Final Report of

The Marin Coastal Watershed Enhancement Project

November, 1995

Prepared by
University of California Cooperative Extension
1682 Novato Boulevard, Suite 150B, Novato, CA 94947

With Funding From Marin Community Foundation

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The Marin Coastal Watershed Enhancement Project

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Acknowledgments

The Marin Coastal Watershed Enhancement Project has been the work of many dedicated individuals representing the agricultural community, natural resource agencies, and environmental groups. We are grateful to the many landowners that participated by attending meetings and workshops, reviewing project materials, and talking with project staff. Several organizations and agencies contributed considerable staff time to the project "staff team"; Marin Agricultural Land Trust, Marin County Farm Bureau, Point Reyes National Seashore, Marin Resource Conservation District, and Natural Resources Conservation Service staff worked closely with University of California Cooperative Extension farm advisors. Coordination of this team allowed the sharing of many resources and ideas which greatly enriched the project.

We are indebted to Advisory Committee members, who provided valuable guidance and feedback on project materials.

Finally, we are deeply grateful to the Marin Community Foundation for their generous support and dedication to preserving agriculture and the environment.

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1. Executive Summary

The Marin Coastal Watershed Enhancement Project (MCWEP) was initiated in Spring, 1994, in response to an increased focus on nonpoint source (NPS) pollution by regulatory agencies. The primary goal of the project is to develop solutions to water quality problems that affect both agriculture and natural resources in West Marin.

While water quality is affected by many natural and human causes, this project focused on agriculture because it is the predominant land use in West Marin, and as such, is one of the few forces that can be positively changed. Many other human induced changes—such as construction of reservoirs, natural occurrences, and intense storms and droughts—can have profound effects on water quality and stream function, but these changes are largely beyond our control.

The project area— including the watersheds of Stemple Creek/Estero de San Antonio, Walker Creek, Lagunitas Creek, and smaller tributaries to Tomales Bay—covers 232 square miles of productive agricultural land that not only produces food, but provides much of Marin County's fish and wildlife habitat.

Many individuals and agencies contributed to this project. A team of staff from the University of California Cooperative Extension, Natural Resources Conservation Service, Point Reyes National Seashore, Marin Agricultural Land Trust, and a local rancher worked together on this project. Guided by an Advisory Committee made up of representatives from agriculture, resources management, and environmental groups, the project team provided outreach and education to landowners and compiled information on local water quality and watershed condition. Personal meetings and informational workshops on ranch planning, water quality testing, and water quality regulations brought critical information to area landowners.

This report summarizes information on the status of natural resources and water quality in the project area, reasons for water quality problems, and steps that can be taken to make improvements. The first sections of the report describe the area's physical characteristics, natural resources, land use, history, agency responsibility and present status of water quality.

The last section is devoted to project recommendations. Recommendations formulated by the Advisory Committee identify existing and needed resources, and recommend additional assessment and funding priorities.

Specific recommendations include creating mechanisms for sharing expertise on water quality; providing technical assistance for writing ranch plans to landowners; continuing educational workshops and other materials; educating the public about agriculture's efforts to improve water quality; and completing specific water quality and resource assessments in area streams to determine needs for enhancement work. Also included in this section is a summary of landowner comments and concerns from personal interviews and public meetings.

2. Introduction

Since the first European immigrants settled here in the early 1800s, agriculture has been a way of life in West Marin. Agriculture is vital to the local economy, contributing over $45 million every year. The spectacular scenery of coastal Marin County—protected largely by the tradition of ranching—draws over 6.5 million visitors to West Marin County each year, a secondary yet important economic effect.

As well as these economic values, agricultural lands preserve important biological and cultural resources. These lands include vast acreages of grasslands, shrublands and forests, habitat for myriad plant and animal species. Much of the history of the area stems from its agricultural heritage, and many of the families that operate ranches today are third and fourth generation descendants of the first immigrants.

The viability of agriculture is threatened by an increasingly restrictive regulatory environment. Since European immigrants first arrived—equipped only with their tools, knowledge, seeds, and animals—ranching has evolved from a simple enterprise to an industry wrought with pressures and regulations.

Increased focus on NPS pollution by federal, state, and local regulatory agencies presents agriculturists with new management challenges when animal agriculture is facing difficult economic times. Similarly, fish and other aquatic resources are suffering from the impacts of years of habitat degradation due to sedimentation, water pollution, and loss or physical alteration of their habitat. Populations of coho salmon *(Oncorhynchus kisutch)* and steelhead trout *(Oncorhynchus mykiss),* two fish species that have been mainstays of commercial and sports fishing industries in coastal California, are at all-time lows throughout the state. Many streams and rivers have lost their entire runs of these fish. Marin County is fortunate to still have several streams that support viable salmon and steelhead runs.

West Marin has changed dramatically since European settlers first arrived in the early 1800s. The human population has increased greatly, and with that, land use has become more intensive. Land that for centuries was used for hunting and gathering by Coast Miwok, is now intensively managed for production of beef, sheep, and dairy products. Population densities have, however, remained much lower than in urban areas. Because of this, rural residents have always been able to provide and manage their own water systems. Ranches of several hundred to several thousand acres generally produce enough water from springs, wells, and streams, to sustain agricultural and residential needs.

In cities, municipalities own watershed land, sometimes far removed from city centers, and residents have little connection to their water sources. City residents often do not know where their water comes from, but in rural areas the connection is more direct, and rural landowners have a high level of responsibility for maintaining their own water quality.

Everyone is affected by water pollution and will somehow benefit from improved water quality. While agriculture is not the only source of water quality degradation in West Marin, it is the predominant land use, and as such, has a greater effect on water quality and natural resources than many other land uses. This report is intended to provide a better understanding of agriculture's effect on water quality and natural resources so that agriculturists and conservationists can work together to improve stream condition and fish populations.

3. Project Area Description

Setting

The project area encompasses 232 square miles (148,480 acres) of land in West Marin that drains into Tomales Bay and Bodega Bay. These bays, their estuaries where fresh and salt water meet, and their freshwater tributaries, provide vital habitat for myriad wildlife species, as well as sustaining commercial fish species, and providing recreational opportunities and aesthetic benefits.

The project area extends from the low hills that define the northern boundary of the Stemple Creek/Estero de San Antonio watershed just north of Dillon Beach, to the southern end of the Lagunitas Creek watershed on the northern slope of Mount Tamalpais (see Figure 1). Major watersheds within the project area include Stemple Creek/Estero de San Antonio watershed (the 25 square miles that are within Marin County), Walker Creek (except for a small area that is within Sonoma County), and Lagunitas Creek. Major tributaries include Chileno, Keys, Salmon, and Arroyo Sausal Creeks within the Walker Creek watershed, and Nicasio, San Geronimo, Olema, Devil's Gulch, and Deadman's Gulch, within the Lagunitas Creek watershed. Also included are the small coastal streams that drain into the east side of Tomales Bay. These include Millerton Gulch, Tomasini Canyon, Grand Canyon, and numerous small unnamed streams. Each of these major watersheds comprise distinct geographic units, with variable climatic, physical, and biological features.

In the northern part of the project area, topography is characterized by the low, gently rolling hills of the Stemple Creek/Estero de San Antonio watershed and the northern part of the Walker Creek watershed. Moving south, the landscape becomes more rugged as Walker Creek and Lagunitas Creek wind through narrow, steep sided canyons.

Variations in climate are most affected by proximity to the coast. For example, Chileno Valley, in the upper Walker Creek watershed, is one of the drier areas. This subtle climatic difference has affected local land use in that Chileno valley was never an important potato growing area, as the climate is too dry. Climatic differences within the project area also control, to a degree, the types of vegetation and stream characteristics in the different watersheds. Average annual rainfall in the lower Lagunitas Creek watershed is nearly ten inches greater than in the lower Walker Creek watershed. This difference affects the quality and quantity of riparian cover on these streams, streamflow, and to a degree fish habitat within the streams. Because of these characteristic differences, each of the project area watersheds is described individually later in this report.

Geology and Erosion

Underlying geology and geomorphic processes play a dominant role in soil formation, erosion, water flow, streambed composition, and many other features that control the way watersheds and streams function. Inherent differences in geology may determine the stability of some streams and watersheds, and intrinsic instability in others.

Some erosional processes are cyclic in nature, occurring periodically when all forces acting on them coincide. Although human land use can dramatically affect erosional processes, inherent geologic characteristics strongly influence the tendency toward erosion. Complex erosional processes have extremely variable rates, often for no clearly evident reason. A hillside may be actively gullied for a few years or decades, then the gullies may stabilize and be covered with vegetation. A stream may have stable banks for decades or centuries, then during one flood may undercut, and the stream may enter a period of active bank cutting and channel shifting. Many of the changes in erosion rate and the processes acting on erosion are probably due to changes in climate, sea level, or to deformation of the land through mountain-building processes (Wahrhaftig and Wagner, 1972).

It is often impossible to distinguish between processes that are the result of human activities and natural processes. Hect (1980) believes that the physical condition of stream habitat in Marin County is strongly affected by the amount and intensity of rainfall, the magnitude and duration of runoff, and upland influences on sediment production, and states that sediment transport in coastal California streams is strongly affected by episodic sediment-producing events. Fires, landslides, land use changes, and numerous other watershed processes often result in sharply increased sediment loads.

In the Tomales Bay area, the most predominant geologic feature is the San Andreas fault. The San Andreas is an active strike-slip fault that moves about 175 miles in 23 million years (slightly less than 1/2 inch per year). The fault follows a northwest trend through the Olema Valley, Tomales Bay, and Bodega Bay. Tomales Bay occupies the northwest end of the fault valley, and the bay was formed by invasion of the sea following the last ice age between 10,000 and 5,000 years ago (Wahrhaftig and Wagner, 1972).

This fault plays a primary role in the topography, geology, and stability of the region and serves as a divide between two distinct underlying geologies. On the northeast side of the fault, bedrock is Franciscan Formation, deposited as muds, sands, and lava flows on a sea floor 80-140 million years ago, that has since been disturbed by thrusting below the continental crust. This formation underlies all of the project area except for the southwestern portion of the Olema Creek subwatershed, which is composed of granitic and young sedimentary rocks. Franciscan Formation is inherently subject to debris flows and landslides, especially on steep slopes.

North of Walker Creek, Wilson Hill Formation (formerly called Merced Formation) was deposited over the Franciscan Formation about 5 million years ago. This formation consists of soft sand, silt, and clay that has uplifted and eroded, leaving remnants on the hilltops. According to Wahrhaftig and Wagner (1972), the Wilson Hill Formation has less tendency toward landsliding, but is highly erodible and easily gullied. Erosion from historic potato farming in the Tomales area was primarily on Wilson Hill Formation soils.

In the millions of years since the Franciscan and Wilson Hill Formations were laid down, various erosional processes have moved material off of hilltops and into valleys. Alluvium, which is eroded material deposited by water, has accumulated in valleys and continues to be deposited where upstream erosion is active. This material is up to 20 to 30 feet thick in some areas. Both Lagunitas and Walker Creek are bordered by alluvial plains several hundred feet wide.

Typical types of erosion that contribute to stream degradation in the project area include streambank erosion, gullies, sheet and rill erosion (on unvegetated areas), and, in naturally unstable areas, landslides and debris flows. Streambank erosion is a problem on streams that lack riparian vegetation, and, because eroded

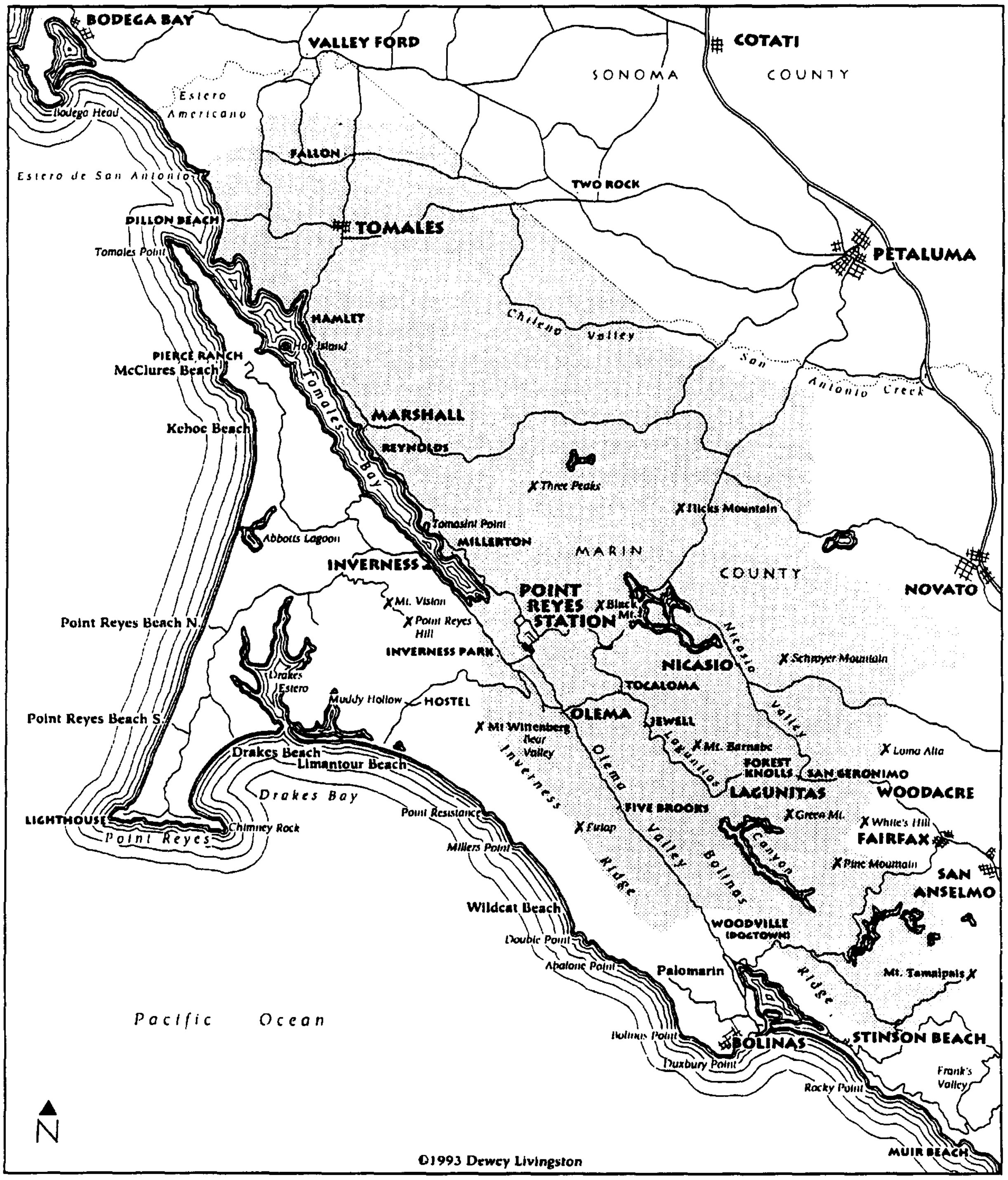


Figure 1
Map of Project Area

material is deposited directly into streams and bays, is a primary source of water quality and habitat degradation. Woody riparian vegetation provides natural armoring against the erosive power of flowing streams, and tree and shrub roots bind soil, increasing its cohesion.

Gullies result from concentrated water flow, often in areas lacking protective vegetation. They commonly result from poorly constructed or maintained roads. Unprotected culvert outlets, road drainage ditches that concentrate water flow, and roads where surface flow is not properly diverted, are common causes of gully initiation. Gopher tunnels and livestock trails in pastures can also help to initiate gullies.

Cultivated fields and overgrazed pastures are potential sources of sheet, rill, and gully erosion. Lack of vegetation leaves soil unprotected and decreases water infiltration in these areas, resulting in increased runoff and removal of surface soil particles. All of these types of erosion result in degradation of soil productivity as well as sedimentation of streams, estuaries and bays. Specific significant erosion problems are discussed in more detail in the Water Quality section and the watershed profiles later in this report.

4. Land Use History

The predominant land use in much of the northern part of the project area, is, and has been for over 100 years, animal agriculture, including beef, sheep and dairy production. Cultivated crops, including potatoes and hay, at one time also played an important role in the local economy. Other land uses now include non-agricultural open space, watershed, and recreation. Tomales Bay and its tributaries also support commercial shellfish production and commercial and recreational fishing.

The importance of the different agricultural commodities produced in this region has ebbed and flowed over the years, and has varied somewhat by watershed, due to the suitability of the land and climate to producing different crops. Dairying, which was widespread throughout West Marin at one time, is now concentrated in the northern part of the project area, where topography is gentle, rural residential development is less extensive, and grasslands are the predominant vegetation type. Beef ranching and some sheep ranching also occur here, but are more prevalent in the steeper, rugged, less fertile hills to the south. Scattered throughout this agrarian setting are several small communities which originated as agricultural and fishing villages and summer tourist destinations.

Further south, on the forested slopes of the Lagunitas Creek watershed, logging was once an important industry. Much of this area is now owned by the Marin Municipal Water District (MMWD) and is used for watershed to supply water to residents of East Marin. The residential communities in the Lagunitas Creek watershed originated as logging towns and summer homes.

Agriculture

Animal Agriculture. Because of a demand for hides and tallow, and later beef, the cattle industry boomed in California in the mid-1800s. In 1850, Marin County was among the ten leading cattle counties in the state, with 6,981 head. Marin County's share of statewide cattle production decreased over the following two decades, and the county did not rank among the top ten again until 1880, at which time cattle were censused at 32,449 head, most of which were dairy cattle. This was the last year that Marin County was among the top ten cattle counties; by this time, cattle production was well established in the Central Valley which substantially outproduced the coastal areas (Burcham 1957).

Sheep became an important commodity in the late 1850s, although sheep numbers have been highly variable between years and decades since then. In 1860, the county's sheep population was 9,979, up from 500 in 1850. Sheep production decreased dramatically in 1880, and did not rebound to the 1860 level until 1920 (Burcham 1957). The next few decades saw sheep numbers that were many times higher than in recent years.

In the dairy industry, Marin was the statewide leader from 1862 until about 1910; by 1920 Marin was the 11th dairy county in the state, having been surpassed by the San Joaquin Valley and Humboldt County. The successes of Marin County's dairy production apparently led to widespread overgrazing by the turn of the century. A number of sources describe the pasturage in many areas as overstocked and depleted in the early 1900s (US. Census Agricultural Statistics; Haible, 1976; Boissevain, M. B., Annual Reports, 1922-1939).

In the 1950s there were about 200 dairies in Marin County. By 1960 this number had dropped to 150, and by 1972, to less than 100. The declining trend in the number of dairies is still continuing. As a result of increasing costs, decreasing milk prices, and deaths or changes in property ownership, West Marin dairies continue to go out of business every year. There are presently 25 operating dairies within the project area—ten in the Stemple Creek/Estero de San Antonio watershed, three within the Lagunitas Creek watershed (in the Nicasio Creek subwatershed), seven in the Walker Creek watershed (four in Chileno valley, two in Keys Creek and one on mainstem), and five along the east side of Tomales Bay.

While the number of dairies has declined since the 1950s, milk production per dairy has increased substantially due to increased production per cow and larger herd sizes. While the typical dairy had a milk herd of less than 100 cows up until the 1960s, today the average herd numbers around 300 cows. When herds were smaller and dairies were often part of a more diversified farming operation, cows were fed less and spent more time grazing in pastures. During these times, the volume of manure produced on dairies was less, and accumulated manure presented less of a problem, although waste facilities were much less sophisticated than today.

Beef ranches, sheep ranches, combination beef and sheep ranches and replacement dairy heifer operations occupy most of the agricultural lands that are not used for dairying. Most ranching families that have traditionally been in the sheep business now graze both sheep and beef cattle. This combined production more efficiently utilizes pasture forage and provides some insulation against volatile prices in the sheep industry.

Potatoes and Other Cultivated Crops. The soil and climate around Tomales was recognized by pioneers as favorable for growth of potatoes. Sea fogs during the summer promoted potato growth, while grains such as wheat and barley did better inland around Chileno Valley. By 1862 Marin was fourth in the state for potato production (133,500 bushels), most of which was occurring in the northern part of the county.

In the mid-1800s most farmers in the Tomales area grew potatoes. In 1860, out of 75 farms in the Tomales area, only eight were producing more than 1,000 pounds of butter, whereas 26 farms produced more than 1,000 bushels of potatoes; only 28 produced no potatoes at all. Wheat, oats and barley were also major crops among these farms. By 1880, most farms were making more than 3,000 pounds of butter per year (some up to 20,000 lbs), and yet almost all of them continued to grow a commercial crop of potatoes averaging 600-2,000 bushels on an average of 30 acres per farm. Wheat, oats and barley production fell. Small apple orchards began to appear in the 1870s as well. Virtually every rancher in 1880 was tilling at least 25 acres of his land, with the average closer to 100 acres. Eventually potato production dwindled; a writer described the state of affairs in the vicinity of Tomales around 1885:

> *In old times, when potatoes were worth several cents a pound, fortunes were often realized in a single crop. But with the opening up of the state other fields have come into the market, with the inevitable result of reducing prices. In due course of time the great profits disappeared and, what was still worse, the productive resources of the soil became seriously impaired. Several years came on during which the price of potatoes was reduced to about the cost of raising them. The consequence was inevitable. Land owners saw their neighbors growing rich around them, who were engaged in butter making .... Most of them changed their base .... Tomales, that once shipped hundreds of thousands of sacks yearly, does not produce ten per cent of the former output. Still, the [Tomales] section continues to affect the market and is noted in all commenced quotations. Tomales potatoes again are noted among the favorite growths of California* (Clark, ca. 1880).

The potato farmers, striving to obtain better marketable varieties and improved methods of growing, worked with the first U. C. Extension Farm Advisor in Marin County, M. B. Boissevain. The British Queen potato was the major type grown, especially around Fallon. Boissevain promoted the Burbank potato and a new variety, the Farley potato, developed by James Farley of Fallon. Nevertheless, Boissevain admitted that, although potatoes continued to be one of the principal cash crops in north Marin, it was "not a very profitable undertaking" due to the need for fertilizers, poor strains of seed potatoes, and the fact that the variety which traditionally grew best in the region did not command a very high price at market. By 1938 he wrote, "potato growing seems to be on the way out in our section." While the market for milk products increased during this time, the potato industry had developed a stronghold in southern California and by 1940 only about 100 acres were given to potato growing in Marin County.

Other Agriculture. The upper Stemple Creek watershed, noted for lack of water needed for both dairying and farming, was once the western outpost of the famous Petaluma chicken industry. Several poultry (turkey and chicken) operations still exist in this watershed. One of the largest local poultry farms is the Reichardt Duck Farm. The duck farm — which produces about 1,000,000 ducks per year—drains into Laguna Lake, at the headwaters of the Walker Creek watershed.

In recent years, several truck farms have also been established in the Lagunitas Creek and Stemple Creek/Estero de San Antonio watersheds.

Non-agricultural Land Uses

Non-agricultural Open Space (Watershed Lands/Wildlife Preserves /Park Lands). Non-agricultural open space comprises a substantial percentage of the Lagunitas Creek watershed, but very little of the remainder of the project area. MMWD owns approximately 20,000 acres, or 30% of the Lagunitas Creek watershed (Dana Roxon, 1995). The MMWD lands, in the southernmost part of the watershed, include Alpine, Bon Tempe, Kent and Lagunitas Lakes and their surrounding subwatersheds. MMWD manages their properties for water supply and allows non-water contact recreation such as hiking, bicycling, horseback riding and fishing. Most of the MMWD property is not grazed, although there are small areas within the Nicasio Creek subwatershed that are grazed.

Golden Gate National Recreation Area (GGNRA) and Point Reyes National Seashore (PRNS) own a combined total of 14,122 acres within the Lagunitas watershed, 8,925 acres of which are in the Olema Creek subwatershed. Within the Lagunitas Creek watershed, 10,822 acres are in ranching, 5,825 of which are within the Olema Creek subwatershed.

Other non-agricultural open space lands within the Lagunitas Creek watershed include a 42 acre wildlife preserve on Olema Marsh owned by Audubon Canyon Ranch, the 2,010 acre Samuel P. Taylor State Park, and six properties owned by the Marin County Open Space District (MCOSD) totaling approximately 700 acres. MCOSD may acquire an additional 1,600 acres in the San Geronimo area pending development of the French Ranch and Sky Ranch properties.

Non-agricultural open space lands make up minor parts of the Walker Creek and Stemple Creek watersheds. MMWD owns 2,100 acres adjacent to Soulajule reservoir, some of which is grazed by cattle. DFG owns 20 acres at the confluence of Walker Creek and Keys Creek.

On the east shore of Tomales Bay between the major watersheds, there are several small wildlife preserves. Twelve properties totaling 370 acres are owned by Audubon Canyon Ranch, and there are numerous smaller parcels that are used as home sites that currently provide non-agricultural open space. Tomales Bay State Park encompasses approximately 2,000 acres along the east shore of Tomales Bay.

Rural Residential Development and Small Communities. Small pockets of residential development are scattered throughout the project area. In the Stemple Creek/Estero de San Antonio watershed, most of the smaller residential parcels are in Sonoma County, outside of the project area. Walker Creek is the least populated of the project area watersheds, with the only densely populated community being Tomales. In the small watersheds draining directly into Tomales Bay, communities include Dillon Beach and Marshall. The most well-developed residential communities are in the Lagunitas Creek watershed and include the communities of Forest Knolls, San Geronimo, and Woodacre, in the San Geronimo Valley; Nicasio, in the Nicasio Creek subwatershed; Olema, in the Olema Creek subwatershed; and Point Reyes Station at the mouth of Lagunitas Creek.

Commercial and Recreational Fishing and Aquaculture in Tomales Bay

Oysters *(Crassostrea gigas)* and (C. *virginica),* halibut *(Paralichthys californicus),* herring *(Clupea pallasi),* and to a lesser degree ghost shrimp *(Neotrypaea californiensis)* and rock crab *(Cancer* spp.) are all commercially harvested from Tomales Bay (Tom Moore, 1995).

The oyster industry has been active on Tomales Bay since the early 1900s. Much of the eastern shore of Tomales Bay has at one time been a growing ground for oysters, with the first recorded plantings near Millerton Point in early 1875. In 1876, newspapers reported that oysters were being shipped to San Francisco, but there was no more mention of Tomales Bay's oyster industry until the early 1900s when pollution in San Francisco Bay drove the oyster growers back to Tomales Bay. Statistics show that Tomales Bay oyster production grew from a small industry (0.1% of the California market) in 1915, to being the largest producer in the state by the 1950s (79.3% in 1953) (Livingston, 1989). Jensen's Oyster beds operated at Hamlet from the 1920s or 1930s until 1983 when DFG ordered abandonment of their leases. The Jensens were plagued with contamination of oysters by their septic system, as well as problems from sedimentation of their beds at the mouth of Walker Creek. Due to sediment buildup at the mouth, Jensen's lease shrank from 88 acres in 1939 to 30 acres in 1980. Heavy storms in January 1982 destroyed what was left of the Jensen oyster beds, filling them with mud and debris, and washing the oysters away (Livingston, 1989).

Oysters are farmed on leased parcels that are managed by DFG. DFG inspects and regulates the amount of seed shipped and planted, collects rent on the leases, and issues and checks mariculture leases (Livingston, 1989). There are seven companies currently fanning oysters in Tomales Bay, and several other leases that are not actively farmed (Olin, 1995). This industry has been fairly stable since its beginning near the turn of the century. Although relatively small in economic terms (approximately $1 million in gross sales annually), it has growth potential, since several of these oyster companies hold leases that await development.

Halibut and herring are commercially harvested from wild populations that fluctuate with environmental conditions. Herring has been harvested commercially in Tomales Bay since the late 1800s, when it went out on the railroad to San Francisco and other destinations. Since 1973, locally harvested herring has been exported to Japan for the roe.

Herring landings have fluctuated dramatically over the years and are limited by quotas set by DFG, based on an estimate of the spawning biomass. This fishery was closed between 1989 and 1993 due to low spawning biomass induced by several years of drought. Since herring thrive in the less saline parts of the bay, years in which fresh water inputs are low diminish the herring population. In 1994, 275 tons of herring, with an approximate value of $462,000, was landed at Tomales Bay.

Halibut is harvested commercially, as well as by recreational fishermen. Tomales Bay is at the northern end of the halibut range due to low water temperatures along the northern California coast. During El Nino years, the range pushes north and halibut fishing improves in Tomales Bay. The commercial halibut take fluctuates year to year and in 1994, the take was 7,500 tons, with a value of approximately $20,000 (Tom Moore, 1995).

5. Habitat Needs of Coho Salmon and Steelhead Trout

Riparian corridors—streams and the vegetation that surrounds them— provide habitat for many important plant and wildlife species. Although some of the creatures that rely on riparian habitats, such as insects, may seem insignificant, they are part of an integral system that helps to support vital fish and wildlife species. The two riparian species that have historically been most important for commercial harvest and recreational use are coho salmon and steelhead trout.

Coho salmon and steelhead runs along the Pacific coast have dropped sharply over the last 50 years. Both wild and hatchery coho salmon in California have declined 70% since 1960, with wild coho at only one percent of their historical abundance. Steelhead populations are less than half of what they were 30 years ago, and both fish are likely to be listed as endangered or threatened species. Many streams and rivers have lost their entire runs of these fish (California Department of Fish and Game, 1994).

In Walker Creek, which probably once had large populations of coho salmon and steelhead (Rich, 1989), both of these species have declined to very low levels. Stemple Creek/Estero de San Antonio and its tributaries historically supported a good run of steelhead, which has now dwindled to almost none. More promising is the fact that Lagunitas Creek, with an estimated run of 500 coho, is thought to support 10% of the total run in California (Cox, 1995 and California Department of Fish and Game, 1994). Salmonid populations in the small streams on the east side of Tomales Bay are undocumented.

Habitat needs of anadromous salmonids, which spawn in fresh water and mature at sea, vary seasonally and by species. Generally, a favorable habitat for salmonids will have an adequate supply of unpolluted water, a favorable range of water temperatures, pools for rearing young and resting, an adequate food supply, water with sufficient oxygen, clean spawning gravel, and a balanced ecosystem with few competitors (Rich, 1989). Steelhead are more flexible in their habitat needs and are more adaptable to change than are coho salmon. Coho inhabit streams for one year and are especially sensitive to stream environments. Coho have a greater need for certain habitat characteristics such as low water temperatures, shade, and cover. Woody debris in the stream from fallen trees and branches are especially important to coho salmon. Coho salmon spend their first year in freshwater streams, migrate out to sea where they live for two years, and return to their native stream where they spawn and die. Steelhead have a similar life cycle, but live in fresh water for one to two years, spend one to four years at sea, and can return to spawn up to four times.

From November to March, mature salmonids return to their native streams in coastal Marin County. At this time of year, good spawning habitat is critical. Requirements for spawning include adequate streamflows, silt-free spawning gravel, appropriate water temperatures, and unpolluted water (Rich, 1989). During late spring and summer, conditions for development and survival of young become more critical. Young coho salmon and steelhead trout prefer habitats which have cool water, shallow riffles for catching food, good cover, uncrowded conditions, and clean water. The ideal temperature range for steelhead is 55°F to 60°F, while coho need water that is only 48°F to 57°F.

Many of the conditions that are necessary for successful reproduction and growth of salmonids have been altered by land use and severe weather. Streamflows have been reduced by water diversion and impoundments for agriculture, and much more significantly, to supply residents of East Marin. Stream temperatures have been greatly affected by destruction of riparian vegetation and, in some areas, by the release of warm water from reservoirs.

Accelerated erosion and resulting sedimentation have contributed to many of the problems that these fish face. Erosion has been increased by both human land uses and by severe winter storms which trigger natural, cyclic erosion events. Sediment accumulation in streams reduces the number and depth of pools where adult salmonids rest and young survive the summer. It also embeds spawning gravel, reducing the oxygen level, and allowing eggs to wash downstream with fine sediment during high flows. Coarser gravel provides a more stable environment for developing eggs.

Habitat destruction has a twofold negative effect on salmonid populations. With the continued decrease in the amount of good habitat available to salmonids, competing fish that are better able to survive the less than optimal conditions compete with salmonids for habitat. Water pollution can stress fish severely, and some pollutants can cause death at high levels. Ammonia, especially in its un-ionized form, low levels of dissolved oxygen (DO), and high levels of salts, can all result from animal waste and can cause stress or death of fish.

Some activities that may seem like good management can actually be harmful to salmonids. Cleaning the woody debris out of streams can decrease vital cover and shade. This type of stream cleanup should be balanced with erosion protection needs, as downed trees and branches provide cover and shade for salmonids.

6. Water Quality

Local Importance of Water Quality

High quality water is vital to fish and other aquatic organisms, as well as many human activities. Surface water is used for watering livestock; for recreation, such as boating and fishing; for domestic use by residents of East Marin; and is the medium that oyster farmers rely on to grow their crop. Water is required to grow and process the food we eat, and directly or indirectly to produce or operate most of the materials and goods that we use every day. Most drinking and domestic water in West Marin is from groundwater—underground aquifers that are pumped through wells up to several hundred feet deep. Clearly, there are many important human activities that depend on abundant sources of dean water.

Water quality can be affected by land use and by natural factors. Background levels of some pollutants occur naturally, and in some cases it can be difficult to know if natural processes, human activities, or a combination of both, are the cause. Human activities have a great impact on the quantity and quality of both surface waters and ground water. Groundwater contamination can be a problem in areas where intensive land uses continually contribute pollutants that percolate into the ground, rather than running off in surface waters. Because West Marin is sparsely populated, topography is hilly, and land use is relatively extensive, pollution of surface waters is more likely than ground water contamination.

Types of water pollutants vary according to land use in different areas. In urban areas sources of water pollution include runoff of oil and gasoline from streets, industrial chemicals, and sewage. Marin residents are fortunate to live in an area where major industrial pollutants are not a primary concern. Local pollution sources include sewage treatment plants and septic systems; runoff from streets and highways; sediment from construction, road building, and agriculture; and waste from animal agriculture and horses. In West Marin, land use is primarily agricultural, with many dairies, beef, and sheep ranches. Because of this, water pollutants that are most likely to occur, and are therefore of greatest concern, are those which are produced by animal agriculture.

The term *nonpoint source pollution* (NPS pollution) is used to describe pollutants contributed from many small sources that cannot be easily identified individually, but collectively degrade water quality. Pollution caused by release of waste or contaminated water through a man-made structure such as a pipe is termed *point source pollution*. Similar types of land use can cause both non-point and point source pollution; it is the way in which pollutants are disseminated that distinguishes between the two. For example, manure that is pumped from a manure pond onto a hillside can become NPS pollution if it is washed off the hill by rain. That same manure would be considered a point source if it was pumped through a pipe directly into a stream. The concept of NPS pollution considers that pollution can accumulate from many diverse sources from all over a watershed, and that many small management improvements can have a beneficial effect on water quality.

Agricultural Sources of Water Pollutants in West Marin

Although generalized statements about the effects of livestock and grazing on water quality are often made, realistically, each operation differs in intensity, management practices, and site characteristics; therefore, the pollution potential on each site is different. Livestock related pollution can be highly variable throughout a ranch and throughout the seasons. On any ranch, most management practices may be very good, but there could be an occasional "event" that contributes significant pollution to a waterway. On some properties many seemingly insignificant pollution sources may cumulatively degrade water quality. Other properties may not contribute to pollution at all. In order to improve water quality and stream conditions, it is essential to identify the activities and sources that are actually causing water quality degradation on a site by site basis.

Nationally, sediment is considered to be the number one category of NPS pollution on rangelands. However, because of the number of dairies in West Marin which, by their nature, require the confinement of large numbers of animals, water quality degradation from animal waste is considered to be the most critical source of water quality degradation locally. Animal waste can contribute to nutrient pollution and can be a source of pathogens. It is important to note that confined horse facilities, which are not technically considered to be agricultural operations, may also be a significant source of animal waste pollution in some areas of Marin County.

Although some compounds found in animal waste (such as un-ionized ammonia) can cause acute toxicity and immediate death to aquatic organisms, they can dissipate fairly quickly. Sediment, however, accumulates in streams, causing greater and greater problems that often cannot be corrected. Examples of this type of damage are the sedimentation of Walker and Keys Creeks and the Estero de San Antonio.

Local representatives from the Regional Water Quality Control Boards (Regional Boards), California Department of Fish and Game (DFG), University of California Cooperative Extension (UCCE), Natural Resources Conservation Service (NRCS), and Point Reyes National Seashore (PRNS), have held several meetings to develop guidelines for local water quality monitoring programs. One of the main purposes of these meetings was to make sure that agency representatives working with landowners to do their own water testing are consistent in their recommendations. Agency personnel have identified water quality variables that are most likely to cause problems in agricultural areas in West Marin. These are, in order of decreasing importance, ammonia, temperature, pH, conductivity, water flow, dissolved oxygen (DO), and sediment.

In certain areas, water quality monitoring has shown that other water quality variables also contribute to water pollution. For example, water testing conducted by the Santa Rosa Subregional System in Stemple Creek/Estero de San Antonio, has revealed elevated levels of copper. Following are descriptions of the common pollutants from animal agriculture.

Ammonia. Ammonia results from decomposition of organic nitrogenous compounds in manure and other organic debris by microbes. Total ammonia is composed of two forms: ionized ammonia (NH_4^+), and un-ionized ammonia (NH_3). Of these two forms, the un-ionized NH_3 is far more toxic. The percent of total ammonia in the harmful un-ionized form increases with higher temperatures and pH values. Un-ionized ammonia can be lethal at concentrations of 0.025 parts per million (ppm).

High levels of ammonia are toxic to fish and other organisms. Ammonia is naturally produced by fish and is excreted primarily through their gills. Ammonia excretion is reduced if there are high ammonia levels in surrounding waters, causing high blood ammonia levels in fish. Fish respond to this increase in blood ammonia by reduced feeding, which slows metabolic ammonia production. High blood ammonia levels increase a fish's need for oxygen, while at the same time reducing the ability of the fish's blood to transport oxygen. Extremely high ammonia levels can damage gills and ultimately kill fish.

Any activity that allows animal waste to be directly deposited in, or very near a waterway, could be a source of NPS pollution.

NPS pollution by nutrients can be caused by animal wastes, decaying vegetation (such as silage), and pasture fertilization. Pollution from animal waste can result from rangeland grazing, but most often occurs when livestock are confined and animal wastes are concentrated. Any activity that allows animal waste to be directly deposited in, or very near a waterway, could be a source of NPS pollution. Accumulation of animal waste in corrals, feeding or watering areas, and alleyways create potential sources of NPS pollution if these areas are located near waterways or where runoff could carry nutrients into waterways.

Incorrect application of animal wastes to pastures and crop fields can also cause NPS pollution. Wastes should be applied at rates appropriate for the crop being fertilized. Improper storage of silage can allow highly concentrated nutrients to flow into waterways or percolate into the groundwater, which can eventually flow into waterways.

Conductivity. Conductivity is a measure of the capacity of water to transmit an electrical current. Conductivity is useful in detecting pollution from livestock urine due to the high concentration of salts in urine and the fact that the salts persist much longer than ammonia. High salt concentrations in surrounding waters disrupt the balance of salts in fish blood. This causes stress, and at extremely high levels can kill fish.

pH. pH is a measure of the hydrogen ion concentration and ranges in value from 0 to 14. A value of 7 is referred to as neutral, while values below 7 are called acidic, and above 7 are said to be basic. The pH of water is influenced by water source, underlying soil, effluent discharges from agricultural, industrial, and urban sources, algae, and microbial activity. The pH of water is important because it influences the amount of total ammonia that is in the most toxic un-ionized form (NH_3). High pH values increase ammonia toxicity because a greater percentage of the total ammonia is in the un-ionized form.

Temperature. Temperature is important because it directly affects animals and also influences the physical characteristics of water and pollutants such as ammonia. Extreme temperatures have harmful effects on animal metabolism, feeding, growth, disease resistance, and reproduction. Cool water contains higher levels of dissolved oxygen than warmer water and has lower levels of toxic un-ionized ammonia. The optimum water temperature range for coho salmon is 48°F to 57°F, well below the summer temperature of many local streams.

Dissolved Oxygen. Dissolved oxygen, often referred to by the initials DO, is a measure of the oxygen that is dissolved in water. DO is critical for all aquatic life, just like oxygen in air is essential to humans and other terrestrial organisms. Because DO makes up a very small percentage of water, changes as seemingly minor as 1 ppm can have a large impact on aquatic life. At a water temperature of 50°F DO would typically be 11 ppm. When water temperature rises to 80° F, DO can drop dramatically to 8.0 ppm, a 27% decrease.

Water Flow. Water flow rate influences the concentration of pollutants and has a significant effect on habitat conditions for fish and other aquatic animals. At low flows, pollutants can become concentrated, increasing their toxicity. Low water flows can also cause rearing and migration problems for salmonids. Adequate water flows are needed in the fall for migration and spawning, and in the summer to maintain rearing pools.

Sediment/Erosion. Excessive sediment from erosion can fill in gravel beds used by salmon and trout for spawning. This can make the beds unsuitable for spawning or smother developing eggs in the gravel. Sediment can also fill in deep pools that remain cool in the summer and provide habitat for young fish.

Sources of excessive sediment include streambank erosion; gullies; sheet and rill erosion from bare corrals, crop fields, unpaved roads, other unvegetated areas; and landslides. Many different ranch activities can cause accelerated erosion.

Streambank erosion is the most serious source of sediment because eroded soil is deposited directly into streams. Upland erosion sources also move sediment, but this sediment may never reach a stream. While some streambank erosion does occur naturally, it is often caused by removal of woody riparian vegetation. Woody riparian vegetation armors streambanks against the force of flowing water, acting like natural rip-rap. Livestock trampling and congregation in streams is another common cause of streambank erosion. Any stream that has significant areas of bare soil on the banks, particularly if the banks are vertical and actively eroding, contributes damaging sediment to the stream system.

Gullies are another major source of damaging sediment. Gullies are often caused by activities that concentrate water flow, such as road building, crop cultivation, and livestock trails. Natural occurrences, such as rodent tunnels, can also initiate gullies. Maintaining good vegetative cover is important for preventing gullies. Vegetative cover improves water infiltration, reducing the chance for concentrated runoff. Overland flow increases on bare soil surfaces and can cause gullies to form.

Landslides may contribute to water quality degradation, but in most cases they cannot be effectively treated. Landslides often occur when saturated soils slide over subsurface bedrock, and are controlled by inherent physical factors.

Sheet and rill erosion commonly occur on unvegetated crop fields, corrals and roads, and can also occur on overgrazed pastures where vegetative cover is poor. When vegetation is inadequate to slow water flow and allow infiltration, water can run off in a continuous sheet, moving soil particles downslope. Concentrated flows can cause rills to form, which can grow into gullies. Sheet and rill erosion increase toward the base of slopes, as water moving downslope accumulates, increasing its erosive power. Sheet and rill erosion tend to cause depletion, or loss of soil near the top of eroding slopes, and accumulation of soil at the base of eroding slopes. Accumulation of soil around fence posts or trees at the base of slopes is a sign that accumulation is occurring. "Pedestalling" of small pebbles, where soil has eroded around them, and formation of small rivulets on the soil surface, are signs of soil depletion.

Pathogens. Since pathogens are transmitted through animal wastes, the same conditions that cause nutrient pollution from animal wastes can cause pathogen pollution. Many of the pathogens that are carried by livestock can cause illnesses in other livestock, humans and wildlife.

Many pathogenic organisms that can be transmitted through livestock waste, including bacteria, viruses, and parasites. Of the potential diseases that can be caused by these organisms, Cryptosporidia, a protozoan which causes the gastrointestinal disorder Cryptosporidosis, is of greatest concern because it is difficult to remove from domestic water systems.

Water Quality Laws and Agency Responsibilities

Water quality is regulated by federal and state laws. Although many government agencies are involved with water quality regulation, most of these laws are enforced locally through the Regional Boards and DFG. In California, authority for enforcing federal water quality laws is passed from the Environmental Protection Agency (EPA), to the State Water Resources Control Board (State Water Board), and then to the Regional Boards. DFG also has authority to regulate water pollutants that are damaging to aquatic life. Water quality laws that specifically address nonpoint NPS pollution include the California Porter-Cologne Act, the federal Clean Water Act (CWA), and the federal Coastal Zone Act Reauthorization Amendments (CZARA). Fish and Game acts under the authority of Section 5650 of the State Fish and Game Code, which prohibits water pollution by "any substance or material deleterious to fish, plant life, or bird life."

The Porter-Cologne Act, enacted in 1969, was California's first water quality law to significantly affect dairy waste management. This act designated the State Water Board as the statewide water quality planning agency and gave local authority to the nine Regional Boards, which were established in the 1940s. Though the Porter-Cologne Act addressed both point and nonpoint sources of pollution, it has focused on point sources and resulted in construction of waste ponds on most dairies in the mid-1970s. The State Board is responsible for developing statewide water quality plans, while the Regional Boards are responsible for developing Regional Water Quality Control Plans (Basin Plans)—which in turn are approved by the State Water Board and the EPA. Both the statewide and Basin Plans identify beneficial uses, water quality objectives, and implementation mechanisms. Regional Boards have the primary responsibility for implementing both the statewide and basin plans.

West Marin falls under the jurisdiction of two Regional Boards. The Stemple Creek/Estero de San Antonio watershed and Estero Americano watershed are within the North Coast Regional Office (Region 1) in Santa Rosa. Marin County south of the Stemple Creek/Estero de San Antonio watershed is within the San Francisco Bay Area Regional office (Region 2) in Oakland.

The federal Clean Water Act, originally enacted in 1972, has been amended numerous times, most importantly by Section 319, in 1987. Section 319 of the CWA was the first law that strongly emphasized control of NPS pollution. Section 319 specifies that sediment, nutrients, pathogens and chemicals are important NPS pollutants. The most recent federal law addressing NPS pollution is the CZARA of 1990, which require landowners to treat NPS pollution. CZARA affects all lands within coastal zones nationwide and the entire state of California.

EPA has authority to implement and enforce the CWA, and along with the National Oceanic and Atmospheric Administration (NOAA), has joint authority to approve state NPS programs related to CZARA. CZARA requires each state water resource agency to establish coastal NPS programs that are consistent with Management Measures and Management Practices specified by EPA. Implementation of these Management Measures and Management Practices is expected to reduce NPS pollution to acceptable levels.

Local Application of Water Quality Regulations

Locally, the two agencies that are primarily responsible for monitoring water quality and enforcing related laws are the Regional Boards and DFG. Responsibility for enforcement of all these federal and state water quality laws, except for Fish and Game code, rests with the Regional Boards. The Regional Boards act on their authority to protect "beneficial uses" of water, which include domestic, municipal, agricultural, recreational, aesthetic, preservation and enhancement of fish, wildlife, and other aquatic resources or preserves, and others. In West Marin, because agriculture is the primary type of land use, these agencies focus on controlling agricultural sources of pollution.

Regional Board staff identify water quality violations through citizen complaints, observation of blatant violations, and by notification from DFG. Regional Board staff have no prior right of access to private property without notification, unlike Fish and Game wardens. Air reconnaissance has also been used to identify violations.

DFG wardens are the prime investigators in reports of water quality violations for Fish and Game. Violations are identified primarily through citizen complaints, but wardens also find violations if they are on a property for another reason (such as reports of poaching), or if there are blatant problems visible from a public road. DFG wardens are deputized, and have the right to enter property with due cause, if a violation is suspected.

Citations occur when DFG staff find levels of chemicals, or physical properties, that are lethal to aquatic life. These levels are set by EPA and represent the same standards that are in the Regional Boards' Basin Plans.

Locally, a cooperative arrangement between the Farm Bureau, the Regional Boards, and DFG is used to address water quality violations caused by animal waste. The Farm Bureau is notified by DFG or the Regional Boards if a violation is suspected, so that a Farm Bureau member can work with the landowner to remedy problems and attempt to avoid enforcement actions.

Water Quality Assessments

The first question that many landowners ask when the relationship of agriculture to water quality is mentioned is "how do I know if I have a problem?" The best way to determine if land use on a particular ranch is contributing to water quality problems is for the landowner to test surface waters for common pollutants.

State Board and Regional Board Assessments. On a larger scale, statewide assessments are produced by the Regional Water Quality Control Boards and the State Water Resources Control Board, and national assessments are made by the Environmental Protection Agency. The national water quality assessments set the framework for state and local agency involvement in water quality assessment and regulation. Section 305 (b) of the Clean Water Act requires that states assess their water quality biennially to determine if the goals of the CWA for fishable and swimmable waters are being met (EPA, 1994). The state and national assessments are respectively called the Water Quality Assessment and the National Water Quality Inventory.

The Regional Boards provide water quality assessment information to the State Water Board for their biennial statewide Water Quality Assessment. This document lists water bodies by region and type (Estuary, Rivers and Streams, etc.), and rates water quality condition as good, intermediate, impaired, or unknown. It also has brief descriptions of problems and needs for impaired water bodies. The State Water Board requires that these assessments be prepared, but Regional Boards do not receive funding to prepare them. Therefore, the assessment information is largely based on sporadic data and observations by staff and concerned citizens. Often "professional judgment," rather than water testing data is used to designate a water body as impaired.

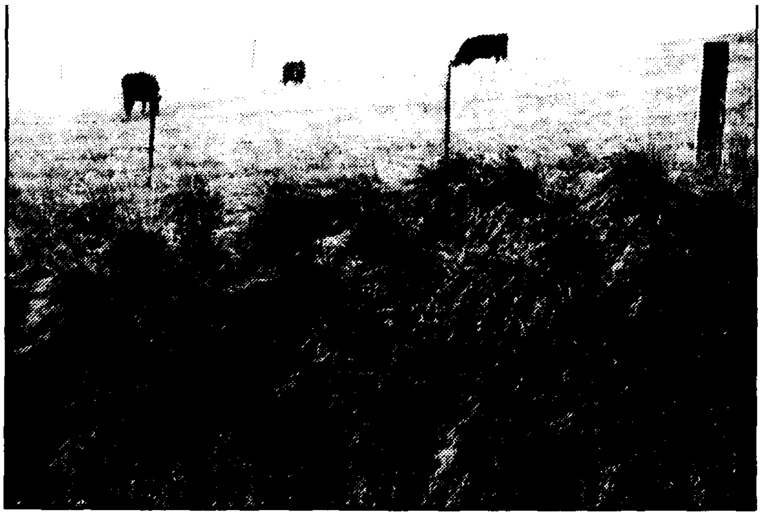
Some data have been used in preparing assessments for Lagunitas Creek, Walker Creek, and Stemple Creek. MMWD has conducted water quality sampling for water rights hearings on Lagunitas Creek that has been used in the state assessment. Data on mercury contamination from the Gambonini Mine have been collected on Walker Creek, and water quality data for Stemple Creek have been collected by the City of Santa Rosa, the Regional Board, and DFG.

Basin Plans prepared by the Regional Boards identify Water Quality Objectives for each beneficial use. These "objectives" are criteria that are based on standards set by EPA. Most of these objectives are in narrative form, but a few specify numerical limits of certain toxins. Since the Basin Plans cover large areas that include many different potential sources of pollution, the narrative objectives give Regional Board staff the ability to decide what substances to test for in different situations.

For example, the narrative objectives for toxicity in the North Coast Basin Plan states "All waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological responses in human, plant, animal, or aquatic life." This objective further describes the tests that can be used to determine toxicity. Pollution from ammonia would come under this objective.

DFG Water Quality Monitoring Program. Between 1991 and 1995, DFG conducted a water quality monitoring program in West Marin to identify localized water quality problems, primarily on dairies. Funding to operate the DFG water quality lab was discontinued as of July, 1995. Information from this program was shared with the dairy industry at the monthly Sonoma/Marin Animal Waste Committee meetings so that industry leaders could work with individual dairy operators to correct pollution sources in problem areas. DFG had 20 water sampling stations at locations that were determined to be high priority areas based on concentration of dairies, siting, and topography. These stations were all in areas that can be accessed from public rights-of-way.

A memorandum summarizing the 1994 results of DFG's Marin-Sonoma Counties Agricultural Runoff Influence Investigation, states that "the majority of stations sampled revealed acceptable concentrations of all parameters, e. g. concentration of dissolved oxygen near saturation, low total ammonia, and conductivity during most sampling events. Even at those locations where exceedances were locally great, the station averages appeared to indicate that conditions were marginally acceptable, most of the time. However, averages can be misleading as fish and aquatic life are quite sensitive to change, and are more likely to be adversely affected by extremes rather than by averages." (Rugg, 1994).



State Department of Health Services. The State Department of Health Services monitors water quality in Tomales Bay and in some of the lower parts of tributary streams, to assess contamination levels from fecal coliform bacteria. This is done to determine if growing waters are suitable for oysters that are consumed raw. The Department of Health Services does not have regulatory authority for water quality laws, but performs this testing to "certify" the safety of commercial oyster leases.

Health Services, in cooperation with the San Francisco Bay Regional Water Quality Control Board and the Tomales Bay Shellfish Advisory Committee, is conducting a study to determine sources of coliform bacteria in the Tomales Bay watershed. This study, which will be completed in 1996, aims to pinpoint sources of coliform and determine whether they are from human or livestock waste based on sampling locations. During the winter of 1994 and 1995, a limited amount of water sampling was conducted to refine the full sampling program to be carried out next winter. Sampling will take place in many areas that are not currently subject to testing by DFG or the Regional Boards.

Solutions —Addressing Water Quality Problems

In West Marin, an impressive array of individual ranchers and agricultural and conservation groups have, for years, implemented projects and programs aimed at conserving soil and improving habitat and water quality. Despite these efforts, water quality problems persist in some areas. Improving water quality will require the continued efforts of these same individuals and groups; unfortunately, this good work is often defeated by a few "bad actors" that don't practice good land stewardship or landowners that simply don't realize the impact they have.

It is well documented that early potato farming had a devastating effect on lower Keys and Walker Creeks and on the Estero de San Antonio. Reported heavy grazing in the late 1800s to early 1900s is also often cited as a cause of rangeland degradation. Recognizing the problems caused by some ranching and farming practices, many ranchers began working with UCCE and the Soil Conservation Service (SCS is now the Natural Resources Conservation Service) in the early to mid-1900s to improve management practices and the condition of their land. Awareness of water quality problems from dairies peaked in the early 1970s with the dairy industry's attempts to comply with pollution control provisions of the 1969 California Porter-Cologne Act.

Assisted by these and other local conservation organizations, West Marin ranchers have implemented numerous soil conservation and pollution control practices on their ranches. The following sections describe these support agencies' programs.

U. C. Cooperative Extension. Beginning in 1920, the University of California hired a farm advisor to work with Marin County's farmers and ranchers. M. B. Boissevain helped area farmers and ranchers improve range and soil conditions, farm production, and livestock management for almost three decades. Most of Boissevain's work focused on northern Marin County, which had the highest concentration of small farms.

In 1922, Boissevain noted that fruit and potato growing were important in the county but that the dairy industry was the major agricultural industry; sheep raising was minimal at the time. He wrote the next year that much of the land had been greatly overstocked (quoting an average of ten acres per cow) and that annual grasses and weeds had taken the place of much of the "original good" grasses. In a drive to improve these "greatly run down" pasture conditions, Boissevain instituted programs of deferred and rotation grazing, and introduced species such as Handing grass in test plots around the county. He also brought his knowledge of feed crops, encouraging dairymen to experiment with improved silage crops such as corn and vetch. Boissevain's work during the 1920s and 1930s had a notable positive effect in the way land was used and in dairy production in the county.

Since Boissevain's time, UCCE has continued to assist local ranchers and farmers with improved practices through the farm advisors. In 1994, UCCE initiated the Marin Coastal Watershed Enhancement Project. This project has provided workshops on water quality regulations, water quality testing, and preparing ranch plans for local ranchers. A series of informational fact sheets on various aspects of water quality has been prepared for distribution. A video and companion workbook on preparing a ranch plan has also been prepared by project staff. Most of these meetings and educational materials have been jointly produced by staff from UCCE, Marin Agricultural Land Trust (MALT), PRNS, NRCS, and MCRCD.

Marin County Resource Conservation District Resource Conservation Districts were established by the federal government in the days of 1930s dust bowl to provide a local link between landowners and the newly formed Soil Conservation Service. Now RCDs function as divisions of state government, governed by an elected Board of Directors. RCDs are non-regulatory and work through voluntary cooperation with landowners (Prunuske, 1987). The Marin County Resource Conservation District (MCRCD) has been assisting West Marin landowners with natural resource conservation work since its formation in 1959. Aided by technical staff from the NRCS and private consultants, the MCRCD's primary purpose is conservation of natural resources. Over the past twelve years, the MCRCD has operated several specific watershed enhancement programs in West Marin.

Lagunitas Creek Watershed Project. In 1983, the trend toward grant-funded, comprehensive watershed projects began when the MCRCD received grants for erosion control in the Lagunitas Creek watershed from the State Coastal Conservancy and the San Francisco Foundation. In 1984 and 1986, additional monies were obtained from DFG. The goal of the Lagunitas Watershed Erosion Control Program was to reduce the rate of sedimentation in both the stream channels and in Tomales Bay (Prunuske, 1988). During the five years of the MCRCD's Lagunitas Watershed Erosion Control Program, over 35 gullies, 21 miles of unsurfaced roads, approximately 13 reaches of streambank erosion on Lagunitas Creek and its tributaries, and several slides and miscellaneous erosion problems were repaired—at a cost of $476,778.

Additional program activities included holding two educational erosion control workshops for landowners, publication of a handbook on erosion control for landowners, and tours of project work. Trout Unlimited joined with MCRCD to sponsor two volunteer work weekends with participation from MMWD, numerous citizen volunteers, and Samuel P. Taylor State Park. Also, many individual streambank erosion sites were repaired in San Geronimo Valley by private landowners.

San Geronimo Creek Watershed Bedload Sediment Reduction Project. This project, which the MCRCD formally became involved with in 1991, focuses on reducing bedload sediment in Lagunitas Creek through source-control measures on various sites in the San Geronimo Valley. Funded by MMWD, the program is based on recommendations from the *Sediment Overview Report: Development of an Initial Sediment-Management Plan for Lagunitas Creek,* that was submitted by MMWD to the State Water Board in 1992. This report summarizes the studies and findings that have led to the current coarse-sediment reduction program proposed as mitigation for enlargement of Kent Lake by MMWD.

The project includes a three-year design and construction phase followed by ten years of maintenance and monitoring. Construction projects include bank erosion repairs and sediment retention structures; the maintenance phase will allow removal of sediment from retention structures. Monitoring will evaluate the effectiveness of sediment reduction projects over a ten year period. An ad hoc committee approves a project priority list, reviews and approves project plans and specifications, and inspects projects.

Walker Creek Watershed Project. In 1986 the MCRCD and NRCS funded an inventory of erosion problems in the Walker Creek watershed (Chatham et al., 1986), which marked the beginning of the MCRCD's Walker Creek Watershed Erosion Control Program. With $1 million in funding from the State Coastal Conservancy, MCRCD repaired major gullies, eroding streambanks, and constructed exclusionary fencing on 15 individual sites. Approximately $150,000 remains unspent; the remaining funds will be used for fish habitat enhancement and related erosion control work in the Walker Creek watershed by June, 1996.

Stemple Creek/Estero de San Antonio. The MCRCD's Stemple Creek/Estero de San Antonio Watershed Enhancement Project was launched in 1991 when work on a Stemple Creek/Estero de San Antonio Watershed Enhancement Plan began with funding from the State Coastal Conservancy. This plan was completed in 1994 after a series of meetings of a project advisory committee, and preparation of biological assessment, vegetation and habitat restoration, erosion and sediment, water resources, and geomorphic and hydrodynamic analysis reports by specialists. During the planning process, watershed landowners were interviewed to help focus the planning effort on local concerns. In addition to the specialists' reports, the plan includes enhancement goals and recommendations drafted with input from the Advisory Committee.

Unlike the previous State Coastal Conservancy funded projects in the Walker Creek and Lagunitas Creek watersheds, the Stemple Creek/Estero de San Antonio Watershed Enhancement Project has not yet received Conservancy funding for implementation. Project implementation will be carried out with multiple, smaller funding sources. These currently include a 319(h) grant from EPA/State Water Board for preparing dairy plans and implementing water quality enhancement demonstration projects ($76,646); riparian fencing and planting paid for by the Shrimp Club; U.S. Fish and Wildlife Service Partners for Wildlife Program; Sonoma County Fish and Wildlife Advisory Board; and Americorps participants working through the NRCS Petaluma office.

The Marin and Southern County Resource Conservation Districts have applied for NRCS PL566 Small Watersheds Program funding for project implementation in the Stemple Creek/Estero de San Antonio Watershed. If approved, this program would provide a Rangeland Conservationist for technical assistance and financial assistance for conservation practices to improve water quality.

Natural Resources Conservation Service (NRCS - formerly Soil Conservation Service - SCS). The first local SCS office was established in Point Reyes Station in the late 1950s. This office was responsible for organization of the MCRCD, through which staff provided technical assistance for erosion control to agricultural landowners. Controlling soil erosion was the primary function of this agency until the mid-1970s, at which time SCS took on a major role in assisting local dairy operators with designing waste control systems.

Between 1974 and 1977, through a cooperative arrangement between the County of Marin and SCS, approximately three-quarters of the dairies in Marin County installed dairy waste ponds. SCS personnel provided waste system design at no cost to the dairy operators. Construction costs were shared by the County, Agricultural Stabilization and Conservation Service, and the dairy owners.

Consolidated Farm Services Agency (CFSA - formerly Agricultural Stabilization and Conservation Service). This agency has provided cost sharing for numerous soil and water conservation projects on Marin County ranches. CFSA administers several federal cost share programs; the program which has been most widely used by local landowners is the Agricultural Conservation Program (ACP), which presently receives approximately $40,000 per year for the county. This funding is distributed to applicants for up to 75% of the cost of conservation projects, though cost share cannot exceed $3,500. Typically, landowners provide labor and a portion of materials costs. Projects—which can include pasture improvements such as reseeding and fertilization, water source development, and fencing—must meet NRCS design criteria. High cost projects, such as waste pond construction can be cost shared through a long term agreement (LTA) which can be accelerated, giving landowners up to $35,000 in five years. Individual projects implemented by landowners through ACP and other CFSA programs within the project area probably number in the thousands.

Sonoma/Marin Animal Waste Committee. The Sonoma/Marin Animal Waste Committee is a committee of the two county Farm Bureaus that is coordinated and facilitated by UCCE. The committee was formed in Marin County in the early 1970s to assist dairy operators with waste management. The Animal Waste Committee serves as a forum for Regional Board and DFG personnel to bring animal waste pollution concerns to industry representatives. It was the first such committee formed in California. At monthly meetings, DFG personnel report the results of their water quality monitoring program, and alert dairy representatives to site-specific and regional water quality problems in need of remediation. In 1992, the committee produced and mailed to all producers in the two counties, *Appropriate Animal Waste Management Guidelines: Containment and Reuse of Manure from Confined Animal Facilities*. This document recommends practices for preventing water pollution by animal waste.

An important function of the committee is to act as a liaison between the Regional Boards, DFG, and ranchers. Under an agreement between these agencies and the Farm Bureaus, when waste discharge violations occur, Animal Waste Committee representatives make the first visit to the subject ranch, then inform the Regional Boards and DFG what corrective action will be taken. The NRCS provides technical assistance to help resolve waste problems. The formalized procedure for dealing with waste discharge problems are described in a document produced by the committee titled *Sonoma-Marin Animal Waste Committee Complaint Investigation Resolution Procedure.*

A subcommittee, including representatives from NRCS, UCCE, Western United Dairymen, and others, has, over the past year, developed a worksheet for evaluating the adequacy of dairy waste handling facilities on individual dairies, titled *A Dairy Resource Conservation and Enhancement Plan.* The committee plans to expand the plan to include assessment of waste management on upland acreage. This will evaluate the potential for proper disposal of liquid and solid manure, and other potential sources of NPS pollution.

Efforts of Individual Ranchers. Many landowners regularly engage in land management practices to maintain good water quality. Some of these practices involve construction of complex, engineered erosion repairs or waste systems, and such projects are usually installed with the help of the Natural Resources Conservation Service and Consolidated Farm Services Agency. Other practices are simpler, and include many seemingly small actions aimed at keeping soil on the land and preventing pollution from livestock waste. Preventive measures often keep small problems from becoming serious. Over the years, the cumulative effect of such practices can have a significant beneficial effect on water quality.

There are many individual landowners who regularly implement conservation practices. Following are three brief profiles of local ranchers who have made an effort to maintain good water quality.

Thornton Dairy and Sheep Ranch. Gordon Thornton, who owns the Thornton Dairy and Sheep Ranch in Tomales with his son, continues the stewardship tradition that was started by his uncles, Jim and Bill Marshall. Before the Marshall Brothers came to the ranch in 1918, it had been leased out, and the soil was in poor condition from years of farming without regular fertilization.

Soon after the Marshall brothers took over the ranch, they began the process of improving soil fertility and pasture condition, and stabilizing erosion sites. In the

1920s, they worked with M. B. Boissevain, UCCE Farm Advisor, to establish clovers. Since that time, periodic reseeding with clovers and perennial grasses, and regular pasture fertilization have kept pastures productive, which is important both for animal nutrition and soil protection.

Careful management of livestock plays an important role in soil and water conservation at the Thornton Dairy and Sheep Ranch. Cross-fencing of 31 pastures and well distributed water sources, allow animals to be moved around to best meet seasonal pasture conditions and avoid overuse of any one pasture. Low wet pastures, and those that include streams, are managed to keep livestock out during the wettest months to avoid damage to these sensitive areas.

Facilities and landscape improvements are also continually added. Simple practices such as cutting ditches across cow trails or filling them with rock are used to prevent gullies from forming. Willows and blue gum trees have been planted on the ranch since the early 1900s to stabilize gullies and streams—the Thorntons still plant willows for shade along streams and to stabilize drainages. Flumes, or small spillways, have been constructed in drainages to stabilize gullies and keep headcuts from growing. The Marshall brothers built flumes out of wood in the 1940s—Gordon Thornton has constructed concrete flumes more recently.

Despite the effort that is put in to erosion protection, nature sometimes takes its course and some erosion is inevitable. In the mid-1980s, Gordon Thornton fenced a big gully that feeds into Walker Creek to keep livestock from breaking down the edges. During the intense storms of 1994/95, this gully became saturated and cut loose, dumping tons of sediment into the creek. The Thorntons are now working with the MCRCD to repair the gully.

Bob Giacomini Dairy. Bob Giacomini's 700-acre dairy is a model of efficient waste management where manure is treated as an asset, rather than a liability. The dairy waste system, which was initially installed in the late 1960s, has been expanded and upgraded over the years, and the Giacominis continue to test new technology for improving manure management.

Overlooking Tomales Bay, the ranch is ideally situated on gently rolling hills allowing cultivation of silage on nearly half of the ranch. The relatively large acreage and gentle topography over much of the ranch allow most manure to be effectively utilized on-site. Carefully coordinated management of animals, pastures, silage fields, and physical waste system components, work together to protect water quality and boost feed production.

During winter, all cows are confined in loafing barns to prevent damage to pastures when soils are saturated. In spring, animals are rotated between eight pastures. Silage fields are planted using a no-till drill, to minimize soil erosion. Waste system components include a manure separator; two manure ponds; pumps for recycling wash water and irrigating; and an extensive network (over three miles) of underground pipe that distributes liquid manure to sprinklers on 350 acres.

Manure from the milking barn and loafing barns is flushed into a pit, then pumped through the separator which extracts most of the liquid. The experimental separator that the Giacominis are presently using is a screw-type rather than screen-type separator, which more effectively separates liquids from solids, producing drier solids. The Giacominis are working with a Petaluma-based company that hopes to market the finer, drier solids as a peat moss substitute for use as a garden amendment.

Separated liquid is held in ponds and recycled for flushing barns. Ponds are emptied only twice a year, in the fall and spring, when application of liquid manure can augment natural rainfall. Fall irrigation with liquid manure provides early green feed in pastures, and spring irrigation produces a second silage crop. Approximately half of the ranch is irrigated with liquid manure. In spring and fall, after ponds have been emptied, barns are flushed with fresh water until ponds have filled up enough to begin recycling wash water. Once sufficient liquid waste has accumulated, it is continually reused for flushing until ponds are emptied again.

Solids, which come out considerably drier than from traditional screen-type separators, are reused for bedding after bacteria have been killed by composting for ten days. Solids which are not used for bedding or sold for garden use are field spread on the portion of the ranch that is not fertilized with liquid manure.

Martin Dairy. Although this dairy is in Sonoma County, outside of the MCWEP area, the Martins have participated in project activities and have generously shared their experiences with water testing and stream protection with other ranchers.

A project that started in response to DFG citation became an award-winning Future Farmers of America (FFA) project for Betsy Martin, and has allowed Paul Martin to improve water quality through diagnosing and remediating animal waste problems. The 80-acre Martin dairy is situated on Stemple Creek, just north of the Marin County border. Paul and his daughter Betsy have taken the job of water quality testing—something that has long been a mysterious regulatory procedure—into their own hands and have implemented management practices to improve water quality in Stemple Creek. In addition to water testing, they have fenced and revegetated Stemple Creek with the help of the Brookside School Shrimp Club.

In 1993, the Martins were cited by DFG for dairy waste pollution of Stemple Creek. By discussing water test results with DFG staff, and attending Animal Waste Committee meetings, Paul became familiar with water quality parameters and testing methods. He purchased simple ammonia and dissolved oxygen test kits, and now regularly tests water samples, records results, and takes photographs to document water quality conditions. He traced the source of contamination that he was cited for to a swale area where manure had been stockpiled for years, and he now avoids storing manure there.

Betsy had been observing erosion on Stemple Creek when the DFG citation occurred. Concerned about the condition of the creek, she was inspired to do her FFA Soil and Water Management project on water quality in Stemple Creek. Her project addressed both water testing and stabilizing and revegetating Stemple Creek. Project results were written up in a paper that earned a statewide Agriscience Student of the Year award. Betsy's water testing program involved testing for total ammonia, dissolved oxygen, temperature, pH, and sediment where Stemple Creek enters and leaves the Martin property. This procedure would be less extensive if it were done solely for identifying dairy waste contamination rather than for a science project.

Test results have been positive, and demonstrate that water quality is generally good—and will only improve—when trees grow up and shade Stemple Creek as it flows through the Martin Ranch.

7. Watershed Profiles

Stemple Creek/Estero de San Antonio

Watershed Summary - The Stemple Creek/Estero de San Antonio watershed is one of Marin County's most productive agricultural areas, supporting numerous dairies, beef and sheep ranches. Historically, potato farming was a major industry, and poor farming practices were a major cause of watershed degradation. Physical characteristics of the Estero have been drastically altered over the past 150 years. Sedimentation, caused primarily by potato farming, has resulted in such a reduction in the Estero's volume, that the mouth no longer flushes completely. This results in a seasonal sand bar that eliminates tidal and estuarine circulation, which adversely affects aquatic life.

The Estero and Stemple Creek provide habitat for the endangered California freshwater shrimp *(Syncaris pacifica)*, and many other species of mammals, reptiles, amphibians, birds, and fish. The Estero does not support coho salmon or steelhead trout; there was a steelhead run as recently as the 1960s (Paul Martin, 1995), but due to habitat degradation, this species no longer inhabits the Estero. Much of the stream system lacks riparian cover, causing water temperatures that are too high for salmonids. Additionally, the streambed substrate in Stemple Creek/Estero de San Antonio is composed of relatively fine sediments and lacks the coarse gravel that salmonids need for spawning.

Water quality testing has shown ammonia to be the most common cause of water quality degradation. Low levels of dissolved oxygen and high water temperatures are also common problems.

Setting. The Stemple Creek/Estero de San Antonio watershed encompasses 50 square miles, nearly all of which is used for agriculture, including dairying, and beef and sheep production. There are also several poultry farms in the watershed, and many dairy ranches grow hay and silage for on-site consumption. Most of the Stemple Creek/Estero de San Antonio watershed is composed of gently rolling hills surrounding a wide, flat valley bottom. Vegetation reflects the fact that much of the watershed is within the Petaluma wind gap; the predominant upland vegetation type is grassland, a mixture of annual and perennial grasses and forbs, with patches of coastal scrub on some of the steeper north facing slopes near the coast. Native trees tend to grow only in areas that are protected from the fierce, drying winds.

In most of the watershed, grasslands are dominated by introduced annual grasses and forbs, although some native grass species still exist in areas. The proportion of native perennial grasses increases near the coast and on the steep slopes toward the mouth of the Estero. Forest and woodland is of very limited distribution. Near the southern edge of the watershed, just west of the Marin/

Sonoma County line, and toward the northeastern end of the watershed, there are patches of mixed oak and bay hardwood forest. Riparian woodland, which has been preserved in some drainages, varies according to stream gradient and location. In low valleys, it is composed primarily of willows *(Salix* spp.), and in the steeper drainages includes coast live oak *(Quercus agrifolia)* and California buckeye *(Aesculus californica).* Many of the tributary channels and most of the main Stemple Creek channel do not currently support riparian woodland. Scattered throughout the watershed are blocks of the non-native blue gum *(Eucalyptus globulus)* which have been planted for windbreaks.

From Bodega Bay inland approximately four miles, the Estero de San Antonio occupies the estuarine portion of this stream system where fresh water from upland tributaries mixes with salt water from the ocean. Tidal and current action, and seasonal rainfall and runoff in this area results in a continuously changing mix of salt and fresh water. Above the estuary, the freshwater part of this system becomes Stemple Creek.

The Estero was formed over the last 10,000 years as rising sea levels invaded the valley of Stemple Creek, following the last ice age (Williams and Cuffe, 1993). Williams and Cuffe speculate that previous to European settlement, watershed vegetation was relatively undisturbed, and that sediment delivery rates were low. During this time period, sea level rose about 1/2 foot per century, exceeding sedimentation and buildup of the valley bottom, and allowing tidal influence to extend inland. Due to accelerated sedimentation over the past 200 years, the Estero mouth is now closed by a sand bar during the late spring and summer. As a result, water quality problems are worse late in the year. Tidal influence is eliminated, and evaporation is high, sometimes resulting in a hypersaline estuary with salinities far above that of the ocean (Madrone Associates, 1977). Because of this, organisms must be able to tolerate a wide range of salinity, water temperature, pH, dissolved oxygen, turbidity, and other physical factors (Madrone Associates, 1977).

Stemple Creek/Estero de San Antonio is unique among streams in the project area both in terms of its morphology, and the flora and fauna that it supports. While Stemple Creek does not provide the quality of Anadromous fish habitat that other local streams do, the tidally influenced Estero supports a unique array of aquatic life and is an important nursery area for many marine fishes. The Stemple Creek/Estero de San Antonio watershed supports numerous types of wetland habitats, including saltwater and brackish marsh within the Estero and freshwater marsh inland of the tidal influence.

The Estero provides habitat for the endangered California freshwater shrimp, and the diversity of the associated habitat types supports many species of mammals, reptiles, amphibians, birds, and fish. At the mouth of the Estero, common species include Pacific herring, Staghorn sculpins, shiner surfperch, tidewater and arrow gobies, starry flounder, surf smelt, and topsmelt.

Land Use History. The Stemple Creek area was originally noted for its heavy black loose soil that produced fine crops of potatoes, wheat, barley and oats.

In 1855 George Burbank built a home and ranch on the banks of Stemple Creek, first producing the crops mentioned above, and later operating a dairy ranch. Potato fields sometimes encroached into the creekbed with the construction of bulkheads; farmers plowed both the level and steep portions of their land with horses, causing winter runoff that clogged the creek. After rains the fords were often miry with silt, making passage dangerous. Wooden bridges and culverts had to be constructed (Dickinson, 1993).

Until the 1940s potato production was one of the main uses of the lower watershed, although dairy ranching had become the dominant land use in the 1880s. The upper watershed, noted for lack of water needed for both dairying and farming, became a popular chicken producing area, forming part of the western outpost of the famous Petaluma chicken industry. The small scale dairy, potato and barley farms enjoyed relative success until the five creameries in the area shut down in the 1930s. Nearly all of the local farmers went into production of market milk, and sheep or beef ranches began to appear (Pozzi, personal communication, 1995). The last potato grower in the area was Frank Gambrosini, whose commercial organic crop was wiped out by floods in January of 1982 (Thornton, personal communication, 1995).

No other industries were prevalent on Stemple Creek. One old-timer recalls a large number of sweet water clams in the creek and lots of fishermen. Stemple was a "well-moving" creek, where one found steelhead as far upstream as Two Rock. He now claims the creek supports only "junk fish." The creek has never had a major dam, but many small dams were developed around Two Rock and in the general watershed for stock ponds. A current concern is sedimentation from the Sonoma County landfill.

The Stemple Creek/Estero de San Antonio watershed now supports dairies, beef, and sheep ranches, a few poultry operations, and an organic truck farm.

Physical Watershed Changes. The character of the Estero and Stemple Creek has been transformed by historic land use changes within the watershed and continues to be affected by sedimentation and poor water quality (Williams and Cuffe, 1993). Over the last 150 years, major human induced changes have occurred that greatly affect the physical functioning of the estuary. Cattle grazing, and later, arable farming in the watershed have resulted in accelerated erosion and significant increases in sediment delivery to the Estero (Soil Conservation Service, 1992). Sediments, mainly eroded by the formation of gullies and arroyos, were carried downstream in large flood events. Coarser sediments have remained in the Estero, filling in the deeper parts of the channel. Over time the Estero became shallow, and fringing shoals became larger, narrowing the channel. Eventually the tidal marshes were smothered with sediment, converting them to floodplain meadows (Williams and Cuffe 1993).

Williams and Cuffe (1993) found that formerly the Estero's tidal prism was large enough to keep it fully tidal throughout the year—the volume of water exchanged between high tide and low tide was great enough to keep the mouth of the Estero flushed out. With increased sedimentation, the scouring potential of currents within the entrance channel was greatly reduced. At some point the entrance channel became small enough to be closed off by beach sand deposited during periods of high wave energy. The first closure probably occurred in the late 1800s. Now, the volume of water exchanged by the Estero daily between mean high tide and mean low tide is only about 20% of the volume that existed in 1862, and the mouth usually closes off in the spring or summer, remaining closed until the first significant flood flow of winter. During drought periods the mouth can stay closed for more than a year. According to Williams and Cuffe (1993), if no action is taken and sediment delivery to the Estero continues at historic levels, further reductions in the tidal prism will occur, gradually changing the Estero from a seasonally closed estuary to one that is closed most of the year.

Once the entrance channel closes in the spring or summer, and depending on the amount of freshwater inflow, the lagoon can become hypersaline (Madrone Associates, 1977) or brackish throughout most of its length. The estuary then becomes a seasonal lagoon where tidal and estuarine circulation is eliminated. The mouth remains closed until the first significant winter storms fill the lagoon and overtop the beach built up in the summer. Once breaching occurs, a deep channel can be scoured quickly, returning the lagoon to tidal action.

Stream Condition and Fish Habitat. Unlike Walker Creek and Lagunitas Creek, the fishery resource in Stemple Creek/Estero de San Antonio does not, and probably never did include a significant coho salmon run. Though there was reportedly a steelhead run at one time, this stream does not now have the potential to support salmonids. Much of the stream system lacks riparian cover, causing water temperatures that are too high for salmonids. Because of land use and inherent physical characteristics—a very low gradient, and abundant sources of fine sediment—sedimentation has decreased stream depth, and created a streambed substrate that lacks the coarse gravel that salmonids need for spawning. Although it may be unrealistic to expect restoration of the historic steelhead run, condition of the riparian corridor and water quality are important for freshwater shrimp and other organisms for which the Estero provides habitat.

Peak average monthly flow in Stemple Creek is 114 cubic feet per second, which is much greater than in nearby Americano creek. The bar typically closes while freshwater continues to flow into Estero de San Antonio, causing the water surface elevations to slowly increase and dilute salinity.

Surveys of fish and other aquatic organisms were conducted in Stemple Creek and The Estero de San Antonio by Commins et al (1990). This study found that the tidewater goby, a fish that is being considered for listing by the State of California as rare or threatened due to habitat loss and degradation, was found to be abundant in the upper reaches of the Estero de San Antonio.

Water Quality. North Coast Regional Water Quality Control Board staff conducted periodic water quality sampling in Stemple Creek from 1990 to 1994. Water quality sampling has also been conducted in the Stemple Creek/Estero de San Antonio watershed by DFG, and Commins Consulting and David W. Smith Consulting, for the Santa Rosa Subregional System. Summaries of water monitoring results in the Stemple Creek/Estero de San Antonio have been compiled by M. Kim Cordell for the Stemple Creek/Estero de San Antonio Watershed Enhancement Plan (Prunuske

Chatham, 1994) and by the Regional Board (California Regional Water Quality Control Board, North Coast Region Staff, 1995).

Water quality data have shown toxic levels of dissolved oxygen, ammonia, copper and nitrate to occur in the Estero. High water temperatures are also a common problem. Ammonia, which is present in the Estero throughout the year, is the most common problem. Some of the highest ammonia levels measured occurred during the winter, when rains cause runoff of animal waste from manured areas and waste ponds. The highest values of un-ionized ammonia occurred in spring (March through May), as rising water temperature and pH increase the percentage of ammonia in the un-ionized form.

Low levels of dissolved oxygen were also shown to be a problem in the Stemple Creek/Estero de San Antonio watershed. This may be attributable to animal waste, as the organic component of manure has a high biological oxygen demand (BOD), which depletes oxygen in the water. Temperature was also identified as a problem. According to Cordell (1994), temperatures above 24°C (75°F) are unacceptable for most aquatic species. In Stemple Creek, summer water temperatures are high due to the absence of riparian vegetation. Copper contamination results from use of copper sulfate for cattle foot baths for the prevention of foot rot.

In Cordell's summary, she states that despite the water quality problems identified by these monitoring programs, the water quality of Stemple Creek is generally good. DFG monitoring data have, however, shown several areas within the watershed to have recurring problems related to animal waste contamination, while other areas are relatively problem free. According to the Regional Board summary (California Regional Water Quality Control Board, North Coast Region Staff, 1995), Stemple Creek exceeded the national criteria for un-ionized ammonia throughout the watershed at different times of the year, stream sediments were high in nutrients, and water temperatures were high, starting in the spring. Regional Board data show that most of the significant nutrient loadings to Stemple Creek takes place in the upper watershed (Sonoma County), but strongly affects the downstream portion of Stemple Creek and Estero de San Antonio. Because of high levels of un-ionized ammonia and dissolved oxygen, in 1990 the Regional Board listed Stemple Creek and Estero 3e San Antonio as impaired waterbodies under section 303(d) of the federal Clean Water Act.

Walker Creek

Walker Creek, named after L. W. Walker who had settled on the creek in the early 1850s, was originally called Arroyo San Antonio on charts and maps.

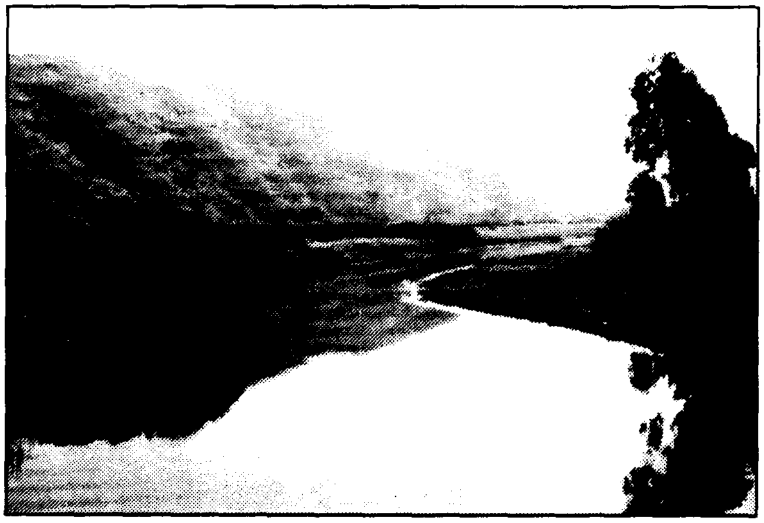
Watershed Summary. The Walker Creek watershed is composed of a small number of large, privately owned parcels. Much of the watershed is steep and rugged, making it less suitable for farming and dairy production than the Stemple Creek/Estero de San Antonio watershed. Dairies are concentrated in the valleys and gentle hills near Tomales and in Chileno Valley, with much of the remainder of the watershed used for beef production. Historic potato farming in the Tomales area filled lower Keys Creek with sediment and contributed to growth of the Walker Creek delta.

Significant geomorphic changes have occurred in the Walker Creek watershed and have been studied by researchers, yet the causes of these changes are largely undocumented. Similarly, reasons for the depleted condition of salmonid populations have been contemplated by various fishery biologists, yet specific factors limiting these fish populations are not fully understood. A program proposed by MMWD to mitigate the effects of enlarging Soulajule Reservoir in the late 1970s failed to restore fish runs.

Stream condition and fish habitat are severely degraded in many areas, characterized by streambank erosion, lack of riparian vegetation, and sediment-embedded spawning gravels. Since 1980, summer flows have been augmented by releases from Soulajule Reservoir. These flows, as well as revegetation work done by the MCRCD and Marin County Office of Education, have improved riparian cover. The MCRCD has conducted an erosion control program in the Walker Creek watershed over the past nine years but significant sediment sources still exist. Remaining critical sediment sources include an old mercury mine and numerous reaches of severe streambank erosion.

Little is known about water quality throughout most of the watershed. Large amounts of sediment can be observed in the creek for many days following rainstorms, and lack of riparian cover on much of mainstem Walker Creek and its tributaries indicates that high water temperatures are a likely problem.

Setting. Walker Creek flows through an alluvial valley encircled by gently rolling to steep hillslopes. The Walker Creek watershed covers 73 square miles, composed of four main subwatersheds that have distinct physical characteristics. These subwatersheds include Chileno Creek, which flows through Chileno Valley; Arroyo Sausal and Salmon Creek, which flow through Hicks Valley; and Keys Creek, which flows through the low hills east of Tomales.



The predominant land use in the Walker Creek watershed is livestock production, primarily beef cattle, with a small number of sheep ranches and seven dairies. Dairying is concentrated in the level and productive valleys of the Chileno Creek and Keys Creek subwatersheds. Some ranchers raise their own hay and silage, and there is small-scale commercial hay production in Hicks Valley. In the upper Chileno Creek watershed, above the northern end of Laguna Lake in Sonoma County, there is a duck farm.

Topography in the upper Walker Creek watershed, including the Arroyo Sausal and Salmon Creek subwater-sheds, consists of steep hills surrounding narrow valleys. Stream channels in the upper Walker watershed, including Arroyo Sausal, Salmon Creek, and the mainstem of Walker Creek, have downcut dramatically, leaving old stream terraces high above the stream channel. Soulajule Reservoir, built and maintained by MMWD, isolates Arroyo Sausal from the rest of the watershed approximately 2.75 miles upstream of Walker Creek.

The dramatic downcutting characteristic of the upper watershed is absent in Chileno Creek and Keys Creek. Chileno Creek originates at Laguna Lake, a shallow, approximately 200 acre freshwater lake at the Sonoma-Marin County line. It flows through the long and narrow Chileno Valley before entering Walker Creek approximately seven miles upstream of Tomales Bay. Topography in the Chileno Creek watershed is somewhat gentler than in the Arroyo Sausal and Salmon Creek watersheds. Keys Creek, which enters Walker Creek only one mile upstream of Tomales Bay, is physically distinct from the rest of the Walker watershed, and is composed of low rolling hills which more closely resemble land forms in the Stemple Creek watershed to the north.

Vegetation in the Walker Creek watershed is approximately 63% open grassland and 37% woodland and shrub communities (Zumwalt 1972). Grasslands are composed of a mixture of native and introduced annual and perennial grasses and forbs. In some parts of the watershed, especially on steep slopes with poor soils, where annual grasses are not as competitive, there are significant stands of native perennial grasses. On deep, productive soils, grassland vegetation is mostly composed of introduced annuals.

Steep hillslopes in the Walker watershed above Keys Creek are wooded with mixed hardwoods and a few conifers. Dense forest and woodland, composed of California bay *(Umbellularia californica),* coast live oak, buckeye, Oregon white oak *(Quercus garryana),* and madrone *(Arbutus menziesii),* with small numbers of

Douglas-fir *(Pseudotsuga menziesii)* and coast redwood *(Sequoia sempervirens)*, occupy steep hillsides. Common shrubs include coyote brush *(Baccharis pilularis)*, ocean spray *(Holodiscus discolor)*, and poison oak *(Toxicodendron diversilobum)*. Vegetation in the Keys Creek subwatershed is almost entirely grassland.

Walker Creek and its four main tributaries all have numerous reaches that are devoid of riparian vegetation. Where woody vegetation exists along Arroyo Sausal, Salmon Creek, and Walker Creek, it includes willows, coast live oak, buckeye, and California bay, with white alder *(Alnus rhombifolia)* on Walker Creek and on the lower reaches of Salmon Creek. Riparian cover on Walker Creek has improved significantly since 1980, when summer releases from Soulajule Reservoir began. Much of upper Chileno Creek is denuded, supporting only sparse clumps of willows. The lower end of Chileno Creek near the confluence with Walker Creek is well vegetated. Keys Creek is largely unvegetated.

Land Use History. Early descriptions of the Tomales area speak of wild oats as high as a deer's shoulder, antelope, deer and elk in great numbers, and fish-filled open streams with tidewaters reaching to the Town of Tomales (Dickinson, 1993).

Bodega potato farmers John Keys and Alexander Noble settled in the Tomales area in 1850 and dozens of newcomers soon followed. From 1850 through the 1870s potato farming, by pioneers who were mostly Irish, was extensive on the low hills and in the fertile valleys; mid-19th century farms also produced commercial crops of oats, wheat, barley and beets, all of which were shipped by schooner at Keys Creek until the railroad went into operation in 1874. John Keys constructed a commercial area at the confluence of Keys and Dutton Creeks below present-day Tomales, complete with wharves, warehouses, a store, and eventually a blacksmith shop and hotel. Fellow potato farmer Warren Dutton joined Keys in 1852 and "Lower Town" prospered until a rivalry between the two broke out five years later. Dutton created a new town above Keys' site and built a competing wharf and warehouse further downstream at the confluence of Keys and Walker Creeks (Dickinson, 1993).

Meanwhile, silt was causing trouble for Keys, whose schooners could not reach Lower Town without dredging. Potato fields were usually plowed in March in preparation for May planting, then plowed again after the fall harvest. The major silt runoff occurred in the late fall and early winter as rains washed the loose, sandy dirt into the waterways and to the bay. By 1870 the problem was so severe that Dutton had to move further downstream to Ocean Roar, and by 1875 had been pushed even further south to the northeastern shore of Tomales Bay, where he established his operation at Hamlet (a 1,000-foot wharf was needed in order for boats to unload at Hamlet during World War I) (Pensotti, 1989). A great deal of commercial activity occurred at the landing on Preston's Point, where there was reportedly eleven feet of water alongside the wharf (Mason, 1976). The rapid siltation of Keys Creek has been generally blamed on the extensive potato farming in the watershed; Keys himself accused road builders for much of the problem (a county road had been built along the east bank of the estuary in 1869) (Livingston, 1989). The *History of Marin County* commented on the situation in 1880:

> *Caused by the debris brought down from the mountain, the [Keys Creek] estuary is fast filling up, and long ere another quarter of a century shall have come and gone, naught but tradition will remain to point out the shipping, the harbor or Keys Creek* (Munro-Fraser, 1883).

In 1874 the North Pacific Coast Railroad built a wood trestle across Walker/ Keys Creek above Ocean Roar and ended the era of sea-going commerce and navigation of the creek. The first freight shipment on the railroad in December of 1874 was 300 sacks of potatoes grown by James Fallon; the second shipment was 140 sacks of oats (Dickinson, 1981 and 1983). During this time a book was published extolling the quality of farming in Tomales:

> *It is the best body offarming land we have, and for that matter is second to none in the state .... This is potato country* par excellence. *Whoever wants a good farm and a cheap one should seek this locality* (Gift, 1875).

Potato farming gave way to dairy ranching during the 1870s but did not entirely disappear. While many ranchers continued to raise potatoes as a cash crop until the 1940s, butter and cheese making became the "great staple product" of the region. The excellent quality of the native grasses brought immigrant dairy farmers, largely from southern Switzerland, to operate the dairies—often as tenants. By the turn of the century most of the land was used for grazing and many of the tenant ranchers owned their lands (Dickinson, 1993; Mason, 1976).

Non-agricultural activities have also had a significant effect on the Walker Creek watershed. Crews from Marin County public works took gravel from Walker Creek, on what are now the Brazil and Thornton Ranches, for a short time in the 1960s. In the 1940s exploration for mercury began in the area. A large mercury mine was developed in 1964 on the Gambonini ranch on Salmon Creek, the only active mine known in the watershed; the Buttes Gas & Oil Company operated the mine until 1970, dumping its tailings and overburden into the drainage and clinker into a small adjacent gully. The mine produced 3,541 flasks of mercury. The 1982 storms caused serious erosion at the site; efforts to clean up the site have been a major focus of conservation interests since 1987. A mercury mine also operated on the Robert Dolcini Ranch in the Chileno Creek subwatershed during this same time.

Representatives of the city of Petaluma reportedly surveyed Walker Creek with the intention of damming the creek and shipping water to that growing city, but these plans were short-lived. The Marin Municipal Water District constructed Soulajule Dam on Arroyo Sausal in 1980, impounding 10,570 acre feet of water which is pumped as needed over the hills to Nicasio Reservoir.

Thornton noted that despite the dam, there has not been much bank change in his lifetime, but a greatly depleted fishery which was affected by the dam. The water releases from Soulajule keep the creek flowing all season and possibly cause a buildup of algae in the creek. He also notes a high amount of silt in the soil near his ranch, citing Brazil's 18-acre dam, built in 1960, filled in with silt (Thornton, 1995). William W. Haible's thesis on Holocene profile changes on Walker Creek states that since 1916 the creekbed has degraded up to eight feet in the upper watershed, leaving streamside terraces that were once the flood plain, and has aggraded downstream, burying fence posts and drowning alder trees (Haible, 1976).

This is largely blamed on overgrazing during the period of the late 19th and early 20th century and fall tilling and grazing, which has caused slope failure and gullying. Haible interviewed Boyd Stewart of Olema, who had worked on the Walker Creek Ranch in 1915, and reported:

> *Based on [Stewart's] description of the stream channel there about 1915, the inner terrace was the flood plain at that time. He pointed out riparian trees that have grown and are now standing on the inner terrace well above the active channel. He states that in the area around Synanon (now Walker Creek Ranch), the stream was narrow enough in many places that one could almost jump across the flow itself and that the width of the channel at the top of its banks was about 1/4 of what it is now at the top of the high terrace. He states that the inner terrace was much wider in this reach and was used for hay production...He also recalls that the sinuosity of the stream channel about 1915 was the same as it is today [1976]; in other words it was not a meandering stream* (Haible, 1976).

Physical Watershed Changes. Significant geomorphic changes, those that affect the form and topography of the earth's surface, have occurred in the Walker Creek watershed during this century. As a result, the habitat values in Walker Creek and its tributaries have been severely degraded. Physical changes in the Walker Creek watershed include downcutting of stream channels in the upper watershed; downstream filling and widening of the channel; destruction of riparian vegetation; isolation of Arroyo Sausal by construction of Soulajule Reservoir; changes in flow regime, from perennial, with low summer flows, to intermittent, with recent restoration of summer flows by releases from Soulajule Reservoir; and increased water temperatures.

Several researchers have attempted to reconstruct the history of erosion and sedimentation that have led to these changes in Walker Creek. Curry in Chatham et al. (1986), Haible (1976), Daetwyler (1966), and Hollibaugh (1995) have speculated about the causes and timing of the worst episodes of erosion and sedimentation.

In July 1985, a field tour of the Walker Creek watershed was conducted by Jerald Curry, NRCS State Geologist and Thomas Smith, NRCS Soil Mechanics Engineer. The report of observations made during this tour are included in Chatham, et al. (1986). According to this report there has been no uplifting within the watershed or any change in the base level—the elevation at the mouth of Walker Creek—in recent geologic time.

An in-depth study of geomorphic changes in the Walker Creek watershed above Keys Creek (Haible, 1976) documents the dramatic changes that have occurred in the Walker Creek watershed in the 60 years leading up to that study. According to Haible (1976), during this time period, stream flow became seasonal, upstream reaches of Walker Creek incised five feet, and downstream reaches filled with sediment. These changes have decreased the gradient of Walker Creek, and have had a profound negative effect on riparian habitat.

Downcutting in upstream reaches leaves unstable, vertical banks, excessive amounts of sediment in the stream channel, and undermines riparian vegetation. The profiles of tributary streams are partially controlled by the elevation of Walker Creek where they join it, so downcutting in upper Walker Creek has caused similar changes in the tributary drainages. Downstream of this cutting, sediment has been deposited, decreasing channel depth and capacity, creating a wide, shallow channel. At the time of Haible's study, downstream filling, or aggradation, was proceeding at the same rate that it had over the previous 60 years. Over the past 100 years, the estuary at the mouth of Walker Creek has been extended seaward several kilometers by this aggradation.

By comparison of historic bathymetric surveys in Tomales Bay, Daetwyler (1966) documented over 20 feet of shoaling at the mouth of Walker Creek and estimated that 3.3 million cubic yards of solid sediment were deposited in that area since 1861 (see Figure 2). Most of this deposition occurred prior to 1931.

According to Hollibaugh (1995), sediment delivery rates over the last five years appear to be about half that of the average over the last fifty years. Smith et al. (submitted) states that sedimentation rates are highly variable; they believe that from 1880 to 1890 sedimentation was close to a long-term average rate. From 1890 to 1900 rapid sedimentation occurred, followed by 40 years of average or below-average sedimentation. From 1940 to 1980 sedimentation was apparently close to the 114 year average, and the past ten years have seen slower than average sedimentation, although 1982, 1983, 1986, and 1993 all had higher than average sedimentation due to intense storms.

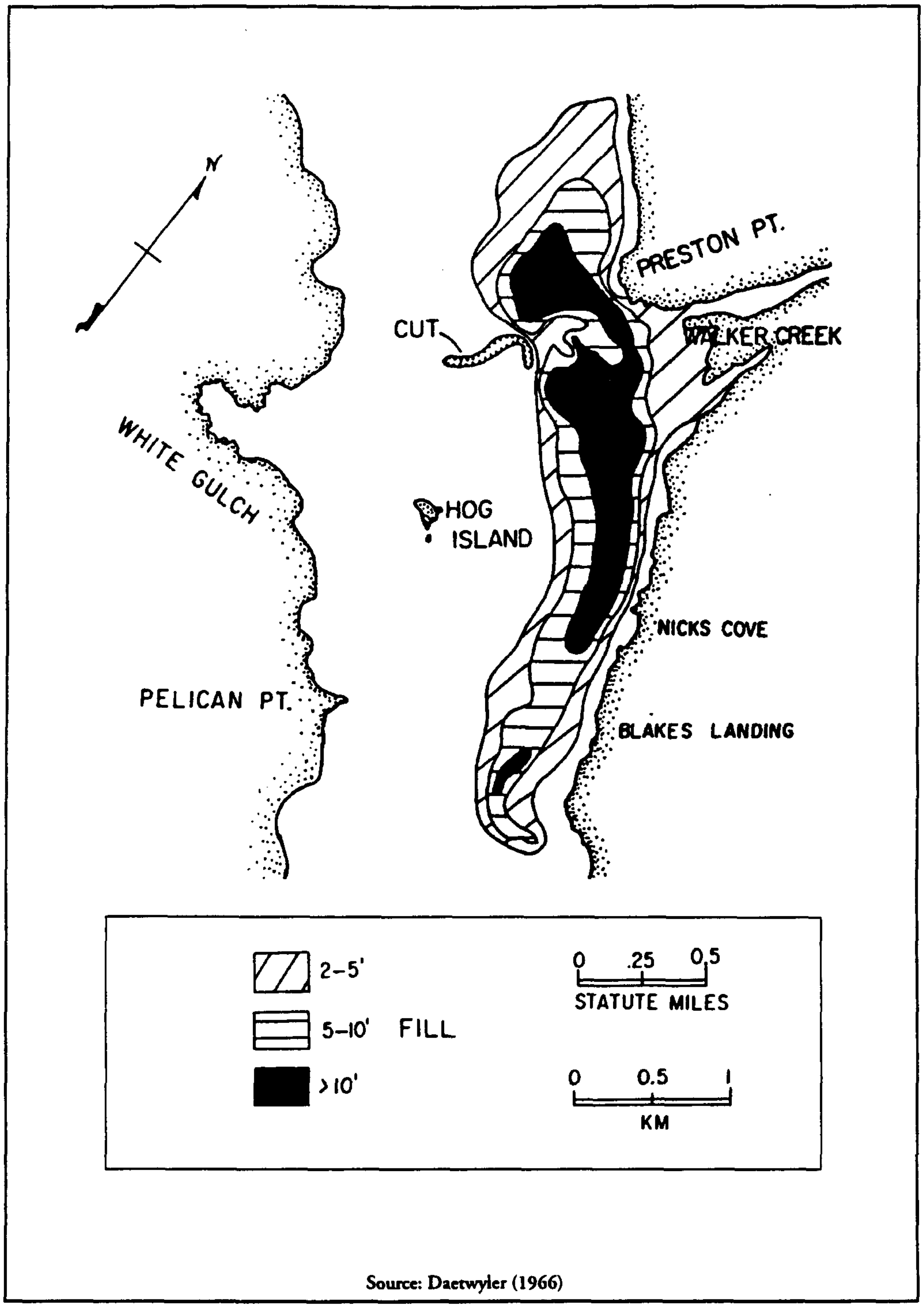
The reasons for these dramatic changes in the functioning of the Walker Creek watershed are complex and numerous, but are believed to be linked to land use. While land use has been primarily agricultural during the past 140 years, different agricultural commodities have been produced during different segments of this time period. Other human disturbances have undoubtedly affected the stability of the watershed. Two mercury mines operated in the Walker Creek watershed in the 1960s and streamflows have also been affected by construction of Soulajule Reservoir in 1968 and enlargement of the reservoir in 1980. Salmonid runs however, had declined to token levels well before the Reservoir was constructed.

No data exists that can actually link prevalent types of land use with corresponding changes in watershed function. Several authors however, have suggested cause and effect relationships, and anecdotal information provides some association between periods of dramatic change and prevalent land uses. It is the opinion of several authors that "overgrazing" has been the primary cause of the dramatic changes in the watershed. Kelley (1976) states that the most reasonable hypothesis to explain the changes in Walker Creek is overgrazing in the watershed. His report suggests that this type of land use has led to accelerated runoff, reduced infiltration into soil, depletion of the moisture storage capacity of the soil, intensification of the flash characteristics of floods and resultant streambank erosion, vertical incision of Walker Creek, and lowering of the water table, resulting in elimination of summer flows.

Daetwyler (1966) states that sedimentation at the mouth of Walker Creek reflects the intensive agriculture of the area. Trussel (1960) believes that, by the late 1860s, overgrazing and poor fanning practices resulted in significant soil erosion and sediment deposition in the Bay. Based on documentation of the potato industry in this area, it seems likely that potato fanning was the primary cause of this damage.

Stream Condition and Fish Habitat. Sedimentation has clearly had a devastating effect on fish habitat in Walker Creek. Many of the deep, cool pools and gravel that salmonids depend on for spawning and rearing young have been filled in with fine sediment. Because of sedimentation, the channel has become wider and shallower and water temperatures have increased; tree canopies are not able to shade the wider stream as effectively, and shallower water heats up more easily.

Fishery biologists have suggested numerous reasons for declining fish populations, including low fall and winter flows (before Soulajule was enlarged); high



Source: Daetwyler (1966)

Figure 2

Map of Shoaling at the Mouth of Walker Creek summer water temperatures due to lack of shading; filling of rearing pools; lack of cover and woody debris in the channel; embedded spawning gravels; and elevated nutrient levels. Local residents observed good runs of salmonids until the late 1970s, when a serious and prolonged drought occurred. Construction of Soulajule Reservoir is thought by some locals to be the cause of declining fish populations. Observations made during field surveys point toward numerous contributing factors. To date, however, recommended habitat enhancement measures have not improved fish populations in Walker Creek. An in-depth analysis of limiting factors is needed to help guide future enhancement efforts.

MMWD *Studies and Mitigation for Soulajule Reservoir* Several studies were commissioned by MMWD in the mid- to late 1970s in anticipation of impacts from enlargement of Soulajule Reservoir. Don Kelley, a fishery biologist hired by MMWD suggested that salmon and steelhead runs could be restored by increasing summer flows via releases from Soulajule Reservoir (Kelley, 1976). He listed three major constraints to the restoration of historic runs: zero summer and fall flows annually reduce rearing habitat to a few small standing pools; winter flows often drop to low levels between storms, leaving many salmon and steelhead eggs to die; and streambank erosion washes away riparian vegetation needed for shade and fills the pools with sand.

Longterm area residents reported to Kelley that in the 1920s and 1930s summer flows were very greatly reduced, but rarely ceased completely, and that pools had been larger. Kelley did not believe that loss of shade was a major reason for the demise of salmon and steelhead runs. He stated that nearly two-thirds of the stream was still well shaded and water temperatures there remained sufficiently cool. Since this report was written, riparian vegetation on some reaches of Walker Creek has increased substantially. Rich (1989), however, believes that salmonid populations have decreased in Walker Creek as a result of the reduced habitat from sedimentation and from high summer water temperatures, and, according to Bill Cox, DFG Fishery Biologist (Cox, 1995), high summer temperatures could be a limiting factor.

The restoration strategy proposed by Kelley in his 1976 report was built around increasing summer and fall stream flows. The report also proposed maintaining a floor on winter flows to increase egg survival. Finally, the report suggested that reducing the flash characteristics of flood flows would reduce bank erosion, thus reducing sand deposition in the bed, improving the quality of spawning and rearing habitat. It was suggested that the combined effect of these controls would encourage reproduction and growth of riparian vegetation to provide shade and maintain lower water temperatures. Ultimately, the report suggests that all of the above described effects would result in average runs of about 600 adult silver salmon per year and 500 to 600 adult steelhead per year.

Little quantitative information exists on the present status of salmon and steelhead runs in Walker Creek, but informal surveys have been conducted by several biologists. Although survey methods have been inconsistent and have not always been scientifically based, they do indicate that rather than improving with increased flows from Soulajule, salmonid populations have continued to decline. Despite the fact that riparian vegetation has increased considerably, fish runs have not. Anecdotal evidence of a thriving historic salmon and steelhead run exists. Peter Worsely wrote that "Walker Creek itself at one time had a good return of spawning coho salmon and steelhead. It is said that 40 to 50 years ago (the 1920s and 1930s) it was difficult to drive a horse and buggy across the stream at the height of the winter run because of the numbers of fish in the shallow water" (Worsely, 1972). Records kept by DFG Warden Lt. Al Giddings document some steelhead angling at the lower end of Walker Creek in the mid-1950s, but very little since then; there is no documentation of salmon angling.

In the summer of 1975, Kelley and his assistants intensively surveyed Walker Creek for salmon and steelhead. A total of eight young-of-the-year salmon and 326 young-of-the-year steelhead were found in the 14 miles of stream above tidewater. A few yearling steelhead were found in the deeper pools. Neither fish were found in unshaded reaches of the stream. Young-of-the-year steelhead were abundant in the lower mile of Frink Canyon Creek in May 1975, but numbers diminished later in the summer as the stream dried up. A few young-of-the-year salmon were found in the high quality salmonid habitat near the mouth of Chileno Creek. During these surveys, as the summer progressed, streamflow diminished, pools became smaller, young fish were preyed on, many pools dried up completely, and most of the young salmonids disappeared. Records from the U. S. G. S. streamflow gauge in Walker Creek showed this to be the typical summer pattern at that time.

In 1976 MMWD and the Department of Fish and Game entered into an agreement to regulate stream flows from Soulajule in an attempt to improve fish habitat conditions. The agreement called for maintaining winter flows of 20 cfs in normal years (63% of years) and 10 cfs in dry years (11 % of years), summer flows of 5 cfs in normal years and 2 cfs in dry years. In critically dry years (26% of years) the flow release was to be maintained at .5 cfs year-round (Emig, 1981). DFG also agreed to stock 18,300 yearling coho salmon each year for three consecutive years to help reestablish this species, and to stock the same number during critically dry years. Efforts to plant coho smolts in 1979 and 1980 were unsuccessful due to high water temperatures and poor condition of the fish. Due to limited supplies of coho eggs, no additional attempts at stocking were made.

Other Fishery Surveys. Emig (1981) surveyed populations of eight fish species in Walker Creek in an effort to estimate fish populations produced as a result of enhancement flows released from Soulajule Reservoir. Only five young-of-the-year salmon and 275 young-of-the-year steelhead were actually found, but populations of salmon and steelhead were estimated at 875 and 36,756 respectively.

In October 1984, Bill Cox, Eric McGuire (MMWD), and fisheries biologist Paul Bratovich (D. W. Kelley and Associates), surveyed Walker Creek and lower Arroyo Sausal from Soulajule Reservoir, downstream to within 1.5 miles of the confluence with Chileno Creek. The purpose of this survey was to qualitatively assess instream flow, instream habitat, riparian vegetation, and streambed, streambank, and overall watershed conditions. In a subsequent memorandum to Don Kelley, Paul Bratovich stated that the condition of the streambed was the major factor adversely affecting aquatic habitat in Walker Creek. He stated that the streambed is largely comprised of sand and other fine materials, and that cobbles and boulders in many of the riffles, which should provide important fish food-producing habitat and juvenile rearing areas, are highly embedded (Bratovich, 1984).

Site specific comments in this memorandum suggest other possible sources and causes of habitat degradation. Dense dumps of filamentous green algae and patches of duckweed were observed in Arroyo Sausal, just downstream from

Soulajule Reservoir, indicating the possibility of elevated nutrient levels below the Reservoir. In a follow-up 1984 memorandum to Richard Rogers, Assistant General Manager of MMWD, Kelley (1984) states that "If we could solve the problem of too much sediment from bank erosion and the restoration of more shade along the stream, I am sure healthy salmon and steelhead runs could be restored."

In the summer of 1989, A. A. Rich and Associates conducted fishery habitat surveys on Walker Creek. Detailed surveys were conducted from the mouth of Walker Creek to Marshall-Petaluma Road. Poor rearing habitat conditions above Marshall-Petaluma Road (due primarily to high silt levels in the water) precluded the usefulness of detailed surveys in this area, and only general observations were made.

These summer surveys focused on evaluating juvenile rearing habitat and availability of spawning areas. Surveys from the mouth of Walker Creek to Marshall-Petaluma Road showed that habitat conditions varied considerably between stream reaches, but that lack of cover and woody debris in the channel, embedded substrate, and high water temperatures were common problems. Some reaches provided acceptable to good salmonid habitat with gravel and cobble substrate, overhanging vegetation and woody debris, and acceptable water temperatures.

The area from Marshall-Petaluma Road to Soulajule Reservoir is in great need of repair. Although spawning gravels were found in this reach, they were highly embedded with silt. Rich states that "Until the excessive bank erosion problems and high silt load within the Creek throughout this area are reduced, the entire reach is unsuitable for salmonid rearing or spawning."

Water Quality. Very little water quality data exists for Walker Creek. It is clear that sediment is a primary water quality problem in this watershed, as large quantities of sediment can be observed in the stream and in bank deposits following heavy rains.

According to the *Draft Water Quality Assessment, A Catalog of the State's Water Bodies and Their Water Quality Condition* (State Water Quality Control Board, 1994), impaired waters are "water bodies that cannot reasonably be expected to attain or maintain applicable water quality standards." Walker Creek is listed as an impaired water body in this document. Problems are listed as sedimentation, NPS pollution from dairies, and mining discharge.

The *Water Body Fact Sheet for Walker Creek* (San Francisco Bay Regional Water Quality Control Board, 1994), which provides more detail on water quality problems within Walker Creek and its tributaries states that agricultural activities and two abandoned mercury mines have contributed to severe sedimentation and nutrient loading problems. These problems were not identified by water quality testing and are not backed up by quantitative data; the method of assessment is listed as Best Professional Judgment.

The DFG water testing program includes two sampling stations in the Walker Creek watershed, at Laguna Lake and Salmon Creek. Though toxic levels of ammonia and high water temperatures have been a problem in Laguna Lake in past years, water quality here has improved considerably over the past few years (Mike Rugg, 1995). Up until 1991, local landowners pumped the water out of Laguna Lake in the summer so that the lake bed could be farmed. Due to thermal pollution and high ammonia levels the landowners have had to discontinue the practice of pumping this water into Chileno Creek.

Bratovich, in his October 1994 memorandum to Don Kelley, stated that lower Arroyo Sausal exuded a strong sulfurous odor, characteristic of hydrogen sulfide where discharge from Soulajule Reservoir entered. Dense clumps of filamentous green algae and patches of duckweed were observed in the Creek. Bill Cox (1995) stated that the eastern arm of Soulajule Reservoir has been choked with phytoplankton, giving it the appearance of pea soup. He believes that the reservoir generates nutrients which could be transported downstream in summer releases.

Lagunitas Creek

Lagunitas Creek was originally called Arroyo San Geronimo, and the lower section of the stream is popularly called Paper Mill Creek.

Watershed Summary. Agriculture is no longer the predominant land use within the Lagunitas Creek watershed. Much of the watershed is owned by MMWD and is now used for water supply to east Marin. Significant portions are also owned by Point Reyes National Seashore and Golden Gate National Recreation Area, some of which are leased for ranching. There are numerous small communities within the watershed, with the highest concentration in the San Geronimo Valley.

As is true throughout the project area, the Lagunitas Creek watershed has undergone significant physical changes since Europeans arrived. The most obvious change is that MMWD has constructed reservoirs in many of Lagunitas Creek's tributaries, drastically altering streamflows. Changes in watershed condition are also likely linked to past agricultural use and logging. Despite these changes, fish populations are in relatively good condition, and Lagunitas Creek is thought to be one of the best coho salmon streams on the California coast.

Physical watershed changes have not been analyzed in as much detail as in other watersheds in the project area. Most studies on Lagunitas Creek have focused on the condition of the fishery, particularly the effect of MMWD's water impoundments on coho salmon and steelhead trout. Conclusions drawn in some of these studies, commissioned by MMWD as required by the State Water Board, have been criticized by environmental groups for focusing too heavily on the effects of sedimentation, and minimizing the importance of water flow. An erosion and sediment study on Olema Creek that was commissioned by Point Reyes National Seashore in the late 1980s attributed some reaches of bank erosion to faulting along the San Andreas.

There is no program for monitoring agricultural sources of water pollution in this watershed. The most regular and comprehensive water quality monitoring program is conducted by MMWD to assure that domestic water sources are clean and that water quality variables are suitable for salmonids.

Setting. Lagunitas Creek and its tributaries occupy the largest drainage area emptying into Tomales Bay, including much of west central Marin County. The watershed area totals 103 square miles. The upper watershed consists mostly of open space and watershed lands, and in the lower watershed there are beef ranches and four dairies.

Water developments have had a major influence on the biotic resources of Lagunitas Creek as well as on local land use.

It originates on the northern slopes of Mount Tamalpais and flows northerly approximately 25 miles before entering the Pacific Ocean at the southern end of Tomales Bay. Lagunitas Creek is fed by five main tributaries. Nicasio Creek, San Geronimo Creek, and Olema Creek are the largest tributaries. Devil's Gulch and Deadman's Gulch are also significant tributaries.

Row within Lagunitas Creek is highly regulated. The only major tributaries which are not regulated are San Geronimo Creek and Olema Creek. Reservoirs in remaining tributaries provide a significant proportion of the water supply for the Marin Municipal Water District (MMWD). Four of these reservoirs (Kent, Alpine, Bon Tempe, and Lagunitas) are located in the upper Lagunitas Creek watershed, while the Nicasio Reservoir is located in Nicasio Creek, approximately one mile upstream from its confluence with Lagunitas Creek (Bellinger, 1995). There are also a number of additional water diversions which service water supply and agricultural water rights within the basin, and a small impoundment is created annually by construction of a small gravel dam across the lower end of Lagunitas Creek on the Giacomini Dairy.

In the upper watershed, where rainfall is heaviest, Lagunitas Creek flows through steep-sided, heavily wooded canyons. Downstream, where rainfall is lighter, the canyons open up and the Creek flows through rolling grasslands on broad alluvial terraces (Roxon, 1992). Most of Lagunitas Creek is well vegetated with dense riparian forest. Between Tocaloma Bridge and the Coast Guard Station in Point Reyes Station a dense riparian forest of willow and alder shades with deep pools. The upper reaches through San Geronimo Valley and Samuel P. Taylor State Park are also well vegetated, primarily with redwood, alder and occasional clusters of willow. The uplands consist of open grasslands on ridgetops and south-facing slopes, and bay, coast live oak, and Douglas-fir forest on the north-facing slopes with redwoods in the draws (Prunuske, 1988).

According to Hect (1979), the watershed is underlain by a diverse and structurally complex group of rock types, which is a predominant influence on habitat. The watershed is underlain largely by Franciscan formation rocks types including graywackes, sandstones, shales, greenstones, and serpentinites. Sediment yields are variable in time, and according to rock type in the source area. Hect (1979) divided the mainstem of Lagunitas Creek into five major reaches based on hydraulic, morphologic, and bed sediment characteristics. Hect (1979) described these reaches as follows:

1. *Lower Lagunitas:* Extending from the mouth to Nicasio Creek.
2. *Tocaloma:* Aggraded and probably aggrading, this reach has sandy and fine gravel beds below dense riparian vegetation and log jams, extending to about one-half mile above the Tocaloma Bridge.

3. *State Park:* From the end of the Tocaloma Reach to the mouth of San Geronimo Creek, this is regarded as the premier habitat in the stream system presently accessible to fish.

4. *Shafter Bridge:* The reach from Shafter Bridge upstream to Peters Dam; it is distinguished from the State Park reach by a steeper gradient and the absence of sand and fine gravel in the bed.

5. *San Geronimo Creek:* This includes the mainstem of the creek and its major tributaries.

The stretch of Lagunitas Creek with preferred rearing habitat (the State Park reach) appears to coincide with the distribution of greenstones underlying the channel in this area. This rock type is a source of clear, cool water, and the boulders and cobbles that weather from the greenstone provide a suitable environment for salmonids.

Lower Lagunitas Creek, below the mouth of Nicasio Creek, is an unusual and geomorphically complex environment (Hect, 1979). Before construction of dams in the watershed, most of the sediment load entered the creek in this reach. Even after construction of Nicasio Reservoir, mineralogy of the bed sediments in this reach indicate that most of the material is derived from the Nicasio Valley.

The Olema Creek watershed is physically distinct from other subwatersheds within the Lagunitas Creek drainage. Olema Creek enters Lagunitas Creek approximately two miles upstream of the Lagunitas Creek delta and is a uniquely linear drainage basin oriented along the San Andreas Rift Zone. Under normal rainfall conditions, Olema Creek flows year around, with the summer flow sustained primarily by the perennial tributaries that drain Inverness Ridge; tributary streams from the west side generally go dry during summer months (Questa Engineering, 1990).

The Olema Creek watershed is almost entirely within Point Reyes National Seashore and Golden Gate National Recreation Area. Geology and topography of the Olema Creek basin are largely determined by the San Andreas Fault. The basin is approximately nine miles long and two miles wide at its widest point. It is bounded by Inverness Ridge on the southwest and Bolinas Ridge on the northeast. Approximately 70% of the watershed lies east of the San Andreas Fault, draining the west flanks of Bolinas Ridge. The remainder of the watershed drains the eastern slopes of Inverness Ridge. Numerous tributary streams flow into Olema Creek from the east and west sides. West side streams are generally steeper than east side streams, with gradients of 15 to 20% on the west side, compared with four to eight percent on the east side. Vegetation is closely related to the different landforms, and is distinct on the west and east sides. West side slopes are forested while east side slopes generally support grassland and shrubland; steep ephemeral drainages on the east side support hardwoods and Douglas-firs.

Land Use History. Water developments have had a major influence on the biotic resources of Lagunitas Creek as well as on local land use. Twenty-six private water companies were consolidated by formation of MMWD in 1912. Prior to that time, the area that now comprises the District had a population of less than 20,000 and was served by two major and over 20 minor private, unrelated companies. Since that time, the District has grown to serve 170,000 people residing in a 147 square mile area.

The first significant diversion from Lagunitas Creek was via Lagunitas Dam, constructed in 1873. Following formation of the District, an engineer was hired to investigate potential sources of water for District distribution. Upon the engineer's recommendation, Alpine Dam was constructed in 1913, marking the beginning of a trend that continued into the mid-1970s to construct new water storage projects within the Lagunitas Creek basin every time District water consumption outpaced the yield of the current water system (Roxon, 1992).

In 1982, Kent Lake was enlarged, doubling the storage capacity. These water developments have been the source of much public controversy, and the State Water Board has required extensive studies on fishery resources and sediment sources in Lagunitas Creek as conditions of the permit for enlarging Kent Lake.

The following history separates the Lagunitas Creek watershed into four geographic areas.

Upper Watershed (headwaters on Mt. Tamalpais to Shafter Bridge/San Geronimo Creek). The northern slopes of Mt. Tamalpais were logged of coast redwood and Douglas-fir in the latter part of the 19th century, evidenced by stumps, sled roads and mature second growth. It is likely that cord wood was also taken here. Further downstream near Lily Lake and at Alpine, sawmills were active in the 1860s and 1870s (Fairley, 1986). Still further downstream, logging activity was heavy during the late 1870s through about 1900; landowners Shafter and Howard built a 3.3-mile railway from the main line into the canyon at Carson Creek to transport logs and lumber to market in San Francisco (Dickson, 1981). Much of this area was clear-cut during the 1940s and early 1950s to make way for Kent Lake, filled in 1954 (Roxon, 1992).

The area between Lake Lagunitas and Lily Lake was once used for dairy and sheep production. Two dairies, one operated by the Bauntempi brothers and the other at Liberty Gulch leased by Loomis Curtis and later Vincent Liberty, were in operation until shortly after the turn of the century. Sheep grazed in many areas until at least 1930; cattle grazing leases in the Pine Mountain area lasted until 1969. There were also a number of small resorts and cabins along the creek in the Liberty/Alpine area (Fairley, 1986). The county road from San Rafael to Bolinas followed Lagunitas Creek for several miles; it was moved uphill during the construction of Alpine Lake in 1919.

The first major dam on the creek, called Lake Lagunitas, was constructed in 1873 at the confluence of the three headwaters forks above Bon Tempe meadows; the earth dam impounded 127 million gallons from a watershed of 1,094 acres and was the first interurban transfer of water in the county. In 1919, the newly formed Marin Municipal Water District built Alpine Dam, with a 4,774 acre watershed, and later enlarged the concrete dam twice to provide a capacity of 2,900 million gallons. Bon Tempe Lake, built in 1949, impounds 1309 million gallons, and Kent Lake, after enlargement in 1982, impounds ten billion gallons. Until the construction of Nicasio Dam in 1960, virtually all of the water supply for eastern Marin County came from Lagunitas Creek (Fairley, 1986; Roxon, 1992).

Fires swept through the upper part of the Lagunitas Creek watershed a number of times. Notable is the fire of 1904, which burned much of the western watershed, and the famous fire of 1945, which devoured practically the entire watershed from San Geronimo to Stinson Beach; it started at the Ruoff saw mill in the canyon above the confluence with Carson Creek (Livingston, 1987).

San Geronimo Creek and Nicasio Creek Subwatersheds. San Geronimo and Nicasio Valleys, more populous than the upper Lagunitas, were settled in the 1850s. Dairy farms occupied virtually all of the grazeable land and no doubt many acres were cleared for the purpose. Small potato farms have been recorded as early as the 1840s in the San Geronimo Valley, and the fertile lowlands around Nicasio were no doubt farmed and plowed at times (Revere, 1872). Most of the dairy ranches grew hay crops, a practice that expanded in the 1920s with the popularization of motorized tractors and died out in the 1940s as central valley hay farms provided feed at a low price (Stewart, 1995). Only one grazing ranch remains in the San Geronimo Valley; of the others, two have been incorporated into a golf course and the rest subdivided. San Geronimo Valley is now a bedroom community with most of its workers commuting to jobs elsewhere. Nicasio Valley has seen less suburban development, but many of the dairies have turned to beef raising and horse breeding. Nicasio Reservoir, built in 1960, flooded hundreds of acres of prime grazing land and put at least five family-owned dairies out of business (Mclsaac, 1994).

Both San Geronimo and Nicasio Valleys have forested areas on their south sides. Both were exploited for lumber beginning in the 1850, continuing as recently as 1960. Fires have burned portions of both areas a number of times during the last 150 years (Livingston, 1987).

Central Watershed (Lagunitas Creek from Shafter to Jewett). This region has seen a surprising amount of industry. Samuel P. Taylor built the west's first paper mill on the banks of Lagunitas Creek near Devil's Gulch in 1856. The original mill was powered by water, captured in a dam opposite Dead Man's Gulch and carried by a flume to the mill; later this dam provided water for steam production. Pollution from the mill was dumped into the creek, raising protests at times from fishermen. The mill operated 24 hours a day until it closed in 1893. Taylor ran dairy cows on the northern hills and in Devil's Gulch, and his son operated a large resort at Camp Taylor, where amenities included a three-story hotel, dozens of canvas-walled cabins, tent sites, a dancing pavilion and bowling alley, and saloons (Livingston, 1987). The fishery apparently recovered after the paper mill closed in 1893, for in 1898 the California Board of Fish Commissioners noted that "Paper Mill Creek is probably more frequented by fishermen than by any other stream in the state." The fishery was soon depleted, however, no doubt a victim of its own popularity. Nearby, the state had established a short-lived fish hatchery on Bear Valley Creek in 1893 where eastern brook trout were raised (Mason, 1976).

A black powder factory operated upstream from Camp Taylor from 1864 until 1870. A small dam and flume provided the power. At Irving (a railroad flag stop) a fur tannery, later a tanbark processing plant, operated for many years until 1893. Wood cutters worked in the surrounding forests cutting oak, tanoak, madrone and other woods for fuel (Livingston, 1987). Logging for lumber is evident in the number and size of redwood stumps which remain.

Lower Watershed (Jewett to head of Tomales Bay). From Jewell to the head of Tomales Bay, dairy farming dominated the landscape. At least ten dairy ranches were in business in this region until 1970. All have converted to beef production and most are owned by the National Park Service. Tree cutting for cord wood has been the only use of the mostly hardwood forests in the area (Mclsaac, 1994)

Roads were constructed along Lagunitas Creek beginning in the 1850s, with an engineered county highway from San Rafael to Point Reyes built in 1867. The North Pacific Coast Railroad constructed its railbed along the banks of the creek from San Geronimo to Point Reyes Station and beyond in 1873-74 (Joslin, 1986). The impacts of the large cuts and fills along the stream banks were no doubt major contributors to siltation and erosion. The railroad was abandoned in 1933 but the grade remains in use as ranch access and a recreational path. At the confluence of Lagunitas and Nicasio Creeks a commercial gravel firm extracted sands and gravel from the creek bed between 1939 and 1962; owners found that after Nicasio Dam was constructed the natural gravel flows ceased. Further downstream a portion of the flood plain at the Gallagher Ranch was reclaimed as a crop field, and still further at the Genazzi Ranch gravel has been taken from the streambed for ranch purposes, a practice common upstream along the creek (Gallagher and Genazzi, 1995). The seasonal gravel dam at the Waldo Giacomini Ranch, adjacent to the confluence of Olema and Lagunitas Creeks, has been in use since the 1950s and is used to trap water for irrigation of the reclaimed pastures at the head of Tomales Bay.

Olema Creek Subwatershed. Land use in this watershed reflects the vegetation patterns found there: cattle and sheep grazed on the eastern grassy slopes, and logging occurred on the forested western slopes. Cattle grazing occurred as early as 1834 and probably earlier; the lands in the valley were divided into dairy ranches beginning in 1856, with fourteen dairies in operation by 1880. Some land clearing occurred although the locations are not specifically known. The 19th century dairy ranchers supplemented their income with crops, mainly potatoes and wheat; they grew their own hay until the late 1940s (Livingston, 1987). Almost 1,000 acres of the Parsons (Lupton) and Randall ranches were grazed by sheep during the 1930s and 1940s. All of the dairy ranches in the Olema Valley went out of business by 1975, largely due to environmental requirements of the early 1970s, and most have made the transition to beef and dairy replacement stock raising. The National Park Service has since bought the entire watershed except for the town of Olema and the adjacent Vedanta Society property.

Portions of the Olema Creek watershed were logged during the 19th century. James McMillan Shafter owned a portable sawmill that he operated at Olema and Laurel Grove (Five Brooks) during the 1880s, providing for the local lumber needs. Shafter also harvested thousands of cords of firewood for use by the railroad for firing the steam engines and for other commercial and domestic uses (Livingston, 1995). The only large scale modern logging operation recorded in the Olema Creek watershed was that of the Sweet Lumber Company at Five Brooks, in operation from about 1956 to 1962. Douglas-fir forests on the Stewart and Tevis properties were clearcut until the National Park Service intervened with the creation of Point Reyes National Seashore.

A local landowner, John Rapp, had a canal constructed to reclaim the flats between Olema and Point Reyes Station in 1922. The former meanders of the stream were plowed and crops planted, including feed crops and artichokes and other vegetables. The flats have been used for cattle grazing for at least 30 years (Livingston, 1995).

Physical Watershed Changes. Geomorphic changes in the Lagunitas Creek watershed have not been analyzed as extensively as in the Stemple Creek/Estero de San Antonio and Walker Creek watersheds. However, apparent major changes can be attributed to significant land uses within the watershed. Geomorphologist Barry Hect (1979) suggests that Lagunitas Creek, as many other streams on the California Coast, has incised in upper reaches and filled near the mouth due to natural and/or land use influences. Smith et al. (submitted) states that logging in the Lagunitas Creek watershed between 1850 and 1870, and again around 1960, was largely responsible for rapid growth of the Lagunitas Creek delta. Erosion and sediment studies within distinct areas of the watershed by Hect (1979; 1980;1992) point to significant changes in sediment transport from construction of water impoundments by MMWD.

A detailed erosion and sediment study was conducted in the Olema Creek sub watershed in the late 1980s (Questa Engineering, 1990). This study, commissioned by PRNS, involved monitoring streamflow and sediment discharge on the main channel of Olema Creek and tributary streams, review and interpretation of historical aerial photographs, and field survey and evaluation of stream channel stability and watershed erosional features. Unfortunately, field work was conducted from 1986 through 1989, years in which rainfall was substantially below normal. The authors state that the study did not benefit from direct observation of erosion and sediment discharge characteristics under normal or above average rainfall-runoff conditions and that the monitoring data and findings are therefore limited in this regard. However, the report provides valuable information on general watershed condition.

The Olema Creek Sedimentation and Erosion Study (Questa Engineering, 1990) includes a Watershed Conditions Inventory based on interpretation of historic aerial photographs, and field examination and evaluation of stream channel stability and significant erosional features. Aerial photographs from 1943 through 1985 were used to assess watershed condition following three major events, including the storms of 1964 and 1983 and extensive logging of the southwest part of the watershed prior to 1964.

Investigators determined that, with the exception of heavy logging in the southwest part of the watershed in 1963 or 1964, land use has changed very little over the 42 year period of the photo record. Most of the existing ranch roads and facilities were in place by 1943. Though approximately one-fifth of the watershed was clearcut tractor logged, with numerous logging roads on steep slopes, aerial photograph interpretation did not conclusively reveal erosion damage that can be linked to the logging. Aerial photographs showed that landslides and soil slips have not enlarged or become more frequent, and significant changes in grassland tributary streams was not evident (forested streams are hidden from view). Landslides and gully advances subsequent to 1942 are believed to have occurred very recently, probably during the winter of 1982-83.

Results of the stream survey confirmed the findings of the upland watershed inventory and stream sediment monitoring studies—the majority of the sediment moving down Olema Creek appears to be originating from the channel banks, and several notable stream bank failures, totaling 6,000 to 7,000 feet were mapped (Questa Engineering, 1990). This study concludes that overall the upland portion of the watershed is in good to fair condition. At least some of the notable reaches of bank erosion on Olema Creek appear to be attributable to faulting. Field examination of erosional features in the Olema Creek watershed by investigators from Questa Engineering showed that few of the advancing gullies and headcutting tributary drainages could be associated with specific practices such as road construction or location.

The investigators believe that most of the current gullies, landslides, and soil slips observed in the eastern side of Olema Creek watershed date back at least 40 years, and possibly originated during the time of intensive sheep grazing around the turn of the century. They state that the single most significant source of erosion appears to be the large landslides that impinge on Olema Creek at Five Brooks, where the stream channel crosses the San Andreas Fault. This area was subject to a 22 foot lateral movement during the 1906 earthquake; the present instability is believed to be largely attributable to this geologic condition. An annual sediment yield to Olema Creek of about 50 tons is estimated for this single erosion feature.

The relatively steep gradient of the Olema Creek alluvial channel, combined with its alignment along the San Andreas Rift Zone, are believed to be major factors contributing to the observed instability of stream banks and the stream channel.

Stream Condition. Relative to other streams in the project area, and throughout coastal California, coho and steelhead runs in Lagunitas Creek are in good condition. In fact, Lagunitas Creek is said to presently support 10% of the coho run in the entire state (California Department of Fish and Game, 1994). Despite this positive circumstance, habitat and fish populations in Lagunitas Creek have declined greatly over the years. Construction of Kent and other reservoirs by MMWD has played a major role in altering the habitat conditions in Lagunitas Creek. These water impoundments have resulted in the drowning of habitat under Kent Reservoir; undependable stream flows for migration, spawning, and juvenile rearing; reduction of habitat by the accumulation of sand in the stream bottom, and reduction of coarse sediment; and increased frequency of egg losses by scour as the stream bottom grew softer (Kelley and ENTRIX, Inc. 1992).

Fishery Studies by Don Kelley and ENTRIX. In response to enlargement of Kent Dam in 1982, the State Water Board required MMWD to conduct studies that would establish appropriate minimum instream flows and other requirements for the protection of salmon, steelhead and other aquatic life in Lagunitas Creek. Numerous studies have been conducted by fishery biologists including Don Kelley and Associates, geomorphologist Barry Hect, and more recently by biologists from ENTRIX, Inc. Studies commissioned by MMWD provide the bulk of the existing biological and geomorphological information on Lagunitas Creek and its tributaries. Some of the conclusions reached in these studies have been challenged by environmental and fishery groups during the State Board hearings. Generally, the studies have been criticized as overemphasizing the role of sedimentation and underestimating the role of streamflows to survival and reproduction of salmonids (Richard Plant, 1995).

Two major problems that have been identified in these studies include deficient instream flows, and accumulation of sand in the stream bottom. Sand accumulation has created a soft streambed which contains small sediments that are easily scoured by high winter flows. During the winter small fish take cover in the gravel and cobble of the streambed. In streams where spaces between these coarser particles are filled with sand, young fish cannot take cover and are washed downstream on high flows or are subject to predation if not sheltered. As a result of scouring, major destruction of coho salmon occurs as often as once every three years. Accumulation of sand also reduces juvenile rearing habitat by filling in dry season pools (Kelley and ENTRIX, Inc., 1992).

Sediment Studies by Barry Hect et al. Hect (1979) cites the lack of adequate dry season rearing habitat as a significant limitation to populations of coho salmon and steelhead in Lagunitas Creek. He states that juveniles of both species are not able to find adequate cover and therefore move downstream to salt water at a premature age, leading to high mortality rates. Preferred habitat, with deep pools, sheltering cobbles and boulders, and overhanging bar and bank vegetation, is very limited below San Geronimo Creek, largely due to coarse sand and fine gravel deposition in the channel.

Sediment studies conducted by Hect (1979) determined that San Geronimo Creek contributes well over half of the sediment in the stream as far as the Tocaloma Bridge, and perhaps to Nicasio Creek. Below Nicasio Creek, channel sediment appears to derive almost exclusively from Nicasio Valley; this reach is not thought to have significant rearing and spawning habitat. In a later study, Hect (1980) concluded that Olema Creek contributes a disproportionate amount of the sediment supplied to the south end of Tomales Bay. He measured sediment delivery from Olema Creek to the upper reaches of Tomales Bay to be greater than that delivered by the rest of the Lagunitas Creek drainage network. This study suggested delivery of about 68,000 tons of sediment to Tomales Bay from Olema Creek in 1979-80, compared to 34,000 tons from the rest of the Lagunitas Creek watershed. This data has been questioned by Questa Engineers (1990), who estimated sediment delivery from Olema Creek to be significantly lower.

The Sediment Overview Report for Lagunitas Creek (Hect et al., 1992) examines the sources, types, transport modes, and effects of sediments on the fishery habitat in Lagunitas Creek. This report concludes that the reduction in flushing flows resulting from the enlarged Kent Reservoir will exacerbate the sand problem unless the amount of sediment contributed to the stream is reduced by an annual 10 to 20%. In an effort to prevent further degradation to streambed conditions from the enlarged dam, the Marin County Resource Conservation District is implementing a sediment reduction plan in San Geronimo Creek with funding from MMWD. Though this program is intended to prevent further degradation of the streambed, additional measures would have to be undertaken to actually improve conditions.

The following is an abbreviated list of findings included in the *Sediment Overview Report:*

- Lagunitas Creek and its tributaries were in a non-equilibrium condition prior to construction of Peters Dam. These streams were incising in their upper reaches and filling near their mouths, due to natural and/or land-use influences.

- The habitat in Lagunitas Creek is impaired primarily by coarse sand and fine gravel.
- Sand mineralogies and gravel lithologies showed that San Geronimo Creek contributes well over half the sediment in the stream as far as the Tocaloma bridge, and perhaps to Nicasio Creek.
- Below Nicasio Creek, channel sediment is almost exclusively from Nicasio Valley. The volume in storage is much larger than that which can be transported by the stream under present flow regime. Minor releases from Kent and Nicasio Reservoirs may be effective in eliminating concentrations of fine sand and silt. However, this reach is not thought to have significant rearing and spawning habitat.
- Detention of coarse sediment in San Geronimo Creek appears to be the most effective control measure. Releases from Kent Lake may be used to supplement gravel removal.

Fish and Habitat Surveys/Studies. No definitive estimates of fish populations are available for Lagunitas Creek. Fish counts have been conducted by several fishery biologists and citizen volunteers; however, sampling has not been consistent, and has not been done in such a way that accurate estimates of fish populations can be projected from these samples. Fishery biologists presently under contract with MMWD have sampled fish populations for two years and conducted habitat typing in the Spring of 1995. This information may be used to generate population estimates (Roxon, 1995).

Fish Surveys by DFG and Lagunitas Creek Citizens Advisory Committee. In 1982, DFG began a periodic monitoring program in which 22 sites were electrofished in September and/or October. Due to budget limitations the number of sampling stations was subsequently reduced to nine, and sampling has been sporadic since. Between 1982 and 1986 DFG electrofishing at 22 stations counted coho salmon from a low of 20 in 1986 to a high of 63 in 1984, and steelhead from a low of 315 in 1983 to a high of 861 in 1982. Bill Cox, DFG Fishery Biologist, has conducted casual counts of adult coho salmon by walking Lagunitas Creek from Woodacre to Devil's Gulch, up Devil's Gulch, and Lagunitas Creek from Shafter Bridge to Peters Dam. He has observed increases from generally around 30 fish in the early 1980s to consistently over 100 fish for the last few years (Cox, 1995).

In fall/winter 1985-86 Bill Cox and Lagunitas Creek Citizens' Advisory Committee (LCCAC) volunteers conducted fish counts on Lagunitas Creek and tributaries (Cox, 1986). Cox's survey documented 52 coho in 3.9 miles of San Geronimo Creek, 25 coho and one steelhead in 3.2 miles of Lagunitas Creek, and four coho in 1.4 miles of Devil's Gulch. LCCAC surveys documented 53 coho and four steelhead in 4.7 miles of San Geronimo Creek, 42 coho and 15 steelhead in 5 miles of Lagunitas Creek, one coho in Devil's Gulch, and 42 coho and 12 steelhead in Olema Creek.

In spring of 1987 Bill Cox described fish habitat between the CalTrans maintenance yard and Lagunitas Creek as "surprisingly good" (Cox, 1987). This reach was described as having good riparian cover, stable banks with a considerable area of undercut, a moderate amount of woody debris providing structural habitat, and several riffle areas with gravel suitable for spawning.

Fish Surveys on Olema Creek. A fish survey of Olema Creek conducted by personnel from the DFG Fisheries Management Unit in Menlo Park in September, 1979 (Anderson and Paulsen, 1979) documented numbers of steelhead sculpin, roach and several other species; notably, no coho were counted at either of the two sampling stations. At a station located upstream of the Bear Valley Bridge 29 steelhead, and 34 each sculpin and roach were counted. Water temperature was relatively cool (59° F) at 9:30 am. At an upstream reach adjacent to the Stewart Ranch, 48 steelhead, 109 roach, and 11 sculpin were counted. Here water temperature was substantially warmer (71° F) though sampling was done at 3:00 PM. Considerable sun exposure was noted here.

Qualitative habitat surveys and quantitative fish surveys have been carried out in Olema Creek by fishery biologists and citizen volunteers. In October, 1985 private fishery biologist Don Kelley, DFG biologist Bill Cox, Point Reyes staff and interested citizens conducted a reconnaissance survey of fish habitat on Olema Creek. In a memorandum following this survey, Kelly (1985) characterized habitat as follows:

- Marsh to Bear Valley Road. This reach was described as poor salmonid habitat due to low flows and a large amount of sand in the stream bottom. Causes for the sandy substrate were cited as eroding banks due to lack of woody vegetation and access to the stream by horses.
- Bear Valley Road to Olema Creek. This reach was describes as having better spawning and rearing habitat than the lower two miles. Riparian cover was good, but the streambed contained much sand, making pools shallow, and embedding cobbles.
- Olema Cemetery to Boyd Stewart's Ranch. This reach meanders in the bottom of an unusual canyon presumed to be the San Andreas Fault. Canyon walls are 100 feet or more high. Two areas of significant bank erosion were noted in this reach.

Generally, Kelly found that the quality of salmonid rearing habitat improved as he moved upstream. Upper reaches contained increasing amounts of unembedded cobbles and boulders. Limiting factors included low flows and sand in the streambed. Fish that were noted during this survey included hundreds of California roach, a few dozen young-of-the-year steelhead, very few that might have been yearlings, and one adult steelhead that had been trapped in the stream the previous year. Kelly estimated that there were thousands of roach and a few hundred steelhead in the stream.

Life History Stage Study by Bratovich and Kelley, An analysis of the important environmental factors that correspond to the life history stages of salmonids in Lagunitas Creek was completed by Bratovich and Kelley in 1988. This study, titled *Investigations of Salmon and Steelhead in Lagunitas Creek, Mann County, California. Volume 1. Migration, Spawning, Embryo Incubation and Emergence, Juvenile Rearing, Emigration*, individually assesses the life stages and associated stream conditions that are required for each life stage. The following paragraphs are adapted from the study summary.

Upstream Migration. Adult salmon begin migrating upstream from the Lagunitas Creek estuary in the fall after rains provide sufficient flow. Based on data generated from experiments that the investigators conducted, and from estimated flows and daily salmon catch at the DFG Nicasio fish trap during the seven years that it operated (1963/64 to 1967/70), Bratovich and Kelley determined that a mean daily flow of 35 cfs at the Point Reyes gauge is needed to attract salmon into Lagunitas Creek. Past lack of flow sufficient for upstream migration has probably had an adverse effect on salmon runs in Lagunitas Creek. They state that there has usually been sufficient unregulated flow in Lagunitas Creek during the winter to provide for upstream migration of the steelhead that migrate later in the winter than salmon.

Note: Rich (1987) states that one of the most important factors known to influence a steelhead's ascent of coastal streams is streamflow connected with storm events. Other factors include passage barriers (e. g. shallow riffles and debris dams), water quality (e. g. siltation problems), water temperature, and angling pressure.

Salmon and steelhead smolts emigrate from Lagunitas Creek from March through June, with most emigrating during April and May.

Spawning. During the study Bratovich and Kelley determined that approximately half of the salmon and steelhead spawned in Lagunitas Creek and half in the tributaries. In Lagunitas Creek, most redds were built in the State Park reach. Nearly all redds were located in the center of the channel where dewatering was unlikely. The total amount of spawning habitat increased with increased flow.

Embryo Incubation. Salmonid embryos incubate under a mound of gravel in the redds during winter and spring. The only problem that was observed with embryo incubation in Lagunitas Creek was streambed scouring. The sandy streambed becomes mobile and is easily scoured at high flows. The magnitude, duration, and frequency of flows that scour the streambed to depths that adversely affect incubating embryos depend on streambed conditions. Sedimented streambeds with loosely compacted fine material are more prone to scour than streambeds of larger, or more tightly compacted material.

Fry Emergence. Salmonid eggs and newly hatched sac fry develop in the gravel of the streambed and subsequently emerge from the gravel as fry. Sediment that accumulates on the redds during incubation can act as a physical barrier to fry emergence. Bratovich and Kelley stated that fry emergence did not appear to be a major problem during the study period but that increased sedimentation of the streambed will reduce salmonid survival during both incubation and emergence.

Juvenile Rearing. Fry of both coho and steelhead remain in the stream feeding and growing during their first summer. Bratovich and Kelley, in agreement with DFG biologists, state that the quantity and quality of summer rearing habitat sometimes limit populations of both salmon and steelhead in Lagunitas Creek. Streamflows directly affect water depths and velocities, and indirectly affect substrate and cover characteristics. Bratovich and Kelley measured juvenile summer rearing habitat increasing with increased flow up to 5 cfs in the State Park reach and up to 12 cfs in the Tocaloma reach. DFG biologist Gary Smith estimated that in 1982 juvenile steelhead habitat increased with streamflow up to approximately 30 cfs.

Cobble larger than about 45 mm in diameter provides cover for juvenile salmonids but loses its value as it becomes embedded in sediment. Bratovich and Kelley found that relatively small increases in embeddedness were associated with large decreases in juvenile steelhead population densities in Lagunitas Creek. A slight increase in embeddedness could easily negate the benefits of increased summer flows.

Salmonid Emigration. Salmon and steelhead smolts emigrate from Lagunitas Creek from March through June, with most emigrating during April and May. During high flow years, emigration can be delayed until June, exposing smolts to high water temperatures. The number of salmon smolts captured during the study continuously increased over the three year study period, the highest number being collected in 1985; the number of smolts is, however, still quite low. Numbers of smolts and the age and size composition of the smolt population were highly variable among the three years. Numbers, age, and size of smolts that emigrate in any given year depend on conditions that occurred earlier that same year and in each of the two previous years.

Estuarine Environment Nearly all salmonids were collected in the upper section of the estuary where there is more shade, riparian and instream cover, and where salinity is lower and water temperatures are cooler. Water temperatures through much of the estuary reached high levels considered to be harmful to juvenile salmonids during part of the emigration period. This is a problem that requires further investigation.

Salmonid smolts and their most important food source, opossum shrimp *(Neomysis mercidis)*, were both associated with cooler water temperatures and lower salinity. Water temperatures and salinity concentrations increased farther upstream in the estuary as flows declined during spring.

Water Quality. MMWD conducts the only routine water quality monitoring program in the Lagunitas Creek watershed; DFG's water monitoring program does not include any stations in this drainage. North Marin Water District (NMWD) also conducts monitoring relating to their wells near the mouth of Lagunitas Creek. Water data have also been collected by Dr. Tim Hollibaugh of the Romberg Tiburon Center for Environmental Studies as part of an ongoing study of nutrient levels in Tomales Bay. Data from Lagunitas Creek is, however, not independently published.

In the late 1980s, at the request of local citizens, MMWD started regular water quality monitoring of Lagunitas Creek downstream of its reservoir system. The program monitors temperature, turbidity, DO, and copper (to test for contamination by copper sulfate algaecide that is used in reservoirs). MMWD's program has been formalized in a self-monitoring program plan that has been submitted to the San Francisco Bay Regional Board. Sampling has shown compliance with applicable water quality standards, and according to Roxon (1992) water quality data in the Lagunitas Creek basin is, for the most part, excellent, particularly in the rocky canyons above Peters Dam (Kent Lake). The clayey grasslands of the Nicasio Reservoir drainage produce a water whose quality is not as good as in the upper reaches of the basin, but still generally good.

Salinity, temperature, and DO data for lower Lagunitas Creek (1000 feet from the mouth) are included in NMWD's report titled the *Summer Dam* (Nelson et al., 1987). Temperatures in July and August ranged from 73° F to almost 80° F at a depth of five feet. By mid-September, temperatures were below 70°. At a depth of 3.5 to 5 feet, dissolved oxygen ranged from 5.5 to over 10 ppm.

Small Tributaries on the East side of Tomales Bay (Millerton Gulch, Grand Canyon, Tomasini Canyon and unnamed tributaries)

No existing studies or anecdotal information on physical watershed changes, stream condition or fish habitat and populations in these watersheds were located. The resource values of these smaller streams seem to have been overlooked.

The area between Point Reyes Station and Hamlet is almost entirely grassland with pockets of hardwood forest and brushy areas in the gulches. The area has been grazed by cattle since the Mexican era, with the heyday of dairy ranching occurring between 1865 and 1965; sheep have also been raised here, mainly during the last 50 years. The largest drainages, Tomasini and Grand Canyons and Millerton Gulch, saw traditional fire wood cutting but no extensive logging. The Martinelli family established West Marin Sanitary Landfill in 1965 in Tomasini Canyon to replace a smaller dump in a side gulch. More recently the Borello family opened a rock quarry in Millerton Gulch; there are also septic waste ponds on the Borello property where pump trucks haul sludge from local septic systems. On the bay shore, a number of industries such as oyster farms, poultry farms, small fishing ports, boat works, restaurants and private homes have existed for more than a century.

8. RECOMMENDATIONS AND ACTION PLAN

The following recommendations have been compiled from several sources and are organized accordingly. Sources include the MCWEP Advisory Committee, MCWEP project staff, suggestions made during landowner interviews and at landowner meetings. These recommendations vary in scope from individual practices that landowners can implement to large-scale programs that will require outside funding.

Landowner Interviews and Meetings

During the summer of 1994, MCWEP staff personally interviewed 54 beef, sheep, and dairy operators to discuss concerns about NPS pollution and familiarize them with the MCWEP. A series of informational meetings were later held to bring this information to a larger audience.

Responses from these interviews and meetings are summarized in the Appendix. These responses illustrate the types of resources that area landowners feel they need to improve water quality, and their related concerns. Responses are summarized in these two general categories. Needed sources of assistance are further arranged by type, and are also summarized in Table 3 in the Appendix.

Advisory Committee Recommendations

In March, 1995, the MCWEP Advisory Committee began the process of recommending a strategy for maintaining "healthy watersheds and viable agriculture in West Marin." Preliminary recommendations made during this Advisory Committee meeting were summarized and categorized into six groups, under the following headings: funding, conservation planning and implementation, education and outreach, assessment and prioritizing, coordinating public resources, and agricultural land and open space preservation. These preliminary recommendations are included in Table 4 in the Appendix.

In July, 1995, these preliminary recommendations were refined by the Advisory Committee, working in small groups. The Action Plan below is the result of these groups.

Staff Recommendations

In May, 1995 project staff, who are involved in other watershed enhancement and conservation programs developed a set of additional recommendations based on their familiarity with natural resources and agriculture within the project area. Both the Advisory Committee recommendations and staff recommendations are summarized in Table 4 in the Appendix.

Action Plan

Following is the Action Plan that was produced by working groups at the July 20, 1995 Advisory Committee meeting. The groups came up with goals and objectives for each topic that was identified at a previous Advisory Committee meeting. Many of the groups also listed specific tasks needed to accomplish the objectives. Some objectives also have timelines and benchmarks, which could be used to evaluate success.

All text that is in plain or bold type was transcribed from the group notes. Text that is in *italics* was added by staff. The Current Efforts sections were added by staff to show activities that are already taking place that relate to these tasks. Tasks that have been initiated by existing programs or efforts are indicated by a V. This does not mean that these tasks have been completed, or that they are not in need of additional attention, but simply points out existing efforts that relate to the tasks.

COORDINATING PUBLIC AND PRIVATE RESOURCES

GOAL: **Identify resources and solicit active participation by public and private parties to improve coastal watersheds and water quality.**

OBJECTIVE #1: Identify and facilitate agency cooperation and participation.

(Potential Agencies and Groups to Implement: RWQCB, US EPA, DFG, RCD's, UCCE, NRCS, Farm Bureau, Private, PRNS, Anybody That has Money, Landowners).

Timeline: As soon as possible - minimum quarterly meeting rotated. *Animal Waste Committee, MCRCD, and Stemple Creek Watershed Restoration Program Advisory Committee meetings provide existing forums.*

Benchmark: Improved water quality for all beneficial uses.

Current Efforts: *This objective has been initiated by the Marin Coastal Watershed Enhancement Project (MCWEP), Sonoma/Marin Animal Waste Committee and others. Stafffrom the above agencies have been involved with the MCWEP Advisory Committee. Stafffrom NRCS, PRNS, UCCE, MALT, and MCRCD have worked together on Ranch Plan Workbook and Fact Sheets. These staff regularly share information regarding local water quality that relates to agriculture. The MCRCD and Southern Sonoma County RCD are also working together to implement the Stemple Creek/Estero de San Antonio Watershed Enhancement Plan. The NRCS has an application pending for PL-566 Small Watershed funding for a project in the Stemple Creek watershed.*

OBJECTIVE #2: Create resource center or mechanism to share expertise.

Tasks:

√Streamline and consolidate state and federal permits and regulations.

√Coordinate distribute information on uniform water testing practices and standards.

√Encourage water quality monitoring by landowners.

√Coordinate Geographic Information System (GIS).

√Distribute information on good practices, such as septic tank care.

√Public agencies should develop award program for good management.

Timeline: *1995-96*

Benchmark: *Various resource agencies are regularly sharing information and materials.*

Current Efforts: *Water quality monitoring tasks have been initiated by UCCE sponsored water testing workshops and Fact Sheets on water testing; by NRCS/Americorps water testing for individual landowners and water testing Fact Sheets; and by upcoming MCRCD water testing workshops in the Stemple Creek watershed.*

There are presently at least four Geographic Information Systems being developed that include information on west Marin. These are owned by the County of Marin, MALT, PRNS, and a private forestry consultant.

Information on septic care is available from the Sonoma County Environmental Health Department. Marin County does not have information.for public distribution.

Resource Conservation Districts have a "Conservation Farmer of the Year" award. Southern Sonoma County RCD gives an annual award.

CONSERVATION PLANNING AND IMPLEMENTATION

GOAL: ***Continue to provide technical assistance and educational information on ranch planning, nutrient budgeting, and wildlife considerations to landowners.***

OBJECTIVE # 1: ***Continue to provide technical assistance for preparing ranch plans.***

Tasks:

√Get as many ranchers as possible doing ranch plans. Note: Ranchers need to understand that this will be mandatory if they don't do it on their own.

Have someone from this group attend Coastal Commission meeting and find out what they are going to want from these watersheds on the coast.

Agencies need to have an inventory of ranches in watersheds and know if they have done a Ranch Plan.

√Use resources that are available, such as: UCCE, NRCS, CFSA, RCD - inter-agency agreements.

Timeline: *See Education and Outreach section for specific timeline regarding Ranch Plans.*

Benchmark: *Landowners are satisfied that technical assistance is being provided. Evaluate through personal communication.*

Current Efforts: *This Objective has been initiated by the ranch planning course that UCCE offered last Spring, Fact Sheet and the Ranch Plan Work book being developed by the MCWEP, the Dairy Resource and Enhancement Plan being developed by a subcommittee of the Animal Waste Committee, and by the MCRCD SSCRCD* 319(70 *grant that will provide ranch plans on two dairies in the Stemple Creek watershed. Some individual ranchers have also completed their own ranch plans.*

Agencies mentioned above have collaborated on ranch planning class and on the Ranch Plan Workbook.

The NRCS has a pending application for funding through PL-566 Small Watershed Projects. This project would provide a full-time NRCS staff person to help with ranch plans and cost-share funding.

OBJECTIVE # 2: Focus on landowners that have shown interest.

Tasks:

Have a non-regulatory person come out to ranch to help identify the problems on the ranch.

Make funding for large projects available to landowners that have ranch plans and take care of management problems

Timeline: *Ongoing.*

Benchmark: *Landowners complete ranch plans and implement projects.*

Current Efforts: *See current efforts under Education and Outreach, Objective* # 2.

EDUCATION AND OUTREACH

GOAL: **Keep all Marin and Sonoma ranchers and landowners informed.**

OBJECTIVE # 1: Fund coordination of ranch plan development. Lead agencies should be UCCE, NRCS, PRNS, and MALT.

Tasks: Obtain number of livestock and dairy operations names and addresses - by 10/95

Write proposal for funding sources - by 12/95

Hire a technician to assist in development of Ranch Plans (visit ranches, educate on NPS, work with them to develop Ranch Plan) - 12/97

Timeline: *See specific times associated with individual tasks above.*

Benchmark: Ranch Plans completed for entire watersheds by 12/97.

Current Efforts: *Winter workshop series completed (1994); spring series planned for Sonoma County.*

OBJECTIVE # 2: Continue educational workshops on:

Water Quality

Grazing Systems

Plant Identification

Use ranch field trips for assessment

Timeline: Ongoing/quarterly

Benchmark: *At least three workshops will occur in 1995/96.*

Current Efforts: *This Objective has been initiated by ranch planning and water testing workshops that were conducted by UCCE in Spring, 1994. As part of their 319(h) grant for Stemple Creek, the MCRCD and SSCRCD plans to hold two water testing workshops in Fall, 1995. The MCRCD will also conduct a tour of the two dairies for which they have prepared ranch plans and of demonstration sites where they have implemented alternative riparian protection techniques. UCCE also plans to hold a water testing workshop for all Marin and Sonoma County ranchers in Fall, 1995.*

OBJECTIVE # 3: Continue newsletters and other educational materials

Tasks: MALT to continue publishing "Downstream" for landowners with contributions from other groups.

Have all educational materials from central location - contact person and place.

Expand project and effort to Sonoma - take the show on the road.

Timeline: *Ongoing.*

Benchmark: *New editions of "Downstream" published; project materials published and distributed widely.*

Current Efforts: *MALT has published three issues of "Downstream," a newsletter on nonpoint source pollution and other water quality issues. "Downstream" has been mailed to all Marin County agricultural landowners and Sonoma County landowners in the Stemple Creek Watershed.*

OBJECTIVE # 4: Provide outreach to public on water quality improvements efforts by agriculturists.

Tasks: Develop schedule and produce press releases regarding positive aspects of ranching, progress being made, new manure systems, etc. - done in an appropriate way. Lead agencies: MALT, Farm Bureau, Western United Dairymen.

√Invite public to tours of ranches

Timeline: *1995/96*

Benchmark: *MALT to hire coordinator to develop education program.*

Current Efforts: *See description of planned MCRCD tour under Objective # 2. MALT is in the process of hiring an education program coordinator. This person will arrange educational tours of local ranches.*

ASSESSMENT AND PRIORITIZING

GOAL: **To assess each watershed to identify and prioritize problems and projects to improve fish habitat.**

OBJECTIVE #1: **Review existing information *(including Project Report)* to determine need for level of assessment for each watershed. Include subwatersheds and determine causes including land uses.**

Tasks: Determine baseline data needed on area resources.

Get water quality assessments for each watershed.

√Complete other needed assessment, i.e. habitat and/or erosion survey.

√Quantify and evaluate data collected - develop GIS to do this.

Prioritize problems and projects.

Note: See Funding section for specific projects suggested for each watershed.

Lead Organizations and Supporting Agencies: MCRCD, PRNS-Olema & Lagunitas Creeks, MMWD, North Marin Water District, Landowners, NRCS Watershed Assessment Team. Could be formal and/or informal - efforts must be multi-agency.

Current Efforts: *This objective has been initiated by compilation of existing resource information in MCWEP Project Report. MCRCD plans to apply for funding for assessment of fish habitat in Walker Creek. See Objective #*

There are presently at least four Geographic Information Systems being developed that include information on west Marin. These are owned by the County of Marin, MALT, PRNS, and a private forestry consultant.

Timeline: One year to conduct *additional more specific* assessment and obtain funding.

Benchmarks: Good, accessible description of water quality and land use by watershed and sub-watershed.

Fish and habitat restoration projects.

Identification of greatest opportunities for "most bang for the buck."

FUNDING

GOAL: **To provide funding to implement critical water quality and conservation projects.**

OBJECTIVE #1: Research and explore the Farmer Security Act - dairy assessment for producer/consumer interest.

Tasks: Earl Holtz to explore idea with Western United Dairymen - if interest there, figure out "how" to administer in a fair manner.

Note: Only 28% milk in fluid production - consumer acceptance. Assessment at processing plant for sheep/cattle/poultry?

Current Efforts: *Discussion level only with Western United Dairymen.*

Timeline: *ASAP*

Benchmarks: *More funding available for implementing water quality improvement projects.*

OBJECTIVE #2: Obtain funding for technical assistance for writing and completing Ranch Conservation Plans.

Tasks: Use NRCS American Corps volunteers if program still funded.

√Continue joint agency effort to put workshops on. Lead Agencies should include MALT, UCCE, NRCS, MCRCD.

Current Efforts: See current efforts under objective # 2 on page 3.

Timeline: Fall/Winter 95-96.

Benchmarks: *Pending funding from federal government.*

OBJECTIVE #3: Obtain funding for erosion control on Stemple Creek. Lead Agency should be MCRCD.

Current Efforts: *This Objective has been initiated by MCRCD funding applications and present contracts. Individual ranchers working on their own and/or with the Shrimp Club have also been working on replanting and stabilizing Stemple Creek.*

MCRCD <u>Applications:</u> *Grant application to the State Coastal Conservancy for $200,000.*

MCRCD <u>Existing Contracts:</u> *MCRCD-SSCRCD presently has a 319(h) grant for $76,646 which includes funds to demonstrate alternative riparian protection measures in the Stemple Creek watershed.*

Timeline: Fall/Winter 95-96

Benchmarks: *Successful funding.*

OBJECTIVE #4: Obtain funding for water quality assessment and enhancement in Walker Creek. Lead Agency should be MCRCD.

Current Efforts: *This Objective will be initiated by the MCRCD's application for funds for habitat assessment on Walker Creek. Riparian habitat enhancement work has been funded through the State Coastal Conservancy and the Northwest Emergency Assistance Program.*

Timeline: *The above application will be made in Fall, 1995.*

Benchmarks: *Successful funding for projects.*

OBJECTIVE #5: Obtain funding for demonstration of profitable waste reclamation projects. Lead Agency should be MCRCD.

Current Efforts: *This Objective has been initiated by a* $120,000 *319(h) grant to the MCRCD to demonstrate "Dairy Waste Treatment and Reclamation Using an Advanced Integrated Waste Water Pond System." The project will probably be constructed at Pt. Reyes National Seashore.*

Timeline: 1995-95.

Benchmarks: *Successful funding for complete implementation of this project.*

9. PROJECT ACTIVITIES AND MATERIALS

The MCWEP accomplished a wide range of activities over an 18-month period. Educating landowners about water quality has been a primary focus of the project. Many of the project materials are diagnostic tools that will help landowners identify water quality problems and determine appropriate remedies.

Another major aspect of the project was facilitating communication within the diverse group of people concerned about water quality and watershed condition in West Marin. Pre- and mid-project interviews with Advisory Committee members showed that many participants gained important information from their involvement in the project. Project accomplishments include:

- Formation of an Advisory Committee with representatives from agriculture, resource management, and environmental groups. The 30 member Advisory Committee held four meetings to work on recommendations and a plan of action for watershed and stream enhancement.
- Landowner meetings and outreach have been accomplished through 54 individual visits with landowners, and three informational public meetings attended by over 100 landowners. These meetings served to familiarize landowners with the current status of water quality laws and their local effect. Many of the landowners that attended these initial meetings participated in other educational activities.
- Formation of a staff team of representatives from natural resource and agricultural agencies facilitated distribution of information to many area landowners. This team met regularly throughout the project to collaborate on production of educational materials.
- A six-week ranch planning course with an emphasis on improving water quality was held in Spring, 1994. The course was attended by 45 people, representing 25 family ranches. Evaluations showed that the most valuable aspect of the course for many participants was a field trip to two ranches to identify potential water quality problems and remedial practices.
- A Ranch Plan Workbook was prepared to provide locally appropriate materials for future ranch planning courses. This workbook, designed to be completed in a class or individually, guides the user through the process of writing a plan. The workbook includes sections on assessing problems, identifying management practices, and monitoring for compliance with water quality laws. Background information on identifying problems and monitoring is provided by MCWEP Fact Sheets. A Rangeland Water Quality Program (UCCE/NRCS) Fact Sheet on Management Practices provides information on appropriate practices.
- A Creek Care Booklet for Rural Landowners provides information about proper management of creeks and their watersheds. The booklet includes information on habitat needs of aquatic organisms, the importance of riparian habitats, and general practices that can be used to improve creek condition.

A series of technical handouts—"Fact Sheets"—on various topics related to water quality was prepared. Some of these Fact Sheets are included as background materials in the Ranch Planning Handbooks and some are for use in water quality testing workshops. All of the Fact Sheets will be distributed by participating agencies.

Topics include Photographic Monitoring, Vegetation Monitoring, Ranch Maps, Writing Ranch Plans, Water Quality Laws and Local Application, Water Quality Variables, Water Testing for Rural Landowners, Recognizing NPS Pollution Sources on Ranches, and Funding Sources for NPS Pollution Management Practices. Other handouts include a Checklist for Sources of NPS Pollution, an Un-ionized Ammonia Table, and Data Sheets for recording water testing results.

Information on water quality improvement projects in coastal California, Oregon, and Chesapeake Bay was compiled to evaluate effectiveness of similar efforts. From this research it is apparent that many West Marin landowners are better informed and more involved in water quality improvement efforts than landowners in other areas.

A video on water quality and how ranchers can work to improve it focuses on the importance of ranch planning. Footage includes interviews with local ranchers, shots of water quality problems, and management solutions.

Two water quality testing workshops for landowners were held in spring, 1995. Landowners learned where to collect samples, how to use test kits, and the importance of different water quality variables.

10. ADVISORY COMMITTEE COMMENTS

A preliminary draft of this report was circulated to the MCWEP Advisory Committee for review and comment. Most of the reviewers comments were incorporated directly into the report text. In some instances comments that were beyond the scope of the report, or did not fit into the text, were not incorporated. These comments are summarized below.

- A suggestion was made that the Tomales wastewater treatment system should be specifically mentioned as it was built in response to failing septic systems in Tomales and their impact on the creeks. Also mentioned were the lack of a waste water system in Point Reyes Station and the presence of the North Marin Water District's Oceana Marin wastewater facility.

  Sewage treatment facilities were not specifically mentioned in the report because the MCWEP Project and report focus on agriculture's effect on water quality. Other potential sources of water quality problems—including sewage treatment plants and septic systems—are referred to in general terms and should certainly be considered in evaluating all of the impacts to water quality in the project area.

- A comment was made that some historical farming practices that are now considered to be damaging were the right thing for the "times."

  This is certainly true. References to historical farming practices are not intended to place blame for current conditions, but are included as they help in understanding the causes of changes to the landscape and streams.

- Comments were made as to the validity of conclusions that researchers have made regarding agriculture's role in water quality and stream degradation.

  This report is intended to summarize resource information from existing sources. It is recognized that many of the studies drawn from have not established a cause and effect relationship between agriculture and water quality/stream conditions. Where opinions or conclusions not based on data were cited, these statements were identified as such.

- A comment was made that causes of many of the watershed problems are not known. There are many conflicting theories and we can only speculate about the causes. Landowners should not be expected to implement costly "fixes" or change management practices until less costly measures are tried and results are documented.

  Less costly measures are of course preferable if they are effective. It is hoped that landowners who are making an effort to improve watershed conditions will document results and share them with others.

List of Abbreviations

ACP	Agricultural Conservation Program
ASCS	Agricultural Stabilization and Conservation Service
BOD	Biological oxygen Demand
cfs	cubic feet per second
CFSA	Consolidated Farm Services Agency
CWA	Clean Water Act
CZARA	Coastal Zone Act Reauthorization Amendments
DFG	Department of Fish and Game
DO	Dissolved oxygen
EPA	Environmental Protection Agency
GGNRA	Golden Gate National Recreation Area
MALT	Marin Agricultural Land Trust
MCOSD	Marin County Open Space District
MCRCD	Marin County Resource Conservation District
MMWD	Marin Municipal Water District
NMWD	North Marin Water District
NPS	Nonpoint source
NRCS	Natural Resources Conservation Service
NOAA	National Oceanic and Atmospheric Administration
PRNS	Point Reyes National Seashore
RCD	Resource Conservation District
SSCRCD	Southern Sonoma County Resource Conservation District
UCCE	University of California Cooperative Extension

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Appendices

A: Summary of Landowner Concerns and Comments from Personal Interviews and Public Meetings

B: Table 3. Summary of Resources Needed by Landowners To Improve Water Quality and Comply With Water Quality Regulations

C: Table 4. Summary of Preliminary Recommendations Marin Coastal Watershed Enhancement Project

Appendix A: Summary of Landowner Concerns and Comments from Personal Interviews and Public Meetings

Some of the items listed here may require assistance from support agencies, while others, such as some of the management practices, landowners may be able to implement on their own.

Concerns and comments:

- Over-correction of pollution problems could exacerbate flooding, over-vegetated channels would create problems;
- The economic viability of ranching is threatened by water quality laws.
- There is a need to differentiate between natural erosion/pollution, that from humans (other than ranching), and that caused by ranching
- What to do about non-agricultural water pollution problems (such as County dumps, fire roads, human population on the coast, non-agricultural animals etc.)?
- Organize watershed groups with designated landowner representatives to go to meetings and report back
- Water testing by the State Department of Health Services may reveal property-specific problems
- Ranchers need to be involved in development of plans
- Agencies need to be educated on agricultural practices
- Work with County government to reduce taxes when making improvements
- What to do about rare and endangered species (if new populations of species are found due to management improvements on a ranch)?

Resources Needed:

Funding:

- To implement improvements
- Materials for improvements should be available at reduced cost
- Incentives for doing plans, making improvements

Conservation Planning and Implementation:

Specific Practices:

- Water developments
- Cross fencing
- Stream crossings
- Seeding
- Sediment control projects (check dams)
- Improved vegetative cover

Technical Information:

- Information on nutrient budgeting, filter strips, manure application etc.
- Guidance on, and examples of a "ranch in compliance" (with water quality laws)
- Grazing schemes - what is working
- Pasture seeding
- Management practices that work in other areas
- Water testing - when, how, and where to do it

Education and Outreach:

- Demonstrate that ranching is not the sole cause of environmental ills
- Keep all Marin and Sonoma ranchers informed
- Demonstrate good management practices (workshops, demonstrations, literature)
- Newsletter addressing regulations, programs

Information on Regulations:

- Guidelines regarding tolerance levels for manure/pollutants
- Information on agencies involved in NPS pollution control, and what practices will be required
- Concrete examples of what NPS regulations will require
- Certification of ranch plans by agencies and assurance that improved practices will mean compliance (wants sign-off on plan, or condition of dairy)

Research:

- New technologies for pollution control
- Research on bacterial pollution - identify and isolate sources
- Cost analysis of different management practices

Assessment:

- Water quality assessments for each watershed and real data/research on nonpoint source pollution
- Information on what the pollution problems are
- What defines a nutrient? What is too much/not enough?

Other:

- Streamlined permit process for projects/improvements
- Elimination/consolidation of groups and agencies
- Need a place to put manure

Appendix B

<u>Table 3:</u> Summary of Resources Needed by Landowners To Improve Water Quality and Comply With Water Quality Regulations

Compiled From:

- **Personal interviews with 54 beef, sheep, and dairy ranchers - August, 1994**
- **Informational Meetings - September and October, 1994**

Funding	Conservation Planning & Implementation	Education and Outreach	Info. on Regulations	Research	Assessment	Other
Funding to implement improvements	Specific improvements: water developments, cross fencing, stream crossings, seeding, sediment control projects (check dams), improved vegetative cover	Demonstrate that ranching is not the sole cause of environmental ills	Guidelines on tolerance levels for manure/pollutants	New technologies for pollution control	Water quality assessments for each watershed and real data/research on NPS pollution	Streamlined permit process for projects & improvements
Materials for improvements at a reduced cost	Info. on nutrient budgeting, filter strips, manure application	Keep all Marin and Sonoma ranchers informed	Info. on agencies involved in NPS pollution control, and what practices will be required	Research on bacterial pollution - identify and isolate sources	Info. on what the pollution problems arc	Elimination/ consolidation of groups & agencies
Incentives for doing plans, making improvements	Guidance on, & examples of, a "ranch in compliance" (with water quality laws)	Demonstrate good management practices (workshops, demonstrations, literature)	Concrete examples of what NPS regulations will require	Cost analysis of different management practices	What defines a nutrient? What is too much, not enough	Need a place to put manure
	Technical assistance with: grazing schemes (what is working); pasture seeding; management practices that work in other areas; water testing - when, how, and where to do	Newsletter addressing regulations, programs	Certification of ranch plans by agencies and assurance that improved practices will mean compliance (want sign-off on plans and ranch condition)			

Appendix C

Table 4: Summary of Preliminary Recommendations Marin Coastal Watershed Enhancement Project

Preliminary Recommendations From:

- Marin Coastal Watershed Enhancement Project Advisory Committee - March 22, 1995 Meeting (Plain type)
- Project Staff - May 25, 1995 Meeting *(Italics)*

Funding	Conservation Planning & Implementation	Education & Outreach	Assessment & Prioritizing	Coordinating Public Resources	Ag Land & Open Space Pres.
Funding incentives	Ranch Conservation Plans- identify practices that will reduce sediment & nutrients	Public support	Prioritize watershed projects & obtain funds	Agency cooperation	Pollution control
Milk surcharge for waste containment- Farmers Security Trust	Grazing plan to control livestock- water & fencing, sample storm run-off, maintain cover, control pollution	Increase understanding of agricultural problems	Prioritize problem sources & solutions	Participation and cooperation of gov't agencies	
County, state, federal funds	Sediment reduction e.g. planting, water development, livestock crossing, riparian pastures, diversion ditches, sediment dams	Bridge gap between urban & rural stakeholders	Identify problem sources	Streamline & consolidate state & federal permits & regulations	
Obtain $ for assessment of fishery resources and sediment source information for Walker Creek & small Tomales Bay tributaries; develop a recovery plan for fish habitat in these streams	Create manure disposal other than just spreading	Create more educational linkages with schools, landowners, non-landowners	Need more information on causes	Uniform water testing practices & standards	
Obtain funding for water quality assessment on Lagunitas Creek	Limit animal access to creeks	Involve community including children	Create a watershed baseline inventory	Create resource center to share various agency expertise (not a place)	
Obtain funding for erosion control in Stemple Creek , Walker Creek, and small Tomales Bay tributaries	Prevent overgrazing- proper road development, pasture rotations, planting & fertilizing	Educational outreach among community, agricultural and non-agricultural, and agency personnel	*Determine what "baseline data" on area resources is most important and needed*	Form a septic maintenance district	

Table 4: Continued

Funding	Conservation Planning & Implementation	Education & Outreach	Assessment & Prioritizing	Coordinating Public Resources	Ag Land & Open Space Preservation
Obtain funding for more educational workshops, including $ for one-on-one follow-up	Creek buffer zones	*Marin County to be included in "Adopt a Watershed" ed. program through CCC Americorps*		*Implement EPA's citizen monitoring workshop in rural residential areas*	
Obtain funding to apply for watershed-wide permits for conservation projects for landowners	Monitoring programs- education on how-to	*Work with high school agriculture programs on water quality education*		*Coordinate citizen driven monitoring programs*	
	Provide information on nutrient balancing: *educational material* *technical assistance* *workshop and one-on-one training*	*Support development of water qualityagricultureliteracy program at Walker Creek Ranch*		*Coordinate water quality testing programs (work with Paul Olin)*	
	Develop new and improved ranch planning workshop and materials and incorporate wildlife enhancement into the ranch planning workshops	*Develop septic education program in cooperation with Env. Health Dept.*		*Coordinate GIS data within the project area and provide access by public, agencies, consultants, and teachers*	
	Continue to improve instream habitat in Lagunitas Creek	*Provide continued educational & technical assistance to landowners:* *• one-on-one assistance* *• monitoring* *• ranch planning* *field trips* *• more demonstrations*			
	Explore new methods for disposing of dairy waste, instead ofjust spreading it	*Provide more landowner outreach, including Chileno Valley which is isolated*			
	Develop animal waste co-op, central locations for bringing waste to for disposal	*Continue cooperative education program with agencies*			