HACCP-Based Source Water Protection Program for the Southern Alameda Creek Watershed in Alameda and Santa Clara Counties, California

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Prepared by:
Sheila Barry, UC Cooperative Extension
(408) 282-3106
sbarry@ucdavis.edu

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Background on the Southern Alameda Creek Watershed Project

In January of 1995, in partnership with U.S. EPA and the USDA Natural Resources Conservation Service, Alameda County Resource Conservation District (ACRCD) began the Southern Alameda Creek Watershed Project. The project has two main objectives: 1) to develop and apply proper management strategies to restore, protect, and improve the water quality and biodiversity of the Southern Alameda Creek Watershed, and 2) to build partnerships among all stakeholders to address watershed management priorities. The project's emphasis is to work directly with grazing leasees and private landowners/ operators. Through workshops and demonstration, the project helps them identify water quality problems and provides them with technical assistance to address those problems.

Although the Southern Alameda Creek Watershed encompasses 140,693 acres in Alameda and Santa Clara Counties, the watershed is largely undeveloped. The predominant land uses are livestock grazing, wildlife habitat, recreation, and watershed. The drainage of the Southern Alameda Creek Watershed includes the southern part of Alameda Creek, San Antonio Creek, Indian Creek, La Costa Creek, Isabel Creek, Smith Creek, Arroyo Hondo, Sulfur Creek, Vallecitos Creek. Ultimately most of the creeks drain into San Antonio or Calaveras Reservoirs which are part of San Francisco's municipal water system, providing drinking water for over 2 million people in the Bay Area.

Grazing Plan for San Francisco

The project gained momentum in February 1997, when the San Francisco Public Utilities Commission (PUC) was prepared to ban cattle grazing in the watershed due to the risk of water contamination by the disease-causing parasite *Cryptosporidium*. Six months later, a barbecue held near Calaveras Reservoir celebrated the signing of a Grazing Management Accord which would allow continued cattle grazing in the watershed while minimizing the risk of *cryptosporidium*. Signatories included ACRCD, San Francisco PUC, California Cattlemen's Association, University of California, USDA Natural Resources Conservation Service, and a San Francisco AIDS activist. The accord was the result of a watershed protection plan developed by ACRCD in cooperation with cattlemen and other watershed stakeholders.

The watershed protection plan utilized the Hazard Analysis Critical Control Points (HACCP) approach, a strategy used by the USDA to ensure food safety. In adapting HACCP principles to watershed protection, five management areas for controlling waterborne pathogens in Alameda Creek watershed were identified: (1)Feral Pigs; (2)Livestock/Grazing; (3)Wildlife; (4)Human/Recreation; (5)Treatment Plant. In regards to livestock, the plan suggested specific measures including managing stocking rates to retain adequate vegetative cover; restricting calving to fall months; locating water and supplemental feed away from streams; and promoting herd health programs.

HACCP-based Plan Expanded

Following the success of the Grazing Management Accord, the HACCP-based plan was expanded to not only address biological hazards i.e. pathogens in the watershed, but also to address physical (sediment) and chemical hazards. This plan provides guidelines for private and public landowners in the Southern Alameda Creek Watershed to protect source water. This plan will also be used as a guide to implement watershed protection measures through future efforts of the Alameda County Resource Conservation District and the USDA Natural Resource Conservation Service.

Introduction to a HACCP-Based Source Water Protection Program

HACCP (Hazard Analysis Critical Control Points) is a system developed nearly 30 years ago for the U.S. Army and NASA. The challenge was to perfect a "zero defect" program to guarantee safety of foods for astronauts while in space. The program focused on preventing hazards that could cause foodborne illnesses by applying science-based controls. In the early 1970s, the Pillsbury Corporation put the HACCP approach into practice in the food-processing industry. It has since been adopted by other food service and manufacturing industries. With newly emerging and re-emerging foodborne illnesses gaining public attention, in 1994 the Food and Drug Administration (FDA) introduced a rationale for mandating HACCP among retail stores and processing plants to prevent food safety problems.

The overall focus of any HACCP program is to prevent the occurrence of an identifiable hazard. The program emphasizes control of a process as far "upstream" as possible. Although HACCP was designed and has been specifically adapted to ensure food safety, protecting and improving water quality also requires the prevention and control of potential hazards. Applying HACCP to address water quality concerns means working to eliminate potential contaminants from ever entering source water. A systematic, proactive approach like HACCP could clearly improve our ability to protect and improve water quality. The Southern Alameda Creek Watershed will be the first watershed in which this state-of-the-art approach is being used to address water quality.

Implementing a HACCP-Based Water Quality Program

Steps for implementing a HACCP-based water quality program are presented in Table 1. It should be recognized that this first attempt at adapting HACCP to water quality issues will create questions as well as answers. In some cases adequate research is not yet available to identify all the hazards, critical control points and monitoring actions for water quality issues. However, outlining a HACCP-based watershed protection program for the Southern Alameda Creek Watershed will help define these questions and establish relevant monitoring and research activities to address them. Implementing a HACCP-based water quality program will require a commitment of resources for monitoring and research, but will be a proactive way to address water quality concerns throughout a watershed.

This source water protection program will address biological, physical and chemical contaminants from rangeland in the Southern Alameda Creek watershed. Additional assessment and management strategies could be developed to address potential contaminants in the Southern Alameda Creek Watershed from vehicles, automobile corridors, utility corridors, residential areas, nurseries, and the Sunol Valley Golf Course.

There are a number of advantages of developing a HACCP-based water quality program to provide for source water protection. In particular, a HACCP-based water quality program:

- Implements management actions outlined in a watershed management plan with monitored control measures.
- Includes recordkeeping that allows for verification of the HACCP program over time.
- Provides an information system to continue to address potential hazards.
- Provides a framework for on-going assessment for potential hazards.

With consumers' apprehensions growing with regard to waterborne illness, a verifiable water quality management program like HACCP makes sense.

Table 1. Steps for Implementing a HACCP-based Water Quality Program

1. Assemble a multidisciplinary, watershed-based HACCP team.
2. Identify the beneficial uses of the water in the system.
3. Describe the water processing requirements required to meet the beneficial use.
4. Develop a schematic diagram that describes the collection, storage and distribution of the water.
5. Verify the schematic diagram.
6. Implement Principle 1: Conduct a hazard analysis. Potential hazards (biological, physical, chemical) associated with water are identified.
7. Apply Principle 2: Identify critical control points. These are points in the collection, storage, and distribution of water - from raindrop to end-use (i.e. tap) - where a potential hazard can be controlled or eliminated.
8. Apply Principle 3: Establish preventive measures with critical limits for each control point.
9. Apply Principle 4: Establish procedures to monitor the control points.
10. Apply Principle 5: Determine corrective actions to be taken when monitoring shows that a critical limit has not been met.
11. Apply Principle 6: Establish effective recordkeeping to document the HACCP system.
12. Apply Principle 7: Establish procedures to verify that the system is working consistently.

Step 1

Assemble a multidisciplinary, watershed-based team. In order to address potential contaminants in the Southern Alameda Creek Watershed, a multidisciplinary team, including individuals with knowledge of the watershed, water issues and other technical experts, was formed. The team identified hazards and management measures to control hazards.

Grazing lessees, private landowners, East Bay Regional Park District staff, San Francisco Water Department staff will review the programs and work to develop implementation strategies. Additional input from watershed stakeholders including water quality regulators (i.e. US EPA, Regional Water Quality Control Board, Dept of Health Services) and water users (i.e. San Francisco consumers, Bay Area water districts) is also requested.

Step 2
Identify the beneficial uses that determine the quality of water required throughout the system. One critical beneficial use of the water in the Alameda watershed is drinking water. In California, the Department of Health Services stipulates and sets water quality monitoring standards for drinking water. Pathogens represent the greatest concern among potential water contaminants.

Step 3:
Describe the water processing (filtration, treatment) requirements necessary to meet the beneficial use. The Surface Water Treatment Rule (SWTR) stipulates that surface water supplies must undergo a multibarrier treatment to remove and inactivate waterborne pathogens. Watershed management and protection is one of those barriers; however all water from the Southern Alameda Creek watershed is also treated at the Sunol Water Treatment Plant. In accordance with the SWTR, DHS requires 99.9 (3 log) reduction of Giardia cysts and a 99.99 percent (4 log) reduction of viruses, to be achieved through filtration and disinfection. According to the Watershed Sanitary Survey completed in October 1995, the Sunol Water Treatment Plant is meeting all current regulations. Current tests (over the past year and a half have not detected viable Cryptosporidium oocysts or Giardia cysts in either Calaveras or San Antonio Reservoirs (SFWD, Water Quality Division Data).

In regards to physical contaminants, raw waters in Calaveras and San Antonio reservoirs show strong seasonal trends for turbidity. Turbidity is greatest during the periods of peak runoff events typically in February and April. Filtration at the Sunol Water Treatment Plant effectively removes particulates from the raw waters to achieve drinking water standards. No problems with chemical contaminants (pesticides) have currently been identified in the raw water from the Southern Alameda Creek Watershed.

Step 4:
Develop a schematic diagram that describes the collection, storage and distribution of the water throughout the system. Although this HACCP-program deals only with the Southern Alameda watershed, it is important to understand the entire San Francisco water system. The system provides the opportunity for water from one part of the system to be blended with water from other parts of the system. For example, Hetch Hetchy water can be stored in the San Antonio Reservoir in the Southern Alameda Creek Watershed. Clearly, in order to completely address and work to control the potential water quality hazards in the San Francisco water system, all watersheds which feed the system will should be part of a HACCP-based program.

The following provides an overview of the entire San Francisco water system and a detailed description of the Alameda Watershed (Watershed Sanitary Survey, 1995).

Overview of the San Francisco Water System
Three primary sources provide the surface water supplies for the entire San Francisco water system: the Tuolumne River in the Sierra Nevada mountains via the Hetch Hetchy system; surface runoff captured from the Alameda watershed; and surface runoff captured from the Peninsula watershed. San Francisco also obtains some water from ground water basins in San Francisco, Pleasanton, and the Sunol Valley. During drought, water has also been purchased

(1991, 1992) from the state of California to augment primary sources. Approximately 80 to 85% of the potable supply to San Francisco Water Department (SFWD) customers is from the Hetch Hetchy system.

A schematic of the overall water system is presented in Figure 1. Water is conveyed to the San Francisco Bay Area from the Hetch Hetchy system across the San Joaquin Valley through a series of aqueducts and tunnels to Alameda County near the community of Sunol. Some of the Hetch Hetchy water is stored in the San Antonio Reservoir (Alameda Watershed), while the remainder flows through the Irvington Tunnel and the Bay Division Pipelines. Sunol Valley ground water and water purchased from the State can also be stored in San Antonio Reservoir.

Water including local runoff in the Alameda watershed reservoirs is treated at the Sunol Filter Treatment Plant and is combined with the Hetch Hetchy water flowing through the Irvington Tunnel and Bay Division Pipelines. This water is then conveyed across the San Francisco Bay and distributed to wholesale customers along the way. Part of this water is stored in the Peninsula Reservoirs where it is blended with local runoff; the remainder is conveyed to wholesale customers along the Peninsula and individual customers within the City. The water stored in the Peninsula Reservoirs is treated at Harry W. Tracy filter plant. This water continues on to San Francisco customers.

The Alameda Creek Watershed

The Alameda Creek watershed lands are located in the Diablo Range portion of the Central Coast Range. The watershed, 633-sq. miles, extends from Mount Diablo in the north, to the Altamount Pass in the east, to Mount Hamilton in the south, and Niles Canyon to the west (Figure 2). It is located within Contra Costa, Alameda, and Santa Clara counties. The watershed is divided into North (Livermore) and South (Sunol) drainage units.

The North (Livermore) drainage unit occupies 423 sq miles within the northern and eastern part of the watershed. The major streams flowing through the Livermore drainage unit are Arroyo del Valle, Arroyo las Positas, Arroyo Mocho, Alamo Creek, San Ramon Creek, and Tassajara Creek. Arroyo del Valle and Arroyo Mocho drain the largest areas, converging to form the Arroyo de la Laguna on the floor of the Livermore-Amador Valley. Sinbad and Vallecitos Creeks join Arroyo de la Laguna before it joins Alameda Creek in the Sunol drainage unit in Sunol. The contribution of this drainage as a water source to the San Francisco water system is minimal. However, it should be considered when interpreting future water quality data. The Sunol Filter Galleries can pick up water from the Arroyo de la Laguna. In addition, if a significant water quality problem occurs in Arroyo de la Laguna, it could impact the surface and groundwaters in and around the Filter Galleries. The HACCP-based water quality program presented in this document will focus on management within South (Sunol) drainage unit or the Southern Alameda Creek Watershed.

The 210-sq mile, Southern Alameda Creek watershed is located in Alameda and Santa Clara Counties and contains East Bay Regional Park lands, San Francisco Water Department reservoir lands, and private land. This drainage can be divided into four subareas (Figure 3):

- The Calaveras drainage area includes lands adjacent to the Arroyo Hondo and the Calaveras Reservoirs. Arroyo Hondo is the principal tributary to Calaveras Reservoir, capturing the runoff from nearly 60 percent of the watershed. Two of the tributaries to Arroyo Hondo, Smith and Isabel Creeks, circle Mount Hamilton, one of the highest points in the watershed.
- The Upper Alameda drainage area includes lands along the Alameda Creek upstream of the Alameda Diversion.
- The San Antonio drainage area includes the entire watershed of San Antonio Reservoir. San Antonio Reservoir receives water from San Antonio, Indian, La Costa, and Apperson Creeks in addition to imported water from Hetch Hetchy, the State via the South Bay Aqueduct (in an emergency), and the Sunol Filter Galleries, which may include groundwater, water from the Livermore drainage unit and Lower Alameda drainage.
- The Lower Alameda drainage area includes the lands downstream of the Alameda Diversion Dam and downstream of the two reservoirs, all of which drains to the Sunol Filter Galleries.

Land use and activities closest to the reservoirs and reservoir tributaries (the Calaveras, Upper Alameda, and San Antonio drainages) have been of more concern to the San Francisco Water Department, than uses downstream of reservoirs which drain to the Sunol Filter Galleries. This is because the Filter Galleries only contribute a small amount of water, provide limited storage, and can be temporarily removed from the system. However, as recognized in the Watershed Sanitary Survey, water quality contributing to the Filter Galleries should not be allowed to degrade since this is also a potential source of water for the City. A HACCP-based water quality program should allow for continued monitoring, development, and implementation of best management practices. These practices based on sound-science and natural resource management principals can be implemented throughout the watershed.

In addition, even within the drainages closest to reservoirs and reservoir tributaries, the San Francisco Water Department is not the sole landowner. To provide safeguards for the water supply, San Francisco PUC must work closely with local landowners throughout the watershed in implementing sound, scientifically based land use practices and principles.

Step 5:
Verify the schematic diagram

Steps 6 – 12:
Application of HACCP principles to control hazards in the Alameda Watershed is described in the sections that follow in this document.

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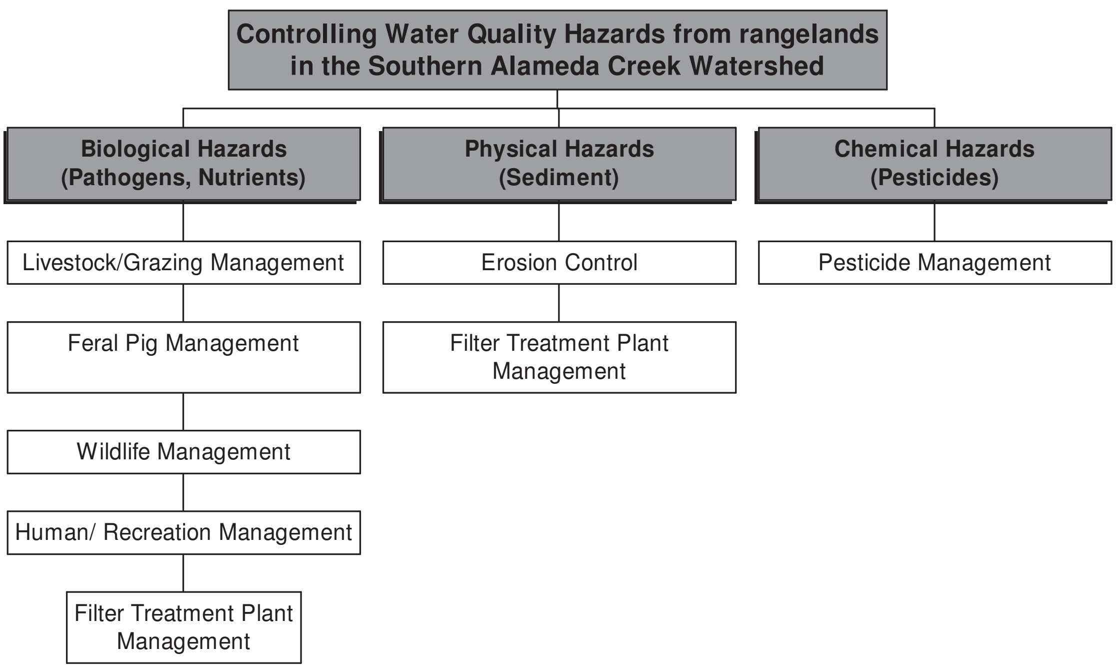
Application of HACCP Principles to Control Hazards in the Southern Alameda Creek Watershed

Hazard Analysis

Step 6
Implement Principle 1: Conduct a hazard analysis. Although on-going assessment is necessary to clearly identify hazards, an initial analysis of hazards in the Southern Alameda Creek watershed identified management areas for each type of hazard (figure 4). The following sections of this document outline Steps 7 - 11 for implementing a HACCP-based source water protection program for the each management area, except the Sunol Filter Treatment Plant. The Sunol Filter Treatment Plant has been evaluated several times by several groups. A project to improve the plant is underway.

Figure 4: Management Areas for Controlling Hazards in the Southern Alameda Creek Watershed.



It should be recognized that in this HACCP-based source water protection plan, the best management practices for each management area are recommended without prior testing. While they are widely accepted effective range management, wildlife management, erosion control and pesticide management practices, their effectiveness for protecting water sources from contaminants is not proven. Scientific research usually is presented in terms of statistical reliability --what percentage of similar treatments will yield results within certain parameters of reliability. These statistics are developed after measuring the treatment results a sufficient number of times to determine what the percentages and parameters are. In managing biological systems, like watersheds we expect variation in the results, and until further assessment and monitoring is conducted we can not quantify that variation in advance.

Wildlife systems, in particular, can be expected to vary widely in their response to treatment. For example, drought or long cold periods in one year can kill many pigs, and render unnecessary the removal you might have done just prior. On the other hand, a year of mild climates and good acorn production can stimulate pig production to the extent that the control measures are more than overcome by the pig population. Similarly, the response to erosion control management measures may vary widely depending on weather patterns and site conditions. Contamination of source water from sediment is a natural process, erosion. Management measures recommended in this source water protection plan are meant to slow the rate of erosion and expedite the natural healing processes. Clearly, the inherent variability in biological systems demands certain accommodations and understanding of the predicted results of the HACCP process.

First, the HACCP process will often be in a reactive mode rather than a preventive mode. It will not be always possible to detect wild biological problems before they exist. Once they exist, they can cause problems in the water supply until they are detected and overcome. This is true in every biological system and in every watershed.

Second, in order to minimize the amount of time during which the biological problems exist, it is necessary to have a permanent, at least annual, monitoring program with adequate financial provision for follow-up control whenever problems or potential problems are detected. The importance of monitoring for evaluating and adjusting current best management practices and for identifying additional hazards and best management practices can not be overstated.

Third, no matter how well the monitoring and control procedures are done, there will be times when one or the other will be overdone or underdone. There is no fiscally reasonable way to avoid this problem. In some cases, it will not be possible to avoid even without any fiscal restraints.

Southern Alameda Creek Watershed Biological Hazards Control Program

Hazard:

Livestock-Grazing Management –
Cattle contaminating source water with fecal pathogens and excess nutrients.

Risk Assessment:

Pathogens

Of major concern in municipal water supplies is the potential of waterborne infections caused by the protozoal parasite, *Cryptosporidium parvum*. This parasite may be shed in animal and human waste and contaminate source water. Unlike *Giardia duodenalis* and pathogenic bacteria, *C. Parvum* is not deactivated by traditional municipal water treatment methods such as chlorination. Recent waterborne outbreaks of cryptosporidiosis in metropolitan areas of the United States, including the outbreak in Milwaukee, Wisconsin in 1993 where 400,000 people suffered have highlighted the need for developing source water protection plans

Pathogenic bacteria such as *Escherichia coli, Leptospira interrogans, Salmonella spp., Campylobacter jejuni* and *Yersinia enterocolitica* may also be carried in animal waste and transferred to humans via water; however, these bacteria are killed by disinfectants like chlorine. Source water protection plans preventing these pathogens from contaminating source water require a multibarrier approach for pathogen protection. In many cases specific management measures i.e. managing residual dry matter, controlling access of livestock in riparian areas will not only provide protection against a variety of pathogens but also nutrient and physical (sediment) contaminants..

Although the risk assessment and management measures discussed in this section of the source water protection plan focus on preventing cattle manure from contaminating source water, it should be recognized that feces and urine from a wide variety of domestic, feral and wild mammals, including humans can contaminate source water with pathogens. There is no scientific evidence supporting the claim that cattle are the primary environmental source of *C. parvum*, *G. duodenalis* or pathogenic bacteria for surface water in California. Concentrations of *Cryptosporidium* oocysts and *Giardia* cysts have been detected in pristine surface water, where there are no cattle or other domestic livestock in the watershed (Madore et al. 1987). Similarly, Stuart et al (1971) has shown that elk were responsible for high bacterial pollution in a high mountain watershed. Risk assessment and management measures for protecting source water from contamination by wildlife are discussed in another section of this source water plan.

An accurate risk assessment regarding cattle grazing and water quality requires knowledge of the prevalence of cattle shedding these pathogens, the survivability of the pathogens on rangeland and in water, and the likelihood that viable bacteria and/or protozoal oocysts within fecal patties can reach bodies of surface water during conditions of rainfall and overland flow.

Research has clearly indicated that the greatest risk from cattle contaminating source water occurs if infected cattle directly deposit fecal matter in source water. Preventing bacterial infections with herd health management and excluding cattle with higher risks of infection from *C. Parvum* from direct contact with source water should limit the risk associated with cattle contaminating surface water with pathogenic bacteria, *C. parvum* or *G. duodenalis*.

Prevalance of cattle shedding pathogenic bacteria or protozoas.

A University of California statewide epidemiological study examined the prevalence of and risk factors for shedding *C. parvum* and *G. duodenalis* in rangeland cow-calf herds. Thirty-eight herds and around 1400 cattle were enrolled in the study. Researchers found that shedding of *C. parvum* in cow-calf herds is primarily limited to calves under 4 months of age. Watershed management practices attempting to reduce the risk of cattle contributing *C. parvum* to waterbodies should focus on young calves.

In addition, given that calves are presumed to develop a sterile immunity to cryptosporidiosis in 10-20 days, it is unclear how a seasonally calving herd becomes reinfected each year. A specific U.C. research project has been initiated to determine whether the precalving-cow is the reservoir of infection or whether some other environmental source is responsible. Thus, the potential role of wildlife in contaminating surface water and serving as a reservoir of infection should not be overlooked.

The occurrence of Salmonellae, E. coli, and Campylobacter in rangeland cattle is very low. Two unpublished studies in California tested feces from a total of approximately 1400 range beef cows across California. Results found only one positive sample for salmonellae and less than 1% (13/1400) positive samples for E. coli. Another study on range beef cows in California test 550 beef cows and found approximately 5% shedding Campylobacter. Both E.coli and Campylobacter are more frequently found in calf feces than from feces of mature cows. The incidence of leptospirosis in beef cattle, which can be shed in the urine, has not been studied in California. However, cattle can be routinely vaccinated for leptospirosis so infections can be avoided.

Survivability of bacteria and protozoal oocysts on rangeland and in water.

If bacteria or protozoal oocysts are shed in feces on rangeland, they can only contaminate source water and pose a potential risk to human health if they remain viable in the manure until they can be transported via overland or subsurface water flow to nearby source water. *Cryptosporidium* oocysts that dry-out become non-infective in just a few hours. If fecal material thoroughly dries before reaching water, the oocysts would presumably become non-infectious to other animals and humans (Anderson 1986; Robertson et al. 1992).

Oocysts shed directly into source water may remain viable for longer periods of time than those shed on rangeland. One study found that after 33 days in river water, 34% - 40% of purified oocysts became non-infective. After 176 days, 88% -99% of the oocysts had become non-infective (Robertson et al. 1992).

A concern regarding bacterial pathogens is their ability to survive in the environment. *Salmonella newport* and *E. coli* have been shown to survive several months in freshwater sediments (Burton et al. 1987). Fecal coliforms may survive up to two months in soil, but within the protective medium of feces can persist up to a year (Bohn and Buckhouse 1985). Many factors including type of pathogen, host medium (i.e. soil, water, sediment, manure), pH, temperature and moisture determine the survivability of pathogenic organisms.

<u>The likelihood of viable pathogens within fecal patties reaching source water during conditions of rainfall and overland flow.</u>

Buffer strips have been shown to provide significant reduction in transport of sediment, nutrients, and bacteria. Glenne (1984) looked at a model, which simulated the generation of water pollution in three watersheds in northern Utah. He noted that a buffer strip approximately 50 meters wide is needed to reduce bacterial concentrations by 90% on a 10% slope, and 90 meters wide on a 20% slope. Bingham et al. (1980) studied buffer strips in relation to sediment control including phosphorus and nitrogen from poultry waste spread across open fields. They concluded that the buffer strips needed to be as wide as the spread width of manure, i.e. if manure was spread 13 meters wide, at least 13 meters of a buffer strip was necessary.

Because evaluating the mechanism of transport involves consideration of numerous variables including source, soil type and permeability, slope, vegetation cover, and rainfall intensity and duration, establishing an appropriate width for a buffer strip must be site and objective specific. In regards to establishing an effective buffer to guard against the transport of fecal contaminants deposited on rangeland environments from free grazing cattle more information is needed. Larsen et al. (1994) monitored runoff from fresh cattle feces placed on grass sod buffer strips and subjected to simulated rainfall. They found that the number of bacteria was reduced by 83% during a 30-minute simulated rainfall event when the collection point was placed 0.61 m from the manure. Bacterial loads were reduced by 95% if 2.13 m of separation between the feces and the collection point was maintained.

A comprehensive U.C. research project is underway which is examining the underlying mechanics of how oocysts move across and move through soil during conditions of rainfall. This project is evaluating how wide a riparian grass buffer strip is needed to filter out these protozoal eggs during conditions of overland flow. This is a critical question when faced with the decision of how far back from a reservoir or river should a fence be placed in order to protect water quality, or is a fence even necessary.

Unlike *C. parvum* in which there is unequivocal evidence for its ability to be transmitted from one species to another, considerable controversy surrounds the issue of whether *G. duodenalis* cysts obtained from livestock can infect humans. Upon reviewing the existing scientific literature with respect to transmission of *G. duodenalis* cysts from livestock to humans via water, Thompson and Boreham, 1994 and Erlandsen, 1994 both concluded that convincing data still does not exist. Finding such evidence remains severely constrained given our historically poor ability to identify the vertebrate source of waterborne *G. duodenalis* cysts (Thompson and Boreham, 1994).

Nutrients

Since most nutrients for range beef cattle in the Southern Alameda Creek Watershed are provided from forage growing in a watershed, there is no significant source of excess nutrients for cattle to contribute to the watershed. Several studies have concluded that excrement from grazing cattle contribute negligible nutrients to waterways. In particular, a research study conducted by Dahlgren and Singer (1991) found that grazing of northern California oak woodlands had no effect on major nutrients. Water quality problems that might arise from nutrients in a grazed watershed would typically result from cattle feces and urine being directly deposited into source water. Management measures used to control grazing livestock to provide protection from pathogens will also minimize any potential water quality problems from nutrients in livestock excrement.

Critical Control Point GM-1: Maintain healthy immune systems and minimize the intensity of infections in grazing herds.

Best Management Practices:
In consultation with their herd veterinarian, livestock owners/managers should establish a herd health program for the prevention and care of general parasitic diseases. At a minimum the herd health program should include the following measures to maintain healthy immune systems and minimize the occurrence of diarrheal infections:
(1) Routine vaccinations of all cattle for preventing BVD (Bovine Virus Diarrhea) which can act as an immunosuppressive disease and *Leptospira pamona* bacterins

(2) Routine internal parasite control (deworming) to prevent clinical parasite infections;

(3) Prevention of selenium and copper deficiencies with appropriate supplementation depending on current herd status

(4) Avoid overcrowding during calving and subsequent grazing when young stock are present in order to minimize animal-to-animal transmission; maintain a sanitary calving place.

(5) Keep herds closed to the introduction of outside suckling (neonatal) calves. Calves from outside the herd may introduce *C. parvum* or other pathogens to the herd.

Monitoring:
Trained ranch personnel should check cattle frequently for disease. Frequency of inspection will depend on herd's reproductive and current health status.

Critical Limits and Corrective Action:
When clinical disease is observed, cattle should be promptly treated. A veterinarian should be consulted as necessary.

Record Keeping: Livestock owners/managers should keep herd health records as follows:

- Records (product, dose, animal ID, employee ID) of vaccinations and routine procedures of groups of cattle.
- Records of treatment disease protocols (diagnosis, product used, dose) or individual treatment records (diagnosis, product used, dose, injection method, date, employee).

Critical Control Point GM-2: Control cattle grazing and access to source water including reservoirs and streams.

Best Management Practices: Potential problems from cattle grazing are most likely to occur when cattle concentrate in or very near source water. Management measures that “lure” livestock away and control their access to riparian areas will have a positive effect on water quality. Depending on the site specifics, the livestock operation, and other resource objectives the following practices are recommended.

Riparian Pastures. Develop and maintain riparian pastures (buffers) around source water reservoirs and streams. To minimize potential water quality risks, riparian pastures should be non-calf and non-corral pastures. These pastures should be designed to be grazed or otherwise managed. To provide for water quality protection minimizing use of riparian areas during the winter (peak flow periods) is advisable. Management practices including grazing management (season of use, stocking rate, and frequency of grazing) will depend on specific resource objectives for each pasture. For example, to minimize impact on tree and shrub foliage in riparian areas, grazing of riparian pastures in the fall should begin once there is adequate new grass growth (> 2 inches) and should end in the late spring/summer once most of the annual grasses have senesced. The addition of riparian pastures along several key streams in the Southern Alameda Creek Watershed will enhance source water protection.

Attraction. Provide shade, drinking water, salt or supplements away from riparian areas. In particular identify locations where additional water sources can be developed to reduce the time livestock spend near source water. There are numerous opportunities to develop springs or pipe water from nearby stockponds in the Southern Alameda Creek Watershed.

Herding. Herders can be used to regulate the amount of time cattle spend in riparian zones. This method may be most appropriate where livestock are herded on a daily basis.

Culling: If attraction practices are partially successful, but some individuals continue to concentrate in the riparian area, removing them from the herd (culling) may be helpful. Within breeds and within herds certain individual cows are “bottom dwellers” and others “ridge climbers.”

Monitoring:
Barrier fences for riparian pastures should be checked weekly by livestock owners/managers.

Riparian / reservoir pastures should be monitored based on objectives identified in grazing plans. Annual monitoring could include riparian photos, bioassessment, riparian inventory, measuring stream channel morphology, mapping utilization and residual dry matter. Critical limits and corrective actions will depend on clearly and specifically identifying objectives for each riparian pasture.

Critical Limits and Corrective Action:
If a fence is broken, it should be promptly fixed. Cattle breaching fencelines should be immediately moved to the appropriate pasture. If resources objectives are not being met by the current grazing plan**, s**eason of use, stocking rate or frequency of grazing should be altered to meet resource objectives.

Record Keeping:
Livestock owners/ managers should keep records of their grazing plan including stocking rates, in-out date, livestock numbers and class of livestock. Records should also be keep identifying situations (including type and number of animals involved), and actions taken to correct any breach or disrepair of riparian pasture fences.

Critical Control Point GM-3: Manage residual dry matter (RDM) to reduce fire hazard and minimize potential for feces transport (minimizing runoff) by controlling grazing utilization and distribution.

Best Management Practices:
Good even distribution of livestock utilization and fecal material is essential for minimizing potential water quality problems. In particular, livestock distribution is the key to decreasing feces deposited near water, reducing transport of fecal material by overland flow, and maximizing fire protection.

Managing residual dry matter (RDM) on an annual range site is the most effective way to monitor and manage for even distribution of livestock utilization. Managing for RDM also a range managers' means of influencing soil surface condition and ultimately soil infiltration capacity, water holding capacity, and plant productivity. Sufficient RDM can minimize runoff and the potential for fecal transport, as well as minimize soil erosion. Appropriate levels of RDM need to be left on range sites after growing season and prior to fall rains to reduce fire hazard and minimize erosion. USDA Natural Resource Conservation Service site specific recommendations for Southern Alameda Creek Watershed lands based on soil, climate, and vegetation indicate that 700 to 1300 lbs of residual dry matter should be left to minimize runoff and protect soils from fall rains as well as maintain productivity for most soils and slopes in the Alameda watershed (USDA, 1966). Specific RDM target levels may be set for each grazing site based on resource objectives.

Managing grazing livestock to achieve a target RDM of 700 -1300 lbs will require appropriate stocking rates, as well as controlled livestock distribution. Controlled grazing is planning-monitoring-controlling-replanning. Stocking rates refer to the amount of land area allocated to each animal unit for the entire grazing period in one year. The stocking rate varies between years due to weather and previous use. Grazing units should be stocked at rates so that target RDM levels can be reached in most years. Livestock owners/ managers should be prepared to move livestock early or provide supplemental forage in drought periods

Monitoring: Identify likely or suspected areas of different use by marking use zones on a map for each grazing unit. A specific grazing unit may consist of a single ecotype or vegetation type, but due to variation in the site, monitoring should evaluate the site by several use zones. Factors that influence wildlife / livestock use should be mapped. This could include topography, water sources, soil and vegetation types. Fences, corrals, gates, shade and roads may also dictate utilization zones of range. The distance and location of these features in respect to each other will be considered when determining zones. The items should all be identified on a map.

Measure RDM at the end of the growing season and record on the grazing unit map. A double sampling method is recommended for determining RDM. The double sampling method will provide for accurate information for decision making regarding watershed/ resource management. Visual-only estimates of RDM are usually not very accurate.

The double sampling procedure involves making a visual estimate of RDM in a specific area, followed by clipping and weighing the same area. After repeating this procedure, usually about 10 paired samples are sufficient, the data collector is "trained" and can visually estimate a large number of specific areas. At the end of the visual-only estimating session, a second collection of paired plots are collected. The two paired sample collections are used to make a "correction factor".

RDM monitoring information collected at the end of the growing season can be used to determine if there is adequate forage to last through the grazing season or if livestock numbers should be reduced. Recording RDM levels on a grazing unit map will help to determine areas of under or overutilization. This information can be used to improve livestock distribution. RDM data can be summarized by utilization class (light, moderate, heavy) and graphed. This summary should provide information to evaluate stocking rates and livestock distribution.

Critical limit:
Corrective actions should be implemented relative to location of utilization zones with light or heavy use. If heavy use zones are identified in areas adjacent to stream channels corrective actions to redistribute livestock must be considered. Corrective actions for livestock distribution should also be implemented if light use zones are noted in areas of severe fire hazards. Fire severity areas have been mapped for San Francisco Water Department property in the Southern Alameda Creek Watershed.

Corrective actions to adjust stocking rates should be implemented if target levels are reached after the growing season ends and before the end of the grazing season.

Corrective Action:
Depending on the livestock operation and other resource objectives the following corrective actions may be considered to effectively manage RDM.

<u>Stocking Rate</u>
The grazing season should end once target RDM levels are reached. If under typically environmental conditions target levels are reached during the growing season, base stocking rates should be reduced in subsequent years. If target levels are not reached during the grazing season, base stocking rates should be increased. Stocking rates must remain flexible to account for year to year precipitation and forage growth variability.

<u>Livestock Distribution</u>
The same tools used to "lure" livestock away from riparian areas can be used to improve distribution. These tools include attraction and herding. Attraction, moving salt/mineral feeding locations away from water is one way of improving livestock distribution. Traditionally, people have thought that cattle must have water after consuming salt. Recent information indicated that cattle do not utilize salt or mineral and then water or vice versa. Distributing livestock with the placement of supplemental feed is also an effective tool for managing livestock distribution. Although developing water is one of the more expensive tools to manage livestock distribution, it is also one of the most effective tools. Recently several springs have been developed by livestock

owners in the Southern Alameda Creek Watershed to improve livestock distribution. To be effective water should be located so that cattle do not have to travel more than ½ to ¾ mile in the hilly topography of the Alameda watershed to drink.

Herding may also be used by livestock owners to improve distribution.

Additional fencing may be needed to solve livestock distribution problems where the above methods prove ineffective.

Record Keeping:
Livestock owners/ managers should keep records of their grazing plan including stocking rates, in-out date, livestock numbers and class of livestock.

Monthly weather records, including amount of precipitation, and temperature (average, maximum, and minimum) should also be kept.

Grazing utilization maps should be updated annually.

Critical Control Point GM-4: Strategically locate areas of livestock concentration.

Best Management Practices:
Both livestock and wild game will concentrate around areas such as watering places or feeding grounds. These areas should be located so that they are hydrological remote and avoid any potential opportunity for concentrated waste to contaminate source water. For example, stock tanks, feed, supplements should not be located in stream channels, swales, or flood plains. In some locations, livestock should be excluded from stockponds and an alternative permanent water source provided.

This best management practice is in complete agreement with Control Point 2 and 3. In general, moving an attraction such as supplement feeders or water to improve livestock distribution will be moving an area of livestock concentration to a hydrologically remote location.

Handling facilities should not be located in flood plains.

Monitoring:
All potential areas of livestock concentration should be included on the grazing unit map.

Critical Limits:
Concentration areas should not be located or cause overutilization problems in areas near source water.

Corrective Action:
Relocate concentration areas to hydrologically remote locations.

Record Keeping:
Areas of heavy utilization should be mapped annually on grazing utilization maps.

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Southern Alameda Creek Watershed Biological Hazards Control Program

Hazard:

Feral Pig Management-

Feral pigs contaminating source water with *Cryptosporidium parvum* and other pathogens.

Risk Assessment:

Feral pigs are abundant in western California and data collected in the summer of 1995 suggest that feral pigs may contaminate nearby surface water with *Cryptosporidium parvum* and *Giardia duodenalis*. In particular, feral pigs focus activities (wallowing and foraging) around the margins of seeps, springs, ponds, streams and lakes during the summer months. Feral pigs in the Alameda watershed have direct access and can deposit fecal material directly into the reservoirs and perennial streams. Sweitzer et al (1997) found that 5% and 8% of all feral pigs sampled during the summer were shedding *C. parvum* oocysts and *G. duodenalis* cysts, respectively. Age-associated shedding of *C. parvum* was 11% for feral pigs less than or equal to 8 months of age and on average 3% for feral pigs older than 8 months of age.

In the study by Sweitzer et al (1997), shedding of *C. parvum* by feral pigs was strongly associated with measures of population density. No pigs from low-density populations were shedding *C. parvum*, compared to 9 -10 % in populations with 2.0 pigs per square kilometer or greater. The odds of shedding *C. parvum* was 4 times greater for feral pigs less than or equal to 8 months of age compared to older pigs. Wild pigs reproduce year round. Pig populations around Calaveras Reservoir are currently considered to be high density. In July 1995 the SFWD in cooperation with the Department of Fish and Game and the East Bay Regional Park District began a program to control feral pigs. The program was suspended in May 1996 but over 350 pigs were removed. It is estimated that there may be 3000 feral pigs in the Southern Alameda Creek watershed.

Although the overall proportion of wild pigs shedding *G. duodenalis* compared to *C. parvum* was similar for pig populations tested, the associated risk factors for shedding were different for the two protozoa. For *C. parvum* shedding, pig age and population density were strong risk factors; however, there was no clear association between *G. duodenalis* shedding risk for feral pigs and demographic or environmental variables.

The potential for feral pigs to contaminate surface water with other pathogens has not been studied; however, pigs may shed pathogenic bacteria such as *Salmonella* in their feces. Efforts to control pig numbers in the watershed should reduce the risk for contamination of surface waters from all potential pathogens from pigs by reducing the number of potential disease reservoirs.

Critical Control Point FM-1: Minimize the population and infection rate of feral pigs.

Best Management Practices:
The risk of environmental contamination of *C. parvum* from high-density pig populations is two-fold: more wild pigs per unit area are serving as a potential reservoir of *C. parvum*, and a higher percentage of pigs are shedding the parasite. Therefore, pig densities should be reduced with a persistent, flexible control program. Reducing pig densities will also reduce the risk of contamination of Giardia spp. and other pathogens by reducing potential reservoirs for disease. The control program could include the following:

- Trapping pigs with box or corral type traps during dry or summer months. To increase the success of trapping, trap sites should be selected based on recent pig activity. Potential trap sites and traps should be pre-baited.

- Hunting with trained pig hounds in the winter and spring.

- Intensive and continual hunting at selected sites. Hunting by police officers working with the local State Fish and Game warden have nearly eliminated feral pig populations in the Hastings Natural Reserve in Monterey County.

Monitoring:
Wild pig populations should be monitored in the late spring along transects that survey for pig activity near source water including riparian habitat.

Critical Limit and Corrective Action:
Because the goal of controlling the pig population is to minimize risk of pigs contaminating source water, control programs should continue as long as pig activity is detected near source water including riparian habitats. (In addition to potentially contaminating water with pathogens, wild pigs can also accelerate erosion processes in a watershed. Refer to section: Physical Hazards Control Program).

If a persistent, flexible pig population control program becomes unfeasible because of legal, social or other reasons, alternative corrective action should be considered. Current available alternatives i.e. strategic fencing are not only very costly, but not very efficient. Strategic fencing may exclude pigs from small areas by fastening a strong wire mesh fencing tightly to the ground or buried for its complete extent. The effectiveness of the fence may be enhanced by adding an electrified wire on the outside, which will keep pigs from trying to burrow under. Excluding pigs with strategic fencing from an extensive area would be an on-going challenge.

Record Keeping:
Record location, method, date, age, results of fecal analysis of trapped and dispatched pigs. Record survey results from semi-annual pig activity survey.

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Southern Alameda Creek Watershed Biological Hazards Control Program

Hazard :

Wildlife Management-
Wildlife contaminating source water with *Cryptosporidium* and other pathogens.

Risk Assessments:
The Southern Alameda Creek watershed not only provides habitat for feral pigs, but also for a variety of wildlife including tule elk, black-tailed deer, beaver, ground squirrels, coyotes, voles, mice, woodrats and kit fox. The watershed also provides winter foraging and resting habitat for migrating and resident bird species, including raptors (i.e. golden eagles, black shouldered kites, sharp-shinned hawks), water fowl and perching birds. A variety of amphibians are also present in the watershed including the California red-legged frog, western pond turtle, and the California tiger salamander. Little is known about the prevalence of pathogens in wildlife excrement, but clearly there is a potential for wildlife to contaminate source water with pathogens including pathogenic bacteria and protozoans.

For example, shedding of *C. parvum* has been confirmed in eighty species of mammals. Given that concentrations of *Cryptosporidium* oocysts ranging from 0.005 - 18 oocysts/ liter, have been detected in pristine surface water (within watersheds with no domestic livestock and limited human activity), the role of wildlife in contaminating surface water with these protozoa should be carefully examined (Madore et al. 1987). Similar to *C. parvum, Giardia duodenalis* and *Samonella* are shed by a wide variety of wildlife species and found in pristine waters. It has not been determined which vertebrate species, including humans and livestock, are the primary sources of *G. duodenalis* or *Samonella* for surface water in California.

To determine the need for controlling various species of wildlife, assessment of prevalence of pathogens among various wildlife species should be conducted. Species to be considered as potential sources of waterborne pathogens in the Alameda Watershed include: deer, elk, coyotes, ground squirrels, mice, voles, gophers, beavers and wood rats.

The following discussion on risks associated with wildlife shedding C. parvum provides an example of potential risks of pathogens from wildlife and management measure that could be implemented to address those risks.

<u>Risk associated with rodents.</u>
It has been hypothesized that a likely candidate for a wildlife reservoir of *C. parvum* could be a ubiquitous rangeland species, such as the California ground squirrel (*Spermophilus beecheyi*) or other such rodent. Gray squirrels are known to shed this pathogen (Sundberg et al. 1982) and *Cryptosporidium* oocysts from wild mice (*Mus musculus*) have been shown to be infectious to calves (Klesius et al. 1986). Sixty three percent (46/73) of wild brown rats (*Rattus norvegicus*) were shedding *C. parvum* in one study (Webster et al. 1995). In fall 1996, the Federation of

American Scientist reported that a pathologist confirmed *Cryptosporidium* was the causative agent in the death of 15 baby squirrels, indicating that *Cryptosporidium* can replicate in squirrels.

Since *Cryptosporidium* seems to be sensitive to heat and desiccation, rodent fecal material scattered on the surface may not present a significant public health problem during much of the year. However, defectoriums (defecating sites) in covered nests or burrow systems could be a problem if they were flushed into the water during storm events. Gopher and ground squirrel burrows are known to serve as macropores or "pipes" for runoff water when one opening is located to receive surface flow, and interconnected burrow outlets are lower in elevation. Reviewed literature does not indicate whether the California ground squirrel (*Spermophilus beecheyi*) defecates in burrow systems. The Columbian ground squirrel (*Spermophilus columbianus*) (Young 1989) and the white-tailed prairie dog (*Cynomys leucurus*) Cooke and Swiecki 1992) construct defectoria in burrow systems, so it is likely that the California ground squirrel does also. Assuming squirrels defecate in burrows, the risk associated with ground squirrels is dependent on whether they are infected with *Cryptosporidium* and the number of burrow systems likely to serve as pipes.

If squirrels are determined to be a potential source of contamination, squirrel control around source water could be implemented.

With woodrats, the risk is associated with the number of nests within a floodplain area and whether the rats carry *Cryptosporidium*. Wood rat nests located in a flood plain can become detached or destroyed, with materials floating downstream. Because many of the stream channels in the Alameda watershed are steep, the floodplain area available for nests is limited and the risk should be slight.

<u>Risks associated with elk and deer.</u>
Elk can shed *C. parvum*; however, they calve in the late spring (just prior to the dry season). Assuming that young elk are more likely to shed *C. parvum* oocysts than mature elk, risk of source water contamination from elk may be minimal. However, if mature elk shed either *C. parvum* , *G. duodenalis* or other pathogens their potential for contaminating source water should not be overlooked, because not only do they have access to reservoirs and other source water, but they are known to wallow in shallow water. If elk were determined to be a significant potential source of contamination, elk-proof fencing could provide a barrier to source water, but at substantial cost.

Mule deer have been shown to shed *C. parvum* (Heuschele et al. 1986). Potential contributions of *C. parvum* and *G. duodenalis* from deer may be less than from elk. Although deer numbers in the watershed are probably greater than elk, deer do not congregate near water and do not socialize in herds like elk. The elk herd resides within the Calaveras reservoir watershed. The deer are distributed throughout the Alameda watershed. Since deer are widely distributed and they have direct access to source water, an effort should be made to determine their prevalence for shedding protozoa. Like elk, deer fawn in the late spring, just prior to the dry season. Cryptosporidial infection has been confirmed in a variety of neonatal (young) captive deer.

Risks associated with waterfowl, fish and amphibians

Although waterfowl, fish and amphibians are not known to be infected by *C. parvum*, they can be the source of other species of *Cryptosporidium* which can cross-react with the ICR procedure for monitoring water for *Cryptosporidium*. Current water tests to determine the presence of *Cryptosporidium* can not differentiate species of *Cryptosporidium*. There are at least eight species of *Cryptosporidiu*m; however only one species has been found to be infectious to humans, *C. parvum.* It is possible that a positive water test for *Cryptosporidium* has detected oocysts that have no implication with regards to human health. These oocysts can be shed by a variety of wildlife including amphibians, fish, and birds. The presence of waterfowl, fish and amphibians should be considered when interpreting results of a positive water test. Research is underway to develop a water test that can differentiate between the various species of *Cryptosporidium.*

In addition to creating a false positive water test, waterfowl could be responsible for transporting *C. parvum* oocysts from a fecal source to a water source via their digestive systems or their feet. A large number of waterfowl such as gulls and other shorebirds are often found on the reservoirs. Gulls in particular may create a risk because they may feed in nearby landfills providing the opportunity for a human - gull - human cycle. In addition, gulls could be responsible for contaminating water with other pathogens. Using bird control methods that discourage waterfowl from using source water could minimize risks from gulls and other waterfowls.

Comprehensive risk assessment is needed before we can clearly understand the potential risk and prescribe management measures. However, maintaining ecological balances with sound wildlife management strategies should provide some level of risk reduction.

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Southern Alameda Creek Watershed Biological Hazards Control Program

Hazard:

Human-Recreation Management-
Humans and/or companion animals contaminating source water with pathogens.

Risk Assessment:
Human waste including treated effluent may contain *Cryptosporidium parvum* and other pathogens. Recent tests on treated effluent from California's central valley detected 150 to 550 oocysts/liter of *Cryptospordium*. Pathogenic E. Coli and Salmonella are also commonly found in sewage effluent. There are numerous sewage facilities located at the watershed cottages, at water system operations facilities, and at recreational sites. The sanitation facilities appear to pose a low risk to the reservoir and creeks water quality because they are either sewage vaults or chemical toilets and they are pumped out frequently. However, there is also a risk associated with an accidental spill from a waste tanker as it travels through the watershed (Watershed Sanitary Survey, 1995).

Recreation within the watershed is restricted to lands owned and leased by the East Bay Regional Park District (EBRPD) and the Sunol Valley Golf Course. Other informal recreational activities occur throughout the watershed on land that is not owned by the San Francisco Water Department. These activities may include hunting on private land and recreational use in Joseph D. Grant County Park, in Santa Clara County.

Recreational activities at the Sunol and Ohlone Wilderness, operated by EBRPD include picnic and overnight backpacking facilities (including group facilities), extensive pedestrian, equestrian, and bicycle trails. There are also naturalist-led weekend programs and special events including a wilderness fair and running races. Approximately 200,000 persons per year use the park.

Much of the park activities occur below the Alameda Diversion; however, water flowing in Alameda Creek through the park below the diversion can enter the water system at the Sunol Filter Galleries. The potential exists for humans, equestrians, or pets to contaminate water with microorganisms.

Prevalences of *C. parvum* shedding range from 0.1% to 27% (mean 4.9%) for human populations in industrialized countries, excluding AIDS patients and outbreaks investigations (Fayer et al 1997). A study by the San Bernardino County Department of Public Health Laboratory found that 2% (4/200) of the people who submitted fecal samples to the lab tested positive. Among the group of people at highest risk to be infected by *Cryptosporidium*, 30 to 60 % of Day Care Center attendees in several studies throughout the U.S. have tested positive. The risk associated with human activity is dependent on the ability of contaminated human fecal material to reach source water. According to EBRPD, less than 10% of the 200,000 people who use the park use the permanent toilet facilities. It is assumed that the remaining people use the chemical toilets or no facilities at all.

Dogs in the park may also present an opportunity to contaminate water. Fecal testing of 200 stray dogs in San Bernadino County revealed that 2% of the dogs were shedding *Cryptosporidium.* Like wildlife, livestock and humans dogs also have the potential to contaminate source water with other pathogens.

Horses have also been examined as a possible source of *Cryptosporidium parvum*. Preliminary data from a state-wide horse survey indicates that less than 1 % of adult horses are shedding *Cryptosporidium*, and none of 311 horses located in the southern Sierras and used as commercial packstock were positive for this parasite. Finally, in a study sponsored by the Backcountry Horsemen of California, none of 91 horses with a recent history of being ridden in the backcountry were positive for *C. parvum* (Johnson et al 1997).

The risk to water quality from pathogens from humans and companion animals is probably minimal based on the prevalence of disease in the population and the opportunity for contaminated fecal material to reach surface water. Providing safeguards to remove human effluent from the watershed and education to recreational users may be helpful in minimizing risk.

Critical Control Point HM-1: Safely transport effluent from sanitary facilities out of the watershed.

Best Management Practice: Identify best routes for the transport of effluent out of the watershed from chemical toilets and septic tanks. Develop emergency procedures and reporting for accidental spills. Provide information on travel routes and emergency plans to drivers.

Monitoring: Monitor transport routes to identify potential road hazards.

Critical Limits and Corrective Actions: Fix road hazards and identify alternative routes if necessary.

Record Keeping: Records on transport of effluent through the watershed including date, travel route should be kept. Records on accidental spill should also be maintained.

Critical Control Point HM-2: Minimize the opportunity for human or companion animal waste to contaminate source water.

Best Management Practice

The key to minimizing the risk of humans or companion animals contaminating source water with microorganisms is education. Through pamphlets and signs, park visitors should be educated about the importance of water supplies, activities that can affect water quality, and measures to protect water quality. Information of appropriate methods of human sanitation in areas not equipped with restrooms should be provided. In addition, materials (i.e. pooper scooper bags) should be provided to encourage people to clean up after their dogs.

Monitoring:

Park facilities operators should evaluate and monitor restroom facilities availability and location. Recreational usage including number of visitors, nature of visit ie day use, campers should be recorded.

Critical Limits and Corrective Actions:

As park use increases additional restroom facilities should be made available. Monitoring park usage and water quality parameters should provide information necessary to plan for additional management measures.

Record Keeping:

Records on park usage and location and maintenance of restroom facilities should be kept.

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Southern Alameda Creek Watershed Physical Hazards Control Program

Hazard:

Soil erosion and resulting sedimentation degrading water quality and filling reservoirs.

Risk Assessment:

Sediment is a major carrier for pathogenic organisms, organic residues, nutrients, and pesticides. It can also fill stream channels and reduce the capacity of reservoirs. At the treatment plant, sediment causes additional problems. The increase in turbidity from the fine particles results in increased treatment operations (e.g. more backwashing of filters, higher disinfectant dosages). The risk of pathogens slipping through the treatment process is also increased.

Soil erosion and the resulting sediment discharged into watercourses in the Southern Alameda Creek Watershed is a function of the rainfall intensity, inherent erodibility of the soil type, slope, vegetative cover and land use. The two largest factors associated with soil erodibility in this watershed are the percent slope and land use. The steep slopes throughout the watershed increase the soil erosion hazard. Soil erosion hazard ratings by slope are as follows: 2-5% –slight; 5-30%–moderate; >30%–severe. Improper land use including poor road construction and/or maintenance and poor grazing management can particularly accelerate erosion on steep slopes.

Within the Southern Alameda Creek Watershed a predominant source of sediment occurs from poorly designed and maintained unpaved roads. There are approximately 90 miles of unpaved roads and many more miles of jeep trails. Many miles of the unpaved roads within the watershed are graded with a ditch to the inside of the road against a hill slope. This design concentrates runoff within the ditch and forms gullies both along the road and on the downhill slopes where runoff leaves the road. Most culverts installed to channel the water under the roads have created gullies from 2 ft to 40 ft in depth. At locations where roads cross streams, sediment is transported directly into the stream.

In addition to soil erosion, mass movement (landslides, gullies, and streambank failures) can also be a major source of sediment. Areas within the Southern Alameda Creek Watershed prone to mass movement include the Williams Gulch and Oak Ridge areas

A comprehensive risk assessment (sediment budget) of soil erosion and sedimentation as it relates to water quality requires a detailed inventory of problem sites, existing and potential mass movement sites, the length, average width and condition of unsurfaced roadways, number, condition and location of roadway drains, rangeland utilization records, type and degree of grading activities and feral pig inventory and locations.

Critical Control Point EC-1: Control erosion from gullies.

Best Management Practices:
The following steps are recommended to control erosion from most gullies.

(1) Investigate and try to address the cause of the gully. Anything that disrupts the natural drainage is a potential cause. This may include a roadway or stockpond spillway. Refer to Critical Control Points EC-4 to address problems created by roadways and stream culverts. In many cases there may be no obvious cause.
(2) Stop the gully from headcutting. With limited resources a landowner may only be able to implement this step, but stabilizing the head of the gully should prevent the gully from expanding. Making the cut invulnerable to erosion stops headcutting. This may be accomplished with protective armor or by diverting and spreading water causing the head cut. In the case of gullies formed in the emergency spillways of stockponds providing an alternative piped, principle spillway can divert water away from the eroding headcut.
(3) Stop the gully from downcutting. Downcutting may be treated by armoring the cuts, constructing check dams or establishing vegetation across the gully floor to slow the flow of water through the cut
(4) Raise the level of the gully. Checkdams provide one of the most effective ways to raise the level of the gully. Sediment is allowed to settle out of water above the dam. Vegetation can be used around the checkdam to provide additional erosion control.
(5) Stabilize the gully's banks. If headcutting and downcutting have been controlled, in time the banks will slope back to a stable angle. Sloping the banks and seeding bare banks may speed the recovery process.

Monitoring: Gullies can be monitored with permanent photo points capturing the cross section and/or by measuring head cut. Permanent photo points maybe recorded By GPS. Permanent markers around the perimeter of the headcut can be used monitor its size. The head cut should be monitored for the following criteria:

- Deliverable to a stream?
- Management induced?
- Reasonably responsive to repair?
- Potential volume of sediment produced?

Critical Limits and Corrective Action: If the following criteria exist and monitoring results indicate that there is a potential for more than 10 cubic yards of material to leave the gully additional armoring and/or diversion of water should be considered.

Record Keeping: Location of gullies can be included on ranch maps. Information on reference markers, monitoring notes, and treatment efforts should also be recorded.

Critical Control Point EC-2: Control erosion from recovering landslides.

Best Management Practices: Many areas are naturally prone to mass wasting so controlling erosion from landslides should be approached with reason. Human impacts around recovering landslides can be minimized by rerouting roads, controlling road runoff, removing structures, and controlling livestock access. Working to stabilize the soil surface so that exposed soils will revegetate may control erosion from small landslides. Many small landslides can recover on their own, but the following management practices will not only help speed recovery but also minimize sedimentation from the site. The appropriate management practice will depend on the particular site and available resources.

Revegetation. If large areas of soil are exposed seeding stable sites in the early fall before the first fall rains may be helpful. A mixture of annual grasses and legumes, like the following is recommended: Seeding rate mix per acre

8 lbs Sub-clover (inoculated) or Hykon Rose Clover
8 lbs Blanco Brome
8 lbs Annual Rye Grass or Fescue

Fertilizer (16-20-0) maybe included with seed mix at a rate of 250 lbs/acre.

Perennial grasses may be considered but generally require a longer period to establish and will not provide immediate soil protection. In the long term, perennial plants with their deep roots may provide better soil stability than annual grasses. Native perennial grasses may be desirable in some areas although the seed is quite expensive. The seed can be hand-broadcast or broadcast with a “belly-grinder”. Livestock impact may be used to “plant” the seed and incorporate additional mulch into the landslide site after the site has received some fall moisture. Hay including hay with seeds can be spread across the landslide to attract a large group of cattle. After livestock have adequately impacted the surface, i.e. hay has been incorporated and sharp banks of the slide have been smoothed, livestock should be excluded from the site until new vegetation is established.

Subsurface Drain. A subsurface drain above the small slides will reduce the amount of water flowing through the slide area. A pipe should be installed at the interface of subsoil and bedrock or clay layer, if present, or in the first couple of inches of the clay layer if present. If there is no distinct change in soil type at a depth of four feet, the slide is too deep for a subsurface drain. The subsurface drain should be set back at least 10 feet from the top of the slide and should outlet into a stable channel or other location where concentrated flow will not cause erosion.

Monitoring: Landslides can be monitored with permanent photo points capturing a cross section. The amount of exposed soil in a landslide area can also be measured or estimated.

Critical Limits and Corrective Action: If monitoring results indicate that the landslide is continuing to move and expose soil to erosion, additional treatment and/or establishment of sediment basin may be considered to prevent sediments from reaching source water.

Record Keeping: Location of landslides can be included on ranch maps. Information on reference markers and treatment efforts should also be recorded.

Critical Control Point EC-3: Minimize sheet, rill and gully erosion from unpaved roads.

Best Management Practices:
Roads can not only be a source of erosion but improper design to control runoff from roads can lead to additional erosion problems like landslides and gullies. Efforts to reduce erosion in the watershed should focus on design and maintain low-maintenance unpaved roads, using the following principles:

- *Hillslope Location.* Roads are best located on hillslopes of 10-40%. Road located on hillslopes of 0-10% or 40-55% may require extra attention to control drainage and potential bank failure.

- *Outsloped.* Where appropriate, roads should be outsloped 4-8%, with outslope being 1-2% greater than the slope of the road grade. Outsloping should be avoided where the road surface is composed of fine, highly erodible soil or on well-traveled curves. Outsloping of 4-season roads should be carefully designed and planned to maximize safe driving conditions.

- *Road Grade*. Roads should have a gradient of 2- 8%. Lengthening the road with switchbacks and/or climbing turns will minimize road grade up steep hills. Roads with gradients of 9-12% can be accommodated for short distances but will require attention to drainage.

- *Road Surface.* Consider surface treatment to problem wet spots. Seep sites should be protected with a gravel road base placed over a layer of filter fabric to prevent the gravel from mixing with the mud. Underground drains may also be needed to remove water from the roadway.

- *Weed Control.* Consider where practical, mowing rather than blading or grading roadways.

- *Rolling* Dips. Install rolling dips when a natural drainage feature is crossed and where necessary to prevent water from accumulating on the roadway. Rolling dips should be at least 12" below grade and have a 15-25 foot approach on the downhill side.

Consideration should be given to removing excessive roads and roads that do not follow the basic design principles for low-maintenance unpaved roads.

Monitoring: Prior to grading, evaluate road sections for channels and ruts as well as road failure. Note sections of road that require extra maintenance.

Critical Limits and Corrective Action: On road sections that fail or require extra maintenance opportunities to provide for additional drainage should be identified. If the road does not follow the basic design principles for low-maintenance unpaved roads, the landowner should consider relocating the road.

Record Keeping: Roads should be mapped on property maps with problem spots identified. Additional records of road maintenance work should be kept.

Critical Control Point EC-4: Minimize erosion from culverts or other stream crossings.

Best Management Practices: Where outsloping or rolling dips are not appropriate for draining water from roadways, water must be diverted in a cross-drain with a protected outlet. Culverts used for cross drainage should be properly placed and large enough to handle expected flows. Culverts may also be used for stream crossings. Culverts carrying stream flows should flow with the natural channel. Water flows should be carried over filled slopes and unstable areas in down spouts or surfaced channels (i.e. rock-lined). Culverts should slope down to prevent sediment from accumulating; a 6% grade is recommended.

Placing a trash rack at the culvert opening may help keep the culvert from plugging.

At some sites, replacing a culvert with a low-water crossing or bridge may be appropriate.

Monitoring:
Culverts should be checked and cleaned before the rainy season and after major storms. Landowners should watch for gullies forming around culvert inlets and outlets.

Critical Limits and Corrective Action: If a culvert plugs after every major storm, a larger culvert or another cross-drainage method such as a ford or low-water crossing should be considered. The landowner should also investigate the source of the debris.

If gullies are forming around the inlet to the culvert, the culvert may not be correctly placed or be too small to handle the flow. Gullies forming around the outlet of the culvert will require additional armor. A rock energy dissipator at the outlet of the culvert can provide soil protection.

Record Keeping: Culverts should be marked on property maps. Culverts with erosion problems should be identified. Culvert maintenance records should be kept.

Critical Control Point EC-5: Minimize erosion from stream banks.

Best Management Practices: Streams are dynamic, constantly modifying their channel shape through erosion. Severe streambank erosion typically suggests that there are other problems in the watershed that are increasing flows and/or increasing sedimentation. Before you consider in-stream repair measures investigate and try to identify and address obvious sources of excessive stream bank erosion. If road design or maintenance is impacting stream banks refer to EC-3 for management measures. Refer to EC-4 to address problems with culverts and EC-7 for livestock management in riparian areas. Excess debris which is impacting stream flow such as fallen trees or trash should be removed from the stream to maintain proper stream function. Where structures and/or roads are in danger engineered repair designs may be necessary. If the cause of the streambank erosion is not obvious monitoring the stream channel will help landowners identify the extent and nature of the streambank erosion problem.

Monitoring: Streambanks can be monitored with permanent photo points and/or by measuring steam channel morphology. To monitor a riparian area with photos, establish a monitoring area, a distance along the stream course that provides a representative view. Two permanent markers (post, tree, etc) should be placed or located at the beginning and end of the monitoring area on the same side of the stream. Markers should be referenced with a compass bearing and a witness point such as a large tree to aid in future relocation. Photos can be taken in several directions from each monitoring marker. Stream channel morphology can be measured by establishing several permanent transects across the steam and measuring the banks elevation with a level at set intervals across the transect.

Critical Limits and Corrective Action: If monitoring reveals that significant amounts of sediment are being removed from a reach of stream, management measures to address the following specific erosion problems should be considered.

Debris. Maintaining the stream channels by removing fallen trees, kitchen appliances, tires, shopping carts and old cars can restore proper stream function. Carefully investigate before removing all debris. Some woody debris is natural in most stream systems and may provide habitat for aquatic species.

Excess Flow. Excess surface runoff and subsurface water flow that is creating gullies or saturating banks may be controlled at the source. Roads, irrigation, roofs and foundation drains are all potential sources of excess flow. If the source can not be eliminated, berms may be used to trap surface flow or subsurface drains may be installed to intercept underground flows. Captured water should be redirected to a non-erodible point.

Downcutting. Checkdams within the streambed may be used to control downcutting. Checkdams raise the level of the channel, preventing banks from toecutting. Checkdams constructed from concrete or compacted earth should be engineered; however, in small stream channels checkdams may be constructed from hay bales, rocks or logs.

Outside curve. Management measures to address erosion on outside curves of streambanks include armoring the bank, deflecting the flow or straightening the curve.

- Armoring the Bank: Armoring must be keyed into both the upstream and downstream banks to prevent cutting from behind. Armoring may be created from rock riprap, gabions, retaining walls, crib walls, post and wire, grassy cover, or woody vegetation.
- Deflecting the Flow: A deflector constructed from logs, rocks or gabions can divert flows away from severe bank erosion. Like armoring a deflector must be keyed into both the upstream and downstream banks.
- Straightening the Channel: In extreme cases when other remedies are not practical a channel can be realigned with heavy equipment. Landowners should seek professional advice before straightening a stream channel.

Record Keeping: Monitoring areas and treatment areas should be recorded on ranch maps. Information regarding permanent markers, channel morphology and treatment efforts should also be recorded.

Critical Control Point EC-6: Minimize soil erosion from graded areas

Best Management Practices: Work which moves soil, disturbs vegetative cover or requires use of unsurfaced roads should be completed before the winter rainy season. In the Southern Alameda Creek watershed rains are usually expected to begin around mid-October, but it some years it may not rain until November or December. If unfinished work that is held over to the spring leaves soils exposed, sediment should be trapped so that it cannot leave the site. The following management measures are recommended to minimize soil erosion during and after construction:

- Conserve existing vegetation.
- Use temporary sediment traps such as filter fabric or hay bales to intercept and filter runoff.
- Install grade stabilization structures where necessary.
- Seed and mulch bare areas and spoil piles. Consider using livestock impact to stabilize loose soil and plant seeds.
- Install and maintain sediment basins.
- Divert surface runoff to non-erodible channels.
- Establish or maintain vegetative buffer to filter surface runoff from graded site.

Monitoring: Monitor runoff from graded areas for sediment.

Critical Limit and Corrective Action: Runoff leaving graded areas should not be carrying sediment. Additional management measures such as those recommended above should be implemented to maintain clear runoff from graded areas.

Record Keeping: Graded areas should be marked on ranch maps. Management measures used to control erosion should be recorded.

Critical Control Point EC-7: Minimize sheet and rill erosion, and stream sedimentation from grazing land.

Best Management Practices: Controlled, planned grazing can minimize erosion from livestock impacts. Controlled grazing on the annual rangelands in the So. Alameda watershed includes managing residual dry matter (RDM), strategically locating areas of livestock concentration, and managing wetland and riparian areas. Best management practices presented here are also presented as measures to control biological hazards GM-2, GM-3, and GM-4.

Managing RDM. Manage stocking rate and livestock distribution to achieve a target residual dry matter (RDM) of 700 -1000 lbs/ acre. USDA Natural Resource Conservation Service site specific recommendations for the Southern Alameda Creek watershed lands based on soil, climate, and vegetation indicate that 700 to 1300 lbs of RDM should be left to minimize runoff and protect soils from fall rains as well as maintain productivity for most soils and slopes (USDA, 1998). Specific RDM target levels may be set for each grazing site based on other resource objectives.

Managing grazing to achieve a target RDM of 700 –1300 lbs will require appropriate stocking rates, as well as controlled livestock distribution. Stocking rates refer to the amount of land area allocated to each animal unit for the entire grazing period in one year. The stocking rate varies between years due to weather and previous use. Grazing units should be stocked at rates so that target RDM levels can be reached in most years.

Strategically Locate Areas of Livestock Concentration. Areas where livestock and/or wild game concentrate should be located so that they are hydrological remote and avoid any potential for exposed soil to be carried as sediment to source water. For example, stock tanks, feed and supplements should not be located in stream channels, swales, or flood plains. In general, moving an attraction such as supplement feeders or water to improve livestock distribution means moving an area of livestock concentration to a hydrologically remote location.

Manage Wetland and Riparian Areas. Livestock grazing in wetland and riparian areas should be controlled. Management measures that may be implemented to control livestock in wetland and riparian areas include:

- Riparian and Wetlands Pastures. Although livestock may be excluded from these pastures, these pastures may be grazed periodically. Specific grazing management (season of use, stocking rate, and frequency of grazing) will depend on specific resource objectives for each pasture. For example, to minimize impact on tree and shrub foliage in riparian areas, grazing of riparian pastures in the fall should begin once there is adequate new grass growth (> 2 inches) and should end in the late spring/summer once most of the annual grasses have senesced.
- Alternative water sources. To control livestock use of wetland or riparian areas alternative water sources can be developed these may include spring developments, trough, stockponds, or fenced gaps in stream corridors.
- Cull (remove from herd) livestock that "hang out" in wetland or riparian areas.

Monitoring: Measure RDM at the end of the growing season and map utilization to determine if stocking rate and distribution is appropriate. Mapping RDM levels will help to determine areas of under or overutilization RDM monitoring information collected at the end of the growing season can be used to determine if there is adequate forage to last through the grazing season or if livestock numbers should be reduced. Mapping RDM will also allow you to identify areas of livestock concentration and evaluate their location in proximity to source water.

Management measures implemented to control cattle access in wetland and riparian areas should be monitored based on objectives. Annual monitoring may include riparian photos, bioassessment, riparian inventory, measuring stream channel morphology and mapping utilization and residual dry matter.

Critical limit:
Corrective actions should be implemented relative to location of utilization zones with light or heavy use. If heavy use zones are identified in areas adjacent to stream channels corrective actions to redistribute livestock must be considered. Corrective actions for livestock distribution should also be implemented if light use zones are noted in areas of severe fire hazards. Fire severity areas have been mapped for San Francisco Water Department property in the Southern Alameda Creek Watershed.

Corrective actions to adjust stocking rates should be implemented if target levels are reached after the growing season ends and before the end of the grazing season.

Corrective Action:
Depending on the livestock operation and other resource objectives the following corrective actions may be considered to effectively manage RDM and manage riparian and wetland areas.

Stocking Rate
The grazing season should end once target RDM levels are reached. If under typically environmental conditions target levels are reached during the growing season, base stocking rates should be reduced in subsequent years. If target levels are not reached during the grazing season, base stocking rates should be increased. Stocking rates must remain flexible to account for year to year precipitation and forage growth variability.

Livestock Distribution
The same tools used to “lure” livestock away from riparian areas can be used to improve distribution. These tools include attraction and herding. Attraction, moving salt/mineral feeding locations away from water is one way of improving livestock distribution. Traditionally, people have thought that cattle must have water after consuming salt. Recent information indicated that cattle do not utilize salt or mineral and then water or vice versa. Distributing livestock with the placement of supplemental feed is also an effective tool for managing livestock distribution. Although developing water is one of the more expensive tools to manage livestock distribution, it is also one of the most effective tools. Recently several springs have been developed by livestock owners in the Southern Alameda Creek Watershed to improve livestock distribution. To be

effective water should be located so that cattle do not have to travel more than ½ to ¾ mile in the hilly topography of the Alameda watershed to drink.

Herding may also be used by livestock owners to improve distribution.

Additional fencing may be needed to solve livestock distribution problems where the above methods prove ineffective.

Areas of livestock concentration that are close to source water should be moved.

Record Keeping:
Livestock owners/ managers should keep records of their grazing plan including stocking rates, in-out date, livestock numbers and class of livestock.

Monthly weather records, including amount of precipitation, and temperature (average, maximum, and minimum) should also be kept.

Grazing utilization maps should be updated annually.

Critical Control Point EC-7: Minimize soil erosion from pig rooting.

Best Management Practices: Since it is not feasible to control access of pigs to source water, best management practices to mimize soil erosion from pig rooting are limited to maintaining a persistent, flexible control program to control the feral pig population. This control program is also covered under biolocical hazards. The control program could include the following:

- Trapping pigs with box or corral type traps during dry or summer months. To increase the success of trapping, trap sites should be selected based on recent pig activity. Potential trap sites and traps should be pre-baited.
- Hunting with trained pig hounds in the winter and spring.
- Intensive and continual hunting at selected sites. Hunting by police officers working with the local State Fish and Game warden have nearly eliminated feral pig populations in the Hastings Natural Reserve in Monterey County.

Monitoring:
Wild pig populations should be monitored in the late spring along transects that survey for pig activity near source water including riparian habitat.

Critical Limit and Corrective Action:
Because the goal of controlling the pig population is to minimize risk of pigs contaminating source water, control programs should continue as long as pig activity is detected near source water including riparian habitats.

If a persistent, flexible pig population control program becomes unfeasible because of legal, social or other reasons, alternative corrective action should be considered. Current available alternatives i.e. strategic fencing are not only very costly, but not very efficient. Strategic fencing may exclude pigs from small areas by fastening a strong wire mesh fencing tightly to the ground or buried for its complete extent. The effectiveness of the fence may be enhanced by adding an electrified wire on the outside, which will keep pigs from trying to burrow under. Excluding pigs with strategic fencing from an extensive area would be an on-going challenge.

Record Keeping:
Record location, method, date, and age of trapped and dispatched pigs. Record survey results from semi-annual pig activity survey.

References

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Southern Alameda Creek Watershed Chemical Hazards Control Program

Hazard:

Chemical pesticides applied to livestock to control insects or used on rangeland sites to control weeds contaminating source water.

Risk Assessment:

Chemical pesticide use on rangelands in the Southern Alameda Creek Watershed is very limited. In some areas, herbicides may be sprayed to control vegetation. In particular along main road corridors a soil acting herbicide containing the active ingredient *diuran* may be applied to act as a barrier to germinating seeds. Roundup with the active ingredient *glyphosate* may also be applied during the growing season to control vegetation and/or a variety of weeds. Roundup is a contact defoliant and does not create runoff. It has a half life of less than 30 days. A new herbicide has recently been registered for use on California's rangelands to control yellow starthistle. This product binds tightly to soil and should not be present in runoff.

In regards to pest control on livestock, livestock producers may use pesticide tags, sprays, powders or feed thru supplements. Pesticide products applied as sprays are made to stay on the animal and contain stickers that are lipophilic, adhere to skin oils. These products should not be present in runoff. Pesticides provided in feed thru supplements break down in the enviroment very quickly and should not pose a threat to water quality if best management practices keep manure distributed and out of source water.

Used properly, chemical pesticides pose little threat to drinking water quality.

Critical Control Point PM-1: Proper application of pesticides to control weeds on rangeland sites and livestock pests.

Best Management Practices: The following best management practices apply for the application of any chemical pesticide.

- Read the product label and use according to label directions
- Check weather conditions before applying pesticides to make sure they are not applied when rain or wind may cause pollution or drift problems.
- Mix carefully just enough product to complete the job at hand.
- Mix product in an appropriate location, away from source water where spills can be easily cleaned up.
- Use the lowest effective rate listed on the label for any one application.
- Identify pests correctly so that the proper pesticide is applied.
- Calibrate spreader or sprayers so that a specified amount is applied.
- Before going to the site, check nozzles, hoses and pumps for leaks. Keep an eye on the equipment during the application to be sure it is working correctly.
- Maintain a buffer area of more than 100 feet between pesticide application area and surface waters.
- Consider alternative control methods such as beneficial insects, improved grazing practices, or controlled burns.
- Rinse application equipment in an appropriate area, away from source water.
- Develop tolerance for certain pests.

Monitoring: San Francisco Public Utilities Commission will keep abreast of current information on chemical pesticides and inform landowners of relevant new information. SFPUC will test water quality in reservoirs as required by the Department of Health Services. Landowners applying chemical pesticides will assess their use of best management practices in storing, handling and applying chemical pesticides.

C**ritical Limit and Corrective Action:** Positive tests for chemical herbicide will be evaluated and efforts will be made to determine source. Additional management measures will be applied to control chemical contaminants from any known source.

Record Keeping: Landonwers will keep records on pesticide treatments including date of application, amount, area treated, applicator, and weather conditions.