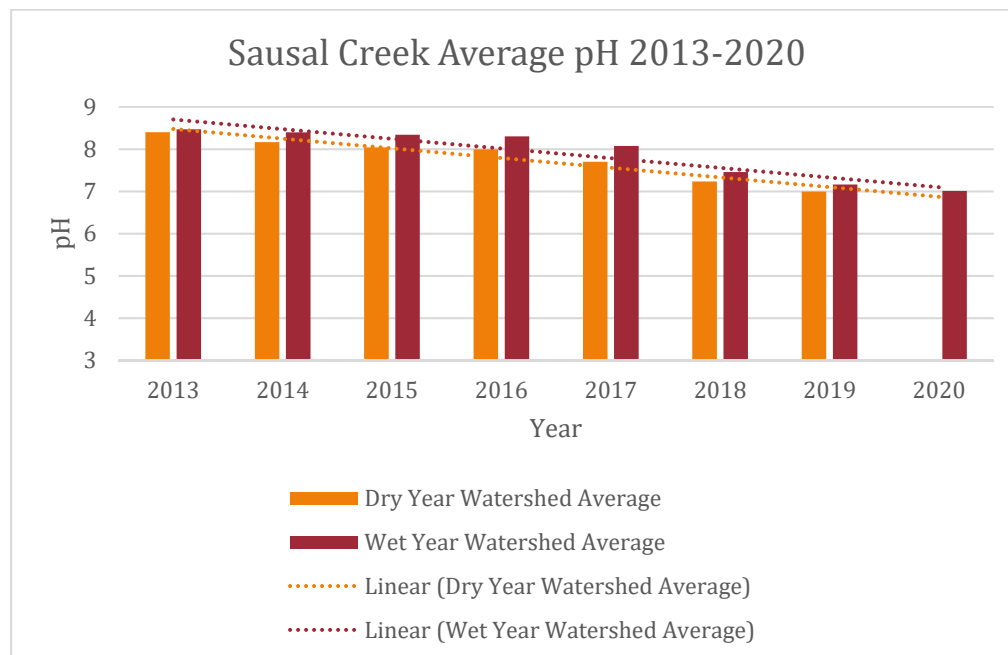


Figure 20. Sausal Creek Average pH 2013-2020. Wet and dry year watershed averages of pH values from a watershed-wide survey compared over 8 years.

Electrical Conductivity

Helen Dickson⁴ analyzed water quality monitoring data from 1999 to 2014 for trends in conductivity, dissolved oxygen, *E. coli*, pH, and water temperature in the watershed. Conductivity, the measurement of an electrical current carried by an aqueous solution, is related to salinity, stream bed geology, temperature, and ultimately ionic concentration of a water body.

Dickson's report on conductivity in Sausal Creek from 2004 to 2007 displays conductivity ranging from 200-1000 μS . Conductivity was measured at three sites throughout the watershed: Palo Seco, Dimond Canyon, and El Centro stream crossing. Conductivity measurements can indicate pollution in the watershed. High conductivity spikes can be a result of fertilizer or sewage leaks, and oil spills can cause decreases in conductivity. According to the EPA, aquatic organisms require a range of conductivity between 150 to 600 μS . Upstream sites displayed lower conductivity than downstream sites, reflecting a higher likelihood of pollution as water flows downstream and is augmented by drainage from increasingly urbanized areas.

Ongoing urban creek monitoring by the San Francisco Bay Regional Water Quality Control Board's Surface Water and Ambient Monitoring Program (SWAMP) was completed through 2018 (Figure 21). The Urban Creeks Monitoring Report completed by SWAMP is a part of the Alameda Countywide Clean Water Program. In 2018, Sausal Creek was monitored using standard procedures for biological monitoring and monitoring for chlorine, nutrients, temperature, and general water quality (DO, pH and specific conductivity). The monitoring focused on the exploration of California Stream Condition Index (CSCI) results and the outcomes of restoration activities along Sausal Creek.

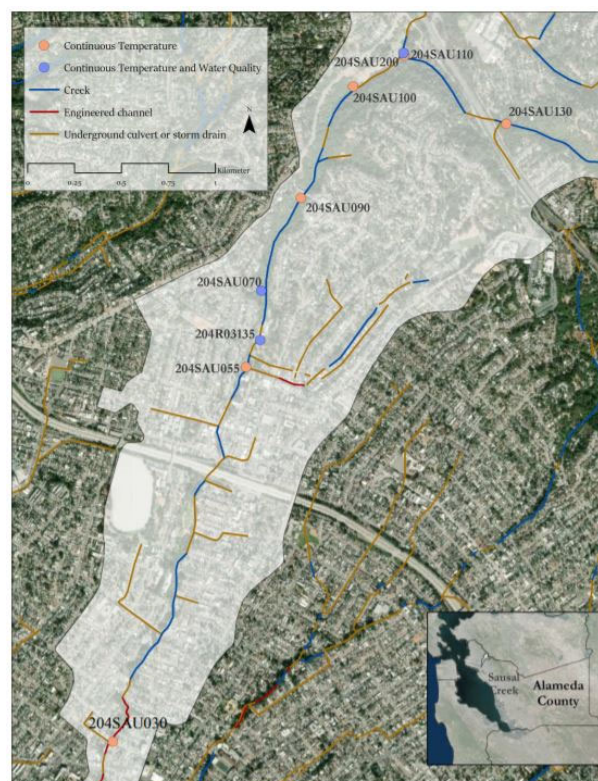


Figure 21. SWAMP Continuous Monitoring and General Water Quality Monitoring on Sausal Creek for the 2018 Water Year.

⁴ Refer to Water Quality analyses at: <https://www.sausalcreek.org/natural-resources>.

Before the 2018 SWAMP monitoring, SWAMP found low CSCI scores at two sites, high *Enterococci* concentrations, and several metals above PEC or TEC thresholds in water years 2016 and 2017. In 2016, samples collected here during the dry season exhibited statistically significant aquatic toxicity to both *C. dubia* and *C. dilutus*.

The 2018 monitoring sought to add to the data set and monitoring how conditions in Sausal Creek had changed since the last water year. Methodology for the 2018 monitoring included continuous temperature monitoring at eight locations at hourly intervals over six months, as well as conductivity monitoring at four of those locations. General water quality monitoring during Spring and Fall at three locations assessed temperature, dissolved oxygen (DO), pH, and specific conductivity at 15-minute intervals. Also, pathogen indicators (e.g., *E. coli* and *Enterococci*) were monitored at five sites. Additional BMI analysis using the CSCI was done to evaluate the success of restoration projects implemented at locations along the creek.

Three sites had two or more weekly average temperatures above the 17°C threshold, and an additional site had one weekly average temperature above the threshold. Greater than 20% of instantaneous dissolved oxygen measurements at two lower watershed sites collected in fall deployments did not achieve the MRP target of ≥ 7 mg/L DO. Concentrations of Fipronil and Imidacloprid were above chronic benchmarks for invertebrates.

BMI analysis using CSCI at the 2016 Sausal Creek restoration site in Dimond Park found physical habitat alteration and lack of mature vegetation connected to the restoration project to be the most likely cause of biological community degradation. The compounding effects of urbanization comprise several types of causal activities that together result in an “urban stream syndrome” of co-occurring, interacting changes in five general stressor categories, water/ sediment quality, temperature, hydrology, physical habitat, and energy sources.

Previous watershed monitoring through the California Rapid Assessment Method (CRAM) was completed in 2017. While much of the CRAM monitoring focused on physical structure and hydrology, the final report noted some water quality attributes with negative and significant negative effects. These include non-point sources of urban runoff, impairment by bacteria and pathogens, and excessive sedimentation and organic debris accumulation from within the watershed.

SWAMP water quality samples for pollutants and toxicity are available from five locations on Sausal Creek and Palo Seco Creek in 2004-2005. All samples exceeded the guidelines for nitrate and total phosphorus. Metals, pesticides, and other contaminants did not exceed the recommended levels. The water and sediment chemistry and toxicity tests indicate some sediment contamination by metals but no acutely toxic effects from water or sediment (Sausal Creek Watershed Enhancement Plan 2010).

Drought and low-flow periods in Sausal Creek can exacerbate water quality degradation by increasing the concentration of pollutants and faster warming during low-flow. Ongoing climate change poses a threat to water quality through more erratic precipitation cycles and temperature changes, including more frequent drought and flooding. Surface runoff increases with more torrential rainstorms, including transporting pollutants and sediment and more into the creek.

Several water quality analytes currently not being monitored could provide much more insight into the overall status of water quality in Sausal Creek as it pertains to the life cycle and health of the resident RBT population. The 2018 SWAMP monitoring report concludes with encouragement for future sampling as the restoration site matures to infer if water quality and habitat are improving around the restoration site and along the creek in general. Monitoring dissolved oxygen, turbidity, TDS, and continued monitoring for pH, temperature, and conductivity continually could provide a better picture of the overall conditions and what areas are top priorities for several actions, including restoration.

Excess Sediment

Healthy streams exhibit a balance between sediment erosion, transport, and deposition that maintains the character and diversity of pools and riffles important to rainbow trout. Stream channels function to

mobilize, sort and flush sediment, and this creates and maintains diverse aquatic habitats. When in balance, these processes create high-quality trout habitat in the form of undercut banks, complex instream cover, a diverse riparian canopy, deep pools, and clean, well-oxygenated gravel in riffles used for spawning. However, in urbanized watersheds such as Sausal Creek, these sediment processes are no longer in equilibrium, often because of excessive sediment inputs (Figure 22). Excessive erosion and sedimentation can adversely affect the health of the trout population by:

- Decreasing the survival of eggs and the early life stages of the trout by filling the interstitial pore spaces in gravel beds used for spawning, and diminishing the permeability and oxygen-holding capacity of the gravel-cobble substrate;
- Decreasing the feeding success of trout, impairing their growth, and altering blood physiology, damaging the respiratory systems of the fish through gill abrasion and trauma, and generally increasing disease and mortality from prolonged exposure to suspended sediment;
- Altering the movement and swimming performance of the fish as high levels of suspended sediment may halt upstream migration, decrease swimming ability, and increase exposure to predators;
- Reducing the abundance and diversity of invertebrates that are the preferred prey of rainbow trout, or by altering invertebrate behavior by smothering suitable gravel-cobble substrates in the streambed;
- Reducing the clarity of the water column with suspended sediment, thereby changing prey selection patterns and or reducing prey abundance (the trout are visual feeders);
- Reducing primary productivity, as suspended sediment can decrease photosynthesis by plants and the availability of dissolved oxygen; and
- Increasing the levels of instream contaminants such as phosphorus, heavy metals, and organic pollutants that bind with sediment particles (Waters 1995, Kjelland et al. 2015).

Excessive delivery of fine sediment from human-caused erosion is known to occur throughout the Sausal Creek watershed. Sources of high sediment input to Sausal Creek include improperly designed or failing stormwater drain outfalls along major open channels, outlets on extremely steep slopes, and storm drains receiving runoff from large land areas. The 2010 Sausal Creek Watershed Enhancement Plan lists high priority erosion sites (Section VII, Recommended Actions).



Figure 22. Excessive sedimentation in the Dimond Canyon reach of Sausal Creek exacerbated by a drinking water pipeline break and in the upper watershed. Too much of such fine sediment can smother rainbow trout eggs and reduce the diversity and abundance of aquatic invertebrates that are important prey for trout. Compare this photo with the clean substrate visible in Figure 12, above. Photo by R. Leidy.

Loss of Native Riparian Vegetation

The loss and degradation of diverse native riparian communities along streams can have harmful effects on rainbow trout. Healthy, native riparian communities perform several critical functions. Diverse riparian vegetation on streambanks and adjacent floodplains provide shading, which moderates water temperatures during warm summer-fall months. Also, riparian vegetation slows-down floodwaters, which promotes sediment deposition and nutrient retention and control. Riparian vegetation improves bank and hill-slope stability, thereby reducing excessive erosion and sedimentation, which helps maintain stream equilibrium. Downed trees that fall into the stream are a source of large woody debris, which creates instream cover for trout, and complex, deep pools used as summer rearing and holding habitat for fish. Leaf litter from deciduous riparian species (e.g., white alder, arroyo willow, red willow, and western creek dogwood) is the primary source of energy for many aquatic invertebrates consumed by rainbow trout.

Non-native Aquatic Species

Non-native aquatic species pose a significant threat to rainbow trout in Sausal Creek through direct competition for space and food, changes in stream trophic structure, and disease spread. The primary mechanism for the introduction of non-native aquatic species into Sausal Creek is through the illegal dumping of unwanted pets such as fish, turtles, and frogs. Non-native aquatic species can often rapidly colonize their new habitat, and thereby compete with trout for limited space and food resources, prey on eggs and juvenile fish, and quickly spread novel diseases. Illegal fishing is another potential pathway for the introduction and spread of non-native aquatic organisms. The use of live bait (e.g., crayfish) and the transportation of non-native invertebrates (e.g., clams and snails) on contaminated fishing equipment is a serious threat to the aquatic ecosystem. Periodically observed in Sausal Creek are single individuals of non-native fish such as goldfish (*Carassius auratus*) and largemouth bass (*Micropterus salmoides*); however, we are unaware of any reproducing, self-sustaining populations of non-native fish.

Similarly, there are anecdotal accounts of non-native frogs (e.g., American bullfrog (*Lithobates catesbeianus*), but there is no evidence of breeding populations. Also, documented from two pools (i.e., the Wellington and El Centro) within Dimond Park and Canyon is the non-native red-eared slider (*Trachemys scripta elegans*), but whether this turtle is successfully reproducing is unknown. There currently are no non-native crayfish within the Sausal Creek watershed. Also, there are no recorded accounts of the non-native zebra mussel (*Dreissena polymorpha*), New Zealand mud snails (*Potamopyrgus antipodarum*), or other exotic clams and mussels. New Zealand mud snails are especially damaging because they are known to reduce populations of aquatic insects, including chironomids, caddisflies, mayflies, and other insects that are essential food for rainbow trout (<https://wildlife.ca.gov/Conservation/Invasives/Species/NZmudsnail>).

Illegal Fishing

Illegal fishing of adult rainbow trout is a significant threat because it can reduce spawning populations (Figure 23). Removing even small numbers of adults can dramatically reduce the natural reproduction of the fish and generational replacement. The adverse effects on trout from illegal fishing in small streams, such as Sausal Creek, could be especially severe because of the small number of spawning adult fish restricted to stream reaches with limited suitable spawning and rearing habitat. In Sausal Creek, large adult trout are particularly vulnerable to illegal harvest, in part, because they tend to congregate in highly visible pools with easy public access. Although the State of California has closed Sausal Creek to recreational fishing, periodic poaching remains a problem (Figure 24).



Figure 23. A thirteen-inch rainbow trout illegally caught in Sausal Creek's Dimond Canyon. Photo by Mark Rauzon.



Figure 24. Fishing is illegal in Sausal Creek by state law! Photo by R. Leidy.

Goals, Objectives, Rationales, and Recommended Actions

Goal 1: Protect, Enhance, and Restore Rainbow Trout Habitat

Objective 1: Map and Assess Existing Rainbow Trout Habitat, Distribution, and Abundance

Rationale: Identifying the location, area, and quality of existing rainbow trout habitat in the watershed is essential to prioritizing conservation activities. Equally important is understanding the distribution of trout, as well as their relative population abundance.

Recommended Actions to Document Existing Rainbow Trout Habitat and Distribution:

1. Use GPS and standard stream assessment methods and protocols to map the locations of existing aquatic habitat along daylighted sections of Sausal Creek and its tributaries by stream reach. Mapping should identify aquatic habitat type (i.e., riffles and pools), including the general physical and ecological characteristics and quality of each habitat type (e.g., perennial/intermittent flow, length, and width, average and maximum depth, substrate type, presence of shading and instream cover, description of the riparian community, habitat condition/quality, etc.);
2. Conduct presence/absence surveys for rainbow trout in Sausal Creek, and its permanent tributaries using standard fish sampling protocols. Record fish number, size, and condition;
3. Periodically conduct qualitative/quantitative trout population monitoring; and
4. Develop an ArcGIS map of existing trout habitat and rainbow trout distribution within the watershed that includes a qualitative/quantitative narrative assessment of habitat quality.

Objective 2: Identify Threats and Stressors Affecting Rainbow Trout

Rationale: Protecting rainbow trout over the long term requires an understanding of the relative importance of various stressors on population viability. Multiple stressors may have harmful effects on trout health, abundance, and persistence.

Recommended Actions to Identify Threats and Stressors to Rainbow Trout:

1. Use GPS to map by stream reach existing and potential threats and stressors affecting rainbow trout distribution and abundance.⁵ Stressors may include identification of:
 - reaches buried in underground culverts;
 - reaches that are channelized or have artificially hardened banks;
 - physical barriers such as drop-or-grade control structures, culverts, dams and road crossings that block or inhibit trout movement;
 - tributaries receiving excessive stormwater runoff linked to impervious surfaces;
 - erosion sites that are sources of excess sediment into the creek;
 - stormwater drains, culverts, failing sewer lines, streets, parking lots, and other impervious surfaces that impair water quality as chronic sources of creek contamination;
 - locations where feces from domestic pets are deposited within and adjacent to creeks;
 - reaches with riparian communities dominated by non-native plants; and
 - locations of non-native, aquatic fauna; and
2. Incorporate threat/stressor locations into an ARCGIS map.

⁵ The Final Sausal Creek Enhancement Plan (March 2010) assesses and recommends actions to remediate several stressors (i.e., major erosion sites, problematic stormwater features, invasive non-native plants, sources of degraded water quality, and altered aquatic and riparian habitats) affecting the quality of aquatic and riparian habitat within the watershed. Where relevant, these findings and recommendations should be reviewed and incorporated into the priorities and strategies outlined in this rainbow trout conservation and management plan.

Objective 3: Identify Mitigation Measures to Enhance and Restore Rainbow Trout Habitat

Rationale for Restoring Connectivity: Reestablishment of longitudinal connectivity focuses on measures that allow for the efficient up- and down-stream movement of rainbow trout between high-quality habitats blocked by fish migration barriers such as drop-structures, culverts, dams, and road crossings. Improved longitudinal connectivity also allows for the natural transport of water, sediment, large-woody debris, and nutrients.

Restoring lateral connectivity allows the stream to reconnect to its floodplain where channelization and artificially hardened banks have confined flows. Improved lateral connectivity allows for water storage during high flows that also reduces channel scour from peak flows, improves water quality, increases sediment deposition, reduces hyporheic water temperatures, and promotes the establishment of healthy riparian communities.

Restoring vertical connectivity aims to reduce and repair channel incision from elevated scour linked to impervious surfaces. Aggrading incised channels can increase floodplain connectivity, sediment storage, and the diversity of riparian vegetation. Channel aggradation can also increase summer baseflows, improve instream habitat diversity through the creation of balanced pool-riffle ratios, reduce riffle scour, and the adverse effects on food production and spawning habitat for rainbow trout.

Recommended Actions to Restore Connectivity:

1. Daylight and restore streams buried in underground culverts to natural configurations;
2. Restore confined, channelized reaches to more natural, unconfined configurations, and replace artificially hardened banks with natural banks using natural stabilization methods; and
3. Remove/redesign physical barriers to rainbow trout movement such as drop-structures, culverts, dams, and road crossings.

Rationale for Reducing the Effects from Impervious Surfaces: Reducing the coverage of impervious surfaces with natural land cover will improve the hydrological and ecological functions of Sausal Creek with benefits to rainbow trout. An increased percentage of natural land cover will allow increased infiltration of water, and reduce excessive peak flows, channel scour, and sediment transport; and buffer the delivery of harmful levels of nutrients and other contaminants to Sausal Creek.

Recommended Actions to Reduce Flow from Impervious Surfaces:

1. Replace existing impervious surfaces with natural landscapes, or porous surfaces that allow for the infiltration of rainfall;
2. Construct stormwater detention and biofiltration basins at strategic locations to intercept, retain, and store excess runoff from impervious surfaces;
3. Construct rain gardens and biofiltration features along streets and at road crossings where stormwater enters the creek; and
4. Retain large woody debris and logjams in stream reaches where they do not pose a threat to public safety, infrastructure, and private property.

Rationale for Remediating Major Erosion Sites, Focusing on Stormwater Drain Outlets, Culverts, Construction Sites, Streambanks, and Failing Hillslopes: Remediating sites characterized by excessive erosion will improve the instream habitat for rainbow trout by reducing sedimentation in pools and riffles. Reducing erosion will enhance the quality of spawning, and rearing habitat, increase the survival of eggs and juvenile trout, increase productivity and improve food quality, and decrease contaminants.

Recommended Actions to Reduce the Delivery of Excessive Sediment into Creeks⁶:

1. Implement recommended measures, listed above, to reduce excessive flows from impervious surfaces that may exacerbate erosion and increased sedimentation;
2. Utilize natural materials to repair, stabilize, and revegetate stormwater drain outlets, culverts, and failing hillslopes;
3. Report to regulators at the City of Oakland and State of California construction projects that are not implementing best management practices (BMPs) for sediment control; and
4. Plant native riparian vegetation to stabilize eroding stream banks.

Rationale for Reducing Major Sources/Inputs of Contaminants into Creeks: Water quality degradation in Sausal Creek from point and non-point sources of pollution can pose threats to the health and long-term persistence of the resident rainbow trout population. Reduced levels of dissolved oxygen, elevated water temperatures, and high contaminant levels can impair trout reproduction and growth, promote disease, and alter food availability and quality.

Recommended Measures to Reduce Chronic Sources of Contamination to Creeks:

1. Implement recommended measures listed above to reduce stormwater flows from impervious surfaces (e.g., streets, parking lots, rooftops) and the delivery of excessive sediment as these measures will also reduce contaminants entering the creek; and
2. Promote community awareness through the development of outreach materials focused on measures to reduce creek pollution, including: (1) picking up dog waste; and (2) the proper disposal of household chemicals and other potential residential and commercial contaminants, so they do not enter the creek through the stormwater drainage system or as overland runoff.

Rationale for Protecting and Enhancing Native Riparian Plant Communities: Healthy, native riparian communities provide shading, which moderates water temperatures during warm summer-fall months. Also, riparian vegetation slows-down floodwaters, which promotes sediment deposition and nutrient retention and control. Riparian vegetation improves bank and hillslope stability, thereby reducing excessive erosion and sedimentation, which helps maintain stream equilibrium. Downed trees that fall into the stream are a source of large woody debris, which creates instream cover for rainbow trout and complex, deep pools used as summer rearing and holding habitat for fish. Leaf litter from deciduous riparian species is the primary source of energy for many aquatic invertebrates consumed by trout.

Recommended Measures to Protect and Enhance Native Riparian Plant Communities:

1. Protect existing native riparian communities, especially where they are threatened by human activities, through the placement of informational signage and the strategic installation of fencing;
2. Eradicate and control the spread of non-native plants within the riparian zone and floodplain; and
3. Plant native riparian species, focusing on eroded streambanks, and areas where non-native plants have been removed.

⁶ Section VII – Recommended Actions of the Final Sausal Creek Enhancement Plan (March 2010) identifies actions to remediate areas contributing excess sediment to Sausal Creek. Where relevant, these actions should be incorporated herein by reference. http://www.documents.sausalcreek.org/SCWEP10_RecommendedActions.pdf

Goal 2: Understand the Ancestry of Sausal Creek Rainbow Trout

Objective 1: Conduct Genetic Testing

Rationale for Understanding the Genetics of Sausal Creek Rainbow Trout: Limited testing has confirmed that rainbow trout in Sausal Creek are 'wild fish' and not the descendants of hatchery fish. However, newer advances in genomics will be able to determine the ancestry of Sausal Creek trout better.

Recommended Measures to Improve our Understanding of Rainbow Trout Genomics:

1. Collect tissue samples (fin clips) from a minimum of 35 rainbow trout for genomic analysis to better understand ancestry of fish in Sausal Creek.

Goal 3: Encourage the Public to Take Ownership in the Protection of Rainbow Trout

Objective 1: Educate the Public about the Importance of Sausal Creek Rainbow Trout

Rationale for Public Education about Rainbow Trout Conservation: All Oakland residents deserve accessible creeks with clean water that support healthy and diverse ecosystems and green open spaces. Effective stewardship of natural resources in urban settings is rarely successful without passionate and committed community involvement. Sausal Creek's rainbow trout are a unique part of Oakland's natural and cultural history. These rare fish cannot persist unless the community appreciates their importance.

Recommended Actions to Educate Public About Rainbow Trout:

1. Host periodic and free Trout Walks for the public in Dimond Park and Canyon. The public will learn about the history and ecology of rainbow trout in the Sausal Creek watershed. The public also will learn about threats to trout and what individuals can do to help protect fish in the watershed. FOSC will advertise Trout Walks through its website and social media; and
2. Host community volunteer restoration workdays aimed at fostering an appreciation of the Sausal Creek watershed (Figure 25).



Figure 25. Students and families volunteering come rain or shine in Dimond Canyon on Earth Day. Sustained community engagement is essential to the protection of rainbow trout. Top photo by FOSC founding member and Laney College Professor Mark Rauzon (photo center wearing blue tee-shirt), bottom photo by R. Leidy.

Goal 4: Provide Educational Opportunities for Local Schools to Learn About Rainbow Trout and How to Protect their Habitat

Objective 1: Create a Science-based Classroom and Field Focused Curriculum on Rainbow Trout Ecology and Protection for Educators

Rationale for Creating an Educational Curriculum on Rainbow Trout: Today's students are tomorrow's citizens and leaders. Sustaining a livable Earth requires that people appreciate the natural world and respect all of its living creatures. Students can and should be stewards of Oakland's natural heritage. Science is a powerful tool used to inform actions aimed at restoring a damaged planet, and a science-based curriculum for educators focused on rainbow trout fosters in students a greater understanding and appreciation for the natural world.

Recommended Actions for Developing an Educational Curriculum on Rainbow Trout:

1. Use rainbow trout ecology and conservation within the Sausal Creek watershed as a case study in alignment with California Next Generation Science Standards (NGSS). FOSC will create a curriculum for educators within the following groupings; grades K-2, 3-5, 6-8, 9-12. The curriculum may include the following components: the history of trout populations in Sausal Creek, trout life-history strategies and tactics, description of suitable trout habitat, current stressors and threats to the trout population, and measures to protect trout. The curriculum will include at least one field trip to Sausal Creek that will feature demonstrations and hands-on activities. Hands-on activities may consist of water quality monitoring, collection and identification of aquatic insects, identification and measurement of riparian vegetation, analysis of physical stream parameters, or measurement of rainbow trout.

Some of the curriculum will be translated into Spanish to ensure maximum participation in schools across Oakland. The curriculum designed by FOSC will be free and publicly available online on the FOSC organization website. The curriculum will accommodate California public school standards; however, all educators will be encouraged to use the resources available.

Objective 2: Provide School Field Trips/Classroom Visits for Schools Within the Watershed in Support of Objective 1

Recommended Actions for Developing a Field Trips/Classroom Focused Program:

1. Use FOSC's full-time education coordinator to lead rainbow trout-focused field trips. Field trips will encourage students from all backgrounds to visit the Sausal Creek watershed (Figure 26). The primary location for field trips will be in Dimond Park and Dimond Canyon - both accessible by public transit. During field trips, students will have the opportunity to observe Sausal Creek and observe trout. Field trips will include instruction on the ecology of trout. They may also involve hands-on restoration activities, water quality testing, riparian vegetation identification and measurement, and benthic macroinvertebrate sampling. FOSC field trips will be available for all school groups. Title 1 school groups will have fees waived to create more outdoor access for underserved communities.

FOSC will also offer classroom visits as an option for educators. Classroom instruction may be alone or in conjunction with field trips. Students will learn about topics such as how to identify rainbow trout, the facets of fish migration and how it applies to local trout populations, and how

water quality conditions affect our local trout population. Students will develop strategies to help protect Sausal Creek trout.



Figure 26. Oakland school students learn about rainbow trout during a field trip to the reach of Sausal Creek in Dimond Park that was daylighted in 2016.

Goal 5: Cultivate Relationships with Local Colleges and Universities and Encourage Faculty and Student Research Projects that Increase our Understanding and Promote the Conservation of Rainbow Trout in Sausal Creek

Objective 1: Identify and Prioritize Research Needs for the Conservation of Rainbow Trout

Rationale for Cultivating Relationships with Institutions of Higher Education: Increasing our understanding of the ecology of rainbow trout will help FOSC prioritize and effectively implement measures outlined in this plan. Environmental challenges to sustaining wild rainbow trout in Sausal Creek are complex, and colleges and universities through basic research are well-suited to develop novel approaches and solutions to address these challenges.

Recommended Actions to Engage Colleges and Universities in Basic Research:

1. Identify, contact, and encourage researchers at local colleges and universities to collaborate on basic research in the Sausal Creek watershed focused on rainbow trout conservation and stream ecology and restoration; and
2. Target grant opportunities aimed at restoring the natural functions of Sausal Creek that offer promising collaborative research opportunities for collaboration colleges and universities.

Goal 6: Provide Sufficient Funding to Protect Rainbow Trout

Objective 1: Raise Funds to Support Implementation of the Sausal Creek Rainbow Trout Conservation and Management Plan

Rationale for Raising Funds to Implement the Rainbow Trout Conservation and Management Plan: Effective implementation of the rainbow trout conservation actions recommended in this plan will require significant financial support from the public and private sectors.

Recommended Actions to Raise Funds for Rainbow Trout Conservation:

1. Target grant opportunities aimed at restoring the natural functions of Sausal Creek, as well as grants funding educational opportunities for schools and the community; and
2. Establish a special fund on its website where individuals and businesses may provide donations in support of the management and implementation of the rainbow trout conservation and management plan. FOSC will describe specific activities that funding will support. Donors will be recognized on the FOSC website and receive either a *Save Sausal Creek Trout* tee-shirt or bumper sticker.

Summary

Sausal Creek's wild rainbow trout are part of the fabric of Oakland's cultural and natural history. These trout demonstrate remarkable resilience as these fish are a precious and rare resource that live entirely within the City of Oakland. Sausal Creek has only limited habitat supporting rainbow trout. Their small and fragmented population is extremely vulnerable to multiple threats and stressors resulting from human activities, past and present. These rare trout cannot persist unless the community appreciates their importance.

This rainbow trout conservation and management plan describes the current environmental conditions of Sausal Creek, profiles the life history and habitat requirements of rainbow trout, and documents the historical and current distribution of rainbow trout. The plan then defines goals, objectives, and rationales for conserving the Sausal Creek ecosystem and the trout population, and recommends actions necessary for decreasing and reversing the harmful effects of human activities, past and present, that continue to imperil the very existence of rainbow trout in Sausal Creek.

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Figure 27. Clockwise from Upper Left. Dimond Canyon. El Centro Avenue culvert. Restored stream channel Dimond Park. Culverted outlet of Sausal Creek into Oakland Estuary. Photos by R. Leidy.