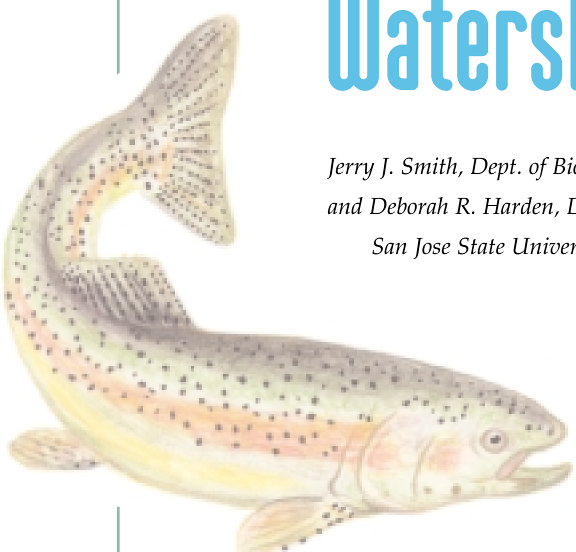
SAN FRANCISQUITO WATERSHED COUNCIL

Adult Steelhead Passage in the Bear Creek Watershed



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This study was supported by a grant from the California Department of Fish & Game.

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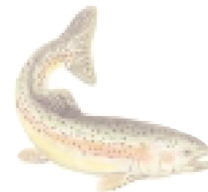
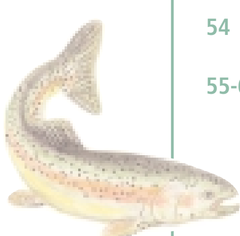
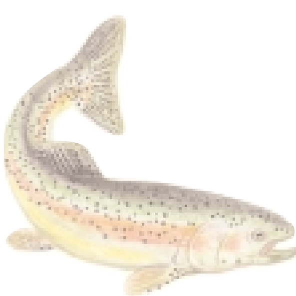






About Us

The San Francisquito Creek Watershed Council is a community-based volunteer organization that was formed in 1993 and is dedicated to coordinated resource management and planning (a CRMP process) among landowners, agencies, and non-profits.

The Watershed Council addresses problems such as flooding, bank stabilization, habitat protection and restoration, access, and pollution prevention. It is an open process that involves the community in (1) monthly Steering Committee meetings among 23 signatory organizations, (2) bi-monthly volunteer workdays, (3) task forces and work groups, and (4) weekly workdays at our native plant nursery. The Watershed Council also seeks grant funding to study important scientific questions relating to the watershed. This study, Adult Steelhead Passage in the Bear Creek Watershed, is an example of how the Watershed Council was able to build a team of experts to address an issue. The Steelhead Task Force is working to implement this report's recommendations. Their mission is to improve watershed conditions and maintain a viable population of native steelhead and rainbow trout.

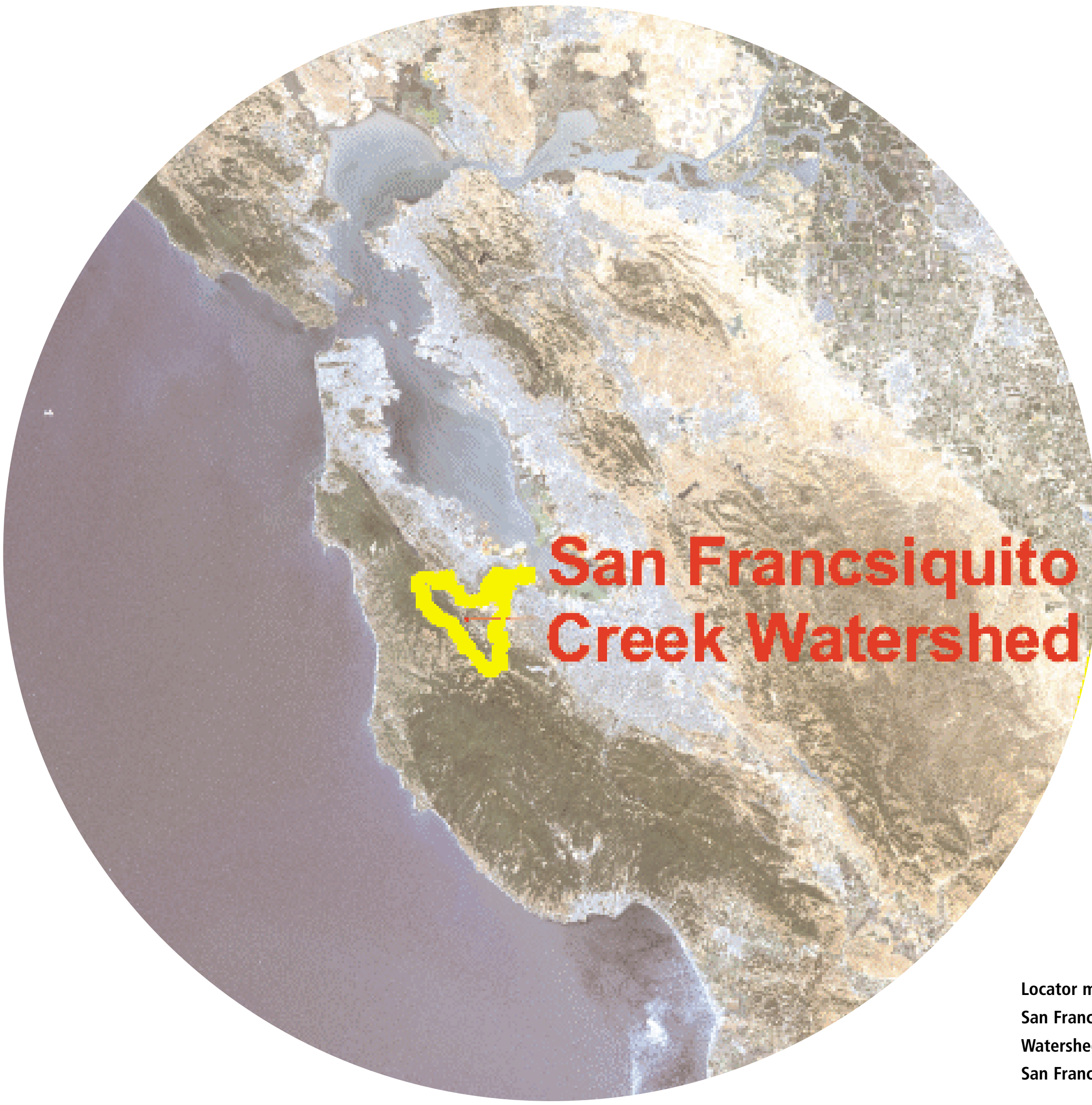
The San Francisquito Watershed, the most inter-jurisdictionally complex in the Bay Area, drains part of two counties (San Mateo and Santa Clara), five cities (Woodside, Portola Valley, Menlo Park, Palo Alto, and East Palo Alto), and most of Stanford University's property. Taking a watershed approach to land use, transportation, and social service decisions is important to maintaining a balance between the natural and human world because they are so closely related. The Watershed Council encourages a comprehensive, regional, and watershed-oriented approach to Creek problem solving. More information can be found at *www.acterra.org/watershed*.

The Watershed Council is a program of Acterra, a Palo Alto non-profit environmental-education and community-action organization that was formed in 2001 by the merging of Bay Area Action + Peninsula Conservation Center Foundation. The mission of Acterra is *"to bring people together to shape sustainable communities and preserve natural resources through education, action and advocacy."*

In addition to its own 18 programs, Acterra currently hosts nine organizations in its environmental center, and has offered "incubator services" to dozens of start-up non-profits over the past 30 years, with 70 successful spin-off organizations to its credit. Through its special blend of community and citizen involvement, Acterra enjoys a significant level of success building and managing coalitions, linking non-profit and for-profit efforts through its board of directors, and the involvement of business, scientific, and community leaders.

Other titles available from the San Francisquito Watershed Council:

- *Draft Watershed Management Plan*
- *Reconnaissance Investigation Report on San Francisquito Creek*
- *Draft Long Term Monitoring and Assessment Plan*
- *Streamside Planting Guide*
- *Guide to Identifying Flora and Fauna in the San Francisquito Creek Watershed*



Locator map for the San Francisquito Creek Watershed within the San Francisco Bay Area.

Executive Summary

Adult Steelhead Passage in the Bear Creek Watershed

Jerry J. Smith, Dept. of Biological Sciences, San Jose State University, San Jose, CA 95192 and
Deborah R. Harden, Dept. of Geology, San Jose State University, San Jose, CA 95192

Background: Steelhead Ecology In the Bear Creek Subbasin of the San Francisquito Creek Watershed, a small population of the species *Oncorhynchus mykiss*, live as steelhead trout. These steelhead are listed as a threatened species under the Endangered Species Act. Migrating between the ocean and the streams, they spawn and spend the first two years of their lives in the freshwater streams of the subbasin such as West Union, Bear, and Bear Gulch Creeks. The steelhead trout spend the adult portion of their lives in the ocean and return briefly to the streams of their youth to spawn. In the Corte Madera Creek subbasin of the watershed, the land-locked version of *Oncorhynchus mykiss*, rainbow trout, live upstream of Searsville Dam.

When steelhead trout have reached about six inches in size, usually by the end of their 2nd spring, they migrate out to the ocean where food is much more abundant and they can grow as adults to 1.5 to 3 feet in length. Rainbow trout seldom reach these sizes, because the food supply in our small streams is much more limited.

If possible, steelhead return to the streams of their birth to spawn. They migrate in for spawning during the high flow portion of the season from January through April. After spawning, steelhead trout return to the ocean within a few weeks.

The young fish called smolt migrate out to the ocean as late in the wet season as they can, taking advantage of the good food sources in the stream in the spring to grow as large as possible before entering the ocean.

Due to the wet and dry season rainfall pattern we have in the Bay Area, our local streams experience huge variations in flow. The rainy season which officially occurs from October to April, supplies water to the streams. San Francisquito Creek usually flows all the way to the Bay from early December to early June. The timing, duration, and quantity of our yearly flow varies with the weather. In wet years we have higher flows and flow is maintained to the Bay for a longer period. In high flow years the steelhead have a better chance to migrate up the stream over any barriers and to migrate out before flows get low. On the other hand, late season storms may destroy eggs laid early.

Barriers to upstream migration are often important factors in steelhead abundance and distribution. Waterfalls, dams, culverts, and logjams may function as barriers for the migrating trout if they are too long or too high for the fish to jump over or have too shallow a pool for the fish to jump from. Some in-stream structures are primarily a barrier to in-migration and some create problems for smolt migrating out to the ocean.

Providing access for adult fish of all sizes probably improves average steelhead abundance and long-term population survivability. In streams where the migrations are long and/or difficult,

spawning by larger, stronger adults tends to be most common. In streams with short or easy migrations many adults return younger and smaller, and potentially return to reproduce numerous times. The later strategy, *reproduce early and often*, is especially useful if reproductive success varies substantially from year to year. Frequent droughts block access and floods may destroy nests of fish eggs. A mixture of adult sizes provides greater population flexibility to meet year-to-year changes in stream conditions.

Purpose of this Study The purpose of this study was to investigate the actual conditions in the stream channel in terms of any structures, manmade or natural, that might serve as a barrier to migrating steelhead trout. During 2000, a fisheries biologist (Professor Jerry Smith) and a geomorphologist (Professor Deborah Harden) hiked up the spawning reaches of the Bear Creek Subbasin to inventory each potential barrier and assess what, if any, modifications would be needed to improve fish passage. Because some structures may serve not as barriers but as habitat enhancing features—for instance a logjam creates hiding places for fish and a dam may create a pool—the San Francisquito Watershed Council hired experts with the knowledge and experience to assess the difference on the spot. After all of the barriers were inventoried, a priority list was established (Table #2) based on the severity of the passage problem, the difficulty of modifying the barrier, and the value of the habitat upstream. Armed with a systematic assessment of barriers in this important spawning area, the Watershed Council planned to apply for additional grant funds from the Department of Fish and Game to make the recommended modifications.

In fact, the modifications required for five of the barriers were so simple that they were carried out by enterprising volunteers and staff in the fall of 2000.

Effects of the San Andreas Fault System on Habitat
The San Andreas Fault bisects the Bear Creek Subbasin, strongly influencing the geology and landscape. The fault controls the overall shape of the watershed, the location of many of the tributary stream channels, and dramatically affects the channels themselves. Long-term fault movement has created many unusual features in the watershed. For instance, the candelabra pattern created by the stream channels has formed as east and west sides of the fault move relative to one another.

The purpose of this study was to investigate the actual conditions in the stream channel in terms of any structures, manmade or natural, that might serve as a barrier to migrating steelhead trout.

In the Bear Creek study area, the San Andreas fault has influenced stream habitats in a number of ways. For instance, the gradient of the channel of West Union Creek is anomalously low, particularly for a mountain stream (Figure A-3). The long reach of relatively flat channel creates high quality steelhead habitat in streams which, without the influence of the fault, might otherwise be too steep, or made impassible because of natural barriers.

Seeps and springs along the fault also supply water for critical fish habitat throughout the long dry season. The crushed rocks along the fault zone create the path of least resistance for stream channels to form. These channels also provide a ready path for ground water to flow to the surface.

The orientation of the stream channels is controlled by the fault. The long, straight, northwest-oriented valleys which contain West Union Creek and lower Bear Creek have formed along the trace of the San Andreas fault and related subsidiary faults (Figure A-1 and A-2). Linear valleys are one of the most common indicators of active faults. One reason for their formation is that rocks along a fault are more sheared and crushed, and thus more easily eroded by streams, than rocks away from the fault. Streams develop preferentially along the path of least resistance.

In some places, the rate of movement along a San Andreas-type fault is so active that stream channels become partly or entirely blocked. When this occurs, ponds or wetlands, like those at Searsville Marsh, may form. In other areas, stream channels may be abandoned because the stream no longer flows across the fault, but rather flows into a new channel. An excellent example of stream abandonment and capture can be found along Bear Creek near Manzanita Way (Figure A-4).

The long reach of relatively flat channel creates high quality steelhead habitat in streams which, without the influence of the [San Andreas] fault, might otherwise be too steep, or made impassible because of natural barriers.

In addition to the fault zone, another geologic factor of importance to the local steelhead trout is the Whiskey Hill Formation (labeled *Tw* on Figure A-2). This formation underlies a large portion of the Bear Gulch and West Union watersheds. Most of this unit is sandstone, which weathers to produce cobble-sized gravels which are ideal for steelhead spawning.

Barriers to Steelhead Passage Thirty four barriers were identified within the five tributaries, West Union Creek, Bear Creek, Bear Gulch, Squealer Gulch, and McGarvey Gulch. Several of the barriers (Table 1) to steelhead passage in the watershed will prevent access under any conditions, but the difficulty of fish passage varies with the magnitude of winter flows as they affect depth, velocity, and jumping distance. In wet years, suitable passage throughout most of the watershed probably occurs much of the winter because of numerous storms and relatively high stream flows between storms. In dry years, suitable passage conditions may rarely occur, with the cumulative effect of multiple barriers blocking many fish from accessing headwater spawning areas.

The barriers found were divided into the five categories of Dams and Weirs, Bridge Aprons and Culverts, Falls, Logjams, and Fences. In the main body of the report each of these categories is described in detail with references to each of the barriers observed.

Dams and Weirs The Bear Gulch Water Supply Dam (barrier #15) is owned by the California Water Service and is the only dam in the watershed used for drinking water supply. Eight other dams or low weirs are present. Most apparently served as bases for seasonal flashboard dams or as sites of summer pumping; none presently have flashboards or diversion pumps. Several of the larger dams presently act as channel grade control structures, and significant channel downcutting would occur upstream if they were completely removed.

Bridge Aprons and Culverts Some of the bridges in the watershed openly span the stream channel, but at other locations concrete aprons or culverts are present under the bridge. Downcutting of the channel downstream of aprons and culverts often produces drops that impede fish passage. The major problem for most culverts and aprons in the watershed is that they spread the flow across the entire width of the channel. This creates shallow depths at low flows and high velocities at higher flows. These problems are particularly acute if the culvert is steeply inclined. There are five bridge aprons or culverts that present significant passage problems in the Bear Creek Subbasin.

Falls Sandstone outcrops produce a steep series of boulder falls on Bear Gulch, Squealer Gulch, and McGarvey Gulch. Extended boulder channels are velocity barriers during high flows and lack adequate jump pools to surmount some steps during lower flows. The boulder configurations periodically change due to severe storms and landslides. The other significant falls in the watershed are unexpectedly in the extremely low gradient (San Andreas Fault zone) upper portion of West Union Creek. This series of falls probably represents a nick point formed during the 1906 earthquake, stabilized by a series of redwood root wads.

Logjams In flat, wide channels logjams rarely become significant fish barriers. The accompanying sandy substrates usually allow erosion of passageways under the jams, and the stream can also usually cut around the jam. In addition, these partial jams usually provide extremely valuable storm flow refuges for overwintering steelhead and can be used by California red-legged frogs as foraging and breeding habitat. The logjams that impede fish passage have been modified; the rest represent very important habitat features, rather than threats to fish passage.

In narrow, entrenched channels the logs can become fully anchored against the stable banks and plug with coarse gravel and cobble, especially in steeper channels. The step produced can be a significant barrier to steelhead passage.

Fences Deer fences can also represent a potential barrier and hazard for steelhead. If the fences are left in during early winter or reinstalled in early spring, adult steelhead could be gilled and killed or injured unless the mesh is large enough to eliminate the threat. Removal of the fence from January through April would also eliminate the problem.

Quality of Available Habitat Within the Watershed
Shading, summer water temperatures and steelhead spawning habitat were good throughout the surveyed portions of the watershed. The upper portions of the watershed are protected in parks or California Water Service lands, and the streambed was clean. However, during 2000, stream flows throughout the watershed were relatively low in late June, and were extremely low during hot weather in September. Most of the channels of West Union Creek and Bear Gulch downstream of Highway 84 lacked surface flow in riffles during the afternoons in September.

With increased development downstream the amount of sediment also increased, but riffles were relatively clean even in the lower portion of the surveyed habitat. General descriptions by reach are included in the report.

Priorities for Barrier Modification or Removal

The highest priority for near-term barrier modification should go where substantial improvements can be provided to large tracts of spawning and rearing habitat with minimal effort or cost. With other factors being equal, the following rules were used to determine priority:

A) severe barriers should be given priority over those that impede passage only at low flows;

B) barriers with substantial or good quality habitat upstream should be given priority over those with a limited amount or lessor quality of habitat upstream; and

C) barriers that can easily or cheaply be modified should be given priority over those that require major cost or effort.

Using these criteria eight of the barriers rated potentially high priority for immediate action (Table 2). In addition, the potentially expensive modification of the Bear Gulch water supply dam (barrier # 15) should be further evaluated because of the high quality of the habitat above the dam.

Five of the high priority sites are in the lowest portion of the watershed, on Bear Creek. One dam (barrier #3) should be modified because it is a severe barrier except during floods. The other dam (barrier #1) and the weir (barrier #4) can be modified with a very limited effort to provide for improved lowflow passage. A logjam (barrier #2) has already been eliminated with very little effort. The other priority barrier (#10) on Bear Creek is the paired bridge culverts at Fox Hollow Road, which are probably an important barrier in drier years. Other high priority sites were two logjams on Bear Gulch (barrier #s 12 and 13), which have already been modified, and the fence across lower West Union Creek. The fence (barrier # 18) can be easily modified after discussions with the landowner.

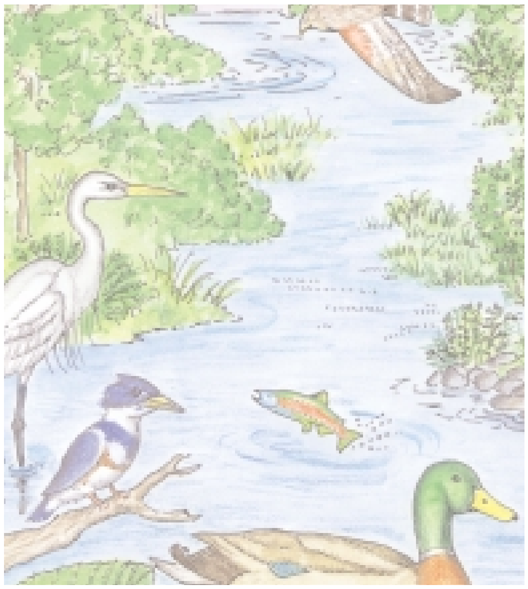
Moderate priority was given to five barriers. The Highway 84 bridge apron on West Union Creek (barrier # 17) can be relatively easily modified to improve low flow passage. The dam on West Union Creek upstream of Kings Mountain Road (barrier # 19) can be slightly lowered to improve passage for smaller adult steelhead. The culvert apron on lower McGarvey Gulch (barrier # 28) can be modified to improve access to the culvert at low flows. The two log/debris jams on Squealer Gulch (barrier #s 24 and 25) have already been removed by county park personnel, providing access to a small amount of additional habitat.

On Bear Gulch, the Highway 84 culvert (barrier #14) was rated low priority. This was because little improved access would be provided by modifying the culvert unless the dam 0.1 miles upstream (Barrier # 15) is modified. Modifying the dam with a fish ladder would be very expensive in order to provide access to less than 0.6 miles of high quality habitat downstream of the natural falls (barrier # 16). However, other alternatives, including lowering the dam in a manner that maintains or improves diversion operations, should be evaluated in consultation with California Water Service. The projects also might be appropriate if a significant source of funding, for example from fines or offsite mitigation requirements, became available.

Table 1. Types, severity (0-5) and recommended actions for potential barriers to adult steelhead migration in the Bear Creek watershed.

STREAM AND BARRIER #	BARRIER TYPE	SEVERITY	RECOMMENDED ACTION
Bear Creek			
1	Dam	2+	cut shallow notch to move attraction flows
2	Logjam	2	cut main log to open jam
3	Dam	4+	lower dam 2-2.5 feet to allow jump; remove concrete block at dam base
4	Weir	1+	cut shallow notch to move attraction flows
5	Weir	1	none necessary
6	Pipe	1	none necessary—passable in winter
7	Logjam	0	none—important habitat feature
8	Logjam	0	none—important habitat feature
9	Weir	0	notch to create better summer pool
10	Bridge apron	3+	install baffles to increase depth and reduce velocity
Bear Gulch			
11	Logjam	0	none—habitat feature
12	Logjam	2+	cut upper log to prevent more severe jam
13	Logjam	3-4+	cut and remove portions of the jam
14	Bridge drop	2-3+	none—installation of baffles & culvert would improve access to only 0.1 mile of accessible habitat
15	Dam	5	evaluate modification options with owner
16	Falls	4+-5	none—47 feet of natural drops
West Union Creek			
17	Bridge apron	2-3	install baffles to increase depth and reduce velocity; move boulders from below drop
18	Fence	1-4	remove in winter or replace with larger mesh (4-6")
19	Dam	2+	lower slightly
20	Logjam	0	none—no threat and important habitat feature
21	Logjam	0	none—no threat and important habitat feature
22	Weir	1+	notch to improve summer habitat
26	Weir	1+	notch to improve summer habitat
33	Logjam	2+	none—valuable habitat feature
34	Falls	5	none—natural feature; removal would destabilize channel upstream
Squealer Gulch			
23	Bridge apron	1-2	apron baffles probably not needed
24	Logjam	4+	start of steep section—remove to provide some additional access
25	Debris jam	4+	steep section, little gain—modify to provide some additional access
McGarvey Gulch			
27	Boulder falls	1-2	none—passable in winter
28	Bridge apron	2+	baffle apron and part of culvert & culvert
29	Logjam	4-5	none—beginning of steep section, little habitat access gain
30	Logjam	4-5	none—steep section
31	Falls	5	none—extensive natural series of drops
32	Culvert	5	none—upstream of impassable falls

Background: Steelhead Ecology

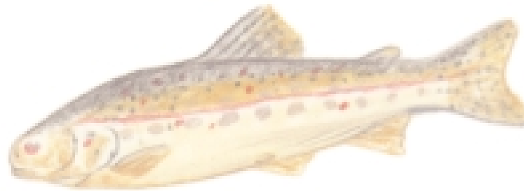


Rainbow trout *(Oncorhynchus mykiss)* occur as both resident fish and as "steelhead," which migrate to and from the ocean (anadromous). Where access to the ocean is available the faster growth and larger potential size (and egg production) at reproduction provided by the ocean usually result in steelhead dominating in the population. Above barriers that regularly block upstream migration, fish that migrate downstream remove most of that tendency from the population that remains above the barrier.

Adult steelhead return to their rearing stream after spending 1 to 2 or more years in the ocean at lengths of 15 to 30 inches. Waterfalls and other barriers to upstream migration are often important factors in steelhead distribution and abundance. In streams where the migrations are long and/or difficult, larger, stronger adults tend to be most common. In streams with short or easy migrations many adults return younger and smaller, but potentially return to reproduce numerous times. The later strategy (*"reproduce early and often"*) is especially useful if reproductive success varies substantially from year to year because of frequent droughts (which block access) or floods (which may destroy nests). A mixture of adult sizes provides greater population flexibility to meet year-to-year changes in stream conditions. Therefore, providing access for adult fish of all sizes probably improves average steelhead abundance and long-term population survivability.

Steelhead spawn (reproduce) by constructing nests in relatively clean gravels, usually at the tail of a pool. Where the stream bed is sandy or contains fine silts, the nests are more likely to be washed away by later storms or have the eggs smothered by fine sediments that block water and oxygen flow through the nest. Adult steelhead migration and spawning takes place from January through early April. Early spawning fish have the advantage that their young emerge earlier and can grow bigger during their first year in the stream. Later spawning fish are less likely to have their nests destroyed by winter storms. Most steelhead populations contain an adaptive mixture of migration and spawning times. Therefore, providing adult access throughout the winter improves average steelhead abundance and long-term population survivability.

Juvenile steelhead usually spend 1 to 2 years in fresh water. Where stream flows are strong all summer, and insects as food are abundant, steelhead may get large enough to enter to ocean after only one year. In central California streams, such habitats are mostly downstream of reservoirs (such as Stevens Creek), where augmented summer flows for streambed percolation provide the fast-water feeding lanes needed for rapid steelhead growth. In most central California streams summer stream flows are very low and juvenile steelhead grow little in mid to late summer. They therefore usually require two years to reach a size sufficient to migrate to the ocean. Heavy stream shading keeps the water cooler (reducing food demands), but also restricts algal growth, as a base of the food chain, ultimately reducing insects as food for juvenile steelhead. In addition, in very shady habitats fish have difficulty seeing and capturing floating or drifting insects. In slightly sunnier habitats (70-80% shade) juvenile steelhead are often more abundant and grow faster, if water temperatures are not too high (above 70 degrees). Silt and sand in the streambed provide unstable habitats and fill crevices in the gravels and cobbles, reducing insect and steelhead abundance and reducing steelhead growth.



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Escape or hiding cover, provided by undercut banks, fallen trees, boulders and overhanging vegetation, is also an important part of year-round rearing habitat for juvenile steelhead, especially for the larger yearling fish. Most artificial bank protection, including concrete walls, sackcrete (stacked bags of concrete) and gabions (rock-filled wire baskets), provides no protective hiding places. Riprap (boulders placed as bank protection) can often produce escape cover if large boulders (2-foot+ diameter) are placed in the streambed at the toe of the slope. However, smaller riprap rarely produces the large pockets and crevices that can be used by steelhead as escape cover.

Since juvenile steelhead must spend 1 or 2 winters in the stream, overwintering habitat that protects them from winter storms is very important. If juvenile steelhead cannot overwinter for 1 or 2 years they may never reach sizes sufficient for ocean survival. Therefore, the abundance of larger, yearling steelhead in most streams is a good index to the quality of yearlong habitat. Deep and/or complex pools provide overwintering habitat, by supplying undercut banks, woody backwaters, calm eddies or other refuges from storm flows. Large logjams may provide calm eddies and pockets even during extreme floods, and may be critically valuable habitat features in wet years. Logjams should be evaluated for their benefits, as well as their potential impacts as barriers to migration, before modification or removal.

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Most adult steelhead return to the ocean quickly after spawning in winter, but juvenile steelhead begin their physiological changes in preparation for entering the ocean (smolting) and migrate to the ocean in late March though May. This late migration allows them to feed and grow for a longer period during the most productive time of the year, increasing their size and potential ocean survival. However, April and May are also a time of rapidly declining streamflows, making downstream passage over shallow riffles or seasonally drying stream reaches very risky. Larger steelhead juveniles require less additional spring growth and tend to migrate earlier, demonstrating the strong interaction between smolt migration success and food abundance in the rearing habitat. For many drier and/or urbanized central coast streams the outmigration period in spring is the major bottleneck to maintaining abundant and persistent steelhead populations. Adult access and spawning and good rearing habitat are insufficient for steelhead success if smolt migrations are blocked in most years. For example, upper Saratoga Creek has a thriving resident rainbow trout population, but no steelhead, because the extensive lower reaches of the stream are usually dry during late spring when smolts would attempt their migration.

Barriers to Steelhead Passage

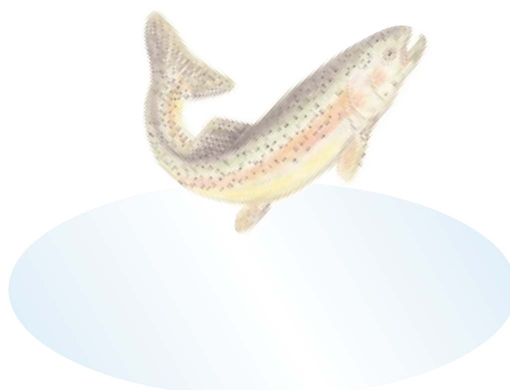
Several of the barriers (Table 1) to steelhead passage in the watershed will prevent access under any conditions, but the difficulty of most of the barriers will vary with winter flows as they affect depth, velocity, and jumping distance. In wet years suitable passage throughout most of the watershed probably occurs much of the winter, because of numerous storms and relatively high stream flows between storms. In dry years suitable passage conditions may rarely occur, and the cumulative effect of multiple barriers may block many fish from access to headwater spawning areas.

Dams and Weirs

The California Water Service dam on Bear Gulch (barrier # 15) is the only actively used water supply dam, but eight other dams or low weirs are present. Most apparently served as bases for seasonal flashboard dams or as sites of summer pumping; none presently have flashboards or diversion pumps. Several of the larger dams (barriers # 1, 3, 15, 19) presently act as channel grade control structures, and significant channel downcutting would occur upstream if they were completely removed.

Where passage is completely blocked by a dam (the Bear Gulch water supply dam, barrier #15), a fish ladder could be installed to provide fish passage. Narrow, steep ladders are cheaper, but are prone to clogging with debris and function well over a relatively narrow range of flows. Wider, flatter ladders are less likely to clog and function over a wider range of flows, but are much more expensive. To provide passage over the 10-foot high Bear Gulch dam, a ladder would probably have to be about 30-40 feet long (3 or 4 to 1 slope). A problem with most long ladders is the difficulty in attracting fish to the base of the ladder when it is so far separated from the dam and from most of the winter flow.

For smaller dams and weirs, steelhead passage difficulty is affected by the height of the dam compared to the depth and hydraulic complexity of the jump pool below the dam. Large adult steelhead can usually handle a jump if the depth of the pool below is 1.25 times the height of the jump (i.e.- a 4-foot jump from a 5-foot deep pool) and if the jump pool is large and lacks complex turbulence or obstructions. Smaller adults require relatively deeper jump pools (1.5+ times the jump). The pattern of spilling over the dam is also important, because it may attract fish to jump at locations where the jump pool is shallower or where hydraulics or obstructions interfere with the jump. In those situations fish waste time and effort on multiple jump attempts, until they finally locate the most advantageous jump location. The channel configuration downstream of the dam can affect



Large adult steelhead can usually handle a jump if the depth of the pool below is 1.25 times the height of the jump. Smaller adults require relatively deeper jump pools (1.5+ times the jump).

the relative depth of the pool and height of the jump; constricted channels downstream backflood the jump pool at high flows, reducing the required jump.

Three dams on Bear Creek immediately upstream of Sand Hill Road (barrier #s 1,3,4) illustrate how the factors described above affect fish passage. The lower two dams require substantial jumps (4.6 and 4.2 feet) to clear, but the pool below the higher dam (barrier # 1) is 6.5-feet deep. It provides for relatively easy (and spectacular) jumping for large adult steelhead, and can probably be passed by most small adults. However, at low stream flow the dam spills to a portion of the pool where a rock shelf only two feet deep would interfere with jumping. Cutting a shallow notch (0.3-feet deep) in the dam 5 feet closer to the east bank would attract jumping fish to the deepest portion of the pool and increase jump success. In contrast, the second dam (barrier # 3), although 0.4 feet shorter, has a shallow (1.5-2.0-feet deep) bedrock pool downstream. In addition, a large block of concrete downstream of the dam further interfered with jumping, until its removal in October 2000. This is the most difficult passable barrier in the watershed and provides potential adult steelhead passage only during flood flows. Removing at least 2 to 2.5 feet from the height of the dam would be necessary to provide for regular steelhead passage. The third dam (barrier # 4) is only 0.9-1.0-feet high, but at low flow most of the spilling is to the 1-foot deep portion of the downstream pool. A limited effort to deepen the notch near the west bank would attract fish to the 2.3-foot deep portion of the pool and provide for easy passage at regular winter flows. A 3.9-foot high dam on West Union Creek immediately upstream of Kings Mountain Road (barrier # 19) has a large jump pool 5.3 feet deep, and probably provides suitable winter passage for large steelhead even without modification. Lowering it somewhat (0.5-1.0 feet) would improve passage for smaller fish.

Fish traversing the shallow flows lose buoyancy and drag the bottom because much of their body is out of water. At the same time, they lose much of their swimming strength since most of their tail is also out of water.

Other smaller weirs do not present significant winter passage problems, but notching several of them (barrier #s 9,22,26) might concentrate scouring flow and improve the depth, complexity and summer rearing quality of the pool immediately downstream.

Bridge Aprons and Culverts

Some of the bridges in the watershed openly span the stream channel, but at other locations concrete aprons or culverts are present under the bridge. Downcutting of the channel downstream of aprons and culverts often produces drops similar to those discussed for dams and weirs. Riprap boulders placed at the base of the apron may reduce downcutting, but can also interfere with jumping from the pool below. However, the major problem for most culverts and aprons in the watershed is that they spread the flow across the width of the channel, and have shallow depths at low flows and high velocities at higher flows. These problems are particularly acute if the culvert is steeply inclined. Fish traversing the shallow flows lose buoyancy and drag the bottom because much of their body is out of water. At the same time, they lose much of their swimming strength since most of their tail is also out of water.

Baffles (numerous alternating partial weirs) can be used to increase depth and reduce velocities across aprons and through culverts. Multiple step aprons are particularly difficult for passage, as fish can not surmount even small (half foot) steps from a flat apron.

Five bridge aprons or culverts present significant passage problems in the Bear Creek watershed. The Highway 84 crossing of Bear Gulch (barrier # 14) requires fish to make a relatively easy 2.3-foot jump from a 3.5-foot deep pool, but then to negotiate almost 75 feet of culvert and concrete-bottomed channel. Access under present conditions is possible under moderate flow conditions (30-100 cfs), but is probably very difficult at lower flows because of shallow depth. At higher flows high velocities are probably a problem. Baffles would improve passage, especially at low flows, but less than 0.1 mile of accessible habitat is present between the culvert and the impassable California Water Service dam. The Fox Hollow bridge over Bear Creek (barrier # 10) requires a 2.3-foot jump from a pool 2.9-feet deep. However, again the biggest challenge is negotiating the twin box culverts that are each 10-feet wide and 30-feet long. Installing an upstream curb on one culvert and baffling the other would concentrate low flows down a deeper and slower pathway, and greatly improve dry year access to most of the watershed. At the Highway 84 crossing of West Union Creek (barrier # 17) the apron is beveled, with low flows concentrated down the center; baffles here would also improve low flow passage. In addition, the apron is 1.3 feet above the pool surface downstream, and riprap boulders at the base restrict the pool depth to 0.8-feet deep below the apron; movement of several boulders would improve the jump. A 4-foot diameter culvert on lower McGarvey Gulch (barrier # 28) is perched 0.7 feet above the flow dissipation apron downstream, and the apron is 0.8 feet above the shallow pool below. The two-step 1.5-foot drop is sufficient to block steelhead passage at lower flows. Removing the apron or placing a 0.5-foot high curb around most of it would allow easier low flow passage. The Greer Road crossing of Squealer Gulch (barrier # 23) has a narrow 25-foot long apron that is probably passable without baffles at times when winter flows are sufficient to allow passage over the numerous cobble riffles in that entrenched stream.

Impassable culverts are present on the upper portions of both Squealer and McGarvey gulches. On McGarvey Gulch the culvert under a park road (barrier # 32) is perched above an 18-foot slope of talus. On Squealer Gulch the culvert under Kings Mountain Road has an impassable drop at the upstream entrance to the culvert. However, in both streams impassable falls are present downstream of the culverts.

Falls

Sandstone outcrops produce a steep series of boulder falls on Bear Gulch (Barrier # 16), Squealer Gulch (upstream of barrier # 25), and McGarvey Gulch (barrier # 31). Such extended boulder channels are velocity barriers during high flows and lack adequate jump pools to surmount some steps during lower flows. The boulder configurations are likely to periodically change due to severe storms and upslope landslides. On Bear Gulch the stream drops 47 feet through 4 major steps with 3 individual drops greater than 5 feet. Under ideal flow conditions an occasional fish might be able to negotiate the barrier, and trout are present above the barrier. However, significant steelhead access would not be possible with the present boulder configuration, and continuous modification efforts are not practical. The falls on Squealer Gulch are less severe, but those on McGarvey Gulch are completely impassable. Additionally, McGarvey Gulch has logjams at steep, narrow, downstream locations.

The other significant falls in the watershed is unexpectedly in the extremely low gradient (San Andreas Fault zone) upper portion of West Union Creek (barrier # 34). At low flows the falls is an 11-foot drop over redwood roots to a 4-foot deep pool. At higher flows the creek also spills over an adjacent drop 10-feet high. The channel downstream of the two amphitheaters immediately below the falls is quite narrow. Therefore, during floods the water may back up and reduce the height of the jump, but probably not enough to provide for steelhead passage. No fish have been seen immediately upstream of the falls, and most of the stream and a major tributary go dry in late summer in the flatter portions of their channels. Excavation to remove this spectacular natural falls would produce extreme channel headcutting in the 0.4 miles of flat habitat upstream.

Logjams

In flat, wide channels logjams rarely become significant fish barriers. The accompanying sandy substrates usually allow erosion of passageways under the jams, and the stream can also usually cut around the jam. In addition, these partial jams usually provide extremely valuable storm flow refuges for overwintering steelhead and can be used by California red-legged frogs as foraging and breeding habitat. Barrier #s 7,8,11,20,21, and 33 represent very important habitat features, rather than threats to fish passage.

These partial jams usually provide extremely valuable storm flow refuges for overwintering steelhead and can be used by California red-legged frogs as foraging and breeding habitat.

In narrow, entrenched channels the logs can become fully anchored against the stable banks and plug with coarse gravel and cobble, especially in steeper channels. The step produced can be a significant barrier to steelhead passage. On Bear Gulch downstream of Highway 84 two logjams (barrier #s 12 and 13) formed at narrow, entrenched portions of the channel. The upper logjam (barrier #13) was over 6-feet high and appeared to be a severe barrier to fish passage; 6 logs were cut and smaller debris was moved to open the jam. The lower logjam (#12) was not a substantial barrier, but could have become one because two logs were wedged in a narrow portion of the channel. Cutting the upper log eliminated the problem. Substantial logjams block fish passage in the steeper portions of Squealer and McGarvey Gulches (barrier #s 24,25,29,30). However, on both streams the jams were not far downstream of boulder falls, so only a small amount of additional access would be achieved by their removal. On Squealer Gulch removal was potentially very easy, and both jams were removed in October 2000. Two logjams are also present 1/3 mile upstream of the boulder falls on upper Bear Gulch.

Fences

A fence on West Union Creek upstream of Highway 84 (barrier # 18) represents a potential barrier/hazard for steelhead. If the fence is left in during early winter or reinstalled in early spring, adult steelhead could be caught ("gilled") and killed or injured in the 2 x 4-inch mesh. Replacement of the fence with a larger mesh (4 x 6 or 6 x 6-inch) would eliminate much of the threat. Removal of the fence from January through April would eliminate the problem. Two swinging, large-meshed gates in the same stream reach are not problems.

Quality of Available Habitat Within the Watershed

Shading, summer water temperatures and steelhead spawning habitat were good throughout the surveyed portions of the watershed. The upper portions of the watershed are protected in parks or California Water Service lands, and the streambed was clean. However, stream flows throughout the watershed were relatively low in late June, and were extremely low during hot weather in September. Most of the channels of West Union Creek and Bear Gulch downstream of Highway 84 lacked surface flow in riffles during the afternoon in September. With increased development downstream the amount of sediment also increased, but riffles were relatively clean even in the lower portion of the surveyed habitat. General descriptions by reach follow.

In most central California streams summer stream flows are very low and juvenile steelhead grow little in mid to late summer.

Bear Creek from Sand Hill Road Upstream to Mountain Home Road

Riffles made up less than 5 percent of habitat in the reach, and pools formed at bends and by alder roots were generally relatively shallow in the upper portion of the reach. In the lower portion of the reach, bedrock outcrops produced deeper pools. Most of the channel is entrenched, but the banks are relatively stable; some bank protection (walls and riprap) is present. Near the bottom of the reach long silty-bottomed pools were present, several due to concrete dams (barrier #s 1 and 3). Because deep, complex pools were relatively rare, overwintering habitat for steelhead may be a problem. Most steelhead seen were young-of-the-year (YOY). California roach and Sacramento sucker were also present, especially downstream where large pools are more common. Flows were low (0.05-0.1 cfs) in September, but surface flow was continuous throughout the reach.

Bear Creek from Mountain Home Road Upstream to Bear Gulch Confluence

Pools were less common than downstream and were mostly located at bends in the channel. Sandy and silty substrate was more common than downstream. Bank protection (riprap, gabions, concrete cribbing) was frequent in the upper portion of the reach. Most steelhead were probably YOY. California roach and Sacramento sucker were present upstream to the Fox Hollow Road bridge, but were not seen upstream within the watershed. In September surface flow was low (<0.05 cfs), but continuous, except at the upstream end of the reach where riffles had no surface flow.

Bear Gulch from Mouth Upstream to California Water Service Dam

Much of the channel was deeply entrenched and steeper than Bear Creek. Cobbles and coarse gravel were abundant. Low stream flow was present in the upper and lower portion of the reach, but absent from just upstream of Why Worry Way downstream for more than 1/4 mile in late June. Immediately up and downstream of the dry zone the pools lacked fish, indicating that most surface flow may have ceased in a larger zone earlier in the summer. Even where flow was present juvenile steelhead were generally scarce, except in and upstream of the pool immediately downstream of Highway 84. In September in the afternoon there was only barely detectable flow beneath the rocks at the mouth of the stream; continuous surface flow was apparently present upstream of Highway 84.

Bear Gulch Upstream of the California Water Service Dam

Upstream of the diversion dam stream flows were higher than in other reaches within the watershed in late June, and the channel was in excellent condition. Step pools were common in the steep, boulder channel for 0.6 mile up to the generally impassable series of falls (barrier # 16). Step pools were common for about 0.2 miles upstream of the falls, than the channel actually became less steep. Resident rainbow trout are present above the falls.

West Union Creek from Bear Gulch Upstream to Kings Mountain Road

Good pools associated with alder roots were relatively common in this reach. Although silt was common in the larger pools, yearling steelhead were apparently more common than elsewhere in the watershed. The channel is less entrenched than up or downstream, but bank protection is relatively common. In September, riffles and runs in much of the channel had no late afternoon surface flow at both ends of the reach.

West Union Creek from Kings Mountain Road Upstream to Greer Road

Stream substrate conditions were better than downstream, good pools were relatively common, and juvenile steelhead, primarily YOY, were abundant. Channel banks were generally more natural than downstream, with the exception of one site of extensive riprap near the upstream portion of the reach. The canopy was frequently more open near the bottom of the reach. In September there were no surface flows through some riffles and runs at both ends of the reach. Past accounts indicate that this reach is subject to very low or intermittent flows in late summer.

West Union Creek from Greer Road Upstream to 0.1 Mile above McGarvey Gulch

The natural channel was densely shaded by evergreens (redwoods and California bays) in the upper half, but the proportion of alders and willows increased downstream. The upper portion was steeper, and pools were primarily associated with boulders and bends. Downstream the pools tended to be deeper, had finer substrate, and were associated with alder and willow roots. Steelhead appeared to be more common downstream, where shading was somewhat less and insects were probably more abundant. Portions of the channel lacked surface flow in September.

West Union Creek from 0.1 Miles Upstream of McGarvey Gulch to Barrier # 34

This portion of channel has been "stretched" within the San Andreas Fault zone and had some of the flattest habitat in the watershed. Pools were frequent, deep, and silty-bottomed. Woody debris and deeply undercut banks provided abundant escape cover. YOY steelhead were relatively uncommon, probably because the dense evergreen shading and silty substrate suppress insect abundance. Larger fish were common in the complex pools, and California red-legged frogs were seen near several of the debris jams. A small west-bank tributary midway in the reach is steep and goes dry in late summer. Stream flows in late summer are very low in the reach, and most of the flatter portions of West Union Creek and a major tributary upstream of barrier #34 go dry in summer.

Squealer Gulch

This tributary was generally steep and very deeply entrenched. It provides about 0.35 miles of predominantly shallow habitat, suitable for YOY steelhead. Substrate is cobble and small boulders. Stream flow was relatively low in late June, but still retained continuous surface flow in September.

McGarvey Gulch

At its mouth the channel of McGarvey Gulch is as large and carried as much water as West Union Creek. This tributary provides about 0.4 miles of habitat similar to West Union Creek. Logjams and falls block the steeper upstream portion, but surface flows there were relatively low, even in June. Fish were absent or scarce for about 0.1 miles downstream of the barriers.

Priorities for Barrier Modification or Removal

The highest priority for near-term barrier modification using restoration funds should go where substantial improvements in access can be provided to large tracts of potential spawning and rearing habitat with minimal effort or cost. With other factors being equal the following rules were used to determine priority: A) severe barriers should be given priority over those that operate only at low flows; B) barriers with substantial or good quality habitat upstream should be given priority over those with a limited amount or lessor quality of habitat upstream; and C) barriers that can easily or cheaply be modified should be given priority over those that require major cost or effort. Using these criteria eight of the barriers rated potentially high immediate priority (Table 2). In addition, the potentially expensive modification of the Bear Gulch water supply dam (barrier # 15) should be further evaluated because of the high quality of the habitat above the dam.

Five of the high priority sites are in the lowest portion of the watershed, on Bear Creek. Two dams and 1 weir should be modified. One dam (barrier #3) should be modified because it is a severe barrier except during floods. The other dam (barrier #1) and the weir (barrier #4) can be modified with a very limited effort to provide for improved lowflow passage. A logjam (barrier #2) has already been eliminated with very little effort. The other priority barrier (#10) on Bear Creek is the paired bridge culverts at Fox Hollow Road, which are probably an important barrier in drier years. Other high priority sites were two logjams on Bear Gulch (barrier #s 12 and 13), which have already been modified, and the fence across lower West Union Creek. The fence (barrier # 18) can be easily modified after discussions with the landowner; it should be modified before winter 2000-2001, if possible.

Moderate priority was given to 5 barriers. The Highway 84 bridge apron on West Union Creek (barrier # 17) can be relatively easily modified to improve low flow passage. The dam on West Union Creek upstream of Kings Mountain Road (barrier # 19) can be slightly lowered to improve passage for smaller adult steelhead. The culvert apron on lower McGarvey Gulch (barrier # 28) can be modified to improve access to the culvert at low flows. The two log/debris jams on Squealer Gulch (barrier #s 24 and 25) have already been removed by county park personnel, providing access to a small amount of additional habitat.

On Bear Gulch, the Highway 84 culvert (barrier #14) was rated low priority. This was because little improved access would be provided by modifying the culvert unless the dam 0.1 miles upstream (Barrier # 15) is modified. Modifying the dam with a fish ladder would be very expensive in order to provide access to less than 0.6 miles of high quality habitat downstream of the natural falls (barrier # 16). However, other alternatives, including lowering the dam in a manner that maintains or improves diversion operations, should be evaluated in consultation with California Water Service. The projects also might be appropriate if a significant source of funding from fines or offsite mitigation requirements became available.

Table 1. Types, severity (0-5) and recommended actions for potential barriers to adult steelhead migration in the Bear Creek watershed.

STREAM AND BARRIER #	BARRIER TYPE	SEVERITY	RECOMMENDED ACTION
Bear Creek			
1	Dam	2+	cut shallow notch to move attraction flows
2	Logjam	2	cut main log to open jam
3	Dam	4+	lower dam 2-2.5 feet to allow jump; remove concrete block at dam base
4	Weir	1+	cut shallow notch to move attraction flows
5	Weir	1	none necessary
6	Pipe	1	none necessary—passable in winter
7	Logjam	0	none—important habitat feature
8	Logjam	0	none—important habitat feature
9	Weir	0	notch to create better summer pool
10	Bridge apron	3+	install baffles to increase depth and reduce velocity
Bear Gulch			
11	Logjam	0	none—habitat feature
12	Logjam	2+	cut upper log to prevent more severe jam
13	Logjam	3-4+	cut and remove portions of the jam
14	Bridge drop	2-3+	none—installation of baffles & culvert would improve access to only 0.1 mile of accessible habitat
15	Dam	5	evaluate modification options with owner
16	Falls	4+-5	none—47 feet of natural drops
West Union Creek			
17	Bridge apron	2-3	install baffles to increase depth and reduce velocity; move boulders from below drop
18	Fence	1-4	remove in winter or replace with larger mesh (4-6")
19	Dam	2+	lower slightly
20	Logjam	0	none—no threat and important habitat feature
21	Logjam	0	none—no threat and important habitat feature
22	Weir	1+	notch to improve summer habitat
26	Weir	1+	notch to improve summer habitat
33	Logjam	2+	none—valuable habitat feature
34	Falls	5	none—natural feature; removal would destabilize channel upstream
Squealer Gulch			
23	Bridge apron	1-2	apron baffles probably not needed
24	Logjam	4+	start of steep section—remove to provide some additional access
25	Debris jam	4+	steep section, little gain—modify to provide some additional access
McGarvey Gulch			
27	Boulder falls	1-2	none—passable in winter
28	Bridge apron	2+	baffle apron and part of culvert & culvert
29	Logjam	4-5	none—beginning of steep section, little habitat access gain
30	Logjam	4-5	none—steep section
31	Falls	5	none—extensive natural series of drops
32	Culvert	5	none—upstream of impassable falls

Table 2. Potential benefit of barrier modification or removal (1-5), effort/cost required to modify or remove (1-5), and priority for near-term modification/removal (High, medium, low) for barriers within the Bear Creek watershed. Barriers with no significant benefits or where modification is not possible are excluded from table.

STREAM AND BARRIER #	BARRIER TYPE	BENEFIT OF MODIFICATION	COST/EFFORT OF MODIFICATION	PRIORITY
Bear Creek				
1	Dam	2+	1-2	high
2	Logjam	2	1	high–done 2000
3	Dam	5	3+	high
4	Weir	1-2	1+	high
5	Weir	0-1	1	low
6	Pipe	1	2-3	low
9	Weir	1	2	low
10	Bridge apron	3-4	3-4	high
Bear Gulch				
12	Logjam	2-3	1	high–done 2000
13	Logjam	3+	2-3	high–done 2000
14	Culvert	2	3	low unless #15 modified
15	Dam	4+	*	*
16	Falls	0	4	low–natural feature stabilizes bank
West Union Creek				
17	Bridge apron	2+	2-3	moderate
18	Fence	0-3	1+	high–2000
19	Dam	2+	2+	low-moderate
22	Weir	1-2	2	low
26	Weir	1	1-2	low
Squealer Gulch				
23	Bridge apron	2	3	low
24	Logjam	1-2	1-2	low-moderate–done
25	Debris jam	1+	1-2	low-moderate–done
McGarvey Gulch				
27	Falls	1-2	2	low
28	Culvert	2+	2	moderate
29	Logjam	1-2	2-3	low
30	logjam	1-2	2-3	low

*Laddering the present structure would be very expensive, but modifying the structure in other ways that improve fish passage and alter the design of the water intake structures should be evaluated because of the high quality habitat upstream of the dam.

Steelhead Migration Barriers in the Bear Creek Watershed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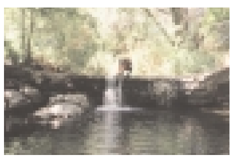
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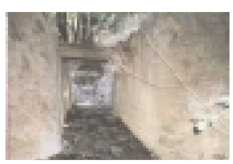
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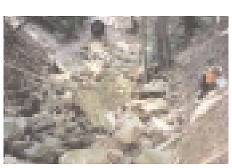
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A fisheries biologist (Professor Jerry Smith) and a geomorphologist (Professor Deborah Harden) hiked up the spawning reaches of the Bear Creek Subbasin to inventory each potential barrier and assess what, if any, modifications would be needed to improve fish passage.

Stream	**Bear Creek**
Barrier Number	**1**
Location	Less than 0.1 mile upstream of Sand Hill Road
Type of Barrier	Concrete Dam

Description Full span concrete and rock dam, 28-feet wide and 2.0-feet thick. Height above low flow pool downstream is 4.6 feet. Pool depth below dam is 6.5 feet, except for rock shelf 2-feet deep immediately below low flow spill from shallow notch. Immediately upstream of dam the pool is approximately 1.5-feet deep. No diversion presently taking place at dam, but it serves as a stream crossing for foot traffic.

Diagnosis The deep pool provides for passage at winter flows, although it may be difficult for smaller adult steelhead. The biggest problem is that at low flows the spilling is onto the shallow portion of the pool over the rock shelf; steelhead would be attracted to jump in the most difficult location. The barrier is important because it is at the bottom of the watershed, and affects access to more than 6 miles of habitat.

Recommended Action A 2-3-foot wide and 0.3-0.5-foot deep notch should be cut in the dam 5 feet closer to the east (left) bank to move the low flow attraction away from the interfering shelf.

Stream	**Bear Creek**
Barrier Number	**2**
Location	Tail of the pool at barrier #3, 0.2 miles upstream of Sand Hill Road
Type of Barrier	Logjam

Description Full span logjam across low flow channel at tail of pool has diverted high flows down a new right bank channel. Small debris and leaves anchored by a 7-inch diameter trunk.

Diagnosis At high flows the new channel provides passage, but at low flows the jam is a barrier to fish movement. The jam would raise the height of the jump pool for barrier #3. However, the new right bank channel is likely to cut deeper and become the new main channel, resulting in bank erosion, channel realignment, and possibly increasing the height of the jump at barrier #3.

Recommended Action The jam can be removed in a few minutes, and should be done before winter 2000-2001. The right bank channel can be blocked by anchoring boulders and woody debris. **Removed by landowner.**

Stream	**Bear Creek**
Barrier Number	**3**
Location	0.2 miles upstream of Sand Hill Road
Type of Barrier	Concrete Dam

Description Full span concrete and rock dam with 9.5-foot wide notch in center of dam. Dam is 2.3-feet thick and anchored in bedrock banks. Center of dam is 4.2 feet above low flow pool downstream, and the pool is only 1.5-2.0-feet deep, with a boulder in the center downstream of dam and a concrete block immediately below the center of the notch. Pool upstream is 1.8-3.0-feet deep immediately above the dam. Presently not used for water diversion. **The concrete block below the notch was removed in October by the landowner and the California Department of Fish and Game. In addition, a bypass on the right bank was cleared to provide potential fish passage during storm flows.**

Diagnosis The worst passable barrier in the entire watershed. Passable only at very high winter flows, and very difficult even under most flood flows. The channel is not constricted downstream of the jump pool, so the pool depth increases slowly with increased flow. This old dam is a grade control, but since the channel is lined with bedrock, no upstream effect is expected. The long pool upstream provides poor summer rearing habitat, since the bottom is silty and there are no feeding lanes.

Recommended Action At least the west half (and preferably all) of the 9.5-foot wide center notch should be cut down at least 2.0-2.5-feet to provide for fish passage during winter flows. Since the structure serves little purpose, modification is the desirable action.

Stream	**Bear Creek**
Barrier Number	**4**
Location	0.3 miles upstream of Sand Hill Road
Type of Barrier	Concrete weir

Description Rock and concrete weir 18-feet wide that is nearly level and 0.9-1.0-feet high. The weir creates a long shallow pool upstream. Pool downstream is lined with concrete on left bank and is up to 2.8-feet deep. Lowest point in weir spills near the left bank to shallow (1.0-feet) portion of pool. Near the right bank the jump pool is 2.3-feet deep.

Diagnosis Spill at low flow attracts fish to the shallowest portion of the pool for difficult jumping. Probably passable at 10-15 cfs.

Recommended Action The weir should be notched about 0.2-0.3-feet deep near the right bank to attract fish to the deepest portion of the pool for jumping. The weir would then be easily passable at low flows (5 cfs).

Stream	**Bear Creek**
Barrier Number	**5**
Location	0.35 miles upstream of Sand Hill Road
Type of Barrier	Concrete weir

Description Concrete weir 12-feet wide across bedrock channel. Weir is only 0.3-0.5-feet high, serving as grade control, and raising 70-foot long pool in bedrock.

Diagnosis Weir and bedrock channels require about 5-10 cfs for passage. Easily passable at winter flows.

Recommended Action No need to modify—not a significant passage problem.

Stream	**Bear Creek**
Barrier Number	**6**
Location	200 feet upstream of the mouth of Dry Creek
Type of Barrier	Pipeline crossing

Description Six-inch diameter pipe crossing stream at grade. Backs up water 4-inches deep upstream of crossing.

Diagnosis Possibly passable for smolts under pipe. Passable for upstream movement of adults at about 6-10 cfs—passable at most winter flows.

Recommended Action Minor problem, no need to modify.

Stream	**Bear Creek**
Barrier Number	**7**
Location	0.3 miles downstream of Mountain Home Road
Type of Barrier	Logjam

Description Partial logjam 20-feet wide and up to 5-feet high. Open at bottom over bedrock, and with 8-foot gap on left bank and 7-foot gap on right bank. Formed from partially uprooted California bay.

Diagnosis Easily passable at winter flows, and does not represent a problem. Potentially important habitat feature, providing calm refuge from storm flows for overwintering juvenile fish.

Recommended Action Desirable feature, with no potential problems. No need to modify.

Stream	**Bear Creek**
Barrier Number	**8**
Location	0.2 miles downstream of Mountain Home Road
Type of Barrier	Logjam

Description Large partial logjam formed of 2 downed alders and a large downed California bay. Jam is up to 7-feet high and 35-feet wide, but is open 10 feet on left bank. Stream bed is sandy. The bay is still alive.

Diagnosis Not a problem, presently open and can scour under with flat channel and sandy bed. Creates complex summer rearing pool and also provides excellent winter refuge against storm flows.

Recommended Action Desirable habitat feature, do not modify.

Stream	**Bear Creek**
Barrier Number	**9**
Location	0.15 miles upstream of Mountain Home Road
Type of Barrier	Unused flashboard dam

Description Eighteen-feet wide by 2-feet high concrete sill and support for unused flashboard dam. Structure still in good and usable condition.

Diagnosis Only 0.3-foot drop to a 1.0-foot deep pool. Slight notch in the center of the sill provides easy passage. Not a barrier—passable at winter flows. Because of 18-foot width, the pool downstream is very shallow and provides little habitat.

Recommended Action No reason to modify as a potential barrier. Cutting a deep notch in the center might concentrate winter flows, producing a deeper summer pool for rearing and providing some winter backwater habitat.

Stream	**Bear Creek**
Barrier Number	**10**
Location	Bridge Crossing at Fox Hollow Road, 0.2 miles downstream of Highway 84
Ownership	City of Woodside
Type of Barrier	Bridge box culverts/aprons

Description Paired 10-foot wide by 30-foot long box culverts. Culverts are flat, but channel downcutting downstream has produced a 2.3-foot drop to a 2.9-foot deep pool

Upward pointing bars are present near the base of the downstream drop.

Diagnosis Pool downstream is sufficiently deep to provide for moderately difficult jump to the culverts at winter flows. However, shallow depth in the culverts makes passage difficult at low flows, and velocity in the culverts is a potential problem at high flows. No California roach or Sacramento suckers were observed upstream of this substantial barrier. The bars serve no purpose and might injure jumping fish.

Recommended Action A low curb (6-inch) should be installed at the upstream entrance to one of the culverts to concentrate low flows down the other culvert. In the second culvert the flow should be concentrated down half of the culvert with curbing. In addition, Washington baffles (alternating baffles perpendicular to the side with baffles pointing upstream) should be installed in the culvert without the curb; these baffles will increase the depth and reduce the velocity to provide for relatively easy low flow passage. The bars should be removed. This barrier and barrier #3 represent the most significant passable barriers in the watershed.

Stream	**Bear Gulch**
Barrier Number	**11**
Location	0.15 miles upstream of mouth
Type of Barrier	Logjam

Description Partial logjam at fallen 10-inch diameter California bay. Jam is 20-feet wide and 2.5-feet high, but open below and through. Pool is only 1-foot deep, but channel is wide, unconfined and sandy-bedded, and the jam can scour under or around.

Diagnosis Because of channel shape and sandy bed, the jam is not a present or potential barrier to fish passage.

Recommended Action No action—the jam is not a present or potential barrier, and provides some habitat complexity.

Stream	**Bear Gulch**
Barrier Number	**12**
Location	0.2 miles upstream of mouth
Type of Barrier	Logjam

Description Partial logjam 15-feet wide and 4.0-4.5-feet high in narrow, confined portion of the channel. Channel bed upstream is 2 feet higher, but pool downstream is up to 3.5-feet deep. Two 15-inch diameter trunks, 20-feet long, form most of the present jam.

Diagnosis The jam is presently not a barrier to adult fish passage, but because of the narrow, confined channel, the jam could become a significant barrier.

Recommended Action The upper log in the jam should be cut and removed as soon as possible (prior to winter 2000-2001). Very limited effort required. The lower log can remain in place to retain the pool downstream. **Upper log cut to eliminate potential problem.**

Stream	**Bear Gulch**
Barrier Number	**13**
Location	0.3 miles upstream of the mouth
Type of Barrier	Logjam

Description Substantial logjam that is 24-feet wide, averages 6-feet high (compared to upstream streambed), and is 16-feet thick. There are 2 feet of channel deposition upstream. The jam may be passable underneath, but otherwise the low point is 4-feet high. Numerous 15-18-inch diameter, 25-foot long logs are wedged into the jam, which is formed at a partially undercut left bank California bay.

Diagnosis This substantial barrier that is probably passable only at very high flows. The large size of the jam and its location in a narrow, confined channel with a large, projecting California bay root wad, indicate that the jam will be stable and will likely get worse.

Recommended Action The jam should be removed as soon as possible (before winter 2000-2001). The logs should be cut to 4-foot lengths or removed from the channel. The California bay may eventually be undercut and slide into the channel, but can presently be left in place. **Six logs cut and smaller debris moved to open barrier.**

Stream	**Bear Gulch**
Barrier Number	**14**
Location	La Honda Road/Highway 84
Ownership	CALTRANS
Type of Barrier	Bridge apron and concrete-lined channel

Description Inclined drop below the bridge apron (sackcrete) is 2.3-feet high and 1.3-feet long into a 3.5-foot deep pool. Apron and 10-foot wide bridge culvert drop 1.5 feet in 58 feet, and an additional 16 feet of flat, curved channel upstream of the culvert is concrete lined.

Diagnosis The jump to the apron presents no significant problem, but the long culvert and concrete-lined channel present significant velocity and depth problems for passage. At low flows the shallow depth and high velocity would be a problem. At high flows the high velocity would make passage difficult, even for large fish. Probably most passable at moderate flows (about 30-100 cfs), when depth may be sufficient to submerge the fish, but velocities are not too high in portions of the channel.

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Recommended Action Washington baffles would reduce the velocity and depth problems in the culvert and lined channel. However, passage is not too difficult at moderate flows. In addition, only about 0.1 miles of habitat exist between the barrier and the impassable dam upstream (barrier #15). Unless that dam is modified to provide for passage, no action is probably justified at this partial fish passage barrier.

If the California Water Service Diversion Dam is modified, improvements at this site will become much higher priority. In addition to the measures mentioned above, the long-term solution of replacing the crossing with a bridge and natural channel should be considered with any future plans for modification or repair of this public structure.

Stream	**Bear Gulch**
Barrier Number	**15**
Location	0.1 miles upstream of Highway 84/La Honda Road
Ownership	California Water Service
Type of Barrier	Diversion Dam

Description Pre-1914 (1860's) dam used as a diversion location for large domestic water supply. The concrete dam is 28-feet wide and 7.7-feet high (from pool level) to top of abutment, but also has 1.6-2.5 feet of flashboards installed at the top. The boards are usually kept in throughout the year to provide diversion through a right bank diversion gallery, but are occasionally removed in winter to pass sediment. There is concrete bank protection for 30 feet downstream on both banks. The bouldery channel downstream is relatively flat but narrow; the pool at the base of the dam is only 1-foot deep. During extreme floods the narrow channel downstream may back up water at the base of the dam, allowing an occasional adult steelhead to leap over the dam. Water is diverted to Bear Gulch Reservoir east of Woodside. Up to 6 feet of sediment is removed from lake bed upstream of the dam each summer to maintain freeboard on intake.

Diagnosis This dam is usually a complete barrier to upstream fish passage, and blocks access to 0.6 miles of habitat with relatively good pools, good substrate conditions, and high summer streamflow.

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Recommended Action Providing passage over the present dam with a fish ladder would require a 10-foot or higher ladder. The 30-40-foot long ladder required would present some problems for attracting fish to the ladder; the lack of a pool downstream would require designs to provide entry to the ladder (such as weirs downstream of the dam). Providing passage would also then require screening of the water intake to prevent diversion of smolts and other juvenile steelhead. The substantial costs of modifying this barrier with a fish ladder (and the culvert downstream, barrier #14), compared to the relatively limited amount of accessible habitat upstream, make this a lower short-term priority than barriers that are cheaper to modify or have more upstream habitat. However, discussions should be undertaken with California Water Service about other potential modifications of the structure (including lowering) that would improve fish passage and maintain or improve water diversion operations.

Stream	**Bear Gulch**
Barrier Number	**16**
Location	About 0.7 miles upstream of Highway 84
Ownership	California Water Service
Type of Barrier	Series of boulder falls

Description Series of natural boulder falls caused by landsliding in a steep, narrow channel cut through a sandstone outcrop. Over 47 feet of drop, including: a 14-foot drop over 48 feet of channel with a 5.5-foot drop at the top to a shallow pool; an 8-foot drop through slide and logjam; an 8-foot drop over 5 feet of channel, with 6-foot single drop; and a 9-foot drop with 6-foot single drop. The configuration probably changes somewhat from year to year.

Diagnosis Most fish would be stopped most of the time through the series of drops, but an occasional fish might be able to pass in some years. The configuration probably changes from year to year, but the narrow channel and numerous slides will always maintain a substantial series of barriers. Modification of individual steps (by blasting or moving individual boulders) would provide only temporary benefit, because of the extensive length of steep, narrow, landslide-prone channel.

Resident rainbow trout are present in the relatively flat habitat upstream of the falls. Logjams from slides on the steep side slopes are present 0.35+ miles upstream of the falls, upstream of the trail crossing.

Recommended Action Modification of the falls to provide access would be difficult and probably require continuous assessments and actions. Barriers 14,15, and 16 should be treated as one cost/benefit problem. High cost makes the 3 barriers a relatively low priority for restoration funding at this time. They may provide suitable offsite mitigation possibilities for habitat impacts (flood control channels, diversions, pollution, or sedimentation incidents) elsewhere in the watershed.

Stream	**West Union Creek**
Barrier Number	**17**
Location	Highway 84 Crossing, immediately upstream of Bear Gulch
Ownership	CALTRANS
Type of Barrier	Bridge apron

Description Apron under bridge is 22-feet long and 20-feet wide and beveled to concentrate flow down the center of the apron. At the downstream end the apron drops 1.3 feet to a generally shallow pool (0.8-feet deep immediately downstream of the drop). Small riprap immediately downstream of the drop extends out 3 feet and interferes with the jump and reduces scour/depth of the pool. The pool is up to 1.7-feet deep 10-feet downstream of the drop.

Diagnosis Probably passable at winter flows of 25 or more cfs. At low flows the jump is difficult and the depth over the apron is probably a problem. A deeper jump pool could probably scour if some of the boulders at the base of the drop were rearranged.

Recommended Action Boulders at the base of the drop should be rearranged to allow some additional scour at the center of the apron. Curbing at the upstream end of the culvert and baffles down the center of the apron should be installed to increase depth and reduce velocity for low flow steelhead passage.

Stream **West Union Creek**

Barrier Number **18**

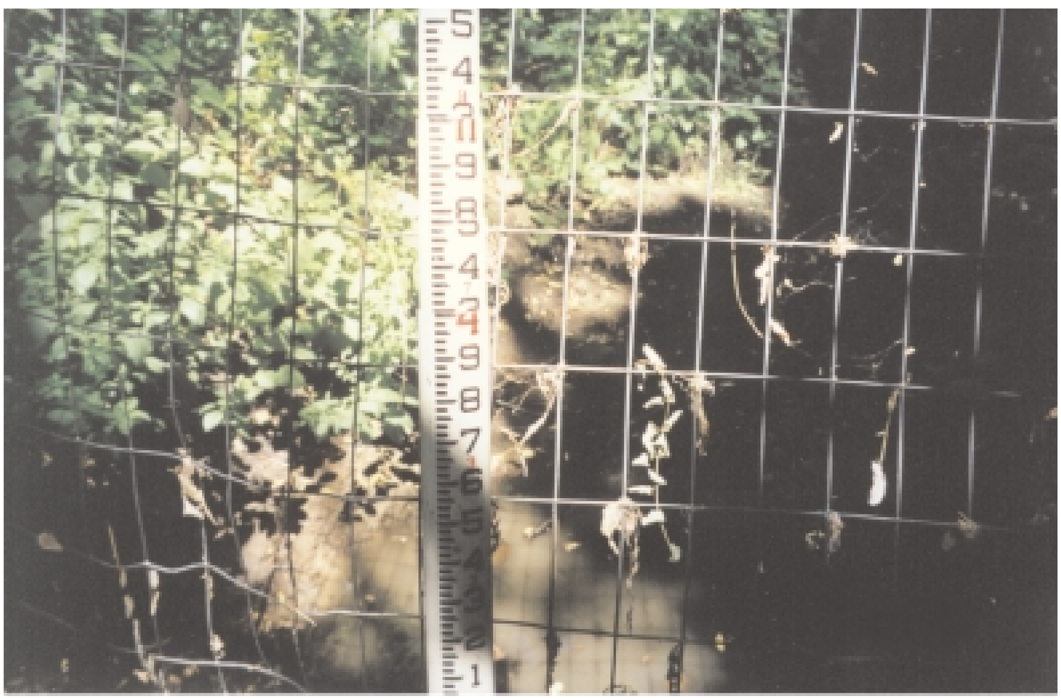
Location Near mouth of Appletree Gulch, 0.3 miles upstream of Highway 84

Type of Barrier Mesh fence

Description Temporary mesh fence (2 x 4-inch) without supporting frames stretched across stream channel.

Diagnosis If fence remains in part of winter, or is installed early in spring, it can block migrating fish and also has the potential to trap ("gill") and injure adult steelhead.

Recommended Action The fence should be replaced with one of larger (4 x 4 or 4 x 6-inch) mesh to eliminate problems with installation or removal dates.



Stream	**West Union Creek**
Barrier Number	**19**
Location	150 feet upstream of Kings Mountain Road
Type of Barrier	Flashboard dam abutment

Description Old 25-foot wide flashboard dam abutment, with 14.8-foot center notch. No longer in use. Streambed upstream is 1 foot lower than top of 2-foot thick sill. The height of the drop from the sill is 3.9-feet to a large downstream pool over 5.4-feet deep.

Diagnosis The depth of the jump pool is sufficient to allow large steelhead to make the jump under most winter conditions. Smaller adult steelhead may have difficulty with the height of the jump.

Recommended Action Cutting a notch 3-feet wide and 0.5-1.0-feet deep in the sill would reduce the jump height to 2.9-3.4-feet and improve passage conditions for smaller adult steelhead.

Stream	**West Union Creek**
Barrier Number	**20**
Location	0.1 miles upstream of Kings Mountain Road
Type of Barrier	Logjam

Description Partial logjam from 2-foot diameter redwood and rootwad plus a multi-trunked California bay. The jam is open under the trunks and also for 5 feet on left bank. The trunks are anchored high on the right bank, and are probably stable. The streambed consists of sand and fine gravel.

Diagnosis The jam is not presently a barrier, the trunks are off the stream bed, and the wide sandy channel will prevent the formation of a significant barrier to fish migration. The jam presently provides summer rearing habitat, and also provides valuable winter refuge against storm flows.

Recommended Action Not a barrier and a valuable habitat feature. Probably stable and not a threat to downstream structures. No need to modify.

Stream	**West Union Creek**
Barrier Number	**21**
Location	0.1+ miles upstream of Kings Mountain Road
Type of Barrier	Logjam

Description Partial logjam formed by two 3-foot diameter eucalyptus trunks fully spanning the channel high enough to crawl under. The trunks are anchored on the banks and probably will be stable.

Diagnosis Not presently a barrier, and will not become a problem for fish passage. The partial jam provides summer rearing habitat and some refuge against winter storm flows.

Recommended Action Not a problem for fish passage or downstream structures. Potentially important habitat feature. No need to modify.

Stream	**West Union Creek**
Barrier Number	**22**
Location	0.3 miles upstream of Kings Mountain Road
Type of Barrier	Concrete weir

Description Old 25-foot wide concrete and rock weir—remnant of old flashboard dam. Eroded around both sides, especially right bank. Height above pool is 1.2-1.4 feet, and pool is 1.5-1.9-feet deep.

Diagnosis Passable at winter flows under present conditions. Notching the weir might produce a deeper, more complex pool for summer rearing habitat.

Recommended Action No need to modify for passage.

Stream	**Squealer Gulch**
Barrier Number	**23**
Location	Under Greer Road, immediately upstream of the stream mouth
Type of Barrier	Bridge apron

Description Inclined (3%) 5-foot wide apron, 25-feet long. The apron drops 0.8 feet to a 1.0-foot deep pool downstream.

Diagnosis The inclined apron presents some depth and or velocity problems for adult fish passage at lower flows. However, the apron is probably passable at the higher winter flows that provide attraction to and passage in this narrow, steep tributary.

Recommended Action Insufficient problem to require modification with baffles.

Stream	**Squealer Gulch**
Barrier Number	**24**
Location	0.3 miles upstream of mouth
Ownership	Huddart County Park
Type of Barrier	Logjam

Description Two logs spanning the channel (18-feet wide) with cobbles and gravels filled in to a height of 4.0 feet. Small opening at the bottom of the lower log passes summer flow. Pool downstream is shallow (0.4-feet deep) and wide.

Diagnosis No jump pool and wide, high step. Potentially passable only during flood flows, when velocity would be a substantial problem. Young-of-year steelhead present in a pool downstream, but none seen upstream. Stream did maintain flow throughout summer in 2000.

Recommended Action Could easily be removed by cutting the logs. If barriers 24 and 25 were removed, several hundred feet of additional habitat with good pools would be accessible. Numerous additional steep steps are present several hundred feet upstream. Worth modifying only if permitting effort is low. **Removed by County Park staff.**

Stream	**Squealer Gulch**
Barrier Number	**25**
Location	0.3 miles upstream of mouth
Ownership	Huddart County Park
Type of Barriers	Debris jams and boulder falls

Description Cobble and boulder debris anchored by an unused 4-inch diameter pipe spanning the channel (20 feet). Height is 3.0 feet above a 0.3-foot deep pool. Numerous 4-6-foot high debris jams and boulder falls are present upstream.

Diagnosis This barrier is probably passable at high flows (200 cfs), but the series of drops in this steep section are probably not regularly passable. No fish were seen upstream of barrier #24, downstream. Impassable culvert present at Kings Mountain Road, 0.15 miles upstream.

Recommended Action Barrier could be removed relatively easily by merely cutting the pipe. Removing this barrier and barrier #24 would provide access to only several hundred feet of habitat (with some good pools), but would be worth doing if permitting effort is low. **Removed by County Park staff.**

Stream	**West Union Creek**
Barrier Number	**26**
Location	At Greer Road crossing, upstream of mouth of Squealer Gulch
Type of Barrier	Concrete weir

Description Weir at base of old bridge abutment is 0.9-feet high with little pool development (0.4 feet) downstream.

Diagnosis Passable at most winter flows with little difficulty.

Recommended Action Modification probably not necessary, but weir could easily be notched slightly to improve low flow passage. A larger notch would potentially improve pool development downstream for summer rearing. The weir is potentially an ideal grade control for stream flow monitoring.

Stream	**McGarvey Gulch**
Barrier Number	**27**
Location	50 feet upstream of mouth
Ownership	Huddart County Park
Type of Barrier	Boulder falls

Description Boulder falls drops 2.8 feet to a low flow pool 0.4-feet deep. Configuration probably changes from year to year.

Diagnosis Natural falls within short, steep, confined reach near mouth of this tributary. Passable during most winter flows.

Recommended Action No action

Stream McGarvey Gulch

Barrier Number 28

Location Trail crossing 0.2 miles upstream of mouth

Ownership Huddart County Park

Type of Barrier Bridge culvert and apron

Description Four-foot diameter, 20-foot long culvert spills 0.7 feet to an apron that is 0.8 feet above the shallow (0.7-feet deep) pool downstream.

Diagnosis The 2-step entrance from the pool to the culvert may present problems for fish at low flows. At the moderate flows (20-30 cfs) suitable to provide negotiation of the 2 steps, the culvert is probably passable. Juvenile steelhead were present up to 0.15 miles upstream of the culvert.

Recommended Action The apron should be eliminated or else rimmed with a curb to pool water below the culvert and eliminate the 2-step entrance to the culvert. Several baffles in the culvert might improve low flow passage if the apron is modified.

Stream	**McGarvey Gulch**
Barrier Number	**29**
Location	0.45 miles upstream of mouth
Ownership	Huddart County Park
Type of Barrier	Logjam

Description Seven-foot high logjam with several steps spans the channel.

Diagnosis Probably a complete barrier to fish passage under most conditions. No fish seen upstream of the barrier. Smaller logjam 200 feet downstream is probably passable at winter flows. Much of the channel upstream is probably dry in summer.

Recommended Action No action. Another jam is immediately upstream, and impassable falls are less than 0.2 miles upstream. Little available habitat upstream.

Stream	**McGarvey Gulch**
Barrier Number	**30**
Location	250 feet upstream of barrier # 29, 0.45 miles upstream of mouth
Ownership	Huddart County Park
Type of Barrier	Logjam

Description Eight-foot high logjam with large stump and numerous smaller trees. Pool downstream is only 0.5-feet deep.

Diagnosis Complete barrier under most flow conditions. Limited habitat upstream.

Recommended Action No action.

Stream	**McGarvey Gulch**
Barrier Number	**31**
Location	0.65 miles upstream of mouth
Ownership	Huddart County Park
Type of Barrier	Series of boulder falls

Description Steep channel through sandstone outcrop, with 80-100-feet of drop. Numerous falls of 8-10+ feet.

Diagnosis Numerous impassable drops. No fish downstream of the falls.

Recommended Action No action. Natural series of falls cannot be modified for fish passage.

Stream	**McGarvey Gulch**
Barrier Number	**32**
Location	0.75 miles upstream of mouth, at road crossing
Ownership	Huddart County Park
Type of Barrier	Culvert and slope

Description Four-foot diameter culvert spills onto an 18-foot high talus chute.

Diagnosis Impassable and upstream of impassable falls.

Recommended Action No action

Stream	**West Union Creek**
Barrier Number	**33**
Location	0.35 miles upstream of mouth of McGarvey Gulch
Ownership	Huddart County Park
Type of Barrier	Logjam

Description Logjam of old and new wood from left bank landslides. Two tanbark oaks, 2 old and 1 new redwood, plus smaller debris have produced a full span logjam 6.5-feet high in a flat sandy portion of stream. Pool is 1.5-feet deep.

Diagnosis Passable at high flows around the jam, and probably passable at lower winter flows through the jam. Provides winter refuge for fish against storm flows, and also provides summer foraging habitat and possibly spring breeding habitat for California red-legged frogs (several yearlings seen).

Recommended Action No action. Not a significant fish barrier and provides extremely valuable habitat feature for fish and frogs.

Stream	**West Union Creek**
Barrier Number	**34**
Location	150 feet upstream of Huddart Park boundary
Type of Barrier	Falls

Description Apparently a San Andreas fault-related waterfall. Falls drops 11.4 feet over redwood roots to a 4.0-foot or deeper pool. An adjacent amphitheater may receive winter flows from a secondary channel; that drop is 10 feet to a 1.0-foot deep pool.

Diagnosis No fish have been observed above, and the falls appears to be a complete barrier. At high flows the constricted channel downstream of the falls may backflood the jump pool, reducing the jump height; passage might very rarely be possible. Cutting the roots would probably allow the stream to downcut to eliminate the barrier, but would also cause the channel to headcut for up to 1/2 mile, destabilizing the channel and banks and causing sedimentation downstream. West Union Creek and a major tributary above the barrier go dry in late summer, except in the steeper portions of the streams, where access would be difficult or blocked.

Recommended Action No action

Appendix A. Effects of the San Andreas fault system on habitat

Like many of the streams that flow along the Bay Area's active faults, San Francisquito Creek and its tributaries are strongly influenced by the San Andreas fault. The fault controls the overall shape of the watershed, controls the location of many of the stream channels, and dramatically affects the channels themselves. Furthermore, long-term fault movement has created many unusual features in the watershed.

In the Bear Creek study area, the San Andreas fault has influenced stream habitats in a number of ways. The impacts of these effects on steelhead barriers and habitat are briefly summarized below.

West Union and Bear Creek Valleys The long, straight, northwest-oriented valleys which contain West Union Creek and lower Bear Creek have formed along the trace of the San Andreas fault and related subsidiary faults (Figure A-1 and A-2). Linear valleys are one of the most common indicators of active faults. One reason for their formation is that rocks along a fault are more sheared and crushed, and thus more easily eroded by streams, than rocks away from the fault. Streams develop preferentially along the path of less resistance. Without the influence of the faults, such valleys would not be present above the alluvial flatlands adjacent to San Francisco Bay.

Stream Gradients Over geologic time, the landscape and the rocks on either side of the San Andreas are continuously moving, with the block on the west side moving northwest and that on the east side moving southeast. As a result, the channels of streams crossing the fault zone are being stretched and flattened. The elongation and offset (or separation) of channels can often be easily seen on maps.

The long reach of relatively low-gradient channels creates accessible steelhead habitat in streams which, without the influence of the [San Andreas] fault, might otherwise be impassible because of natural barriers.

The gradient of the channel of West Union Creek is anomalously low, particularly for a mountain stream (Figure A-3). The long reach of relatively low-gradient channels creates accessible steelhead habitat in streams which, without the influence of the fault, might otherwise be impassible because of natural barriers.

Lower Bear Gulch Capture In some places, the rate of movement along a San Andreas-type fault is so active that stream channels become partly or entirely blocked. When this occurs, ponds or wetlands, like those at Searsville Marsh, may form. In other areas, stream channels may be abandoned because the stream no longer flows across the fault, but rather flows into a new channel. An excellent example of stream abandonment and capture can be found along Bear Creek near Manzanita Way (Figure A-4).

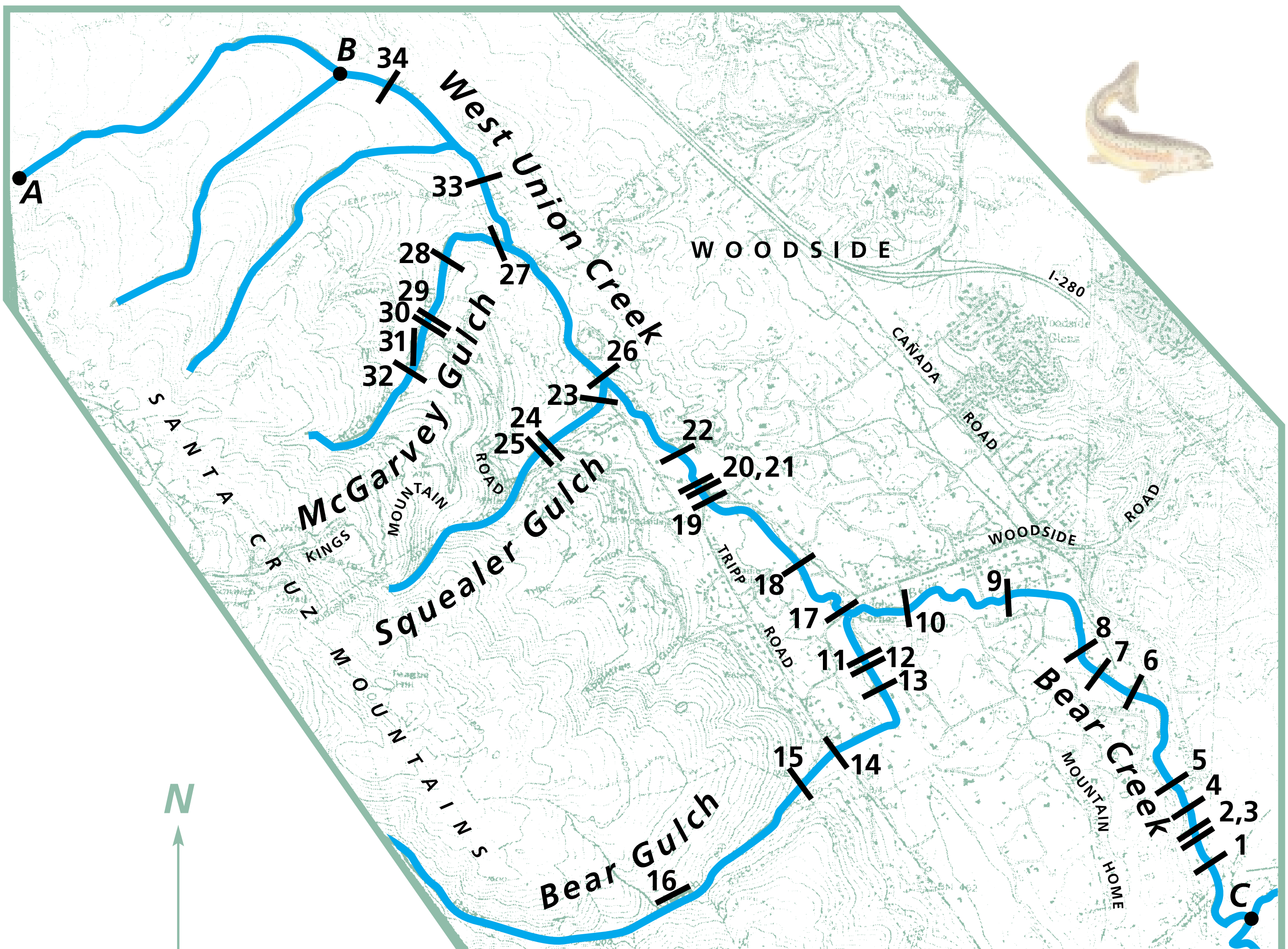
Spawning Gravels A large portion of the Bear Gulch and West Union watersheds are underlain by the Whiskey Hill Formation (labeled *Tw* on Figure A-2). Most of this unit is sandstone, which weathers to produce spawning gravels which are ideally sized for steelhead spawning.

West Union Nick Point (barrier #34) Barrier number 34 (Figure A-1) is a naturally formed falls in the otherwise unusually flat reach of upper West Union Creek. To find such a drop along a gentle channel is highly anomalous, and the most likely explanation for the drop must involve the fault itself. We hypothesize that the falls may have originated as a 1906 earthquake scarp downstream of its present location, where the trace of the fault crosses West Union Creek. In the subsequent century, this falls (termed a "nick point" by geologists) migrated upstream to its present location, perhaps very rapidly. At present, upstream migration of the nick point has been halted by a substantial mass of redwood roots.

Location Map of Steelhead Migration Barriers

Deborah R. Harden and Jerry Smith, San Jose State University

Figure A-1. Location map of Bear Creek watershed, showing elongate fault-controlled valley. Points A, B, and C are points on Figure A-3, longitudinal profile, for reference. Woodside and Palo Alto 7.5' base maps.



Prepared for the San Francisquito Creek Water Council, June 2000

Figure A-2. Geological map of the Bear Creek watershed, with the main trace of the San Andreas fault highlighted. Source U.S. Geological Survey; http://greenwood.cr.usgs.gov/pub/mf-maps/mf-2332
Tw = Whiskey Hill Formation; QTsc = Santa Clara Formation

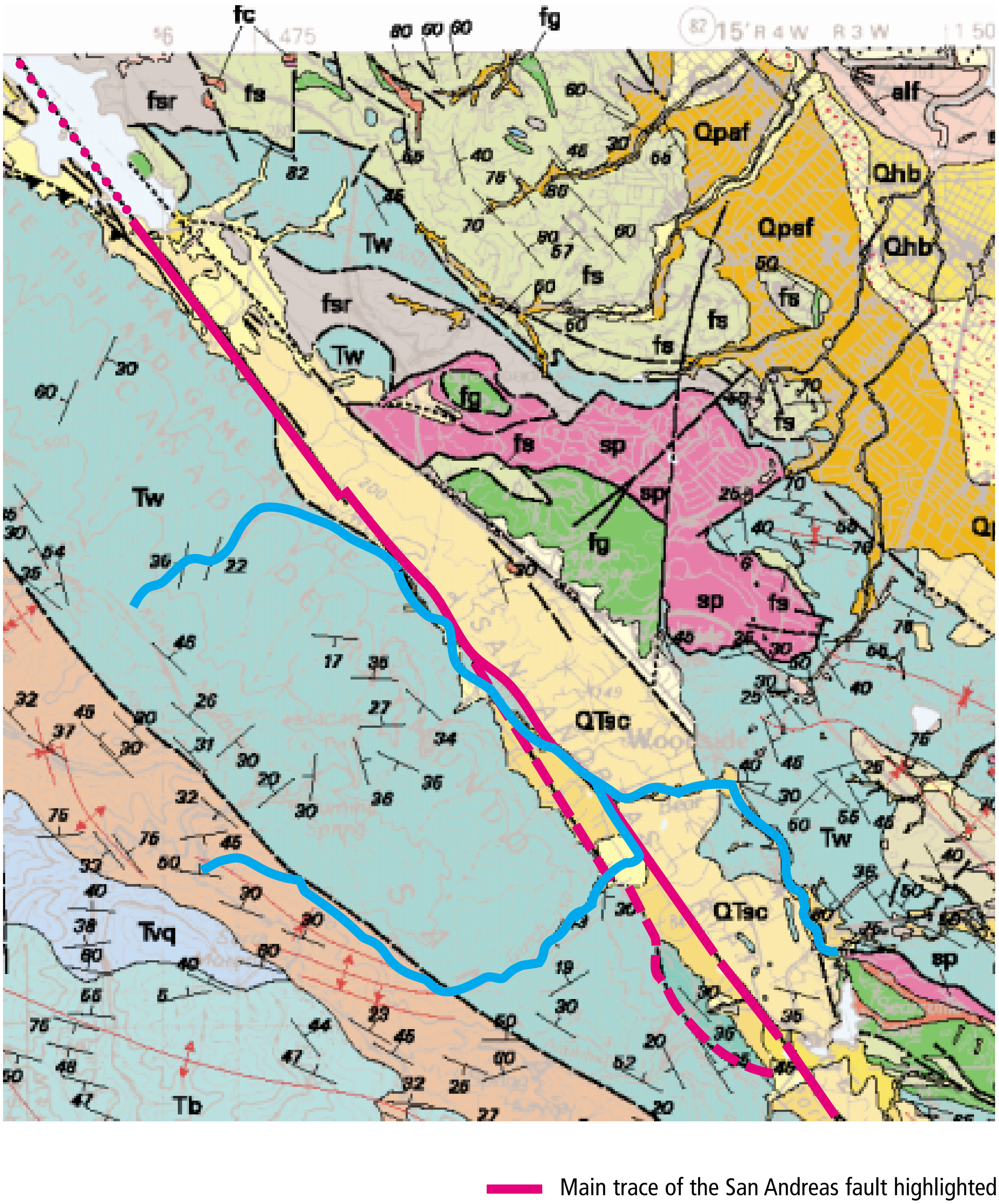


Figure A-3. Longitudinal profiles of West Union, Bear Gulch, and Bear Creeks. Point A, B, and C are shown in Figure A-1. Note the flattening of the gradients between B and C, where the creeks flow mainly in the San Andreas fault zone.

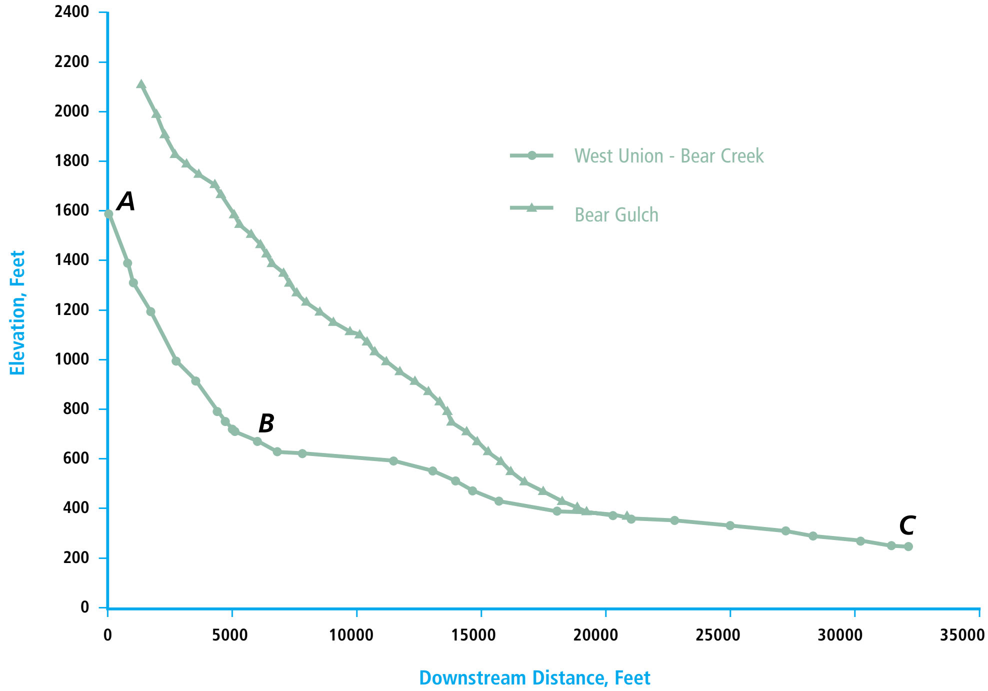
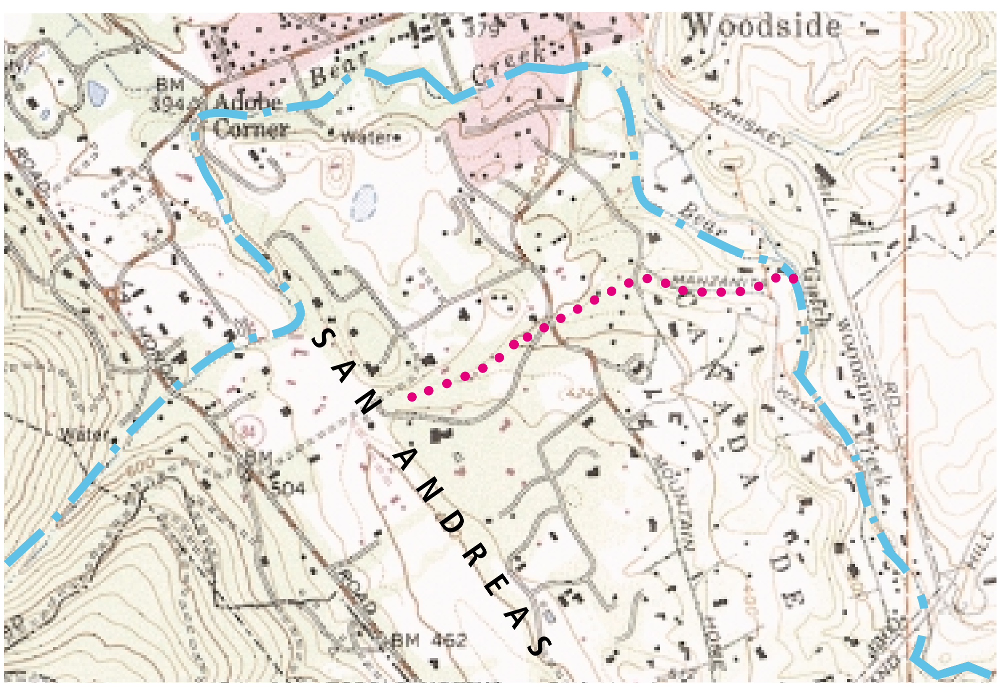


Figure A-4. A portion of the Woodside and Palo Alto 7.5' topographic maps, showing the capture of Bear Gulch along the San Andreas fault. Before capture, Bear Gulch Creek flowed in the depression shown by the dotted line. After blockage along the San Andreas, the creek was captured, and it now flows into Bear Creek at Adobe Corner.



Appendix B. Barriers Outside of Bear Creek Subbasin

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The purpose of this entire study was to identify barriers to steelhead trout migration in the Bear Creek Subbasin of the San Francisquito Creek Watershed, proposing modifications to improve fish passage and setting priorities for their modifications. The original assessment did not take as long as originally expected, so some funds remained in the grant. After checking with Department of Fish and Game staff, the Watershed Council decided to evaluate several structures outside of the Bear Creek Subbasin that may serve as barriers to fish migration. Appendix B includes those evaluations.

Rather than wait until there was time and funding for an assessment hike of the entire watershed, the Steelhead Task Force identified structures that they suspected created fish passage issues. The structures evaluated were not identified on a continuous hike up the stream channel, but instead based on the collective personal knowledge that task force members have gained over many years of observations. There are probably other structures in the watershed that function as barriers that were not identified. At some future time it may be possible to conduct the complete assessment process, including both hike and evaluation, to the entire watershed.

The scientists applied the same evaluation methodology to these structures as they used in the Bear Creek Subbasin. This systematic evaluation procedure serves as a good basis for setting priorities about which structures need to be modified and applying for funding to modify them.

Stream **San Francisquito Creek**

Type of Barrier Concrete Grade - Stabilization Weir

Ownership

Location Along Clark Avenue

Description Eight-foot wide concrete weir across the stream channel. A 3.4-foot wide and 0.4-0.5-foot deep slot has been cut in the center of the weir, with a shallow lip on the downstream end. Downstream of the main weir a shallow 8-foot wide, rough concrete ramp (4% gradient) is present; depth is 0.15 feet at 5 cfs.

Diagnosis At 5 cfs, steelhead could power up the short incline to the slot with difficulty. Natural riffles in the reach present similar difficulties. At 25 cfs, passage would be easy.

Recommended Action None. The notching of the weir has eliminated any significant passage problem.

Stream	**San Francisquito Creek**
Type of Barriers	Concrete Grade Control Weirs
Ownership	
Location	Immediately downstream of Waverly Street

Description Three 1-foot wide concrete grade control structures span the entire channel. The lower two structures are only 0.1-0.3 feet above the water levels downstream. The upper structure has a 0.7-0.9-foot drop downstream, and depth immediately downstream is 1.0-1.7 feet.

Diagnosis The lower two weirs present no significant upstream passage problems during winter. The upstream weir probably requires 30-50 cfs for easy upstream passage. At low flows (< 5 cfs), all three weirs may restrict smolt downstream passage by spreading the flow as a very shallow sheet across the weirs.

Recommended Action A 0.5-foot deep and 3.0-foot wide notch should be cut in the upper weir to provide for easy adult and smolt passage. A 0.2-foot deep and 3.0-foot wide notch should be cut in each of the lower 2 weirs to provide for easy low-flow smolt passage.

Stream	**San Francisquito Creek**
Type of Barrier	Concrete Weir
Ownership	
Location	Downstream of El Camino Real

Description Ten-foot wide concrete weir nearly level across entire channel. The inclined weir (10% gradient) is about 0.7 feet above the channel bed on the upstream side. Pool downstream is over 3-feet deep.

Diagnosis Because the weir spreads the flow across most of the channel and is inclined, it presents substantial velocity and depth problems for passage. Very difficult passage is probably possible at 30 cfs, but 100+ cfs is probably necessary for most fish. The barrier is probably regularly passable only during storms in most years.

Recommended Action The City of Palo Alto will study the barrier for modification or removal. The barrier can be modified to partially (but substantially) improve low flow passage by cutting a level notch 4-feet wide and 0.7-feet deep through the center of the weir. There would still be some velocity and depth problems for low-flow passage at the downstream portion of the notch, but most fish could pass.

Stream	**San Francisquito Creek**
Type of Barrier	Concrete Flow Gauge Weir
Ownership	US Geological Survey
Location	0.1 miles upstream of Junipero Serra Boulevard

Description Concrete weir 5-feet wide across entire channel. The weir is inclined from both banks to the center of the channel, with the center 5-6 feet relatively flat. The flow drops 2.5 feet to small concrete slabs. The large pool downstream is over 3-feet deep at low flow, with boulders and concrete slabs at the tail of the pool.

Diagnosis The slabs at the base of the drop present the biggest problem for passage. Their placement interferes with jumping fish by forcing them to jump from further downstream and to jump through complex turbulence (which at most flows would affect their momentum). In addition, the flow dissipation effects of the slabs reduce the depth of the pool immediately downstream of the weir. Fish must now make a difficult jump and are then faced with velocity problems across the weir. The boulders and slabs at the tail of the pool raise its height relative to the weir at high flows. In most years the weir is probably passable only during storms, when flows exceed 100 cfs.

Recommended Action The slabs should be removed from the base of the drop to eliminate jump interference and to allow the pool to deepen immediately downstream.

The boulders and concrete slabs at the downstream end of the pool could also be rearranged to create a partial weir that would increase pool depth at higher flows.

Stream Los Trancos Creek

Type of Barrier Flashboard Dam with Concrete-lined Basin

Ownership

Location 0.1 miles upstream of Los Trancos Road / Alpine Road intersection, 200 feet upstream of private road bridge

Description Concrete flashboard dam 5-feet thick at base and 6-feet tall. Center opening is 5.3-feet wide, with a 5-foot long apron about 1.5-feet thick. Step at upstream end of apron is 0.7-feet high, but partially inclined in center (0.3-foot step). Apron is about 1.0 foot above pool surface at 4 cfs, and jump pool is 1.8-2.4-feet deep immediately downstream. The notched flashboard supports are on the upstream face of the dam.

The channel downstream of the dam is incised and relatively flat (<2%).

Upstream of the dam the right (east) bank and streambed are lined with concrete, and the left bank is lined with a boulder and concrete wall. The left half of the impoundment basin is filled with a 5-foot high boulder and cobble bar, leaving a 6-foot or wider channel along the right wall. The bar is old (large trees are present on the bar), but if excavated, would likely reform in the backwater of the dam during a large flood. The first 12 feet of concrete-bottomed channel upstream of the flashboard dam are inclined 1.5-feet high and bend from the center to the right bank of the channel. An additional 55 feet of concrete-bottomed channel has about a 3% gradient. The natural channel immediately upstream has a 4-6% gradient for 35 feet with cobbles and boulders.

Diagnosis The jump to the apron is relatively easy, but the apron and the step 5 feet upstream would be difficult to negotiate at low flows (<8-12 cfs). The 12 feet of sharply inclined concrete channel immediately upstream of the apron would require at least 15 -25 cfs to provide sufficient depth for passage, but would present significant velocity problems at most flows, even for a fish using the inside of the bend (left bank). The 55 feet of channel upstream presents less of a velocity problem, but would still require 12-18 cfs to provide sufficient depth for passage. Higher flows present additional velocity problems upstream of the dam, but there would probably be a backwater effect immediately upstream of the opening in the dam at flows greater than 50 cfs. At very high flows (200+ cfs) velocity through the opening in the dam would probably restrict passage; this is not a frequent problem for passage. The presence of the cobble/boulder bar reduces the amount of flow required for passage through the dam and basin; merely removing the bar would make passage substantially more difficult.

The barrier is presently passable with difficulty during moderate storm flows (20-100 cfs). At very high flows (400+ cfs) the incised channel downstream of the dam probably results in backflooding of the barrier, also allowing passage. In dry years or between storms in wet years few fish would be able to pass.

The dam is presently not used. Perennial, shaded spawning and rearing habitat exists in most years between the dam and the East Fork of Los Trancos Creek (1/2 mile) and also in the upper portion of Los Trancos Creek (1+ miles of habitat).

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Recommended Action The cobble bar and left and right bank walls can be left in place. The 6-8-foot wide and 65-foot or longer concrete-bottomed channel upstream of the dam should be partially removed (its thickness is not presently known). One and a half-foot wide "wings" of the concrete can be left to extend out three feet from the right wall. The wings should be spaced every 10 feet to create deeper, lower velocity resting pockets.

A concrete or steel curb 1.0-feet high and 3.5-feet long can be installed at the downstream edge of the apron to increase depth over the apron (with the opening on the right side). Bedload movement of large cobbles and boulders is likely to periodically damage the curb, requiring replacement. Alternatively, a fabricated steel basin 0.7-feet deep can be inserted on the 5.3 by 5-foot apron and anchored in the upstream flash-board supports.

The dam is a minor channel grade control, so its complete removal may also require removing the right wall.

Stream	**Los Trancos Creek**
Type of Barrier	Double Box Culvert Road Crossing
Ownership	
Location	First Los Trancos Road crossing upstream of Alpine Road

Description Paired concrete box culverts 8-feet wide, 6-feet high and 77-feet long. Gradient in the culverts and in the channel up and downstream is about 2%. The downstream ends of the culverts are 0.5 feet above the water surface (at about 4 cfs), with water depths of only 0.4-0.6-feet deep below the drops. The culverts are generally aligned with the relatively straight channels up and downstream, but the left (west) culvert apparently receives most of the bedload movement at high flows. The floor of the culvert has been eroded to 0.1-feet deep in places, exposing the tops of some reinforcing bars.

Diagnosis The flow is spread approximately evenly between the two culverts, requiring a flow of about 25-40 cfs to provide sufficient depth for passage. At that flow, or at higher flows, no jump into the culvert is required, and velocities in the relatively flat (but long) culverts would not prevent passage. At lower flows the shallow depth in the long culverts would usually block most fish. Passage over riffles in the natural channel probably requires at least 5 cfs. In most years the barrier is probably passable only during storms, but storms are sufficiently frequent to allow some steelhead access.

Recommended Action Modify the culverts by placing a 0.5-foot high steel or concrete curb at the upstream end of one of the culverts (left) to concentrate low flows down the other culvert. Install 0.5-foot high steel Washington baffles in the other culvert to reduce velocities and increase water depth at low flows. Because of cobble and small boulder bedload movement during large floods, the baffles will probably have to be occasionally repaired or replaced.

Stream	**Los Trancos Creek**
Type of Barrier	Double Box Culvert Road Crossing
Ownership	
Location	Emergency fire access road 0.1 miles downstream of second road crossing on Los Trancos Road

Description Paired concrete box culverts 10-feet wide, 7.5-feet high, and 35-feet long, that are presently flush with the streambed up and downstream. Channel and culvert gradients are approximately 2%. The culverts are aligned with the channel downstream, but the channel upstream bends to the right (east) to enter the culverts. The right bank culvert (inside bend) is filled with 0.6 feet of gravels and cobbles.

Diagnosis The left culvert requires flows of about 15-20 cfs to provide sufficient depth for passage. At that flow, and at higher flows, velocity would not be a major problem in the culverts; at high flows fish could use the right culvert, where velocities along the right bank would be less. In most years the culverts are probably passable only during storms, but storms are sufficiently frequent to allow some steelhead access.

Recommended Action Install 0.5-foot high steel Washington baffles in the right half of the left (west) culvert to reduce velocities and increase water depth at low flows. The other half of the left culvert should be sectioned off by a steel or concrete curb at the upstream end of the culvert and also down the length of the culvert. Because of cobble and small boulder bedload movement during large floods, the baffles will probably have to be periodically repaired or replaced.

Stream	**East Fork of Los Trancos Creek**
Type of Barrier	Undersized Road Culvert
Ownership	
Location	Los Trancos Road crossing

Description Small diameter (2-foot) corrugated pipe under 30-foot wide road. The pipe appears to be relatively level (about 2% gradient), but bends to the right under the road. No drop present on downstream end of culvert. Channel upstream drops 1 foot to pool immediately above culvert. The culvert appears undersized for the amount of watershed drained upstream, and sheet flow across the road apparently occurs during some storms.

Diagnosis The culvert would probably be passable only during a small range of moderate flows (4-10 cfs), when the culvert is filled to 0.4-1.0-feet deep. At lower flows the depth would be insufficient, at higher flows velocity would probably greatly restrict passage. A small concrete diversion structure across part of the channel 100 yards downstream, and a steep (10-foot long, 2-foot drop) channel drop downstream of the structure, are probably passable at 4-10 cfs.

The East Fork of Los Trancos Creek provides most or all of the summer flow for Los Trancos Creek downstream of the fork. However, the streambed is silt immediately up and downstream of the crossing, and the value (or potential value) of the tributary for steelhead may be small. A small willow/sedge wetland occurs immediately downstream of the crossing, but the stream downstream of the wetland is ditch-like. Upstream of the crossing an extensive willow/sedge wetland is present, and is 20-40-feet or wider and at least 300-feet long. This unique feature probably provides extremely valuable breeding and foraging habitat for **California red-legged frogs.**

Recommended Action Modification of the structure to provide improved steelhead passage is probably not justified. However, if the structure is modified to provide increased flood capacity, steelhead passage should be considered in the design. In addition, the design should also prevent any adverse impacts to the extremely valuable wetland upstream of the crossing (such as channel incision and draining of the wetland).

Stream	**San Francisquito Creek**
Barrier Name	Searsville Dam
Location	0.2 miles upstream of the Bear Creek Confluence
Owner	Stanford University
Type of Barrier	Dam

Description Located within the Jasper Ridge Biological Preserve, Searsville Dam was built from 1889-1891 and is the largest dam in the watershed. The dam is constructed of interlocking concrete blocks and measures approximately 64 feet in height (from the base to crest) and 240 feet in crest length. Water releases are controlled with flashboard inserts at the top and center of the dam crest. Currently all water released flows down the face of the dam over the concrete blocks. Approximately 1.5-million cubic yards of sediment is deposited behind the dam, reducing the original 350-million gallon capacity of the reservoir by 86%.

Diagnosis This dam blocks steelhead from accessing the watershed's largest tributary (Corte Madera Creek) and a large percentage of spawning and rearing habitat in the watershed. Upstream of Searsville Dam, Corte Madera Creek and its associated tributaries contain over 8 miles of spawning and rearing habitat and supply the watershed with the greatest amount of flow at 42%. The presence of a sustainable rainbow trout population in these upstream tributaries attests to the adequate spawning and rearing conditions and late summer flows that exist above Searsville Reservoir. Prior to construction of the Dam, this upstream habitat would have been accessible to steelhead.

Recommended Action Due to the high quantity and adequate quality of spawning and rearing habitat upstream of the dam, fish passage upstream of Searsville Dam should be investigated. The height of the dam and limited amount of flow makes a fish ladder alternative highly unfeasible.